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Original research

Whole-body vibration exercises improving the functionality of the Chronic Obstructive Pulmonary Disease individuals: a quasi-experimental non-randomized clinical trial comparing two different postures

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Abstract

Background: Whole-body vibration exercises (WBVE), inserted on the Pulmonary rehabilitation (PR) program of chronic obstructive pulmonary disease (COPD) individuals can improve the exercise capacity, postural control and muscle power. This study evaluated the functionality of the COPD submitted to WBVE, comparing two different postures on the vibrating platform. **Methods:** The WBVE protocol (5 bouts, 1 time per week for 6 weeks, 25Hz, 2.5 of peak-to-peak displacement) were performed on a side-alternating vibratory platform (SAVP). Two different postures were adopted: the Siting group (SitG) were sitting in a chair with the hands maintained in contact with their knees and the Stand group (StandG) were standing with 30º knee flexion on the SAVP; both positing the foot on the base of the SAVP. The functionality was assessed by the Short Physical Performance Battery (SPPB). **Results:** 38 COPD individuals completed the WBVE protocol. Significant ($p \leq 0.05$) improves was presented by the SitG (balance test p=0.03; 3mSG test p=0.05; 5CS test p=0.04; total score p=0.003) and StandG (3mSG test p=0.02). The body mass index (BMI) and dyspnea had a negative correlation (r=-0.10, p=0.65 and r=-0.25, p=0.26) and positive correlation (r=0.19, p=0.44 and 0.10, p=0.69) with the total score of the SPPB, for SitG and StandG respectively. **Conclusion:** WBVE can be considered a safe, suitable kind of exercise on the PR program for COPD individuals, improving their functional capacity and minimizing the exacerbation of symptoms such as dyspnea. Additionally, the SPPB showed an adequate tool to identify the functional parameters of this population.

Keywords: Chronic Obstructive Pulmonary Disease, Quality of Life, vibration, exercise, Functional Performance, Rehabilitation

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1. Introduction

Chronic obstructive pulmonary disease (COPD) is one of the three main causes of death worldwide, and it is also a major cause of chronic morbidity (1), generally, it manifests at an older age as part of multimorbidity, but there is increasing evidence that events early in life contribute to impaired lung function in adults (2).

COPD represents an important public health challenge that is both preventable and treatable. COPD individuals often have respiratory related symptoms (1) as dyspnea, fatigue and shortness of breath, which can lead to functional limitations (3,4), influencing quality of life and mortality, and are associated with increased longitudinal risk of disability (5). Smoking cessation programs, increasing physical activity, and early detection and treatment of comorbidities are further key components to reduce the burden of the disease (6).

To reinforce the importance of the regular physical activity, the pulmonary rehabilitation (PR) program has been conventionally used for COPD individuals to improve the physical performance, reduces dyspnea and other common exacerbations, and offering a better quality of life to COPD individuals (7,8,9,10). For Yang and Yang (9), the improvement of physical and mental conditions and the return to family and society more promptly of the individuals are the goals of PR.

Due to the presence of skeletal muscle dysfunction and cardiovascular diseases as main concerns in the management of COPD individuals (11,12,13), the exercise training has been encouraged to improve physical performance in COPD (1). Authors considered that exercise is a key component of PR, highlighting the individualized exercise training, beneficial for COPD individuals (14,15).

Different types of exercises might be used in the PR program (16-28) improving the muscle strength and quality of life, and increasing the exercise capacity in these individuals, including the whole-body vibration exercise (WBVE) as shown in Figure 1. The WBVE (29-32), which has also been understood as systemic vibration therapy (33), generated due to transmission to an individual of mechanical vibrations produced in a vibrating platform (VP), has been considered a safe, suitable and recommended kind of exercise including on a PR program to perform by COPD individuals (30,31,34). WBVE is an exercise or treatment method used in sports, physiotherapy and rehabilitation (34). WBVE is able to counteract age-related multi-organ deterioration and/or degenerative diseases, promoting improvement in quality of life and potential reduction in public health costs (35). Previous studies showed the WBVE favored the enhanced exercise tolerance, no exacerbations of the disease, as a feasible and safe exercise modality including in individuals with severe COPD (32). A narrative review (29) reported effects of WBVE, as a component of the PR in COPD individuals and evidenced the beneficial use of WBVE to improve functional performance of the lower limbs and quality of life of COPD individuals. Other authors reinforced that WBVE can be suggested as part of the procedures involved with the PR program for COVID-19 infected subjects, even in intensive care unit's settings (36). As well as in comorbidities developed after this infection, COPD individuals can be assisted by this type of physical exercise still in the hospital environment, minimizing the evolution of the respiratory disorder.

