Cardiopulmonary exercise test in chronic obstructive pulmonary disease at high altitude: A case report

Wilder Villamil-Parra[1], Erica Mancera-Soto[2], Joan Ramon Torrella[3], Ginés Viscor[3], Édgar Cristancho-Mejía[1]

ABSTRACT

Chronic obstructive pulmonary disease (COPD) generates functional limitations due to functional deterioration and low tolerance to fatigue. Altitudinal hypoxia leads to a deterioration of physical fitness in patients with COPD. The Initiative for Chronic Obstructive Lung Disease recommends prescribed physical exercise programs as an essential element for the treatment of COPD; therefore, cardiopulmonary exercise tests (CPET) should be performed to identify maximum performance thresholds. However, typical CPET protocols may be inadequate for COPD patients residing at >2500 m as altitudinal hypoxia leads to a deterioration of physical fitness in patients with COPD. We present a case report of a COPD patient residing at >2500 m who underwent 3 different CPET protocols until reaching maximum thresholds of physical performance at high altitude. Each test was performed on the same patient two weeks apart between tests. It was found that the CPET protocol for COPD developed at low altitude is not relevant for COPD patients residing in conditions of altitudinal hypoxia, since the minimum criteria of the American Thoracic Society (ATS) are not met, and the values could not be recorded ventilatory and metabolic maximal. We believe that CPET protocols for people with COPD should be adjusted based on environmental conditions.

Study registration: NCT04955977 [ClinicalTrials.gov] - NCT04955977 [WHO ICRTP].

ABBREVIATIONS AT: anaerobic threshold, CPET: Cardiopulmonary exercise test, COPD: chronic obstructive pulmonary disease, HR: heart rate, RQ: respiratory quotient, SpO_2: oxygen saturation measured by pulse-oximetry, VO_2peak: peak oxygen consumption, PO_2: partial pressure of oxygen

AFFILIATION

1 Departamento de Biología, Universidad Nacional de Colombia, Facultad de Ciencias, Bogotá, Colombia
2 Departamento del Movimiento Corporal Humano, Universidad Nacional de Colombia, Facultad de Medicina, Bogotá, Colombia
3 Physiology Section, Department of Cellular Biology, Physiology, and Immunology, Universidad de Barcelona, Faculty of Biology, Barcelona, Spain

CORRESPONDENCE TO

Wilder Villamil-Parra. Department of Biology, Universidad Nacional de Colombia, Bogotá Campus, Faculty of Sciences, Street 30 No. 45-03, Bogotá, Colombia.
Email: wavillamip@unal.edu.co
ORCID iD: https://orcid.org/0000-0002-1717-1020

KEYWORDS

cardiopulmonary exercise testing, chronic obstructive pulmonary disease, high altitude, hypoxia

Received: 30 January 2024
Revised: 10 March 2024
Accepted: 29 March 2023

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) generates functional limitations as a result of dyspnea, even on mild exertion, impairing functionality and quality of life[1]. Multiple investigations and organizations, such as the Initiative for Chronic Obstructive Lung Disease GOLD[2], recommend prescribing physical exercise for pulmonary rehabilitation programs in patients with COPD. The dosage of training loads applied are based on the maximum performance thresholds attained after a cardiopulmonary exercise test (CPET)[3,4].

At high altitude, understanding this as a geographical altitude above 2500 m and below 5500m, there is a decrease in the environmental partial pressure of oxygen (PO_2)[5]. Exposure to hypobaric hypoxia in patients with COPD leads to increased dyspnea and further clinical deterioration[6]. Performing a CPET under these hypoxic conditions can lead to biased final results that would affect the prescription of the exercise[7]. Thus, since around 10% of known COPD cases worldwide live at high altitude[6], it is essential to design an adequate CPET for these patients. As a preliminary approach, here we present a case report of a COPD patient living at high altitude who performed three different CPET protocols until achieving its maximum threshold.

