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Original article

Effects of Whole-Body Vibration on Egyptian Patients with Chronic Obstructive Pulmonary Disease: A randomized Controlled Trial

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ABSTRACT

Background: Chronic obstructive pulmonary disease [COPD] is a chronic lung disease affecting other body systems, like musculoskeletal system causing weakness. Muscle weakness is a major problem, causing poor functional lung capacity; and a negative impact on daily life activity. Muscle weakness in COPD may be a form of disuse and/or a form of myopathy is a question need answer. Exercise is a basic unit of pulmonary rehabilitation causing increased quality of life. So, PR regarded as effective non-pharmacological treatments in COPD.

Aim of the work: Whole-body vibration [WBV] is a type of exercise that improve muscle function specially in debilitated patients like COPD, WBV not yet studied in Egyptian patients with COPD.

Patients and Methods: Fifty patients with COPD were assessed for an 18-weeks in outpatient rehabilitation center, the patients were randomly assigned into: Group 1, using dynamic exercise on a side alternating vibration platform at 25–30 Hz three times per week [WBV], and group 2 as a control group [CON] with the same amount of exercise without WBV.

Results: Pulmonary function tests results: showing FEV1 pred. 39.8 ± 12.2 and 41.3±4.6 before and after intervention respectively. PaO_2: 49.60 ± 80and 82±90 before and after intervention respectively; PaCO2: 65 ± 70and 33±50before and after intervention respectively the difference was significant in intervention group than in control. The distance walked [DW] increased after the WBV period [397±133m] compared with the control period [359±111m].

Conclusion: WBV was good complementary training exercise which could be an effective new modality for COPD patients.

Keywords: Chronic obstructive pulmonary disease; Skeletal muscles atrophy; Myopathy; Exercise; Whole body vibration.

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* Main subject and any subcategories have been classified according to researchers' main field of study.

INTRODUCTION

Chronic obstructive pulmonary disease [COPD] is a disease that affect not only lungs but can affect many systems of the body as part from the disease or as a complication to it, including musculoskeletal system, as muscle weakness [myopathy]. [1] There is a reduction in both muscular mass and power. Many factors are responsible for development of myopathy that include disuse, inactivity, systemic inflammation, malnutrition, corticosteroid usage, hypoxemia, aging, and smoking. [2] Physical activity can be identified as bodily movements that results in energy expenditure. Exercise is a special type of physical activity which is planned to produce improvement or maintaining of body fitness. Exercise is one of the basic components of pulmonary rehabilitation in patients with COPD.[3] High intensity loading exercises are needed in COPD patients to improve exercise capacity and to alleviate symptoms but ventilatory limitation with apparent muscle weakness in those patients making them unable to sustain high exercise intensities for sufficiently long periods. [4] So, in patients with advanced COPD, interval exercising consisting of repeated bouts [30-60s] of high or even maximal intensity [80-100% peak] separated through periods [30-60s] of decrease intensity intervals, has been proven to be tolerated by patients with COPD permitting it to be of greater efficacy than with constant-load exercises. [5]

Whole body vibration [WBV] is a new exercise modality that done on a vibrating platform. Many randomized clinical trials had demonstrated greater improvement in COPD patients with different COPD stages of trained on the WBV platform when compared to a control on conventional training.[6] However, the effect of combination of WBV with exercise on lung function and exercise capacity did not fully studied in patients with COPD.

AIM OF THE WORK

The study aimed to investigate the effect of whole-body vibration [WBV] and exercise [in combination] on lung function and exercise capacity in people with chronic obstructive lung disease [COPD].

