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Assessment of aerobic capacity in young women after the COVID-19 pandemic, a pilot study

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ABSTRACT

Introduction: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection causes multi-organ damage, including in the respiratory and circulatory systems, the basic systems associated with aerobic capacity. Many researchers describe long-term persistent changes in many people who have had a viral infection. This study aimed to investigate the effects of coronavirus disease 2019 (COVID-19) pandemic on the level of physical fitness in female students.

Materials and methods: Women (n = 72; 21–23 years old) were divided into 3 groups of 24. The first group was studied in 2015, the second in 2018, and the third in 2022. In the third group, the subjects were infected with SARS-CoV-2. The maximal oxygen consumption (VO_{2max}) parameter was evaluated in the subjects. The Astrand test was used for the assessment. Results were statistically analyzed.

Results: The differences between the mean VO_{2max} were statistically significant ($p \leq 0.001$). The mean VO_{2max} from 2022 was significantly lower than in 2015 and 2018.

Conclusions: Infection with SARS-CoV-2 can cause long-term impairment of physiological functions of the body, which may be associated with a decrease in aerobic capacity.

Keywords: SARS-CoV-2; health; VO_{2max}; aerobic capacity; pandemic.

INTRODUCTION

The first cases of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection were identified in December 2019, and a global pandemic was officially declared by the World Health Organization (WHO) on March 11, 2020 [1]. The consequences of the coronavirus disease 2019 (COVID-19) pandemic were many deaths, mental disorders, and a drastic reduction in human-to-human contact [2]. In a review of recent new scientific research, the SARS-CoV-2 can cause pathology in various systems and organs of the human body [3, 4, 5, 6, 7, 8, 9].

Aerobic capacity is one of the characteristics of physical fitness that is most often cited as the most important in maintaining good physical performance and good health. Aerobic endurance is related to the ability to exercise for long periods of time at low or moderate intensity. This activity mainly involves transformations in the aerobic transformation zone below the anaerobic threshold. One of the most important parameters for assessing this type of fitness is the maximum oxygen consumption (VO_{2max}). One of the possibilities to evaluate this parameter is indirect evaluation based on the Astrand test [10].

While most SARS-CoV-2 infected patients recovered very quickly, the potential long-term problems caused by the infection make it imperative to look for and study late complications caused by SARS-CoV-2 [11]. Therefore, the aim the present study is to assess the the aerobic capacity of a specific group of female students before and after the pandemic. Previous studies by many authors indicate long-term changes in systems in the human body and it can be assumed that these changes may contribute to a decrease in aerobic capacity.

MATERIALS AND METHODS

Participants

The research was conducted at the Karkonosze University of Applied Sciences in Jelenia Góra, Poland. The study was conducted in 3 groups of 24 people each. One group was tested in 2015 and the second group was tested in 2018 before the SARS-CoV-2 pandemic. The third group was tested in 2022 after the pandemic. In the 2022 study, subjects also reported having been infected with SARS-CoV-2.

Seventy-two female students were studied.

Inclusion criteria:

1. no sports training,
2. oxygen activity 2–3 times a week, for 1–2 h,
3. female sex,
4. age between 21–23,
5. no current injuries,
6. written consent to participate in the study,
7. no smoking habit,
8. in the study conducted in 2022, the subjects additionally declared having been infected by SARS-CoV-2.

Exclusion criteria:

1. sedentary lifestyle,
2. competitive sports training,
3. age below 21 and above 23,
4. male sex,
5. an injury preventing participation in the research,

6. poor health or feeling unwell,
7. lack of consent to participate in the study.

Ethics

Before the study, voluntary consent was obtained from the student. Tests taken as part of the didactic program on the physiology of physical effort were accepted. The test was adapted to the physical abilities of the student.

Methods

The study was based on the Astrand test. It is a few minutes of work on the Monark 828 E stationary bike with an individually selected load to achieve dynamic balance in the heart rate range of 130–150 beats per minute. Heart rate was monitored with the Polar RS800. After obtaining the steady-state value, the VO_{2max} value was found in the corresponding tabular intervals. Efficiency was determined using the Astrand fitness classification table [10].

Statistical analysis

Descriptive statistics were used. The mean, standard deviation (SD), and median (Me) were calculated. The nature of the distributions of the VO_{2max} parameter in each year was examined for conformity to the model normal distribution (normality of distribution). The Shapiro–Wilk test was used for analysis. In all cases, the distributions deviated significantly from the model distribution (skewed distributions). Therefore, the non-parametric equivalent of the one-way analysis of variance – the Kruskal–Wallis rank ANOVA – was used to examine the significance of the difference between the mean VO_{2max} values in each year. All calculations were performed using Statistica version 13.3 (TIBCO Inc., USA). A level of p-value ≤0.05 was adopted in the assessment of statistical significance.

RESULTS

The effect of the COVID-19 pandemic on exercise capacity was evaluated in this study. Basic statistics of VO_{2max} were calculated in 3 study groups. The first group was examined in 2015, the second in 2018, the third in 2022. Maximum oxygen consumption was determined in milliliters per minute per kilogram of body weight (mL/min/kg) – Table 1.

