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Rehabilitation Programs Effectiveness Model: a Retrospective Comparative Study of Patients with Post-Acute COVID-19 Syndrome

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ABSTRACT

AIM. To evaluate the expected effectiveness of post-COVID rehabilitation strategies.
MATERIAL AND METHODS. The study was conducted August, 2021 – March, 2022 in the republican and federal rehabilitation centers: Krasnodar Territory (n=25), the Republic of Buryatia (n=25), and Moscow (n= 25). The data were obtained by a retrospective analysis of medical records and by interviewing the study participants who had an indication or had been treated in a rehabilitation centre for post-acute COVID-19 syndrome (U 09.9). The average length of time after the onset of the acute period of the disease was 6.5 ± 2.5 months. A prognostic model was constructed to estimate the expected effectiveness of the rehabilitation programme, as measured by a reduction in the severity of dyspnea. Nonlinear maximum likelihood logit regression was used to build the model.
RESULTS AND DISCUSSION. According to the presented model, the best expected rehabilitation effectiveness was found in the National Medical Research Center (Moscow) (β=-1.788685, p=0.009964604), a slightly lower expected rehabilitation effectiveness was observed in the resort with a curative climate (Krasnodar Territory) (β=0.9913501, p=0.182944), the lowest expected effectiveness was registered in the regional rehabilitation center (the Republic of Buryatia) (β=1.054594 p=0.2642723). The need for an integrated approach in the treatment of patients with post-acute COVID-19 syndrome was pointed out by many domestic and foreign researchers, however, the choice and content of treatment strategies is debatable. Our study provides a preliminary answer to this question.
CONCLUSION. The developed model of the expected effectiveness of the rehabilitation of patients suffering from shortness of breath after undergoing COVID-19 has a specificity of 54.54%, sensitivity of 91.3% and an overall accuracy of 84.21%. The best expected rehabilitation effectiveness was found in the National Medical Research Center of Rehabilitation and Balneology of the Ministry of Health of the Russian Federation (Moscow) (β=-1.788685, p=0.009964604), somewhat lower in the resort with a curative climate (Krasnodar territory) (β=0.9913501, p=0.182944), the lowest expected efficiency was registered in the regional rehabilitation center (the Republic of Buryatia) (β=1.054594 p=0.2642723).
KEYWORDS: post-acute COVID-19 syndrome, rehabilitation programmes, dyspnea

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Модель эффективности реабилитационных программ: ретроспективное сравнительное исследование пациентов с постковидным синдромом

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РЕЗЮМЕ

ЦЕЛЬ. Оценить ожидаемую эффективность стратегий реабилитации постковидного синдрома.

МАТЕРИАЛ И МЕТОДЫ. Исследование проводилось в период с августа 2021 года по март 2022 года, на базе Региональных (Краснодарский край (n=25), Республика Бурятия (n=25), и Федерального реабилитационных Центров (г. Москва) (n=25). Данные получены путем ретроспективного анализа историй болезни и опроса участников исследования, которые имели показания или проходили лечение в реабилитационном центре в связи с постковидным синдромом (U 09.9). Средняя продолжительность времени после начала острого периода заболевания составила 6,5± 2,5 месяцев. Степень выраженности одышки оценивалась по шкале Борга. Была построена прогностическая модель, оценивающая ожидаемую эффективность реабилитационной программы по уменьшению выраженности одышки. Для построения модели использовалась методика нелинейной логит-регрессии методом максимального правдоподобия.

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ. Согласно, представленной модели наилучшая ожидаемая эффективность реабилитации выявлена в ФГБУ «Национальный медицинский исследовательский центр реабилитации и курортологии» Минздрава России (г Москва) (β=-1,788685, p=0,009964604), несколько меньшая ожидаемая эффективность реабилитации наблюдалась в условиях курорта, обладающего лечебным климатом (Архипо-Осиповка, Краснодарский край) (β=0,9913501, p=0,182944), наименьшая ожидаемая эффективность зарегистрирована в региональном реабилитационном центре (республика Бурятия) (β=1,054594 p=0,2642723). На необходимость комплексного подхода в лечении больных с постковидным синдромом указывали работы многие отечественные и зарубежные исследователи, однако выбор и содержание стратегий лечения дискутабелен. Наше исследование даёт предварительный ответ на данный вопрос.

