

Original article (short paper)

Pulmonary rehabilitation and whole-body vibration in chronic obstructive pulmonary disease

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Abstract—The Whole-Body Vibration (WBV) has been described as an alternative therapeutic resource for patients with Chronic Obstructive Pulmonary Disease (COPD) with similarity to the Pulmonary Rehabilitation Program (PRP). The aim of the study was to compare PRP to WBV on functional capacity and quality of life in patients with COPD. Twenty individuals with COPD were assigned to PRP and WBV, who were evaluated regarding their lung function, functional capacity and quality of life through spirometry, 6-minute walk test (6MWT) and St. George Respiratory Questionnaire (SGRQ), respectively. The main results for the WBV group were, there were improvements in the walked distance on the 6MWT and in the symptoms and total domains of the SGRQ. For the PRP group, we observed improvement in the activity, impact and total domains of SGRQ. We could conclude that the WBV group increased the walked distance in regard to the PRP group and both programs improved the quality of life.

Keywords: COPD, exercise therapy, quality of life, rehabilitation, WBV

Introduction

According to World Health Organization, chronic obstructive pulmonary disease (COPD) is a major cause of morbidity and mortality in the world and represents a threat to public health. The number of deaths due to tobacco use has reached the amount of 4.9 million per year worldwide, corresponding to more than 10 thousand deaths per day (Hurd, 2000; *Global Initiative for Chronic Obstructive Lung Disease - GOLD*, 2015). The complexity of the implications of COPD results in high economic costs to public health due to frequent hospitalizations and long-term drug use (GOLD, 2015; Spruit, Troosters, Trappenburg, Decramer & Gosselink, 2004; Shrikrishna & Hopkinson, 2009).

The pulmonary rehabilitation program (PRP) as a strategy for treating muscle disorders and physical reconditioning in COPD patients has shown benefits for this population (Spruit *et al.*, 2013). There are reports in the literature that well-targeted pulmonary rehabilitation programs result in reduction of respiratory symptoms, improvement in ability to perform exercises, increased peripheral muscle mass, reducing the frequency of exacerbations and hospitalizations and consequent increasing the expectation of quality of life for these individuals (Spruit *et al.*, 2013; Troosters, Gosselink, Langer & Decramer, 2007). However, some patients are intolerant to exercise, and therefore, they do not fully benefit from a conventional pulmonary rehabilitation program (Gloeckl *et al.*, 2012). Pleguezuelos *et al.* have used the whole-body vibration (WBV) as a therapeutic approach for improving muscle strength as a more tolerable training alternative for patients with COPD (Pleguezuelos *et al.* 2013).

Muscle activation principle occurs through the “tonic vibration reflex”, when influences of spinal reflex mechanisms

contribute to increased muscle strength (Macfield, Hagbarth, Gorman, Gandevia & Burke, 1991; Kouzaki, Shinohara & Fukunaga, 2000). Although the WBV has been used in elderly people, those that have cystic fibrosis and had chronic strokes (Beaudart *et al.*, 2013; Tankisheva, Bogaerts, Boonen, Feys & Verschueren, 2014, Rietschel, Van Koningsbruggen, Fricke, Semler & Schoenau, 2008), there are few studies investigating its use in patients with clinically stable COPD (Gloeckl *et al.*, 2012; Pleguezuelos *et al.* 2013). Given that individuals with moderate to severe COPD may have lower tolerance to the efforts, the WBV seems to be a plausible alternative to conventional training programs for these patients, since the PRP requires greater demand for physical exercise when compared with WBV. Thus, this study aimed to compare the effects of PRP and WBV on functional capacity and quality of life in patients with COPD.

Methods

Participants

Twenty male and female COPD subjects recruited from referral hospitals for the treatment of lung diseases in Recife, Brazil were included, all agreed to participate in the study. Subjects were selected according to the inclusion criteria defined as follows: diagnosis of COPD according to GOLD with moderate to severe obstruction, active smoking history or passive exposure to pollutants, forced expiratory volume in one second/forced vital capacity (FEV_1/FVC) < 70% post-bronchodilator and FEV_1 < 80% from the expected (GOLD,

2015), who presented ability to perform the 6-minute walk test and were clinically stable during the study period. We excluded individuals with associated comorbidities (systemic arterial hypertension, severe pulmonary hypertension, myocardial infarction, congestive heart failure and neuromusculoskeletal changes), with cognitive, hearing or visual impairment.

