



Downhill walking influence on physical condition and quality of life in patients with COPD: A randomized controlled trial

Azar Moezy*¹, Azadeh Erfani², Ali Mazaherinezhad¹, Seyed Ali Javad Mousavi³

Received: 31 May 2017

Published: 14 June 2018

Abstract

Background: Chronic Obstructive Pulmonary Disease (COPD), in addition to its respiratory problems, is accompanied by several musculoskeletal consequences. The aim of this study is to investigate the effectiveness of eccentric exercise in the form of downhill walking (DW) on respiratory capacity, physical function and quality of life (QOL) in patients with COPD.

Methods: The randomized controlled trial was carried out during 2014 - 2015 in Hazrat-e-Rasool Hospital in Tehran, Iran. The study design was as an assessor blind RCT on 32 patients with COPD that randomly assigned to the eccentric training (ET) and control (CON) groups. Patients in ET group received a 12-week DW exercise on the treadmill while the patients in the control group were only treated by COPD conventional medications and walked on paved surfaces. Functional tests, FEV1, FEV1 to FVC and St. George's Respiratory Questionnaire (SGRQ) were used to assess the subject's physical status and QOL pre and post-intervention.

Results: The FEV1 ($p=0.008$), FEV1/FVC ($p=0.002$), six-minute walk test ($p=0.029$), timed up & go test ($p=0.023$), SGRQ symptom ($p=0.022$), SGRQ activity ($p=0.007$), SGRQ impact ($p=0.033$) and total score of SGRQ ($p=0.013$) improved significantly in the ET group compare to the CON group.

Conclusion: DW could have positive influence on physical status and QOL of patients with COPD.

Keywords: Chronic obstructive pulmonary disease (COPD), Eccentric training, Downhill walking, Quality of life (QOL), Physical function, RCT

Copyright© Iran University of Medical Sciences

Cite this article as: Moezy A, Erfani A, Mazaherinezhad A, Mousavi SAJ. Downhill walking influence on physical condition and quality of life in patients with COPD: A randomized controlled trial. *Med J Islam Repub Iran.* 2018(14 June);32:49. <https://doi.org/10.14196/mjiri.32.49>

Introduction

Chronic obstructive pulmonary disease (COPD), besides a progressive and irreversible airway obstruction, is usually associated with extra-pulmonary co-morbidities (1) such as activity intolerance (2,3). COPD patients may experience dyspnea during exertion, causes difficulties in performing an activity of daily living (ADL), job-related tasks and decreasing the patient mobility (3). The muscle mass and cardiovascular capacity reduce as the immobility progress and lead to deteriorating the patient's health condition, make them be homebound, isolated and depressed

(4). Skeletal muscle dysfunction involves both respiratory and extremities muscles (5-7), due to wasting and loss of oxidative phenotype (5,8,9). Physical inactivity is identified as an important factor contributing to the skeletal muscle weakness especially during acute exacerbations (10). Reduced muscle strength, especially quadriceps weakness (11) is observed in one-third of all COPD patients even at very early stages of the disease (12,13). Muscle dysfunction and breathlessness are the primary determinants of patients QOL which are negatively im-

Corresponding author: Dr Azar Moezy, moezy.a@iums.ac.ir

¹ Department of Sports Medicine, Hazrat Rasool Hospital, Iran University of Medical Sciences, Tehran, Iran.

² Iran University of Medical Sciences, Tehran, Iran.

³ Department of Internal Medicine, School of Medicine, Iran University of Medical Sciences, Tehran, Iran.

↑What is "already known" in this topic:

Muscle dysfunction and breathlessness are the primary determinants limiting physical ability in COPD patients with a great negative impact on their quality of life. Despite the benefits of exercise in decreasing COPD musculoskeletal complications, the patients have often reduced their mobility in order to avoid dyspnea.

→What this article adds:

Eccentric exercise in the form of downhill walking on treadmill is a safe and well tolerated training modality for COPD patients which cause no dyspnea and need no supplemental oxygen. Downhill walking has favorable effects on the COPD patients' quality of life, respiratory capacity and physical function.

pacted by COPD with a great negative impact (14,15). Patient's disability (16), abnormal gait (17), impaired postural stability (16, 18), higher risk of hospital admissions and mortality (7) are among common consequences of muscle weakness. Despite the benefits of exercise in decreasing musculoskeletal complications, improving the patient's function and survival, COPD patients often reduce their mobility in order to avoid activity-related dyspnea (19).

Recently more attention has been paid to eccentric training as an effective protocol for COPD patients (2,16, 20-23). The eccentric muscle contraction, characterized by elongation of the muscle during contraction, and can produce greater forces than concentric contraction with less energy consumption (20). So eccentric exercise seems to be more appropriate training for COPD patients whose exercise tolerance are reduced (20). Of the benefits of eccentric training (ET) is its low ventilatory cost. The eccentric oxygen demand reported as only one-sixth to one-seventh of that concentric exercise at the same workload (24). The two great properties of eccentric contraction; high force production and low energy cost make it a convenient task which could potentially increase muscle mass and strength in COPD patients (22).

