ORIGINAL ARTICLE

Effectiveness of cardiopulmonary rehabilitation after COVID-19 in Poland

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KEY WORDS

cardiopulmonary rehabilitation, cardiorespiratory fitness, COVID-19

ABSTRACT

INTRODUCTION Patients with a history of COVID-19 are characterized by a deteriorated level of cardiorespiratory fitness (CRF). The COVID-19 rehabilitation program of the National Health Fund (NHF) was developed and financed by the public insurer in Poland to help convalescents return to full health.

OBJECTIVES We aimed to evaluate the effectiveness of cardiopulmonary rehabilitation (CR) after COVID-19, carried out under the NHF program.

PATIENTS AND METHODS The study included 553 convalescents at a mean age of 63.5 years (SD, 10.26; 316 women [57.1%]), hospitalized at the Cardiac Rehabilitation Department of the Ustroń Health Resort, Poland, after a median of 23.10 weeks (interquartile range [IQR], 16.25–29.00) following COVID-19. The mean duration of CR was 21 days (IQR, 21–28). The effectiveness of CR was assessed based on the improvement in spirometry and clinical parameters, as well as indicators of CRF and exercise tolerance.

RESULTS The mean baseline CRF level, as assessed by the 6-minute walk test (6MWT), was reduced to 76.32% of the predicted value (SD, 15.87) in men and 85.83% of the predicted value (SD, 15.60) in women, while the mean values of the spirometry parameters were normal. During CR, there was an improvement in the median 6MWT distance by 42.5 m (95% CI, 37.50–45.00; P <0.001), and in the median exercise tolerance assessed on the Borg scale (fatigue, by −1 point; 95% CI, −1.0 to −1.0; P <0.001; dyspnea, by −1.5 points; 95% CI, −1.5 to −1.0; P <0.001). We observed a decrease in the mean resting blood pressure by 8.57 mm Hg (95% CI, –11.30 to –5.84; P <0.001) for systolic and by 3.38 mm Hg (95% CI, –4.53 to –2.23; P <0.001) for diastolic values. The most pronounced improvement was seen in the patients with low CRF level at baseline, who were eligible for lower-intensity rehabilitation models. The CR effectiveness was not dependent on the severity of COVID-19 or the time from the disease onset to the commencement of rehabilitation.

CONCLUSIONS CR is a safe and effective intervention that can accelerate recovery from COVID-19, including an increase in exercise capacity and exercise tolerance.

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INTRODUCTION A new strain of coronavirus, SARS-CoV-2, is one of 3 highly pathogenic coronaviruses that cause severe interstitial pneumonia in humans.[1] In the course of SARS-CoV-2 infection, both lung tissue involvement and multiorgan complications may occur.[2] In two-thirds of patients, symptoms of COVID-19 may persist for weeks or months after the end of the acute phase of the disease, a phenomenon referred to as post-COVID / long COVID syndrome.[3]

Disease complications and the post-COVID / long COVID syndrome are responsible for the deterioration of the general condition and cardiorespiratory fitness (CRF) level of convalescents due to the following factors: 1) slow regression of inflammatory changes in the lungs

WHAT'S NEW?

We analyzed a group of patients with a history of COVID-19 who participated in the cardiopulmonary rehabilitation (CR) program of the National Health Fund in Poland. We showed that CR improved the exercise capacity and effort tolerance of the convalescents. CR was effective regardless of the severity of the acute phase of the disease and the time from the onset of symptoms to the beginning of rehabilitation. The effectiveness of CR was the highest among the patients with the lowest baseline exercise capacity and severe dyspnea. Our study confirms that CR is recommended for all COVID-19 convalescents as it can expedite recovery from the disease.

and persistence of respiratory failure with dyspnea, chronic cough, and development of interstitial pulmonary fibrosis,[4] 2) cardiological complications, including myocarditis and ventricular arrhythmias,[5] 3) thromboembolic events, including pulmonary embolism,[6] 4) neurological complications, such as myopathy and neuropathy, associated with prolonged immobilization and leading to motor disabilities and limitations in performing daily activities,[7] 5) persistent osteoarticular pain,[3] 6) chronic fatigue or muscle weakness,[3] 7) depression and anxiety worsening the quality of life and physical effort tolerance,[3,8] and 9) exacerbation of chronic diseases. Therefore, comprehensive CR of symptomatic patients with a history of COVID-19 has been recommended by experts worldwide.[9,10] The COVID-19 rehabilitation program of the National Health Fund (NHF)[11] was developed and financed by the public insurer in Poland to help convalescents return to full health as well as to social and professional activity.

The aim of the study was to retrospectively evaluate the effectiveness of CR after COVID-19 in terms CRF level improvement.

