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Balance and fear of falling in subjects with Parkinson's disease is improved after exercises with motor complexity

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ABSTRACT

Resistance training with instability (RTI) uses exercises with high motor complexity that impose high postural control and cognitive demands that may be important for improving postural instability and fear of falling in subjects with Parkinson's disease (PD). Here, we hypothesized that: 1) RTI will be more effective than resistance training (RT) in improving balance (Balance Evaluation Systems Test [BESTest] and overall stability index [Biodex Balance System®]) and fear of falling (Falls Efficacy Scale-International [FES-I] score) of subjects with Parkinson's disease (PD); and 2) changes in BESTest and FES-I after RTI will be associated with changes in cognitive function (Montreal Cognitive Assessment [MoCA] score – previously published) induced by RTI. Thirty-nine subjects with moderate PD were randomly assigned to a nonexercising control, RT, and RTI groups. While RT and RTI groups performed progressive RT twice a week for 12 weeks, the RTI group added progressive unstable devices to increase motor complexity of the resistance exercises. There were significant group × time interactions for BESTest, overall stability index, and FES-I scores ($P < 0.05$). Only RTI improved BESTest, overall stability index and FES-I scores, and RTI was more effective than RT in improving biomechanical constraints and stability in gait (BESTest sections) at post-training ($P < 0.05$). There were strong correlations between relative changes in BESTest and MoCA ($r = 0.72$, $P = 0.005$), and FES-I and MoCA ($r = -0.75$, $P = 0.003$) after RTI. Due to the increased motor complexity in RTI, RTI is recommended for improving balance and fear of falling, which are associated with improvement in cognitive function of PD.

1. Introduction

Postural instability, which is one of the most debilitating motor symptoms for subjects with Parkinson's disease (PD), increases the prevalence of falls [1,2] and is associated with increased fear of falling [3,4]. Postural instability and fear of falling can lead to decreased mobility, physical activity avoidance, and social isolation, [4–7] resulting in reduced quality of life [8]. Despite being effective for bradykinesia, rigidity, and to some extent tremor, levodopa therapy and deep brain stimulation do not have a clear therapeutic effect on postural instability [9–11]. Thus, interventions able to mitigate postural instability and fear of falling in subjects with PD are needed.

Progressive resistance training (RT) is an effective intervention to improve bradykinesia [12,13] and muscle strength in subjects with PD [14–16]. Reductions in muscle strength increase the risk of falls in PD [2] and are negatively associated with postural impairments [17,18] and fear of falling [3]. Therefore, RT-induced strength gains may improve both postural control and fear of falling in PD. Some studies have reported similar improvements in postural control when comparing RT and balance training [19,20] and weak evidence that RT is more

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beneficial than balance training on postural control [21]. On the other hand, it has been suggested that combining RT with balance or task-specific functional training may be more effective to improve postural control than RT alone in subjects with PD [14].

Recently, we found that compared to RT alone, RT performed on unstable devices (Resistance Training with Instability [RTI]) improved clinical (*i.e.,* mobility, motor signs, cognitive function, and quality of life) [22], neuromuscular [23], and spinal inhibitory mechanisms outcomes [24] in subjects with PD. RTI requires not only muscle strength but also postural control while performing resistance exercises with unstable devices (*e.g.,* BOSU® and balance disc) due to the concomitant and progressive increases in load/resistance and degree of instability over time (*i.e.,* high motor complexity) [22], which may impose a greater challenge to postural control and higher cognitive demand than RT alone. Taken together, we hypothesized that RTI would be more effective than RT to improve balance and fear of falling of these subjects. In addition, it has been showed that cognitive function has a strong association with postural instability/gait disturbance [25] and gait performance parameters [26], suggesting that improvements in cognition may also positively affect balance, and as a consequence decrease the fear of falling. As we have previously demonstrated that RTI improved cognitive function in subjects with PD [22], we hypothesized that changes in cognition induced by RTI can be associated with changes in balance and fear of falling; however, these hypotheses require further testing.

Therefore, the purposes of this randomized controlled trial were: a) to compare the effects of RT and RTI on balance and fear of falling in moderate subjects with PD; and b) to examine the association between the changes in balance and fear of falling and the changes in cognitive function previously published [22].

2. Methods

2.1. Subjects

All of the subjects with PD were recruited from the Brazil Parkinson Association. The diagnosis of idiopathic PD was confirmed by a movement disorders specialist in accordance with UK Parkinson's Disease Society Brain Bank diagnostic criteria [27]. Eligibility criteria were: I) Hoehn and Yahr stage between 2 and 3, II) stable medication, III) age between 50 and 80 years, IV) not being engaged in any exercise training (*e.g.*, aerobic and/or resistance training) in the past three years, V) not presenting with a neurological disorder other than PD, VI) not having significant arthritis, cardiovascular disease, and cognitive impairment by Mini-Mental State Examination (score < 23) [28]. The University's Ethical Committee (approval number – 2011/12) approved the experimental procedures associated with the present trial, which was registered at the National Clinical Trial (www.ensaiosclinicos.gov.br; RBR-53S3RK). Subjects signed an informed consent form after being fully informed of experimental procedures involved in the present study.

