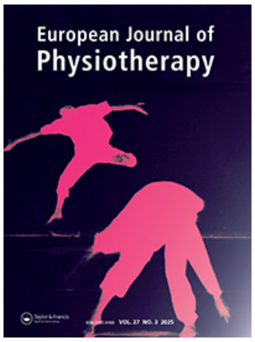

European Journal of Physiotherapy

ISSN: 2167-9169 (Print) 2167-9177 (Online) Journal homepage: www.tandfonline.com/journals/iejp20

“The complexity of what to do” – clinical perspectives of tailored physiotherapy interventions in patients with respiratory symptoms in post-COVID condition

Monika Fagevik Olsén, Louise Lannefors, Ewa-Lena Johansson, Niklas Sinderholm Sposato, Malin Nygren-Bonnier & Jenny Danielsbacka

To cite this article: Monika Fagevik Olsén, Louise Lannefors, Ewa-Lena Johansson, Niklas Sinderholm Sposato, Malin Nygren-Bonnier & Jenny Danielsbacka (24 Oct 2024): “The complexity of what to do” – clinical perspectives of tailored physiotherapy interventions in patients with respiratory symptoms in post-COVID condition, European Journal of Physiotherapy, DOI: 10.1080/21679169.2024.2419051

To link to this article: https://doi.org/10.1080/21679169.2024.2419051

EUROPEAN JOURNAL OF PHYSIOTHERAPY
https://doi.org/10.1080/21679169.2024.2419051

RESEARCH ARTICLE

"The complexity of what to do" – clinical perspectives of tailored physiotherapy interventions in patients with respiratory symptoms in post-COVID condition

Monika Fagevik Olsén[a,b], Louise Lannefors[a,b], Ewa-Lena Johansson[a,b], Niklas Sinderholm Sposato[a,c], Malin Nygren-Bonnier[d,e] and Jenny Danielsbacka[a,b]

[a]Department of Health and Rehabilitation/Physiotherapy, Institute of Neuroscience and Physiology, University of Gothenburg, Gothenburg, Sweden; [b]Department of Physiotherapy, Sahlgrenska University Hospital, Gothenburg, Sweden; [c]School of Public Health, University of Technology Sydney, Sydney, New South Wales, Australia; [d]Department of Neurobiology, Care Sciences and Society, Division of Physiotherapy, Karolinska Institutet, Huddinge, Sweden; [e]Women's Health and Allied Health Professionals Theme, Medical Unit Allied Health Professionals, Karolinska University Hospital, Stockholm, Sweden

ABSTRACT

Purpose: Knowledge gaps exist regarding the effects of interventions due to continuing respiratory symptoms in patients with post-COVID condition. The aim of the present study was to present the clinical outcomes of individualised treatments for patients with remaining respiratory symptoms due to post-COVID condition.

Methods: This prospective longitudinal study included a consecutive series of 57 patients with remaining respiratory post-COVID symptoms. Breathing pattern, thoracic pain/mobility, occurrence of cough, and respiratory muscle strength were assessed before and after the administration of individually tailored physiotherapy interventions.

Results: The median treatment duration was 3 months (range 1–36 months). Dysfunctional breathing pattern was the most common symptom ($n = 55/57$) at inclusion. After treatment, 95% of patients had a normalised or improved breathing pattern ($p < 0.001$). The treatments for pain, productive and unproductive cough, and respiratory muscle strength resulted in significantly improved symptoms ($p < 0.01$). With other targeted treatments, inspiratory muscle strength improved by 20 cmH2O and expiratory muscle strength by 11 cmH_2O (both $p < 0.001$).

Conclusions: This study indicates positive outcomes of physiotherapy treatment based on the patient's symptomatology and test results. Therefore, individualised physiotherapy treatment of post-COVID conditions may have an impact on recovery.