PATIENTS AND METHODS The study group consisted of adult convalescents (≥18 years of age) who participated in the CR program after COVID-19 when hospitalized at the Cardiac Rehabilitation Department of the Ustroń Health Resort from May 2021 to February 2022. Eligibility criteria for the hospitalization and CR, and the methods of verification of the treatment effects were fully consistent with the outlines of the NHF rehabilitation program after COVID-19.

The eligibility criteria for hospitalization were as follows: 1) complications or consequences of a symptomatic SARS-CoV-2 infection affecting the respiratory, cardiovascular (CV), nervous, or musculoskeletal system, 2) a decrease in muscle strength assessed using the Medical Research Council (MRC) scale, or 3) persistent dyspnea of the intensity of 2–3 points on the modified MRC scale (mMRC). The time from the end of the acute phase of the disease to the onset of CR was less than 12 months, and the duration of CR was 2 to 6 weeks. The only exclusion criterion was failure to complete the minimal rehabilitation cycle of at least 10 days of rehabilitation sessions (2 weeks of hospitalization).

Based on the initial physical examination, the severity of dyspnea on the mMRC scale,[12] the exercise intensity on the Borg scale (Borg Rate of Perceived Exertion scale, RPE scale),[13] the exercise capacity in the 6-minute walk test (6MWT),[14,15] and analysis of additional data (age, resting arterial oxygen saturation [SpO_2], blood pressure, electrocardiogram, chest X-ray, spirometry, and laboratory investigations), the patients were referred for 1 of 4 rehabilitation models (A, B, C, or D, depending on training intensity) (TABLE 1). The patients aged over 75 years were prequalified for a less intensive CR model than the one they would be eligible for based on the 6-minute walking distance (6MWD) and the RPE scale score. The patients with low exercise tolerance (mMRC dyspnea intensity of 4 or perceived fatigue >8 on the Borg scale) during their daily activities were referred for model D, omitting the walk test.

CR comprised monitored cyclo-ergometer interval training, general kinesiotherapy, and breathing exercises (TABLE 2). In model D, the exercises were carried out individually in the patient's room, in bed or in a sitting position, depending on the patient's condition. The intensity of dyspnea and fatigue, heart rate (HR), as well as SpO_2 (target SpO_2 in pulse oximetry measurements >90%) were monitored during the exercises. The initial effort loads set at the beginning of the training session are indicated in TABLE 2. The effort load was increased to the maximum value depending on the patient's tolerance. During the CR program, it was also possible to change the rehabilitation model to a more intensive one (D/C, C/B, B/A) after individual assessment of the patient's motor and exercise performance. The breathing exercises consisted of prolonged exhalation, deepened inhalation, diaphragmatic breathing, exercises to increase the lower ribcage respiratory movement, exercises to relax the shoulder girdle, and exercises to strengthen the respiratory muscles. Effective coughing was taught, and model D also included chest tapping and postural drainage.

Additionally, depending on the indications, thermal radiation with a red or blue filter, local cryotherapy, magnetotherapy, electrotherapy, laser biostimulation, dry carbonic acid bath, group exercises in a brine pool, postural drainage, vibration massage of the chest, and inhalations were performed. In all the models, individual and group workshops with a dietitian as well as behavioral and relaxation trainings were carried out to promote healthy lifestyle changes, reduce anxiety, and improve functioning during convalescence.

The effectiveness of rehabilitation was assessed by determining changes in the following parameters over time (measured at the beginning and end of hospitalization):

TABLE 1 Eligibility criteria for cardiopulmonary rehabilitation models after COVID-19

Borg Rate of Perceived Exertion scale	Distance in the 6-minute walk test			
	>520 m	450–520 m	300–450 m	<300 m
0–1 points	model A	model B	model C	model C/D
2–3 points	model A	model B	model C	model C/D
4–6 points	model A/B	model B/C	model C	model D
7–8 points	model B	model C	model C	model D

TABLE 2 Characteristics of cardiopulmonary rehabilitation models after COVID-19

Characteristics	Rehabilitation model			
	A	B	C	D
Maximum effort load	55–70 W	45–60 W	10–45 W	–
Initial effort load during exercise	50%–70% of the maximum	50% of the maximum	40% of the maximum	up to 20% increase in HR
Type and frequency of training	Monitored cyclo-ergometer training in an interval form and walking training 4–5 times/week			–
	A series of resistance exercises 3 times/week	Elements of resistance exercises 3 times/week		–
	General kinesiotherapy 5–6 times/week			
	Breathing exercises, effective coughing, drainage techniques 6 times/week			
Duration of training sessions	120 min/day	120 min/day	up to 120 min/day	30–60 min/day
RPE scale target range, points	4–6/10	4–6/10	4–6/10	3–4/10

