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Original

APLICACIÓN DE UN PROGRAMA DE ENTRENAMIENTO DE BOXEO EN UN INDIVIDUO CON ENFERMEDAD DE PARKINSON DE INICIO TEMPRANO. ESTUDIO DE CASO

THE APPLICATION OF A BOXING TRAINING PROGRAM IN AN INDIVIDUAL WITH EARLY-ONSET PARKINSON'S DISEASE. CASE STUDY

Suárez-González, I.[1]; González, F.[1-2]; Monroy-Gómez, J.[1-2]

[1] *Applied Neuroscience for Health and Sports Research Group., Institución Universitaria Escuela Colombiana de Rehabilitación. Bogota, Colombia*

[2] *Human Capabilities, Health, and Inclusion Research Group., Institución Universitaria Escuela Colombiana de Rehabilitación. Bogota, Colombia*

Correspondence to:
Suarez-Gonzales Ingrid
Monroy-Gomez Jeison
Institución Universitaria Escuela Colombiana de Rehabilitación.
Address. Av. Cr 15 no. 151-68
Tel. +57 1 4321530
ingidsuarez@ecr.edu.co
jeison.monroy@ecr.edu.co

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editor@journalshr.com

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RESUMEN

Objetivos: Determinar el efecto de la aplicación de un programa de boxeo en las habilidades motoras y la percepción de la calidad de vida de una persona con Parkinson temprano.

Material y métodos: Para el desarrollo de la investigación, se contó con la participación de una persona diagnosticada con Parkinson temprano. Se aplicó un programa de entrenamiento de boxeo que consta de 36 sesiones distribuidas en 12 semanas, cada sesión con duración entre 60 a 90 minutos distribuidas en 15 a 20 minutos con ejercicios de calentamiento y 40 a 60 minutos de entrenamiento específico. Las mediciones de la función motora, el equilibrio, la funcionalidad y la calidad de vida se realizaron antes y después de la aplicación del programa de boxeo.

Resultados: Se determinó que el programa de boxeo generó efectos positivos en equilibrio, precisión, selectividad tanto de movimientos globales como finos, la capacidad de moverse y la ejecución de la marcha. Además, fue posible determinar que existe una mejora en la percepción de la calidad de vida en relación con los síntomas motores, la sensación de bienestar y el apoyo social.

Conclusiones: El entrenamiento de boxeo en pacientes con Parkinson podría generar efectos positivos principalmente en la función motora, el equilibrio, las características de la marcha.

Palabras clave: Enfermedad de Parkinson, boxeo, Ejercicio Físico, actividad motora, Análisis de la Marcha, calidad de vida

ABSTRACT

Objectives: To determine the effect of the application of aboxing program on motor skills and quality of life perception in an individual with early-onset Parkinson’s disease.

Methods: One individual, who had been diagnosed with early-onset Parkinson’s disease, participated in the present study. A boxing training program, which consisted of 36 sessions, distributed over 12 weeks, was implemented. Each session was 60-90 minutes long, distributed into 15-20 minutes of warm-up exercises, and 40-60 minutes of specific training. Motor function, balance, functionality, and quality of life measurements were taken before and after boxing program implementation.

Results: It was determined that the boxing program did improve balance, precision, selectiveness of global and fine movements, and the ability to move and walk. It was further possible to determine the existence of an improvement in quality of life perception, as related to motor symptoms, the sensation of well-being, and social support.

Conclusions. Boxing training in Parkinson’s patients may generate positive results, mainly in motor function, balance, walking characteristics.

Keywords: Parkinson’s disease, boxing, exercise, motor activity, gait analysis, quality of life

INTRODUCTION

Parkinson's Disease (PD) is a neurodegenerative alteration produced by environmental and genetic factors. It mainly affects motor (Castro & Buritica, 2014; Hurtado, Cárdenas, Cárdenas & León, 2016) and certain cognitive domains that emerge, as the disease progresses (Nadeau et al., 2017). Its prevalence is estimated to be between 41 and 5,703 individuals per 100,000 inhabitants, and its incidence is between 17 and 346 per 100,000 inhabitants (Hirsch et al., 2016; Ariza-Serrano, Guerrero-Vega, Ortiz, & Moreno-López, 2016).

PD motor alterations are characterized by the presence of a tremor, bradykenesia, postural instability, reduction of manual skills, propulsive gate, and dysautonomia (Cusso, Donald & Khoo, 2016; Martínez, Gasca, Sánchez & Ángel, 2016). Cognitive alterations involve deficits in attention, memory, and visuospatial and executive functions (Picelli et al., 2016). Together, these manifestations progressively affect subjects' participation in activities in daily life, and in general, their quality of life. (Borrione, Tranchita, Sansone & Parisi, 2014).

Currently, the main treatment for PD is pharmacological (Martínez et al., 2016), which strives to offer control over the illness' symptoms. There are various types of medications available: dopamine precursors such as levodopa (L-Dopa), dopamine agonists, and Catechol-O-Methyltransferase inhibitors (COMT) (Ellis & Fell, 2017). Advances in the pharmacological treatment of PD has made great progress in recent years. However, it does generate long-term side effects, such as dyskinesia, low medication utility, and quality of life impacts (Jenner, 2015).

Other alternatives that have proven to be effective in PD treatment include deep neural stimulation, thalamotomy, pallidotomy (Ellis & Fell, 2017; Hurtado et al., 2016), and physiotherapeutic intervention strategies whose methods have shown increased improvement potential, with neuromuscular facilitation, Bobath, relaxation (Tomlinson et al., 2012), functional training, and physical exercise (Borrione et al., 2014).

