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Functional Features of Adolescent Students Who Underwent COVID-19

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Abstract

The study was conducted based on the Moscow State Pedagogical University with the involvement of 126 students aged 17 to 21 years. Of these, 101 students suffered a coronavirus infection (experimental group). The control group consisted of 25 people who did not have COVID-19. The study included a questionnaire on the scale of asthenic condition, measurement of lung capacity, calculation of the Skibinsky index, determination of breath holding time, assessment of exercise tolerance, and cardiac rhythmography. Statistical data processing was carried out using the Microsoft Excel, STATISTICA 10 software package. Differences in the occurrence of deviations in the subjective and objective status of recovered and not ill students were noted. Most of the surveyed, who had asthenia, suffered from COVID-19 (85%). The recovered patients showed a significant decrease in the vital capacity of the lungs, and the presence of more pronounced shortness of breath in the six-minute walk test compared to the control group. According to the majority of the conducted tests, it was noted that the disease left fewer consequences for students who previously regularly went in for sports. To prevent the development and weakening of the manifestations of the post-COVID syndrome, all students should be strongly advised to increase the level of regular physical activity in any sport.

Keywords: Students, Adolescence, Post-COVID syndrome, Physical activity, Sports, Functional status

Introduction

The causative agents of infectious diseases are constant companions of mankind (Ceravolo *et al*., 2020). Throughout its history, society has not been able to eliminate infectious diseases (Shah *et al*., 2021). At the same time, to the infections known in the 20th century, a "new" one has now been added, the causative agent of which is the SARS-CoV-2 coronavirus. More than 600 million cases of infection with the COVID-19 virus have already been recorded in the world, more than 21.5 million of them in Russia (Mishununa *et al*., 2021; Remizova *et al*., 2021). Studies of the consequences of coronavirus infection indicate the danger of this disease associated with the development of the so-called "long covid" or post-covid syndrome (Carod-Artal, 2021; Shalabodina & Nalobina, 2022). It becomes clear that this infection can have a serious scale and lead to negative consequences for the body, which sharply raises the question of the rehabilitation of those who have been ill (Zavalishina, 2020).

As the statistics on recovered patients show, the prevalence of symptoms after suffering from COVID-19 depends on the severity of the disease (Karpov *et al*., 2020). There is increasing evidence that people with a mild course of coronavirus infection often complain of the appearance of various dysfunctions when they go to work or study, and more than half of those who have recovered have a decrease in exercise tolerance (Karpov *et al*., 2021b). It is already known that the course of a new coronavirus infection consumes not only the pulmonary system but also the cardiovascular, nervous, and musculoskeletal systems of the body (Hsieh *et al*., 2018). Many of the most common symptoms of the post-COVID syndrome (fatigue, shortness of breath, anxiety, depression, arthralgia, cough, myalgia) (Bassetti, 2020) can be corrected by non-pharmacological means, the leading place among which is occupied by adequately selected dosed physical activity (Shalabodina & Stradze, 2020; Gusakova & Tkachenko, 2021).

However, studies of the post-COVID state do not provide a holistic picture of the nature of symptoms and their prevalence (Bahramy *et al*., 2021; Baig *et al*., 2021). Due to the incomparability and fragmentation of samples, different periods of observation, and other factors, it is difficult to build a unified picture of the situation and plan recovery measures for people who have had a coronavirus infection, taking into account the current functional status, age and sex characteristics, duration and nature of the disease (Rahman *et al*., 2021). For this reason, this study was designed and carried out.

The purpose of the study: is to find out the features of the functional state of students who have undergone COVID-19, taking into account their level of physical activity.