Abbreviations: HR, heart rate; RPE scale, Borg Rate of Perceived Exertion scale; W, Watt

1. Severity of dyspnea during daily activity on the mMRC scale (0–4 points);
2. Exercise tolerance with the assessment of 2 components (ie, fatigue and dyspnea during 6MWT on the RPE scale) (0–10 points);
3. Performance in activities of daily living on the Barthel scale (0–100 points);
4. Intensity of pain in muscles and joints assessed with the Visual Analog Scale (VAS) (0–10 points)[16];
5. Exercise capacity, measured as 6MWD (in meters). The predicted value of 6MWD was calculated according to the following formula[14]: for men, 6MWD [m] = (7.57 × height [cm]) – (5.02 × age [years]) – (1.76 × weight [kg]) – 309; and for women, 6MWD [m] = (2.11 × height [cm]) – (2.29 × weight [kg]) – (5.78 × age [years]) + 667. To determine the lower limit of normal (LLN) for 6MWD, 153 or 139 was subtracted from the obtained value calculated for men or women, respectively.
6. SpO_2 (%) measured at rest and after 6MWT;
7. Spirometry parameters,[17] such as:
a. forced vital capacity (FVC, %), as compared with the predicted value (%pred) for age and sex;
b. forced expiratory volume in 1 second (FEV1, %), as compared with %pred for age and sex;
c. the FEV1/FVC ratio (%);
d. peak expiratory flow (PEF, %), as compared with %pred for age and sex;
8. HR at rest and post exercise;
9. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) at rest and post exercise.

Additionally, the nutritional status of the participants was assessed with the body mass index (BMI) measurement on admission and at discharge.

Statistical analysis The results were analyzed using the MedCalc software, version 20.106 (MedCalc, Ostend, Belgium). Quantitative parameters were presented as the arithmetic mean and SD or median and interquartile range (IQR), depending on the normality of the distribution as assessed by the Kolmogorov–Smirnov test. Qualitative data were expressed as the number and percentage and were compared using the χ^2 test. Changes in the parameters reflecting the effectiveness of CR over time were calculated using the *t* test for related variables (with 95% CI for mean difference) or the Wilcoxon rank test (with the Hodges–Lehmann median difference and 95% CI for median difference), as required, both for the whole group and subgroups divided according to sex, rehabilitation model, severity of the acute phase of COVID-19, and the time from disease diagnosis to the start of CR. A comparison of differences in the magnitude of the above parameters among the groups was performed using the 1-way analysis of variance (with the Tukey–Kramer post-hoc test) or the Kruskal–Wallis test (with the Conover post-hoc test), as appropriate. A *P* value lower than 0.05 was considered significant.

The study was approved by the Bioethical Committee of the Medical University of Silesia in Katowice, Poland (PCN/CBN/0022/KB1/68/21 of May 15, 2021).

RESULTS

The study involved 553 consecutive patients at a mean (SD) age of 63.5 (10.26) years, including 316 women (57.1%). Five of the hospitalized patients met the exclusion criteria. The median duration of hospitalization was 21 days (IQR, 21–28), and the median number of days with rehabilitation treatment was 18 (IQR, 18–24). The median time from the diagnosis of COVID-19 to the onset of CR was 23.1 weeks (IQR, 16.25–29.00), including 72 patients (14.4%) hospitalized less than 12 weeks since the diagnosis, 195 patients (38.9%) admitted within 12 to 24 weeks since the diagnosis, and 234 individuals (46.7%) hospitalized more than 24 weeks since the diagnosis.

The initial diagnosis of acute COVID-19 was based on either reverse transcription–polymerase chain reaction testing or qualitative assessment of the presence of SARS-CoV-2 antigen in nasopharyngeal swab samples in symptomatic patients.[18] Of the patients enrolled, 262 (48.3%) had mild (stage I), 172 (31.7%) had moderately severe (stage II), and 86 (15.9%) had severe

TABLE 3 Determinants of cardiopulmonary rehabilitation effectiveness at the beginning and end of the rehabilitation program

