REVIEW

Samba, deep water, and poles: a framework for exercise prescription in Parkinson's disease

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Abstract

Parkinson's disease is a brain disorder that leads to tremor, slowness, muscle stiffness, and other movement disorders. The benefits of exercise for reducing disability in individuals with Parkinson's disease are numerous. However, not much is known about the designing and prescription of exercise in neurodegenerative diseases. A brief review and indications for exercise prescription and evaluation are discussed throughout. In this scoping review, we specifically aimed to describe the applicability of walking tests (6-min/10-m) for the prescription of exercise in individuals with Parkinson's disease and to propose training (undulating periodized) designs in three exercise modalities, Brazilian dance rhythms (Samba and Forró), deep-water exercises, and Nordic walking. These training models and evaluation methods may assist coaches and therapists in organizing exercise programs adequate to people with Parkinson's disease, and are essential steps toward a comprehensive and more detailed understanding of the training loads in motor disorders and disease states.

Keywords Parkinsonian disorders · Aquatic exercises · Nordic walking · Dance therapy · Rehabilitation · Training and evaluation protocols

Introduction

Parkinson's disease (PD) is the second most prevalent neurodegenerative disease worldwide. In developed countries, approximately 1% of the population over 65 years and 3–5% of people over 85 years are affected by the disease [1]. PD patients present motor and nonmotor symptoms such as rigid muscles, *bradykinesia*, tremors, postural instability, changes in gait, autonomic dysfunction, sleep, cognitive, and neuropsychiatric disorders [2, 3]. These symptoms provoke a severe impairment in the functional autonomy of people with PD. In addition, reduced social interactions contribute to depressive symptoms and impair the quality of life of this population [4]. Another critical feature of the PD is that reduced functional mobility is related to muscle voluntary activation deficits mediated by muscle/motor and transmission/machine efficiency (Fig. 1) [5, 6]. Most of the symptoms result from the death of dopaminergic neurons and changes in the pathways of the base nuclei [7]. Furthermore, the gait impairment in these patients also seems to be related to muscle weakness and central and muscular fatigue [8]. The practical implication of this rationale is that some exercise interventions may represent impressive improvements in the functional parameters (e.g., timed up and go and 10 m walk test) due to concomitant enhancements on muscle efficiency (mitochondrial and cardiorespiratory adaptations) and transmission efficiency (intersegmental coordination, mechanical work production, and muscle co-contraction) [6].

The conservative management of PD is the pharmacological treatment that alleviates the symptoms, but does not reduce all clinical signs. The research data indicate that, together with drug therapy, regular physical activity could promote additional improvements in the functionality and clinical symptoms of people with PD [9]. Walking

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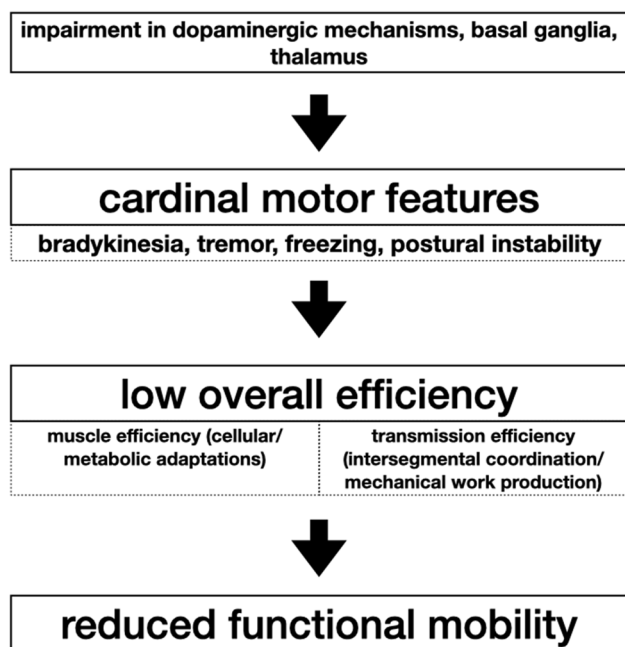
Fig. 1 A framework for conceptualizing the top-down effects of Parkinson's disease on reduced functional mobility. The nigrostriatal dopaminergic loss and degeneration and thalamic circuitry impaired result in the cardinal motor symptoms (bradykinesia, tremor, freezing, and postural instability), which in turn imply a low overall efficiency caused by cellular and metabolic alterations (muscle efficiency) and intersegmental coordination and mechanical production impairments that negatively impacts the functional mobility in individuals with Parkinson's disease