Considering functional aspects, the most used physical performance tests in COPD individuals are field walking tests (37). Considered a tool to test lower extremity function, the Short Physical Performance Battery (SPPB) (38,39) is used as a screening tool to identify older adults who may benefit from interventions aimed at delaying or preventing age-related disability (39-42).

Agreeing several authors (43), although there is currently no cure for COPD, the available self-management strategies can result in improving the symptoms, slowing the disease progression, reducing the frequency of acute exacerbations, improving the patients' quality of life and minimizing health care utilization-associated costs.

In this sense, this current study aimed to evaluate the use of the WBVE as a one more PR´s modality of exercise for COPD individuals. It is hypothesized that the effects of WBVE promote significantly improve on the functional capacity of COPD individuals, suggesting this physical modality as one more option of exercise of the PR.

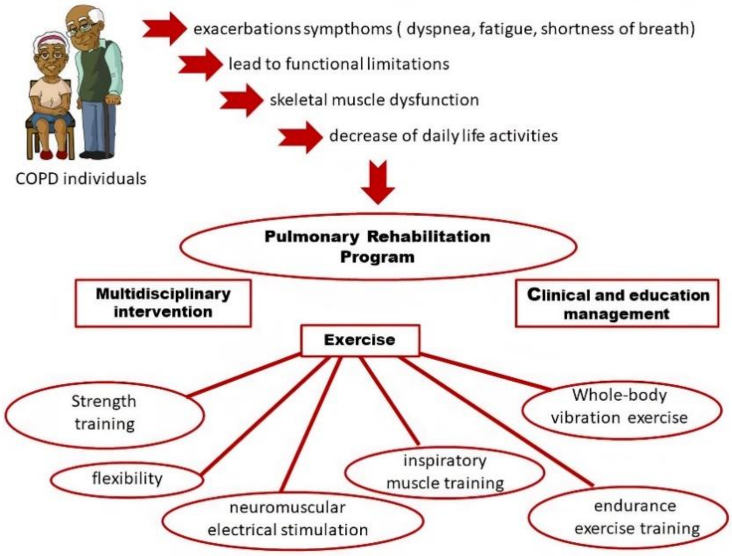

Figure 1. Pulmonary rehabilitation program and different modalities of exercises for COPD individuals.

2. Material and methods

2.1 *Design*

This current study is a quasi-experimental non-randomized clinical trial comparing two different postures. It was approved by the Research Ethics Committee of the *Hospital Universitário Pedro Ernesto* (HUPE), *Universidade do Estado do Rio de Janeiro* (UERJ) under protocol number (49219115.3.0000.5259) and is in accordance with the principles expressed in the Declaration of Helsinki. This intervention was based on the CONSORT guidelines (41). This study was also registered with ReBEC at number RBR-72dqtm and on the procols.io platform (dx.doi.org/10.17504/protocols.io.376grre). All individuals signed a consent form before any procedure. The study was performed, Rio de Janeiro, RJ, Brazil.

2.2 Patients

The COPD individuals included in this study were recruited at the Department of Pneumology, *Policlínica Universitária Piquet Carneiro* (PPC), at the *Universidade do Estado do Rio de Janeiro* (UERJ). The COPD individuals performed the WBVE protocol at the *Laboratório de Vibrações Mecânicas e Práticas Integrativas* (LAVIMPI), PPC, UERJ, and the evaluations were performed before and after the intervention.

