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Metabolic, anthropometric, and functional characteristics of individuals with severe COVID-19 nearly 20 months after recovery: low physical activity and cardiovascular endurance indicators

V.I. Kravchenko¹,
T.F. Zakharchenko¹,
V.G. Gurianov²,
V.A. Kovtun¹,
V.A. Makarenko¹,
O.M. Yakovenko¹,
V.B. Shchupachynskyi³
and M.D. Khalangot^{1,4}

¹State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the National Academy of Medical Sciences of Ukraine»

²Bohomolets National Medical University

³Kyiv Municipal Clinical Hospital №8

⁴Shupyk National Healthcare University of Ukraine

Abstract. Diabetes mellitus (DM) and age are associated with increased severity of viral illness and in-hospital mortality in patients with coronavirus disease 2019 (COVID-19). It has also been suggested that COVID-19 and DM may independently or indirectly affect biological age (BA). **The aim.** To evaluate the metabolic, anthropometric and functional characteristics of patients who have recovered from severe forms of COVID-19 and to develop approaches to assess their BA. **Material and methods.** Persons who suffered a severe form of COVID-19 with radiologically confirmed pneumonia and were hospitalized in the 4th quarter of 2021 in one of the Kyiv municipal hospitals and were discharged, and persons of the control group without a history of hospitalization due to COVID-19. The documents of 164 patients were processed, 136 of them recovered. During 2023, telephone contact was made with 93 individuals, of whom 29, median age 67 (52-73) years, signed informed consent and were examined according to a program that included a glucose tolerance test, anthropometric measurements, body composition, glycated hemoglobin (HbA1c), functional study of cardiovascular and respiratory systems according to spirometry (FEV₁) and 6-minute walking test (6 MWT). Physical activity (PA) was objectively assessed according to the data of a 7-day actigraphy, which included quantitative assessment of metabolic equivalents of task (MET), moderate-intensity PA (MA) and vigorous PA (VA). Combined tooth attachment loss (AL) was assessed using a graduated periodontal probe (PCP2). The time period from the discharge of patients to the examination at

Оригінальні дослідження

the State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the National Academy of Medical Sciences of Ukraine» was 22.0 (21.0-23.0) months, median and Q_1 - Q_3 , respectively. The control group consisted of 10 people, median age 61.5 (53-69) years, who were not treated for COVID-19 in the hospital. **Results.** In 10 (34.5%) of the examined patients, DM was known earlier or diagnosed during the course of COVID-19. According to a medical archive analysis (2021), the diagnosis of DM in hospitalized patients for COVID-19 was associated with elevated levels of procalcitonin, D-dimer, and erythrocyte sedimentation rate. The proportions of newly detected DM (2023) in the COVID-19 group (6 cases, 31.6%) and the control group (1 case, 10%) were not statistically different. The same applies to the category of prediabetes detected by glucose tolerance test. Individuals in the COVID-19 group compared to the control group showed an increase in body mass index (BMI), $p=0.022$, a decrease in 6 MWT ($p=0.007$) and PA: MET ($p=0.015$), MA ($p=0.008$) and VA ($p=0.015$). There was a positive correlation between age and body fat percentage, combined AL, systolic blood pressure (SBP), HbA1c and a negative correlation between age and actigraphic measures and 6 MWT results. **Conclusions:** a study of 29 people with a history of severe COVID-19 found DM in 16 (55.1%) of them. In 34.5% of the studied people DM was diagnosed before or during the COVID-19, which may indicate a more severe course of the disease. However, an increase in newly diagnosed DM almost 2 years after recovery from severe COVID-19 has not yet been found. An increase in potential risk factors for DM (higher BMI, lower PA and functional endurance) was found in this group, comparing to the control. Correlations between age and characteristics of the studied subjects were identified, which can be used to assess BA. **Keywords:** severe COVID-19, survivors, glucose tolerance test, diabetes mellitus, physical activity, 6-minute walking test, spirometry.

In 2022, more than 2 years after the beginning of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic, British DM researchers, reviewing several observational studies on DM and the COVID-19 pandemic, recognized that patients with DM were at increased risk of COVID-19-related hospitalization and mortality. Male gender, older age, obesity, poor glycemic control, impaired renal function, socioeconomic deprivation, and previous stroke or heart failure were associated with increased mortality from COVID-19 in both type 1 and type 2 DM. During the coronavirus pandemic, an increase in DM cases was observed. The British authors indicated the following issue related to DM and COVID-19 pandemic: was the infection of COVID-19 directly related to higher frequency of new DM cases, or was this due to a contribution of indirect factors, such as the long-term changes in the incidence of DM after the pandemic or long-term impact of COVID-19 on diabetic people [1].

According to the results of our observation study, DM was known in 150 of 1,097 hospitalized patients with a severe course of COVID-19 (13.7%), who were treated in the infectious disease hospital of Kostyantynivka (Donetsk Oblast, Ukraine) from 02/12/2020 to 07/01/2022. Mortality among patients with DM was higher: 20.0% vs. 12.4%, respectively ($p=0.014$). Male gender, older age, and fasting plasma glucose (FPG) were independently and positively associated with the risk of death in patients without DM [2]. During 2023, we focused on researching long-term treatment results of patients with COVID-19, who recovered in the 4th quarter of 2021 and were discharged from one

of the municipal hospitals of Kyiv. In particular, it was found that in patients with COVID-19 and DM known at the time of hospitalization, in-hospital mortality was three times higher than in patients without DM (unpublished data). Thus, the presence of DM was associated with a several-fold increase in mortality of hospitalized patients with COVID-19. The issue of newly diagnosed DM in recovered patients and the assessment of risk factors of DM and cardiovascular disease in this group remained unsolved. The influence of age-related factors on the mortality of patients with COVID-19 and the possibility of influencing these factors [3] called for a study at the beginning of the pandemic. Thus, Italian researchers discovered an acceleration of biological age after severe COVID-19 [4]. That is why another task of our research was the development of approaches to the assessment of biological age (BA) in patients with severe COVID-19.

Material and methods

Study design

An observational case-control study was conducted and included the following stages:

1) Studying archived medical documents of all patients with COVID-19 who were hospitalized in one of the departments in Kyiv Municipal Clinical Hospital N 8 in the 4th quarter of 2021;

2) Communicating with patients, who recovered after treatment for COVID-19 and inviting them to State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the National Academy of Medical Sciences of Ukraine» (IEM) for an interview;

3) Information about the study of patients and obtaining written informed consent during the interview, as well as clarifying the status of the patient with regard to known DM and its treatment, determining patient's general condition and suitability for the study.

Patients, who recovered after being treated at the hospital for COVID-19, as well as the members of the control group who agreed to be examined at IEM and signed an informed consent were evaluated. Their results are presented in this study.