ARTICLE HISTORY
Received 7 May 2024
Revised 11 October 2024
Accepted 14 October 2024

KEYWORDS
Post-COVID condition; physical therapy modalities; respiratory; signs and symptoms; dysfunctional breathing; breathing exercises

Introduction

The number of patients with prolonged symptoms after SARS-CoV-2 infection continues to increase [1–3]. Patients with a post-COVID condition, which is defined as the continuation or development of new symptoms 3 months after the initial SARS-CoV-2 infection and lasting at least 2 months with no other explanation, have reported a variety of new, recurrent, or ongoing symptoms of different degrees [3–9]. Previous studies have demonstrated a broad spectrum of reported symptoms and dysfunctions, with the most common including dyspnoea, shortness of breath or difficulty breathing, fatigue, myalgia, joint pain, reduced exercise tolerance, memory loss, persistent cough, chest pain, affected cognition and/or mental health, depression, anxiety, and concentration or sleep problems [4,6,10–13]. The optimal rehabilitation needs or outcome measures have not yet been defined, though the need for long-term rehabilitation, organised as outpatient care, is extensive [2,7,14,15]

For many patients with post-COVID condition, various tests have indicated no pathology despite considerable symptomatology [16]. In addition, trials evaluating the effects of rehabilitation interventions for the diverse symptoms are primarily based on ordinary test data collected at control visits or by subjective questionnaires [17,18]. The complexity and variability of symptoms caused by the disease can make it difficult to create and adapt rehabilitation programmes [6,14,15,19,20], and the importance of identifying safe and effective long-term such has not been thoroughly discussed. However, some studies have shown that a holistic assessment based on each patient's medical history, focusing on dysfunction, disability, and the patient's desire to return to participation in society, can guide the physiotherapist in finding an individually tailored,

CONTACT Monika Fagevik Olsén monika.fagevik-olsen@gu.se Department of Health and Rehabilitation/Physiotherapy, Institute of Neuroscience and Physiology, BOX 455, Sahlgrenska Academy, University of Gothenburg, SE 405 30 Gothenburg, Sweden

Supplemental data for this article can be accessed online at https://doi.org/10.1080/21679169.2024.2419051.

progressive treatment plan [6,18,20,21]. Considering the disease from several points of view may maximise the chances for each patient to improve their physical function and quality of life.

In a previous study, 60 non-hospitalised participants with remaining respiratory symptoms after COVID-19 were examined by physiotherapists with respiratory speciality [21]. In addition to the traditional outcome measures (spirometry, oxygen saturation, and physical capacity), the breathing pattern, chest mobility and pain, respiratory movement, and respiratory muscle strength were assessed. Only a few patients had decreased spirometry, but more than 50% had decreased respiratory muscle strength. In addition, 59% had decreased physical capacity, but only a few desaturated during the test. Unproductive cough was seen more often than productive cough, a majority of patients (67%) suffered from pain in the thoracic area, and a dysfunctional breathing pattern was seen among 95% of the patients. An individualised treatment plan was tailored from the results of the increased battery of tests and examinations. The aim of this study was to present the clinical outcome of this individualised treatment for patients with remaining respiratory symptoms due to post-COVID condition.

Methods

Participants

This follow-up was based on a consecutive, unselected series of 60 patients who participated in a prospective longitudinal study [21]. They were referred to the physiotherapy outpatient clinic at Sahlgrenska University Hospital because of remaining symptoms after COVID-19 confirmed by tests and/or clinical examination. From August 2020 until September 2023, the patients met one of three available physiotherapists specialised in respiratory care. During the first appointment, the patient's symptoms were assessed by a variety of tests to capture their symptomatology [21]

Symptom assessment

Breathing pattern was determined by visual clinical ocular assessment of the upper and lower thorax and abdominal movements in the supine, sitting, and standing position. A normal breathing pattern was defined as predominantly abdominal and lower thoracic movements during tidal volume breathing while sitting and standing. A dysfunctional breathing pattern was defined as a breathing pattern not appropriate for the current situation and in which a high costal breathing pattern at rest was dominant [22]

Thoracic pain was assessed bilaterally in all sternocostal joints and anterior intercostal muscles by manual palpation. Pain was registered as yes/no. Thoracic expansion was assessed using a measuring tape (marked in mm) around the circumference at the level of the xiphoid process [23]

Productive and unproductive cough was evaluated by the COPD Assessment Test (CAT) [24] and standardised auscultation using a stethoscope. In addition, respiratory muscle strength was determined by measuring the maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) using a micro-RPM (Care Fusion, Yorba Linda, CA, USA) in a standardised manner (expressed as cmH_2O) [25].

