Influence of Endured Coronavirus Infection on Bioelectric Activity of the Brain in Students

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Abstract: In the paper, differences in the spectral power (SP) of EEG rhythms of the main frequency ranges (alpha, beta) in two groups of students, before and after the tests for attention are assessed. The first group consisted of students, who did not have a coronavirus infection in their anamnesis (control), the second group consisted of students recovered from a coronavirus infection no more than 3 months ago. EEG was recorded with NVX 36 digital DC EEG system according to the international scheme 10-20. The subjects were tested for attentiveness. After passing the tests, the results were above the minimum indicating the strain of the attention process. The registration time was 1 minute. It was found that students who underwent coronavirus infection, compared with the control group, showed a statistically significant change in the SP of the alpha and beta rhythms in several leads. In particular, there was an increase in the SP of the alpha rhythm in the frontal lead Fz and the central lead C3. When comparing beta1 rhythm, an increase in SP in the frontal lead Fz was also noted. Analysis of the beta 2 rhythm showed a decrease in the SP of the rhythm in students with coronavirus infection in the occipital O2 lead. The results show the effects of coronavirus infection on the bioelectrical activity of the brain in students. Despite the fact, that all the students at the time of the study were recovered, there is still a difference between those who did not get sick and those who had recovered. This indicates the effect of the coronavirus on the activity of the human brain.

1 INTRODUCTION

At present, it is generally accepted that sustainable or harmonious development includes a whole range of concepts, but most of it is aimed primarily at ensuring the quality of life of people, which is impossible without high-quality health care (Bobylev, Girusov, Flight, 2004).

Recently, the health and well-being of people has been declining due to the new coronavirus infection, which, of course, leads to an imbalance in one of the most important goals of sustainable development, such as the health and well-being of the world's population.

At the end of 2019, an outbreak of a new coronavirus infection occurred in the People's Republic of China, in the city of Wuhan. On February 11, 2020, the World Health Organization offered the official name for the infection caused by the new coronavirus – COVID-19 ("Coronavirus disease 2019"). In turn, the international committee on the taxonomy of viruses on February 11, 2020 assigned the official name to the causative agent of the infection – SARS-CoV-2 (Conradi, Nedoshivin, 2020).

Emergence of COVID-19 has challenged healthcare professionals to quickly diagnose it and provide medical care to patients. Currently, an intensive study of the clinical and epidemiological characteristics of the disease continues, as well as the development of new means of its prevention and treatment. The most common clinical manifestation of a new variant of coronavirus infection is bilateral pneumonia. Some patients develop hypercoagulable syndrome with thromboembolism and thrombosis, and other organs and systems are also affected, and large vessels may be damaged even in young people (Klok, Kruip, VanderMeer, Arbous, Gommers, Kant,

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Kaptein, vanPaassen, Stals, Huisman, 2020), (Oxley, Mocco, Majidi, Kellner, Shoirah, Singh, De Leacy, Shigematsu, Ladner, Yaeger, 2020). However, damage to the lungs, kidneys, liver, or chronic heart failure are not the only complications caused by the coronavirus. Quite often, even several months after recovery, patients experience cognitive impairments: a decrease in mental performance, memory, and other intellectual functions. It was found that neurological consequences after COVID-19 can also be long-term (Heneka, M.T., Golenbock, D., Latz, E., Morgan, D., Brown R.., 2020).

It was revealed that SARS-Cov-2 affects the brain and nervous system in a completely different way than other viruses. Researchers examined samples of cerebrospinal fluid from patients with COVID-19 who had cognitive impairment and mental problems and found a marked increase in inflammatory markers that indicate activation of immune cells in the brain. However, at the same time, scientists did not find characteristic markers for viral damage to the central nervous system (Egbert, A.R., Cankurtaran, S., Karpiak, S., 2020). Many researchers also note that the mechanism of damage to the nervous system in coronavirus differs from the effects of other pathogens (Mao, L., Jin, H., Wang, M., Hu, Y., Chen, S., He, Q., Chang, J., Hong, C., Zhou, Y., Wang, D., et al., 2020). Thus, the pathogenetic mechanisms of the effect of SARS-CoV-2 on the central nervous system require detailed study (Baig, A.M., 2020).

The aim of this paper was to study the effect of the previous coronavirus infection on the bioelectrical activity of the brain in students during tests for attention.