Downhill walking (DW) is a whole-body exercise, involves the lower limb antigravity muscles, (20) including hip extensors, knee extensors and tibial muscles, eccentrically (11,25). The heart rate (HR) of trained people re-

ported to be significantly lower at the negative slope than at the positive slope during walking on the treadmill (26).

To our knowledge, a few studies evaluated the patients' respiratory function after eccentric biking. No clinical trial regarding the application of DW in the COPD patients has yet been conducted. Less energy consumption (27), low ventilatory cost (28) and lower heart rate (27) are the potential advantages of DW training to rehabilitate patients with COPD. The present study aims to appraise the effects of DW on functional abilities, QOL, FEV1, FEV1/FVC (%), rest HR and O₂ Saturation (SpO₂ %) in individuals with COPD.

Methods

Study design

The study was designed as an assessor blind randomized controlled trial (RCT registration number: IRCT 201303315486N3) with ethical approval from the Research Ethics Committee of Iran University of Medical Sciences (No: 92-01-30-21659) based on the latest version of the Declaration of Helsinki. This RCT was carried out in Sports Medicine Clinic, Hazrat-e-Rasool Hospital in Tehran, Iran, from May 2014 to December 2015.

Participants

Forty five patients were volunteered through notices in the university hospitals in Tehran during 2014 - 2015. A respiratory disease specialist examined the patients and

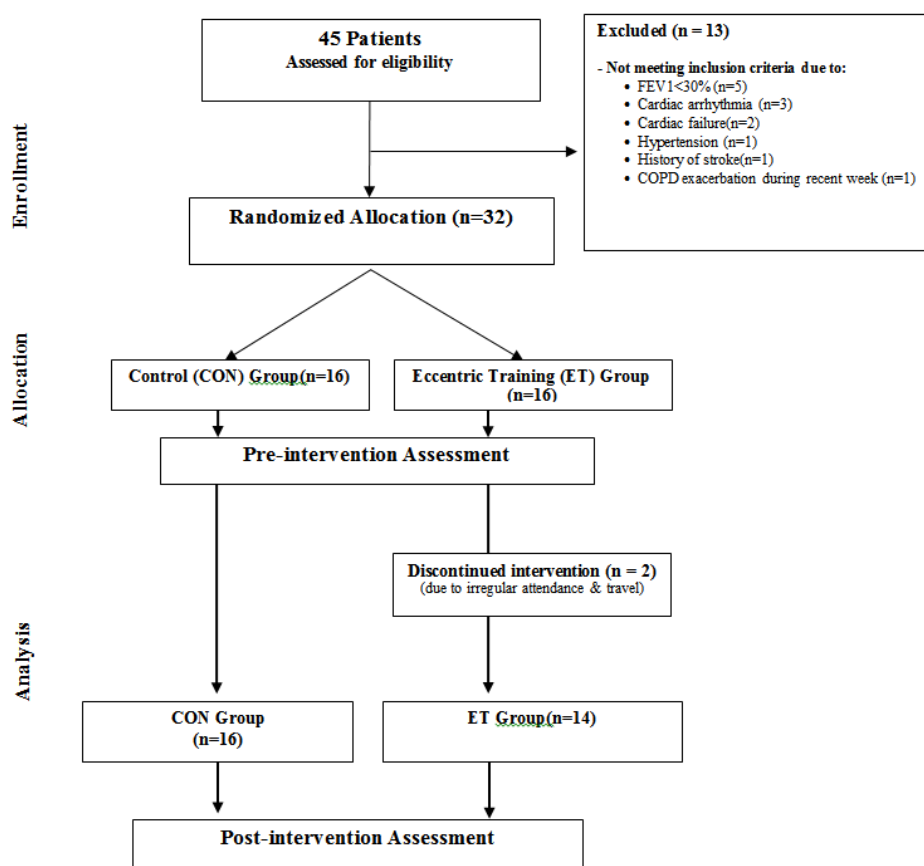


Fig. 1. Study profile for participants in ET and CL groups

judged about the inclusion criteria. The inclusion criteria were: 1) ambulatory male and female, mentally fitted, over 40 years of age with a clinical diagnosis of COPD, for whom exercise is not contraindicated; 2) the presence of a post-bronchodilator FEV1 < 80% predicted together with an FEV1/FVC < 0.70 which confirm the presence of airflow limitation that is not fully reversible, and FEV1 \geq 30% of predicted normal (29); and 3) BMI between 18-30 kg/m². The exclusion criteria were: 1) any new systemic disorder or exacerbation; 2) unstable vital signs during the intervention; 3) incomplete assessment and training; 4) active treatment for cancer; 5) severe anemia; 6) uncontrolled diabetes or hypertension; 7) need for oxygen therapy during physical activity; 8) history of cardiac, rheumatologic, neurologic, orthopedic, liver and renal diseases; 9) history of pulmonary surgery; 10) attendance in rehabilitation program within the three recent months and 11) history of COPD exacerbation during the last four weeks. Of the 45 people enrolled in the study, 32 were eligible according to inclusion criteria and recruited. The patients were allowed to withdraw from the study at any time. Two subjects in ET group were dropped out due to travel and irregular attendance in training sessions (Fig. 1).

