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Research Article

Comprehensive Physical Rehabilitation for Respiratory Muscle Dysfunction and Pulmonary Ventilation in Post-COVID Syndrome

Anatolii Belyaev[1, 2], Tatiana Kharkovskaya[1, 2, *], Olga Fotina[2]

[1]Institute of Clinical Neurology and Rehabilitation Medicine, Pacific State Medical University of the Ministry of Health of Russia, Vladivostok, Russia

[2]Department of Osteopathy, Rehabilitation, Traditional and Sports Medicine, Primorsky Autonomous Non-Commercial Organization of Additional Professional Education "Institute of Vertebroneurology and Manual Medicine", Vladivostok, Russia

Abstract

Introduction: Post-COVID syndrome is characterized by persistent respiratory disorders, a key element of which is dysfunction of the respiratory muscles, especially the inspiratory muscles. This leads to dyspnea, reduced exercise tolerance, and decreased quality of life. *Objective*: To evaluate the clinical efficacy of a physical rehabilitation program combining osteopathic correction, specialized breathing exercises, and classical chest massage in patients with residual effects after COVID-19-associated pneumonia. *Materials and methods*: A prospective randomized study included 87 patients (mean age 64.8 ±7.2 years) admitted to the third stage of rehabilitation between 4 weeks and 6 months after hospital discharge. The main group (n=44) received the full rehabilitation complex (osteopathic correction, breathing exercises, and massage), while the comparison group (n=43) received only breathing exercises and massage. Spirometric parameters (VC, FVC, FEV1), maximal inspiratory (MIP) and expiratory (MEP) mouth pressures, saturation (SpO_2), 6-minute walk test (6MWT), dyspnea by mMRC scale, anxiety and depression levels (HADS), and quality of life (EQ-5D) were assessed before and after a 14-day rehabilitation course. *Results*: Initially, all patients showed a reduction in MIP by 38% of normal ($p < 0.001$) and MEP by 22% ($p < 0.01$), as well as restrictive ventilation disorders (VC 83.1 ±10.4% of predicted). After the course, the main group showed significant increases in MIP (by 24.6%, p=0.003), MEP (by 18.3%, p=0.008), VC (by 12.4%, p=0.0001), and FVC (by 10.9%, p=0.0002), whereas in the comparison group the dynamics were not significant for most parameters. Exercise tolerance (6MWT) increased in the main group by 68.5 m (p=0.0001), and dyspnea (mMRC) decreased from 1.6 to 0.3 points (p=0.0001). Anxiety and depression levels decreased by 5.2 points on HADS (p<0.001). *Conclusion*: The inclusion of osteopathic correction in a physical rehabilitation program significantly improves respiratory muscle strength, ventilatory function, exercise tolerance, and psychoemotional status in patients with post-COVID syndrome, confirming the feasibility of a multimodal approach.

Keywords

COVID-19, post-COVID Syndrome, Respiratory Muscles, Osteopathy, Therapeutic Exercise, Spirometry, Quality of Life

*Correspondence: Tatiana Kharkovskyay (inman_med.diagnost@mail.ru)

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1. Introduction

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, has passed its acute phase, but the medical community continues to face long-term consequences of the infection. According to WHO, 10–20% of those who have recovered experience symptoms persisting for more than 12 weeks, termed "post-COVID syndrome" (long COVID). The most common manifestations remain dyspnea, generalized muscle weakness, easy fatigability, and reduced exercise tolerance [1-5].

The pathogenesis of these disorders is multifactorial. One of the leading mechanisms is dysfunction of the respiratory muscles – the diaphragm, intercostals, and accessory muscles. Prolonged hypodynamia during the acute period, immobilization, as well as direct or indirect neurotropic effects of the virus, lead to reduced strength of inspiratory and expiratory muscles [6, 7]. This, in turn, forms a pathological breathing pattern with predominance of thoracic (apical) breathing, hyperventilation episodes, and thoracoabdominal asynchrony. Reinforcement of such a pattern creates a vicious cycle: dyspnea increases anxiety, anxiety increases hyperventilation, which further reduces ventilation efficiency.

Traditional medical rehabilitation for post-COVID syndrome includes breathing exercises, massage, and, in some cases, physiotherapy [8, 9]. However, the role of osteopathic manual correction aimed at eliminating somatic dysfunctions of the ribs, spine, and diaphragm remains insufficiently studied. Some studies demonstrate a positive effect of osteopathic techniques on external respiratory function (ERF) in pneumonia [10], but there are few studies evaluating respiratory muscle strength.