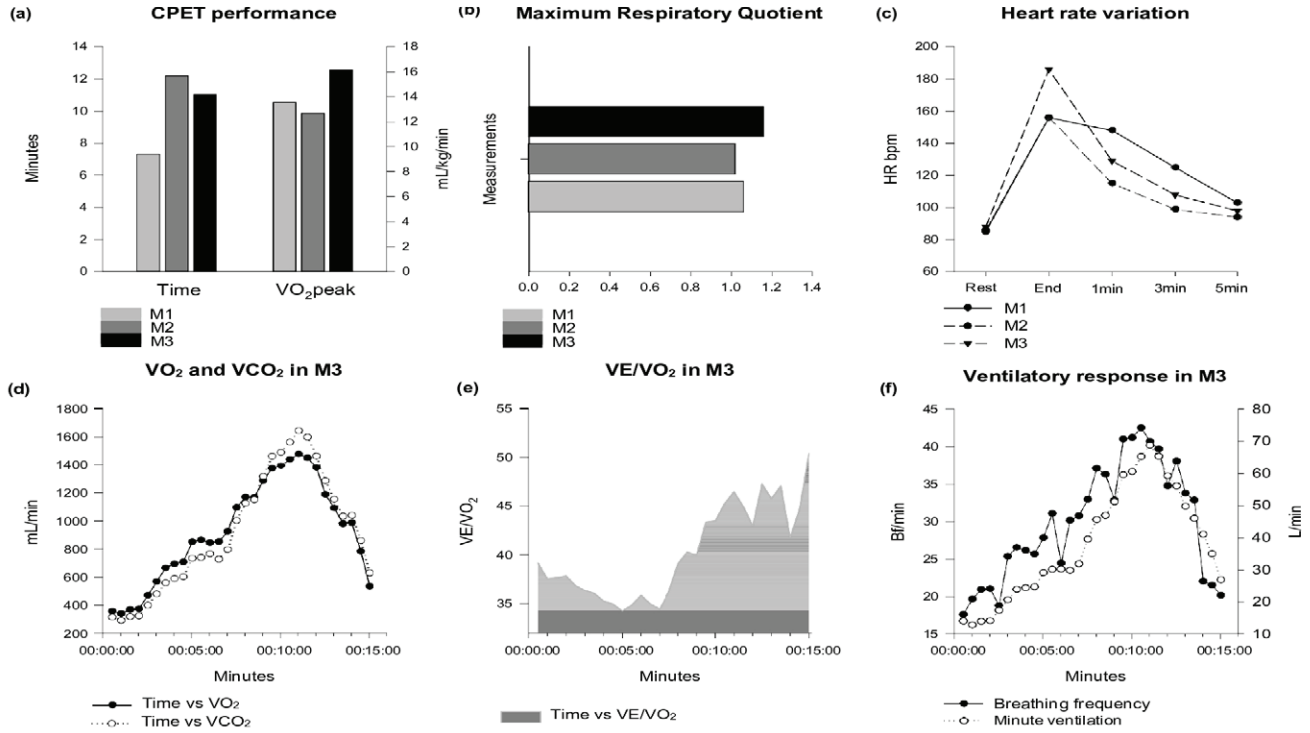
This case report was prepared to consider the indications of The CARE case report guidelines that should be followed (Supplementary file).This research was carried out following the principles of the Declaration of Helsinki and was endorsed by the institutional ethics committee of the Faculty of Sciences of the Universidad Nacional de Colombia granted on 7 December 2020, and registered with approval number 14-2020. The participant signed an informed consent agreeing to her participation.

CASE PRESENTATION

Our patient was a 66-year-old woman diagnosed with COPD GOLD1B, without pulmonary hypertension (mean pressure in pulmonary arteries of 21 mmHg), and respiratory exacerbations during the 6 weeks before the measurements, with a record of cigarette consumption for 43 years with 38 pack-years, but currently a non-smoker (23 years ago). She has a history of pharmacologically controlled hypothyroidism and type II diabetes, without a medical history of neurological, hematological diseases,

Pneumon 2024;37(2):21
https://doi.org/10.18332/pne/186261

Figure 1. Cardiopulmonary exercise test (CPET) results



Environmental variables during measurement: altitude 2640 m, barometric pressure 752.1 hPa, temperature 14°C, humidity 62%. Bpm: beats per minute. CPET: minutes in cardiopulmonary exercise test. HR: heart rate. M1: First measurement. M2: Second measurement. M3: Third measurement. RQ: respiratory quotient. VO_2peak: peak oxygen consumption.

cardiovascular diseases, or sleep disorders that would affect arterial saturation measurements. No disabilities were found that limited the execution of the CPET.

The patient presented arterial desaturation at rest (SpO_2 84%) without requiring oxygen therapy and without signs of respiratory distress (Table 1). The patient reported a score of 17 on the COPD assessment test (CAT, 2009) and dyspnea with score 3/4 on the Medical Research Council Dyspnoea Scale (mMRC, 1959). She also reported a low level of physical activity presenting 1.2 METs/hour and more than 3000 steps/day, measured by accelerometry for 7 days with Triaxial ActiGraph GT3X+ (Pensacola, USA).

