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Does mild chronic obstructive pulmonary disease need a standard pulmonary rehabilitation program? A case report

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ABSTRACT

Background: Patients with mild chronic obstructive pulmonary disease (COPD) are usually not recommended for a standard pulmonary rehabilitation (PR)program based on the GOLD guideline in mild COPD GOLD A classification. Especially, the scientific evidence on exercise capacity that can be identified for recruitment in PR programs has been less reported. Thus, a preliminary case study to identify the exercise capacity under cardiopulmonary responses by aerobic exercise testing among patients in mild COPD GOLD A classification was the aim of this study.

Objective: To evaluate the cardiopulmonary responses from exercise capacity testing in individual COPD patients with mild COPD GOLD A Classification.

Materials and methods: Four participants with mild COPD GOLD A performed an exercise endurance capacity test at home using Spot Marching Exercise Test (SMT), marching on the spot with high hip and arm raising. The load of SMT was indicated by a controlled stepping rate at 70, 80, 90, 100, and 110 steps/min. Every participant performed Incremental SMT (ISMT) with every 3 min incremental load, and the Constant SMT (CSMT) at the peak load. Both exercise tests were terminated at symptom limit. Resting time between ISMT and CSMT was at least 30 minutes. Cardiopulmonary exercise responses, Borg perceived breathlessness (RPB) and exertion (RPE) were monitored every minute during the exercise test. The duration of exercises was recorded.

Results: Peak exercise capacity using ISMT was low with the end exercise load at 70, 80, 80, and 90 steps/min which is equivalent to moderate to high intensity at 81%, 62%, 65% and 93% of age-predicted maximum heart rate (HRmax). The exercise test was stopped by breathlessness at RPB 7, 8, 6, and 5. Respiratory rates (RR) were 36, 26, 38, and 38 breaths/min. With CSMT, the results showed very short exercise duration 1.78, 4.60, 2.15, and 2.47 mins with RPB 7, 8, 5, and 5 and RR of 33, 27, 34, and 41 breaths/min respectively.

Conclusion: This preliminary report reveals that all four mild COPD GOLD A show low exercise capacity and very poor exercise endurance that should identify the appropriated standard PR program in the future.

Introduction

COPD is a progressive lung disease characterized by persistent airflow limitation. Patients with COPD exhibit chronic respiratory symptoms, including dyspnea, cough, sputum, and exacerbations.[1] The prevalence of COPD is increasing globally due to factors like increased exposure to inhaled particles and a rising ageing population.[2]

The airflow limitation is one of the factors that relate to exercise capacity although it is weakly correlated.[3]

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However, it is important to consider that even mild COPD (%FEV1≥80) who has mild airflow limitation has already established pathophysiological changes.[4,5] Previous studies reported that exertional dyspnea and dynamic hyperinflation of lungs even occur in mild COPD[4] There are various factors that can influence the individual's exercise capacity such as musculoskeletal system, cardiovascular system etc.[6]

The pulmonary rehabilitation (PR) guidelines recommend the PR should be provided in chronic respiratory diseases, especially in symptomatic patients.[7-11] Meta-analysis of PR trials in COPD demonstrated that the benefits of PR could improve health status, exercise capacity, dyspnea, quality of life and particularly rate of re-hospitalizations in both stable and post exacerbated patients.[12]

The COPD GOLD guidelines 2023-recommend promoting physical activity for every individual with COPD.[1] However, the recruitment of a standard PR program is based on symptom/risk assessment. According to this guideline, the symptom/risk assessment used two questionnaires: modified medical research council dyspnea scale (mMRC) and COPD assessment test (CAT) as well as previous 1-year history of exacerbation or hospitalization into three groups: GOLD A (low symptoms and 0-1 moderate exacerbation), GOLD B (moderate-severe symptoms and 0-1 moderate exacerbation), and GOLD E (whichever severity of symptoms and ≥2 moderate exacerbation or hospitalization. PR is recommended to only GOLD B and GOLD E but not for GOLD A.