Study Design

The training program was developed in Cardiopulmonary Laboratory of the Federal University of Pernambuco. All volunteers were properly informed about the risks and benefits of the study and only those who signed the free and informed consent form were included in the sample.

This project was approved by Ethics Research Committee of the Health Sciences Center of the Federal University of Pernambuco by record CAAE- 0108.0.172.000-11.

Sample calculation

For sample calculation, a pilot study was performed of 5 patients with COPD and used the mean and standard deviation of the variables distance walked (DW) obtained in the six-minute walk test (6MWT) and the total domain of the questionnaire of Saint George Respiratory Questionnaire (SGRQ_{TOTAL}) after intervention. Adopting an alpha 0.05 and a power of 0.95, a minimum of 8 participants to the vibrating platform group was found (DW= 349.00 ± 32.58m; SGRQ_{TOTAL} = 29.20 ± 3.28) and for the PRP (DW= 466.00 ± 18.01m; SGRQ_{TOTAL} = 18.87 ± 5.22). Considering a sample loss of 20% the final sample consisted of 10 participants for each group. The sample calculation was performed in GPower software version 3.1.9.2 (Faul, Erdfelder, Lang & Buchner, 2007; Faul, Erdfelder, Buchner & Lang, 2009).

Evaluation Procedures

The evaluations were performed at the beginning and end of the programs. Were evaluated the functional capacity by the 6MWT, the quality of life using the SGRQ and pulmonary function by spirometry.

The 6MWT was performed in a 34 meters length open corridor duly signalized. During testing, the patients were monitored for peripheral oxygen saturation and heart rate using a pulse oximeter and transcutaneous (Nonin Onyx 9500, Plymouth, MN). At the end, the distance walked (DW), walking time (WT) and the perception of effort index (PEI) were recorded through Borg's visual scale (Borg, 1982). The tests were performed according to *American Thoracic Society* (ATS, 2002) recommendations.

The evaluation of quality of life from the SGRQ, addressed the aspects related to four domains where the respiratory disease inflicts on the patient: (I) total: summarizes the impact of the disease on the health condition, (II) symptoms: related to the frequency and severity of the disease, (III) activity: include

activities that cause dyspnea or are limited by dyspnea and (IV) psychosocial impact: includes social functioning and psychological disorders resulting from the disease. The points for each answer were added together and the total was referred to as a percentage of the maximum value. Values above 10% reflect quality of life changed in that domain. Changes equal to or greater than 4% after an intervention in any domain or in the total score indicate any significant changes in the quality of life of patients (Souza, Jardim & Jones, 2000).

The evaluation of pulmonary function was performed using a properly calibrated portable spirometer (Micromedical Microloop MK8, Kent, England) according to the recommendations of the ATS (Miller *et al.*, 2005). The evaluated parameters were the forced expiratory volume in one second (FEV₁), forced vital capacity (FVC) and relation FEV₁/FVC and COPD severity classification according to the *GOLD* (GOLD, 2015).

Intervention

1. Protocol for PRP:

The PRP included aerobic activities on a treadmill and muscle strength in weight training equipment, individually prescribed and according to the clinical condition of the patient with COPD, composed of three weekly sessions on alternate days for 12 weeks (Casaburi & ZuWallack, 2009). Aerobic training on the treadmill without incline lasted 30 minutes per session. Every 5 minutes, blood pressure, peripheral oxygen saturation and the perception of effort index (PEI) were assessed for controlling cardiovascular parameters. From the incremental test was possible the monthly adjustment of the treadmill speed at 75% of maximum load.

Skeletal muscle training approached muscle groups of the upper limbs and lower limbs. To calculate the load to be used in training, the test of a maximum repetition was performed (Pereira & Gomes, 2003), and the prescribed load calculated at 60% of that obtained in this test. For the upper limbs, 3 sets of 8 repetitions for the elbow flexors, elbow extensors, shoulder flexors and adductors of the upper limbs were performed. The number of sets and repetitions for the lower limbs followed the same parameters provided for the upper limbs and muscle groups addressed were flexors and knee extensors.