2 METHODS

This paper was performed on 20 students aged 20 to 25 years. Ten students did not have a coronavirus infection in their anamnesis (group 1), the other 10 had recovered from a coronavirus infection (group 2) and were examined three months after recovery. Group 1 included 4 males and 6 females, group 2 consisted of 5 males and 5 females. Students were included in the study on the basis of informed voluntary and confirmed written consent. All stages of the experiment were carried out in accordance with the rules of bioethics used in studies of physiological functions in humans. The subjects were subjected to electroencephalographic examination. The electroencephalogram was recorded using NVX 36 digital DCEEG system. Lead electrodes were placed on the subjects' heads in accordance with the international scheme "10–20" in the following standard leads: Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, Oz, O2. A combined ear electrode (A1, A2) was used as a reference. Each student's EEG was recorded twice: in the initial state and after the tests for attention. In the process of EEG registration, the subjects sat in a chair in a dark room with their eyes closed. After a five-minute period of adaptation to the experimental setting, a background EEG was recorded from the subjects for 1 minute. Re-registration of the EEG was also carried out within 1 minute after performing the tests for attention. Changes in the spectral power (μV^2) of the EEG rhythms within the main frequency ranges were analyzed on the EEG: alpha (8-13 Hz), beta (13-35 Hz), theta (4-8 Hz).

As the first test for attention, we used the Bourdon-Anfimov proofreading test (crossing out the specified letters in the form). This test took 5 minutes to complete. As the next, the Landolt ring test was used for 5 minutes. The final stage of testing was the execution of the attention test from the KornFerry company (Judge, T. A., Heller, D., Mount, M. K., 2002). In accordance with the testing conditions, it was required to check all the presented pairs of numbers within 2 minutes and identify coinciding ones. After passing the tests, all subjects had results higher than the minimum level indicating the tension of attention.

Since sample data distribution differed from normal ($P < 0.05$: Shapiro-Wilk test for normality), the Mann-Whitney rank sum test was used to assess statistically significant differences in the spectral power of EEG rhythms between students who had recovered from coronavirus infection and the control group of students. The Wilcoxon signed rank test was used to assess the differences before and after testing for attention. Differences were considered statistically significant at $P < 0.05$.

3 RESULTS

It was found that students who had recovered from coronavirus infection showed changes in the EEG, which were expressed in a change in the spectral power of the alpha rhythm in some leads. In the initial state (before the performance of attention tests), the median power of the alpha rhythm in the median frontal lead Fz in students, who had coronavirus infection in their anamnesis, was significantly higher than that in students of the control group by 7.30 μV^2 ($P = 0.037$: Mann-Whitney rank sum test). After passing the tests for attention, an equally directed tendency to decrease in the spectral power of the alpha rhythm in lead Fz was observed in students of both groups, however, a statistically significant effect of testing on the value of this parameter was found only in students who had undergone coronavirus infection (decrease in the median by 7.15 μV^2; P = 0.039: Wilcoxon signed rank test), while in intact students the change did not reach the level of statistical significance (decrease in the median by 0.70 μV^2; P = 0.203: Wilcoxon signed rank test). After testing, no difference was found between the power of alpha rhythm in the Fz lead in intact students and students recovered from coronavirus infection (P = 0.185: Mann-Whitney rank sum test), though the median of this parameter was higher in those who had recovered by 0.85 μV^2. Statistical data on the values of the spectral power of the alpha rhythm in the median frontal lead Fz in the subjects of both groups before and after testing are shown in Fig. 1.

Statistically significant differences in the spectral power of the alpha rhythm in students who had undergone coronavirus infection compared with intact students were also detected in the central lead C3. In this lead, the median of the power of the alpha rhythm in students who had recovered from coronavirus infection turned out to be significantly higher than in intact students both before (by 15.05 μV^2; P = 0.007: Mann-Whitney rank sum test) and after testing for attention (by 6.60 μV^2; P = 0.017: Mann-Whitney rank sum test). Testing did not significantly affect the spectral power of the alpha rhythm in lead C3 of intact students (P = 0.129: Wilcoxon signed rank test), in whom the median of this parameter increased by 0.40 μV^2 after testing. In students who had recovered from the coronavirus infection, the spectral power of the alpha rhythm in lead C3 after testing for attention decreased comparing to the initial level by 8.85 μV^2 (P = 0.027: Wilcoxon signed rank test). Statistical data on the values of the spectral power of the alpha rhythm in the central lead C3 in the subjects of both groups before and after testing are demonstrated in Fig. 2.