This recommendation is not based on the actual exercise capacity but only symptom/risk assessment.[1,13] Therefore, there is an ambiguity, as to whether missing out on the mild COPD GOLD A from the standard PR program is good practice for this group. It is difficult to include every patient with COPD into standard PR because referring COPD patients to PR is limited by Thai COPD clinical practice guideline that follow GOLD guideline.[1] However, it is also important that patients who have low exercise capacity should not lose the benefit of attending standard PR programs.[14] Therefore, this study aimed to evaluate exercise capacity and cardiopulmonary responses in patients with mild COPD GOLD A. This preliminary study would inform the way of clinical practice in PR that should be based on pre-exercise testing and include patients who need it.

Materials and methods:

Study design and participants

This study was a descriptive study. The participant's recruitment was done from Nam-Phong Hospital and Srinagarind Hospital, Khon Kaen Province, Thailand between December 2022 to March 2023. This study included mild COPD (FEV1% predicted > 80%), aged between 40 to 80 years, with good communication, cooperation, and cognition as well as 0-1 moderate exacerbation or hospitalization prior to 1 year, and mMRC 0-1. In addition, participants who had exacerbation within 4 weeks before the study were also excluded. Before the enrollment, every participant signed an informed consent. This study was approved by Center for Ethics in Human Research, Khon Kaen University (HE641234).

Procedure

After recruitment, the participants were interviewed with CAT, mMRC scores, exacerbation history from the previous year, current medications, and assessed the vital signs (Nihon Kohden, Vismo PVM-4763). The participants then were assessed the lung function by the spirometry Vyntus™ PC SPIRO by a certified investigator (Thoracic Society of Thailand under Royal Patronage) following the American Thoracic Society (ATS)/European Respiratory Society (ERS) guideline for spirometry (2019) with the Thai predicted reference value. (2000).[15,16]

Before the exercise test, the participants were instructed as following: resting for a minimum of two hours, refraining from vigorous exercise for at least 24 hrs prior, avoiding caffeine on the day of the test, and refraining from smoking for at least 8 hours. Moreover, every participant was requested to wear comfortable clothing and shoes that are appropriate for exercise.[17] They were also taught how to score of their dyspnea and exertion sensation using Borg's CR-10 (zero as no symptoms, three as moderate, five as severe, seven as very severe, and ten as maximum) until they could express clearly. Exercise testing procedure, consisted of three phases: resting (5 min in comfortable sitting and 1 min standing), testing phase, and recovery phase (at least 5 min). Electrocardiogram, heart rate (HR), oxygen saturation (SpO2), blood pressure (BP), respiratory rate (RR), and end-tidal carbon dioxide (End-tidal CO2) were monitored at the end of every phase.

Exercise testing

Spot Marching Exercise testing, a new field exercise test was used. To define exercise capacity, there were 2 steps of exercise test; (1) Incremental Spot Marching Test (ISMT) to determine peak exercise load, and (2) Constant Spot Marching Test (CSMT) to determine exercise endurance capacity Symptom-limited exercise test was used according to the American Association of Cardiovascular and Pulmonary Rehabilitation guidelines and the European Respiratory Society statement on standardization of cardiopulmonary exercise testing in chronic lung diseases.[8,15] Patients who had any contraindications for exercise testing were excluded from this study. The participants completed the ISMT first. They rested for at least 30 minutes before starting CSMT. Details of both tests were as follow:

Incremental Spot Marching Exercise Testing (ISMT)