A preliminary power analysis was used to estimate a proper sample size with 0.80% power, $\alpha=0.05$, and expected effect size=0.8. The required sample estimated 15 patients for each treatment group. The expected effect size was chosen based on 20% improvements in 6MWT (minute walk test) with 7 points as standard deviation and a significance level of 0.05.

32 patients were randomly (block random sampling with a block size of 4) allocated into two groups: (1) eccentric training (ET) and (2) control (CON). Participants first signed university-approved written informed consent forms and completed demographic data sheets. The measurements were done before and after intervention.

Intervention protocols

The participants in both groups, in addition to their regular medications, began a 12-week program (three times per week). Before starting the study, there was two familiarization sessions for patients to learn Modified Borg Dyspnea (MBD) scale to recognize and rate the difficulty of their breathing during walking. The patients in ET group additionally were trained for DW on a treadmill. The starting intensity by the Borg scale selected between 3 to 4 because the patients in both groups did not use to do any exercise during their life.

The eccentric protocol was an interval treadmill DW. Before starting DW on treadmill, to warm up, patients done a 10 minutes slow walking and five static stretching exercises for quadriceps, hamstrings and calf muscles in

each session.

The range of walking speed was determined based on the score 3 and 4 (respectively; for low and high-speed) of MBD scale. We planned ratios of low to high-speed walking based on Borg scale to have an intermittent exercise program. The duration of walking was set 15-30 minute in the initial stages with progress to 60 minutes per day in final sessions. In the first three weeks, ET was done in three sets with a 90 – 120 second rest between them. Furthermore; the negative slope of treadmill was set at -5° in the early stages of training to enhance the patients' compliance with the exercise process and preventing muscle fatigue and decreasing SpO₂ % level. From the week six, the negative slope of the treadmill increased to -7.5° . Table 1 shows the progressive ET program during treatment sessions in detail.

The necessary emergency equipment such as oxygen and CPR system were available in the training room. The researcher monitored SpO₂ % by a digital pulse oximeter at regular intervals (every 3 minutes) during ET. The exercise intensity was increased according to the patient's tolerance but not above the level at which the subjects' SpO₂ % fell below 90%.

DW was performed on DK City treadmill (Orkid in Shape Type LX5-38-017, DK City Corporation, Taiwan). In order to create a negative slope on the treadmill, wooden panels (with specific size that had been set based on trigonometric calculations to make the slope -5° and -7.5°) were placed under the base of the treadmill. (The details of trigonometric calculations to adjust treadmill's negative slope is explained in the supplementary material). The CON group were asked to have a free walk (with an attendant) three times a week on flat surface as conventional exercise and avoiding any vigorous activities. The duration and speed of walking had been set up by patients themselves due to the fatigue and shortness of breath (3 and 4 of MBD scale) at the beginning and progressively increased through telephone counseling during 12 weeks. Warm-up program in the CON group was similar to the ET group. The control group were also trained to control their SpO₂ % by a digital pulse oximeter every 3 minutes during walking and not allow the intensity of walking to increase to the level at which the SpO₂ % fell below 90%.

Short and long acting beta2 agonist bronchodilator inhalers, inhaled steroids and antibiotics (periodically) were the common medications that the patients were taking during exercise therapy.

Outcome measures

The primary outcomes of the study were pulmonary function tests, heart rate, O₂ saturation, functional tests (six-minute walk test, timed up & go test and stair climb-

Table 1. Eccentric training (DW) protocol

Rehabilitation Course	Exercise Time (Min)	Rest Time (Sec)	Treadmill Slope (Degrees)	Treadmill Speed
First to 3 rd week	15	90-120	-5°	Low – speed (<3 km/h)
3 rd to 6 th week	15-30	-	-5°	A combination of low and high speed with ratio of 3 to 2
6 th to 9 th week	30-45	-	-7.5°	A combination of low and high speed with ratio of 2 to 3
9 th to 12 th week	45-60	-	-7.5°	High- speed (>5 km/h)

ing test) and the secondary outcome was Quality of Life in COPD patients. The outcome measures were evaluated at the baseline or pre-intervention and post-intervention after 12 weeks.

Pulmonary function tests and heart rate and O₂ saturation

Lung function was assessed by measuring FEV1 and FEV1/FVC ratio with a standard laboratory spirometer (Master lab, Jaeger AG, Würzburg, Germany) under the supervision of a respiratory disease specialist. Arterial oxygen saturation (SpO₂ %) and HR was measured in the rest by a digital pulse oximeter device (Acare, Oxismarter I, Acare Technology Co., Taiwan)

Functional tests

Three tests with high intra- and inter-tester reliability including six-minute walk test (6MWT), timed up & go test (TUG) and stair climbing test (SCT) were used to assess the functional status of the patients. (30, 31) All patients were accompanied by a sports medicine assistant who was blinded to the assigned groups and assessed their blood pressure, HR, respiratory rate, SpO₂ % and symptoms before and immediately after the tests. All functional tests were performed twice with an interval of 30 minutes and the best result was recorded for the patient before and after intervention.

Quality of life

QOL was measured using the St. George respiratory questionnaire (SGRQ) which is an originally designed and validated 50-item disease-specific questionnaire that provides an overall measure for QOL and health impairment in COPD patients. The SGRQ is a valid measure for assessing QOL in COPD. SGRQ has three subscales including symptoms, activity, and impact of disease on daily

life. The items were scored from zero to 100 and expressed as a percentage, the higher the percentage of scores, the lower the QOL of the patient. Tafti et al translated SGRQ into Persian language, assessed its validity and reliability and demonstrated its suitability for Iranian culture and society (32).