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Materials and Methods

The study was carried out based on the Moscow City Pedagogical University. The study involved 126 students of this university 1-3 courses aged 17 to 21 years. All of them attended elective physical education classes according to the approved curriculum. Of those observed, 101 students had a new coronavirus infection (experimental group). They included 52 girls and 49 boys. The control group consisted of 25 1st-3rd year students of the Moscow City Pedagogical University who had never had COVID-19 (15 girls and 10 boys). To assess the influence of gender factors, physical activity, and the duration of the disease on the functional capabilities of the body, the experimental group was further divided into subgroups:

1. Girls/boys;
2. Physical activity less than 1 time per week / 2-3 times a week/athletes (go in for sports more than 3 times a week;
3. Those who have been ill for less than 6 months / those who have been ill in the period from 6 months to 1 year / those who have been ill more than a year ago from the time of the study.

The program for examining the functional state of the body of students who underwent COVID-19 consisted of subjective and objective parts. A subjective assessment of well-being was carried out using a questionnaire on the asthenic state scale (ASS) by L.D. Malkova and adapted by T.G. Chertova based on MMRI (Rogov, 2011).

An objective assessment of the functional capabilities of the respiratory system was carried out based on the measurement of VC, the calculation of the Skibinskaya index, and a breath-hold test. Exercise tolerance was assessed using a clinical six-minute walk test (Kurzanov, 2016; Chernozemov *et al.*, 2017). Additionally, the state of the adaptive reserves of the body of the study participants was assessed using the Varicard apparatus, not earlier than 40-60 minutes after eating, in a calm atmosphere at a constant temperature of 24-26°C. A background recording of the cardiorhythmogram was carried out in a state of relative rest for 5 minutes, which indicated the initial vegetative tone. The analysis of heart rate variability (HRV) indicators was carried out according to the method of R.M. Baevsky (Baevsky & Ivanov, 2007).

Statistical packages Microsoft Excel, and STATISTICA 10 were used for statistical processing. Correlation analysis was carried out to study the relationship between indicators. The following classification of the correlation strength was used depending on the value of the correlation coefficient: $R \leq 0.25$ — weak correlation, $0.25<R<0.75$ — moderate (medium) correlation, and $R \geq 0.75$ — strong correlation.

Results and Discussion

It was found that among the students who underwent diagnostics for SAS, 65 people scored from 30 to 50 points, which indicated that they did not have asthenia. Among them, 49 students were ill with coronavirus infection (48.5%). At the same time, 48 students scored from 51 to 75 points, which showed the presence of mild asthenia. Of these, 39 people had COVID-19 (38.5%). Of the observed 13 people scored from 76 to 100 points, which could be interpreted as the presence of moderate asthenia. Of these, all suffered coronavirus (13%). At the same time, not a single student scored more than 101 points, which indicates the absence of severe asthenia in them.

To assess the effect of physical exercises on the course of the recovery period after the illness, a comparison was made of the state of health after suffering COVID-19 in groups with different amounts of physical activity. Among those who do not regularly engage in physical culture and sports (67 people), 29 people did not feel a difference in their condition. At the same time, 20 people noted a short deterioration with a quick return of their condition to normal, and 19 people indicated significant prolonged deterioration in their condition. In the group of athletes (training more than 3 times a week - 34 people), the number of people who did not notice changes was 14, 15 people noted minor changes, and 4 had significant changes in their condition (Alharbi *et al*., 2022; Al-Khotani *et al*., 2022; Fernandes *et al*., 2022; Mubayrik *et al*., 2022; Wu *et al*., 2022).

Figure 1 shows that the largest percentage of people who did not have signs of increased fatigue after an illness wasin the group with an increased regimen of physical activity (more than 3 times a week). The opposite position was taken by students who do not regularly exercise. They most often had mild and moderate asthenia.

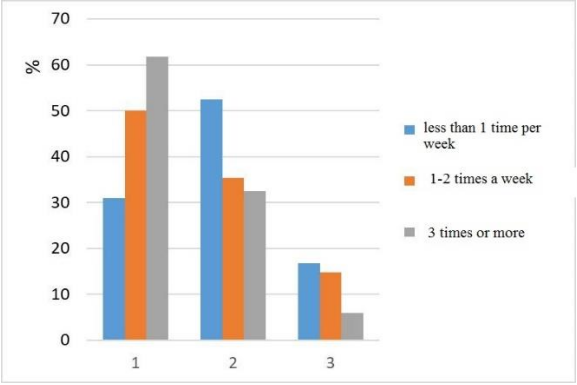

Figure 1. The severity of asthenic syndrome (%) in students who recovered from coronavirus infection, depending on the regularity of playing sports

Note: 1 - there are no signs of asthenia; 2 - asthenization is weakly expressed; 3 - moderately pronounced asthenization.

