competitive examinations (67%), wage increases (66%), the possibility of combining patient care and research (44%), and improved work/life balance (40%).

Despite the possible selection bias, our study shows that most cardiologists decided to subspecialize after residency, often through poorly paid fellowships, and that postresidency contracts tend to be temporary, a situation not limited to the early years. Furthermore, young cardiologists perceive their work situation to be unstable, insecure, and underpaid. For these reasons, we consider that measures should be taken to improve their employment conditions.

FUNDING

None.

AUTHORS' CONTRIBUTIONS

C. Lozano Granero contributed to the conceptualization, design, data acquisition, analysis, and interpretation and wrote the article. E. Díaz-Peláez, A. Barradas-Pires, G. Barge-Caballero, M.T. López-Lluva, and P. Díez-Villanueva made substantial contributions to the conceptualization, design, and drafting of the manuscript and performed a critical review of the intellectual content. All authors approved the final version of the manuscript and agreed to accept responsibility for all aspects of the article and to investigate and resolve any question related to the accuracy and veracity of the study.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

Cristina Lozano Granero,[a,b,*] Elena Díaz-Peláez,[c,d]
Ana Barradas-Pires,[e,f] Gonzalo Barge-Caballero,[d,g]
María Thiscal López-Lluva,[h] and Pablo Díez-Villanueva[i]

[a]*Servicio de Cardiología, Hospital Universitario Ramón y Cajal, Madrid, Spain*
[b]*Instituto Ramón y Cajal de Investigación Sanitaria (IRYCIS), Madrid, Spain*
[c]*Complejo Asistencial Universitario de Salamanca, Instituto de Investigación Biomédica de Salamanca (IBSAL), Salamanca, Spain*
[d]*Centro de Investigación Biomédica en Red de Enfermedades Cardiovasculares (CIBERCV), Spain*
[e]*Adult Congenital Heart Centre and Centre for Pulmonary Hypertension, Cardiology Department, Royal Brompton Hospital, Guy's and St. Thomas' NHS Foundation Trust, Londres, United Kingdom*
[f]*Departamento de Medicina, Universidad Autónoma de Barcelona, Barcelona, Spain*
[g]*Unidad de Insuficiencia Cardiaca y Trasplante Cardiaco, Servicio de Cardiología, Complexo Hospitalario Universitario A Coruña, A Coruña, Spain*
[h]*Servicio de Cardiología, Hospital Universitario de León, León, Spain*
[i]*Servicio de Cardiología, Hospital Universitario de la Princesa, Madrid, Spain*

* Corresponding author.
E-mail address: cristina.lozano@hotmail.es (C. Lozano Granero)
@JovenesSec

Available online 13 October 2022

REFERENCES

1. Barber Pérez P, González López-Valcárcel B. Estimación de la oferta y demanda de médicos especialistas. España 2018-2030. Equipo de Economía de la Salud. *Universidad de Las Palmas de Gran Canaria.* 2018. Disponible en: https://www.sanidad.gob.es/profesionales/formacion/necesidadEspecialistas/doc/20182030EstimacionOfertaDemandaMedicosEspecialistasV2.pdf. Consultado 19 Jun 2022
2. Lewis SJ, Mehta LS, Douglas PS, et al. Changes in the Professional Lives of Cardiologists Over 2 Decades. *J Am Coll Cardiol.* 2017;69:452–462.
3. Vis JC, Borleffs CJ, Zwart B, Nuis RJ, Scherptong RWC. Short-term career perspectives of young cardiologists in the Netherlands. *Neth Heart J.* 2017;25:455–460.

https://doi.org/10.1016/j.rec.2022.08.012
1885-5857/

Ventilatory efficiency in response to maximal exercise in persistent COVID-19 syndrome patients: a cross-sectional study

Eficiencia ventilatoria en respuesta al ejercicio máximo en pacientes con diagnóstico de COVID-19 persistente: un estudio transversal

To the Editor,

Currently, the clinical course of infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) remains uncertain, particularly given the variety of chronic symptoms in the subsequent weeks and months.[1] Parameters such as ventilatory efficiency and exercise capacity allow objective assessment of an individual's ventilatory and functional response, and also provide prognostic information on their clinical status, with important implications for treatment.[2]