Statistical analysis

The SPSS (Version 16, SPSS Inc., and Chicago, IL, USA) was used for statistical analysis. Dropout data were not included for analysis. Normal distribution of data was determined by the Kolmogorov-Smirnov test and parametric tests were used to analyze the data. Paired-sample t-test and independent sample t-test were applied respectively to determine the within-group and between-group differences at the baseline measurements and at the end of intervention. To assess the test-retest reliability of all functional tests, 10 healthy subjects repeated measurements taken one week apart. The interclass correlation coefficient measured to evaluate the reliability. The level of significance was set to 0.05.

Results

A total of 45 patients participated in this study, 13 subjects did not fulfill the inclusion criteria and two patients in ET group were excluded due to travel and irregular attendance in training sessions, thus 30 patients completed the treatment and the evaluation sessions (Fig. 1).

The interclass correlation coefficients as a measure of reliability for the 6MWT, TUG and SC were 0.98, 0.94 and 0.97, respectively. Percentages of categorical variables and participants' demographic data of both groups have been shown in Tables 2 and 3, respectively. As shown in Table 3, independent-sample t-test revealed no significant differences between two groups at the beginning of the study.

Table 2. Percentages of categorical variables of the participants in the ET and CON groups

Characteristics	Groups	ET Group (n=14) (%)	CON Group (n=16) (%)
Female		28.6 %	12.5%
Male		71.4%	87.5%
Current smokers		18.8%	21.4%
Ex-smoker		57.1%	43.8%
Education Level (Higher than high school diploma)		30 %	25%
Education Level (Lower than high school diploma)		70 %	75%

Table 3. Baseline characteristics of the participants in the ET and CON groups

Baseline measurements	Groups	ET Group (n=14) Mean ± SD	CON Group (n=16) Mean ± SD	p
Age (yr.)		64.71±7.52	66.37 ±8.20	0.327
Weight (kg)		66.50±10.42	66.90 ±9.74	0.165
Height (m)		166.57±9.06	165.31 ±8.41	0.873
BMI (kg.m ²)		23.87±2.43	24.42 ±2.91	0.286
History of COPD (yr.)		7.65±4.08	2.31±4.46	0.175
Smoking, pack-years		20.78±27.54	15.68 ±13.50	0.637
FEV1/FVC (%)		59.65±9.42	52.38±10.45	0.131
FEV1 (%)		60.23±14.01	59.01±18.01	0.925
Six minute-walk test (m)		422.88±136.75	438.87±110.47	0.794
Timed up & go test (sec)		7.79±1.30	8.74±2.36	0.196
Stair climbing test (m)		590.21±488.10	617.87±462.41	0.279
SGRQ ¹ (Symptoms)		71.07±23.83	52.61±27.43	0.061
O ₂ Saturation in rest (%)		92.00±3.46	91.43±11.06	0.232
Heart Rate in rest (pulse/min)		80.35±12.55	82.62±13.94	0.645

1. St. George respiratory questionnaire

Table 4. The outcomes within the ET and CON groups pre and post-intervention

Groups	ET Group (n=14)			CON Group (n=16)		
	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	p	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	p
Measurements						
FEV1/FVC (%)	59.65±9.42	64.58±7.60	0.033*	52.38±10.45	51.15±7.33	0.350
FEV1 (%)	60.23±14.01	71.36±11.19	0.011*	59.01±18.01	63.53±12.24	0.086
Six-minute-walk test (m)	422.88±136.75	521.15±109.26	0.043*	438.87±110.47	406.12±137.54	0.263
Timed up & go test (sec)	7.79±1.30	6.19±1.00	0.066	8.74±2.36	8.16±1.63	0.132
Stair climbing test (m)	590.21±488.10	903.38±562.90	0.001*	617.87±462.41	778.75±452.97	0.719
SGRQ (Symptoms)	71.07±23.83	50.98±26.70	0.005*	50.61±27.43	62.40±25.65	0.102
SGRQ (Activity)	73.31±14.74	61.91±25.27	0.0001*	34.47±26.11	34.52±25.37	0.121
SGRQ (Impacts)	61.20±28.98	40.97±25.98	0.0001*	22.06±25.25	22.71±15.03	0.156
SGRQ (Total Scores)	31.24±16.47	67.69±22.51	0.0001*	43.05±23.09	50.92±22.28	0.094
O ₂ Saturation in rest (%)	92.00±3.46	94.53±2.36	0.007*	91.43±11.06	91.62±8.29	0.867
Heart Rate in rest (pulse/min)	80.35±12.55	77.76±11.89	0.968	82.62±13.94	80.31±15.30	0.031

* = Significant

Table 5. Changes in the outcomes measurements between the ET and CON groups post-intervention