ISMT is the incremental exercise test to define peak exercise load. This test involves participants' marching on the spot with alternate knees raising (hip flex 45-70 degrees) and arm raising above shoulder height (shoulder flex >90 degrees). The intensity or load of SMT is stepping rate. There was a good correlation of stepping rate and oxygen consumption (VO_2) in COPD patients (r0.709), therefore increasing stepping rate could result in increasing exercise intensity.[18,20] The starting stepping

rate was 70 steps/min then incrementally 10 steps/min for every 3 minutes. The stepping rates were controlled by using a metronome. The arms and legs range of motions was controlled via visual feedback (individualized tape markings of the height of arm and leg raising were placed on the wall in front of them). Moreover, verbal feedback was also given to encourage and control their consistency of step rates and range of motion. Parameters of uncoordinated step rate within ±5% were allowed. However, if an uncoordinated step rate >±5% occurred and verbal instruction was unable to correct this, the exercise test was terminated. The participants performed exercise testing until their symptoms ceased. The peak step rates and duration of the exercise test were recorded.

Constant Spot Marching Exercise Testing (CSMT)

The procedure of CSMT was the same as ISMT except using peak step rates achieved in ISMT as a constant load. Peak step rate of ISMT has been found to be submaximal exercise intensity based on VO_2 response of this exercise testing in a previous study.[18] The duration of exercise test was recorded.

Outcome measurement

Cardiopulmonary responses during exercise testing

- Heart rate (HR) was monitored with electrocardiogram (ECG) every minute.
- Blood pressure (BP) was measured with arm cuff sphygmomanometer every 2 minutes.
- Oxygen saturation (SpO_2) was measured with finger pulse oximeter every minute.
- Respiratory rate (RR) was derived from capnography.
- Maximum heart rate (%HRmax) was calculated using 206.9-0.69 * age.[21]

Rate of perceived breathlessness and exertion

- Borg's CR-10 was used to assess the severity of exercise-induced dyspnea and physical exertion.
- These outcomes were monitored in resting, exercise, and recovery phases.

Data Analysis

Demographic characteristics and the outcomes were reported with descriptive statistics using median and interquartile range (IQR).

Results

The demographic and clinical characteristics of four mild COPD patients are presented in Table 1. All participants were old age (68-80 years old), long-term smokers with a smoking history were 23.50 (21.25, 32.50) pack-years. Additionally, there were no reports of exacerbation in the previous year for all participants.

Table 1 Demographic and clinical characteristics of 4 participants.

Variable	No.1	No.2	No.3	No.4	Median
Age: years old	80	68	75	77	76 (69, 79)
Weight: kg	50	79	46	49	49 (46, 72)
Hight: cm	155	171	160	162	161 (156, 168)
BMI: kg/m^2	20.8	27.2	18.0	18.7	19.74 (18.14, 25.59)
Smoking Status					
Ex-smoker: pack-years	25	35	21	22	23.50 (21.50, 30.00)
Dyspnea Questionnaires					
CAT score	4	4	4	4	4 (4, 4)
mMRC	1	1	1	1	1 (1,1)
Exacerbation in previous 1 yrs.	0	0	0	0	
Symptoms/Risk Classification	A	A	A	A	
Pulmonary Function					
FVC: L	2.09	3.18	2.54	2.75	2.65 (2.20, 3.07)
FVC: %pred	95.87	99	100	110	99.50 (96.65, 107.50)
FEV_1: L	1.43	2.03	1.54	1.56	1.55 (1.46, 1.91)
FEV_1: %pred	85	84	80	83	83.50 (80.75, 84.75)
FEV_1/FVC	62.37	63.95	69.46	56.67	63.16 (58.09, 68.08)
Medication	S FL	B FO TI	S FL	S FL	
Comorbidity	HT	HT	No	HT	

Note: *Data represent as median (IQR), BMI: body mass index, FVC: force vital capacity, FVC%pred: percent predicted of force vital capacity, FEV1: force expiratory volume in 1 second, FEV1%pred: percent predicted force expiratory volume in 1 second, FEV1/FVC%: percent ratio of force expiratory volume in 1 second by force vital capacity. Medication S: salmeterol, FL: fluticasone, B: budesonide, FO: formoterol, TI: tiotropium. Comorbidity HT: hypertension.*

All participants followed the protocol of ISMT and CSMT. No adverse events occurred during the tests. The individualized and median (IQR) data of RR, SpO2, ETCO2, BP, HR, %HRMax, %HRR, RPB, RPE, step rates and exercise duration of ISMT and CSMT, were shown in Table 2 and Table 3 respectively. All participants reached the peak exercise load with severe symptoms of breathlessness and RR in 2.8-8 minutes of low load at 70-90 step/min. The end exercise HR were 63-93 % HRmax as shown in Table 1.