PATIENTS AND METHODS

Our study included 100 patients with COPD. Patients divided into two equal groups by simple random technique at baseline. The first group received WBV- exercise and usual rehabilitation program with continuation of medical treatment. The second group continued on rehabilitation program with equal time of exercise and continuation of medical treatment. The patients were selected from outpatient clinics and inpatients of rheumatology and chest departments of Al-Hussein University hospitals [Cairo] and Al-Azhar University Hospital [New Damietta], Egypt in the period between March 2018 and April 2019. The purpose of the study was explained to whom included in the study. A written consent was taken with the guidelines and approval of the local ethics committee of Al-Azhar Faculty of Medicine [Cairo], Egypt. COPD diagnosis was made based on American Thoracic Society [ATS] guidelines. [7] The program of Exercise was administered a total of 3 times/weak over an 18-week period. We measured pulmonary function tests [PFT] including: 1st second forced expiratory volume [FEV_1] and forced vital capacity [FVC], neurological and electro-physiological examinations also were carried out. The secondary outcome measures were the 6-minute walking test [6MWT], walking distance, clinical COPD questionnaire [CCQ], Sit-to-stand test five times, and systemic inflammatory biomarker levels [ESR and CRP].

Patients inclusion and exclusion criteria:

We excluded patients with diseases other than COPD that could cause neuropathy and or myopathy. Individuals with osteoporosis; peripheral vascular disease and/or thromboembolism, decompensated cardiovascular disease, malnutrition, and postoperative patients are excluded. The included patients with COPD had no history or manifestation of endocrine disease, congenital muscle diseases or diabetes. None of the patients use medication identified to cause neuropathy and or myopathy aside from those used habitually in COPD. All or a few of the patients were on aminophylline, inhaled beta-2 mimics, anticholinergics and steroids at any stage of treatment. Complete Clinical examination and complete lab investigations were done, which included complete blood count, biochemical analysis, electrolytes, total protein, albumin levels and body mass indices were considered. All the patients were on a regular daily activity not more.All patients and controls tested by spirometer and plethysmography for lung function [Geratherm respiratory series]. All patients tested in

clinically stable condition. The tests were performed by the same doctor to all patients examined by the same clinician. The best mensuration out of 3 was taken into thought. Forced vital capacity [FVC], forced expiratory volume in one second [FEV1], and FEV/ FVC ratio were measured to confirm the diagnosis of COPD and assess the severity. Results were expressed as % of predicted values.[8]

Respiratory Muscle Function Tests: Maximum inspiratory pressure [PI_{max}] and maximum expiratory pressure [PE_{max}] as cmH_2O were measured by the same doctor using the same device as lung function tests. PI_{max} was measured throughout a greatest breath effort against associate occluded airway residual volume and PE_{max} was measured through-out a greatest breath effort against the closed airway at total lung volume. [9] The best effort of three trials was taken into consideration.

The CCQ is brief [10 items] divided into 3 domains [symptom, functional, and mental state]. Patients ware asked concerning their experiences throughout the previous week [week version]. They answer every question in a 7-point scale from zero = asymptomatic/no limitation to six = extraordinarily symptomatic/totally restricted. Adding all the scores along and dividing this add by the quantity of queries calculate the total clinical COPD management score and the domains scores. Thus, the general clinical COPD control score also the score on every of the 3 domains varies between zero [very healthiness status] to six [extremely poor health status]. [10]

All subjects were evaluated clinically by neurologist not abreast of concerning the patients clinical or laboratory findings.

The electrophysiological examinations were done to the median, ulnar, common peroneal and posterior tibial nerves were evaluated; also, the sensation of median, ulnar and sural nerves were examined. Needle EMG examinations of deltoid, biceps, abductor pollicis brevis, rectus femoris, anterior tibialis and extensor digitorum brevis muscles were obtained throughout rest, lowest and greatest contractions. Electrophysiological measurements were created by using 4-channel medical instrument SURPASS LT [EMG device]. All patients were examined in resting state.[11]

Electromyography [EMG] was done in all groups in the first and last day of the intervention [before and after the sessions].