Spirometry was performed according to guidelines [26] using a portable ultrasonic spirometer (Easy One ndd, Medical Technologies, Switzerland). Forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and peak expiratory flow (PEF) were also measured. Breathing movements were evaluated with the Respiratory Movement Measurement Instrument (RMMI; ReMo, Reykjavik, Iceland) [27]. The RMMI measures the anteroposterior breathing movement by calculating differences in the body surface level during inhalation and exhalation [27]. The degree of functional limitation was rated by the Swedish version of the Post-COVID Functional Status (PCFS) [28]

Respiratory symptoms were rated on the CAT scale [24]. To improve the interpretation, minor additions were made to three of the eight statements. In question number 2, 'secretion in the chest', the word 'lungs' was added. In statements number 5 and 8, 'because of my lung condition' was added in accordance with statement number 6 in the original version.

The patient's physical activity level was rated using Grimby and Saltin's Physical Activity Level Scale [29].

Interventions

The individually tailored physiotherapy interventions consisted of breathing retraining, thoracic mobility techniques, cough education, airway clearance techniques and respiratory muscle training. Following interventions were prescribed when indicated:

Breathing pattern

The intervention for a dysfunctional breathing pattern consisted of instructions to relax and normalise the breathing pattern in 10 steps (see Appendix 1, supplementary material). The programme was based on earlier research [30] and current treatment instructions to patients with other kinds of breathing pattern dysfunction. The programme was designed to increase the demands of the complex function of breathing from lying supine to standing while doing different activities.

During the first appointment the first four exercises were performed whilst being instructed. The participants were taught to continue to the next exercise in the program once they could perform the ones they were practicing, gradually gaining more of a normal breathing pattern.

Thoracic pain/mobility

For participants with thoracic pain, stretching techniques to increase the range of mobility in the ribcage joints and muscles (i.e. lateral flexion, rotation, flexion, and extension of the thorax) were taught. In addition, chest expansion techniques were performed by maximal inspirations with a 5-second post-inspiratory hold in two positions twice a day:

1. Sitting upright with hands positioned at both sides of the lower part of the thorax;
2. Sitting forward with arms resting on a firm surface.

These exercises aimed to facilitate increased thoracic movement, as well as an awareness of the breathing movements.

During the instruction phase, the exercises were guided by a demonstration by the physiotherapist. If these exercises were not enough to relieve the pain, the participants were referred to manual therapy including passive joint mobilisation without impulse and soft tissue treatment. Joint mobilisation was directed mainly to the costovertebral and costosternal joints, whereas the main aim of the soft tissue treatment was to reduce muscle pain and reactive tension in accessory respiratory areas, such as the cervical and lumbar spine.

Unproductive cough

The aim of the intervention for unproductive cough was to teach the participants to be conscious regarding their coughing behaviour and to avoid coughing. When they became more conscious about when and how much they coughed, the participants were told to deliberately choose not to cough and to decrease the irritation caused by the cough, thereby breaking the negative coughing spiral.

Productive cough

The participants with a productive cough were taught huffing techniques, and positive expiratory pressure (PEP) was prescribed and trained when necessary. PEP was instructed to be used at least twice daily with 10 breaths in three sessions interspersed with huffing and coughing to remove the secretions [31]. The huffing techniques aimed for a gentler way to remove secretions than the coughing alone, decreasing the irritation caused by the extensive coughing.

Respiratory muscle strength

If the patient's respiratory muscle strength was below the lower limits of normal and their breathing pattern was normal, the participants were prescribed inspiratory muscle training (IMT) and/or expiratory muscle training (EMT). This was based on clinical experience that it otherwise may be counterproductive and create a more predominant abnormal breathing movement in the upper part of the chest.

The training started with resistance in which a normal breathing pattern was maintained during the breathing manoeuvres. To not overload the participants, 10–15 consecutive breaths was recommended in three sessions, three times a week. The first five participants in the cohort received a pressure-regulated device (Threshold IMT™) but, as a normal breathing pattern was difficult for the participants to maintain during the training, a decision was made to prescribe flow-regulated devices, such as the PEP/RMT™ system, PEP-aid™, or BA-tube™ (Figure 1). The resistance was increased according to the achievements in respiratory muscle strength, but never more than what a normal breathing pattern could maintain. If the participants had limitations maintaining a normal breathing pattern while sitting and performing the respiratory muscle training, they were told to perform the exercises lying down.

The effects of the interventions were evaluated by the same outcome measures at discharge from the clinic as at inclusion. The discharge was determined on clinical grounds (i.e. when the patients had recovered or could perform the remaining treatment by themselves). The effects between these two occasions were defined as 'normalised' if the results were within normal values or pattern and 'improved' when they were better but not within the normal range of values or pattern.