Physical exercise is an important tool in rehabilitation processes for those with PD. Its effects have been confirmed in various traditional physiotherapeutic intervention studies, thus showing the positive effects of the treatment of motor and cognitive manifestations of the disease, by way of training on stationary bicycles or cycloergometers (Ridgel, Philips, Walter, Discenzo, & Loparo, 2015; Nadeau et al., 2017), treadmills (Borrione et al., 2014; Nadeau, Pourcher & Corbeil, 2014; Rose, Løkkegaard, Sonne & Jensen, 2013; Picelli et al., 2016), multimodal training with cardiovascular endurance, strength, coordination, and balance exercises (Tanaka et al., 2009; Teixeira-Arroyo et al., 2014), and even aquatic exercise (Ayan & Cancela, 2012).

Further research has been performed with unconventional physical exercise alternatives, such as Tai Chi, tango, and virtual reality, which demonstrate that it is possible to generate positive effects, not only on motor, but also on cognitive characteristics, and even quality of life (Lauzé, Daneault, & Duval, 2016; Gonçalves, Leité, Orsini & Pereira, 2014; Rios, Anang, Fereshtehnejad, Pelletier, & Postuma 2015; Nocera, Amano, Vallabhajosula, & Hass, 2014). These emerging unconventional alternatives promote more integral styles and dynamics that generate interaction between different cognitive-motor systems and abilities, thus increasing the benefit produced by physical exercise in individuals with PD.

Thanks to these studies, and the effectiveness shown throughout history, in favor of PD physiotherapeutic intervention with physical exercise, several authors have even identified specific characteristics under which a program may provide greater benefit. Among others are activities directed toward cognitive strategies, balance, and endurance (Borrione et al., 2014). These characteristics have been proposed in different types of interventions. However, one of those which is most widely recommended, currently, is boxing training, as this involves them all naturally. However, although it is an intervention strategy that complies with current recommendations, studies do admit that its effects are limited (Morris et al., 2019). As such, the objective of this investigation was to determine the effect of the implementation of a boxing program on motor skills and quality of life perception in an individual with early-onset PD.

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Regarding effects of the boxing practice in Parkinson Disease, Combs et al, (2011) describe the relation to may exist in habitual boxing and the needs of patients. The endurance, strength, movements in multiple directions with lower, upper limbs and whole body, high speed motions and anticipatory postural adjustments are some of characteristics of boxing offers, and its possible affinity with the neurophysiological mechanisms of plasticity, neuronal repair and angiogenesis (Acevedo, Avila & Cárdenas, 2014; Hirsh et al, 2018; Nadeau, 2017) of traditional exercise in patients with Parkinson's disease, it becomes an attractive strategy in the rehabilitation of these patients. As such, the objective of this investigation was to determine the effect of the implementation of a boxing program on motor skills and quality of life perception in an individual with early-onset PD.

METHODS

Study type

For the implementation of this investigation, a single, quasi-experimental case study was performed, in order to determine the effect of the implementation of a boxing program on the motor skills and quality of life perception of an individual with early-onset PD

Participant:

The participant was a fifty-year-old male, who had been diagnosed in April of 2017 with PD, with an early-onset rigid-akinetic classification. He was from Colombia and had been a public transport driver. Participant selection occurred non-probabilistically and intentionally, in compliance with the inclusion criteria, which were as follows: having been diagnosed with PD level one or two, on the Hoehn and Yahr scale (1967), being able to receive and respond to visual, auditory, and kinesthesic stimuli, being older than 18 years of age and younger than 70 years of age, not having cognitive alterations or attention different from that which could occur as a result of the disease, health alterations, having medical situations that would impede physical activity.

Participant's medical history

In October of 2016, the participant requested general medical advice, indicating difficulty in performing certain movements with the right half of his body. This limited his eating, writing, and driving activities. Said symptoms had manifested and progressed during the past 10 months. The doctor authorized the following diagnostic aids: Simple brain CT scan, doppler of the upper and lower limbs, and electromyography of lower limbs. The result of the exams indicated that he was within normal parameters. However, given his clinical presentation, he was referred to neurology. In April of 2017, he informed his neurology professional that his symptoms had become more severe. Based on the preceding and diagnostic aids, he was diagnosed with PD, with early-onset rigid akinetic classification (G20X-CIE 10).

At the time that the investigation began (two years after the diagnosis), the subject under study presented bradylalia, bradyphrenia, diaphoresis, hypofluency, tone increase on right side of body, and bradykinesia. He had been prescribed pharmacological treatment: 250/25 mg (two tablets daily, one every 12 hours) L-DOPA/carbidopa, Mirapex (4.5 mg once daily, at night), and 1 mg Rasagiline (every third day). The participant additionally performed light-moderate physical activity a minimum of five days per week, of which three occurred with his health entity's physical rehabilitation program. Therein, each session was 45 minutes long, and began with joint movement, low-intensity resistance exercises with elastic bands, or bodyweight exercises. Thereafter, they included light to moderate aerobic exercise on a treadmill or stationary bike, and ended with stretching. The remaining two days, he exercised independently on his bicycle, outdoors. It´s important to note that before the diagnosis the participant also had exercise habits, which consisted of cycling 2 to 4 times a week at moderate to vigorous intensity

He did not smoke, and drank socially, prior to his diagnosis. During his participation in the investigation, and with previous medical authorization, he ceased attendance to his health care entity's exercise program, temporarily, as said participation might have skewed the results and achievement of the research objective.