Parameter	On admission	At discharge	*P* value
Dyspnea, mMRC, points	2 (2–2)	1 (1–1)	<0.001
6MWD, m	390 (332–420)	421.5 (380–460)	<0.001
6MWD, %pred	76.32 (15.87)	85.83 (15.6)	<0.001
HR at rest, bpm	79.84 (13.56)	75.92 (12.26)	<0.001
HR post exercise, bpm	87.75 (15.17)	83.74 (13.64)	<0.001
SBP at rest, mm Hg	133.63 (19.61)	125.07 (19.68)	<0.001
DBP at rest, mm Hg	79.95 (9.76)	76.57 (9.36)	<0.001
SBP post exercise, mm Hg	135.38 (21.77)	132.50 (20.25)	0.03
DBP post exercise, mm Hg	79.56 (10.98)	76.65 (9.63)	<0.001
Fatigue, RPE scale, points	5 (3–6)	4 (2–5)	<0.001
Dyspnea, RPE scale, points	4 (1–5)	1 (0–4)	<0.001
SpO_2 at rest, %	96.71 (1.22)	96.99 (1.1)	<0.001
SpO_2 post exercise, %	97.35 (0.84)	97.52 (0.79)	<0.001
FVC, %pred	94.16 (18.26)	94.47 (17.65)	0.65
FEV1, %pred	89.45 (18.49)	89.07 (17.21)	0.55
FEV1/FVC ratio, %	101.01 (10.92)	100.06 (9.57)	0.03
PEF, %pred	94.45 (22.38)	96.37 (21.18)	0.02
Barthel scale[a], points	90 (85–95)	100 (100–100)	<0.001
Pain intensity, VAS, points	5 (2–5)	1 (1–1)	<0.001
BMI, kg/m^2	29.32 (26.22–32.47)	29.24 (26.18–32.28)	0.11

Data are shown as mean (SD) or median (interquartile range).

a In the patients with a baseline Barthel score <100 points

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; FEV1, forced expiratory volume in 1 second as compared with the predicted value; FVC, forced vital capacity as compared with the predicted value; HR, heart rate; mMRC, modified Medical Research Council dyspnea scale; 6MWD, distance in the 6-minute walk test; PEF, peak expiratory flow as compared with the predicted value; %pred, percentage of the predicted value; SpO_2, arterial oxygen saturation in pulse oximetry measurements; SBP, systolic blood pressure; VAS, Visual Analog Scale; others, see TABLE 2

(stage III) COVID-19, that is, pulmonary embolism, lung tissue involvement equal to or greater than 50% confirmed by computed tomography and / or acute respiratory failure requiring high-flow oxygen therapy or noninvasive ventilation.[2] In the acute phase of the disease, 22 participants (4.1%) required intensive care due to the necessity of invasive ventilation, multiorgan failure, or septic shock (stage IV). The proportion of patients with a more severe acute disease (stages III and IV) was higher in men than in women (59 [25.4%] vs 49 [15.8%]; *P* = 0.006). The characteristics of the study population are presented in Supplementary material, *Table S1*.

On admission for CR, symptoms of the post-COVID / long COVID syndrome were present in a significant percentage of the patients, including weakness / fatigue in 541 (99.6%), exercise dyspnea in 534 (98.3%), and muscle pain / joint stiffness in 525 participants (96.7%) (Supplementary material, *Table S1*). The mean resting HR was 79.84 bpm (SD, 13.56), and 44 patients (8%) had a baseline HR equal to or greater than 100 bpm. The mean resting blood pressure was 133.63 (SD, 19.61) / 79.95 (SD, 9.76) mm Hg, and 295 patients (53.3%) had blood pressure greater than or equal to 140/90 mm Hg. The mean baseline exercise capacity of the convalescents as assessed by the 6MWT was reduced to 76.32 %pred (SD, 15.87) in men 85.83 %pred (SD, 15.6) in women (*P* <0.001). The median 6MWD obtained on admission and at discharge from CR, as compared with the predicted value and the LLN for the male and female subgroups is presented in Supplementary material, *Table S2*. The numbers of patients with abnormal spirometry test results on admission were as follows: for FVC, there were 86 patients (28.1%) with a result below 80 %pred, for FEV1, 127 patients (46%) with a result below 80 %pred, for the FEV1/FVC ratio, 3 patients (0.8%) with a result below 70%, and for PEF, 111 patients (37.9%) with a result below 80 %pred. However, the mean values of these parameters in the study population remained normal (TABLE 3).

During CR, there was a median increase in 6MWD by 42.5 m (95% CI, 37.5–45; *P* <0.001) and an improvement in exercise tolerance, both in terms of perceived fatigue (–1.0 point on the RPE scale [95% CI, –1.0 to –1.0; *P* <0.001] and dyspnea (–1.5 point on the RPE scale [95% CI, –1.5 to –1.0; *P* <0.001) (TABLE 3). The average HR value decreased by 4 bpm (95% CI, –5.34 to –2.69, *P* <0.001) and was equal to 75.92 bpm (SD, 12.26) after rehabilitation. The number of patients with resting tachycardia with an HR greater than or equal to 100 bpm decreased to 23 (4.2%). The mean resting blood pressure also significantly decreased after CR completion, by 8.57 mm Hg (95% CI, –11.30 to –5.84; *P* <0.001) for SBP and by 3.38 mm Hg (95% CI, –4.53 to –2.23; *P* <0.001) for DBP.