Maximum oxygen consumption in all 3 groups was tested for conformity to the model normal distribution. The Shapiro–Wilk test was used for analysis. In all cases, the distributions deviated significantly from the model distribution. These are skewed distributions (Tab. 2).

TABLE 2. The Shapiro–Wilk test to analyze compliance with the model normal distribution in 3 test groups

Year	Shapiro–Wilk W	p
2015	0.88296	0.00954
2018	0.89072	0.01375
2022	0.73273	0.00003

To investigate the significance of the difference between mean VO_{2max} values in individual years, the non-parametric equivalent of univariate analysis of variance – ANOVA rank Kruskal–Wallis, was used (Tab. 3 and 4).

TABLE 3. Assessment of the significance of the difference between mean VO_{2max} values in individual years: 2015, 2018, and 2022

Year	2015	2018	2022	Global
≤Me: observed	7.0	6.0	24.0	37.0
Expected	12.3	12.3	12.3	
Observed – expected	-5.3	-6.3	11.7	
>Me: observed	17.0	18.0	0.0	35.0
Expected	11.7	11.7	11.7	
Observed – expected	5.3	6.3	-11.7	
Global observed	24.0	24.0	24.0	72.0

χ^2 = 34.13745; df = 2; p = 0.0000; Me – median

TABLE 4. Kruskal-Wallis ranked ANOVA

Year	n	Global
2015	24	1150.5
2018	24	1144.5
2022	24	333.0

Kruskal–Wallis test: H (2, n = 72) = 42.18411; p = 0.0000

The differences between the mean VO_{2max} are statistically significant (p ≤ 0.001). The average value of the VO_{2max} parameter from 2022 is significantly lower than in 2015 and 2018. The average values of the parameter in 2015 and 2018 do not differ significantly (Fig. 1).

DISCUSSION

Despite the resolution of typical symptoms, infection with SARS-CoV-2 can leave a lasting mark on many people in the form of damage and dysfunction of certain systems and organs [11,

TABLE 1. Basic statistics of the 3 studied groups

Year	n	Me	Min.	Max.	SD	Variance	Skewness	Kurtosis
2015	24	47.4	41.1	54.9	4.7	21.9	0.3	-1.3
2018	24	46.2	41.1	54.9	5.2	26.6	-0.3	-0.9
2022	24	37.3	23.0	41.8	2.1	22.0	-2.1	4.9

Me – median; SD – standard deviation

12, 13]. Based on reports by other authors, 2696 people with documented SARS-CoV-2 infection were examined 3 months after the onset of symptoms. The analyzed group was in the age range of 18–55 years. In this group, 62.3% of the subjects had disorders referred to as post-COVID syndrome, including disorders of the nervous system [14].

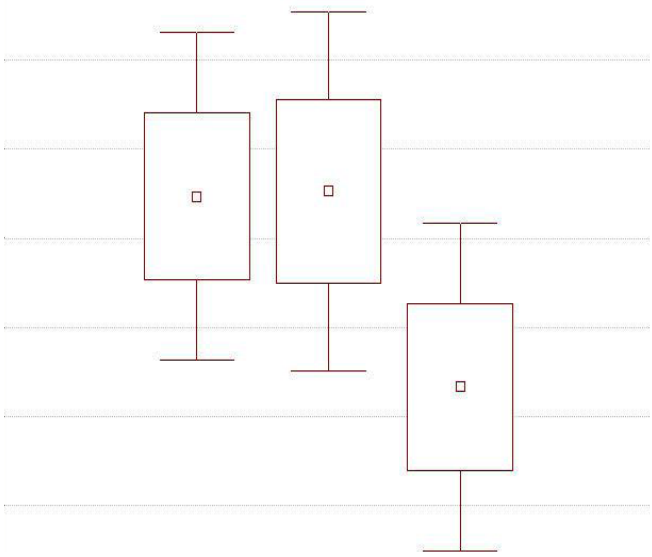

FIGURE 1. Differences between average VO_{2max} in individual groups (in 2015, 2018, and 2022)

According to research by Leo et al., more than half of people tested 6 months after SARS-CoV-2 may have a reduced level of exercise capacity. In addition, the following changes were frequently observed: rapid development of fatigue, decrease in aerobic strength, decrease in lung diffusion capacity, increase in CO_2-Fe content. Some subjects also reported pulmonary fibrosis, scarring of lung tissue, dyspnea, and persistent cough [15, 16, 17, 18, 19, 20, 21]. People who were infected and hospitalized had follow-up examinations 1 year after the onset of the disease. Reduced pulmonary diffusing capacity and respiratory efficiency were observed, especially during physical exertion [22, 23, 24].