Medical documents of 164 patients were analyzed, 136 patients of whom have recovered. Telephone contact was established with 93 patients of them and 29 signed the informed consent and were examined at IEM according to the protocol of this study. It should be noted that remote communication and the participation of patients in our study were hindered by the circumstances of the Russian invasion of Ukraine, due to the displacement of the population from Kyiv and Kyiv Oblast to other regions.

The time period from the discharge of patients to the examination at the IEM was 22.0 (21.0-23.0) months, median and Q_I - Q_{III} , respectively.

Biochemical measurements

Blood sampling was collected on an empty stomach and 2 hours after consuming a glucose solution (75 g of glucose was dissolved in 200 ml of water). Plasma was separated from blood cells no later than 30 minutes after blood sampling using centrifugation. Blood plasma glucose levels were determined with the Microlab-300 analyzer (Vital Scientific, Netherlands) using the glucose-oxidase method and the Liquick Cor-Glucose kit (Cormay, Poland). Assessment of HbA1c was performed with an express analyzer and test cartridges Clover A1c (Infopia OSANG Healthcare Co., Ltd, Korea) using the boronate affinity method. Regarding HbA1c measurement, this study was supported by the National Research Fund of Ukraine grant No. 2021.01/0213.

The categories of normal / impaired fasting glycemia and / or glucose tolerance and DM were determined according to the criteria of the World Health Organization (WHO, 1999), agreed with the International Diabetes Federation (IDF, 2006) [5]. Patients with fasting plasma glucose of 7.0 mmol/L and above or 11.1 mmol/L and above 2 hours after ingestion of 75 g of glucose (2hPG) were considered as DM. The third independent

criterion for DM was HbA1c, equal to or greater than 6.5% [6]. The category of increased DM risk included persons who reached the corresponding levels in any of the three categories of glycemia: FPG – from 5.6 to 6.9 mmol/L, 2hPG – from 7.8 to 11.0 mmol/L, HbA1c – from 5.7 to 6.4% [6].

Anthropometric measurements

Body weight and height were measured using certified electronic scales Seca 890 (Germany) and portable stadiometer Keller (Germany). BMI was calculated as the ratio of body weight in kg to height in meters squared. Body composition was assessed with the bioelectrical impedance method using the BODYSTAT device (<https://www.bodystat.com/>). In our study, indicators of body composition are presented as the percentage of fat in the body (body fat, %).

Determination of lung function

Lung function was determined by spirometry using a SP-10 portable spirograph (Heaco, China), measuring the forced expiratory volume in one second (FEV₁). Disposable mouthpieces were used, and the device was sterilized with a suitable solution Akadent Extra (Detrol Healthcare Kimya Sanayi A.S., Turkey, www.detrox.com.tr).

Assessment of cardiovascular endurance (fitness)

Cardiovascular fitness was determined using the 6 MWT. SBP and diastolic blood pressure (DBP) dynamics, heart rate (HR), respiratory rate, and oxygen saturation (SpO₂) were evaluated using a pulse oximeter, and the distance traveled in meters per 6 minutes.

The American Thoracic Society's Functional Standards Committee has developed guidelines for the use of the 6 MWT, which can be used to assess functional status, as well as in epidemiological studies. The distance covered in 6 minutes accurately predicts morbidity and mortality from cardiovascular diseases. Absolute contraindications are a history of unstable angina pectoris or myocardial infarction within the previous month. Relative contraindications are resting tachycardia (HR more than 120/min) or uncontrolled arterial hypertension. Two large studies involving thousands of elderly subjects undergoing 6 MWTs reported no adverse events [7-10].

Examination of gum health

Gum health was evaluated because the relevant marker is included in modern BA assessment models [11]. The depth of periodontal pockets was measured with a special graduated periodontal

Оригінальні дослідження

probe (PCP2) along the vertical axis of the tooth in three areas (mesiobuccal, buccal, and distal-lingual) from the marginal edge of the gums to the bottom of the periodontal pockets with a pressing force of no more than 0.25 newtons. Measurements were made along the surface in three areas of each tooth, after which their average value in mm was calculated (third molars were not taken into account) [11]. The results of the measurements were interpreted as follows: degree I – up to 4 mm, degree II – from 4.1 to 6.0 mm, degree III – more than 6.0 mm. The combined AL was estimated in millimeters by the distance from the enamel-cementum border to the bottom of the periodontal pockets of the gums, the value of which consisted of the sum of the depth of the periodontal pockets and the recession of the gums of each examined tooth [12-14]. The periodontal status was assessed based on these indicators. The periodontological examination card was filled out based on an objective examination by a dentist (V.A.M.).

Assessment of PA

We applied the description of categories and standards set out in the 2010 WHO recommendations to the levels of PA necessary to maintain health (Global recommendation on PA for health, WHO 2010) [15].

MA: on an absolute scale, moderate intensity defines PA that is performed 3.0-5.9 times more than the resting intensity. According to the scale relative to a person's personal capabilities, PA of average intensity is usually 5 or 6 on a scale from 0 to 10. VA: on an absolute scale, this intensity means PA that is 6.0 or more times the resting intensity for adults and, as a rule, 7.0 or more times for children and young people [16-18]. Aerobic activity, also called endurance, improves heart and respiratory function. MET also belongs to the category of PA and is an objective measure of the ratio of the amount of energy that a person spends during the performance of a certain PA in comparison with the standard, established under the condition of consuming 3.5 ml of oxygen per 1 kg of body weight per minute. This roughly equals to the energy expended while sitting quietly.

Adults aged 18 to 64 years should have at least 150 min of moderate-intensity aerobic PA per week or at least 75 min of VA per week, or an equivalent combination of moderate and VA.

To assess PA, we used accelerometry (actigraphy), which is proposed for epidemiological

studies in adults [15]. We used ActiGraph devices and software (<https://www.actigraphcorp.com/>) obtained under IAEA Technical Assistance Project RER 6034. To create a protocol containing quantitative PA categories such as METs, MA, VA we used the work of Canadian PA researchers in adults [16] and WHO recommendations [15, 17, 18]. In our study, we presented results, obtained from 38 people who agreed to constantly wear the device (accelerometer) for 7 days. Some details regarding the measurement of PA and body composition have been described by us previously [19].

The control group consisted of 10 people without COVID-19 hospital treatment during 2020-2023.