Groups	ET Group (n=14) Post-intervention Mean ± SD	CON Group (n=16) Post-intervention Mean ± SD	p
Measurements			
FEV1/FVC (%)	64.58±7.60	51.15±7.33	0.002*
FEV1 (%)	71.36±11.19	63.53±12.24	0.008*
Six minute-walktest (m)	521.15±109.26	406.12±137.54	0.029*
Timed up & go test (sec)	6.19±1.00	8.16±1.63	0.023*
Stair climbing test (m)	903.38±562.90	778.75±452.97	0.516
SGRQ (Symptoms)	50.98±26.70	62.40±25.65	0.022*
SGRQ (Activity)	61.91±25.27	34.52±25.37	0.007*
SGRQ (Impacts)	40.97±25.98	22.71±15.03	0.033*
SGRQ (Total Scores)	67.69±22.51	50.92±22.28	0.013*
O ₂ Saturation in rest (%)	94.53±2.36	91.62±8.29	0.232
Heart Rate in rest (pulse/min)	77.76±11.89	80.31±15.30	0.052

* = Significant

FEV1/FVC, FEV1, SpO₂ %, physical function and QOL

In the ET group, there were significant differences in FEV1, FEV1/FVC, SpO₂ %, 6MWT, SCT and the score of SGRQ between pre and post intervention ($p < 0.05$). As seen in Table 4; no significant differences were observed in the evaluated parameters in the CON group.

FEV1/FVC, FEV1, 6MWT and SCT results have shown significant increases in ET group. The scores of SGRQ subscales have a significant decrease in ET patients compare to CON group. Also, O₂ saturation of ET patients has a significant increase in rest, as presented in Table 5.

There were significant differences in the outcomes changes of FEV1/FVC ($p = 0.002$), FEV1 ($p = 0.008$), 6MWT ($p = 0.029$), TUG ($p = 0.023$) and SGRQ; symptoms ($p = 0.022$), activity ($p = 0.007$), impacts ($p = 0.033$) and total score ($p = 0.013$) between ET and CON group (Table 5). No significant differences were shown in the remaining variables. The findings of this study showed that there were significant increases in FEV1/FVC and FEV1 of the ET group which shows the positive impact of eccentric exercises on COPD. All functional tests showed significant differences between the pre and post-intervention in the ET group. Also, in the comparison between the groups, there were significant increase in the 6MWT and TUG outcomes changes in favor of the ET group. The total score and the three sub-scale scores for SGRQ were higher in the ET group than the CON group. This increase could indicate reductions in symptoms, improvement of activities, and positive effect on QOL of ET group, from the patients' perceptions and point of view.

Discussion

ET has favorable effects on the COPD patients' QOL, motor functions, and pulmonary functions. However, we did not observe between-group differences in rest HR.

Our finding is similar to the outcome of Hoff et al. in which FEV1 and FVC improved significantly in the COPD patients after leg press training (33). Furthermore, Incorvaia et al found the mean of FEV1 slightly raised in exercise training group as an add-on to their medications (34). Gohar et al showed a significant improvement of both FVC and FEV1 parameters in COPD patients who undergo lower limb exercise for 6 weeks (35). Similarly, Elkhateeb et al showed the aerobic training program for 6–8 weeks has the capability to improve FVC and FEV1(36).

The increase occurred in FEV1 of the ET group suggests DW may be a useful intervention beside pharmacotherapy and smoking cessation which slow down the FEV1 decline in COPD. FEV1 enhancement may be attributed to the improvement of expiratory muscles performance, especially the abdominal muscles. Some evidence report decrease of strength in the expiratory muscle for unknown reasons in COPD patients. Due to the negative impact of COPD in reducing airways elasticity and increasing their resistance, it is possible that the strength of expiratory muscles is increased as a result of DW, which in turn could leads to improvement of forced expiration.

COPD patients' exercise tolerance which was measured by 6MWT and SCT); showed statistically significant difference within the ET group and no significant differences were achieved in the CON group. There were also signifi-

cant differences between the groups in 6MWT and TUG tests. Rooyackers et al. findings were consistent with our results about 6MWT; they found a significant increase in 6MWT between eccentric and general exercise training groups (2). Elkhateeb et al, also, detected a significant increase in the 6MWT between the exercise and non-exercise groups (36). The improvement in 6MWT can be attributed to the effects of eccentric exercise in increasing lower extremities' muscle strength. ET probably makes the COPD patients increase their function by consuming less energy and oxygen for a longer time (2,20,37). After, DW the capability of patients to perform ADL has increased. Roig et al stated that ET may be safely used to restore musculoskeletal function in chronic conditions such as COPD (20). Improvement in 6MWT could be attributed to the DW as this kind of training could improve the ADL of the patients. Our findings concurred with most of the studies showing improvements of functional capacity and exercise tolerance in COPD patients. Some studies have noted reduced balance and impaired motor control in COPD patients (16,18,38). TUG was used to provide a timed measure of balance and functional mobility in the patients. Our results indicated a significant decrease in TUG outcomes between the ET and CL groups. In contrast to our study, a sub-maximal exercise task did not affect the TUG performance in Chang et al. study (39). The discrepancy could be as a result of the different types of training used in the two studies. Moreover; there was a significant increase in SCT within the ET group and a statically significant difference in of SCT between the groups. The improvement in the functional test results in the ET group may be related to physiological adaptation of muscles, increasing muscle function, increasing activity tolerance and desensitization to dyspnea (2, 11, 16, 22, 30, 34, 40).