He frequently spent time with his children, wife, and other family members, including siblings and nieces and nephews. He performed activities in the home, such as crafts and puzzles, among other things. He indicated feeling impotent and concerned by his inability to generate income for his household and the increasing expenditures owing to his medical appointments.

Methodology

I order to achieve the objective of the investigation, a characterization and evaluation of function, functionality, and functioning in the subject was performed, both before and after participation in the boxing program.

Subject characterization

A structured interview was performed, which revealed clinical, personal, and familial antecedents, diagnoses, treatments he had received, context, prior experiences, expectations regarding quality of life, and treatment. His clinical history was also reviewed, with previous authorization and informed consent. The degree of disease severity was categorized in I score of Hoehn and Yahr (1967) scale, which permits PD classification by states, considering motor deterioration and quality of life.

Evaluations pre and post

The tests and protocols mentioned below were performed before and after the application of the training program. It was realized indoor in different spaces of the Fundación Universitaria Escuela Colombiana de Rehabilitación: gait specialized laboratory, physical exercise center and the practice center.

The spaces were adapted according to the dimensions and measurement instruments required for each of the procedures to be performed. Time control as well as heart rate monitoring were followed through a heart rate monitor Sigma pc 10.11.

Both the evaluation and program was realized in ON phase of medication, in the morning one or two hours arfter taking medicine, taking into account that it favors the safe practice for patients (Rafferty et al, 2017), as well as the performance in program activities and test showing better favorability (Dibble, LE, 2015; Prodoehl, et al 2014; Schootemeijer, S et al, 2020).

Function assessment (motor and balance)

To evaluate motor function, the unified scale for PD, modified by the MDS (MDS-UPDRS) was used. This is a classification system designed for longitudinal follow-up over the course of the illness, and consists of four domains (Martínez-Jurado, Cervantes-Arriaga, & Rodríguez-Violante, 2010). Part III of the scale was considered for the motor function evaluation specific to the illness. In terms of balance evaluation, the Berg Scale (Berg Balance Scale-BBS) was employed (Berg, Wood-Dauphinée, Willams, & Gayton, 1983).

Functionality assessment

To evaluate mobility and quantify subject locomotor performance, the Up and Go test was applied. The six-minute test evaluates both endurance and the maximum distance that an individual can walk in six minutes (Combs et al., 2011). Finally, time and space walking parameters were evaluated: speed, cadence, length, and width of steps, by way of the 3D motion analysis system (3DMA) (Tan et al., 2019).

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Functioning assessment

In the evaluation of daily life activities, Part II of the MDS-UPDRS scale was applied, this includes, in its evaluation items, motor aspects of daily life experiences. So as to measure their quality of life perception the PD quality of life questionnaire PDQ-39 was applied. (Navarro-Peternella & Silva, 2012). Additionally, the result from the scale may be compared with the PDSI index (PD Summary Index) the impact generated by the disease on the individual's functioning and disability level (Jenkinson, Fitzpatrick, Peto, Greenhall, & Hyman 1997).

Program application

The program was implemented at the Institución Universitaria Escuela Colombiana de Rehabilitación facilities in Bogota, Colombia. The boxing training program utilized in this study consisted of 36 sessions, distributed over 12 weeks. Each session lasted 60-90 minutes (Table 1), which the designed and application was considered acording to symptomatology, charact eristics of the disease and the changes it generates in phisical abilities (Borrione et al., 2014).

Table 1. Program application. General description

Duration	Stage	Week	Sessions	Characteristics of the sessions
12 Weeks	First	1	3	Duration: 60-90 min (Combs, 2011) **Phase** Initial Phase- warm up Central Phase – Main Final Phase - Recovery
		2	3	
		3	3	
		4	3	
	Second	5	3	**Focus: Boxing** Conditional and coordinative physical abilities Fitness cardiorespiratory Resistance Training Muscle Stretching Balance Coordination (Motor learning and task training)
		6	3	
		7	3	
		8	3	
	Third	9	3	
		10	3	
		11	3	**Exercise prescription:** Mode/type Exercise Duration, frequency, intensity, volume Sets and repetitions
		12	3	

They began with 15-20 minutes of warm-up exercises, such as dynamic stretching or low-intensity aerobic endurance exercise, followed by 40-60 minutes of specific training, with aerobic endurance exercises on a treadmill, elliptical trainer, stationary bicycle, jump rope, body-weight strength exercises, resistance exercises with dumbbells, fitballs, agility, skill, and movement coordination exercises, through activities that involve the extremities and the entire body, generally and in parts, together with specific boxing tasks such as punching cylindrical bags, the speed bag, cylindrical heavy bags, defensive actions, movement, and rhythm changes. The sessions ended with 15-20 minutes of cool-down exercises, such as stretching, breathing, relaxation, and balance exercises. The program included scheduled breaks. However, the subject was permitted take breaks whenever he needed. The activities related to boxing were performed in contactless form, such that the subject would never be in direct combat with another individual (Appendix 1).

Ethical considerations

The study had the approval of the ethical committee at the Institución Universitaria Escuela Colombiana de Rehabilitación, Bogota, Colombia (Memorandum ECR-CI-INV-023-2019). The present investigation agreed and complied with the guidelines established by international, national, and institutional norms for the control of research on human beings.

RESULTS

Function assessment

During the program, the subject's function improved. Measured on the MDS UPDRS - III scale, a reduction in disability of 12% was achieved following intervention, as was a 15% reduction in the risk of falling, as measured by the Berg scale. Additionally, an improvement in performance of the Berg test, for 360° turn execution and time to climb and descend stairs was shown, together with an

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increase in the amount of time balancing, in tandem and unipodally (tables 2 and 3).