Statistical estimates

The statistical analysis was carried out using the MedCalc® Statistical Software version 22.018 (MedCalc Software Ltd, Ostend, Belgium; <https://www.medcalc.org>; 2024). The Shapiro-Wilk test was used to test the law of distribution of quantitative data. In case of non-normal distribution, median (Me) and interquartile range ($Q_I - Q_{III}$) or arithmetic mean with standard deviation were calculated (for normally distributed data). Comparisons were made using Wilcoxon's W-test or Student's test, accordingly. In all tests, a value of $p < 0.05$ was considered significant. Spearman's rank correlation or Pearson's linear correlation method was used to analyze the relationship between indicators. Calculation of the risk ratio for DM between groups was performed by determining the event risk and confidence intervals, employing Fisher's inverse sine transformation with Yates' correction for continuity.

The study was performed in accordance with the standards of the bioethical committee of IEM (permit dated April 1, 2021, №35/5-KE), of the main provisions of the «Convention on the Protection of Human Rights and Dignity in the Application of Biology and Medicine: Convention on Human Rights and Biomedicine», adopted by the Council of Europe on April 4, 1997 of Good Clinical Practice (GCP) from 1996, the Declaration of Helsinki of the World Medical Association «Ethical Principles of Medical Research with Human Subjects», adopted in June 1964 and revised during 1975-2008 and the Order of the Ministry of Health of Ukraine «On the approval of the Procedure for conducting clinical trials of medicinal products and examination of clinical trial materials and the Standard Regulations on the

Commission on Ethics» dated February 13, 2006 №66 with changes in 2006-2008.

Results and discussion

Anthropometric and clinical data extracted from the medical archive in 2021 for 29 patients who were examined by us in 2023 are presented in **Table 1**. During hospital treatment in 2021, the average levels of FPG and BMI in all COVID-19 inpatients were increased versus the usual normal parameters and even reached the criteria of DM (7.0 mmol/L or higher) and obesity (30 kg/m²), whereas SpO₂ was significantly decreased (90%) versus normal parameters (95% or higher). Average erythrocyte sedimentation rate and C-reactive protein test levels expectedly exceeded the norm (below 20 mm/hr and 5 mg/L respectively).

The patients were divided into 2 categories: patients without DM at the time of hospitalization (n=22) and patients who had this diagnosis (n=7). In addition to the expected difference in FPG levels, the DM subgroup showed higher levels of erythrocyte sedimentation rate, Diastolic BP, procalcitonin, and D-Dimer compared to the «No DM» subgroup. There was also a tendency towards decreasing of the relative number of lymphocytes

in the blood of diabetic patients. Almost a third of patients from this group were treated with mechanical ventilation.

The mean level of FPG in the «No DM» subgroup exceeded the normal level, and the median level of the relative number of lymphocytes in the DM subgroup was below normal: 14 (9-20) %, while the normal range is usually considered to be 18-42% [20]. A decrease in the relative number of lymphocytes was associated with an increased risk of 3-year mortality in people with chronic obstructive pulmonary disease [21].

During 2023, a study of the anthropometric, biochemical and functional indicators of 29 people with a severe form of COVID-19 with radiologically confirmed pneumonia, who were treated and discharged from Kyiv Municipal Clinical Hospital N8 in the 4th quarter of 2021, was conducted (**Table 2.1**). A similar research program was used for the control group: 10 people of a similar age who did not have severe COVID-19 and did not require hospitalization were examined.

Glucose tolerance according to the standard test was evaluated in only 27 subjects because this test was not performed in patients with known DM at the time of examination (n=10). Another

Table 1. Anthropometric and clinical indicators of the studied persons during their hospital treatment for COVID-19 pneumonia in 2021 depending on known DM

Characteristics	All patients (n=29)	No DM (n=22)	DM (n=7)	p (No DM vs. DM)
Age, yrs	61.9 (13.2)	60.6 (13.8)	66.1 (11.1)	0.336
BMI, kg/m ²	30.1 (4.7)	29.5 (4.6)	31.2 (5.1)	0.528
FPG, mmol/L	7.8 (6.0-11.8)	6.8 (5.8-8.6)	13.5 (11.1-22.1)	0.002
ESR, mm/hr	31.4 (13.6)	28.4 (13.6)	40.0 (9.9)	0.050
WBC, G/L	7.12 (2.5)	7.13 (2.5)	7.1 (2.7)	0.980
Lymphocytes, %	19.9 (7.5)	19 (15-27)	14 (9-20)	0.075
SpO ₂ , %	90 (80-94)	90.5 (84-95)	85.5 (75-92)	0.343
Temperature, °C	37.8 (37.2-38.5)	38.04 (1.1)	37.97 (0.8)	0.866
Systolic BP, mm Hg	140 (130-150)	140 (130-150)	145 (140-160)	0.126
Diastolic BP, mm Hg	90 (80-90)	90 (80-90)	95 (90-100)	0.035
Duration of hospital stay, days	13.5 (7.0)	13.3 (6.6)	14.1 (8.6)	0.782
Procalcitonin, ng/ml	0.1 (0-0.12)	0 (0-0.1)	0.14 (0.11-1.52)	0.019
D-Dimer, mg/L	0.518 (0.487)	0.252 (0.262)	1.050 (0.375)	0.007
CRP, mg/L	43.55 (24.20-103.15)	55.08 (41.6)	62.4 (47.6)	0.800
Treatment with mechanical ventilation, n (%)	2 (6.9)	0	2 (28.6)	0.082

Note: Data are medians and interquartile range (Q₁-Q₃) or means and standard deviations (SD) or n and %; SpO₂ – peripheral capillary oxygen saturation; WBC – white blood cells; ESR – erythrocyte sedimentation rate; CRP – C-reactive protein.

Оригінальні дослідження

2 individuals (1 person from the control group and 1 person from the COVID-19 group) refused to take the test at the last moment.

Table 2.1. Studied anthropometric, biochemical and functional indicators of all examined persons.

Characteristics	n	Me	Q _I	Q _{III}
Age, yrs	39	66	52	72
Fat, %	37	38	28.5	42.9
BMI, kg/m ²	39	28.9	25.9	34.6
FPG, mmol/L	39	5.64	5.33	6.71
2hPG, mmol/L	27	6.48	5.49	7.4
HbA1c, %	39	6.2	5.9	6.5
WBC, G/L	39	6.3	5.8	7.9
SBP, mm Hg	38	129.5	118	145
DBP, mm Hg	38	79	70	83
6 MWT, m	37	441	309	504
MET	38	1.18	1.11	1.33
MA, min/week	38	48.35	0	133
VA, min/week	38	0	0	12
AL, mm	37	2.41	2.06	3.05
FEV 1, L	38	2.37	1.82	3.04

Note: Fat, % – percentage of fat in the body; 2hPG – 2 hours after ingestion of 75 g of glucose; WBC – white blood cells.

Glucose tolerance according to the standard test was evaluated in only 27 subjects because this test was not performed in patients with known DM at the time of examination (n=10). Another 2 individuals (1 person from the control group and 1 person from the COVID-19 group) refused to take the test at the last moment.