Inclusion criteria were subjects with diagnosis of COPD, cognitive ability to provide informed written consent, and ability to understand and complete questionnaires. Moreover, individuals of (i) both gender and (ii) outpatient at the PPC, diagnosed with COPD based on criteria established by the Global Initiative for Obstructive Lung Disease (GOLD) with stable disease with Expiratory Volume Forced in the 1st Second (FEV1) <50% and independents were enrolled (44). Exclusion criteria were ongoing exacerbation of COPD, inability to exercise, and comorbidities limiting the individual's physical performance more than the COPD alone (e.g., neurological disorder, severe angina); individuals with exacerbation of the disease for less than 3 months; some diseases, such as labyrinthitis, osteoporosis, decompensated cardiovascular disease or other respiratory diseases; malnutrition; "fear" to the movements on the VP or serious or incapacitating clinical illness, at the decision of the investigator, were considered.

Discontinued from the study was allowed for the COPD individuals that (i) made a request by personal reasons or no financial conditions, (ii) developed clinical conditions, such as heart disease or stroke, and became inappropriate in the opinion of the investigator or (iii) manifested adverse responses related to the WBVE.

Finally, thirty-eight COPD individuals performed the WBVE protocol (25 males and 13 females, 66.18±8.73 years). During this protocol, the blinding was provided: a first investigator did the assessments (baseline and after the WBVE intervention) and assigned participants to interventions; the allocation in two different groups (SitG x StandG) was randomly made by a group of investigators; and another investigator did the statistical analysis.

2.3 *Intervention protocol*

Side-alternating vibratory platform (SAVP) (Novaplate fitness evolution, DAF Produtos Hospitalares Ltda, from Estek, São Paulo, Brazil) was used. The WBVE protocol was performed at 5 bouts, once per week for 6 weeks, with 25Hz of frequency and 2.5 of peak-to-peak displacement. The working time (WT) of 1 min interposed with a rest time (RT) of 1 min was considered.

The COPD individuals were evaluated on baseline and after the 6 weeks WBVE protocol, divided in two groups: Sitting group-sitting on an auxiliary chair in front of the SAVP, with the hands maintained in contact with their knees (SitG) (Figure 2A) and Standing group-standing on the SAVP (StandG); both without footwear and with the foot on the base of the SAVP and knee flexion at 130º (Figure 2B).

2.4 *Anthropometric data*

Anthropometric parameters as blood pressure, heart and respiratory rate, pain level, were screened by the same examiner. Height was evaluated using an extensometer. Body composition, body mass index (BMI), fat mass, percent body fat, fat free mass and skeletal muscle mass were measured by bioimpedance analysis using a bioelectrical impedance analysis (BIA) (In Body 370, Korea) with multi-frequency and eight electrodes. Blood pressure, heart and respiratory rate were measured at resting condition, before and after each session, using an automated device (OMRON, model HEM-7113, China). Chronic conditions such as cancer, hypertension and diabetes were assessed by self-reporting.

Borg fatigue and dyspnea were assessed by Modified Borg scale, routinely used to quantify the perception of leg fatigue during physical exertion or functional capacity tests (45,46).

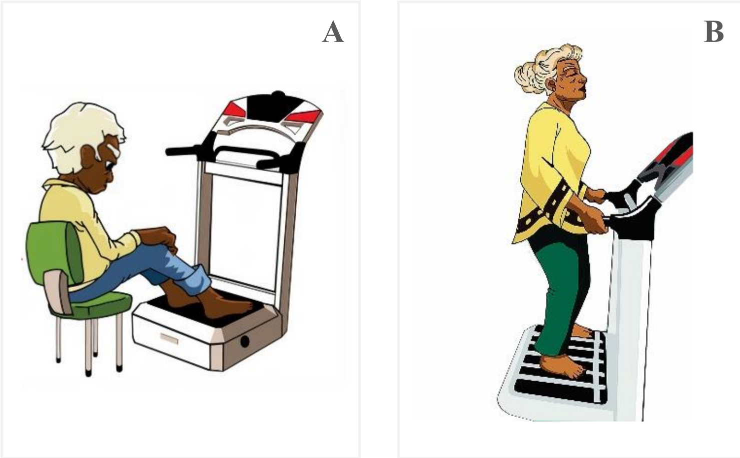

Figure 2. Individuals position on vibrating platform. (A) sitting position, (B) standing position - WBVE protocol

2.5 Short Physical Performance Battery

The SPPB is a reliable and valid (38) test of lower extremity function and was performed at baseline and immediately after the last WBVE session. The capacity parameters evaluated (balance, gait time and lower limb muscle strength) and interpreted in an associated way, have been considered valid and as a predictive factor for the global and lower limbs performance.