Table 2. Motor function and equilibrium scores.

	Pre-intervention	Post-intervention
Berg scale	48 / 56	56 / 56
MDS UPDRS - III	35/148	17/148

Table 3. Berg scale scores

Scale item	Unit	HI		HD	
		Pre	Post	Pre	Post
Anterior inclination with arm at 90°	cm	29	33	24	33
Inverse rotation	Points	4	4	3	4
360 rotation	Seg.	2'36	1'7	3'11	1'7
Raise and lower	Seg.	18'56	10'5	22'44	10'2
Tandem	Seg.	19'95	>30'	8'68	>30'
Equilibrium	Seg.	6'5	>10'	>10'	>10'

Abbreviation: LH: Left Half, RH: Right Half of body

Functionality assessment

The boxing program increased the subject's ability to move by 15.2%, in terms of the distance covered in the six-minute walking test, and there was an evident increase in his agility of movement, with a 23% reduction in Up and Go test execution time (Table 4). The walking analysis showed positive changes in temporal-spatial parameters, in which there was an increase in stride length, a reduction in the extent of the support base, decrease in stride time, and increase in speed of movement (tables 4 and 5).

Table 4. Functionality scores

Scale	Pre-intervention	Post-intervention
Six-minute test	551.12 meters	650.5 meters
Up and go	8.27 seconds	6.32 seconds
Walking		
Double support	19.57 %	20.56 %
Step length	0.54 m	0.60 m
Supportive base	0.20 m	0.13 m
Speed	1.04 m/sec	1.22 m/sec
Stride length	1.08 m	1.20 m
Cadence	114.92 steps/min	117.82 steps/min

Table 5. Cinematic walking characteristics by limb.

	Left		Right		Reference values
	Pre	Post	Pre	Post	
Total strides registered	9	8	12	10	-
% balance	37.16	34.98	38.39	38.75	38 – 42
% support	62.84	65.02	61.61	61.25	58 – 62
Balance time (sec.)	0.39	0.36	0.40	0.40	0.41 – 0.45
Support time (sec.)	0.66	0.66	0.64	0.63	0.44 – 0.46
Stride duration (sec.)	1.05	1.02	1.04	1.02	0.90 – 1.02
Step duration (sec.)	0.53	0.54	0.51	0.48	0.47 – 0.52
Stride length (meters)	1.08	1.20	1.08	1.2	-
Step length (meters)	0.56	0.63	0.53	0.58	-
Maximum heel height (meters)	0.15	0.17	0.14	0.14	-

Additionally, positive changes were identified that were related to mobility ranges during the walking analysis, evaluated with 3DMA software. Therein, increases in the hip flexion, abduction, and abduction ranges of movement were observed. Additionally, there was greater proximity in degrees of movement toward values that indicate greater walking pattern efficiency (Figure 1). The knee flexion range increase, of approximately 12° to 15° bilaterally, in the different phases of the cycle, were evident (Figure 2). Finally, ankle joint movements on both the sagittal and transversal planes showed favorable results following the intervention, with an increase in

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dorsiflexion of the two lower limbs, improvement between 8° and 15°, approximately, in the angle of internal rotation for both limbs (Figure 3).

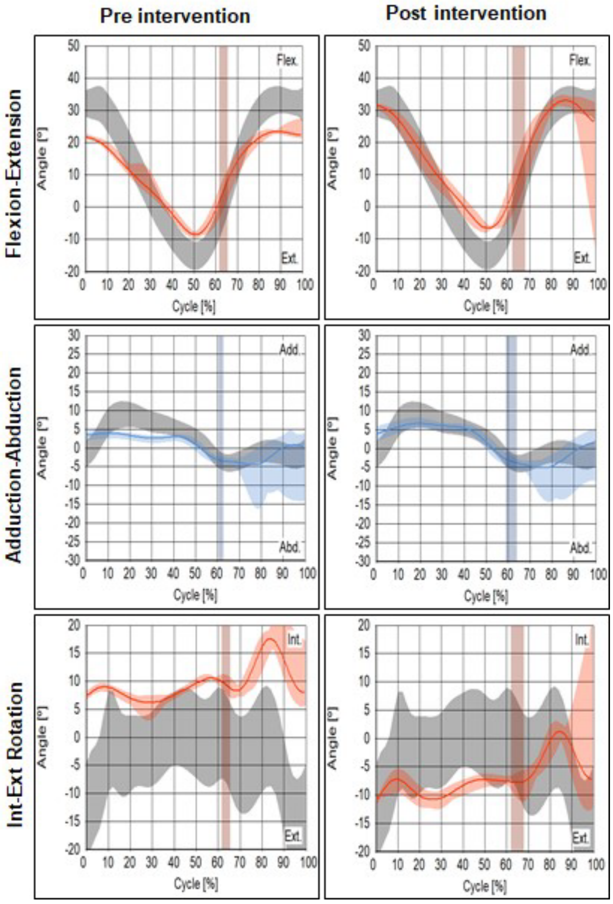

Figure 1. Hip. Flex-ext: it was shown that, post-intervention, there was greater hip flexor muscle activity, which permits the curve to be plotted on the reference arcs (28°-38°) in the walking cycle from 0-10% and between 80-100% (beginning and end of the cycle) considered within the reference range. Add-Abd between 10-40% post-intervention walking cycle, improved coactivation of the adductor muscles and internal rectus for preparation for contralateral balance. Rot Int-Ext: Post-intervention, it was shown that curve behavior is within the reference values in between 50-100% of the walking cycle. However, in between 0-40% thereof, the curves approach the lower limit of the reference ranges, reflecting significant importance of the coactivation of the pyriform and flat triangular muscle, as part of directing the limb in balance previous to heel strike, in between 80-100% of the walking cycle. (Blue figures right hemisegment, red figures left hemisegment)