Correlation analysis of the studied parameters revealed a positive correlation of age with the percentage of fat (Fat, % R=0.472), systolic blood pressure (R=0.514), AL (R=0.476) and a negative correlation with 6 MWT (R=-0.728), MET (R=-0.635), FEV 1 (R=-0.676) (Table 2.2).

According to Kendall's rank criterion a relationship was found between HbA1c and age: Tau=0.225, p=0.04. These data indicate the prospect of successfully creating a model of biological age. An interesting result was the detection of a negative correlation between the percentage of fat and indicators of PA (MET, MA, VA), the function of external respiration (FEV 1). However, the causal relationship remains unknown. 2hPG expectedly demonstrated a positive relationship with HbA1c. Meanwhile an increase in FPG positively correlates not only with HbA1c which indicates the adequacy of measurements, but also with systolic BP. HbA1c is positively correlated with BMI, SBP and negatively with MA.

Table 2.2. Correlation analysis of the studied variables

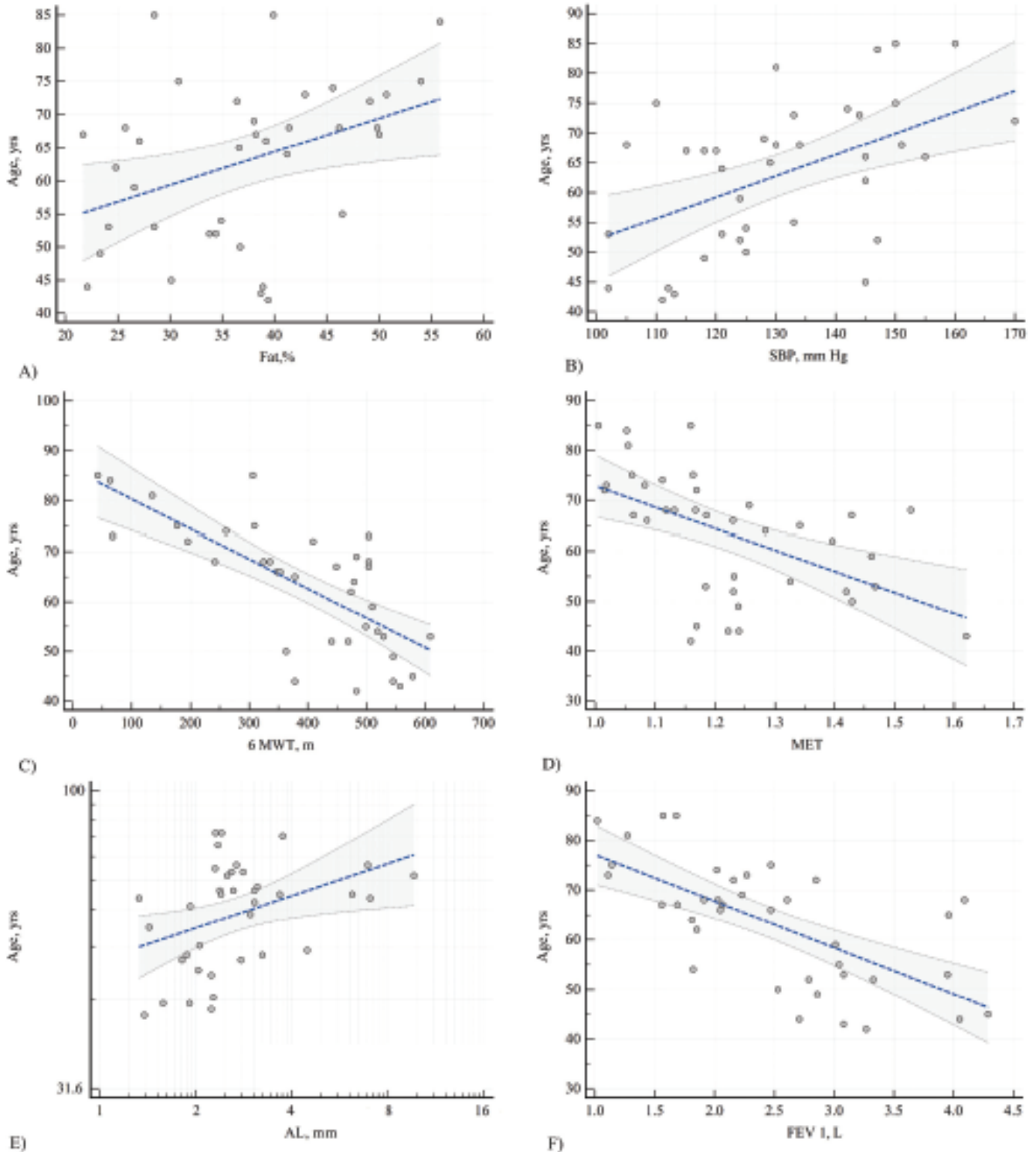
Variables	Age	Fat	BMI	FPG	2hPG	HbA1c	WBC	SBP	DBP	6 MWT	MET	MA	VA	AL	FEV 1
Age	-	0.5	-	-	-	-	-	0.5	-	-0.7	-0.6	-	-	0.5	-0.7
Fat	0.4	-	0.5	-	-	-	-	-	-	-0.6	-0.6	-0.4	-	-	-0.5
BMI	-	0.5	-	-	-	0.3	-	-	-	-0.4	-0.4	-0.4	-	-	-
FPG	-	-	-	-	-	0.8	-	0.3	-	-	-	-	-	-	-
2hPG	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-
HbA1c	-	-	0.3	0.8	0.5	-	-	0.3	-	-	-	-0.4	-	-	-
WBC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SAT	0.5	-	-	0.3	-	0.3	-	-	0.5	-0.5	-0.3	-	-	-	-
DAT	-	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-
6 MWT	-0.7	-0.6	-0.4	-	-	-	-	-0.5	-	-	0.7	0.4	0.4	-	0.7
MET	-0.6	-0.6	-0.4	-	-	-	-	-0.3	-	0.7	-	0.7	0.7	-0.4	0.6
MA	-	-0.4	-0.4	-	-	-0.4	-	-	-	0.4	0.7	-	0.6	-	-
VA	-	-	-	-	-	-	-	-	-	0.4	0.7	0.6	-	-	-
AL	0.4	-	-	-	-	-	-	-	-	-	-0.4	-	-	-	-0.4
FEV1	-0.6	-0.5	-	-	-	-	-	-	-	0.7	0.6	-	-	-0.4	-

Note: the given values of Spearman's rank correlation coefficients are statistically significantly (p<0.05) different from 0. The absence of a numerical value of the coefficients indicates the absence of a corresponding correlation relationship.