Statistical analysis

Data were analysed using the Statistical Package for Social Sciences (IBM, SPSS Statistics 29.0, Armonk, New York, USA). The results were considered significant if the two-sided p-value was < 0.05. All continuous variables are presented as medians with the interquartile range (IQR; 25–75) and minimum – maximum. Categorical variables are presented as the

Figure 1. The breathing devices used in the study.

number and/or percentage. Within group comparisons were made by Wilcoxon's rank-sum test, between groups comparisons by the Mann-Whitney U test, and categorical data were compared by the sign test.

Results

The patients received tailored interventions based on the results of their tests. Three patients chose not to continue after the first visit because they considered the information, they received during the first visit sufficient. Therefore, the study continued with 57 participants. Details of demographics and tests are given in Table 1

Forty-four of the 57 participants experienced fatigue and 36 of the 57 participants experienced a cognitive impact connected to the post-COVID condition as measured by the PCFS or based on the patient's medical history.

The length of the treatment period varied, depending on the patients' individual needs. The median treatment duration was 3 months (min 1, max 36, IQR 4–10 months) with a median of 3 (1–16) physical appointments (IQR 2–5) and 4 (0–15) telephone appointments (IQR 2-5).

Dysfunctional breathing pattern

Fifty-five participants had a dysfunctional breathing pattern at baseline. After the treatment period, the breathing pattern was assessed as normalised in 60% of the participants and improved in more than 35% ($p < 0.001$) (Table 2).

Thoracic pain/mobility

Three participants had previous pain from the thoracic region and were excluded from the analysis. Of the remaining 54 participants, 32 had thoracic pain at baseline. Seven participants with did not receive any treatment due to a heavy disease burden that affected them severely (e.g. extensive fatigue, cognitive impairment, gastrointestinal symptoms, and sleep deprivation). Four of the participants who improved also had complementary treatment from a physiotherapist in the form of orthopaedic manual therapy orientation or from an osteopathic practitioner. After following the treatment advice given by the physiotherapist, the patients had significantly fewer symptoms: 32% reported no pain, 64% a decrease in pain, and 4% had unchanged thoracic pain ($p < 0.001$, Table 2).

Table 1. Demographics and baseline data.

		All, $n = 57$	Men, $n = 9$	Women, $n = 48$
Age, years		44.3 (9.3)	41.9 (12.4)	44.6 (8.8)
Time since the acute phase, months		10.9 (4.5)	9.3 (5.5)	11.0 (4.3)
Tested positive for COVID-19, n		30	7	23
BMI, kg/m^2		25.1 (9.3)	24.6 (3.5)	24.1 (6.2)
Overweight (BMI 25–29.9)/ Obese (BMI > 30), n		13/6	2/1	11/5
Smokers, n		3	0	3
Previously diagnosed pulmonary disease, n		5	0	5
Modified CAT		20 (15–26)	3.8 (11–21)	22 (16–26)
Physical activity levels pre-COVID, n	Sedentary	1	1	1
	Lighter	36	3	33
	Regular	15	3	12
	Elite	4	2	2
Functional limitation by PCFS, n	Negligible	3	2	1
	Slight	19	3	16
	Moderate	27	4	23
	Severe	8	0	8
FVC, % predicted		104.8 (12.6)	107.9 (10.0)	104.2 (13.0)
FEV_1, % predicted		100.3 (13.7)	101.6 (7.6)	100.1 (14.5)
PEF, % predicted		100.2 (19.1)	104.5 (16.2)	99.4 (19.7)
MIP, % predicted		81.1 (26.6)	100.4 (27.3)	77.8 (25.3)
MEP, % predicted		101.0 (28.5)	106.9 (27.3)	100.0 (29.4)
Thoracic expansion, % predicted		74.6 (36.7)	95.5 (28.6)	70.1 (37.0)

Data presented as M (SD), median (IQR) or n.
CAT: COPD Assessment Test; PCFS: Post-COVID Functional Status; FVC: forced vital capacity; FEV_1: forced expiratory volume in 1 s; PEF: peak expiratory flow; MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure.

Table 2. Changes in symptom (normalised/improved/unchanged) from baseline to after the treatment period.