Six Minute Walk Test [6MWT]: An exercising test used to determine walking power and aerobic capacity. Participants will walk in hall or prepared region for walking for a whole of six minutes**.** The rating of the test is the distance a patient can walks in 6 minutes [measured in meters]. Equipment included stopwatch, chair, measuring instrument [meters], a 30-meter-long hallway with a smooth, consistent surface, cones to indicate turnaround, mechanical lap counter or pencil and paper. The patient instructed to sit in a chair, rested, close to the beginning point of the test. Reviewing of any contraindications was done, and resting vital signs were documented. The patient was informed "The purpose of the test is to walk as possible in six minutes; you'll walk backward and forward in the hall. Six minutes could be a very long time for you; thus, you'll be exerted, you'll get breathless or go tired. you'll lock up, to stop, and to rest as you need. You can stand and rest, however resume walking as shortly as you're ready. Are you ready to do that?" [12]

Sit-to-stand test five times[5STS]: It evaluates an individual's activity for daily living and measures the repetition of standing-up and siting down on a chair. The test begins with the individual sitting in a chair, in erect position, feet on the floor, and arms crossing the chest. After the signal of the supervisor, the individual will stand up fully and then returns to the fully seating position, patients advised to sit and stand for five consecutive times. The supervisor records the time taken to finish the test. This test will be performed on the first and last day of the intervention. [13]

Intervention: Patients followed a multi-disciplinary inpatient rehabilitation program of 18-weeks duration; 3 days per week. The program consisted of medical treatment, breathing therapy, health education, nutritional education and psycho-logical support. Exercise training consisted of endurance training 10 min cycling and strengthening exercise for major muscle groups. These components were equal for all patients. Additionally, patients were randomly assigned to one of two intervention groups. First group attended a supervised manner of 3×3 minutes/day on a whole-body vibration plate [SKYYWORLD VIBRAFIT®, China] at 25–30Hz and 6mm peak-to-peak amplitude that's evokes muscle contractions on the entire flexor

and extensor muscles all over the body, that occurs passively.[14] Control group with same time of exercise were performed by each participant. The task includes flexion and extension of the trunk and the lower limps in extension. The task was explained and demonstrated before the experiment and a verbal instruction was used for movement control during activity.

Statistical analysis: Continuous variables were explicated in the form of mean, and standard deviation [SD]. For paired normally distributed data, data were compared using paired *t*-test. Furthermore, correlation analysis was conducted using Pearson correlation coefficient for continuous normally distributed data. The significance is established when $P < 0.05$. Statistical analysis was performed using SPSS software version 23 for Windows [SPSS Inc., Chicago, IL, USA].

RESULTS

We observed no significant demographic differences at baseline between the intervention group and the control. The gender distributions in both groups with more males around [82%] in each group as seen in table [1]. In our study we observed significant statistical change in the following parameter:

Pulmonary function tests results: forced vital capacity [FVC], forced expiratory volume in one second [FEV1], partial pressure of arterial oxygen [PaO_2], and partial pressure of arterial carbon dioxide [$PaCO_2$] displaying difference in each group however was significant in intervention group than in control.

FEV1 pred. 39.8 ± 12.2 and 41.3±4.6 before and after intervention respectively. PaO_2: 49.60 ± 80 and 82±90 before and after intervention respectively; $PaCO_2$: 65 ± 70 and 33±50 before and after intervention respectively as presented in tables [1 and 2].

Clinical COPD Questionnaire [CCQ] results:

There was no significant difference in CCQ score between intervention and control groups at the beginning of intervention [Table 3]. The clinical COPD questionnaire scores showed significant difference between intervention and control groups in symptoms, function, mental domains and total scores [Table 4]. There was a total reduction in the domain scores after WBV training. CCQ 2.22 ± 1.36 and 1.02 ± 0.66 before and after intervention respectively.

Five-repetition sit-to-stand test results: No significant outcome was found between the two groups regarding the 5STS at the beginning of study [Table 1], with significant deference at the end of study. [Table 2]. 5STS score, 14.3±7.8 seconds and 10.1±4.3 seconds before and after intervention respectively.