The study of objective physiological parameters of the respiratory system showed that in girls, the average lung capacity was lower than in boys. At the same time, the vital capacity of the lungs of girls in the experimental group, on average, is below the age norm. The value of the vital capacity of the lungs of girls in the control group was approaching the lower limit of the norm. When assessing the vital capacity of the lungs, it was observed to decrease in patients by 14.1%. A more pronounced decrease in lung capacity was noted in girls who do not regularly engage in sports (16%), compared with athletes who have recovered from illness (8.6%) **(Table 1)**.

Given the large scatter of data, the indicators of the respiratory system of the experimental group were evaluated in subgroups depending on the timing of the infection. It turned out that a significant decrease in lung capacity by 28.9% was observed in girls who had been ill in the period from 6 months to one year ($p<0.05$). The values of the breath-holding time and the value of the Skibinskaya index tended to be higher among female athletes.

Table 1. The state of the respiratory system of the examined girls, M±m

Indicators	Experimental group						Control group
	groupaverage	sports women	notathletes	Haveyoubeenill			
				<6 months	from 6 monthsto 1 year	>1 year	
n	52	13	39	19	15	18	15
Vital capacity of the lungs, ml	2450.0±627.0	2607.0±779.0	2397.0±570.0	2684.0±697.0	2026.0±440.0*	2556.0±526.0	2851.0±810.0
Breath holding, s	59.7±20.0	71.4±29.0	55.7±14.4	63.5±26.8	58.8±16.4	56.3±13.3	59.2±19.3
Skibinskaya index, c.u.	24.25±16.8	30.2±21.3	22.8±14.9	28.2±20.4	21.02±14.4	22.8±14.5	22.1±9.1

Note: * - difference with the results of the control group is significant at $p<0.05$;

The indicators of the vital capacity of the lungs of young men fit into the age-sex norms, approaching its lower limit **(Table 2)**. Boys who recovered from coronavirus infection, unlike girls, did not show a significant decrease in lung capacity compared to those who had not been ill. This can be explained by the higher initial indicators of the functional capabilities of their respiratory system. At the same time, the indicators of the vital capacity of the lungs of young men who were ill in the period from six months to one year ago are lower than those who were ill less than six months ago.

Table 2. The state of the respiratory system of the examined young men, M ± m

Indicators	Experimentalgroup						Control group
	group average	sports women	notathletes	Haveyoubeenill			
				<6 months	from 6 monthsto 1 year	>1 year	
n	49	26	23	20	21	8	10
Vital capacity of the lungs, ml	3894.0±790.0	3750.0±722.0	4040.0±840.0	3995.0±737.0	3814.0±884.0	3850.0±719.0	3792.0±566.0
Breath holding, s	76.7±27.0	75.7±25.9	77.9±28.8	77.1±30.0	79.9±26.4	67.5±21.6	76.5±15.3
Skibinskaya index, c.u.	40.92±18.5	37.9±16.0	44.4±20.8	42.5±20.8	40.6±17.2	38.0±17.6	39.05±10.7

Conducting a six-minute walk test showed that the standard load is tolerated by students quite easily **(Table 3)**. According to the subjective assessment of the study participants, the test was performed with virtually no shortness of breath. The surveyed had only isolated cases of shortness of breath for 2 or 3 points. The average dyspnea in the group of those who were not ill was 0.16 points, and in the group of those who had been ill, it was 0.33 points, which is 106.3% higher. A significant difference ($p<0.05$) was found between the severity of dyspnea in those who were ill and not involved in sports and the control group.