The time course of changes in HR, RR, RPB and RPE during CSMT was presented in Figure 1. Participants stopped exercise in 2-5 minutes with RR of 26-41 breath/min at the RPB of 5-8 and RPE of 3-9.

Table 2 Cardiopulmonary and exercise responses of 4 participants at the end of the Incremental Spot Marching Exercise Test (ISMT).

Responses	No.1		No.2		No.3		No.4	
	Resting	End exercise	Resting	End exercise	Resting	End exercise	Resting	End exercise
Intensity and Duration								
Symptoms limited Intensity (step/min)	NA	80	NA	90	NA	70	NA	80
Duration: min	NA	5	NA	8	NA	2.8	NA	5.95
Cardiovascular system								
HR (beat/min)	85	123	76	100	61	102	91	144
HRMax (%)	56	81.1	47	62.5	39	65.7	59	93.6
HRR (%)	0	56.7	0	28.2	0	43.2	0	84.3
SBP (mmHg)	120	144	114	145	116	141	125	142
DBP (mmHg)	55	78	74	76	77	83	73	105
Pulmonary System								
RR (breath/min)	19	36	17	26	12	38	12	38
SpO_2 (%)	97	97	98	96	97	95	100	96

Note: *RR: respiratory rate, HR: heart rate, HRMax%: percentage of maximal heart rate, HRR%: percentage of heart reserve, %SpO_2: percentage of oxygen saturation, SBP: systolic blood pressure, DBP: diastolic blood pressure, MAP: mean arterial pressure, RPB: rate perceives of breathlessness, RPE: rate perceives of exertion.*

Table 3 Cardiopulmonary and exercise responses of 4 participants at the end of exercise endurance test using Constant Spot Marching Exercise Test (CSMT).

Responses	No.1		No.2		No.3		No.4	
	Resting	End exercise	Resting	End exercise	Resting	End exercise	Resting	End exercise
Intensity and Duration								
Symptoms limited Intensity (step/min)	NA	80	NA	90	NA	70	NA	80
Duration: min	NA	1.78	NA	4.60	NA	2.15	NA	2.47
Cardiovascular system								
HR (beat/min)	89	123	76	98	63	75	88	150
HRMax (%)	59	81	47	61	40	48	57	97
HRR (%)	NA	53	NA	25	NA	13	NA	94
SBP (mmHg)	112	141	107	123	107	108	125	124
DBP (mmHg)	63	81	73	84	71	91	74	81
Pulmonary System								
RR (breath/min)	24	33	14	27	13	34	14	41
SpO_2 (%)	95	97	96	96	96	97	99	96

Note: *RR: respiratory rate, HR: heart rate, HRMax%: percentage of maximal heart rate, HRR%: percentage of heart reserve, %SpO_2: percentage of oxygen saturation, SBP: systolic blood pressure, DBP: diastolic blood pressure, MAP: mean arterial pressure, RPB: rate perceives of breathlessness, RPE: rate perceives of exertion.*