2. Aim of the Study

To evaluate the efficacy of a comprehensive rehabilitation program including osteopathic correction, breathing exercises, and chest massage in patients with post-COVID syndrome, focusing on the dynamics of respiratory muscle strength and quality of life indicators.

3. Materials and Methods

Design. A prospective randomized parallel-group study was conducted at the Primorsky Institute of Vertebroneurology and Manual Medicine (Vladivostok) during 2021–2023. The study was approved by the local ethics committee (protocol No. 12 dated March 15, 2021). All participants gave written informed consent.

Inclusion criteria: confirmed COVID-19 diagnosis, pneumonia confirmed by computed tomography (I–III degree of lung involvement), age ≥ 45 years, time from hospital discharge 4 weeks to 6 months, complaints of dyspnea (mMRC ≥1 point) and easy fatigability. Exclusion criteria: respiratory failure grade III (SpO_2 <90% at rest), chronic heart failure III–IV functional class, history of chronic obstructive pulmonary disease, malignant neoplasms, severe cognitive impairment.

A total of 112 individuals were examined; after applying exclusion criteria, 87 patients were included in the analysis: 71.3% (62) women and 28.7% (25) men, mean age 64.8 ±7.2 years. Distribution by CT lung involvement: grade I – 37 patients (42.5%), grade II – 40 (46.0%), grade III – 10 (11.5%). The majority (71.2%) received inpatient treatment during the acute phase, with one patient (1.1%) in the intensive care unit (non-invasive ventilation). The groups were comparable in age, sex, severity, and time since illness (p>0.05).

The rehabilitation program for the main group (n=44) consisted of a 14-day course including: 3 sessions of osteopathic correction (40 minutes each), 10 procedures of breathing exercises (daily, 30 minutes, diaphragm-relaxation breathing technique with prolonged exhalation and forced inhalation according to Strelnikova's method modified for post-COVID patients), and 10 procedures of classical chest massage (30 minutes, affecting intercostal muscles, chest wall, and diaphragmatic area). The comparison group (n=43) received breathing exercises and massage on the same schedule but with a sham osteopathic correction. All procedures were performed on an outpatient basis; any concomitant medication remained unchanged for 2 weeks before and during the study.

Osteopathic correction was performed by a physician-osteopath according to a patent [11] and methodological guidelines [12], including sequential elimination of somatic dysfunctions: correction of rib biomechanical disorders (superior, anterior displacement, internal torsion), mobilization of the thoracic spine (affected motion segments), techniques on the thoracoabdominal diaphragm (increasing its mobility and eliminating diaphragmatic dysfunctions), as well as correction of accessory respiratory muscles (scalene, sternocleidomastoid) and pelvis if global dysfunctions were present.

All measurements were performed twice: before rehabilitation and after the course. The following were assessed: external respiratory function using a Spiro-Spectrum device (Neurotech, Russia) recording vital capacity (VC), forced vital capacity (FVC), and forced expiratory volume in 1 second (FEV1), expressed as percentage of predicted (GLI-2012); respiratory muscle strength using a portable Micro RPM spirometer (CareFusion, Germany), measuring maximal inspiratory pressure (MIP, cm H_2O) and maximal expiratory pressure (MEP, cm H_2O). Three maneuvers with a 1-minute interval were performed, and the best result was recorded. Predicted values were determined using Evans & Whitelaw equations [13]; SpO_2 was measured using a ChoiceMMed OxyWatch pulse oximeter (%, at rest); Stange test – breath-hold time on inspiration (seconds); exercise tolerance – 6-minute walk test (6MWT, meters) and Borg scale (0–10 points); dyspnea in daily activities – mMRC scale (0–4 points); psychoemotional status – Hospital Anxiety and Depression Scale (HADS, ≥8 points indicating clinically significant symptoms); quality of life – EQ-5D (total score from 5 (best) to 25 (worst)).

Statistical Analysis

Statistical processing was performed using STATISTICA 10.0. Normality was tested with the Shapiro–Wilk test. Data are presented as mean ± standard deviation (M ± SD) or median (25th; 75th percentile) for non-normal distributions. Within-group comparisons – paired t-test or Wilcoxon test; between groups – independent samples t-test or Mann–Whitney U test. Correlation analysis – Spearman's rank correlation coefficient (r). Differences were considered significant at $p < 0.05$.