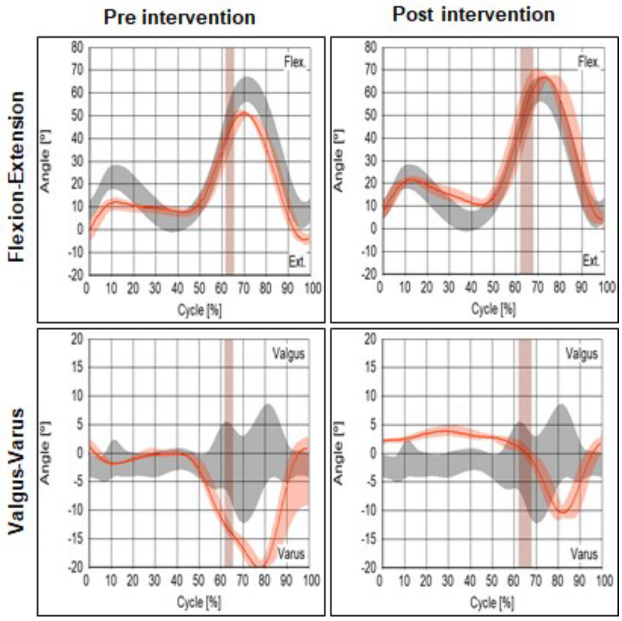

Figure 2. Knee: Flex-Ext: Important post-intervention progression is shown toward the reference ranges in between 0-30% of the walking cycle, which shows greater semitendinosus, sartorius, and internal rectus coactivation, in preparation for heel strike, with effective movement in the accentuation of the physiological valgus at the time of heel strike. Between 60-100% of the walking cycle, post-intervention, is shown to be within the curve reference ranges. Valgus-Varus: Post-intervention, the curve approaches the reference limits during the entire walking cycle, the synergies between semitendinosus, sartorious, and internal rectus with respect to the femoral stem, vastus externus, and fascia lata tensor favors curve symmetry with respect to valgus-varus. (Left hemisegment figures)

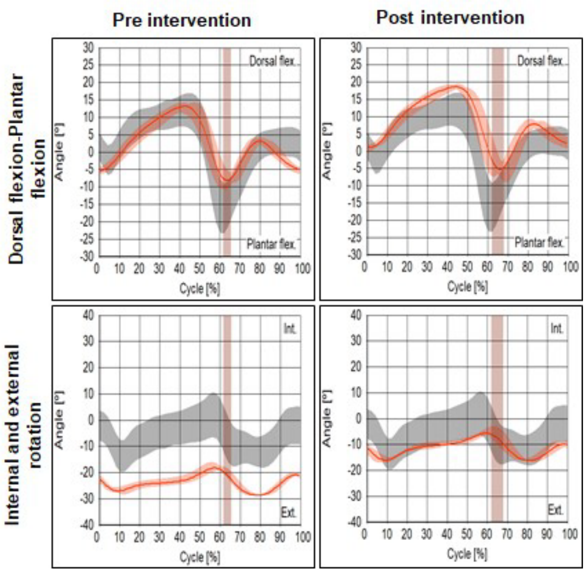

Figure 3. Ankle. Dorsal and plantar flexion: Post-intervention, the curves continue to be within the reference values, or above

the upper limit, which shows greater dorsiflexor coactivation, observed positively in the MDS-UPDRS in the heel-toe test. Internal-external rotation: Post-intervention, it was shown that the behavior of the curve is within the reference values. There is greater coactivation in the posterior tibials, and a positive synergy between this muscle and the anterior tibial during the entire walking cycle. (Left hemisegment figures)

Functioning assessment

The assessment of Functioning in activities from daily life and quality of life was performed with two parameters (Table 6). It was determined that the program implemented in this study generated a decrease in the MDS UPDRS II scale score, which represents an increase in the subject's quality of life perception. In terms of the PDQ-39 scale, there were no modifications to the direct score. However, the change in the subject's perception of certain items generated a slight increase in the PD Summary Index (PDSI) score (Table 7).

Table 6. Functioning scores

Scale	Pre-intervention	Post-intervention
MDS UPDRS - II	6 / 52	2/52
PDQ 39	17 / 156 PDSI index = 12.8	17/156 PDSI index = 13.3

Table 7. Domain scores.

	Pre		Post	
Dimension	**Score**	**Disability**	**Score**	**Disability**
Mobility	1/40	2.5	1/40	2.5
Daily activities	3/24	12.5	2/24	8.33
Feeling of well-being	2/24	8.33	1/24	4.16
Stigma	0/16	0	(+)1/16	6.25
Social support	1/12	8.33	0/12	0
Knowledge	6/16	37.5	(+)7/16	43.75
Communication	1/12	8.33	1/12	8.33
General discomfort	3/12	25	(+)4/12	33.3
Total	**17 / 156**	**102.49/800**	**17 / 156**	**106.6 / 800**
PDSI index	**12.8**		**13.3**	