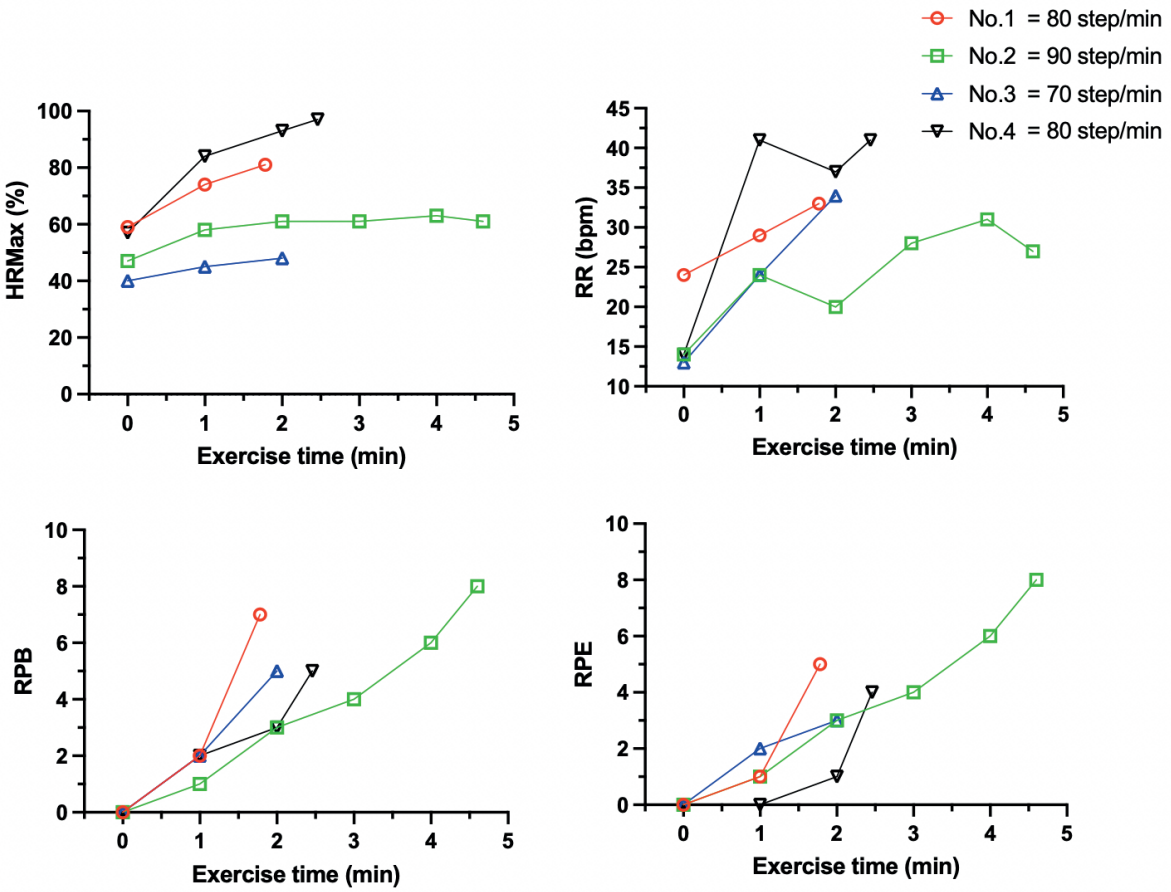

Figure 1 *Cardiopulmonary and Borg's perceived breathlessness and exertion responses during Constant Spot Marching Exercise Test.*
HRmax%: percentage of maximal heart rate, RR: respiratory rate,
RPB: rate perceived of breathlessness, RPE: rate perceived of exertion.

Discussion

This study reveals surprisingly low exercise capacity in mild COPD GOLD A during incremental and constant load of exercise with the Spot Marching Exercise test (SMT). All participants had low peak exercise capacity and poor exercise endurance as seen with very short exercise duration at submaximal exercise intensity. Exercise endurance was early terminated because of severe breathlessness. However, there were different cardiac responses to the exercise test at the same load.