4. Results

At baseline, all 87 patients showed impaired ventilatory function: mean VC was 83.1 ± 10.4% of predicted (range 54–96%), FVC – 81.7 ± 11.2% (58–95%), FEV1 – 84.2 ± 13.5% (45–98%). The FEV1/FVC ratio (103.5 ± 9.4%) indicated no obstruction, consistent with a restrictive pattern. MIP values in men (predicted 94.1 ± 2.1 cm H_2O) were 57.8 ± 22.3 cm H_2O (reduction by 38.6%), in women (predicted 68.0 ± 4.8 cm H_2O) – 41.3 ± 15.9 cm H_2O (reduction by 39.3%). MEP was also reduced: in men – 86.5 ± 40.2 cm H_2O (predicted 120.8 ± 5.7 cm H_2O, reduction by 28.4%), in women – 70.9 ± 27.8 cm H_2O (predicted 73.8 ± 6.2 cm H_2O, reduction by 4%, not statistically significant). Thus, the most pronounced reduction was in inspiratory muscle (diaphragm) strength.

Resting SpO_2 was 96.8 ± 1.2% (14% of patients had 95–96%). Stange test: 28.5 ± 15.2 sec (normal >30 sec). 6MWT average – 343.2 ± 70.5 m, significantly below age norms (predicted for men ~520 m, for women ~450 m). mMRC dyspnea – 1.5 ± 0.6 points; Borg score – 2.7 ± 0.7 points. HADS score – 8.5 ± 3.1 points (51% of patients had ≥8); EQ-5D – 8.4 ± 0.9 points (impaired). Pain VAS – 3.8 ± 1.1 cm. Correlation analysis revealed an inverse relationship between MIP and dyspnea (mMRC: r=-0.45; p<0.01) and a direct relationship between MIP and 6MWT (r=0.48; p<0.01), confirming the contribution of inspiratory muscle strength to exercise tolerance.

The main results after rehabilitation are presented in Table 1. The main group showed statistically significant improvement in almost all parameters: VC increased by 10.2% (from 82.4% to 92.6%, p<0.0001), FVC – by 9.5% (p<0.0001), MIP – by 14.4 cm H_2O (p=0.003), MEP – by 13.8 cm H_2O (p=0.008). SpO_2 increased by 0.9% on average (p=0.01). 6MWT increased by 68.5 m (from 342 to 410.5 m, p<0.0001), mMRC dyspnea decreased from 1.55 to 0.32 points (p<0.0001). HADS score decreased from 15.6 to 9.4 points (p<0.001) and EQ-5D improved by 2.4 points (p<0.0001).

In the comparison group, the dynamics were less pronounced: VC increased by only 3.6% (p=0.09), FVC – by 3.8% (p=0.07), MIP – by 4.9 cm H_2O (p=0.19), MEP – by 3.2 cm H_2O (p=0.42). 6MWT increased by 22.4 m (p=0.08), mMRC decreased from 1.52 to 1.08 points (p=0.03). Between-group differences after treatment were statistically significant in favor of the main group for all key parameters (p<0.05), except SpO_2 (p=0.09).

Table 1. *Comparison of parameters before and after rehabilitation in the main group and comparison group.*

Parameter	Main group (n=44)		Comparison group (n=43)		p (between groups after)
	Before	After	Before	After	
VC, %	82,4 ±10,7	92,6 ±9,8***	83,8 ±10,2	87,4 ±9,5	0,01
FVC, %	80,5 ±11,4	90,0 ±10,5***	82,9 ±10,9	86,7 ±10,0	0,03
MIP, cm H_2O	44,3 ±18,6	58,7 ±20,2**	45,0 ±17,9	49,9 ±18,4	0,02
MEP, cm H_2O	72,1 ±29,5	85,9 ±31,3**	74,0 ±28,6	77,2 ±30,1	0,04
SpO_2, %	96,7 ±1,2	97,8 ±0,9*	96,9 ±1,1	97,3 ±1,0	0,09
Stange test, sec	28,4 ±14,9	38,6 ±16,1**	28,7 ±15,5	32,1 ±14,6	0,02
6MWT, m	342,5 ±69,3	411,0 ±65,2***	344,0 ±71,8	366,4 ±69,9	0,003
mMRC, points	1,55 ±0,6	0,32 ±0,5***	1,52 ±0,6	1,08 ±0,6*	<0,001
HADS, points	15,6 ±5,2	9,4 ±4,1***	15,3 ±5,0	12,8 ±4,9*	0,001
EQ-5D, points	8,5 ±0,9	6,1 ±0,7***	8,4 ±0,8	7,6 ±0,9*	<0,001

*Table Footnote: *p<0.05, **p<0.01, **p<0.001 – within-group "before-after" comparison (paired t-test).