The aim of the present study was to examine the—as yet unassessed—effect of persistent coronavirus disease 19 (COVID-19) on parameters of ventilatory efficiency and exercise capacity, in comparison with a group of patients with no history of COVID-19. The sample for this exploratory observational study included 95 individuals (77% were women) with a diagnosis of COVID-19 and mild or moderate symptoms, who had not previously been hospitalized, and had no structural heart disease or lung disease. Patients were considered to have persistent COVID-19 on the basis of compatible signs or symptoms and a positive polymerase chain reaction test for SARS-CoV-2. In addition, they were required to have symptoms persisting for 3 months after the infection, as assessed with a semistructured questionnaire previously used and validated by international expert consensus, which included self-diagnosis of 21 relevant symptoms 3 months after infection (yes/no answers).[3]

The group of patients with no history of COVID-19 (n = 95; 54% women) had not had SARS-CoV-2 infection and were recruited from the exercise capacity and cardiometabolic risk assessment clinic in our hospital. They underwent clinical assessment and functional testing of resting calorimetry, ergospirometry, vascular function, and body composition. Patients were also asked about their physical activity level. The study was approved by the ethics committee of Hospital Universitario de Navarra, and the participants gave signed informed consent (PI_2020/140).

The most prevalent persistent symptom was chronic fatigue (96.1%), followed by headache (81.4%), memory loss (80.4%), and difficulty concentrating (79.4%), the same symptoms as observed in previous studies.[4,5] The results of the univariate general linear model (ANCOVA), adjusted for age, sex, and body mass index, showed that, during exercise, the group with persistent COVID-19 had lower oxygen uptake and metabolic equivalents (METs), as well as significantly higher oxygen pulse, the ratio between oxygen uptake and heart rate (VO_2/HR), at the first ventilatory threshold (VT_1) and at maximum load ($P < .01$). Significant between-group differences were also observed at peak VO_2, as well as in the pulmonary ventilation (VE)/CO_2 output (VCO_2) slope ($d = 0.708$), the VE/VO_2 slope ($d = 0.531$), watts ($d = 0.436$), VE ($d = 0.257$), VO_2/HR ($d = 0.424$), METs ($d = 0.836$), and heart rate (HR) as percentage of predicted ($d = 0.314$) (table 1). Approximately 85% of the patients with COVID-19 had a moderate/severe ventilatory limitation score (table 2).

In previous studies,[1] patients with COVID-19 showed peak VO_2 values that were 35% lower (~15 mL/kg^{-1}·min^{-1}) than the control group (~23 mL/kg^{-1}·min^{-1}) at 30 days after hospital discharge. Debeaumont et al.[4] reported on parameters of VO_2 and maximum power of, respectively, ~80% and ~90% of predicted values for age at 6 months after discharge. Similarly, patients with persistent COVID-19 symptoms had a significant reduction in 6-minute walk

Table 1
Clinical characteristics and ergospirometry parameters of the study population by group