A 6 MWT negatively correlates not only with age, but also with indicators of obesity (Fat, %, BMI). SBP positively correlates with indicators of PA (MET, MA, VA) and the function of external respiration (FEV 1). Determining the causality of

this relationship should be the subject of further research.

The detected linear correlation between age and the studied indicators is presented in **Fig. 1**.



Оригінальні дослідження

Fig. 1A. Linear correlation between the percentage of fat (%) and age (years). 95% CI is presented.

Note: $Age=0.5026*Fat\%+44.29$ Sample size: $N=37$. Linear correlation coefficient $R=0.393$, number of degrees of freedom $k=35$. There is a linear correlation relationship, $R>0$ at the significance level $p=0.016$. Coefficient of determination= 0.154.

Fig. 1B. Linear correlation between SBP (mm Hg) and age (years). 95% CI is presented.

Note: $Age=0.3562*SBP+16.49$ Sample size: $N=38$. Linear correlation coefficient $R=0.522$, number of degrees of freedom $k=36$. There is a linear correlation relationship, $R>0$ at the significance level $p<0.001$. Coefficient of determination= 0.273.

Fig. 1C. Linear correlation between 6 MWT (m) and age (years). 95% CI is presented.

Note: $Age=-0.05893*6\ MWT+86.19$ Sample size: $N=37$. Linear correlation coefficient $R=-0.730$, number of degrees of freedom $k=35$. There is a linear correlation relationship, $R<0$ at the significance level $p<0.001$. Coefficient of determination= 0.533.

Fig. 1D. Linear correlation between MET and age (years). 95% CI is presented.

Note: $Age=-42.12*MET+114.9$ Sample size: $N=38$. Linear correlation coefficient $R=-0.532$, number of degrees of freedom $k=36$. There is a linear correlation relationship, $R<0$ at the significance level $p<0.001$. Coefficient of determination= 0.284.

Fig. 1E. Linear correlation between combined AL and age (years) using logarithmic transformation of variables. 95% CI is presented.

Note: The dependence is expressed by the equation $Age = 52*AL^{0.179}$. $\log(y) = 1.716 + 0.179 \log(x)$ $r=0.39$; $p=0.017$.

Fig. 1F. Linear correlation between FEV 1 and age. 95% CI is presented.

Note: $Age=-9.333*FEV\ 1+86.41$ Sample size: $N=38$. Linear correlation coefficient $R=-0.669$, number of degrees of freedom $k=36$. There is a linear correlation relationship, $R<0$ at the significance level $p<0.001$. Coefficient of determination= 0.448.

Study of indicators in control and after severe COVID-19 groups is presented in the **Table 3**. Indicator comparisons between the control and severe COVID-19 groups revealed a statistically significant difference in BMI ($p=0.022$), an indicator of cardiovascular endurance of 6 MWT ($p=0.007$), indicators of PA: MET ($p=0.015$), PA ($p=0.008$), IA ($p=0.015$).

Other compared indicators including those reflecting the presence or absence of DM or recognized categories of its risk did not differ.

The calculation of DM risk ratio in the control groups and after severe COVID-19 is presented in the **Table 4**. Patients with COVID-19 had statistically significant change in the risk ratio in the group of DM ($RR=5.5$, $p=0.027$) and previously

Table3. Indicators in control groups and in group after severe COVID-19

Indicators	Control Group	n	COVID-19	n	p
Age, yrs	61.5 (53-69)	10	67 (52-73)	29	0.469
Fat, %	36.21 (5.13)	10	37.39 (10.66)	29	0.657
BMI, kg/m ²	26.97 (4.16)	10	31.5 (5.44)	29	0.022
FPG, mmol/L	5.45 (5.30-6.05)	10	5.7 (5.47-6.77)	29	0.187
2hPG, mmol/L	6.49 (5.71-6.91)	9	6.43 (5.49-7.40)	18	0.877
HbA1c, %	6.1 (6.0-6.3)	10	6.2 (5.8-6.6)	29	0.584
Leukocytes, G/L	6.15 (5.6-7.2)	10	6.5 (5.9-8.0)	29	0.376
SBP, mm Hg	127 (18.54)	10	133.4 (17.81)	29	0.343
DBP, mm Hg	74.9 (6.04)	10	78.61 (10.26)	29	0.292
6 MWT, m	504 (479-519)	10	353 (242-483)	27	0.007
MET	1.305 (1.184-1.430)	10	1.165 (1.074-1.235)	28	0.015
MA, min / week	128.4 (75.6-155.4)	10	22.15 (0-101.85)	28	0.008
VA, min / week	11.62 (0-31.10)	10	0 (0)	28	0.015
AL, mm	2.55 (2.04-3.24)	10	2.41 (2.06-3.05)	27	0.934
FEV 1, L	2.4 (2.07-3.01)	10	2.31 (1.68-3.15)	28	0.643

Note: these data are medians and interquartile ranges or average values with standard deviation; p is the significance level of the difference between the control group and the COVID-19 group, Comparisons were made using Wilcoxon's W-test or Student's test.

known DM ($RR > 2.9$, $p = 0.044$), which indicates an increase in the proportion of DM (55.1%).

Table 4. Calculation of the risk ratio (RR) of DM in the control groups and after severe COVID-19

Categories of hyperglycemia	Control, n	COVID-19, n	RR	p
DM				
yes	1	16	5.5 (1.0-36.5)	0.027
no	9	13		
Prediabetes				0.568
yes	8	9		
no	1	4		
Known DM			>2.9	0.044
yes	0	10		
no	10	19		
Revealed DM				0.392
yes	1	6		
no	9	13		
IFG				0.968
yes	3	3		
no	6	10		
IGT				0.882
yes	1	0		
no	8	12		
HbA1c, % (5.7-6.4)				0.568
yes	8	9		
no	1	4		

Note: the risk ratio is indicated only if the risk is statistically significant; IFG – impaired fasting glucose, IGT – impaired glucose tolerance

Thus, the group of COVID-19 convalescents did not statistically differ from the control group in terms of the frequency of diagnosing new DM or its risk categories (IFG, IGT, prediabetic HbA1c level).

Among the 29 individuals studied nearly 2 years after suffering from severe COVID-19 and in a control group of 10 people, 10 cases of previously known DM (25.6%) were identified. Furthermore, based on criteria of FPG or 2hPG / HbA1c, 7 cases (17.9%) of newly diagnosed DM and 17 cases (43.6%) of prediabetes were discovered. It is important to highlight the notably high proportion of individuals with «prediabetes» levels of HbA1c in both the control group and among those with a history of severe COVID-19.