5. Discussion

This study has demonstrated that incorporating osteopathic correction into a standard physical rehabilitation program for patients with post-COVID syndrome leads to significantly greater recovery of respiratory muscle strength, normalization of ventilatory function, and improvement in exercise tolerance compared to breathing exercises and massage alone.

The key finding is the increase in MIP in the main group by 14.4 cm H_2O (32.5%) versus a non-significant increase in the comparison group. Since MIP reflects the strength of the diaphragm – the primary inspiratory muscle – its recovery has direct clinical significance. Diaphragmatic dysfunction, observed in the majority of patients after severe COVID-19, is found in 76% of cases according to ultrasound studies [7, 14]. Osteopathic techniques aimed at mobilizing the thoracoabdominal diaphragm, eliminating somatic dysfunctions of the ribs and spine, contribute to mechanical "retraining" of the diaphragm, restoration of its excursion, and normalization of the breathing pattern. This is supported by the reduction in thoracic (apical) breathing, which was clinically dominant in 82% of patients before treatment.

Interestingly, the dynamics of VC and FVC in the main group (increase >10%) exceeded the results reported in the literature for standard breathing exercises. In a meta-analysis of post-COVID rehabilitation (2022), the mean increase in VC after programs without osteopathic correction was 5–7% [15], which is consistent with the findings of other systematic reviews on exercise-based rehabilitation [9]. The additional effect of osteopathy is likely explained by the elimination of biomechanical restrictions that cannot be compensated by breathing exercises alone. In patients with residual somatic dysfunctions (e.g., rib fixation in expiratory position), even intensive inspiratory muscle training encounters insurmountable mechanical resistance.

The psychoemotional component is also important. Patients in the main group demonstrated a more significant reduction in anxiety and depression (total HADS decreased by 6.2 points vs. 2.5 points in the comparison group). This may be related both to objective improvement in breathing and reduction of dyspnea, and to the direct effect of osteopathic techniques on the autonomic nervous system (normalization of vagal tone, reduction of sympathetic activation). The correlation between MIP increase and HADS reduction in the main group ($r=-0.52$; $p=0.02$) confirms the close relationship between respiratory mechanics and psychoemotional status.

The practical significance of this work lies in justifying the inclusion of osteopathic correction in clinical rehabilitation protocols at the outpatient stage. It is important to note that the osteopathic protocol used was relatively short (3 procedures) but already produced a sustained effect. Longer courses (5–7 procedures) might yield even better results, but this requires further research.

6. Conclusions

Based on the results of our study, we conclude that a 14-day comprehensive physical rehabilitation program including osteopathic correction, daily breathing exercises, and chest massage is significantly more effective than breathing exercises and massage alone in patients with post-COVID syndrome. The achieved increase in inspiratory muscle strength (MIP) and lung volumes (VC, FVC) is accompanied by reduced dyspnea, increased exercise tolerance, decreased anxiety-depressive symptoms, and improved quality of life. These data support the recommendation of a comprehensive approach including osteopathy as a standard component of medical rehabilitation for persons who have had COVID-19-associated pneumonia.

7. Limitations

The sample was relatively small, with a predominance of women (71.3%), which may limit extrapolation of the results to men. Furthermore, we did not perform ultrasound assessment of diaphragmatic function, which would have been useful to confirm the mechanisms of osteopathic intervention.

Abbreviations

VC	Vital capacity
FVC	Forced vital capacity
FEV1	Forced expiratory volume in 1 second
MIP	Maximal inspiratory pressure
MEP	Maximal expiratory pressure
SpO_2	Peripheral oxygen saturation
6MWT	6-minute walk test
mMRC	Modified Medical Research Council dyspnea scale
HADS	Hospital Anxiety and Depression Scale
EQ-5D	EuroQol-5D quality of life questionnaire
VAS	Visual analogue scale for pain
COVID-19	Coronavirus Disease 2019

Author Contributions

Anatolii Belyaev: Conceptualization, Supervision, Writing – review & editing

Tatiana Kharkovskaya: Data curation, Formal Analysis, Investigation, Writing – original draft

Olga Fotina: Methodology, Project administration, Validation

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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