The results of several studies have been shown that rehabilitation leads to a significant improvement in QOL (34, 36, 40, 41). The findings of the study showed significant decreases in total score as well as three subscales of the SGRQ namely symptoms, activity, and impact of disease on daily life in favor of the ET group. In comparing the two groups, the score of the three parts of SGRQ showed significant decreases and the ET group's scores were considerably improved.

Based on our knowledge, there is no study about the effect of on DW of COPD patients using the SGRQ. Most studies had used chronic respiratory disease questionnaire (CRDQ) to assess the QOL in COPD. Troosters et al demonstrated improvements in QOL 18 months after a combined multimodality endurance and strength training program. Guell et al. observed the improvement of COPD patients QOL using CRDQ after 12-week exercise training (42), consistent to our findings. Vogiatzis et al achieved a significant improvement in the total score of CRDQ after 12 weeks of continuous and Interval exercise therapy in COPD patients (43).

Contrary to the authors' expectation, a significant decreases in the score of symptoms subscale of the SGRQ was observed between the two groups which suggest the beneficial effects of DW in symptoms reduction among

the COPD patients. The improvement in all subscales of the SGRQ scores may be attributed to the lower extremity muscle strength increase, reducing muscle dysfunction, increasing respiratory capacity and improving the patients' confidence in performing physical activities without fear of shortness of breath and aggravation of pulmonary symptoms.

One of the important factors that might influence the SGRQ scores was the supervision of a sports medicine specialist during exercise therapy, which could improve the patients' self-esteem, symptoms, and their physical performance. Lack of supervision in the CON group is probably one of the reasons for the lack of significant improvement in patients' conditions in spite of walking.

An improvement in SpO₂ % was seen within ET group which may be due to the improvement of tissues' oxygen supply or the physiological properties of eccentric exercise (16). There was no significant difference in SpO₂ % between the groups. Similarly, HOFF et al observed no change in SpO₂ % between training and control groups after 8 weeks (33). It seems blood oxygen saturation measured by pulse oximetry depends on several factors such as poor perfusion, dyshaemoglobinaemias, and skin color (38); so to detect the changes in blood oxygen saturation more accurate tests such as blood sampling is advised.

HR in rest showed no significant difference within and between groups. Camillo et al indicated that high-intensity compared to low-intensity exercise improves HR at rest in COPD patients (11). Our finding correlated with a study done by Rooyackers et al, in an inpatient pulmonary rehabilitation program, no significant improvements in HR and SpO₂ % were seen between eccentric cycle exercise and general exercise training groups (2). Lack of change in HR may be explained by the effects of medications that patients were taking during study.

In this study the patients easily adapted to DW; furthermore, no complaints of shortness of breath, no O₂ saturation, and no muscle soreness were observed during training.

The most important limitations of the study were the lack of follow-up period. In addition, there was no supervision on the physical activity of the CON group; similar to other studies that prescribe home-based exercise for the participants, there is no complete control over their daily activities and prescribed exercise and it is only possible to check their activity by telephone.

Conclusion

The finding supports the feasibility of application of DW on treadmill for COPD patients as a safe and well tolerated training modality that can be performed without causing breathlessness or needing supplemental oxygen in these patients. By doing the exercise with appropriate intensity, eccentric trainings such as downhill walking could have positive effects on physical functions and QOL of COPD patients.

Acknowledgment

The authors wish to thank the participants for their val-

uable time and their excellent cooperation. The authors gratefully acknowledge the valuable help of the academic members and the staff of the Sports Medicine Clinic of Hazrat Rasool Hospital, especially sports medicine residents, Dr. Ahmad Nazari and Dr. Seyed Salman Khaliefeh Soltani. This project was supported by a grant from Iran University of Medical Sciences (Grant number: 92-01-30-21659).

Conflict of Interests

The authors declare that they have no competing interests.