The overall number of diagnosed and already known DM in the COVID-19 group was 16 cases (55.1%) whereas the corresponding figure in the control group was 1 newly detected case (10.0%),

($p < 0.027$). Regarding the number of newly diagnosed DM the COVID-19 group (6 cases, 31.6%) and the control group did not statistically differ. The same applied to the category of prediabetes identified through impaired glycemia.

Individuals in the COVID-19 group showed reduced functional characteristic of the cardiovascular but not respiratory systems according to 6 MWT and FEV 1 data respectively.

Quantitative assessment of PA based on actigraphy data revealed a significant reduction in moderate and VA and METs in individuals of the COVID-19 group compared to the control group.

A positive correlation was found between age and Fat (in percentage), Diastolic BP, HbA1c, AL and a negative correlation between age and indicators of PA, 6 MWT.

Among 29 individuals, surveyed in 2023, who were hospitalized in 2021 due to COVID-19 induced pneumonia, a significant portion (55.1%) were patients with DM. In 34.5% of these persons DM was diagnosed before or during COVID-19 which may indicate a connection with the severe course of the disease that required hospitalization. Currently, we have not yet been able to establish a causal relationship between severe COVID-19 and the subsequent development of new DM. At the same time, the detection of reduced PA and cardiovascular and pulmonary endurance in those who have recovered indicates the presence of a significant risk of developing DM and cardiovascular diseases in this group.

In the systematic review of 14 observational studies, Italian researchers showed that the prevalence of DM among people with a previous infection with SARS-CoV-2 is ~16% and reaches 20% if we take into account people who have experienced severe forms of COVID-19. New-onset DM diagnosis ranged from 0.2% to 8.6% and the pooled proportion of new DM after at least 60 days from SARS-CoV-2 infection was 1.6% [22]. In this context, it is difficult to compare our data on DM prevalence / incidence (50% / 31.6% respectively) due to the small size of the group (29 survivors) and the long follow-up period (2 years).

Continued follow-up and re-examination of individuals with the COVID-19 and control groups may provide a more reliable estimate the risk of new-onset DM associated with COVID-19.

The functional (FEV 1, 6 MWT) tests we used to assess cardiovascular and respiratory function

Оригінальні дослідження

which were also used by other researchers of the consequences of COVID-19 within 12 months after the acute illness [23-25]. We consider the low level of 6 MWT, which we found 2 years after discharge from the hospital, to be a new result.

Our quantification of PA after COVID-19 using actigraphy may also be a first, as this method appears to have been previously only used to assess sleep characteristics in the context of the effects of COVID-19 [26].

An increase of potential DM risk factors (higher BMI, lower PA and functional endurance) was revealed in this group, comparing to the control. Correlations were found between the age and characteristics of the subjects (FEV1, AL, HbA1c), which can be used to evaluate BA in the near future.

Conclusions

A study of 29 people with a history of severe form of COVID-19 revealed DM in 16 of them (55.1%). In 34.5% of the studied DM was diagnosed before or during COVID-19, which may indicate a more severe disease course. However, an increase in newly diagnosed DM almost 2 years after recovery from severe COVID-19 has not yet been found. An increase in potential DM risk factors (higher BMI, lower PA and functional endurance) was found in this group compared to controls. Correlations between the age and the characteristics of the studied persons were revealed, which can be used to assess biological age.

References

1. Khunti K, Valabhji J, Misra S. Diabetes and the COVID-19 pandemic. *Diabetologia*. 2023 Feb;66(2):255-66. doi: 10.1007/s00125-022-05833-z.
2. Khalangot M, Sheichenko N, Gurianov V, Zakharchenko T, Kravchenko V, Tronko M. RAAS inhibitors are associated with a better chance of surviving of inpatients with Covid-19 without a diagnosis of diabetes mellitus, compared with similar patients who did not require antihypertensive therapy or were treated with other antihypertensives. *Front Endocrinol (Lausanne)*. 2023 Jan 19;14:1077959. doi: 10.3389/fendo.2023.1077959.
3. Mongelli A, Barbi V, Gottardi Zamperla M, Atlante S, Forleo L, Nesta M, et al. Evidence for biological age acceleration and telomere shortening in COVID-19 survivors. *Int J Mol Sci*. 2021 Jun 7;22(11):6151. doi: 10.3390/ijms22116151.
4. Blagosklonny MV. From causes of aging to death from COVID-19. *Aging (Albany NY)*. 2020 Jun 12;12(11):10004-21. doi: 10.18632/aging.103493.
5. World Health Organization. Definition and diagnosis of diabetes mellitus and intermediate hyperglycaemia: report of a WHO/IDF consultation. 2006. Available from: http://apps.who.int/iris/bitstream/handle/10665/43588/9241594934_eng.pdf?sequence=1 [Cited 20th December 2023].
6. American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care*. 2014 Jan;37 Suppl 1:S81-90. doi: 10.2337/dc14-S081.
7. Enright PL. The six-minute walk test. *Respir Care*. 2003 Aug;48(8):783-5.
8. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med*. 2002 Jul 1;166(1):111-7. doi: 10.1164/ajrccm.166.1.at1102.
9. Roomi J, Johnson MM, Waters K, Yohannes A, Helm A, Connolly MJ. Respiratory rehabilitation, exercise capacity and quality of life in chronic airways disease in old age. *Age Ageing*. 1996 Jan;25(1):12-6. doi: 10.1093/ageing/25.1.12.
10. Enright PL, McBurnie MA, Bittner V, Tracy RP, McNamee R, Arnold A, et al. Cardiovascular Health Study. The 6-min walk test: a quick measure of functional status in elderly adults. *Chest*. 2003 Feb;123(2):387-98. doi: 10.1378/chest.123.2.387.
11. Belsky DW, Caspi A, Houts R, Cohen HJ, Corcoran DL, Danese A, et al. Quantification of biological aging in young adults. *Proceedings of the National Academy of Sciences*. 2015 Jul 28;112(30):E4104-10.
12. Kopchak OV. Evaluation of the clinical effectiveness of a modified technique of injecting PRP-therapy in complex treatment of generalized periodontitis patients with concomitant cardiovascular diseases. *Journal of Education, Health and Sport*. 2017;7(5):868-77. doi: 10.5281/zenodo.1068348. (Ukrainian).
13. Moradi Haghgo J, Torkzaban P, Farhadian M, Moosavi Sedeh SA. Association between the severity of periodontitis, COVID-19, C-reactive protein and interleukin-6 levels in hospitalized patients: a case-control study. *BMC Oral Health*. 2023 Aug 11;23(1):556. doi: 10.1186/s12903-023-03270-x.
14. Botero JE, Yepes FL, Roldán N, Castrillón CA, Hincapie JP, Ochoa SP, et al. Tooth and periodontal clinical attachment loss are associated with hyperglycemia in patients with diabetes. *J Periodontol*. 2012 Oct;83(10):1245-50. doi: 10.1902/jop.2012.110681.
15. World Health Organization. Global strategy on diet, physical activity and health. Resolution WHA55.23. In: Fifty seventh World Health Assembly, Geneva, 17-22 May 2004. Resolutions and decisions, annexes. Geneva: World Health Organization; 2004. Available from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://apps.who.int/gb/ebwha/pdf_files/WHA57/A57_REC1-en.pdf [Cited 20th December 2023].
16. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian adults: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep*. 2011 Mar; 22(1):7-14.
17. The U.S. Department of Health and Human Services. 2008 physical activity guidelines for Americans. Available from: <chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://health.gov/sites/default/files/2019-09/paguide.pdf> [Cited 20th December 2023].
18. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. 2020 Dec;54(24):1451-62. doi: 10.1136/bjsports-2020-102955.
19. Kravchenko VI, Zakharchenko TF, Pisarenko YuM, Kovtun VA, Gonchar IV, Khalangot MD. Anthropometric, biochemical and actigraphic characteristics of a population sample of randomly selected adult rural residents of Ukraine who were not diagnosed with «diabetes mellitus» at the time of the study. *Endokrynologia*. 2021;26(4):34356. doi: 10.31793/16801466.2021.264.343. (Ukrainian).
20. Omman Reebea A, Kini Ameet R. Leukocyte development, kinetics, and functions. In: Keohane Elaine M, Otto Catherine N, Walenga Jeanine N, (eds.). *Rodak's Hematology: Clinical Principles and Applications* (6th ed.). St. Louis, Missouri: Elsevier; 2020. pp. 117-35.
21. Acanfora D, Scicchitano P, Carone M, Acanfora C, Piscosquito G, Maestri R, et al. Relative lymphocyte count as an indicator of