During the training patients were instructed to use pursed lip breathing.

2. Protocol for WBV:

The intervention program on the vibration platform (Power Plate MY3 – United Kingdom) was developed with three weekly sessions on alternate days for 12 weeks. By the protocol, the first five to 10 minutes were destined to overall muscles stretching, in the first four weeks. The duration of the vibration was 10 minutes and the exercises were performed in a static position with semi-flexed knees. The amplitude of vibration used was 2 mm and lasted 30 seconds, interspersed with a 60 second rest period in the standing position alongside the platform. During the following four weeks, readjustments were made at the time of vibration for 60 seconds and the total training time of 15 minutes, keeping the 30 seconds rest interval between vibrations

and amplitude used of 4 mm. From the eighth week, the patient stands on the platform for 20 minutes, 4 mm amplitude and 30 seconds rest between the vibrations. Along the training, every 5 minutes, blood pressure, peripheral oxygen saturation and the perception of effort index (PEI) were assessed for control of cardiovascular parameters.

Statistical analysis

Initially we performed the Shapiro-Wilk normality test for all variables. The means, standard deviations and frequency for the 6MWT variables (DW and WT) were calculated, SGRQ (impact, symptoms, activity, and total domains). To compare the outcomes mentioned among WBV and PRP we used the unpaired Student's *t*-test and the comparison between the initial and final evaluations of each group, we used paired Student's *t*-test. To evaluate the minimum clinically important difference

(MCID) the four of the SGRQ (total, symptoms, impact and activity) was considered a reduction of 4% (Dourado, Antunes, Tanni & Godoy, 2009) and for DW was considered an increase of 35m at the end of training of groups domains (Puhan *et al.*, 2008). Subsequently patients were categorized as 'reached the MCID' and 'not reached the MCID' and conducted the comparison to frequency of occurrence between the PRP and WBV groups using Fisher's exact test. Data analysis was performed using the software SPSS (SPSS Inc., Chicago, IL, USA) version 20.0 and adopted the significance level 5% ($p < 0.05$) for all tests.

Results

The programs were well accepted by the patients and the adhesion was complete by the end of the sessions. The monitoring flowchart of the participants is shown in Figure 1.