We also carried out a comparative analysis of the spectral power of EEG beta rhythms (β1 and β2 rhythms) in intact students and students who had recovered from coronavirus infection before and after performing attention tests.

Statistical analysis revealed differences in the spectral power of beta rhythms in several leads.

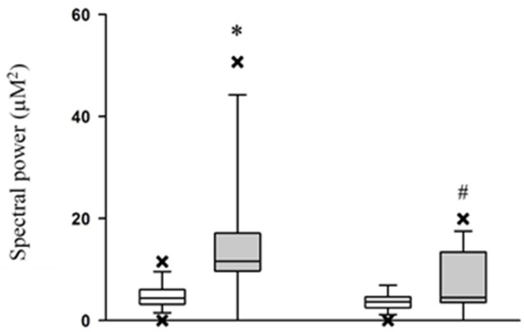

Figure 1: The difference in the spectral power (μV^2) of the alpha rhythm in the median frontal lead Fz in intact subjects (white boxes) and students who had endured a coronavirus infection (gray boxes) before the test (left boxes) and after the test (right boxes) for attention. An asterisk marks a statistically significant difference between the two groups of subjects before testing (* P <0.05: Mann-Whitney rank sum test). The # symbol indicates a statistically significant difference between the state before and after testing for attention in students with endured coronavirus infection (# P <0.05: Wilcoxon signed rank test).

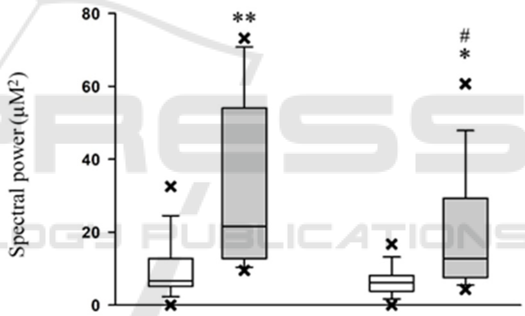

Figure 2: The difference in the spectral power (μV2) of the alpha rhythm in the central lead C3 in intact subjects (white boxes) and students who had endured a coronavirus infection (gray boxes) before the test (left boxes) and after the test (right boxes) for attention. Asterisks denote statistically significant differences between the two groups of subjects (* P <0.05; ** P <0.01: Mann-Whitney rank sum test). The # symbol denotes a statistically significant difference between the state before and after testing for attention in students with endured coronavirus infection (# P <0.05: Wilcoxon rank test).

Before testing for attention, the median power of the β1 rhythm in the median frontal lead Fz was higher in the group of students with coronavirus infection by 6.05 μV^2 than in intact students (P = 0.011: Mann-Whitney rank sum test). However, after testing, the spectral power of the β1 rhythm in this lead in students who had undergone coronavirus infection no longer had a statistically significant difference from that in intact students (P = 0.103: Mann-Whitney rank sum test), although the median of this parameter in intact students at that moment was lower than that of those who had recovered by 2.30 μV². As a result of testing, a weak tendency towards a decrease in the spectral power of the β1 rhythm in the Fz lead in intact students (by 0.50 μV²; P = 0.383: Wilcoxon signed rank test) was found, while in the group of subjects who had recovered from coronavirus infection, the tendency of this parameter to the reduction was more pronounced (by 4.25 μV²), although the change also did not reach the level of statistical significance (P = 0.055: Wilcoxon signed rank test). Statistical data on the values of the β1 rhythm spectral power in the median frontal lead Fz in the subjects of both groups before and after testing for attention are shown in Fig. 3. Statistically significant differences in the spectral power of the β1 rhythm in intact students and those had endured a coronavirus infection were also found in the central lead C3. The power of the β1 rhythm in persons who had undergone coronavirus infection turned out to be higher than in intact subjects both before and after testing.

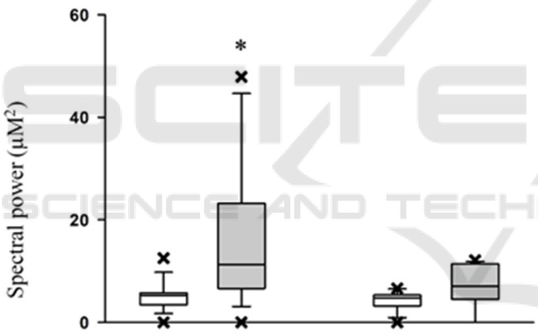

Figure 3: The difference in the spectral power (μV²) of the β1 rhythm in the median frontal lead Fz in intact students (white boxes) and students who had endured a coronavirus infection (gray boxes) before the test (left boxes) and after the test (right boxes) for attention. An asterisk marks a statistically significant difference between the two groups of subjects before testing (* P <0.05: Mann-Whitney rank sum test).