endurance training is a usual exercise because it is considered a functional activity and, therefore, well recommended for people with PD [10]. This exercise method assists in functional mobility and the improvement of spatiotemporal gait parameters. Moreover, Nordic walking, a newer exercise intervention using one pair of poles, is recognized as a powerful method to improve functional mobility and quality of life in healthy [24, 28] and PD [5, 11, 12] individuals. Dance is another kind of practice that has emerged as a possible complementary therapeutic strategy to promote physical, psychological, and social benefits [13]. Dance practices, like walking, require constant weight transfer between legs at different rhythms according to musical stimuli and changes in direction. In addition to being accessible to Parkinsonians [10], dance classes can help improve motor parameters [14], increase quality of life, stimulate socialization, and provide greater motivation to adhere to body movement practices [13, 15]. Randomized controlled trials [16, 17] have shown aquatic exercise as an effective method to reduce the disability in PD. Therefore, many studies have sought to investigate the effects of exercise in people with PD [9, 10, 18, 19]. However, information about protocols, interventions, methodologies is still poorly described [20, 21]. An exciting

exercise framework was recently proposed based on the constraint-focused agility exercises, including progressive levels of sensorimotor, resistance, and coordination challenges.

Nevertheless, the training program is poorly explained in terms of volume and intensity [22]. In general, individuals with PD perceive the aspects of low outcome expectative from exercise and the fear of falling as critical barriers to engaging in exercise programs [23]. In this sense, we proposed applying the training principles to improve the quality of life, resulting in optimized gains from exercise. The detailed program is in supplementary material 1 (https://doi.org/10.6084/m9.figshare.14230427.v1).

Further, we present three exercise methods that have some positive aspects in the stability of ambulatory patients throughout walking using poles, deep-water exercises, and dance classes in pairs (Fig. 2). The exercise program including evaluation and prescription procedures for individuals with PD is defined as PPT-PARKINSON.

Thus, the objective of this scoping review is to help establish a means for a programming prescription and evaluation for aerobic training for people with mild-to-moderate PD. Specifically, we described the applicability of the 6-min and 10-m walking tests to, besides evaluation, using these outcomes to design the training loads for periodization in PD. Also, to propose three training protocols lasting approximately 3 months (22 sessions): (1) dance lessons inspired in Forró and Samba musical Brazilian rhythms, (2) Nordic walking or walking with poles, and (3) deep-water exercises, including walking and running without touch the pool bottom, using a floating belt. Although the study does not report outcomes directly from human intervention, all assessment and exercise prescription procedures were approved by the local ethics committee (HCPA, register 555 123).

Brief literature review on evaluation and training protocols in PD

Although the importance of exercise on improving nonmotor and motor symptoms related to PD, only a few studies have investigated the training and evaluation protocols [5, 9, 10, 13, 20, 23]. Therefore, we carried out a narrative synthesis rather than a systematic review approach to exercise interventions and PD evaluation. The most studied types of exercise intervention are aerobic as walking, Nordic walking, cycling, treadmill walking [9, 11, 12, 24], muscle strength [25], Tai Chi [26], and dance [13–15]. Aquatic exercises are less studied, although initial evidence shows that these interventions have good potential for people in advanced stages of the disease due to the aid of fluctuation during exercise [16, 17, 20]. Besides, most dance studies focusing on tango and Brazilian rhythms also have the potential for adherence due to