At discharge, a significant but clinically negligible increase in the mean resting and post-exercise SpO_2 was found, by 0.28% (95% CI, 0.15–0.40; *P* <0.001) and 0.17% (95% CI, 0.08–0.26; *P* <0.001), respectively. No significant (by ≥4% or below 90%) post-exercise decrease in SpO_2 was recorded in any of the patients. With respect to the spirometry parameters, we only noted an improvement in the mean value of PEF, by an average of 1.92 %pred (95% CI, 0.27–3.57; *P* = 0.02). In addition, 33 patients (100% of those whose baseline performance in basic activities was impaired) improved on the Barthel scale. Of all the participants, 86.5% reported a reduction in pain intensity assessed on the VAS scale, and the median reduction was by 3 points (95% CI, –3.0 to –2.5; *P* <0.001).

The most significant improvement in the CRF level and in the performance of daily activities was seen in the group with impaired exercise capacity and severe dyspnea at baseline, who were referred for rehabilitation models C and D (TABLE 4, raw data presented in Supplementary material, *Table S3*). The increase in 6MWD and improvement in exercise tolerance depended neither on the severity of the acute phase of COVID-19 (respectively, *P* = 0.82 for 6MWD, *P* = 0.53 for the degree of fatigue on the RPE scale, and *P* = 0.86 for degree of dyspnea on the RPE scale), nor on

TABLE 4 Changes in the determinants of cardiopulmonary rehabilitation effectiveness depending on the rehabilitation model

Change in parameter	Rehabilitation model				*P* value
	A (n = 27; 4.9%)	B (n = 162; 29.3%)	C (n = 303; 54.8%)	D (n = 61; 11%)	
Dyspnea, mMRC, points	–1 (–1 to –0.25)	–1 (–1 to –1)	–1 (–1 to –1)	–1 (–1 to –1)	0.09
6MWD, m	30 (0–45)	30 (0–60)	40 (20–62.3)	90 (40–141)	<0.001[a]
Percentage of baseline 6MWD, %	5.6 (0–7.2)	6.3 (0–11.8)	10.3 (5.1–16.7)	27.4 (13.3–42.8)	<0.001[a]
Fatigue, RPE scale, points	0 (–1 to 1)	0 (–2 to 1)	–1 (–3 to 0)	–2 (–3 to –1)	<0.001[a]
Dyspnea, RPE scale, points	–1 (–2 to 0)	–1 (–3 to 0)	–1 (–4 to 0)	–1.5 (–4 to 0)	0.28
SpO_2 at rest, %	0.08 (1.47)	0.36 (1.5)	0.26 (1.58)	0.19 (1.5)	0.77
SpO_2 post exercise, %	0.04 (0.82)	0.21 (1.13)	0.18 (0.97)	0.07 (1.21)	0.74
FVC, %pred	0.46 (12.62)	0.11 (13.56)	0.50 (12.21)	–0.33 (16.29)	0.99
FEV1, %pred	0.54 (12.35)	0.52 (12.34)	–0.86 (11.67)	–2.12 (16.47)	0.66
FEV1/FVC, %	0.15 (5.31)	–0.69 (7.95)	–1.13 (8.54)	–2.12 (11.27)	0.76
PEF, %pred	–1.73 (18.37)	1.37 (14.58)	2.16 (16.72)	6.42 (16.40)	0.32
Barthel scale[b], points	5 (5–5)	5 (5–5)	10 (5–10)	15 (10–20)	0.005[c]
Pain intensity, VAS, points	–3 (–4 to –0.75)	–3 (–4 to –1)	–4 (–4 to –2)	–3 (–4 to –1)	0.62
BMI, kg/m^2	0 (–0.82 to 0.09)	0 (–0.36 to 0)	0 (–0.36 to 0.34)	0 (–0.09 to 0)	0.45

Data are shown as mean (SD) or median (interquartile range).

a *P* <0.05 for models A vs C, A vs D, B vs C, B vs D, C vs D

b In the patients with a baseline Barthel score <100 points

c *P* <0.05 for model C vs model D

Abbreviations: see **TABLES 2** and **3**

the time from the onset of COVID-19 to the beginning of CR (respectively, *P* = 0.54 for 6MWD, *P* = 0.2 for the degree of fatigue on the RPE scale, and *P* = 0.26 for the degree of dyspnea on the RPE scale) (**TABLES 5** and **6**, raw data presented in Supplementary material, *Tables S4* and *S5*).