References

- MacNee W. Systemic inflammatory biomarkers and co-morbidities of chronic obstructive pulmonary disease. *Ann Med.* 2013;45(3):291-300.
- Rooyackers J, Berkeljon D, Folgering H. Eccentric exercise training in patients with chronic obstructive pulmonary disease. *Int J Rehabil Res.* 2003;26(1):47-9.
- Varga J. Mechanisms to dyspnoea and dynamic hyperinflation related exercise intolerance in COPD. *Acta Physiol Hung.* 2015;102(2):163-75.
- Kohli P, Pinto-Plata V, Divo M, Malhotra A, Harris RS, Lazaar A, et al. Functional Capacity, Health Status, and Inflammatory Biomarker Profile in a Cohort of Patients With Chronic Obstructive Pulmonary Disease. *J Cardiopulm Rehabil Prev.* 2015;35(5):348-55.
- Barreiro E, Sieck G. Muscle dysfunction in COPD. *J Appl Physiol.* 2013;114(9):1220-1.
- Franssen F, Broekhuizen R, Janssen PP, Wouters E, Schols A. Limb muscle dysfunction in COPD: effects of muscle wasting and exercise training. *Med Sci Sports Exerc.* 2005;37(1):2-9.
- Man W, Kemp P, Moxham J, Polkey M. Skeletal muscle dysfunction in COPD: clinical and laboratory observations. *Clin Sci.* 2009;117:251-64.
- Allaire J, Maltais F, Doyon JF, Noel M, LeBlanc P, Carrier G, et al. Peripheral muscle endurance and the oxidative profile of the quadriceps in patients with COPD. *Thorax.* 2004;59(8):673-8.
- Taivassalo T, Hussain SN. Contribution of the Mitochondria to Locomotor Muscle Dysfunction in Patients With COPD. *Chest.* 2016;149(5):1302-12.
- Troosters T, Probst VS, Crul T, Pitta F, Gayan-Ramirez G, Decramer M, et al. Resistance training prevents deterioration in quadriceps muscle function during acute exacerbations of chronic obstructive pulmonary disease. *Am J Respir Crit Care Med.* 2010;181(10):1072-7.
- Camillo CA, Burtin C, Hornikx M, Demeyer H, De Bent K, van Remoortel H, et al. Physiological responses during downhill walking: A new exercise modality for subjects with chronic obstructive pulmonary disease? *Chron Respir Dis.* 2015;12(2):155-64.
- Seymour J, Spruit M, Hopkinson N, Natanek S, Man W-C, Jackson A, et al. The prevalence of quadriceps weakness in COPD and the relationship with disease severity. *Eur Respir J.* 2010;36(1):81-8.
- Gifford JR, Trinity JD, Layec G, Garten RS, Park S-Y, Rossman MJ, et al. Quadriceps exercise intolerance in patients with chronic obstructive pulmonary disease: the potential role of altered skeletal muscle mitochondrial respiration. *J Appl Physiol.* 2015;119(8):882-8.
- Amann M, Regan MS, Kobitany M, Eldridge MW, Boutellier U, Pegelow DF, et al. Impact of pulmonary system limitations on locomotor muscle fatigue in patients with COPD. *Am J Physiol Regul Integr Comp Physiol.* 2010;299(1):R314-R24.
- Benzo RP, Abascal-Bolado B, Dulohery MM. Self-management and quality of life in chronic obstructive pulmonary disease (COPD): The mediating effects of positive affect. *Patient Educ Couns.* 2016;99(4):617-23.
- Isner-Horobeti M-E, Dufour SP, Vautravers P, Geny B, Coudeyre E, Richard R. Eccentric exercise training: modalities, applications and perspectives. *Sports Med.* 2013;43(6):483-512.
- Yentes JM, Sayles H, Meza J, Mannino DM, Rennard SI, Stergiou N. Walking abnormalities are associated with COPD: An investigation of the NHANES III dataset. *Resp Med.* 2011;105(1):80-7.
- Beauchamp MK, Sibley KM, Lakhani B, Romano J, Mathur S, Goldstein RS, et al. Impairments in Systems Underlying Control of Balance in COPD. *Chest.* 2012;141(6):1496-503.
- Rugbjerg M, Iepsen UW, Jørgensen KJ, Lange P. Effectiveness of pulmonary rehabilitation in COPD with mild symptoms: a systematic review with meta-analyses. *Int J Chron Obstruct Pulmon Dis.* 2015;10:791.
- Roig M SB, Reid WD. Eccentric exercise in patients with chronic health conditions: a systematic review. *Physiother Can.* 2008;60(2):146-60.
- Kapchinsky S, Jagoe T, Baril J, Purves-Smith F, Sena RDS, Sgarlato N, et al. Comparison Of Skeletal Muscle Hypertrophy In Eccentric Versus Concentric Cycling In COPD. *Am J Respir Crit Care Med.* 2013;187:A3810.
- LaStayo P, Marcus R, Dibble L, Frajacomo F, Lindstedt S. Eccentric exercise in rehabilitation: safety, feasibility, and application. *J Appl Physiol.* 2014;116(11):1426-34.
- Rocha Vieira DS, Baril J, Richard R, Perrault H, Bourbeau J, Taivassalo T. Eccentric cycle exercise in severe COPD: feasibility of application. *COPD.* 2011;8(4):270-4.
- Bridgeman L, Gill N, McGuigan M. Eccentric exercise as a training modality: a brief review. *JASC.* 2015;23(5):52-65.
- Maeo S, Yamamoto M, Kanehisa H. Muscular adaptations to short-term low-frequency downhill walking training. *Int J Sports Med.* 2015;36(02):150-6.
- Sabatier MJ, Wedewer W, Barton B, Henderson E, Murphy JT, Ou K. Slope walking causes short-term changes in soleus H-reflex excitability. *Physiol Rep.* 2015;3(3):e12308.
- Minetti AE, Moia C, Roi GS, Susta D, Ferretti G. Energy cost of walking and running at extreme uphill and downhill slopes. *J Appl Physiol.* 2002;93(3):1039-46.
- Perrey S, Fabre N. Exertion during uphill, level and downhill walking with and without hiking poles. *J Sports Sci Med.* 2008;7(1):32-8.
- Rabe KF, Hurd S, Anzueto A, Barnes PJ, Buist SA, Calverley P, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. *Am J Respir Crit Care Med.* 2007;176(6):532-55.
- Bennell K, Dobson F, Hinman R. Measures of physical performance assessments: Self-Paced Walk Test (SPWT), Stair Climb Test (SCT), Six-Minute Walk Test (6MWT), Chair Stand Test (CST), Timed Up & Go (TUG), Sock Test, Lift and Carry Test (LCT), and Car Task. *Arthritis Care Res.* 2011;63(S11):S350-S70.
- Bisca GW, Morita AA, Fernandes NA, Probst VS, Pitta F. Simple lower limb functional tests in patients with Chronic Obstructive Pulmonary Disease: a systematic review. *Arch Phys Med Rehabil.* 2015;96(12):2221-30.
- Tafti SF, Cheraghvandi A, Mokri B, Talischi F. Validity and specificity of the Persian version of the Saint George Respiratory Questionnaire. *J Asthma.* 2011;48(6):589-92.
- Hoff J, Tjonna AE, Steinshamm S, Hoydal M, Richardson RS, Helgerud J. Maximal strength training of the legs in COPD: a therapy for mechanical inefficiency. *Med Sci Sport Exer.* 2007;39(2):220.
- Incorvaia C, Russo A, Foresi A, Berra D, Elia R, Passalacqua G, et al. Effects of pulmonary rehabilitation on lung function in chronic obstructive pulmonary disease: the FIRST study. *Eur J Phys Rehabil Med.* 2014;50(4):419-26.
- Gohar GM. Ventilatory response to upper versus lower limbs exercises in males with chronic obstructive pulmonary disease. 2010.
- Elkhateeb Naglaa Bakry, Elhadidi Ahmed A, Masood Hosam H. Pulmonary rehabilitation in chronic obstructive pulmonary disease. *Egypt J Chest Dis Tuberc.* 2015;64:359-69.
- Erfani A, Moezy A, Mazaherinezhad A, Mousavi SAJ. Does Downhill Walking on Treadmill Improve Physical Status and Quality of Life of A Patient With COPD? *Asian J Sports Med.* 2015;6(4):e25821.
- Pretto JJ, Roebuck T, Beckert L, Hamilton G. Clinical use of pulse oximetry: official guidelines from the Thoracic Society of Australia and New Zealand. *Respirology.* 2014;19(1):38-46.
- Chang AT, Seale H, Walsh J, Brauer SG. Static balance is affected following an exercise task in chronic obstructive pulmonary disease. *J Cardiopulm Rehabil Prev.* 2008;28(2):142-5.