(+) Categories the increase scores, (-) Categories that decrease scores,

DISCUSSION

Motor function

The evaluation of the disease's specific symptomology, as measured by the MDS-UPDRS, showed a positive, 18-point change, considered clinically significant by other authors (Shulman et al., 2010). This result corresponds to those of other studies, in which improvements were obtained on application of the post-treatment test in individuals with PD. These included dynamic cycling in the tandem test (Ridgel et al., 2015) short, medium, and long-term interventions in which improvements were similar and/or greater (Arcolin et al., 2015; Chang et al., 2018), treadmill activities (Schenkman et al., 2019), stretching (Rawson et al., 2019), aquatic exercises (Cugusi et al., 2019), and dance (Dos Santos et al., 2018), training alternatives in the upper limbs and high-intensity exercises, which have also demonstrated positive effects on the characteristics evaluated by the scale (Rose et al., 2013). Finally, the present study demonstrated that the motor function in subjects with PD improve with boxing-based exercise, changes which were not found in other studies that used both this type of intervention and scale (Combs et al., 2011).

The improvements obtained in the present investigation may be attributable to the fact that endurance exercise may favor electromyographic activity, associated with the improvement of motor unit activity, muscle use, and as such, movement synchronization (Borrione et al., 2014), as well as effects produced by training in tasks that involve dynamic and static stability, motor training, and physical exercise in general (Allen, Sherrington, Paul & Canning, 2011). Further, it has been considered that unconventional strategies for PD subjects, such as dance, incorporate tasks at different rhythms, speeds, turns, and multiple tasks that may influence factors associated with bradykinesia (Borrione et al., 2014). Exercise in individuals with early-onset PD generates neuroplasticity changes, in the dopaminergic signaling associated with balance improvement, which is also favored by the decrease of bradykinins evident on the MDS-UPDRS scale and other motor learning strategies, not measured in this investigation (Claesson, Grooten, Lökk J & Ståhle, 2017).

Balance

The protocol used in this study demonstrated that boxing is a strategy that may improve balance in those with PD, generating the maximum level of independence when measured by the BBS, and may additionally lead to a reduction in the risk of falls, facilitate the performance of daily activities, and improve independence (Pinto, Salazar, Marchese, Stein, & Pagnussat 2018).

In contrast to traditional therapeutic interventions, which focus on improving balance, boxing achieves this through sport-specific functional activities (Combs, et al., 2013). This result may be attributed to the effects produced by boxing, which involves dynamic and static stability tasks, motor training, physical exercise, agility and speed, walking backward, and anticipatory and reactive postural adjustment components (Allen et al., 2011, King & Horak, 2009). These may stimulate neurogenesis, an increase in the synthesis and liberation of dopamine, and enhance neuroplasticity, neuroprotection, and deceleration of neuron degeneration (King & Horak, 2009), as well as promote greater perception of self-efficacy in balance (Combs-Miller & Moore 2019).

However, balance changes are not statistically significant in the boxing-based programs, as compared to traditional interventions (Combs et al., 2013). The present study demonstrated an increase of 15%, in favor of the subject's independence, a result which is consistent with interventions based on others in individuals with PD, such as the prescription of exercise at home (Flynn, Allen, Dennis, Canning, & Preston 2019). These well-being programs include education, exercise circuits like extension, rotation, reach, strides and symmetrical walking (Horne, Soh, Cordato, Campbell, & Schwartz 2019), use of virtual reality though with low evidence levels (Wang et al., 2019), popular dance Sardiana (Solla et al., 2019), and hydrotherapy with or without land-based therapy (Pinto et al., 2018; Cugusi et al., 2019). In general, all of these interventions report improvements in the performance of activities related to walking balance and speed, in individuals with early to moderate levels of PD, without substantial cognitive deficit. However, maximum levels of independence are not always achieved, as in the program used in this study. There are also reports that demonstrate the contrary: in which interventions such as the use of games, based on Kinect, with individuals with PD fail to generate balance improvements (de Melo et al., 2020).

It should be considered that, in accordance with the review performed, independent of the type of intervention, improvements are not maintained following the intervention period, or after short periods of time, for which reason these types of exercises will only have short-term effects (Flynn et., 2019; Horne et al., 2019). In this case, there is no information available to determine whether the effect of boxing is short or long-term. However, the majority of models suggest that high levels of exercise intensity may be important to maintain improved function and quality of life over time, for those with PD (Combs-Miller & Moore 2019).

The improvements obtained in balance and motor ability favor functionality in activities related to walking, agility, and the ability to move, as described below, generating impact in the functioning related to participation in activities and quality of life.

Functionality

The effect of the boxing-based physical exercise program in this study generated positive changes in terms of the ability to move and walk. In the six-minute walking test were identified, as were increases in walking speed and improvements in the individual's kinematic parameters. Previous studies in which boxing training was applied found that 83% of participants increased the distance covered in the six-minute test, and 100% increased their walking speed. Consequently, there was an increase in cadence and step length, and decreased stride length (Combs et al., 2011).

Additionally, improvements in the six-minute walking test had been reported with resistance strength training (aerobic exercise and strength training)(Demonceau et al., 2017), a two-year community dance program (Duncan & Earhart, 2014), multicomponent program (Gazmuri-Cancino, Regalado-Vásquez, Pavez-Adasme, & Hernández-Mosqueira 2019), as well as in investigations that compared the effects of conventional and non-conventional programs, using treadmills and virtual reality, positive effects on speed and distance covered have been identified in individuals with PD (de Melo et al., 2020). These findings have been observed not only in subjects with PD in the initial stages, but also in more advanced stages, following multidisciplinary rehabilitation designed for subjects with PD (Ortelli et al., 2018).