Fig. 2 The three training programs included in the research and training project (PPT-PARKINSON). The deep-water exercises program is in the superior panel, the Brazilian dance program is in the middle panel, and the Nordic walking program is in the inferior panel
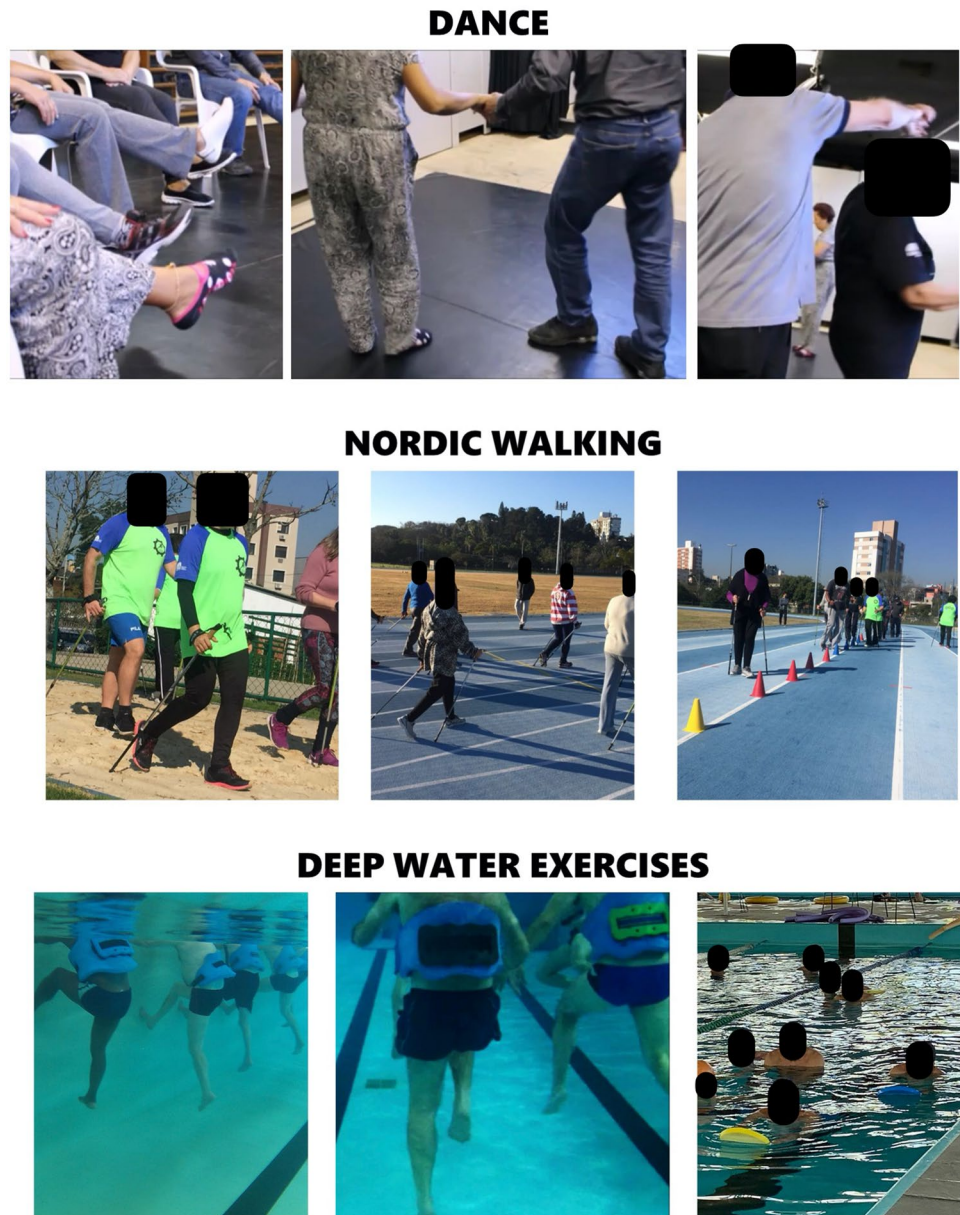
the challenging and motivational rhythmic characteristics of Forró and samba. Nordic walking has assistive potential compared to free walking as it increases safety and mobility, demonstrated from an acute [27] and chronic [5] point of view. In addition, the use of poles allows a higher self-selected speed improving the pendulum walking mechanism [24, 28]. Another type of intervention less studied for people with PD is the high-intensity (interval) exercises. Recently, we confirmed the safety and feasibility of the sprint as an exercise method for PD. However, some biomechanical adjustments must be considered in this training, such as impaired mechanical effectiveness

and increased maximal force employed due to slowness features [29].

The lack of standardized training and evaluation protocols in PD has hampered comparisons between different interventions and studies using similar interventions. One critical concern is unclear or missing volume and intensity load information, precluding the possibility of determining the overall load of interventions and, thus, possible comparisons [27].

The most studied outcomes are quality of life, motor and disease staging, physical mobility, and depressive symptoms [5, 12, 14, 30]. Few studies have studied biomechanical and balance outcomes, especially on anticipatory postural

adjustments and the relationship with falls. Also, many studies do not present in detail the assessment procedures and how this evaluation helps in the prescription of exercise. Again, there is a notable lack of evaluation protocols to determine training loads [27].