ЗАКЛЮЧЕНИЕ. Разработанная модель ожидаемой эффективности реабилитации пациентов с постковидным синдромом обладает специфичностью – 54,54%, чувствительностью – 91,3%, общей точностью – 84,21%. Наилучшая ожидаемая эффективность реабилитации выявлена в Национальном медицинском исследовательском центре реабилитации и курортологии Минздрава России (г. Москва) (β=-1,788685, p=0,009964604), несколько меньшая в условиях курорта, обладающего лечебным климатом (Краснодарский край) (β=0,9913501, p=0,182944), наименьшая ожидаемая эффективность зарегистрирована в региональном реабилитационном центре (Республика Бурятия) (β=1,054594 p=0,2642723).

КЛЮЧЕВЫЕ СЛОВА: постковидный синдром, реабилитация, реабилитационные программы, стратегии лечения, одышка

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INTRODUCTION

Treatment of post-acute COVID-19 syndrome has placed a heavy burden on national health care, requiring a more rational use of allocated funds and decision-making management [1-6]. For this purpose, it was necessary to construct a model of the expected effectiveness of rehabilitation depending on the type of institution and the range of techniques employed. To date, the new coronavirus infection pandemic (COVID-19) has affected more than 523 million people and caused more than 6 million deaths since 17 May 2022 [1]. A large proportion of the patients infected with SARS-COV-2 does not fully recover and continues to experience a large number of symptoms in the absence of a diagnosable viral infection. This condition has been called post-acute COVID-19 syndrome (Long-COVID-19) [7]. The prevalence of post-acute COVID-19 syndrome among outpatients and hospitalized patients ranges from 68.7% to 77.1% [8-10]. Researchers have identified clusters of patients [11] who have different symptomatology, rehabilitation potential and require different rehabilitation interventions [12, 13].

In a study of the evolution of patients with post-acute COVID-19 syndrome and the impact of the rehabilitation process 3 and 6 months after the acute phase of COVID-19, Spanish researchers found that respiratory and mobility complications were partially reversible after 3 months

[1] COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University. Available at: https://github.com/CSSEGISandData/COVID-19 (accessed 18.05.2022).

of the rehabilitation treatment [14]. Another group of researchers studying a cohort of patients hospitalized with COVID-19 showed that their functional scores improved from 2-6 weeks to 18 weeks of the follow-up [15].

However, in a study of 1,137 French patients hospitalised during the acute phase of COVID-19, a quarter of the patients were described as having three or more persistent symptoms after six months and persistent disability in 29% of patients. [16]. Similar information comes from our Chinese colleagues, reporting data on 20 patients (24%) with persistent symptoms and radiological changes one year after hospital admission [17].

Of the entire range of symptoms of post-acute COVID-19 syndrome, dyspnea is the most common, with its frequency and impact on major life activity categories, and its association with abnormalities in respiratory function [8, 11, 12, 18], being the most detrimental to exercise tolerance and quality of life [12, 19]. The pathogenesis of dyspnea in this condition is complex and may have a pulmonary component due to impaired gas exchange after pneumonia [20], damage to the central nervous system [21], vegetoasthenic and phobic disorders [22], consequences of previous myocarditis [22, 23], and damage to vegetative regulation of breathing and the receptor system [5]. In view of the above, it is practically important to identify the rehabilitation method that reduces the severity of dyspnea to the greatest extent.

There is an active discussion in the professional community about the role and effectiveness of rehabilitation in institutions with different methodologies: 1) Rehabilitation in the patient's residential area; 2) Rehabilitation in a spa environment that enables the use of local natural healing resources; 3) Rehabilitation provided by a national scientific medical centre with state-of-the-art equipment and considerable human resources. Estimating the expected effectiveness of rehabilitation has a great importance for evidence-based management decisions and the rational use of funds allocated for the rehabilitation of patients with post-acute COVID-19 syndrome.

Rehabilitation of patients in regional rehabilitation centers at the place of their residence does not cause additional adaptation stress when the patient moves to another region, is the most accessible and requires less financial investment.