	COVID-19 (n = 95)	Control (n = 95)	Cohen's *d*	*P*
Characteristics [a]				
Sex (male/female), No.	73/22	51/44	–	–
Age, y	47.37 (45.45-49.31)	52.21 (49.84-54.60)	0.441	< .001
Height, m	1.66 (1.64-1.68)	1.66 (1.63-1.68)	0.026	.303
Weight, kg	74.52 (71.30-78.42)	71.27 (69.30-75.13)	0.159	.185
Body mass index	27.12 (25.99-28.26)	26.03 (24.85-26.65)	0.262	.063
Total fat, %	38.93 (37.35-40.51)	33.01 (31.13-34.88)	0.686	< .001
Lean mass, %	58.9 (57.44-60.36)	64.55 (62.80-66.31)	0.707	< .001
PA, MET-min/week	983.59 (754.73-1212.47)	1732.77 (1395.45-2070.11)	0.517	< .001
Physical activity levels (low/medium/high), % [b]	56/42/4	37/40/23	–	< .001
Calorimetry at rest [c]				
Caloric expenditure at rest, kcal/d	1511.13 (1450.75-1571.52)	1544 (1484.87-1605.01)	0.150	.434
Caloric expenditure per kg, kcal/d/m	20.37 (19.78-20.96)	21.52 (20.99-22.04)	0.349	.005
VO_2, mL/min	222.97 (207.87-238.07)	223.74 (214.99-232.50)	0.014	.932
VCO_2, mL/min	177.80 (170.65-184.95)	180.73 (173.21-188.26)	0.054	.575
Respiratory quotient	0.82 (0.80-0.83)	0.81(0.80-0.82)	0.175	.396
Risk factors [c]*, %*				
Overweight [b]	33	47	-	.006
Obesity [b]	29	10	-	.006
Systolic blood pressure, mmHg	128.35 (125.26-131.44)	133.18 (130.04-136.32)	0.321	.031
Diastolic blood pressure, mmHg	83.83 (81.89-85.77)	90.90 (77.68-104.13)	0.138	.280
Blood pressure > 135/85 mmHg, % [b]	60	63	-	.721
Coronary score	-	214.68 (105.30-324.05)	-	-
Cardio-ankle vascular index	6.86 (6.60-7.12)	6.81 (6.38-7.24)	0.340	.848
Ankle-brachial index	1.11 (1.09-1.13)	1.06 (1-1.13)	0.123	.248
Cardiovascular response [c]				
VO_2 at VT1, mL/kg^{-1}·min^{-1}	9.55 (8.96 – 10.14)	11.02 (10.37 – 11.68)	0.488	.002
VO_2 at maximum load mL/kg^{-1}·min^{-1}	21.30 (20.17 – 22.43)	26.24 (25.01 – 27.48)	0.825	< .001
O_2 pulse at VT1, mL/beat	6.83 (6.34-7.32)	8.42 (7.71-9.14)	0.601	< .001
O_2 pulse at maximum load, mL/beat	10.92 (10.17-11.67)	12.76 (11.56-13.97)	0.505	.007
Watts at VT1	42.73 (39.24 – 46.22)	46.16 (42.33 – 49.98)	0.199	.203
Watts at maximum load	125.31 (118.12 – 132.50)	140.81 (132.94 – 148.69)	0.436	.006
HR at VT1, bpm	105.83 (102.82 – 108.84)	98.90 (95.36 – 102.25)	0.472	.004
HR at maximum load, bpm	148.15 (143.76 – 152.53)	155.26 (150.21 – 160.30)	0.257	.042
METs at VT1	2.73 (2.56 – 2.90)	3.15 (2.97-3.34)	0.504	.001
METs at maximum load	6.08 (5.76 – 6.40)	7.71 (7.36 – 8.06)	0.836	< .001
Ventilatory efficiency [c]				
VE/VCO_2 slope	34.37(33.18-35.56)	31.44 (30.58-32.30)	0.737	< .001
Baseline $PECO_2$, mmHg	21.65 (20.72-22.58)	23.11 (22.33-23.88)	0.463	.021
$PECO_2$ at VT1, mmHg	25.18 (24.26-26.10)	26.79 (25.84-27.73)	0.432	.017
$PECO_2$ at maximum load, mmHg	25.23 (24.37-26.09)	27.48 (26.57-28.38)	0.663	< .001
$VEVCO_2$ at VT1	33.24 (31.89-33.59)	30.89 (30.04-31.74)	0.491	< .001
$VEVCO_2$ at maximum load	34.64 (33.64 – 35.64)	31.12 (30.02 – 32.22)	0.708	< .001

Table 1 *(Continued)*
Clinical characteristics and ergospirometry parameters of the study population by group

	COVID-19 (n = 95)	Control (n = 95)	Cohen's *d*	*P*
$VEVO_2$ at VT1	36.59 (35.50–37.67)	33.73 (32.54–34.92)	0.531	.001
$VEVO_2$ at maximum load	36.59 (35.50–37.67)	33.73 (32.54–34.92)	0.531	.001
VE at VT1, L/min	21.72 (20.41–23.03)	20.94 (19.50–22.37)	0.121	.439
VE at maximum load, L/min	60.93 (57.33–64.52)	65.50 (61.56–69.44)	0.330	.101
OUES at maximum load	2097.36 (1933.54-2261.18)	2301.02 (2081.40-2520.63)	0.244	.134
Effort exerted[a]				
Exercise time, min	13.05 (11.99-14.11)	16.11 (14.69-17.53)	0.594	.001
VO_2 (≥ 85% predicted)[b]	68.13 (64.92-71.35)	85.02 (80.33-89.72)	0.869	< .001
HR (≥ 85% predicted)[b]	86.29 (84.11-88.47)	91.92 (89.54-94.33)	0.314	.005
Respiratory quotient at maximum load	1.05 (1.04-1.07)	1.08 (1.07-1.10)	0.329	.010