Another current topic on exercise interventions in PD is on COVID-19 pandemic. The reduction of physical exercise during the COVID-19 pandemic-related quarantine measures is worrying and challenging, especially for individuals with PD. Individuals with PD have impaired their nonmotor and motor symptoms due to increased sedentary behavior [31]. Therefore, many recent studies on telerehabilitation, telemedicine, and patient-initiated intervention exercises have been published, assisting remote exercise in helping PD individuals maintain functional mobility and mental well being [32].

Further randomized trials with larger sample sizes and higher methodological quality, particularly evaluation and prescription protocols, are needed to confirm the level of improvements in different exercise interventions for potential applications.

A proposal for evaluation protocol

The evaluation battery that we have been using here, denominated Porto Alegre test battery, is divided into two main sets of outcomes: functional mobility and clinical symptoms (Table 1). The functional mobility part is composed of the 6-min walk test (6MWT), 10-m walk test (self-selected and maximum speeds) and, timed up and go test (TUG—self-selected speed and forced speeds) [33]. The clinical symptom part is organized into the motor and nonmotor symptoms. The motor symptom section is composed of the following tests and procedures: Unified Parkinson's Disease Rating Scale (UPDRS—Part III—motor symptoms) [34] and Hoehn and Yahr Scale (H&Y) [35] to measure the severity of PD. The nonmotor symptoms comprised the following instruments: the Montreal cognitive assessment (MoCA) [36], the Geriatric Depression Scale—15 items (GDS-15), the Parkinson's Disease Questionnaire (PDQ 39) [37].

Determining training volume and intensity

In addition to the utility to evaluate functional mobility, the 10-m walk test and the 6MWT have helped design training loads in individuals with Parkinson's disease. Although the 10-m walk test is used as an intensity marker for Nordic walking training, the 6MWT has been utilized as a volume marker for dance, deep-water exercises, and Nordic walking.

Ten-meter walk test

The 10-m walk test permits the determination of self-selected speed, also termed preferred velocity or gait velocity. It is a reliable, valid, and specific measure that correlates with functional mobility and mortality [38, 39]. The protocol is applied in two conditions, at self-selected and maximum speeds. Everyone completes three consecutive trials for each walking test, for a total of 6 walking trials. The order of application of the two different walking speed conditions is randomly varied among practitioners to avoid sequencing effects. It involves a 14 m straight path, with 2 m provided for acceleration, 10 m for steady-state walking, and 2 m for deceleration. These distances are provided at the beginning and end of the walkway to allow participants space to accelerate/decelerate outside the data collection area to help reduce gait variability introduced during these phases. Therefore, the markers are placed at the 0, 2, 12, and 14 m positions along the path. The individuals are asked to walk the 14 m, and begin to walk "at a comfortable pace, usual pace at one end of the path, and continues walking until he or she reaches the other end. The individuals are instructed to walk at maximum pace, maximum speed, without running for the maximum condition. The evaluator uses a stopwatch to register how much time it takes for the individual to cross the 10 m center of the path, starting the stopwatch as soon as the individual's hip crosses the second marker and stopping the stopwatch as soon as the individual's hip crosses the third marker.

Besides self-selected and maximum walking speeds, the test permits analyzing the locomotor rehabilitation index

Table 1 Outcomes and instruments

Outcomes	Instruments
Functional mobility	6-min walk test (6MWT); 10-m walk test (self-selected and maximum speeds); Timed Up and Go (TUG) test
Motor symptoms of PD	The motor part of the Unified PD Rating Scale (UPDRS III), questions 18–31; Hoehn and Yahr Scale (H&Y), to assess the severity of PD
Non motor symptoms	Geriatric Depression Scale (GDS-15), to evaluate depression aspects; Montreal cognitive assessment questionnaire (MoCA), to evaluate the Global Cognition; Parkinson's Disease Questionnaire (PDQ39), to assess quality of life, is a questionnaire specific for people with PD divided in eight domains (mobility, daily life activities, emotional well-being, stigma, social support, cognition, communication, and body discomfort)
Anthropometric evaluation	Body mass, height, body mass index