The performance of mind-body strategies on subjects with PD has also been favorable for functionality. The moderate and significant effects thereof have been demonstrated in the six-minute walking test (Kwok, Choi, & Chan, 2016). Therapeutic strategies have improved spatial-temporal characteristics, also shown in our study. These include an increase in stride length, cadence, and consequently the distance covered in the six-minute walking test. These were obtained through the use of rhythmic auditive stimulation walking (Song et al., 2015). This strategy, although not included in a specific physical training program, obtained positive effects with auditory stimulation during the performance of a motor skill like walking. In general, physical therapy treatment, based on conventional strategies, physical exercise, training on a treadmill, dance, and martial arts significantly improved walking speed and six-minute test results (Tomlinson et al., 2012; Van et al., 2013).

The intervention program proposed in the present investigation includes multiple aerobic activities that use these mechanical devices. Additionally, the stimulation of movement, by way of dynamic sensorial signs and asymmetrical movements in boxing gestures, favor feedback and bradykinesia, balance, and walking improvements (Ridgel et al., 2015). This not only spurs the functional mobility of individuals with PD but may also generate positive impact in the decrease of the risk of falling (Giardini et al., 2018).

The increase in the distance covered in the six-minute walking test may owe to the increase in stride length, smaller support base, consequent speed, cadence, and length of stride increase described in the walking analysis with 3DMA software following program application. This on cycloergometers, treadmills, or other rhythmic movement mechanisms for the lower limbs may positively affect the activation of central pattern generators, as well as other temporal spatial walking dominions (Arcolin et al., 2015). Such three-dimensional analyses are not only important to determine the effects of training programs on kinetic and kinematic variables, but also on disease progression (Albani et al., 2014; Son et al., 2017).

As such, it is important to consider these aspects with physical exercise intervention programs, as it has been determined that aquatic, land-aquatic, short and long-term conventional physical therapy, and assisted rehabilitation with robots (Lokomat) generate significant changes in stride length, support and double support time, walking speed, and stride length (Ayán, Cancela, Gutiérrez, & Prieto, 2014; Rodriguez, Cancela, Ayan, do Nascimento, & Seijo, 2013; Nardo, Anasetti, Servello, & Porta, 2014), and increases range of movement in the hip and knee, upper limb joints, and vertical and lumbar spine (Sohmiya, Wada, Tazawa, Okamoto, & Shirakura, 2013, Mirek et al., 2016). However, significant changes in joint mobility ranges in the lower limbs are rare (Ayán, Cancela, Gutiérrez, & Prieto, 2014). Generally, these findings suggest that traditional and alternative physiotherapeutic interventions positively impact the normalization of walking patterns in subjects with PD, approximating the physiological walking pattern both qualitatively and quantitatively (Mirek et al., 2016).

Functioning

Quality of life refers to the subject's perspective, as reflected in cognitive and affective reactions to their personal ideas and current situation (Martínez-Jurado, Cervantes-Arriaga, & Rodríguez-Violante, 2010). It has been suggested that improved quality of life perception may produce a positive health impact. As such, it is necessary to increase efforts, such that those with PD, as well as their family members, can coexist more effectively with the disease (Navarro-Peternella & Silva, 2012). Quality of life is measured with a tool that permits the quantification of the impact of PD. The PDQ-39 scale measures various aspects, which include mobility, emotional well-being, stigma, social support, cognitive status, communication, and physical discomfort. It is characterized as a multidimensional, easily understood test (Martínez-Jurado et al., 2010;

Cabello, & Trandafir, 2018). On the other hand, the MDS-UPDRS is a validated instrument for use on those with PD. It offers advantages such as the inclusion of various non-motor disease symptoms (Rodríguez-Violante & Cervantes-Arriaga, 2014). Part II focuses on the individual's motor experience in daily life, and describe the impact thereof themselves (Regnault et al., 2019).

The application of a boxing-based exercise program demonstrated that there is an improvement in quality of life perception, in relation to motor symptoms (measured with the MDS-UPDRS II), and on the perception of improvement in daily activities, and the sensation of well-being and social support (measured by PDQ-39). However, the global PDQ-39 scale does not describe changes stemming from the program, as in some domains, such as stigma, knowledge, and general discomfort, subject increases in the perception of disability have been reported. Previous studies had demonstrated, generally, that there were no changes in the perception of quality of life in those individuals measured with the PDQ-39 test, as in occupational therapy interventions (Welsby, Berrigan, & Laver, 2019).

There are, however, reports of improvement in quality of life perception (measured with the PDQ-39) in subjects with PD, six months following Deep Brain Stimulation (DBS) surgery in the subthalamic/pallid nucleus, therapy with subcutaneous apomorphine bomb in continuous perfusion, and therapy with continuous Duodopa levodopa gel infusion through the duodenum. These are considered advanced therapies for PD treatment. The domains that show improvement are physical discomfort and communication (Cabello, & Trandafir, 2018). These results echo those reported by Llagostera-Reverter, López-Alemany, Sanz-Forner, González-Chordá, and Orts-Cortés (2019), who describe that the communication domain is the least affected in Parkinson's subjects referred to neurology services. Said results are unlike those described in the present investigation, in which the communication domain did not present changes. This may be attributed to the perception of a single participant. In certain cases, domains such as social support have been reported to not improve in those submitted to advanced therapies (Cabello, & Trandafir, 2018). Generally, in the cognitive domain, of those referred to neurology services (Llagostera-Reverter et al., 2019), in this study, there were no changes to the mobility and communication domains. There was, however, an increase in the sensation of disability in the cognitive domain.