Rehabilitation of patients in climatic and balneological resorts enables the use of the powerful potential of natural healing factors, gives impetus to mechanisms of sanogenesis, but imposes a significant adaptation load on the organism of a patient weakened by a serious illness, arriving for treatment in a contrasting climatic zone.

Treatment at the National Medical Research Centre combines medicinal and non-medicinal methods of treatment, modern physiotherapy and the use of natural healing factors. Highly qualified staff and diagnostic facilities enable a fully multidisciplinary approach to be used, which has proved highly effective [5, 24-27].

To develop healthcare tactics for the treatment of patients with post-acute COVID-19 syndrome, a number of researchers have attempted to use predictive scales and models of the course of post-acute COVID-19 syndrome [28, 29] to create more effective rehabilitation programmes that take into account a multidisciplinary approach to treatment [24, 25]. At the same time, these models did not take into account the experience of rehabilitation of patients in different types of institutions and could not serve as a basis for management decisions, which required the development of a model for estimating the expected effectiveness of rehabilitation depending on the type of institution in order to solve this practical problem.

AIM

To evaluate the expected effectiveness of post-acute COVID-19 syndrome rehabilitation programmes.

MATERIAL AND METHODS

The study was conducted from August, 2021 until March, 2022 and involved 114 people from regional, republican and federal rehabilitation centers: Krasnodar Territory (n=34), the Republic of Buryatia (n=56) and Moscow (n=25).

The data were obtained by a retrospective analysis of medical records and by interviewing the study participants, who had signed an information consent form. All the interviewees were over 18 years of age, had had PCR-confirmed SARS-COV-2 and had an indication or had been treated in a rehabilitation centre for post-acute COVID-19 syndrome (U 09.9)[1] [12, 30]. The study was supported by the Independent Ethics Committee of the Federal State Budgetary Institution National Medical Research Center of Rehabilitation and Balneology of the Ministry of Health of Russia (protocol No. 6 of 26.07.2021). The groups were comparable by sex, age, degree of lung damage and rehabilitation routing scale scores. The average length of time after the onset of the acute period of the disease was 6.5 ± 2.5 months. The survey was conducted retrospectively by the same interviewer. The patient was asked to provide information about the severity of the breathlessness and the health care institution, where the patient had received rehabilitation. The severity of dyspnea was assessed using the Borg scale. A prognostic model was constructed to estimate the expected effectiveness of the rehabilitation programme, as measured by a reduction in the severity of dyspnea. Nonlinear maximum likelihood logit regression was used to build the model [31].

Binary feature: dyspnea/no dyspnea. The rehabilitation programmes carried out at the second stage were used as variables:

1) Regional Rehabilitation Centre (the Republic of Buryatia), where traditional medicine methods were used: acupuncture, Chi Quong breathing, instrumental physiotherapy: magneto- and laser therapy in the lung root projection, exercise therapy [32-34].

2) In the resort (Arkhipo-Osipovka, Krasnodar Territory), where climate therapy, balneotherapy, Nauheim baths, halotherapy, magnetic therapy, inhalation of mineral water, massage, exercise therapy, Terrainkur were used [32].

3) in the National Medical Research Center of Rehabilitation and Balneology of the Ministry of Health of Russia in Moscow, where aqua training in a pool with fresh and mineral sodium chloride water, mud therapy, manual therapy,

[1] WHO/2019-nCoV/Post_COVID-19_condition/Clinical_case_definition/2021.1. Available at: https://apps.who.int/iris/bitstream/handle/10665/345824/WHO-2019-nCoV-Post-COVID-19-condition-Clinical-case-definition-2021.1-rus.pdf (accessed 18.05.2022)

acupuncture, massage, laser therapy, halotherapy, exercise therapy and breathing exercises, psychological correction, medication therapy were used [18, 24, 30, 35, 36].

RESULTS AND DISCUSSION

According to the presented model, the best expected rehabilitation effectiveness was found in the National Medical Research Center (Moscow) (β=-1.788685, p=0.009964604), a slightly lower expected rehabilitation effectiveness was observed in the resort with a curative climate (Arkhipo-Osipovka, Krasnodar Territory) (β=0.9913501, p=0.182944), the lowest expected effectiveness was registered in the regional rehabilitation center (the Republic of Buryatia) (β=1.054594 p=0.2642723) (Table 1).