[40]. The index considers how much longer the patient's self-selected speed is from his/her optimum walking speed (the speed at metabolic cost is lowest). Using the theory of dynamical similarities proposed by Prof. Alexander [55], we estimate the optimum walking speed, considering the Froude number equals to 0.25 as follows:

$$\text{optimum walking speed} = \sqrt{0.25 \times g \times l}, \quad (1)$$

where g is the gravitational acceleration (9.81 m s^{-2}), and l is lower limb length (from the ground to the greater trochanter, m). The locomotor rehabilitation index is numerically calculated as follows:

$$\text{locomotor rehabilitation index} = 100 \times \frac{\text{SSWS}}{\text{OWS}}, \quad (2)$$

where SSWS is the self-selected walking speed, and the OWS is the optimum walking speed. The practical relevance of an improved locomotor rehabilitation index besides the better walking speed is that it represents an enhanced energetical economy and mechanics. In other words, a better locomotor rehabilitation index means the participants are performing their locomotory activities, spending less metabolic energy and optimizing the pendular mechanism. This index has been applied to individuals with chronic heart failure [41], PD [5], heart transplant [42], visual impairment [43], chronic obstructive pulmonary disease [44], amputees [45], and elderly [28].

Furthermore, the walking speed test is used as an intensity marker for Nordic walking training. As observed in Table 2, the intensity is based on the perceived gait speed, using the following rates: comfortable: self-selected speed; intermediate: between the comfortable and maximum speed; Fast: the maximum speed of walking; Maximum: jog.

Six-minute walk test

The 6MWT is a well-known measure of functional exercise capacity in adults and children with chronic respiratory or cardiac disease. The individuals cannot use poles or other assistive devices. It has proved to be easy, safe, inexpensive, and reliable to apply [46]. Also, it correlates well with critical functional results comprising mortality [47]. Although its widespread use, there are no standard values for people with Parkinson's disease. Therefore, we have been applying the 6MWT as usually described in the literature [46], using the protocol standard 30 m walkway. According to the American Thoracic Society (ATS) protocol, the test location is characterized by a flat, clean, illuminated, and enclosed (indoor) walkway 30 m in length. The protocol requires 180° turns at either end of the walkway, and additional space for turning is needed. In our experience, and based on the studies using the 6MWT in seniors with intellectual disabilities [48], we suggest a prior 20-min session for familiarization to test. They are asked to walk up and down, avoiding jogging or running, as fast as they can and as far as possible. The practitioners can terminate at any time but are motivated to restart as soon as possible. During the 6 min, participants are continuously verbally encouraged using standardized messages. The walkway is marked with cones every meter, and at both extremes of the corridor, two researchers and two different cones are allocated to show where participants must change the direction. During the 6MWT, ratings of perceived exertion are monitored accordingly [49]. The number of meters is registered at the end of the test to the closest 0.5 m.

Therefore, the training volume of three training methods is calculated based on distance coefficient, in turn, determined by the ratio between the distance covered in the 6MWT and the predicted distance based on age, height, and body mass (Eqs. 3, 4, and 5) [50]:

For men,

$$\begin{aligned} \text{predicted distance(m)} = {} & 510 + (2.2 \times \text{height}) \\ & - (0.93 \times \text{body mass}) \\ & - (5.3 \times \text{age}) + 17. \end{aligned} \quad (3)$$

And, for women,

$$\begin{aligned} \text{predicted distance(m)} = {} & 493 + (2.2 \times \text{height}) \\ & - (0.93 \times \text{body mass}) \\ & - (5.3 \times \text{age}). \end{aligned} \quad (4)$$

Hence,

$$\text{Distance coefficient} = \frac{\text{performed distance}}{\text{predicted distance}} \quad (5)$$

Therefore, the participants are divided into three groups, A1: those who walk with a distance coefficient lower than 0.85, A2: those who walk with a coefficient between 0.86 and 1.2, and A3: those walking above 1.2.

Table 2 Perceived exertion scale and verbal or rhythm anchors

Intensity	Dance (beats per minute)	Deep-water running	Nordic walking (perceived rhythm)
1. Comfortable	76–108	Comfortable	Self-selected
2. Intermediate	108–120	Intermediate	Intermediate
3. Fast	120–168	Fast	Max walk
4. Maximum	168–200	Maximum	Jog

In the dance, we measured the session volume according to the beats per minute of the songs. Every beat represents one step, and we calculated the session volume, considering the step equalizing 1 m. The training volume for the deep-water exercises is determined by applying a modified 6MWT. We asked individuals to do the same 'terrestrial' 6MWT, however, in the deep-water running mode.