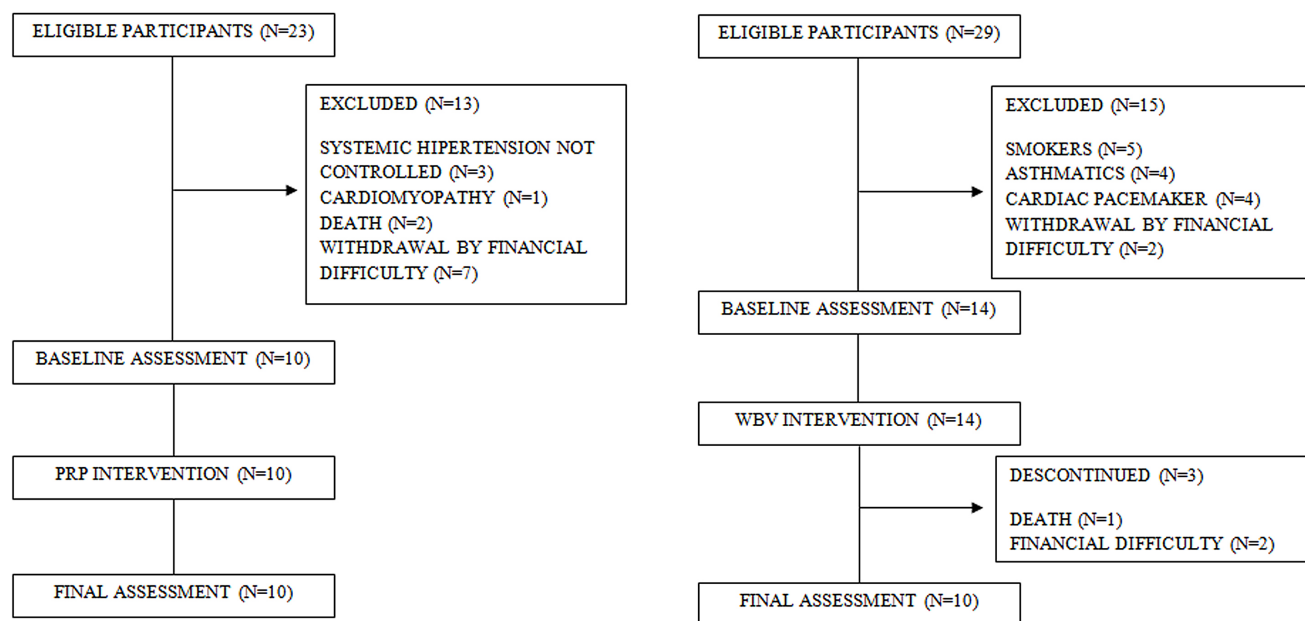


Figure 1. Flow chart of participant selection between groups.

No adverse effects were reported during the study period. In general, both groups were on bronchodilators, anticholinergics, and corticosteroids therapy. The anthropometric, spirometry and smoking-related characteristics of participants in the study are shown in Table 1.

When the groups were compared (PRP and WBV), there was observed reduction of the SGRQ symptoms domain only for the WBV group at the end of the training programs ($p = 0.03$). Both groups (PRP and WBV) showed improvement in total domain (SGRQ_{TOTAL}) at the end of interventions ($p = 0.01$ and $p = 0.02$ respectively). In the PRP group was found improvement to the impact and activities domain of the SGRQ ($p = 0.03$ for both),

while for the WBV group improvement was observed only for the symptoms domain of the questionnaire ($p = 0.001$).

Regarding the performance in the 6MWT, there was observed increase in distance walked only for the WBV group when the final – initial comparison was done ($p = 0.002$). However, there was not observed a difference between the averages of the groups (DW = 64.3m; IC 95% = - 29.01 to 157.65; $p = 0.235$). The other variables (WT and PEI) show no changes (Table 2).

The evaluation of the minimum clinically important difference (MCID) to the quality of life for SGRQ in patients with COPD who underwent PRP and WBV noted that 70% and 80%

of the patients reached the minimum difference ($\chi^2= 0.267, p= 0.60$) for the symptoms domain, 90% and 70% ($\chi^2= 1.250, p= 0.26$) for the activity domain, 80% and 70% ($\chi^2= 0.267, p= 0.60$) for the impact domain respectively and total domain of 90% for

both groups ($\chi^2= 0.000, p= 1.00$). The MCID for the distance walked on 6MWT was obtained in 50% and 80% of patients in the PRP and WBV programs respectively, not being found differences between groups ($\chi^2= 1.978, p= 0.16$).

Table 1. Baseline characteristics of patients with COPD allocated in the pulmonary rehabilitation program (PRP) and whole body vibration program (WBV).

	PRP GROUP (n=10)	95% CI	WBV GROUP (n=10)	95% CI
Age (years)	65.20 ± 4.15	62.78 – 69.40	66.30 ± 9.17	59.73 – 72.87
Wheight (Kg)	61.74 ± 9.20	56.26 – 68.18	62.14 ± 13.47	52.49 – 71.78
Height (m)	1.61 ± 0.05	1.58 – 1.66	1.56 ± 0.08	1.50 – 1.62
BMI	23.43 ± 2.25	22.05 – 24.94	25.11 ± 5.57	21.12 – 29.09
Smoke (years)	40.00 ± 9.97	34.32 – 48.59	40.90 ± 10.60	33.31 – 48.49
Cigarettes p/day	28.00 ± 18.13	17.28 – 40.90	25.50 ± 12.12	16.83 – 34.49
Packs/year	54.55 ± 31.49	32.02 – 77.08	50.15 ± 25.71	31.75 – 68.54
Comorbidities				
SAH	7 (70%)		5 (50%)	
DM	-		3 (30%)	
Cancer	1 (10%)		2 (20%)	
Others	3 (30%)		4 (40%)	
2 or more comorbidities	80%		50%	
FEV ₁ (%)	41.81 ± 21.31	28.49 – 55.70	30.40 ± 12.36	21.56 – 39.24
FVC (%)	60.65 ± 17.96	48.58 – 72.72	52.31 ± 14.23	40.56 – 62.63
FEV ₁ / FVC (%)	52.63 ± 15.59	43.18 – 63.23	47.44 ± 12.13	38.76 – 56.11
Classification				
GOLD 2	4 (40%)		-	
GOLD 3	2 (20%)		6 (60%)	
GOLD 4	4 (40%)		4 (40%)	