Table 1. *Logistic regression model coefficients*

Calculated parameter	Constant	Regional rehabilitation center	National Medical Research Center, Moscow	Resort (Krasnodar Territory)
Coefficient β	1,625059	1,05459	-1,78869	0,99135
Standard error	0,586423	0,9397	0,68182	0,73962

Note: *Maximum likelihood estimate (MS-err. scaled to 1) final parameters: Θ=45.894202395; $\chi^2(5)$=20.050; p=,00123*

The Hosmer-Lemeshow test was used to check the consistency of the model with the raw data. For our model, the achieved significance level for this criterion is p>0.05, i.e. there is an agreement between the model and the real data (Table 1, Note).

The calculated area under the ROC curve was 0.84, which corresponds to "very good" quality, according to the AUC scale.

The results of the validation of the model in the "examination" sample were as follows: specificity 54.54%, sensitivity 91.3%, and overall accuracy 84.21%, which indicates the stability of the model (Table. 2).

Table 2. *Estimates of the model*

	Estimated absence of dyspnea	Estimated presence of dyspnea	Quality parameters of the model
Virtual absence of dyspnea	12	10	54,54546
Actual presence of dyspnea	8	84	91,30434

The pathogenesis of dyspnea after COVID-19 is quite complex and may include impaired lungs ventilation, which may be facilitated by destruction of alveoli as a result of pneumonia, impaired regulation of the optimal ventilation-perfusion ratio, damage to the microcirculatory bed of lungs, depletion of respiratory musculature reserve. An equally important role is played by impaired central regulation of breathing, which can be facilitated by disturbances in the centers responsible for the formation of dyspnea at the level of the brain stem and cortex, vagus nuclei, hippocampus, reticular formation, hypothalamus, exhaustion of the respiratory musculature reserve, lesions in the microcirculatory bed of the lungs [24, 35, 37-39].

The polysystemic nature of the lesion means that the treatment methods used must be comprehensive, including medication, hardware physiotherapy, exercise therapy, massage, manual therapy, acupuncture, and breathing exercises [40, 41]. These techniques aim to reduce inflammation in the airways, reflexively activate the respiratory centre and respiratory muscles and reduce the feeling of shortness of breath [38].

The need for a comprehensive approach in the treatment of patients suffering from post-acute COVID-19 syndrome has been expressed by many national and foreign researchers [24, 35, 37-39, 42, 43]. Currently, the protocols of several multicentre European studies are being discussed to find an answer to the question of the effectiveness of the five or the most commonly used rehabilitation treatment strategies [26, 44].

However, based on these studies, it is difficult to predict the effectiveness of these techniques in practical medicine. The model we have built allows us to predict the effectiveness of the rehabilitation techniques, which is essential to improve the efficiency of investment in the rehabilitation of patients suffering from post-acute COVID-19 syndrome in the context of the pandemic.

CONCLUSION

1. The developed model of the expected effectiveness of the rehabilitation of patients with dyspnea after COVID-19 has a specificity of 54.54%, a sensitivity of 91.3% and an overall accuracy of 84.21%, which indicates the stability of the model and allows its use for the planning of rehabilitation care for this category of patients.

2. According to the model developed, the effectiveness of the rehabilitation of dyspnea patients after COVID-19 was demonstrated when using all types of rehabilitation programmes.

3. The best expected rehabilitation effectiveness was found in the National Medical Research Center (Moscow) (β=-1.788685, p=0.009964604), a slightly lower expected rehabilitation effectiveness was observed in the resort with a curative climate (Arkhipo-Osipovka, Krasnodar Territory) (β=0.9913501, p=0.182944), the lowest expected effectiveness was registered in the regional rehabilitation center (the Republic of Buryatia) (β=1.054594 p=0.2642723).

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Author's contribution:
All authors confirm their authorship according to the ICMJE criteria (all authors contributed significantly to the conception, study design and preparation of the article, read and approved the final version before publication).
Special contribution:
Grishechkina I.A., Andronov S.V., Popov A.I., Terentiyeva M.V. – review of publications on the topic of the article, selection and examination of the patients, interpretation of data, statistical processing of data, writing of the text, participation in the approval of the final version of the article;
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