6-minute walk test results: The distance walked [DW] increased after the WBV period [397±133m] compared with the control period [359±111m]. Distance walked in 6 min [m] 3 25. 4 ± 1 1 5. 2 and 397 ±133 before and after intervention respectively. [tables1 & 2].

Neurophysiological data results: No statistical difference in the neurophysiologic data of the studied groups after ending of the study were found but there was a difference to the side of WBV [Table 5 & 6].

Table [1]: Basic investigation of intervention and control groups

Characteristic	Intervention [Mean ± SD]	Controls [Mean ± SD]	p Value
Age [yr]	74.4 ± 3. 7	72.5 ± 2.9	0.41
Male [%]	82. 1 ± 0. 2	80.0 ± 0.5	0.42
BMI	2 4. 7 ± 2. 5	23.2 ± 3.1	0.39
FVC [liter]	7 0. 9 ± 1 8. 9	71.2 ± 17.6	0.38
FEV1 [% of predicted value]	39.8 ± 12.2	37.4 ± 11.0	0.43
PaO_2	49.60 ± 80	50±70	0.31
$PaCO_2$	65 ± 70	66 ± 75	0.45
Distance walked in 6 min [m]	3 25. 4 ± 1 1 5. 2	331.0± 105.0	0.41
5STS	14.3±7.8	14.8±8.5	0.47

FVC forced vital capacity, FEV1 forced expiratory volume in one second. BMI The body mass index is the weight in kilograms divided by the square of the height in meter, PaO2 partial pressure of arterial oxygen, PaCO2 partial pressure of arterial carbon dioxide, 5STS five-repetition sit-to-stand test.

Table [2]: Basic investigations of intervention and control groups at end of intervention.

	Intervention Group [Mean ± SD]	Control Group [Mean ± SD]	P-value
FVC	71.0±8.2	92.0±8.44	<0.05*
FEV1	41.3±4.6	35.4±6.8	<0.05*
FEV1/ FVC	57.5±9.6	87.60±5.57	<0.05*
PaO_2	82±90	53±20	<0.001*
$PaCO_2$	33±50	51±90	<0.001*
Distance walked in 6 min [m]	397±133	359±111	<0.05*
5STS	10.1±4.3	13.8±6.5	<0.05*

FVC forced vital capacity, FEV1 forced expiratory volume in one second, PaO2 partial pressure of arterial oxygen, PaCO2 partial pressure of arterial carbon dioxide 5STS five-repetition sit-to-stand test.

Table [3]: The Scores of Clinical COPD Questionnaire score [CCQ] and its components in 100 patients with chronic obstructive pulmonary disease [COPD] before study.

Variable	Intervention Score [mean ± SD]	Controls Score [mean ± SD]	p Value
CCQ item			
CCQ1	1.1 7 ± 1. 37	1.16± 1.35	0.43
CCQ2	3.2 ± 2.02	3.4 ± 2.1	0.45
CCQ3	1.94 ± 1.71	1.89± 1.6	0.41
CCQ4	1.63 ± 1.51	1.7± 1.5	0.42
CCQ5	2.59 ± 1.82	2.5± 1.88	0.44
CCQ6	2.35 ± 1.57	2.37± 1.51	0.43
CCQ7	2.98 ± 1.68	3.0. ± 1.56	0.42
CCQ8	2.52 ± 1.54	2.53± 1.52	0.41
CCQ9	1.35 ± 1.56	1.37± 1.52	0.46
CCQ10	0.57 ± 1.06	0.58± 1.07	0.47
CCQ domain			
Symptoms	2.28 ± 1.27	2.26± 1.29	0.42
Functional status	1.76 ± 1.21	1.72± 1.20	0.41
Mental status	1.67 ± 1.38	1.65± 1.36	0.43
CCQ total score	2.22 ± 1.36	2.30± 1.28	0.45

Each CCQ item refers to one question in CCQ, and each CCQ domains contains multiple question; symptoms [includes question 1, 2, 5, and 6], functional state [includes question 7, 8, 9, and 10], and mental state [includes question 3 and 4].