In addition to changes in the lungs, the SARS-CoV-2 can affect the function of almost all organs. The main organs affected are the heart, blood vessels, nervous system, kidneys, and liver. These effects have been noted relatively recently and may indicate an increased risk of long-term health problems [11]. Among the many factors that determine the level of VO_{2max}, those closely related to the efficiency of the respiratory and circulatory systems stand out. These factors include, but are not limited to, minute ventilation of the lungs, diffusion capacity of the lungs, and cardiac output. Other determinants of aerobic capacity are related to the efficiency of the respiratory system, such as: blood oxygen capacity, diffusion of oxygen to mitochondria [10]. It can be concluded that reduced respiratory efficiency as a result of complications after SARS-CoV-2 infection may be one of the factors causing reduced aerobic capacity.

Based on the present study, significant differences between the obtained VO_{2max} values in the studied groups before and after the pandemic may indicate a significant impact of reduced aerobic capacity. After the tests in which the level of aerobic capacity was assessed, the average value of the measured VO_{2max} in the 2015 group was 47.4. Compared to the 2018 group, it was 46.2. The differences in VO_{2max} between the 2 groups before the pandemic were not statistically significant. On the other hand, a comparison of the results of this parameter with the 2022 group showed significant differences. The VO_{2max} parameter decreased to 37.3. This would confirm the assumptions included in the research problem.

The pandemic had a significant impact on the level of aerobic fitness of the tested group of young people. Similar problems have been observed in professional athletes. Research by Wilson et al. shows that athletes may have persistent or periodic cardiorespiratory dysfunction many weeks or months after the initial infection following a diagnosis of COVID-19. These disturbances may manifest as tachycardia, cough, and extreme fatigue, along with decreased physical performance [19].

Many researchers describe the SARS-CoV-2 as causing multi-organ damage, which is thought to be due to a systemic increase in inflammatory mediators. A viral infection-induced cytokinin storm is responsible. The release of a large number of pro-inflammatory cytokinins causes a significant increase in blood vessel permeability and impaired blood clotting, which easily leads to organ damage. The same mechanism is thought to cause increased permeability of cerebral microvessels, allowing the virus to easily cross the blood-brain barrier and invade the nervous system. It causes a number of disorders that are not only neurological, which means that it also affects other systems and organs [12]. As the disease progresses, there is a cascade of inflammatory responses that can destroy surrounding tissues, including the lungs, heart, and kidneys [20].

There are reports that people diagnosed with COVID-19 who did not require hospitalization may still be at risk of physiological deterioration [21]. The SARS-CoV-2 uses transmembrane serine protease 2 and angiotensin converting enzyme 2 receptor (ACE2) to infect host cells. In addition to the lung, ACE2 is expressed in many tissues, including the cardiovascular, gastrointestinal, and hepatic systems. Damage to these organs has been observed in patients with COVID-19 as a result of the infection process described above [1, 22]. Such changes may provide a basis for consideration of the effect of the virus on exercise capacity.

Reports by various researchers indicate that a viral infection can develop even a few months after the disease and affect even young people who are not burdened with additional chronic diseases that could worsen the course of the infection. In the case of a convalescent, shortness of breath is observed with even minor physical exertion. As a result, the amount of physical work performed is reduced [11]. This could explain the significantly lower VO_{2max} results obtained in this study in the group of people studied after the pandemic. Many studies indicate that the virus is a neutrophic virus, which means that the virus can enter the nervous system and cause dysfunction. This increases the likelihood of long-term effects after the disease.

The damage caused by COVID-19 can lead to chronic degenerative disease of the nervous system [12]. The exact mechanism of change, symptoms, and neurological effects are unknown. Based on many recent studies, it is believed that degenerative damage may occur to neurons and glial cells, which are essential for efficient nerve conduction and physiological function of the nervous system. The nervous system, along with the circulatory and respiratory systems, is the leading system in determining the level of physical performance [23]. Qi et al. reported in their study that the long-term consequences of infection in the subjects were related to long-term symptoms, including chronic fatigue, in more than half of the subjects. The aforementioned results are largely consistent with the research results obtained in this study. Chronic fatigue is associated with reduced physical performance [24].

Complications of viral infection due to reduced immunity and impaired organ function after infection become a health problem. While most patients infected with SARS-CoV-2 recover very quickly, the potential long-term problems caused by the infection make it necessary to search for and study late complications caused by the SARS-CoV-2, which most likely in many cases may manifest as reduced physical performance, even in people who have had COVID-19 without the need for hospitalization.

The results of the research presented in this report are an inspiration to continue and expand the work to obtain an answer to the extent to which SARS-CoV-2 infection has reduced the level of exercise capacity in the long-term aspect. Many of the research results of other authors cited in this paper explain a number of processes and consequences of recovery from COVID-19. However, there are still many unknowns in this area that need to be clarified.

CONCLUSIONS

The physical performance of the examined persons differs significantly and is significantly lower in the group of respondents who have been infected with SARS-CoV-2. There are many reports that late complications can persist after infection, including the nervous, respiratory, and circulatory systems. It can also manifest itself in reduced physical performance. Both older and younger people without previous health problems who have recovered from an initial SARS-COV-2 infection may be at risk for long-term impairment, known as post-COVID syndrome. This issue requires more extensive and long-term research.

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