HR, heart rate; METs, metabolic equivalents; OUES, oxygen uptake efficiency slope; PA, physical activity; $PECO_2$, expired CO_2 pressure; VE/VCO_2, slope of the pulmonary ventilation and VCO_2 ratio; $VEVCO_2$, ventilatory equivalent for CO_2, $VEVO_2$, ventilatory equivalent for O_2; VO_2, oxygen uptake; VT1, first ventilatory threshold.
[a] Data are presented as mean and 95% confidence intervals (95% CI) without adjustment or percentage as appropriate.
[b] Data presented as percentage (%).
[c] Data presented as marginal mean and 95% CI. General linear univariate model (ANCOVA), adjusted for age, sex, and body mass index. The ergospirometry test on cycle ergometer (Lode Excalibur Sport, Germany) consisted of incremental ramp increases in load, starting with 25 W with 25-W increments every 2 min (pedaling cadence, 50-60 revolutions/min). The variables VO_2 ($mL/kg^{-1}{\cdot}min^{-1}$), oxygen pulse ($VO_2$/HR), parameters VE and VT (L/min^{-1}), ventilatory equivalents of O_2 and CO_2 ($VEVO_2$, $VEVCO_2$), and expiratory CO_2 pressure ($PECO_2$) were recorded at the first ventilatory threshold (VT1) and at maximum load using flow analysis and concentrations of inhaled and exhaled respiratory gases in the mixing chamber (QUARK CPET, Cosmed, Italy).

test at 6 months after onset of symptoms.[5] In our series, the COVID-19 group showed peak VO_2 values ~18% lower than the control group. There was also a mixed pattern of abnormalities in parameters of ventilatory efficiency including VO_2 at VT_1 (70% vs 54%), abnormal VE/VCO_2 (46% vs 36%), and a very low VE/VCO_2 ratio (COP) (11% vs 0%), indicating a higher risk of functional deterioration.

To date, the mechanisms to explain the reduced exercise capacity in patients with persistent COVID-19 are unknown, but it has been hypothesized that excess adiposity (as seen in this series) and low levels of physical activity could partly explain the findings of this study.[1] The myopathic effect of SARS-CoV-2 has also not been excluded as a cause of functional deterioration in patients after COVID-19.[2] However, experimental studies are needed to corroborate these hypotheses.[2,4] The main limitations of our study are the number of patients included, the inclusion of a majority of women (a characteristic of persistent COVID-19 syndrome) and the lack of previous measures of exercise capacity, a limitation that is difficult to solve given the emergent nature of the pandemic.

More research is needed to better understand the long-term consequences of COVID-19 on functional capacity over the whole spectrum of the disease, especially the underlying biological mechanisms that characterize its pathophysiology. Considering the central role of exercise capacity in patients with persistent COVID-19, exercise rehabilitation could be fundamental in this new and little-known situation. Therefore, it is essential to

Table 2
Comparison of ergospirometry criteria and ventilatory performance score by study group

Criteria	Categories	COVID-19 (n = 95)*		Control (n = 95)*		χ^2	*P*
VO_2 inflection at VT_1[a]	Normal > 11, mL/kg/min	29	(30)	44	(46)	4.587	.006
	Abnormal < 11, mL/kg/min	67	(70)	51	(54)		
VE/VCO_2[b]	Normal < 34, slope in degrees	51	(54)	74	(77)	11.318	.001
	Abnormal > 34, slope in degrees	44	(46)	21	(23)		
OUES[c]	Normal > 1550 mL	65	(68)	72	(76)	0.942	.331
	Abnormal < 1550 mL	30	(32)	23	(24)		
COP[d]	Normal < 30 L	85	(89)	95	(100)	8.550	.003
	Abnormal > 30 L	10	(11)	0	0		
$\Delta VO_2/HR$ VT_2 vs VT_1[e]	Normal > 0	92	(97)	89	(94)	0.467	.494
	Abnormal < 0	3	(3)	6	(6)		
Ventilatory performance score[f]	No limitation	14	(15)	29	(31)	9.847	.007
	Moderate limitation	62	(65)	58	(61)		
	Severe limitation	19	(20)	8	(8)		

