Streszczenie w języku angielskim/summary

1.1.Background

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). It was identified in December 2019 in Wuhan, China, and has evolved into a global health crisis. The World Health Organisation (WHO) declared the COVID-19 pandemic on March 11, 2020. It is estimated that the infection affected almost 800 million people around the world and caused approximately 7 million deaths. One of the most important problems after the pandemic is the long COVID syndrome. Long COVID is defined as the continuation or development of new symptoms at least 3 months after the initial SARS-CoV-2 infection, with these symptoms lasting at least 2 months without any other explanation. Symptoms may reappear after initial recovery from COVID-19 or persist after illness; they may change or recur over time. Common symptoms include chronic fatigue, dyspnea, anosmia, ageusia, and cognitive dysfunction. Individuals recovering from COVID-19 also present exercise intolerance. Cardiopulmonary exercise testing (CPET) has become an important tool to evaluate the etiology of exercise intolerance. Furthermore, it is considered the gold standard for the assessment of physical fitness and evaluating the interaction of cardiovascular, respiratory, and metabolic systems. In view of the above, CPET may be a valuable tool to assess physical capacity in patients with long-COVID syndrome.

1.2.Objectives

The objective of the studies was to assess the impact of COVID-19 on the development of cardiovascular diseases and evaluate the factors influencing exercise intolerance after recovery.

Article 1.

The first study presented in the paper titled „***Factors of Persistent Limited Exercise Tolerance in Patients after COVID-19 with Normal Left Ventricular Ejection Fraction***" examines the mechanisms influencing exercise intolerance in patients recovering from COVID-19.

Methods: The study consists of 120 individuals recovering from COVID-19 at three to six months after diagnosis. The clinical examinations, laboratory tests, echocardiography, spiroergometry, and non-invasive body mass analysis were evaluated. Patients were divided into the two groups based on maximal predicted oxygen consumption ($\%VO_{2pred}$) in CPET:

study group [n=47] presented with < 80%VO_{2pred} and control group [n=73] presenting with ≥ 80%VO_{2pred}.

Results: The study showed that men have over twice the risk of persistent exercise intolerance than in women. Furthermore, decreased echocardiography parameters: late diastolic filling velocity (A wave), global longitudinal peak systolic strain (GLPS) and tricuspid annular plane systolic excursion (TAPSE) were related to limited exercise tolerance after COVID-19. The results of the multiple logistic regression model show that A wave and male gender were independently associated with %VO_{2pred}.

Conclusions: Men have over twice the risk of persistent limited exercise tolerance in Long-COVID than women. The decreased (A) velocity, TAPSE, GLPS, and hydration status are related to limited exercise tolerance after COVID-19 in patients with normal left ventricular ejection fraction (LVEF).

Article 2.

In the study described in the paper "***Diagnostic Usefulness of Spiroergometry and Risk Factors of Long COVID in Patients with Normal Left Ventricular Ejection Fraction***" the utility of CPET parameters in long COVID patients was analyzed.

Methods: The 146 patients (3 to 6 months after COVID-19 recovery) were divided into two groups: a group with long COVID symptoms [n=44] and a group without symptoms [n=102]. The clinical examinations, laboratory tests, echocardiography, spiroergometry, and non-invasive body mass analysis were evaluated.

Results: Patients with long COVID symptoms had significantly higher age, metabolic age, left atrial (LA) diameter, left ventricular mass index (LVMI), A wave, the ratio of peak velocity of early diastolic transmitral flow to peak velocity of early diastolic mitral annular motion (E/E'), and a lower ratio of early to late diastolic transmitral flow velocity (E/A) compared to the control group. In CPET, long COVID patients presented lower forced vital capacity (FVC), maximal oxygen uptake (VO_{2max}), respiratory exchange ratio (RER), forced expiratory volume in one second (FEV1) and a higher Tiffeneau index (FEV1/FVC%). The laboratory results pointed out that patients with long COVID symptoms also had a lower rate of red blood cells (RBC), a higher level of glucose, a lower glomerular filtration rate (GFR), and a higher level of high-sensitivity cardiac troponin T (hs-cTnT). On the multivariate model, only FEV1/FVC% independently predicted the long COVID symptoms. Using the receiver operating characteristic

curve (ROC) analysis, the FEV1/FVC% ≥ 103 was the most powerful predictor of spiroergometry parameters (0.67 sensitive, 0.71 specific, AUC of 0.73; $p < 0.001$) in predicting the symptoms of long COVID.

Conclusions: Spiroergometry parameters are useful in diagnosing long COVID and differentiating it from cardiovascular disease.

Article 3.

The last study presented in the paper titled "***Predictors of Long COVID and Chronic Impairment of Exercise Tolerance in Spiroergometry in Patients after 15 Months of COVID-19 Recovery***" is the continuation of previously mentioned study. Of the 146 patients included in the study described in publication 3., 82 completed one-year follow-up. The same diagnostic procedure was performed. Changes in laboratory parameters, echocardiography, spiroergometry and body composition analysis were analyzed after one year follow-up.

Methods: The aim of the study was to assess the mechanisms contributing to the limitation of exercise tolerance in patients who had COVID-19 after a one-year follow-up. Of 146 patients, 82 completed the follow-up.

Results: The study demonstrated that patients, after one-year follow-up, had significantly higher levels of hs-cTnT, LA diameter, RER, and total body water content percentage (TBW%) compared to the 3-month assessment. They also had lower FVC. Fat mass (FM), end-diastolic volume (EDV) and end-systolic volume (ESV) were independently associated with a decline in VO_{2max} in one-year follow-up.

Conclusions: Higher left ventricular volumes and fat mass (%) were associated with a reduced maximal oxygen uptake (VO_{2max}) when assessed 15 months after COVID-19 recovery.

Article 4.

The review article titled "***The Role of Multidisciplinary Approaches in the Treatment of Patients with Heart Failure and Coagulopathy of COVID-19***" discusses the impact of SARS-CoV-2 infection on myocardial damage and the occurrence of thromboembolic complications. Particular attention was paid to the relationship between COVID-19 and heart failure (HF).

1.3.Summary

The referenced papers attempt to broaden the understanding of complex interactions in COVID-19 and cardiac damage, particularly a development of HF. Thanks to the observed relationships, it will be possible to start appropriate diagnostic procedures early, select personalized treatment, develop a model of cardiac care and rehabilitation programs for people after SARS-CoV-2 virus infection, and thus improve the quality of their lives.