Note: n= number of subjects; BMI= body mass index; FEV1= forced expiratory volume in one second; FVC= forced vital capacity; FEV1/ FVC= FEV1/ FVC ratio; SAH= Systemic Arterial Hypertension; DM= Diabetes Mellitus; Others (kidney stones, arthrosis, varicose veins, depression, cataracts, Parkinson's disease); GOLD (Global Initiative for Chronic Obstructive Lung Disease); CI (confidence interval).

Table 2. Comparison between the PRP and WBV groups to the beginning and end of the training.

	PRP GROUP		WBV GROUP		95%CI	p-value	
	Begin (n=10)	End (n=10)	Begin (n=10)	End (n=10)		Between-group differences	Intergroup analysis
WT6min							
WT (sec)	311.09 ± 84.60	328.10 ± 79.14	301.40 ± 102.95	285.20 ± 64.13	-18.70 – 110.30	NS	NS
DW (m)	391.45 ± 144.89	444.50 ± 95.73	349.07 ± 121.64	380.20 ± 102.77	-16.30 – 167.17	NS	0.002 [†]
EPI	11.80 ± 1.68		11.20 ± 2.48		-1.27 – 2.50	NS	
SGRQ							
Symptom	40.83 ± 23.90	27.90 ± 17.96	26.49 ± 13.80	13.09 ± 9.47	-0.64 – 26.35	0.03*	0.001 [†]
Activity	56.93 ± 19.55	41.15 ± 21.25	60.87 ± 24.12	49.88 ± 13.50	-30.33 – 5.39	NS	0.03 [§]
Impact	31.10 ± 15.82	16.71 ± 13.25	26.59 ± 16.54	18.64 ± 11.24	-14.88 – 7.99	NS	0.03 [§]
Total	42.15 ± 17.80	25.77 ± 14.44	39.96 ± 15.39	24.94 ± 4.91	-12.22 – 9.37	NS	0.01 [§] /0.02 [†]

Note: n = number of subjects; WT = walking time; DW = distance walked; SGRQ = Saint George Respiratory Questionnaire; EPI = effort perception index. CI= confidence interval of the difference between groups (final PRP and final WBV). NS = not significant. P-value in the last two columns indicates the results of the Independent Student test and Paired Student test. Symbols show: § Difference from end to begin assessment for PRP group; † Difference from end to begin assessment for WBV group; * Difference of end assessments between PRP and WBV groups. Data are expressed as mean ± standard deviation.

Discussion

Our results show benefits in quality of life between the pulmonary rehabilitation and whole-body vibration

programs. Though, the performance improvement on the 6MWT walked distance was obtained only in patients with COPD who underwent WBV. To our knowledge, this is the first study to compare the results of a traditional program of

pulmonary rehabilitation with training in vibrating platform for patients with COPD.

The first published study that used in an associated way the WBV to a PRP was that of Gloeckel (2012), who reported an increase in performance of the 6MWT and improved quality of life for these patients, regarding those who only underwent pulmonary rehabilitation program (Gloeckel *et al.*, 2012). Taking into account that the increase of the level of obstruction in patients with COPD results in greater effort intolerance (Derom, Marchand & Troosters, 2007), access to exercise programs involving additional physical effort may be harmed, especially for those most affected for the obstructive point of view. The isolated training program in vibrating platform as the developed in the present study, can provide clinically significant improvement in quality of life (Schünemann *et al.*, 2003) and daily activities reflected by the performance in the 6MWT (Puhan *et al.*, 2008) for patients with moderate to severe obstruction, similar to PRP; however, with lower effort by the patient.