- 3-year mortality in elderly people with severe COPD. *BMC Pulm Med.* 2018 Jul 13;18(1):116. doi: 10.1186/s12890-018-0685-6.
22. Bellia C, Andreoli A, D'Ippolito I, Scola L, Barraco S, Meloni M, et al. Prevalence and risk of new-onset diabetes mellitus after COVID-19: a systematic review and meta-analysis. *Front Endocrinol (Lausanne).* 2023 Sep 4;14:1215879. doi: 10.3389/fendo.2023.1215879.
 23. Eksombatchai D, Wongsinin T, Phongnarudech T, Thammaravanucupt K, Amornputtisathaporn N, Sungkanuparph S. Pulmonary function and six-minute-walk test in patients after recovery from COVID-19: a prospective cohort study. *PLoS One.* 2021 Sep 2;16(9):e0257040. doi: 10.1371/journal.pone.0257040.
 24. Curci C, Pisano F, Bonacci E, Camozzi DM, Ceravolo C, Bergonzi R, et al. Early rehabilitation in post-acute COVID-19 patients: data from an Italian COVID-19 Rehabilitation Unit and proposal of a treatment protocol. *Eur J Phys Rehabil Med.* 2020 Oct;56(5):633-41. doi: 10.23736/S1973-9087.20.06339-X.
 25. André S, Bruyneel AV, Chirumberro A, Roman A, Claus M, Alard S, et al. Health-related quality of life improves in parallel with FEV1 and 6-minute walking distance test at between 3 and 12 months in critical COVID-19 survivors. *Am J Med Open.* 2023;10:100055. doi: 10.1016/j.ajmo.2023.100055.
 26. Ferreira-Souza LF, Julianelli-Peçanha M, Coelho-Oliveira AC, da Silva Bahia CMC, Paineiras-Domingos LL, Reis-Silva A, et al. Impacts of COVID-19 pandemic on sleep quality evaluated by wrist actigraphy: a systematic review. *J Clin Med.* 2023 Feb 2;12(3):1182. doi: 10.3390/jcm12031182.

Abbreviation

- AL** – attachment loss
BMI – body mass index
COVID-19 – coronavirus disease 2019
DBP – diastolic blood pressure
DM – diabetes mellitus
FEV 1 – forced expiratory volume in one second
FPG – fasting plasma glucose
HbA1c – glycated hemoglobin
IEM – State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the National Academy of Medical Sciences of Ukraine»
MA – moderate-intensity physical activity
MET – metabolic equivalent of task
PA – physical activity
SBP – systolic blood pressure
VA – vigorous-intensity physical activity
6 MWT – 6-minute walking test

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Метаболічні, антропометричні та функціональні характеристики осіб із тяжким перебігом COVID-19 майже через 20 місяців після одужання: низька фізична активність і показники серцево-судинної витривалості

В.І. Кравченко¹, Т.Ф. Захарченко¹, В.Г. Гур'янов², В.А. Ковтун¹, В.А. Макаренко¹, О.М. Яковенко¹, В.Б. Щупачинський³ та М.Д. Халангот^{1,4}

¹ДУ «Інститут ендокринології та обміну речовин ім. В.П. Комісаренка НАМН України»

²Національний медичний університет ім. О.О. Богомольця

³КНП «Київська міська клінічна лікарня №98»