In this current study, the SPPB was assessed before and after the WBVE protocol (6 weeks) and it was performed with the supervision of an investigator, co-author of this work. The first test, (i) the hierarchical standing balance test, required that subjects maintain three stances for 10s each: side-by-side, semi tandem, and tandem; the second test, (ii) walking speed test, timed three-meter at habitual gait speed (3mGS); the third test, (iii) five-repetition chair stands (5CS) test, timed the muscle strength performed as fast as possible. All the three tests have possible scores ranging from 0 to 4 points, each test and then, a total score of SPPB from 0 to 12 points. The scoring (total of the 3 tests) represent: 0 to 3- disability or poor ability; 4 to 6- low capacity; 7 to 9-moderate capacity and 10 to 12- good capacity functional (38,40) The time of execution of the 3mGS test was registered before and after the WBVE protocol.

2.6 *Sample size and data analysis*

For a statistical power of 95 %, sample size of 6 subjects was calculated, using the formula [n= ((Zα/2. δ) / E)2] where, n=sample size; Zα/2 - critical value for the desired degree of confidence, usually: 1.96 (95%); δ - population standard deviation (SD) of the variable; E - standard error, usually: ± 5% of proportion of cases (absolute precision) or ± 5% of the mean (47). The values of mean±standard deviation (SD) 17.34(1.14) considered were reported in a previous study that assessed the SPPB on WBVE intervention (40).

Normality data distribution was evaluated using the Shapiro-Wilk test. Wilcoxon test for paried analysis (before and after the WBVE protocol) and unpaired t tests for comparative analysis intergroups were used. The results were described as mean±SD, percentual or score of the tests (min-max). The $p \leq 0.05$ was used for significance level. Pearson correlation analysis was performed to determine the relationships between BMI, dyspnea and the total score of the SPPB of the COPD individuals. The software used for all analysis was the Graph Pad Prism 6.0.

3. Results

Initially, 75 COPD individuals were recruited and after the criteria analysis, 54 subjects were assessed eligibility, allocated in SitG (n=30) and StandG (n=24). 16 subjects discontinued the study, and thirty-eight COPD subjects concluded the WBVE protocol (Figure 3).

Table 1 presents the baseline characteristics of COPD individuals. Participants older adults (25 males and 13 females, aged between 64 and 70 years) classified between overweight and extreme obesity, showed a mean: BMI of 28.51 kg/m^2 [1.67 SD] and 39.5 kg/m2 [11.78 SD], RR of 20.62 breaths/min [0.82 SD] and 19.75 breaths/min [0.48 SD], for SitG and StandG respectively. This last parameter (RR) reinforces the respiratory manifestation characteristic of this population, with a borderline respiratory rate (20 breaths/min), which requires caution in the execution of daily activities as a recommendation for the practice of exercises. Considering the Borg scale, participants from both groups manifested a score between 1.38 -1.40, while in the analysis of the Borg dyspnea scale they ranged between 1.08 -1.64. All the participants reported a low pain level [0.57 - 0.76 NPS score], 71% are diagnosed with hypertension, 81% T2DM and 95% smokers. The data presented in this table show the homogeneity between the groups.

Table 2 presents each score of the three tests of the SPPB and the total score in both groups. The time of the walking test also is show. A significant ($p \leq 0.05$) improvement of the functionality was found in SitG (balance test $p=0.03$; 3mSG test $p=0.05$; 5CS test $p=0.04$; total score $p=0.003$), and in StandG (3mSG test $p=0.02$). The Walking time (sec) presented significant decrease after the WBVE protocol in both groups (intragroup).