A proposal for training protocols and application

We organized the training protocols over the years in meetings where the training loads were structured following the principles of training: individualization, specificity, and overload [51]. All interventions are performed in groups, the particularities of each intervention are followed, and
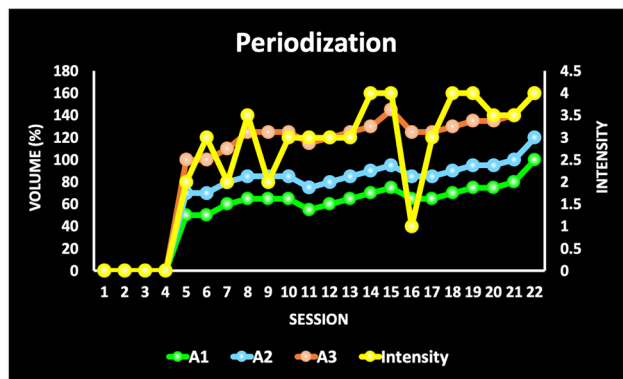
Fig. 3 The training volume (A1, A2, and A3; left vertical scale) is in meters, and intensity (red line, right vertical scale) is the category ratings during 22 training sessions. For the intensity, the number 1 represents comfortable, 2 comfortable and intermediate, 2.5 intermediate and fast, 3 comfortable, intermediate and fast, 3.5 intermediate and fast, and 4 comfortable, intermediate, fast and jog as shown at the first column of Table 2. The individuals included in the Group A1 are those who walk at 50% of the 6MWT (coefficient lower than .85), A2: those who walk at 70% of the 6MWT (coefficient between .86 and 1.2) and A3: those walking at 100% of the 6MWT (coefficient above 1.2) in the fifth session

the peak of the levodopa concentration is monitored. In all exercise methods, the volume is structured to include an average session time of 60 min, including an initial 10 min of warm-up and a final 10 min of recovery. The intensity is controlled by specific categories relative to ratings of perceived exertion, as shown in Table 2 and explained in detail in Sects. 4.1, 4.2, and 4.3. The training protocols proposed here lasted 11 weeks, twice a week, 2 h per week, totaling 22 sessions (4 sessions of familiarization and 18 sessions of training).

The overall periodization is represented in Fig. 3. The intensity is characterized by the right vertical axes (intensity) representing 1 (comfortable), 2 (intermediate), 2.5 (intermediate and fast), 3 (fast), 3.5 (fast and maximum), and 4 (maximum) and the individual volume based on % of 6MWT as explained in Sect. six-minute walk test.

Brazilian dance program

The Brazilian dance program consists of dance classes inspired by the Forró and Samba rhythms (Table 3). Samba and Forró are two popular Brazilian dances, danced in pairs, which originate from African musical and dance culture [52]. Both musical rhythms involve percussion instruments that generate a pulse through the binary (Samba) and quaternary (Forró) rhythms. In the Brazilian Dance Program, the participants were encouraged to perform body movements in space in various directions (i.e., forwards, sideways, backwards), involving turns and weight transfers that increase pelvic tilt, stimulate lumbopelvic movements, and dissociate the shoulder and pelvic girdles.

During the 11 weeks of dance training, and after the four familiarization sessions, 9 weeks were spent applying Forró-based sessions and nine Samba-based sessions). The familiarization sessions introduced the participants to the basic steps used in Forró and Samba. The structure of the sessions is described in Table 3 (adapted from Haas, Delabary, and Donida [53]). The intensity is determined based on the songs comprising the following rhythms in beats per minute: 76–108 (comfortable); 108–120 (intermediate); 120–168 (fast); 168–200 (maximum). Exercise examples

Table 3 General structure of dance classes

Part	Time (min)	Description
1	10	Joint warm-up, stretching and body awareness, sitting on chairs in a circle
2	20	Strength, coordination, balance, and rhythm exercises, walking and clapping the hands with the Ballet barre support
3	20	Exercises in front of the mirror with movements throughout the room inspired by basic Forró and Samba steps (Brazilian ballroom dances). To explore movements in the rhythm of the music, moving in different directions and at different space levels. Dancing in pairs
4	10	Rhythmic and playful activities that stimulate socialization, motor coordination, and creativity through improvisation. Dual task activities, using visual cues. Final cool down in a circle

can be visualized in supplementary material 2 (https://doi.org/10.6084/m9.figshare.14230415.v1).