DISCUSSION The presented study assessed a large, representative group of convalescents who participated in CR after COVID-19 under the NHF program enforced in Poland. The study population was dominated by middle-aged patients (39.1% of the respondents were of working age) and older individuals, without numerous comorbidities, on average 4 months after the diagnosis. The proportions of mild-to-moderate (80%), severe (15.9%), and critical (4.1%) cases corresponded to the typical COVID-19 incidence structure described by other authors.[19] As in an analysis by Huang et al,[3] symptoms of the post-COVID / long COVID syndrome were present in a significant percentage of the patients, and included general weakness / fatigue in 99.6%, exercise dyspnea in 98.3%, and muscle pain / joint stiffness in 96.7% of the participants, which could have had an impact on the baseline exercise capacity.

The baseline CRF level of the convalescents was significantly lower than that of the healthy population. A total of 44 patients (8%) had resting tachycardia with HR greater than or equal to 100 bpm. In men, the mean 6MWD was 390.76 m (SD, 74.09), and in women, it was 362.73 m (SD, 85.95), representing 73.24 %pred (SD, 13.66) and 78.46 %pred (SD, 17.15), respectively. The better results obtained by women in 6MWT were most likely due to the lower rate of severe COVID-19 in this group. No significant postexercise desaturation was observed in any of the participants, and the mean value of postexercise SpO_2 was 97.35% (SD, 0.84%). Daher et al[20] also reported a shorter-than-expected 6MWD (median, 380 m [IQR, 180–470]) in 79% of the patients with severe acute COVID-19; these results were obtained at 48 to 71 days (mean, 56 days) after hospital discharge. As in the presented population, Daher et al[20] did not observe desaturation during or after exercise, with a median SpO_2 of 96% (IQR, 94%–98%). Huang et al[3] analyzed a large population of 1733 convalescents at a median age of 57 years (IQR, 47–65) and confirmed that exercise capacity impairment, with a median 6MWD of 495 m (IQR, 440–538) persisted 6 months after the onset of the disease in 22% to 29% of the participants.

No significant abnormalities were found in the mean values of the spirometry parameters in the study group. Similarly, in the analysis by Daher et al,[20] the spirometry and gasometry parameters obtained in the convalescents were normal (total lung capacity was 94 %pred [IQR, 85–105], vital capacity was 93 %pred [IQR, 78–101], FEV1 was 95 %pred [IQR, 72–103], and the FEV1/FVC ratio was 79% [IQR, 76%–85%]), except for a slight decline in diffusing lung capacity for carbon monoxide (DLCO), which was equal to 77 %pred (IQR, 69–95). In a group of 224 convalescents aged 61 years (IQR, 50–71) who were, on average, 4 months post discharge

TABLE 5 Changes in the determinants of cardiopulmonary rehabilitation effectiveness depending on the severity of the acute phase of COVID-19

Change in parameter	COVID-19 acute phase stage				*P* value
	I (n = 262; 48.3%)	II (n = 172; 31.7%)	III (n = 86; 15.9%)	IV (n = 22; 4.1%)	
Dyspnea, mMRC, points	–1 (–1 to –1)	–1 (–1 to –1)	–1 (–1 to –1)	–1 (–1 to –1)	0.51
6MWD, m	40 (15–70)	37.5 (15–60)	40 (10–65)	40 (15–95)	0.82
Percentage of baseline 6MWD, %	8.7 (3.9–16.7)	9.2 (3.2–14.6)	9 (2.2–15.7)	11.5 (3–20.4)	0.83
Fatigue, RPE scale, points	–1 (–2 to 0)	–1 (–2 to 1)	–1 (–2 to 0.5)	–2 (–3 to 0.5)	0.53
Dyspnea, RPE scale, points	–1 (–3 to 0)	–1 (–3 to 0)	–1 (–3 to 0)	–2 (–3 to 0)	0.86
SpO_2 at rest, %	0.23 (1.58)	0.25 (1.48)	0.39 (1.56)	0.15 (1.27)	0.85
SpO_2 post exercise, %	0.15 (1.03)	0.17 (1.06)	0.29 (1.04)	0.1 (1.12)	0.76
FVC, %pred	–0.19 (13.55)	0.90 (12.35)	1.25 (12.97)	–1.87 (10.59)	0.75
FEV1, %pred	–0.89 (12.04)	0.41 (13.16)	0.31 (12.16)	–3.20 (9.37)	0.63
FEV1/FVC, %	–0.96 (8.64)	–0.89 (9.29)	–1.02 (6.47)	–1.13 (3.89)	>0.99
PEF, %pred	1.54 (14.82)	2.59 (16.77)	2.70 (19.51)	–1.67 (12.15)	0.76
Barthel scale[a], points	5 (5–10)	10 (5–15)	15 (7.5–23.8)	–	0.11
Pain intensity, VAS, points	–4 (–4 to –2)	–4 (–4 to –1)	–2 (–3 to 0)	–3.5 (–4 to –2)	0.002[b]
BMI, kg/m^2	0 (–0.38 to 0.3)	0 (–0.37 to 0.34)	0 (–0.36 to 0)	0 (0–0.66)	0.5