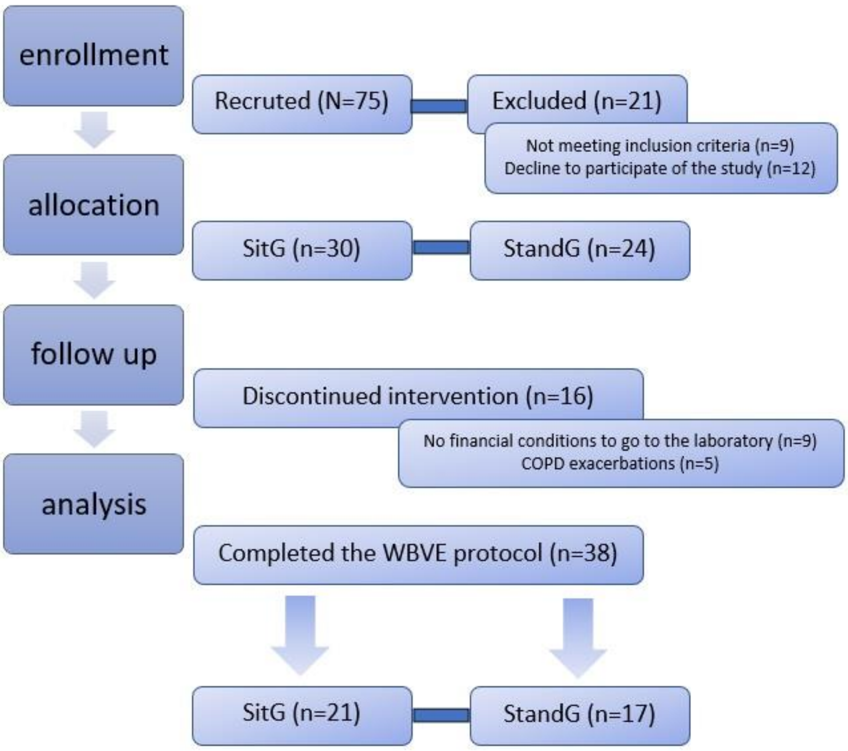

Figure 3. CONSORT Flowchart.

When analyzing the correlation between the degree of functionality of individuals with COPD, with dyspnea and BMI, relevant results are found (Figure 4). In the SITG (Figure 4A and 5B), BMI and dyspnea had a negative correlation with the total SPPB score (r=-0.10, *p*=0.65 and r=-0.25, *p*=0.26 respectively). This demonstrates that the COPD individuals able to achieve a greater degree of functionality, through the practice of activity such as WBVE, tended to decrease the manifestation of dyspnea and reduction of BMI. The StandG presented a positive correlation (r=0.19, *p*=0.44 and 0.10, *p*=0.69), analyzing the same parameters (Figure 4C and 4D).