				Effect of treatment			
Symptoms	Tested, n	Not affected, n	No intervention given despite symptoms, n *	Normalised, n	Improved, n	None, n	*p*-value
Dysfunctional breathing pattern $n = 57$	57	2	0	33	20	2	<0.001
Thoracic pain $n = 54$	54	22	7	8	16	1	<0.001
Unproductive cough $n = 57$	57	31	0	17	9	0	<0.001
Productive cough $n = 57$	57	37	0	11	8	1	<0.001
Inspiratory muscle strength $n = 57$	57	15	16	14	8	4	<0.001
Expiratory muscle strength $n = 57$	57	25	15	7	5	5	0.002

*These patients did not receive treatment due to dysfunctional breathing pattern or heavy disease burden in other symptoms from COVID-19.

Table 3. Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) before and after training with IMT and/or EMT.

	At baseline	After training	p-value
MIP, $n = 26$	63 (31–95, 52–72.5)	83.5 (53–146, 65.75–93.5)	0.001
MEP, $n = 17$	80 (44–133, 54–88)	91 (57–151, 69.5–116.5)	0.001

Data presented as Median (min-max and IQR). *MIP* maximal inspiratory pressure, *MEP* maximal expiratory pressure.

Unproductive cough

At baseline, 26 participants reported, either through the CAT protocol or when asked during a physiotherapist visit, an unproductive cough that disturbed their talking and activities. At follow-up, 65% reported that the cough had vanished, and 35% reported that it had improved/become less of a burden ($p < 0.001$, Table 2).

Productive cough

The presence of productive cough was reported at baseline by 20 participants. After treatment, the symptoms were significantly improved; 55% reported that the cough had vanished, 40% that it improved/become less at follow-up, and 1 patient (5%) reported that the cough and secretions remained unchanged ($p < 0.001$).

Respiratory muscle strength

Low MIP and MEP were found in 42 participants, but 16 of them did not receive treatment for decreased inspiratory muscle strength due to a dysfunctional breathing pattern or heavy disease burden of other symptoms from COVID-19. A combination of IMT and EMT was prescribed to the remaining 17 participants, and 9 participants received only IMT. The results are presented in Tables 2 and 3. The IMT resulted in a significant improvement in 22 of the 26 patients ($p < 0.001$) and an average increase of 20.5 cmH_2O ($p < 0.001$). Corresponding figures for EMT were 12 of 17 patients ($p = 0.002$) and 11 cmH_2O ($p < 0.001$).

Discussion

Post-COVID respiratory symptoms can be heterogenous, variable over time, and difficult to identify by traditional tests [12,21,32]. Consequently, an expanded battery of tests is needed and different interventions in diverse combinations. This study reports the findings of such tailored interventions in a cohort of patients with post-COVID conditions.

The results from our previous post-COVID study [21] showed that the overarching respiratory symptom is a dysfunctional breathing pattern. The pattern was observed by the physiotherapists and described by the participants. This is in line with the results from earlier studies [33,34] in which patients with dysfunctional breathing reported dyspnoea during activities, ribcage pain, and a feeling of tight armour/girdle around the chest. Patients who were able to lie supine with an almost normal breathing pattern lost the ability to maintain this pattern when sitting upright or standing [21]. As a majority of the patients either normalised or improved their breathing pattern during the treatment period, there is an indication to restore a normal breathing pattern using specific breathing exercises.

The recovery process of post-COVID condition varies, which may be due to COVID-19 being a multi-organ disease causing long-term injuries to different organ systems. One hypothesis is that it is caused by vasculature damage and subsequent hypoxia [35]. Patients need to be informed that setbacks can occur and are to be considered normal [32]. It is also important to inform patients that the changed breathing pattern is a physiological response to decreased diaphragm function in which the intercostal muscles have to take over the responsibility of the breathing movements. This increases the work of breathing, and the over-use of these muscles may eventually cause other symptoms, such as pain or decreased thoracic mobility [36]. This became apparent in the present study because thoracic pain and other discomfort during physical examination were reported by 44% of the participants. When receiving treatment for their thoracic pain in addition to their dysfunctional breathing pattern, 24 of the patients recovered or improved. When seeing patients with diffuse or odd respiratory symptoms, it is important to ask questions about dysfunctional breathing at rest and during different physical activities, especially demanding activities such as ones requiring the arms above shoulder level, walking uphill, or climbing stairs combined with talking.