⁴Національний університет охорони здоров'я України ім. П.Л. Шупика

Резюме. Цукровий діабет (ЦД) і вік асоціюються зі збільшенням тяжкості вірусних захворювань і внутрішньолікарняною смертністю пацієнтів із COVID-19. Також було припущено, що COVID-19 і ЦД можуть незалежно або опосередковано впливати на біологічний вік (БВ). **Мета.** Оцінити метаболічні, антропометричні та функціональні характеристики пацієнтів, які перенесли важку форму COVID-19, і розробити підходи до оцінки їхнього БВ. **Матеріал і методи.** Особи, які перенесли важку форму COVID-19 із рентгенологічно підтвердженою пневмонією, які перебували на стаціонарному лікуванні в 4 кварталі 2021 року в одній із міських лікарень м. Києва та були виписані, і особи контрольної групи без госпіталізації з приводу COVID-19 в анамнезі. Опрацьовано документи 164 пацієнтів, із них 136 одужали. Протягом 2023 року було здійснено телефонний контакт із 93 особами, з яких 29, медіана віку – 67 (52–73) років, підписали інформовану згоду та були обстежені за програмою, що включала тест на толерантність до глюкози (ГТТ), антропометричні вимірювання, композицію тіла, глікований гемоглобін (HbA1c), функціональні дослідження серцево-судинної та дихальної систем за даними спірометрії (FEV 1) та тесту 6-хвилинної ходьби (6 MWT). Фізичну активність (РА) об'єктивно оцінювали за даними 7-денної актиграфії, яка включала кількісну оцінку метаболічних еквівалентів (MET), РА середньої інтенсивності (МА) та РА високої інтенсивності (ВА). Комбіновану втрату прикріплення (AL) зубів оцінювали за допомогою градуйованого пародонтального зонда. Період часу від виписки хворих до обстеження в ДУ «Інститут ендокринології та обміну речовин ім. В.П. Комісаренка НАМН України» становив 22,0 (21,0–23,0) місяці, медіана та Q₁–Q₃ відповідно. Контрольну групу становили 10 осіб, медіана віку – 61,5 року (53–69 рр.), які не лікувались від COVID-19 у стаціонарі. **Результати.** У 10 (34,5%) обстежених пацієнтів ЦД був відомий раніше або діагностований під час перебігу COVID-19. Згідно з аналізом медичного архіву (2021), діагноз ЦД у госпіталізованих пацієнтів із приводу COVID-19 був пов'язаний із підвищеним рівнем прокальцитоніну (PCT), D-димеру та швидкості осідання еритроцитів (ШОЕ). Частки вперше виявленого ЦД (2023) у групі COVID-19 (6 випадків, 31,6%) та групі контролю (1 випадок, 10%) статистично не відрізнялися. Те ж саме стосується категорії предіабету, виявленого за ГТТ. Особи з групи COVID-19 порівняно з контрольною показали збільшення індексу маси тіла (ІМТ), $p=0,022$, зниження показників 6 MWT ($p=0,007$) і РА: MET ($p=0,015$), МА ($p=0,008$) та ВА ($p=0,015$). Спостерігався позитивний кореляційний зв'язок між віком та відсотком жиру в тілі, комбінованою AL, систолічним артеріальним

Оригінальні дослідження

тиском (САТ), НbА1с та негативний кореляційний зв'язок між віком та актиграфічними показниками та результатами 6 MWT. **Висновки:** дослідження 29 осіб з анамнезом важкої форми COVID-19 виявило ЦД у 16 із них (55,1%). У 34,5% досліджуваних ЦД був діагностований до або під час COVID-19, що може свідчити про тяжчий перебіг хвороби. Однак, збільшення вперше діагностованого ЦД майже через 2 роки після одужання від важкої форми COVID-19 поки що не виявлено. У цій групі виявлено збільшення потенційних факторів ризику ЦД (вищій ІМТ, нижчі фізична активність та функціональна витривалість) порівняно з контролем. Виявлено кореляційні зв'язки між віком і характеристиками досліджуваних осіб, які можна використовувати для оцінки ББ.

Ключові слова: тяжкий перебіг COVID-19; ті, що вижили; тест толерантності до глюкози; цукровий діабет; фізична активність; 6-хвилинний тест ходьби; спірометрія.

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Correspondence address: Zakharchenko Tamara Fedorivna, zata@ukr.net, State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the NAMS of Ukraine», Vyshgorodska Str., 69, Kyiv 04114, Ukraine.

Information about the authors: Kravchenko Viktor Ivanovych, Dr. Sci. (Medicine), Prof., Head of Department of Epidemiology of Endocrine Diseases, State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the NAMS of Ukraine», ORCID: 0000-0003-0867-2023; Zakharchenko Tamara Fedorivna, Cand. Sci. (Biology), Senior Research Fellow, Senior Researcher of Department of Epidemiology of Endocrine Diseases, State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the NAMS of Ukraine», ORCID: 0000-0002-4394-8833; Gurianov Vitaliy Hryhorovych, Cand. Sci. (Physics and Mathematics), Docent of the Department of Health Care Management, Bohomolets National Medical University, ORCID: 0000-0001-8509-6301; Kovtun Volodymyr Anatoliyovych, Leading Software Engineer of Department of Epidemiology of Endocrine Diseases, State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the NAMS of Ukraine», ORCID: 0000-0003-4140-5744; Makarenko Viktoriya Andriivna, Dentist of the Polyclinic Department, State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the NAMS of Ukraine», ORCID: 0000-0001-6632-9106; Yakovenko Oleksandr Mykhailovych, Head of the Day Hospital of the Polyclinic Department, State Institution «V.P. Komisarenko Institute of Endocrinology and Metabolism of the NAMS of Ukraine», ORCID: 0009-0007-5999-0968; Shchupachynskiy Volodymyr Bohdanovych, Head of the Department of Intensive Care and Resuscitation, Kyiv Municipal Clinical Hospital №8, ORCID: 0009-0009-5951-4085; Khalangot Mykola Dmytrovych, Dr. Sci. (Medicine), Prof., Professor of Department of Endocrinology, Shupyk National Healthcare University of Ukraine, ORCID: 0000-0002-4632-5447.

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Адреса для листування: Захарченко Тамара Федорівна, e-mail: zata@ukr.net, ДУ «Інститут ендокринології та обміну речовин ім. В.П. Комісаренка НАМН України», вул. Вишгородська, 69, Київ 04114, Україна.

Відомості про авторів: Кравченко Віктор Іванович, д-р мед. наук, проф., завідувач відділу епідеміології та обміну речовин ім. В.П. Комісаренка НАМН України, ORCID: 0000-0003-0867-2023; Захарченко Тамара Федорівна, канд. біол. наук, старш. наук. співроб., старша наукова співробітниця відділу епідеміології ендокринних захворювань ДУ «Інститут ендокринології та обміну речовин ім. В.П. Комісаренка НАМН України», ORCID: 0000-0002-4394-8833; Гур'янов Віталій Григорович, канд. фіз.-мат. наук, доцент кафедри менеджменту охорони здоров'я Національного медичного університету ім. О.О. Богомольця, ORCID: 0000-0001-8509-6301; Ковтун Володимир Анатолійович, провідний інженер-програміст відділу епідеміології ендокринних захворювань ДУ «Інститут ендокринології та обміну речовин ім. В.П. Комісаренка НАМН України», ORCID: 0000-0003-4140-5744; Макаренко Вікторія Андріївна, лікарка стоматолог поліклінічного відділення ДУ «Інститут ендокринології та обміну речовин ім. В.П. Комісаренка НАМН України», ORCID: 0000-0001-6632-9106; Яковенко Олександр Михайлович, завідувач денного стаціонару поліклінічного відділення ДУ «Інститут ендокринології та обміну речовин ім. В.П. Комісаренка НАМН України», ORCID: 0009-0007-5999-0968; Щупачинський Володимир Богданович, завідувач відділення інтенсивної терапії та реанімації КНП «Київська міська клінічна лікарня №8», ORCID: 0009-0009-5951-4085; Халангот Микола Дмитрович, д-р мед. наук, проф., професор кафедри ендокринології Національного університету охорони здоров'я України ім. П.Л. Шупика, ORCID: 0000-0002-4632-5447.

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