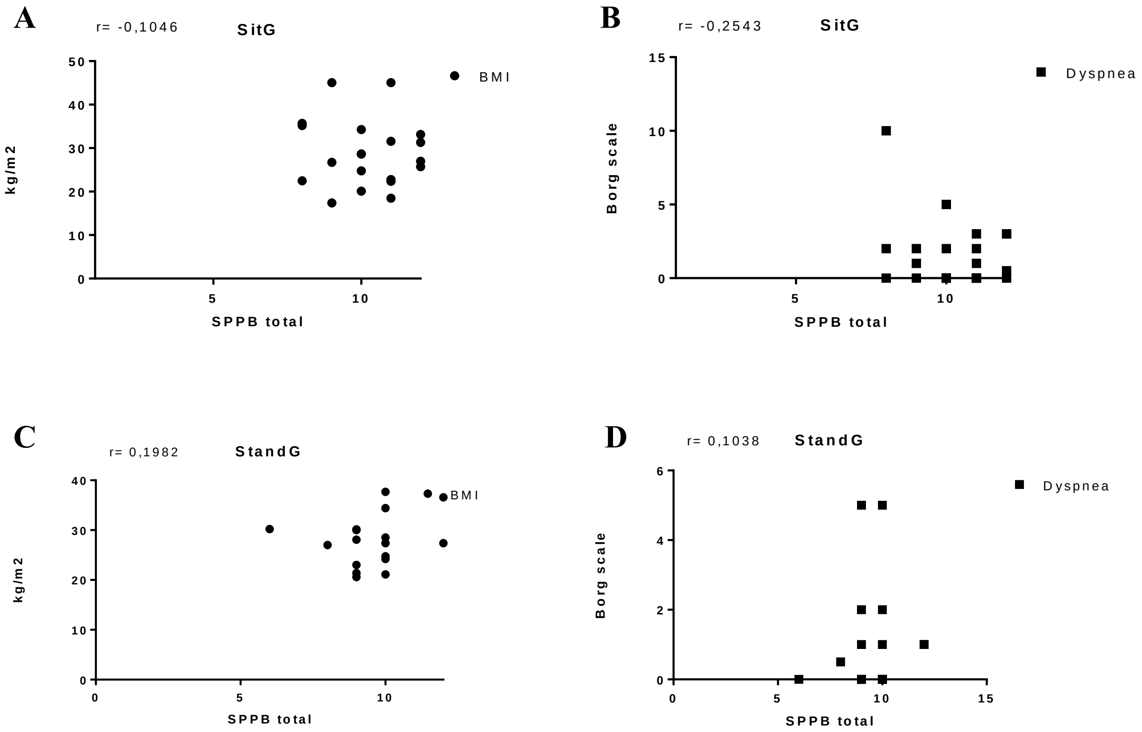

Figure 4. Pearson correlation (r) analysis. Fig. 4A, (r) analysis - the total SPPB score *x* BMI of the siting group (SitG). Fig. 4B, (r) analysis - the total SPPB score *x* Borg scale (SitG). Fig.4C- Pearson correlation (r) analysis: the total SPPB score *x* BMI of the stand group (StandG). Fig.4D, (r) analysis - the total SPPB score *x* Borg scale of the StandG. Short Physical Performance Battery (SPPB); body mass index (BMI).

4. Discussion

The static balance and a better gait execution time are functional aspects evaluated by the SPPB in this current study. These findings confirm that the WBVE can be considered as a safe, suitable, and recommended kind of exercise to perform by COPD individuals to improve their functional capacity.

In COPD individuals, the PR programs are the most effective non-pharmacological intervention for improving health status (13). Authors reinforced that before training, the rehabilitation therapists should measure different responses and conditions of COPD individuals, including symptoms, endurance and strength, and health-related quality of life (14). As well as after a certain time of training, it recommended the follow up to evaluate the subjects' performance and the program effectiveness.

There is a compelling evidence base for benefits of PR programs in COPD, reversing the effects of deconditioning, improving exercise capacity and quality of life. The cost of PR is significantly better than for pharmacotherapy in COPD (10).

Considered as an appropriate training strategy for COPD individuals, some authors (25) agree that strength training combined with endurance training produce more improvements in muscle power and endurance performance, besides to prevent the cognitive decline and the associated comorbidities. Benefits responses for COPD individuals as the improvement of the exercise capacity, postural control, and muscle power (32) have been reported.

Gloeckl *et al*. (44), investigated 48 patients with severe COPD (FEV1:37 ±7% predicted) and low exercise performance (6 min walk distance (6MWD):55 ±10%predicted) during a 3-week inpatient pulmonary rehabilitation. After the WBVE protocol, they found that WBV can improve balance performance and muscular power significantly more compared to conventional balance training.

Particularly, the SPPB is a useful tool for evaluating physical performance in COPD individuals during the PR, is intended for use in seniors; there is also an increased interest to evaluate the physical responses in younger, physically frail or with chronic diseases (40). In previous study (38), the investigators concluded that gait test of the SPPB was associated with psychological factors.

As in this current study, the SPPB already was previously used to assess the functionality of individuals with different chronic diseases (40), showing significant responses.

The findings regarding the correlation of Person between dyspnea, BMI and total SPPB score deserve special attention in this study. The negative correlation in SITG stands out, since we understand the importance of controlling exacerbation of symptoms, such as dyspnea. Anzueto and Miravitlles (46) pointed that dyspnea is an important symptom in COPD, where it is associated with limited physical activity, increased anxiety and depression, decreased health-related quality of life, and reduced survival. Defined as an uncomfortable sensation of breathing, the dyspnea needs to be management because it is multifactorial, affects quality of life and it is the main cause of disability in this population (47).