Nordic walking program

The Nordic walking program is conducted outside with a demarcation of 400 m to calculate the distance covered in each training. The intensity is determined based on the rating of the perceived rhythm that is comfortable, intermediate, maximum, and jog. Comfortable rhythm is the speed that the person walks typically in the street (self-selected walking speed). The intermediate velocity is the range of speeds between the comfortable and the maximum, and the maximum speed is the one that the person can walk as fast as possible without running. Finally, the jog is the intensity in which the individuals will run for a short time.

In the familiarization sessions, the individuals learn the correct technique of Nordic Walking [54]. The structure of the Nordic walking sessions is described in Table 4. Exercise examples can be visualized in supplementary material 3 (https://doi.org/10.6084/m9.figshare.14230418.v1).

Deep-Water Exercises Program

The deep-water exercises program consists of exercises of stability, strength, and mobility of the trunk, horizontal displacements of the body with a different kick, stride techniques, and arm exercises. This program takes place with the individual immersed in a deep pool, in an upright position, with the aid of a floating device (flotation belt) so that there is no contact between the feet and the ground during the exercise. In familiarization sessions, the objective is to learn the correct technique of moving in deep water and training adaptation to the aquatic environment and body control. The deep-water exercise sessions were divided into four stages described in Table 5. Exercise examples can be visualized in supplementary material 4 (https://doi.org/10.6084/m9.figshare.14230418.v1).

The modified 6MWT (see Sect. six-minute walk test) is performed in the deep pool at the end of the familiarization period, and the distance achieved is used to determine the session volume. The intensity is determined based on the category rates of comfortable, intermediate, fast, and maximum (Table 1).

Concluding remarks

Owing to the chronic, progressive, and neurodegenerative characteristics of PD, whose incidence increases with the aging population [55], there is a need to understand the possible effects of non-drug therapies. By considering the possibilities of dance, deep-water exercises and Nordic walking as a complementary therapy for people with mild-to-moderate PD and after noticing a gap in the literature of a detailed description of exercise protocols used as an intervention for people with PD, the objective of this scoping review was to propose training and evaluation protocols for mild-to-moderate PD. In general, the adherence and compliance to these intervention programs proposed here are high (> 90%). Based on this practical know-how on exercise and Parkinson's disease, we can decidedly state that:

- exercise needs to be applied in an individualized approach, according to the capabilities and preferences of the individual, instead of the "one size fits all" strategy.
- deep-water exercises intervention has potential benefits for patients with a high degree of disability.
- Nordic walking and Brazilian dance help to reduce the freezing events increasing; thus, safety and range of movement, during exercise.
- the deep-water exercises, dance, and Nordic walking have particular characteristics that strengthen the motivation

Table 4 General structure of Nordic walking classes

Parts	Time (min)	Description
1	10	Warm-up and coordination exercises
2	40	Nordic walking
3	10	Stretching and calm down

Table 5 General structure of deep-water running classes

Part	Time (min)	Description
1	10	Joint warm-up and muscular stretching near the edge of the pool
2	30	The principal part of the class, individual daily deep-water running training according to the specific functional capacity of each participant. Volume and intensity vary according to the distance to be traveled and speed
3	10	Specific exercises of muscle strength, balance, postural control, coordination, double task and/or diving
4	10	Final cool-down (stretching and relaxation) close to the edge of the pool

and engagement factors, resulting in greater adherence and benefits.

- these training and evaluation protocols are the outcomes of mixing different expertise from Dance, Medicine, Physiotherapy, and Sport Science areas.
- even though these training protocols, the optimal dosage of exercise is still unknown.
- besides individualized, undulating volume and intensity loads need to be structured in periods.

The proposal of the conditioning process and proper exercise prescription presented here will impact people with Parkinson's disease and patients suffering from other motor disorders. In conclusion, these innovative training models and evaluation methods may assist coaches, physicians, dance teachers, and therapists in organizing exercise programs adequate for people with PD. Furthermore, we hope that these protocols will foster progress in the development of studies toward a comprehensive and more detailed understanding of training loads for individuals with neurodegenerative diseases.

Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval We have included the approval from local ethical committee (final of introduction): Although the study does not report outcomes directly from human intervention, all assessment and exercise prescription procedures were approved by the local ethics committee (HCPA, register 555 123).

Informed consent Springer Nature advances discovery by publishing robust and insightful research, supporting the development of new areas of knowledge and making ideas and information accessible around the world. We provide the best possible service to the whole research community.

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