Previous study developed a WMV program for patients with severe COPD with duration of 6 weeks and found that the patients improved their functional capacity through the 6MWT at the end of the program. However, they did not evaluate the impact of these results on quality of life and have not even compared them with PRP. Nevertheless, these authors observed changes in functional capacity of patients only with training of WBV, similarly to what happened in our study (Pleguezuelos *et al.*, 2013).

A recent study reported improvement in all domains of quality of life and increase in the distance walked at the end of a training program in vibrating platform for patients with COPD, thereby demonstrating that even in the face of a severe obstructive condition, the patients responded favorably to WBV program with a good adhesion and acceptance (Braz Júnior *et al.*, 2015).

Regarding to quality of life, it was observed in this study significant improvement in activity, impact and total domains for the PRP group and symptoms and total domains for the WBV group. Although, the effects of different training developed in this study achieved the domains of MCID, differences were observed (Troosters, 2011). Our results are similar to the study of Teixeira *et al.*, where the patients who participated in a PRP showed higher scores in activity, impact and the total domains (Teixeira Braz Júnior, Barros, Dornelas de Andrade, Marinho, 2014). Physical training promotes the improvement of aerobic performance and muscle as well as providing social interaction and these factors affect the quality of life of patients involved in the PRP.

The improvement in the symptoms domain for the WBV group may have been provided by physiological effects on the muscle groups subjected to vibration, which resulted in significant performance improvement on 6MWT, reflecting in more disposition for daily activities with a reduction in respiratory symptoms.

The importance of evaluating the MCID for the quality of life (Schünemann *et al.*, 2003) and functional status of patients with COPD (Puhan *et al.*, 2008) after an intervention program enables the professional to consider changes or

adjustments in the conduct of the patient, reflecting the significant effect of an intervention (Troosters, 2011). In the study by Teixeira *et al.*, 2014, MCID was reached in symptoms, activity and total domains after a pulmonary rehabilitation program when compared with a control group (Teixeira *et al.*, 2014). In our study, both groups reached the MCID for the quality of life in all domains, reflecting the effectiveness of training programs.

Regarding 6MWT, our patients reached the MCID for the walked distance according to the Puhan study *et al* in both programs (PRP=64m and WBV=59m, respectively) (Puhan *et al.*, 2008). However, no differences were observed between them as the distance walked, thereby indicating that both programs were effective regarding this outcome.

The results presented here are satisfactory, considering that a training program in vibrating platform for patients with moderate to severe obstruction may be beneficial for the most intolerant patients to exercise, which is very common at this stage of the disease. COPD, a disease with systemic characteristics, considering its effects on peripheral muscle dysfunction (ZuWallack & Hedges, 2008), WBV training provides adjustments that involve increased synchronization in the motor units, co-contraction of synergist muscles and inhibition of antagonistic muscles (Torvinen *et al.*, 2002) and these effects are due to myotatic stretch elicited by vibratory tonic reflex (Esmailzadeh, Akpınar, Polat, Yildiz & Oral, 2015; Gloeckel *et al.*, 2015).

Another possible mechanism involved in the muscle-building process, its related to the effects of gravitational acceleration on body weight offered by the vibrating platform (Osawa, Oguma & Ishii, 2013), associated with the posture adopted during the training program, facilitating the propagation of vibratory stimulus by the body (Crewther, Cronin & Keogh, 2004). This kind of training may be more acceptable to patients with COPD because it does not involve additional physical effort. This aspect reinforces positively to the establishment of WBV for patients who are more intolerant for efforts and could not perform a conventional PRP.

Among the limitations of our study, we can mention the non-verification of muscle strength in this group of patients. We believe that the study of muscle strength and the evaluation of cardiopulmonary effects in patients subjected to WBV program could provide more objective answers about the behavior of these patients facing the training program. Our results suggest that more patients with COPD could be trained in WBV in order to ascertain more precisely information about their effects compared with the PRP group. We concluded, therefore, the WBV group increased the walked distance in regards to the PRP group and both programs improved the quality of life.

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