Before testing, the spectral power of the β1 rhythm in this lead in students with endured coronavirus infection, exceeded that in intact subjects by 10.05 μV² (P = 0.013: Mann-Whitney rank sum test); after testing, the value of this parameter in the group of recovered patients also turned out to be higher than in intact students by 6.00 μV² (P = 0.005: Mann-Whitney rank sum test). Testing for attention did not have a statistically significant effect on the spectral power of the β1 rhythm neither in intact students, nor in students who had undergone coronavirus infection. Wherein, both those and others showed a tendency towards a decrease in the spectral power of the β1 rhythm in lead C3, respectively, by 1.45 μV² (P = 0.055: Wilcoxon signed rank test) and 7.40 μV² (P = 0.164: Wilcoxon signed rank test). Statistical data on the values of the spectral power of the β1 rhythm in the central lead C3 in the subjects of both groups before and after testing for attention are shown in Fig. 4.

Under these experimental conditions, no statistically significant differences were found in the spectral power of the β2 rhythm of students who were intact and who had endured a coronavirus infection in the median frontal lead Fz before and after testing for attention. In the initial state (before testing), the median power of this rhythm in students who had endured a coronavirus infection exceeded that in intact students (by 0.9 μV²), however, the difference was not statistically significant (P = 0.344: Mann-Whitney rank sum test). Similarly, there was no difference in the spectral power of the β2 rhythm between the two groups of subjects after testing (P = 0.265: Mann-Whitney rank sum test), when the value of the median power of the β2 rhythm in students who had undergone coronavirus infection turned out to be by 0.65 μV² higher than that of intact students. As a result of testing, the median β2-rhythm power tended to decrease both in intact students (by 0.25 μV²) and in students who had undergone coronavirus infection (by 0.50 μV²), however, these changes were not statistically significant (P = 0.250 and P = 0.156, respectively: Wilcoxon rank sum test).

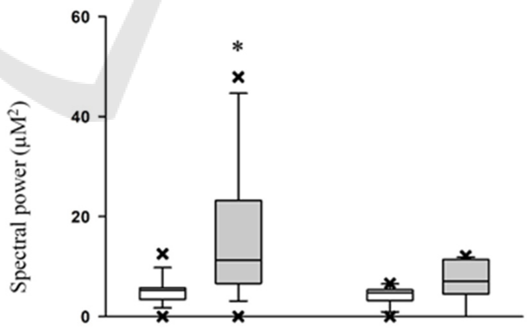

Figure 4: The difference in the spectral power (μV²) of the β1 rhythm in the central lead C3 in intact students (white boxes) and students who had endured a coronavirus infection (gray boxes) before the test (left boxes) and after the test (right boxes) for attention. Asterisks mark statistically significant differences between the two groups of subjects before testing (*P <0.05: Mann-Whitney rank test) and after testing (** P <0.01: Mann-Whitney rank sum test).

In the central lead C3, there was also not statistically significant difference in the spectral power of the β2 rhythm in intact students and students who had endured a coronavirus before and after testing for attention. In students recovered from coronavirus, the median β2 rhythm power before testing was higher by 6.00 μV^2 than in intact students, but this difference was not statistically significant ($P = 0.081$: Mann-Whitney rank sum test). After testing, there was also no statistically significant difference between the spectral power of the β2 rhythm in subjects who were intact and who had endured a coronavirus ($P = 0.054$: Mann-Whitney rank sum test), although in the latter group, the median of this parameter was higher by 2.95 μV^2. Testing had no effect on the power of the β2 rhythm in lead C3 neither in intact students ($P = 0.275$: Wilcoxon signed rank test), nor in those who had endured a coronavirus infection ($P = 0.203$: Wilcoxon signed rank test), despite the trend towards a reduction in the value of this parameter in subjects of both groups (by 0.80 μV^2 and 3.85 μV^2, respectively).