COP, cardiorespiratory optimal point; HR, heart rate; OUES, oxygen uptake efficiency slope; VCO_2, carbon dioxide produced; VE, pulmonary ventilation; VO_2, oxygen uptake; VT_1, first ventilatory threshold; VT_2, second ventilatory threshold.
[a] Point of inflection of VO_2 expressed in mL/kg/min and estimated manually on the graph of VO_2 at VT_1.
[b] Ventilatory efficiency or class derived from the VE/VCO_2 slope.
[c] OUES VO_2 efficiency slope.
[d] COP estimated based on the minimum VE/VCO_2 ratio.
[e] Difference in oxygen pulse between VT_2 and VT_1, derived from VO_2/HR ratio.
[f] Ventilatory performance criteria score was derived from the sum of the abnormal criteria in a-e, then classified as: no ventilatory limitation (no abnormal criteria), moderate limitation (1-2 abnormal criteria), and severe limitation (more than 3 abnormal criteria).
Values are expressed as No. (%).

establish strategies with multicomponent programs, to optimize recovery in these patients.

FUNDING

This study was funded in part by a grant (PID2020-113098RB-I00) corresponding to the call for RD&I projects from the national programs for knowledge generation and scientific and technical strengthening of the RD&I system aimed at the challenges of society, within the framework of the National Plan for scientific and technical research and innovation 2017-2020.

AUTHORS' CONTRIBUTIONS

All authors contributed substantially to the concept and design, data acquisition, analysis, and interpretation, as well as the writing, review, and intellectual content of the manuscript.

CONFLICTS OF INTERESTS

The authors have no conflict of interests to declare.

Robinson Ramírez-Vélez,[a,*] Nora García-Alonso,[a]
Gaizka Legarra-Gorgoñón,[a] Sergio Oscoz-Ochandorena,[a]
Julio Oteiza,[b] and Mikel Izquierdo[a]

[a]*Navarrabiomed, Hospital Universitario de Navarra (HUN), Universidad Pública de Navarra (UPNA), IdiSNA, Pamplona, Navarra, Spain*
[b]*Servicio de Medicina Interna, Hospital Universitario de Navarra (HUN), Universidad Pública de Navarra (UPNA), IdiSNA, Pamplona, Navarra, Spain*

[*]Corresponding autor.
E-mail address: robin640@hotmail.com (R. Ramírez-Vélez).

Available online 24 October 2022

REFERENCES

1. Pleguezuelos E, Del Carmen A, Llorensi G, et al. Severe loss of mechanical efficiency in COVID-19 patients. *J Cachexia Sarcopenia Muscle.* 2021;12:1056–1063.
2. Berenguel Senen A, Borrego-Rodríguez J, de Cabo-Porras C, Gigante-Miravalles E, Arias MÁ. Rodríguez-Padial L. Ergoespirometría en pacientes con disnea persistente tras la COVID-19. *REC CardioClinics.* 2021. http://dx.doi.org/10.1016/j.rccl.2021.07.002.
3. Whitaker M, Elliott J, Chadeau-Hyam M, et al. Persistent COVID-19 symptoms in a community study of 606,434 people in England. *Nat Commun.* 2022;13:1957.
4. Debeaumont D, Boujibar F, Ferrand-Devouge E, et al. Cardiopulmonary exercise testing to assess persistent symptoms at 6 months in people with covid-19 who survived hospitalization: a pilot study. *Phys Ther.* 2021;101:pzab099.
5. Delbressine JM, Machado FVC, Goërtz YMJ, et al. The impact of post-COVID-19 syndrome on self-reported physical activity. *Int J Environ Res Public Health.* 2021;18:6017.

https://doi.org/10.1016/j.rec.2022.08.017
1885-5857/