Table [4]: The Scores of Clinical COPD Questionnaire score in intervention and control groups after study.

	Variable	Intervention Score [mean±SD]	Controls Score [mean ± SD]	p Value
Items	CCQ1	0.7 ± 0.9	1.0± 0.6	0.05*
	CCQ2	1.2 ± 1.12	2.1 ± 1.2	0.05*
	CCQ3	1.02 ± 0.9	1.7± 1.3	0.05*
	CCQ4	0.52 ± 0.72	1.07± 1.5	0.05*
	CCQ5	1.32 ± 0.96	1.5± 1.08	0.05*
	CCQ6	1.20 ± 1.17	1.9± 1.8	0.05*
	CCQ7	1.21 ± 0.88	2.0 ± 1.0	0.05*
	CCQ8	1.2 ± 1.04	1.93± 1.6	0.05*
	CCQ9	0.75 ± 0.86	1.±0 .8	0.05*
	CCQ10	- 0.5 ± 0.06	0.08± 0.7	0.05*
CCQ domain	Symptoms	1.06 ± 0.7	1.4± 1.0	0.05*
	Functional status	0.6 ± 0.41	1.02± 0.8	0.05*
	Mental status	0.6 ± 0.8	1.0± 0.7	0.05*
	CCQ total score	1.02 ± 0.66	1.50± 1.1	0.05*

Table [5]: Neurophysiologic data of the studied group before study.

Variable	Intervention [mean ± SD]	Controls [mean ± SD]	p Value
Median nerve MNCV [M/S]	51.49±4.3	55.56±6.8	<0.05
Ulnar nerve MNCV [M/S]	53.55±6.1	56.49±5.9	>0.05
Common peroneal MNCV [M/S]	36.45±3.4	43.75±4.5	<0.05
Posterior tibial MNCV [M/S]	38.43±4.6	45.67±4.4	<0.05
Median nerve SNCV [M/S]	50.55±4.9	53.86±5	<0.05
Ulnar nerve SNCV [M/S]	50.88±4.6	52.78±5.3	<0.05
Sural nerve distal latency [msec]	43±4.3	47.35±6.1	<0.05

MNCV Motor nerve conduction velocity, SNCV: sensory nerve conduction velocity

Table [6]: Neurophysiologic data of the studied groups after study.

Variable	Intervention [mean ± SD]	Controls [mean ± SD]	p Value
Median nerve MNCV [M/S]	50.49±4.3	53.46±3.8	<0.05
Ulnar nerve MNCV [M/S]	52.51±3.1	54.49±4.9	<0.05
Common peroneal MNCV [M/S]	37.45±2.4	40.75±3.5	<0.05
Posterior tibial MNCV [M/S]	36.43±4.2	38.67±3.4	<0.05
Median nerve SNCV [M/S]	49.55±3.9	50.86±4.3	<0.05
Ulnar nerve SNCV [M/S]	47.88±2.6	48.78±7.3	<0.05
Sural nerve distal latency [msec]	42±3.3	44.35±4.1	<0.05

MNCV: Motor nerve conduction velocity, SNCV: sensory nerve conduction velocity.

DISUCSSION

During the last years there was increasing interest on the effect of WBV on human body ether in health or different diseases from which COPD patients. In COPD Pulmonary rehabilitation program improves exercise capacity and quality of life but not to the degree to increase pulmonary function. [15]

We claim, the combination of pulmonary rehabilitation and WBV can improve pulmonary function more than pulmonary rehabilitation alone if we use this combination for an enough time.

The randomized trial reported in this manuscript is designed to examine the effect of a combination of WBV and exercise on lung function and exercise capacity in people with COPD and measuring the improvement in muscular power.