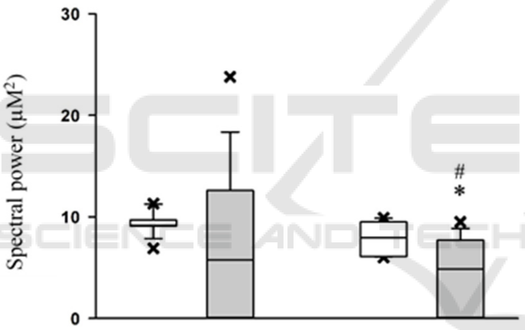

Figure 5: The difference in the spectral power (μV^2) of the β2 rhythm in the occipital O2 lead in intact students (white boxes) and students who had endured a coronavirus infection (gray boxes) before the test (left boxes) and after the test (right boxes) for attention. An asterisk denotes a statistically significant difference between the two groups of subjects after testing for attention (* $P < 0.05$: Mann-Whitney rank sum test). The # symbol denotes a statistically significant difference between the state before and after testing for attention in students who had endured a coronavirus infection (# $P < 0.05$: Wilcoxon signed rank test).

The only EEG lead, in which statistically significant differences between the groups of subjects in the spectral power of the β2 rhythm were found was the occipital O2 lead. In this lead, the median power of the β2 rhythm in persons who underwent coronavirus infection was lower by 3.10 μV^2 than that of intact subjects after testing ($P = 0.014$: Mann-Whitney rank sum test). The value of this parameter before testing was also lower in students who had recovered from coronavirus infection by 3.40 μV^2, however, at that moment, the differences between the groups of subjects were not statistically significant ($P = 0.161$: Mann-Whitney rank sum test). Testing for attention had no effect on the spectral power of the β2 rhythm in the O2 lead in intact subjects ($P = 0.131$: Wilcoxon signed rank test), despite the trend towards a decrease in the median of this parameter (by 1.2 μV^2). Wherein, as a result of testing, the median spectral power of the β2 rhythm decreased by 0.90 μV^2 in subjects who had undergone coronavirus infection ($P = 0.031$: Wilcoxon signed rank test). Statistical data on the values of the spectral power of the β2 rhythm in the occipital O2 lead in the subjects of both groups before and after testing for attention are presented in Fig. 5.

Typical examples of the EEG of a student who had endured a coronavirus infection before and after testing for attention are shown in Fig. 6.

4 DISCUSSION

During SARS-CoV-2 infection, mental disorders and symptoms of stress disorders are recorded in almost 70 % of people, which leads to a decrease in the quality of life and disrupts work productivity (Shepeleva, I. I., Chernysheva, A. A., Kiryanova, E.M., Salnikova, L.I., Gurin O. I. , 2020).

In this paper, we investigated the spectral power of EEG rhythms before and after performing tests for attention in intact students and students who had suffered from coronavirus infection COVID-19 three months ago. Three months after recovery, at least a half of the patients retain neurological symptoms such as dizziness, headache, and impaired consciousness (Li, X., Geng, M., Peng, Y. et al., 2020; 16. Niazkar, H.R., Zibaee, B., Nasim,i Q., Bahri, N., 2020). In our opinion, it is necessary to investigate the long-term effect of SARS-CoV-2 infection on the central nervous system, especially on structures that are easily attacked by the virus.

Use of the EEG technique is a traditional method for studying the biopotentials of the brain, while it is well known that for various levels of wakefulness, the predominance of EEG signals of a certain frequency with pronounced activity in the alpha range is characteristic (Corsi-Cabrera, M., Guevara, M.A., Del Rio-Portilla, Y., Arce, C., Villanueva-Hernandez, Y., 2000). Analysis of the main EEG rhythm, alpha activity is one of the approaches to an objective assessment of the disorganization of the functional state of the cortical mosaic in the central nervous system (Ivanov, L. B., 2005), (Livanov, M.N., 1984). The alpha rhythm is recorded mainly in the occipital regions with closed eyes in a state of calm wakefulness and is blocked by light stimulation, concentration, and mental stress (Kostandov, Э. A., Cheremushkin, E. F., 2012). According to modern concepts, the generation of the alpha rhythm is associated with the reverberation of impulse activity along the intercortical and thalamocortical neural networks, and its severity reflects the synchronization of the activity of various brain systems, namely, the connection of information received from the afferent system of the body with the mechanisms of working memory. The EEG alpha range traditionally attracts increased attention of researchers due to its high sensitivity to various external influences and subtle