Early reports stated that respiratory muscle function was impaired after COVID-19, which has been confirmed [21,37,38]. Of the participants who received respiratory muscle training in the current study, the muscle strength normalised or improved in 85% of those who performed IMT and 71% of those who performed EMT. Thus, our findings confirm that respiratory muscle training is feasible and can be successful for post-COVID condition [21,39]. IMT and EMT are often included in physiotherapy for many categories of patients [40] but, in this study, it was tailored individually to not negatively affect the dysfunctional breathing pattern. Therefore, not all participants who may have needed IMT or EMT received it. The treatment was only initiated if a normal breathing pattern could be maintained and if it did not increase the disease burden of other symptoms. Respiratory muscle training has been recommended but the prescription needs to be individualised [35,41,42]. The cost of the devices used for the training is low, but measuring MIP and MEP is necessary to optimise the treatment, as well as to evaluate the results.

Unproductive and productive cough was a common symptom among our participants. All participants receiving advice on how to avoid unproductive cough and to treat productive cough recovered partly, if not completely. These results indicate the efficacy of physiotherapy interventions including advice and breathing exercises, a cost-effective treatment as the low-cost devices can be used in different clinical settings.

The strengths of this study include the use of a consecutive series of patients from the Vastra Gotaland region who were referred to Sahlgrenska University Hospital's physiotherapy outpatient clinic. The participants were assessed individually according to an extended protocol and were treated by physiotherapists specialised in respiration. The clinic has access to special equipment, including RMMI, spirometers, and digital manometers to measure the symptoms described by the participants. However, most of the treatment was based on common holistic physiotherapy practises when treating patients with respiratory symptoms.

A limitation of this study is the lack of a control group. The results should be interpreted with this in mind, but the findings may constitute a basis for a randomised controlled trial of a similar intervention structure. The content and intensity of the treatment was adapted to the results of the tests at the first visit, but also the results obtained during the treatment. As the study was performed during clinical practise, both the content of the treatment plan and the duration of it varied. However, this became a part of the tailored intervention, reflecting the complex clinical reasoning underlying the different approaches and the importance of adapting the intensity of the rehabilitation to the participants. It would have been of interest to report compliance with the intervention, but no treatment diary was included. Retrospectively, a structured assessment of the ability to be physically active should have been included after the treatment period. Respiratory function is intricately connected to physical activity and training, and future studies should be designed to incorporate this perspective.

Conclusion

The findings of this study indicate positive clinical outcomes after a tailored, individualised treatment of respiratory function in post-COVID conditions. The time needed to restore a normal breathing pattern varied greatly. However, positive effects of interventions to improve the breathing pattern, thoracic mobility, pain, coughing, and respiratory muscle function in patients with post-COVID respiratory symptoms were seen during the clinical follow-up.

Ethics statement

The Swedish Ethical Review Authority approved the study (registration number 2020-02149, amendment 2021-01101). The patients were provided oral and written information and included in the study after giving written consent.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

References

[1] Montani D, Savale L, Noel N, et al. Post-acute COVID-19 syndrome. Eur Respir Rev. 2022;31(163):210185. doi: 10.1183/16000617.0185-2021.

[2] Simon M, Simmons JE. A review of respiratory Post-Acute Sequelae of COVID-19 (PASC) and the potential benefits of pulmonary rehabilitation. R I Med J. 2022;105(7):11–15.

[3] National Institute for Health and Care research. Living with covid – second review; 2021. Available from: https://evidence.nihr.ac.uk/collection/living-with-covid19-second-review/.

[4] Crook H, Raza S, Nowell J, et al. Long covid-mechanisms, risk factors, and management. Bmj. 2021;374:n1648. doi: 10.1136/bmj.n1648.

[5] Ladds E, Rushforth A, Wieringa S, et al. Persistent symptoms after Covid-19: qualitative study of 114 "long Covid" patients and draft quality principles for services. BMC Health Serv Res. 2020;20(1):1144. doi: 10.1186/s12913-020-06001-y.

[6] Jacobson KB, Rao M, Bonilla H, et al. Patients With Uncomplicated Coronavirus Disease 2019 (COVID-19) have long-term persistent symptoms and functional impairment similar to patients with severe COVID-19: a cautionary tale during a global pandemic. Clin Infect Dis. 2021;73(3):e826–e9. doi: 10.1093/cid/ciab103.

[7] Araújo BTS, Barros A, Nunes DTX, et al. Effects of continuous aerobic training associated with resistance training on maximal and submaximal exercise tolerance, fatigue, and quality of life of patients post-COVID-19. Physiother Res Int. 2023;28(1):e1972.