Environmental variables during measurement

The cardiopulmonary physical exercise test in the patient with COPD was developed under the following geographical and environmental conditions: 1) region Andean, 2) altitude 2640 m, 3) barometric pressure during measurement 752.1 hPa, 4) temperature 14°C, 5) humidity 62%, and 6) Measurement time 10:00 to 10:30 a.m.

Cardiopulmonary exercise test

For the recognition of the physical condition, the CPET protocol presented by Schneider et al.[8], was followed, which is a protocol indicated and developed for people with COPD. The first measurement (M1) was achieved according to what was postulated by the author (Table 1) using the Velotron DynaFit Pro-RacerMate cycle ergometer (Seattle, USA) accompanied by the Cosmed Quark-B2 gas analysis system (Rome, Italy).

After performing the M1, we found that the test did not meet the minimum time required according to the American Thoracic Society (ATS) (Statement on Cardiopulmonary Exercise Testing)[9]. Therefore, two new measurements (M2 and M3) were defined by adjusting workloads, rpm, and times of each phase (Table 1), until the ATS criteria were achieved.

The patient performed each test with a 2-week difference to avoid distorting the results due to cumulative fatigue. The following variables were taken into account as maximum result variables of the CPET: duration of the test (time in minutes); peak oxygen consumption ($\dot{V}O_2$peak in mL/kg/min); respiratory quotient (RQ); maximum heart rate at the end of the CPET (final HR); recovery heart rates at 1, 3 and 5 minutes after the end of the test; ventilatory O_2 and CO_2 equivalents ($\dot{V}_E/\dot{V}O_2$, $\dot{V}_E/\dot{V}CO_2$); and volume of oxygen consumed ($\dot{V}O_2$) and produced volume of CO_2 ($\dot{V}CO_2$).

In the first protocol (M1), we recorded a 19% higher HR, 31% higher BF, and a 5% lower RQ in a shorter test time (6 min), than the results presented by Schneider et al.[8]. Values of $\dot{V}_E/\dot{V}O_2$ of 34.5 and $\dot{V}_E/\dot{V}CO_2$ of 35.3, were recorded without reaching the anaerobic threshold (AT), lactate 1.6 mmol/L, and RQ of 1.06. In M1, the time on the test did not meet ATS recommendations, as a successful CPET test should last at least 8–12 minutes, with reported RQs >1.10

Table 1. Patient characteristics and CPET protocols

Characteristics		CPET protocols				
		Timeline	Phase	Time (min)	Workload (W)	Speed (rpm)
Sex	Female	First measurement (M1)[8]	Rest	2	0	0
Age (years)	66		Warm-up	3	0	60
Height (cm)	160		Start of load	2	25	60
Weight (kg)	87.5		Load increase	Every 3	25	60
BMI (kg/m^2)	33.6		Active recovery	2	10	30
Physical activity level			Passive recovery	2	No specified	
METs/hour	1.04					
Steps/day	2037	Second measurement (M2)	Rest	2	0	0
Pulmonary function			Warm-up	3	15	15
FVC (%)	70		Start of load	2	20	40
FEV1 (%)	78		Load increase	Every 2	10	60
FEV1/FVC (%)	65.5		Active recovery	2	10	30
PEF (L/S)	5.7		Passive recovery	2	No specified	
Other						
mMRC	3/4	Third measurement (M3)	Rest	1	0	0
CAT	17		Warm-up	2	0	30
Vital signs - baseline			Start of load	2	30	60
SpO_2 (%)	84		Load increase	Every 2	15	60
HR (bpm)	87		Active recovery	2	0	40
BP (mmHg)	120/86		Passive recovery	5	Sitting, without pedaling and quantifying the HR after 1, 3 and 5 min	
BF (breaths/min)	16					

Environmental variables during measurement: altitude 2640 m, barometric pressure 752.1 hPa, temperature 14°C, humidity 62%. BF: breathing frequency. BMI: body mass index. BP: blood pressure. CAT: COPD assessment test. CPET: cardiopulmonary exercise tests. FEF: mean expiratory flow. FEV1: forced expiratory volume in 1 s. FVC: forced vital capacity. FEV1/FVC: forced expiratory volume in 1 s /forced vital capacity. mMRC: Medical Research Council Dyspnea Scale. HR: heart rate. METs: metabolic equivalents. PEF: peak expiratory flow. rpm: revolutions per minute. SpO_2: pulse oxygen saturation.

(Figures 1a and 1b)[9].