In our study we found significant statistical change in nearly all parameter of the study as follow: the gender distribution in both groups with male predominance than female. In

We found increase in 6MWT about 130 m, that was greater than value found by Puhan et al. who reported that, 6MWT was equal to 54m [16]

Our study showed more improvement in DW. Braz Junior et al. study found improvement in 6MWT in patients with severe COPD but the patients not corporate in rehabilitation program.[17] However, it is obvious that patients in the WBV-group were able to improve their functional capacity to a significantly and considerably to greater extent when compared to the conventional group.

Our study provides improvement in all areas of quality of life as measured by CCQ which shows improvement in the total score from 2.22 ± 1.36 to 1.02 ± 0.66 after intervention.

These results found training on WBV improves quality of life and functional capacity to a similar manner like exercise in pulmonary rehabilitation program [PR] as in Gloeckl et al. study which found significant improvement in quality of life parameters in comparison to control group who don't do exercise[18].

The outcome of the sit-to-stand test [5STS] provided similar results in favor of the WBV-group with significant difference between intervention and controls. These results going with the results of Vaidya et al. who found the exercise is effective in COPD patients and the 5STS test is a good indicator tool.[19]

COPD patients mostly suffering from a decreasing muscle mass and power special with advancing of the disease[20].

We found that WBV can increase muscle power and strengthening the lower limb muscle in the intervention group more than control but without significant difference in EMG as in Klijn et al. who found nonlinear exercise training like WBV in advanced chronic obstructive pulmonary disease is superior to traditional exercise training.[21] So training with WBV may be a promising new exercise modality.

Conclusion

The combination of WBV and pulmonary re-habilitation program, need to be administered in early stage of the COPD before a greater loss of lung function and exercise capacity occurs. WBV should be used in addition to usual exercise but not as alternative as it increases the effects of a comprehensive multidisciplinary rehabilitation program.