40. Lacasse Y, Martin S, Lasserson T, Goldstein R. Meta-analysis of respiratory rehabilitation in chronic obstructive pulmonary disease. A Cochrane systematic review. *Eura Medicophys.* 2007;43(4):475-85.

41. Jácome CI, Marques AS. Pulmonary rehabilitation for mild chronic obstructive pulmonary disease: a systematic review. *Respir Care.* 2013; 02742.

42. Guell R, Casan P, Belda J, Sengenis M, Morante F, Guyatt GH, et al. Long-term effects of outpatient rehabilitation of COPD: a randomized trial. *Chest.* 2000;117(4):976-83.

43. Vogiatzis I, Nanas S, Roussos C. Interval training as an alternative modality to continuous exercise in patients with COPD. *Eur Respir J.* 2002;20(1):12-9.

Supplementary Material

Calculating Treadmill Gradient

The percentage gradient (grade) is the ratio of height distance (H) and the length distance (L):

$$\% \text{ gradient} = H/L \times 100$$

To calculate the angle of inclination the formula is arcsine (H/D)

Example:

A level/flat treadmill will have a grade of 0 percent. A 45-degree angle, when both H and L are the same, is equal to a gradient of 100 percent. A completely vertical but impossible treadmill would have a grade of infinity!

Calculating the Slope

Using a tape measure or ruler, you can do manually what the treadmill does via its internal mechanism: measure the "rise," that is, the vertical height of the belt from the horizontal, and the "run," which is the distance along the floor from the back of the belt to the point directly underneath the front of the inclined belt.

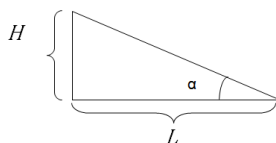
To calculate the percent grade, simply divide the rise by the run and multiply by 100. For example, if you raise the belt so that the front is 0.5 feet higher than the back, and the front and the back are separated by 8 feet along the floor, then the percent grade is $(0.5/8) * 100 = 6.25$ percent.



Angle to percent grade

The slope is the tangent of the angle. The slope is rise/run, and the % grade is 100 times the slope. So a slope of 1/1 would be a 100% grade, which is indeed a 45-degree angle. So if you know the degree of the angle, just enter it into a scientific calculator then hit Tangent.

The Tangent of 39-degree angle is: 0.809784, that is the slope, now multiply by 100 to get the % grade which is equal to 80.9784 %.



L = Treadmill (Deck) Length=139 cm
H= Height requirements to create a slope

$$\sin \alpha = \frac{H}{L}$$

$$\alpha = 7.5^\circ$$

$$\alpha = 5^\circ$$

$$\sin 7.5^\circ = \frac{H}{139}$$

$$\sin 5^\circ = \frac{H}{139}$$

H = 0/121 (sin 7.5°) × 139 = 18/07 ≈ 18cm
H = 0/087 (sin 5°) × 139 = 12/093 ≈ 12 cm