[8] World Health Organization. Rehabilitation needs of people recovering from COVID-19: scientific brief; [cited 2021 Nov 29]. [Available from: https://www.who.int/publications/i/item/WHO-2019-nCoV-Sci-Brief-Rehabilitation-2021.1.

[9] World Health Organization. Post COVID-19 condition (Long COVID); 2022 Available from: https://www.who.int/europe/news-room/fact-sheets/item/post-covid-19-condition.

[10] Augustin M, Schommers P, Stecher M, et al. Post-COVID syndrome in non-hospitalised patients with COVID-19: a longitudinal prospective cohort study. Lancet Reg Health Eur. 2021;6:100122. doi: 10.1016/j.lanepe.2021.100122.

[11] Bouteleux B, Henrot P, Ernst R, et al. Respiratory rehabilitation for Covid-19 related persistent dyspnoea: a one-year experience. Respir Med. 2021;189:106648. doi: 10.1016/j.rmed.2021.106648.

[12] Bellan M, Baricich A, Patrucco F, et al. Long-term sequelae are highly prevalent one year after hospitalization for severe COVID-19. Sci Rep. 2021;11(1):22666. doi: 10.1038/s41598-021-01215-4.

[13] Cabrera Martimbianco AL, Pacheco RL, Bagattini ÂM, et al. Frequency, signs and symptoms, and criteria adopted for long COVID-19: a systematic review. Int J Clin Pract. 2021;75(10):e14357. doi: 10.1111/ijcp.14357.

[14] McNarry MA, Berg RMG, Shelley J, et al. Inspiratory muscle training enhances recovery post-COVID-19: a randomised controlled trial. Eur Respir J. 2022;60(4):2103101. doi: 10.1183/13993003.03101-2021.

[15] Estebanez-Pérez MJ, Pastora-Bernal JM, Martín-Valero R. The effectiveness of a four-week digital physiotherapy intervention to improve functional capacity and adherence to intervention in patients with long COVID-19. Int J Environ Res Public Health. 2022;19(15):9566.

[16] Vanichkachorn G, Newcomb R, Cowl CT, et al. Post-COVID-19 syndrome (long haul syndrome): description of a multidisciplinary clinic at mayo clinic and characteristics of the initial patient cohort. Mayo Clin Proc. 2021;96(7):1782–1791. doi: 10.1016/j.mayocp.2021.04.024.

[17] Fugazzaro S, Contri A, Esseroukh O, et al. Rehabilitation interventions for post-acute COVID-19 syndrome: a systematic review. Int J Environ Res Public Health. 2022;19(9):5185.

[18] Lemhöfer C, Gutenbrunner C, Schiller J, et al. Assessment of rehabilitation needs in patients after COVID-19: Development of the COVID-19-rehabilitation needs survey. J Rehabil Med. 2021;53(4): jrm00183. doi: 10.2340/16501977-2818.

[19] Vaes AW, Goërtz YMJ, Van Herck M, et al. Recovery from COVID-19: a sprint or marathon? 6-month follow-up data from online long COVID-19 support group members. ERJ Open Res. 2021;7(2): e00141-2021. doi: 10.1183/23120541.00141-2021.

[20] O'Sullivan O, Barker-Davies RM, Thompson K, et al. Rehabilitation post-COVID-19: cross-sectional observations using the Stanford Hall remote assessment tool. BMJ Mil Health. 2023;169(3):243–248. doi: 10.1136/bmjmilitary-2021-001856.

[21] Fagevik Olsén M, Lannefors L, Nygren-Bonnier M, et al. Long COVID–respiratory symptoms in non-hospitalised subjects–a cross-sectional

study. Europ J Physioth. 2023;25(5):283–290. doi: 10.1080/21679169.2022.2101692.

[22] Courtney R, Greenwood KM, Cohen M. Relationships between measures of dysfunctional breathing in a population with concerns about their breathing. J Bodyw Mov Ther. 2011;15(1):24–34. doi: 10.1016/j.jbmt.2010.06.004.

[23] Olsén MF, Lindstrand H, Broberg JL, et al. Measuring chest expansion; a study comparing two different instructions. Advances in Physiotherapy. 2011;13(3):128–132. doi: 10.3109/14038196.2011.604349.

[24] Jones PW, Harding G, Berry P, et al. Development and first validation of the COPD Assessment Test. Eur Respir J. 2009;34(3):648–654. doi: 10.1183/09031936.00102509.