There are several field tests and laboratory tests such as the 6-minute walk test, shuttle walk test, and treadmill test cycle ergometry, that have been used in previous studies of COPD.[22-24] The present study used SMT, a form of simple field test of moderate intensity based on criteria of oxygen consumption.[18] This exercise test was chosen because of the functioning pattern, minimum space and devices needed and easy to do at home. It is also suitable for people with lung dysfunction. This new exercise testing protocol has been used in moderate to severe COPD patients.[18,19,25-27]

Although participants No.1 and 4 exercised with a low stepping rate of 80 steps/min but this contributed to high stress of cardiopulmonary functions in just about 2 minutes of exercise. The exercise heart rate reached a high percentage of HRmax and severe breathlessness (Table 2, 3, Figure 1). This indicates poor exercise capacity and exercise endurance as the previous reports.[18,28]

Participant No 3 showed different responses of cardiac function from others with mild intensity less than 50 % HRmax at low load (70 steps/min). Even at this low intensity, this participant also presented early exercise termination of less than 3 minutes. Again, severe breathlessness was the limiting factor.

The exercise capacity and endurance of participant No 2 were better than the others with the longer exercise time of 5 minutes at moderate intensity of 60%HRmax. However, the breathless score reached a severe level in a short time as well.

This phenomenon of poor exercise capacity and endurance is usually seen in COPD especially in moderate to severe COPD due to dynamic hyperinflation (DH). Some previous studies showed that COPD has the main characteristic of airflow limitation that is usually associated with DH and so dyspnea, reduced exercise capacity, and restrictions in activities.[29,30] Moreover, it has been proved that individuals with mild COPD have a wide range of lung structure abnormalities such as vessels, lung compliance,

and trapping of the air.[31,32] Therefore, DH could occur even in mild COPD regardless of static hyperinflation.[29] Furthermore, the increased effort/displacement ratio which is usually high in DH strongly correlates with dyspnea due to neuro-ventilatory mismatching.[33,34] Therefore, the present study hypothesized that although mild COPD has minimal symptoms, there might be an increasing ventilatory limitation during exertion because of DH and so reduced exercise tolerance.

The low exercise capacity and poor endurance found in this study could possibly be not only due to DH but also the amount of working muscles including respiratory muscles during the exercise and the age of all participants. SMT is a whole-body exercise that requires whole-body muscle work. The exercise involves both upper and lower limb movement together with body stabilization. Typically, this exercise places more constraints on the weak respiratory muscles as a result of the arm raising over 90 degrees.[35,36] Khaweephab *et al*. 2016 compared CSMT (self-pacing) and 6 MWT in COPD patients and found that the CSMT stress greater lung function than 6MWT with similar cardiovascular loading.[25] Therefore, the limiting exercise factors would be due to more muscle work and overload on the respiratory system. This effect is seen in high RR at the relatively lower intensity based on the percentage of %HRmax.

Aging lung would be another exercise limiting factor. Since all participants in the present study were old with declining lung capacity. The previous studies by Chaw Su Win *et al*. evaluated cardiopulmonary responses of ISMT in older adults with age 65±4 years 60-70 years.[28] They found that the majority of the older adults stopped exercise at a load of 100 steps/min with a duration of 9.26±3.74 minutes (95%CI 7.97-10.10.54 minutes). Most of the participants terminated exercise in their study due to leg fatigue. In contrast, every participant in the current study terminated the test in both ISMT and CSMT due to the reason of severe dyspnea as a result of added-on lung pathology. However, one of our participants aged 68 years old terminated ISMT at the load of 90 steps/min with a duration of 8 minutes which is slightly lower than the previous study. This participant would be the ideal mild COPD GOLD A.

Limitation

The limitation of the current study is a very small sample size.

Conclusion

Mild COPD GOLD A shows unexpectedly low exercise capacity and endurance. This led to the answer that this group of COPD should be reconsidered by being enrolled in exercise training in a standard PR program. Every participant with COPD should be assessed for their exercise capacity with the whole-body exercise test to detect their exercise limitation before being excluded from the PR program.

Conflict of interest

There are no conflicts of interest in this study.

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