Data are shown as mean (SD) or median (interquartile range).

a In the patients with a baseline Barthel score <100 points

b *P* <0.05 for stage II vs III

Abbreviations: CR, cardiopulmonary rehabilitation; others, see **TABLES 2** and **3**

TABLE 6 Changes in the determinants of cardiopulmonary rehabilitation effectiveness depending on the time between the diagnosis of COVID-19 to the onset of rehabilitation

Change in parameter	Time from the onset of COVID-19 to CR			*P* value
	<12 weeks (n = 72; 14.4%)	12–24 weeks (n = 195; 38.9%)	>24 weeks (n = 234; 46.7%)	
Dyspnea, mMRC, points	–1 (–1 to –1)	–1 (–2 to –1)	–1 (–1 to –1)	<0.001[a]
6MWD, m	45 (16.3–90)	40 (11.3–73.8)	30 (15–60)	0.54
Percentage of baseline 6MWD	11.1 (3.5–18.8)	9.3 (2.5–18.8)	8.7 (3.5–14.3)	0.56
Fatigue, RPE scale, points	–1 (–2 to 1)	–1 (–2 to 1)	–1 (–3 to 0)	0.20
Dyspnea, RPE scale, points	–2 (–3 to 0)	–1 (–3 to 0)	–1 (–4 to 0)	0.26
SpO_2 at rest, %	0.38 (1.58)	0.25 (1.63)	0.30 (1.41)	0.81
SpO_2 post exercise, %	0.37 (1.15)	0.14 (1.04)	0.15 (1.03)	0.27
FVC, %pred	0.92 (13.52)	0.18 (1.71)	0.56 (10.86)	0.93
FEV1, %pred	–2.67 (15)	0.63 (13.26)	–0.34 (10.25)	0.24
FEV1/FVC, %	–3.54 (9.86)	–0.32 (8.78)	–0.70 (7.31)	0.04[b]
PEF, %pred	1.23 (17.1)	2.95 (16.86)	1.63 (15.26)	0.71
Barthel scale[c], points	5 (5–10)	10 (5–15)	10 (5–15)	0.44
Pain intensity, VAS, points	–1 (–3 to 0)	–4 (–4 to –2)	–4 (–4 to –3)	<0.001
BMI, kg/m^2	0 (–0.38 to 0.4)	0 (–0.37 to 0)	0 (–0.36 to 0.3)	0.51

Data are shown as mean (SD) or median (interquartile range).

a *P* <0.05 for <12 weeks vs 12–24 weeks and 12–24 weeks vs >24 weeks

b *P* <0.05 for <12 weeks vs 12–24 weeks

c In the patients with a baseline Barthel score <100 points

Abbreviations: see **TABLES 2** and **3**

from the hospital, Bellan et al[21] found no impairment of the spirometry parameters, with FEV1 of 101 %pred (IQR, 91.5–112) and FVC of 98.5 %pred (IQR, 90–109). However, they described a significant (<60 %pred) deterioration of DLCO in 15.5% of the patients. The risk factors for impaired DLCO were female sex, coexistence of chronic obstructive pulmonary disease, and hospitalization in an intensive care unit during the acute phase of the disease.

Most of our patients participated in rehabilitation models B (29.3%) and C (54.8%) due to the reduced baseline CRF level. During the 3-week CR program, the participants achieved improvements in exercise capacity (by 42.5 m in 6MWT; median difference, 8.9% of the starting value) and exercise tolerance (ΔRPE scale, –1 point for fatigue and –1.5 points for exercise dyspnea), as well as a reduction in dyspnea during daily activity (ΔmMRC, –1 point). Due to physical training, the average HR decreased by 4 bpm, while SBP and DBP values were reduced by 8.57 mm Hg and 3.38 mm Hg, respectively. However, there were no significant changes in the spirometry parameters, as the mean values at discharge did not differ significantly from the values on admission. Only an improvement in PEF was noted, on average, by 1.92%.

Szczegielniak et al[22] carried out a preliminary analysis of 298 patients in the age range corresponding to that of our cohort, who participated in the 21-day CR pilot program in the Specialist Hospital of the Ministry of Internal Affairs and Administration in Głuchołazy, the government's Agency for Health Technology Assessment and Tariff System. The authors reported an average improvement in 6MWD by 52.8 m (10% of the baseline value). In turn, Zampogna et al[23] found an increase in 6MWD from 229 m (SD, 102.5; 47.7 %pred) to 327.9 m (SD, 97.8; 68.4 %pred) in the group of elderly patients at the median age of 71 years (IQR, 61.5–78), who were referred for rehabilitation immediately after the acute phase of COVID-19. Liu et al,[24] during a longer CR program of 6 weeks, reported an improvement both in 6MWD (from 162.7 m [SD, 72.0] to 212.3 m [SD, 82.5]) and in the results of the pulmonary function tests, including an increase in FVC (from 1.79 l [SD, 0.53] to 2.36 l [SD, 0.49]) and DLCO (from 60.3 %pred [SD, 11.3] to 78.1 %pred [SD, 12.3]).