[25] Laveneziana P, Albuquerque A, Aliverti A, et al. ERS statement on respiratory muscle testing at rest and during exercise. Eur Respir J. 2019;53(6):1801214. doi: 10.1183/13993003.01214-2018.

[26] Quanjer PH, Tammeling GJ, Cotes JE, et al. Lung volumes and forced ventilatory flows. Report Working Party Standardization of Lung Function Tests, European Community for Steel and Coal. Official Statement of the European Respiratory Society. Eur Respir J Suppl. 1993;6(Suppl 16):5–40. doi: 10.1183/09041950.005s1693.

[27] Ragnarsdóttir M, Kristinsdóttir EK. Breathing movements and breathing patterns among healthy men and women 20–69 years of age. Reference Values. Respiration. 2006;73(1):48–54. doi: 10.1159/000087456.

[28] Klok FA, Boon GJ, Barco S, et al. The post-COVID-19 functional status scale: a tool to measure functional status over time after COVID-19. Eur Respir J. 2020;56(1):2001494. doi: 10.1183/13993003.01494-2020.

[29] Grimby G, Börjesson M, Jonsdottir IH, 29., et al. The "saltin-grimby physical activity level scale" and its application to health research. Scand J Med Sci Sports. 2015;25(Suppl 4):119–125.

[30] Hagman C, Janson C, Emtner M. Breathing retraining – a five-year follow-up of patients with dysfunctional breathing. Respir Med. 2011;105(8):1153–1159. doi: 10.1016/j.rmed.2011.03.006.

[31] Fagevik Olsén M, Lannefors L, Westerdahl E. Positive expiratory pressure – common clinical applications and physiological effects. Respir Med. 2015;109(3):297–307. doi: 10.1016/j.rmed.2014.11.003.

[32] Twomey R, DeMars J, Franklin K, et al. Chronic fatigue and postexertional malaise in people living with long COVID: an observational study. Phys Ther. 2022;102(4):pzac005.

[33] Huang C, Huang L, Wang Y, et al. 6-month consequences of COVID-19 in patients discharged from hospital: a cohort study. Lancet. 2021;397(10270):220–232. doi: 10.1016/S0140-6736(20)32656-8.

[34] Fagevik Olsén M, Lannefors L, Johansson EL, et al. Variations in respiratory and functional symptoms at four months after hospitalisation due to COVID-19: a cross-sectional study. BMC Pulm Med. 2024;24(1):63. doi: 10.1186/s12890-024-02866-5.

[35] Halle M, Bloch W, Niess AM, et al. Exercise and sports after COVID-19-guidance from a clinical perspective. Transl Sports Med. 2021;4(3):310–318. doi: 10.1002/tsm2.247.

[36] De Troyer A, Kirkwood PA, Wilson TA. Respiratory action of the intercostal muscles. Physiol Rev. 2005;85(2):717–756. doi: 10.1152/physrev.00007.2004.

[37] Vonbank K, Nics H, Zwick RH, et al. Decreased phrenic nerve compound muscle action potential, inspiratory muscle strength, and exercise capacity after COVID-19. Front Neurol. 2024;14:1308443. doi: 10.3389/fneur.2023.1308443.

[38] Regmi B, Friedrich J, Jörn B, et al. Diaphragm muscle weakness might explain exertional dyspnea 15 months after hospitalization for COVID-19. Am J Respir Crit Care Med. 2023;207(8):1012–1021. doi: 10.1164/rccm.202206-1243OC.

[39] Vieira da Costa K, Tainá Cordeiro de Souza I, Felix JVdS, et al. Efficacy of a rehabilitation protocol on pulmonary and respiratory muscle function and ultrasound evaluation of diaphragm and quadriceps femoris in patients with post-COVID-19 syndrome: a series of cases. Monaldi Arch Chest Dis. 2022;93(1):6. doi: 10.4081/monaldi.2022.2206.

[40] McConnell A. Respiratory muscle-training theory and practice. 1st ed. London Elsevier; 2014.

[41] Davis HE, McCorkell L, Vogel JM, et al. Long COVID: major findings, mechanisms and recommendations. Nat Rev Microbiol. 2023;21(3):133–146. doi: 10.1038/s41579-022-00846-2.

[42] Wright J, Astill SL, Sivan M. The relationship between physical activity and long COVID: a cross-sectional study. Int J Environ Res Public Health. 2022;19(9):2093.