Table 3. Results of the test with a six-minute walk in the examined, M ± m

Indicators	Experimentalgroup						Control group
	groupaverage	sports women	notathletes	Haveyoubeenill			
				<6 months	from 6 monthsto 1 year	>1 year	
n	101	39	62	39	36	26	25
Distance, m	564.8±74.8	561.9±63.7	566.7±81.5	574.1±81.5	550.1±66.7	570.6±75.0	559.2±65.4
Dyspnea according to Borg, points	0.33±0.68	0.04±0.13**	0.5±0.8*	0.31±0.77	0.29±0.48	0.38±0.79	0.16±0.37
Load tolerance, c.u.	9.4±2.3	8.1±2.0	10.2±2.1*	9.1±2.2	9.4±2.3	9.9±2.5	7.8±1.9

Note: * - difference with the results of the control group is significant at $p<0.05$;

** - The difference in the results between those involved in sports and those who did not go in for sports was significant at $p<0.05$.

When assessing the adaptive resources of the study participants using the method of cardiointervalography **(Table 4)**, it was found that the index of regulatory systems tension in the control group tended to exceed the values in the experimental group. The integral indicator of the state of the regulatory mechanisms of cardiac activity corresponded to the state of the norm or satisfactory adaptation. In the control and experimental groups, this figure was on average higher for boys than for girls.

Table 4. Integral characteristics of heart rate variability in the examined boys and girls, M ± m

Indicators	Experimental group						Control group
	group average	sports women	notathletes	Haveyoubeenill			
				<6 months	from 6 monthsto 1 year	>1 year	
				girls			
n	52	13	39	19	15	18	6
Stress index (norm 70-150), c.u.	110.4±55.9	96.9±36.9	115.3±61.1	100.78±39.7	126.97±63.5	109.28±52.7	128.6±50.7
Indicator of activity of regulatory systems (norm 1-3), points	3.18±1.10	3.0±0.70	3.25±1.20	2.74±0.90	3.87±1.25	3.11±0.76	2.93±1.20
				young men			
n	49	26	23	20	21	8	10
Stress index (norm 70-150), c.u.	110.96±62.5	98.19±47.0	125.4±74.8	113.0±81.3	104.9±46.6	121.6±49.2	132.9±36.2
Indicator of activity of regulatory systems (norm 1-3), points	3.76±1.30	3.73±1.20	3.78±1.50	4.1±1.25	3.43±1.43	3.75±1.28	3.6±0.52

Note: * - difference with the results of the control group is significant at $p<0.05$;
** - The difference in the results between those involved in sports and those who did not go in for sports was significant at $p<0.05$.

Symptoms that are usually identified with post-COVID syndrome, including shortness of breath and asthenia, occur in adolescents not only those who have had COVID-19 infection (Ladds *et al*., 2020). They can also occur in non-ill students. The situation is complicated by difficulties in finding a correlation between the manifestation of symptoms and the timing of the illness. It was noted that in the first month after COVID-19, there were no signs of asthenia in more than half of those observed (52%). There is reason to believe that the symptoms of asthenia are most pronounced during the first three months after the infection while maintaining increased fatigue for quite a long time. Of particular concern was the tendency found in the work to increase the manifestation of general asthenia in a significant part of students (46%) with the preservation of its signs for more than one year after the illness.

An assessment of the relationship between well-being after suffering COVID-19 and the level of physical activity showed that most often (in 27.5% of cases), a pronounced deterioration in well-being was observed in those who had been ill and did not regularly engage in physical culture (1-2 times a week). At the same time, the worsening of well-being (12%) was most rarely observed in professional athletes. This pattern confirmed our assumption that people who go in for sports regularly are less prone to asthenia as part of the post-COVID syndrome. Moreover, with an increase in the frequency of classes throughout the week, this symptom weakens or does not occur at all. Thus, regular muscle loads before the disease reduce the risk of developing asthenic syndrome during recovery from coronavirus infection.