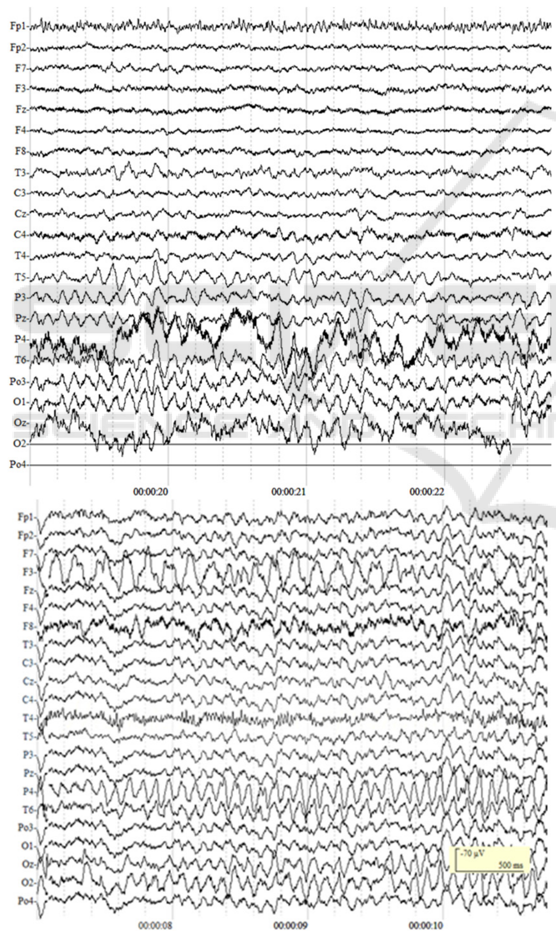

Figure 6: EEG of a student who had endured a coronavirus infection before (above) and after (below) passing tests for attention.

changes in the functional state of the cerebral cortex accompanying sensory, motor, cognitive and mental processes (Basar, E., Schurmann, M., Karakas, S., 1997), (Itil, T.M., Le Bars, P., Eralp, E., 1994).

In the present study, we found that students who had recovered from COVID-19 had an increase in the spectral power of the alpha rhythm both before and after passing the tests, compared to a group of intact students. As for the influence of tests on attention on the spectral power of the alpha rhythm, we can note the similar tendency in the two groups. After passing the tests, the spectral power of the alpha rhythm decreased. This effect is quite natural, since the EEG alpha rhythm is characteristic of the state of calm wakefulness and disappears with increased attention or mental activity (Ivanov, L. B., 2005), (Livanov, M.N., 1984).

According to the results of the study, beta rhythms (β1; β2) varied ambiguously in the subjects. In those who had endured a coronavirus infection, the spectral power of the β1 rhythm was higher than in those who did not have it, in the central (C) and frontal (F) leads. This fact may indicate that the previous coronavirus infection can desynchronize the activity of cortical neurons, in turn, increasing the level of cortical excitation. In the dynamics of the β1 rhythm in two groups, a tendency towards a decrease in the spectral power of waves after the solution of the tests prevailed, which may indicate an increased level of brain activation (Livanov, M.N., 1984). These data are confirmed by a decrease in the spectral power of the β2 rhythm in occipital leads in subjects who had endured the infection comparing to the control group, as well as a decrease in this parameter as a result of testing.

5 CONCLUSION

1. In the present study we found that the endured coronavirus infection has a direct effect on the alpha and beta rhythms of the EEG of students.

2. It was found that the spectral power of the alpha rhythm in students who have recovered from coronavirus infection is higher than in intact students. A statistically significant increase in the spectral power of the alpha rhythm was found in the frontal lead Fz and central lead C3.

3. When studying the spectral power of the beta 1 rhythm in students who had endured a coronavirus infection, there was a statistically significant increase in the frontal lead Fz compared to the group of intact students. Analysis of the beta 2 rhythm showed a decrease in the spectral power of the rhythm in students recovered from coronavirus infection in the O2 lead.

4. The results of the study indicate the influence of previous coronavirus infection on the bioelectrical activity of the brain in students passing tests for attention. Despite the fact that all the students were healthy at the time of the study, the difference in EEG rhythms between intact and recovered subjects still exists. This indicates the impact of COVID-19 on the human brain, even in a delayed period after the infection.

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