Recognizing that as COPD mitochondrial degradation increases, the proportionality of oxidative fibers decreases, muscle capillarization is reduced, and the hypobaric hypoxia in COPD increases the intensity and frequency of bronchospasm, decreases ventilatory muscle capacity, decreases fatigue tolerance and reduction physical fitness, for the second protocol (M2) we decided reduce the warm-up time, the initial load to 20 W, and the load increased to 10 W every 2 minutes with a 40 rpm. In this way, the initial load was reduced to optimize the test time and the values of HR, RQ, and $\dot{V}O_2$peak according to the recommendations of ATS. We found that although the test time increased by 35%, the RQ, $\dot{V}O_2$peak, HR were lower than in M1, and a $\dot{V}_E/\dot{V}O_2$ of 34.6 and $\dot{V}_E/\dot{V}CO_2$ of 35.2 were found without AT achievement, lactate 1.4 mmol/L and RQ of 1.02 (Figures 1a and 1b).

In the third protocol (M3) we reduced the heating speed (rpm), maintaining the same time, increasing the initial load by 35%, increasing 15 W every 2 min, and the speed (rpm) by 35%, to achieve the AT in a shorter testing time. After this protocol we found: 1) an optimal test time without counting the warm-up; 2) a final HR 16% higher than the previous tests; 3) an RQ of 1.16, which is 9% greater than that recorded in M1; 4) a 16% increase in the $\dot{V}O_2$peak recorded in the first determinations; 5) an increase in the levels of ventilatory response (Figures 1d–1f); and 6) the highest record of $\dot{V}_E/\dot{V}O_2$ of 36.4 and $\dot{V}_E/\dot{V}CO_2$ of 37.3 with lactate 2.4 mmol/L, and RQ of 1.16. Finally, we consider important to specify the criteria for the recovery phase when adjusting the protocol, since the scientific literature does not provide detailed information on this phase.

DISCUSSION

Based on the preliminary results derived from the case reported here, the standardized protocol M1 proposed for patients with COPD GOLD1 is not the best CPET for patients residing at high altitudes. In these patients, dyspnea considerably increases with physical exertion because of the effect that the environmental hypoxia (low PO_2) has on the patients' cardiorespiratory function.

The results found in this case report lead us to think that a CPET protocol for people with COPD exposed to high altitude could be the incremental protocol that was executed in M3, which consists of: one minute of measurement at rest on the cycle ergometer, two minutes of warm-up at 30 rpm without load, start of the test with a pedaling at 60 rpm for 2 minutes with a load of 30 W, and increasing the load by 15 W every 2 minutes until fatigue, two minutes of active recovery, pedaling without load at 40 rpm, and 4 minutes of passive recovery in a sitting position.

The decreased tolerance to fatigue and performance of CPET in people with COPD at high altitudes may be related to the effects of hypobaric hypoxia on increased bronchospasm and the acute inflammatory response[10], the decreased efficiency of the ventilatory muscles, the increase in physiological dead space, and the exacerbation of pulmonary hypertension[11]. Considering that low PO_2 environments exacerbate the clinical condition of people with COPD, it is advisable to adjust CPET protocols for high-altitude environments. It can be considered that a CPET test that does not adjust to the environmental conditions can lead to biased results regarding the physical condition of the people; which would affect pulmonary rehabilitation programs based on prescribed physical exercise[7].

All healthcare professionals working with respiratory patients must search for the most effective and forceful intervention strategies and adapt them to the real state of the patients to favor the pulmonary rehabilitation process in patients with diagnoses of respiratory diseases and deterioration of the health condition due to a sedentary lifestyle. Considering that altitudinal hypoxia deteriorates the global function of patients with COPD and that pulmonary rehabilitation programs are based on physical exercise programs, we consider necessary to recognize which CPET protocol is more convenient and efficient for people with COPD exposed to altitudinal hypoxia. Knowledge of the maximum thresholds of physical fitness is necessary to establish physical training programs according to the conditions of each patient. We recognize the need to stipulate CPET protocols that accommodate the hypobaric hypoxia present in high-altitude geographical regions. Finally, we believe that the results obtained could be taken as a starting point to develop CPET tests in COPD at high altitude.

CONCLUSION

The reported patient presented a better performance in CPET with moderate rpm and low watts increase. Altitudinal hypoxia may decrease the physical fitness of patients with COPD. CPET protocols not adjusted for environmental conditions (e.g. altitude) can bias CPET results.

ACKNOWLEDGMENTS

We are grateful to the contribution of Camilo Povea, Francisco Nazar, Vannesa Lozano, Laura Espitia, and Yessica Higuera. We would also like to thank Jonny English for his assistance in proofreading the English text.