In this study, another characteristic observed was BMI. Karanikas *et al*. (48) pointed that the nutritional and functional status derangement is a commonly seen in COPD patients, and this is associated with a higher disease severity and mortality. They found in an observational study, the body composition parameters and functional status related to acute exacerbation risk incidence.

Considering that the obesity contributes to respiratory symptoms and exercise limitation (49), it is relevant to investigate this relationship. The seated position (SitG) proposed in this study showed a negative correlation, when was analyzed the BMI and the total score SPPB. StandG expressed a positive correlation response. Although the results were not significant (p>0.05), knowing previously the importance of the effects of WBVE on body weight control, makes us want to expand and deepen this investigation.

The strength of this current study is justified in the need to increasingly be offered to COPD individuals, appropriate exercise modalities for their clinical conditions. Agreeing with Sritharan *et al*. (50), the practice of the any physical activity by COPD individuals assists in relies on dyspnea symptoms, anxiety, fatigue, and increases quality of life and functional capacity. These authors also reinforce that it need to be implemented in daily life in people with COPD. Specifically in the current scenario in which we face a pandemic caused by COVID-19, the regular practice of physical activity needs to be massively stimulated, given its already known numerous benefits that culminate in the improvement of quality of life. However, it is also necessary to offer modalities that are related to each population. The WBVE has been presented as easy to perform, well tolerable, accessible and adaptable for different populations with chronic clinical worsening, including COPD individuals. Additionally, in this study, we found that in view of the benefits presented, the sitting position can be recommended and adhered to the WBVE protocol.

4.1 *Limitations*

As limitations of this work, its important highlight that the SPPB may not detect changes in high functioning subjects because of ceiling effects, as well longer physical performance tests may identify functional limitations due to dyspnea more accurately than the shorter SPPB. Additionally, other modalities of exercise and the physical activity levels of the COPD individuals did not consider during this current study. Another important limitation to be declared refers to the absence of the control group. In this study, the individuals allocated in the control group were evaluated (baseline), continued to practice usual daily life and would return after 6 weeks. However, with the pandemic caused by COVID-19, many patients were prevented from continuing the proposed protocol and their reassessments were not performed. Thus, the comparison between control and intervention groups was not possible.

5. Conclusion

This study showed that the WBVE can be considered a safe, suitable, and recommended kind of exercise for COPD individuals, inserted on the PR program to improve their functional capacity. During the performance of the WBVE, sitting posture is feasible and effective, without causing exacerbation of symptoms such as dyspnea. Additionally, the SPPB is an evaluation tool capable of identifying the improvement of the functional parameters in this population.

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Author contributions

Literature search - Laisa Liane Paineiras-Domingos, Eliane de Oliveira Guedes-Aguiar, Bruno Bessa Monteiro-Oliveira, Luiz Felipe Ferreira de Souza; **Data collection**- Laisa Liane Paineiras-Domingos, Eliane de Oliveira Guedes-Aguiar, Bruno Bessa Monteiro-Oliveira, Luiz Felipe Ferreira de Souza; **Study design**- Laisa Liane Paineiras-Domingos, Eliane de Oliveira Guedes-Aguiar, Danúbia Cunha Sá-Caputo, Redha Taiar, Mario Bernardo-Filho; **Analysis of data**- Laisa Liane Paineiras-Domingos, Eliane de Oliveira Guedes-Aguiar, Bruno Bessa Monteiro-Oliveira; **Manuscript preparation**- Laisa Liane Paineiras-Domingos, Eliane de Oliveira Guedes-Aguiar, Bruno Bessa Monteiro-Oliveira; **Review of manuscript**- Dulciane Nunes Paiva, Danúbia Cunha Sá-Caputo, Redha Taiar, Mario Bernardo-Filho.

Conflicts of Interest

The author declares no conflict of interest.

Ethical approval: This work was approved by the *Comitê de Ética em pesquisa de seres humanos do Hospital Universitário Pedro Ernesto* (HUPE), *Universidade do Estado do Rio de Janeiro* (UERJ), (CAAE: 49219115.3.0000.5259), also registered with ReBEC (RBR-72dqtm) and on the procols.io platform (dx.doi.org/10.17504/protocols.io.376grre).

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