It is contradictory that the perception of the subject under study, in the mobility domain, would not improve, although the majority of positive program results were reflected in motor processes. This shows discrepancies in the tests, in terms of motor perception, as with the MDS-UPDRS II, improvements were indeed reported. Other studies have demonstrated that, with trampoline and treadmill training, the perception of quality of life was greater. Thus, bouncing exercises, in addition to physical health, may improve mental health and generate positive feelings of trust in oneself. (Daneshvar, Ghasemi, Zolaktaf & Karimi, 2019). However, one must be wary when asserting an improvement in quality of life measured with MDS-UPDRS, as recently it has emerged that different scoring scales may be more appropriate for the evaluation of motor skills, when reported by the individual themself, as well as the impact of PD that the MDS-UPDRS-II has on early-onset Parkinson's. Many psychometric problems have been encountered on analysis, including selection errors, imbalances, inadequacy of response scales, and modest reliability (Regnault et al., 2019).

Lastly, it should be mentioned that the changes described in favor of each of the abilities may be highly influenced in the stimulation of plasticity (BFDN), angiogenesis, neurogenesis that occur owing to metabolic response mechanisms with exercise, associated with stimulus alternation, repetition, task-based learning, and in the case of walking, the evocation of fixed-action patterns may be directly related (Arcolin et al., 2015; Borrione et al., 2014). Thus, the sum of the positive effects generated in PD subjects' symptomology may promote a direct impact on participation in daily activities and subjects' quality of life, as demonstrated by the study performed by Combs and collaborators (2011), although this was not evident in the present investigation. Owing to the above, the characteristics of boxing may contribute to benefits in the improvement of motor symptomology and enhance certain cognitive domains. In previous

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studies, it has been shown that boxing significantly improves speed, walking endurance, balance, and quality of life in individuals with PD (Combs et al., 2011; Combs et al., 2013).

The application of a boxing program generated positive effects in motor symptoms and quality life of participant. However, the scope of the study does not allow us to identify if these effects can only be attributed to the application of the program, taking into account that the participant practiced physical activity prior to the program and diagnosis. Possibly the physical activity carried out by the participant before starting boxing training could favor its effects. In fact, it has been considered that physical activity can slow down the disease process (Fayyas et al., 2018), decrease pain, prolong independent mobility, improve sleep, mood, memory, non-symptomatic motor (depression, apathy, fatigue, constipation) and the secondary complications of immobility (cardiovascular, osteoporosis) in Parkinson's disease (Bhalsing et al., 2018; Fayyas et al., 2018, Paolucci et al., 2020).

Although the study contemplated the execution of the activities while the patient was in phase on the drug, being a unique case, it was not possible to compare them with respect to an off application. Additional limitation was the non-correlation of comorbidities with the effects of the program, the possibility of comparison between long and short term program, as well as the difference or similarity of effects between previously active or sedentary subjects. Future research could develop case-control analyzes in which the phases of the drug, the different stages of the disease, as well as the physical condition and exercise habits prior to the investigation are considered.

CONCLUSIONS

In conclusions the present study permitted the identification of the effects of a boxing-based physical exercise program for individuals with early-onset Parkinson's disease, with positive results, mainly in motor symptoms, motor function, balance, walking characteristics, and movement abilities.

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Appendix 1. Program application. Specifically, description

General program characteristics:			Physical fitness components (Based on boxing training characteristics)					
Phase	**Week**	**Task progression**	**Cardiorespiratory Fitness**	**Resistance Training**	**Muscle Stretching**	**Balance y proprioception**	**Coordination and agility**
1	1-4	Discrete task: Movements with a recognizable beginning and end (push-up, squat)	A conditioning phase: Very light and light intensity.	Body weight exercises, full body and light weight loads.	Mobility and light muscle elongation	Somatosensory stimulation. Static and dynamic balance with anticipatory adjust.	Easy tasks involve upper and lower limbs
2	5-8	Serialtask: Series of discrete movements combined in a sequence.	Progretion phase: Moderate-high intensity	Body weight exercises. Light and moderate weight loads.	Increased muscle length with light-moderate intensity perception	Static and dynamic balance involve double task, cognitive and motor.	Tasks involves global movements and walking, or some moves around place.
3	9-12	Continuous task: Repetitive and uninterrupted movements.	Maintenance phase: Moderate-high intensity	Body weight exercises. Moderate weight loads. (Increase volume)	Increased muscle length with light-moderate intensity perception	Static and dynamic balance involve double task (cognitive and motor), with and without equipment.	Full body movement sequences with and without equipment.
Boxing activities example		*Punch the bag. Only one movement of basics punches (Jab, cross). *Rhythmic and speed punches to speedbag or combination of two or more punches to bag. *Combination of two or more punches to punch mitts or bag involving lower limbs movements.	Jump rope, Skeeping, high knees. Punch the bag or shadow Boxing	Squat, push up, medicine ball squat, Punch the bag.	Exercises base on activities realized.	Sequences of sport specific movements. Combination of static and dynamic balance, double task (cognitive and motor) with and without equipment. According to the level progression.	Punch the bag, speed bag and mitts. Shadow Boxing and rolling.
Evidence		Combs et al (2011) Kisner (2010)	Combs et al (2011) Heyward (2014) Rubiano (2013) Tanaka (2009)	Rubiano (2013) Tanaka (2009)	Heyward (2014)	ACSM (2014) Heiward (2014) Tanaka et al (2009) Tarantino (2017)	Borrione (2014) Tanaka (2009)