2.2. Procedures

We conducted the instability resistance training trial in PD (IRTT-PD [prospective, single center, parallel-group, randomized controlled trial]) between March 2013 and September 2014. Importantly, balance and fear of falling are secondary outcomes of our IRTT-PD study. The primary outcome measures have been previously published [22]. Subjects were assessed in the clinically "on" state (fully medicated) within 1.5 to 2 h of taking their morning dose of dopaminergic drugs. Balance, body stability, fear of falling, cognitive function, and lower limb force production capacity were assessed at baseline and at the end of experimental period (*i.e.,* 12 weeks), in the same order and at the same time of day (in the morning). A physical therapist, masked to the experimental design, assessed balance, fear of falling and cognitive function indices on two consecutive days. On the first day, the cognitive function outcome (Montreal Cognitive Assessment [MoCA]) was assessed. On the second day, balance was assessed using both the Balance Evaluation Systems Test (BESTest), and the Biodex Balance System® (*i.e.* overall stability index), and fear of falling was assessed using the Falls Efficacy Scale-International (FES-I). BESTest was chosen as a clinical balance outcome because this test is widely used in clinical practice, valid, reliable, low cost, and assess several underlying systems involved in balance control [29,30]. Overall stability index estimated by the Biodex Balance System® was chosen as a laboratory-based measure of balance, due to its high reliability and validity for an aged matched healthy population[31]. FES-I was selected as an index of fear of falling because it has the highest reliability index among the available tests used for subjects with PD [32]. Following, maximum ballistic voluntary isometric contraction (MBVIC) tests of the knee extensor and plantar flexor muscles of the most affected leg were performed to assess changes in peak torque [23]. Finally, subjects were classified into quartiles based on their timed-up-and-go test score. Subjects from each quartile were randomly assigned to the non-exercising control group (C), RT group, or RTI group [22].

2.3. Outcome measures

BESTest is comprised of 36 items grouped into six sections as follow: (I) biomechanical constraints, (II) stability limits/verticality, (III) anticipatory postural adjustments, (IV) reactive postural responses, (V) sensory orientation, and (VI) stability in gait. Total BESTest (BESTest total) score is obtained by dividing the actual score by the maximum score (*i.e.,* 108 points) and, then multiplying by 100. Individual section scores are obtained in a similar fashion. The closer the score to the maximum score the better is one's balance [29]. The BESTest total score and the BESTest sections scores were used for analysis.

Biodex Balance System® (Biodex®, Inc., Shirley, NY, USA) is comprised of a movable balance platform that provides up to 20° of surface tilt in a 360° arc of motion. Subjects followed the complete fall risk protocol suggested by the Biodex Balance System®, which is consisted of 12 dynamic stability levels being level 12 the most rigid and level 1 the most unstable. The main outcome measure is the overall stability index that represents the total variance of the platform displacement (anterior/posterior and medial/lateral stability index), measured in degrees, with higher scores indicating worse postural stability [33,34]. The formula ($OSI = [(\Sigma(0-Y)^2 + \Sigma(0-X)^2 \cdot \text{number of samples}^{-1})]^{\wedge 0.5}$), where Y and X represent the degree of platform tilt in the sagittal and frontal planes respectively, was used to calculate the overall stability index. Subjects performed three attempts and the average value of these attempts was used for analysis.

Subjects answered how concerned they were about the fear of falling if they had to perform 16 different activities. Responses were provided using a four-point scale (not at all, somewhat, fairly, or very concerned). Test score ranges from 16 to 64 (higher = worse) [32]. The FES-I score was used for analysis.

MoCA was used to assess changes in cognitive function from pre- to post-training [35–37]. The assessment was conducted in a quiet room without distractions by a physical therapist trained in the administration of the MoCA questionnaire. MoCA's maximum score is 30 and a score of ≤25 indicates mild cognitive impairment [38,39]. A point was added to the total score for individuals with 12 or fewer years of education. MoCA assesses seven cognitive domains, such as visuo-spatial and executive functions (5 points), naming (3 points), attention (6 points), language (3 points), abstraction (2 points), delayed recall (5 points), and orientation (6 points). The compound MoCA score was used for further analyses [35–37].

Peak torque of knee extensors and plantaflexors were assessed using Biodex System 4, Biomedical Systems®, Newark, CA, USA as described previously [23]. In brief, subjects were seated in the isokinetic dynamometer chair in an upright position. Following, they performed a