The results of this study allow us to resolve the issue regarding the consideration of conceptual and methodological approaches in the field of physical culture and sports. For all students of the Moscow State Pedagogical University of 1-3 courses, the curriculum and study schedule provides practical classes in selected options for physical culture and sports, which are held once a week. This is not enough to affect the manifestations of the post-COVID syndrome, to have a pronounced general health-improving effect, and to increase the functionality of the students' respiratory system. Thanks to the study, it became clear that it is very difficult to restore the health of students who have had COVID-19 only in elective physical education and sports classes, even if students attend them regularly. Therefore, it seems important that these classes be held more often and not only provide physical training but also have an educational element on the issues of maintaining health and improving its level, forming a desire among students to engage in physical culture and sports for a long time.

Evaluation of the functional capabilities of the respiratory system of students by taking into account the value of the vital capacity of the lungs, the value of the Skibinskaya index, and the hypoxic test made it possible to establish a tendency for these indicators to worsen in the girls who had been ill (Zavalishina *et al*., 2022). This was consistent with the literature data on a decrease in the functionality of the respiratory system after a COVID infection (Polastri *et al*., 2018). Significant intergroup differences in girls revealed in terms of lung capacity were most pronounced in the period from 6 months to a year after the disease. In the same period, the girls also registered the lowest values of the Skibinskaya index. The development of a deterioration in health and a decrease in the working capacity of female students who have had COVID-19 for six months after the disease isassociated primarily with a weakening of the respiratory system and, to a lesser extent, with changes in the cardiovascular system (Zavalishina *et al*., 2021a).

There were no significant intergroup differences in young men. However, attention is drawn to a tendency, similar to girls, to a decrease in the value of the vital capacity of the lungs in the period from 6 months to a year after the disease. Probably, the reduction in their lung volume indicators contributes to the activation of compensatory mechanisms that lead to an increase in the resistance of the respiratory center to hypoxia and provide an increase in the time of holding breath in young men 6-12 months after suffering COVID-19. Thus, the indicators of hypoxic tests in young men who had been ill in the period less than six months before our study are higher than in those who had been ill more than one year ago by 12.5%. The same feature was observed in girls (the difference was 11.3%).

Thus, a tendency to the development of an increase in the severity of the consequences of the disease six months after recovery was found. This fact can be explained by the different tolerance of SARS-CoV-2 strains that persist among students during different periods of the pandemic. It is known that the variant of the virus mutation that has dominated in recent months, omicron, is more easily tolerated and has fewer complications.

Comparison of the functional capabilities of the cardio-respiratory system in groups with different levels of physical activity showed that female athletes who underwent COVID-19 have higher resistance of the respiratory center to hypoxia and higher reserve capabilities compared to female students in the control group. According to all monitored indicators in the group of athletes, the results were better than those of people who do not regularly engage in physical culture and sports.

In young men, the benefits of regular physical culture and sports were revealed only by the Skibinskaya index when compared with those who did not have COVID-19 and did not go in for physical culture.

Likely, the differences in the functional capabilities of the cardiorespiratory system in boys and girls who have had a coronavirus infection are associated with gender morphological features, which were manifested in the value of lung capacity. In addition, the consequences of the disease on the respiratory system in young men were less noticeable, while for girls, the presence of systematic physical activity played a large role in the presence of post-COVID syndrome and the severity of its manifestations (Zavalishina *et al*., 2021b).

When conducting a test with a six-minute walk, there were no functional disorders in the cardiovascular system in all the subjects. However, the subjective sensations of exercise tolerance significantly differed between those who recovered from the disease and those who did not go in for sports and in the control group. There was also a difference in the distance traveled. It turned out to be minimal in the group of those who had been ill and those who did not go in for physical culture. When comparing the distance traveled among the observed students, the greatest result was shown by those who had the disease less than 6 months ago, and the smallest was observed in those who had the disease from 6 months to a year ago.