Financial and Non-Financial Relationships and Activities of Interest

None

REFERENCES

1. **Choudhury G, Rabinovich R, MacNee W.** Comorbidities and Systemic Effects of Chronic Obstructive Pulmonary Disease. Clin Chest Med **2014**: 35, [1], P 101–130. [DOI: 10.1016/j.ccm.2013.10.007].
2. **Jaitovich A, Barreiro E.** Skeletal muscle dysfunction in chronic obstructive pulmonary disease. What we know and can do for our patients. Am J Respir Crit Care Med. **2018**:198 [2]:175-186. [DOI: 10.1164/rccm.201710-2140CI].
3. **Andrianopoulos V, Klijn P, Franssen FM, Spruit MA**. Exercise training inpulmonary rehabilitation. Clin Chest Med. **2014**: 35 [2]: 310-318. [DOI: 10.1016/j.ccm. 2014. 02.013].
4. **Lee A, Holland A.** Time to adapt exercise training regimens in pulmonary rehabilitation – a review of the literature. Int J COPD **2014**:9[1]: 1275—1288. [DOI: 10.2147/ COPD.S54925].
5. **Södergren M, Sundquist J, Johansson SE, Sundquist K.** Physical activity, exercise and self-rated health: A population-based study from Sweden. BMC Public Health **2008**: [8]: 352-362. [DOI:10.1186/1471-2458-8-352].
6. **Gloeckl R, Jarosch I, Bengsch U, Claus M, Schneeberger T, Andrianopoulos V, et al.** What's the secret behind the benefits of whole-body vibration training in patients with COPD? A randomized, controlled trial. Respir Med. **2017**; 126:17-24. [DOI: 10.1016/j.rmed].
7. **Celli BR, MacNee W.** Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. Eur Respir J. **2004**; 23:932–946. [DOI: 10.1183/09031936.04.00014304].
8. **Vogelmeier CF, Criner CJ, Martinez FJ, Anzueto A, Barnes PJ, Bourbeau J, et al.** Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Lung Disease 2017 Report GOLD Executive Summary. Am J Respir Crit Care Med. 2017: 195 [5]:13-31. [DOI:10.1164/rccm.201701-0218PP].
9. **Spruit MA, Singh SJ, Garvey C, ZuWallack R, Nici L, Rochester C, et al.** An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. Am J Respir Crit Care Med. **2013**;188: e13–e64. [DOI: 10.1164/rccm.201309-1634ST].
10. **Sundh J, Janson C, Lisspers K, Montgomery S, Stallberg B.** Clinical COPD Questionnaire score [CCQ] and mortality. Int J Chron Obstruct Pulmon Dis. **2012**; 7: 833–842. [DOI: 10.2147/COPD.S38119].
11. **de Miranda Rocco CC, Malosá Sampaio LM, Stirbulov R, Ferrari Corrêa JC.** Neurophysiological aspects and their relationship to clinical and functional impairment in patients with chronic obstructive pulmonary disease. Clinics **2011**; 66 [1]: 125-129. [DOI:10.1590/S1807-59322011000100022].
12. **Pereira JS, de Aguiar Lemos F, Naso FCD, Krüger R, de Oliveira A, Knorst MM, Dias AS.** Effect of six-minute walk test on neuromuscular properties of patients with chronic obstructive pulmonary disease. Clin Respir J. **2017** Nov;11(6):812-819. [DOI: 10.1111/crj.12420].
13. **Morita AA, Bisca GW, Machado FVC, Hernandes NA, Pitta F, Probst VS.** Best Protocol for the Sit-to-Stand Test in Subjects With COPD. Respir Care **2018**; 63 [8]: 1040–1049. [DOI: 10.4187/respcare.05100].
14. **Zhou J, Pang L, Chen N, Wang Z, Wang C, Hai Y, et al.** Whole-body vibration training – better care for COPD patients: a systematic review and meta-analysis. Int J COPD **2018**:13 P 243—325. [DOI: 10.2147/COPD. S176229].
15. **Kharbanda S, Ramakrishna A, Krishnan S.** Prevalence of quadriceps muscle weakness in patients with COPD and its association with disease severity, International Journal of Chronic Obstructive Pulmonary Disease. 2015:10[1]:1727-1735. [doi:10.2147/COPD.S87791].
16. **Puhan MA, Mador MJ, Held U, Goldstein R, Guyatt GH, Schünemann HJ.** Interpretation of treatment changes in 6-minute walk distance in patients with COPD. Eur Respir J. **2008**; 32 [3]: 637–643. [DOI: 10.1183/ 09031936.00140507].
17. **Braz Junior D, Dornelas de Andrade A, Sales Teixeira A, Amorim Cavalcanti C, Morais A, Marinho PE.** Whole-body vibration improves functional capacity and quality of life in patients with severe chronic obstructive pulmonary disease [COPD]: a pilot study. Int J COPD **2015**: 10[1] pp. 125-132. [DOI: 10.2147/COPD. S73751].
18. **Gloeckl R, Heinzelmann I, Baeuerle S, Damm E, Schwedhelm AL, Diril M, et al.** Effects of whole-body vibration in patients with chronic obstructive pulmonary disease–a randomized controlled trial. Respir Med. **2012**; 106: 75-83. [DOI: 10.1016/j.rmed.2011.10.021].
19. **Vaidya T, Chambellan A, de Bisschop C.** Sit-to-stand tests for COPD: A literature review, Respiratory Medicine. **2017**:128, pp.70-77. [DOI: 10. 1016/j.rmed. 2017. 05.003].
20. **Jarosch I, Gehlert S, Jacko D, Andreas R, Marion K, Tobias W, et al.** Different training-induced skeletal muscle adaptations in COPD patients with and without alpha-1 antitrypsin deficiency. Respiration **2016**; 92: 339–347. [DOI: 10.1159/000449509].
21. **Klijn P, van Keimpema A, Legemaat M, Gosselink R, van Stel H.** Nonlinear exercise training in advanced chronic obstructive pulmonary disease is superior to traditional exercise training. A randomized trial. Am J Respir Crit Care Med. **2013** Jul 15;188[2]:193-200. [DOI: 10.1164/rccm.201210-1829OC].