CONFLICTS OF INTEREST

The authors have each completed and submitted an ICMJE form for Disclosure of Potential Conflicts of Interest. The authors declare that they have no competing interests, financial or otherwise, related to the current work. All authors report support from Universidad Nacional de Colombia (this research is funded by Universidad Nacional de Colombia (UNAL) for the "Convocatoria para el apoyo a proyectos de investigación y creación artística de la sede Bogotá de la Universidad Nacional de Colombia - 2019, código HERMES, 47970"). Also, they report support for the presentation of the results of this research at the 56th congress of the Spanish Society of Pneumology and Thoracic Surgery (SEPAR), which took place 8–10 June 2023.

FUNDING

This research was financed by the Universidad Nacional de Colombia, through the "Call for the support of research projects and artistic creation of the Bogotá campus – 2019, code HERMES, 47970". The funding organization was not involved in the investigation.

ETHICAL APPROVAL AND INFORMED CONSENT

Ethical approval was obtained from the Universidad Nacional de Colombia (Approval number: 14-2020; Date: 7 December 2020). The participant provided informed consent.

DATA AVAILABILITY

The raw data supporting the conclusions of this article will be made available by the authors, upon reasonable request.

PROVENANCE AND PEER REVIEW

Not commissioned; externally peer reviewed.

AUTHORS' CONTRIBUTIONS

WV: design of the investigation, collection of results, analysis and interpretation of data, drafting of the manuscript. EM: design of the investigation, collection of results, analysis and interpretation of data. RT: analysis and interpretation of data, and drafting of the manuscript. EC: collection of results, analysis and interpretation of data. All authors have read and approved the final version of the manuscript.

REFERENCES

1. Clímaco DCS, Lustosa TC, Silva MVFP, et al. Sleep quality

in COPD patients: correlation with disease severity and health status. J Bras Pneumol. 2022;48(3):e20210340. doi:10.36416/1806-3756/e20210340
2. 2023 GOLD REPORT. Global Initiative for Chronic Obstructive Lung Disease. Accessed March 10, 2024. https://goldcopd.org/2023-gold-report-2/
3. Li L, Huang H, Song J, et al. Network Meta-Analysis of the Effects of Different Types of Traditional Chinese Exercises on Pulmonary Function, Endurance Capacity and Quality of Life in Patients With COPD. Front Med (Lausanne). 2022;9:806025. doi:10.3389/fmed.2022.806025
4. Dal Corso S, de Camargo AA, Izbicki M, Malaguti C, Nery LE. A symptom-limited incremental step test determines maximum physiological responses in patients with chronic obstructive pulmonary disease. Respir Med. 2013;107(12):1993-1999. doi:10.1016/j.rmed.2013.06.013
5. Luks AM, Ainslie PN, Lawley JS, Roach RC, Simonson TS. Ward, Milledge and West's High Altitude Medicine and Physiology. 6th ed. CRC Press; 2021.
6. Guo Y, Xing Z, Shan G, et al. Prevalence and Risk Factors for COPD at High Altitude: A Large Cross-Sectional Survey of Subjects Living Between 2,100-4,700 m Above Sea Level. Front Med (Lausanne). 2020;7:581763. doi:10.3389/fmed.2020.581763
7. Villelabetia-Jaureguizar K, Díaz-Buschmann I, Vaquerizo-García E, Castillo-Martin J, Mahillo Fernandez I, Abeytua-Jiménez M. Protocolo Bruce: errores habituales en la evaluación de la capacidad funcional y en el diseño de un entrenamiento físico en cardiopatía isquémica. Rehabilitacion (Madr). 2013;47(3):162-169. doi:10.1016/j.rh.2013.03.008
8. Schneider J, Lee Giesser I, Laux S, Brückner U, Schneider-Lauteren S. Comparative Assessment of CPET Versus Typical Work-related Activities in Women With and Without Mild COPD. In Vivo. 2019;33(1):115-124. doi:10.21873/invivo.11447
9. American Thoracic Society; American College of Chest Physicians. ATS/ACCP Statement on cardiopulmonary exercise testing. Am J Respir Crit Care Med. 2003;167(2):211-277. doi:10.1164/rccm.167.2.211
10. Karnati S, Seimetz M, Kleefeldt F, et al. Chronic Obstructive Pulmonary Disease and the Cardiovascular System: Vascular Repair and Regeneration as a Therapeutic Target. Front Cardiovasc Med. 2021;8:649512. doi:10.3389/fcvm.2021.649512
11. Georges T, Le Blanc C, Ferreol S, Menu P, Dauty M, Fouasson-Chailloux A. Effects of Altitude on Chronic Obstructive Pulmonary Disease Patients: Risks and Care. Life (Basel). 2021;11(8):798. doi:10.3390/life11080798