All students who recovered from COVID-19 felt shortness of breath when walking, although the distance they walked without it was slightly longer than in the control group. The strongest feeling of shortness of breath was in the group of students who had the disease more than 1 year ago. Athletes who recovered from illness subjectively endured the load easier than those who did not go in for sports. The found significant intergroup differences in subjective feelings of shortness of breath between recovering athletes and non-athletes testified to the powerful health-improving possibilities of regular physical activity. Undoubtedly, they ensure the development of pronounced adaptive changes in the bodyand reduce the subjective threshold of physical and psychological stress. Because shortness of breath is a purely subjective phenomenon, it cannot be defined in terms used in assessing the physical performance or aerobic capacity of the body (Mikhaylova *et al*., 2021). The standard six-minute walk test cannot be considered a completely reliable test for assessing exercise tolerance in adolescents, including those who have had a new coronavirus infection.

Evaluation of heart rate variability in the study groups allowed us to determine the severity of the adaptive response of the body based on the parameters of autonomic balance and neurohumoral regulation under the action of an infectious factor on the body. The most informative indicators reflecting nonspecific reactions of the body to the action of various factors were the index of tension of regulatory systems and the indicator of the activity of regulatory systems. We considered an increase in the stress index as evidence of a decrease in the body's functional reserves with an increase in the tension of regulatory systems. A low degree of tension betweenregulatory systems and normal indicators of the functioning of the body wasconsidered by us as a manifestation of the physiological norm (Karpov *et al*., 2021a).

The results of the cardiorhythmogram of the observed students confirmed the higher adaptive capabilities of the body in athletes. So the index of tension of the regulatory systems was the lowest (less than 100 c.u.) in the groups of boys and girls who regularly performed physical exercises. This indicated that they had a satisfactory adaptation to changing environmental conditions and sufficiently high functional capabilities of their organism. According to the degree of tension in the regulatory systems of students who had a coronavirus infection, there were gender differences. The maximum tension of regulatory systems occurred in young men (121.6±49.2 c.u.) who had diseases more than a year ago and in girls (126.97±63.52 c.u.) in the period from 6 months to 1- year after an illness. At the same time, the girls showed a clear relationship with the functional capabilities of the body. They revealed the lowest values of the Skibinskaya index and lung capacity. There was no clear intersystem dependence of indicators in young men. Their vital capacity was maximally reduced in the period from 6 to 12 months after the disease, and breath holding was impaired for more than a year after the disease.

The indicator of the activity of regulatory systems in the studied groups of students did not differ significantly and was in the range of 3-4 c.u. This corresponded to a state of moderate tension of regulatory systems when the body needs activation of existing functional reserves for successful adaptation to environmental

conditions. This was due to the loads observed by students associated with their participation in the educational process. At the same time, the athletes had a combination of physical and mental stress, however, the indicator of the activity of regulatory systems in people who regularly exercise was lower than in the group of non-athletes. In this regard, it can be argued that regular physical education and sports do not interfere with the educational process and contribute to a significant increase in the body's adaptive capabilities in relation to any adverse environmental factors (Shalabodina & Stradze, 2020).

This fragment of the study showed less severity of the consequences of COVID-19 in students who regularly go in for sports, which indicated the need to revise the mode of physical activity in all students in the direction of its increase, regardless of the duration of the coronavirus infection.

Conclusion

Post-covid syndrome in students is manifested in 52.8% of cases by increased fatigue, ranging from mild to moderate severity; in 46.5% of cases there is shortness of breath of mild and moderate severity; insomnia is present in 37.8% of cases; in 32.5% of cases - some cognitive impairment. For students who underwent COVID-19, it turned out to be characterized by a decrease in the functionality of the respiratory system and tolerance to a standard load. The relationship between the development of asthenic syndrome in students who had the disease more than six months ago and who did not regularly experience physical activity was traced. It is becoming clear that traditional exercise tolerance tests need to be improved for use in screening studies of young COVID-19 survivors with varying attitudes towards exercise and sports. In addition, existing student physical education programs need to be reviewed for people who have had a new coronavirus infection.

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