Hayden et al[25] showed that the improvement in the CRF level was independent of the time (<30 days vs ≥30 days) between the end of COVID-19 treatment and the initiation of CR (ie, an increase in 6MWD of 131 m [95% CI, 107–155] vs 96 m [95% CI, 72–120]; $P = 0.006$, vital capacity of 12.5 %pred [95% CI, 7.3–17.7] vs 6.7 %pred [95% CI, 0.5–12.8]; $P < 0.001$, and FEV1 of 12.16 %pred [95% CI, 6.5–17.8] vs 6.4 %pred [95% CI, 1.4–11.5]; $P < 0.001$). Gloeckl et al[26] assessed the effectiveness of CR depending on the course of the acute phase of COVID-19, confirming a significant improvement in the CRF level in the patients with mild / moderate COVID-19 (increase in 6MWD by 48 m [IQR, 35–11]; $P < 0.001$, increase in FVC by 7.7% [IQR, 1.0–17.8]; $P = 0.002$) as well as in the patients after a severe / critical course of the acute phase (increase in 6MWD by 124 m [IQR, 75–145]; $P < 0.001$, increase in FVC by 11.3% [IQR, 1.0–16.9]; $P < 0.001$). Similarly, in our analysis, the time of CR commencement and the severity of the acute period of the disease did not affect the effectiveness of the rehabilitation.

In the analyzed population, as many as 25.2% of men and 13.2% of women did not achieve LLN for 6MWD after the end of CR, despite significant improvements in exercise capacity. Also, in studies by other authors, the mean 6MWD obtained at discharge was still equal to only 68.4 %pred in the group of patients who started the rehabilitation immediately after the acute period of the disease,[23] and ranged from 70.5%pred (after a severe / critical course of the acute phase) to 81 %pred (after mild / moderate acute phase) in a longer follow-up.[26] In the presented study, the greatest improvement was achieved in the group of patients with the most impaired CRF level and severe dyspnea at baseline, who followed the rehabilitation models C and D. Similar results were found in the group who underwent CR in the Specialist Hospital of the Ministry of Internal Affairs and Administration in Głuchołazy,[22] where the 6MWD increased by 14% to 16% in the patients referred for the models C and D, and by 7% to 9% in those participating in the models A and B. Spielmanns et al[27] presented different results, observing that the convalescents with initially shorter 6MWD, worse motor performance, and lower FVC on admission less frequently achieved the expected improvement in the CRF level despite intensive CR.

Taking into account the long-term outcomes of convalescents with a history of a similar infection with the severe acute respiratory syndrome–related coronavirus (SARS-CoV), which was the cause of the disease in a large population in 2003, the impairment of the CRF level may persist even 1 to 2 years after the acute phase.[1] The results of studies on SARS-CoV infection indicate that a significant spontaneous improvement in the CRF level should be expected after 3 to 6 months of recovery, followed by a long (possibly indefinite) period of residual dysfunction with 6MWD at the level of 72% to 79% of the normal value.[1] Therefore, it seems all the more important to implement intensive CR even later in the recovery period.

Considering the high percentage of patients with atherosclerotic CV disease and risk factors for atherosclerosis in the Polish population after COVID-19, rehabilitation also has a potential long-term impact on improving CV risk factors and the quality of life, which has been documented, for example, in patients after an acute coronary event.[28,29]

Study limitations In our study group, we did not assess the muscle strength, although it may

significantly impact the exercise capacity of the convalescents.[3,30] Similarly, the analysis of pulmonary parameters was limited to functional testing (according to the NHF program) and did not include the DLCO assessment. It is worth noting that the routine assessment of the CRF level during CR is based primarily on the 6MWD measurement, the result of which depends on the patient's motivation to exercise, and on subjective scales assessing dyspnea and exercise intensity, such as mMRC and RPE. The effect of natural recovery cannot be ruled out, although, during the 3-week CR, carried out 4 months after the end of the acute phase of COVID-19, its impact seems negligible.

Conclusions CR is a safe and effective intervention that can accelerate recovery from COVID-19 as well as increase exercise capacity and exercise tolerance. The benefits of CR are not limited by the severity of the acute phase of the disease, the time frame from diagnosis to initiation of rehabilitation, or by the degree of CRF level impairment on admission.

SUPPLEMENTARY MATERIAL

Supplementary material is available at www.mp.pl/paim.

ARTICLE INFORMATION

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