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Original article

CHANGES IN CARDIO-PHYSIOLOGICAL PARAMETERS ANALYZED WITH BRUCE PROTOCOL FOLLOWING SARS-COV-2 INFECTION IN SOCCER PLAYERS

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Abstract

The aim of this study was to analyze the possible differences in the endurance of soccer players, based on parameters obtained by Bruce protocol, before and after the COVID-19 pandemic. This was achieved by comparing cardio-physiological parameters between convalescents and non-infected athletes.

We designed a retrospective case-control study. Sixteen male soccer players, aged from 18 to 35 years, were included. According to the anamnestic data (COVID-19 questionnaire) players were divided into two subgroups: infected (N=10) and non-infected (N=6). The general endurance and maximal oxygen consumption ($VO2_{max}$) were assessed utilizing the Bruce sub-maximal treadmill test. Cardio-physiological parameters were taken during the pandemic period (May/ June 2021) and one year later (June 2022).

The heart rate (HR) at rest showed no statistical difference between the two cohort groups (infected and non-infected) before (p=0.8996) and after the pandemic (p=0.6968). HR at recovery also did not show significant difference between the cohort groups before (p=0.3719) and after the pandemic (p=0.6930). ET (exercise time) and $VO2_{max}$ values were without a significant difference between the groups at the two testing periods (p=0.2860; p=0.9835 and p=0.4957; p=0.9469, respectively). The difference between $VO2_{max}$ values for the whole soccer team before and after the pandemic was statistically significant and higher (+2.42 mL/kg/min) at the second testing point (p=0.04).

The cardio-physiological parameters obtained with Bruce protocol following SARS-CoV-2 infection in male soccer players manifested no significant difference compared to non-infected participants from the same soccer club and compared to the period before pandemic. The single parameter that was different and higher after the pandemic was maximal oxygen consumption for the whole team regardless the COVID-19 status.

Keywords: maximal oxygen consumption, heart rate, Bruce test, COVID-19, soccer players

Introduction

During the COVID-19 pandemic, social isolation and lockdowns were recommended in most countries around the world as a protective measure against the spread of the virus. The restriction of movement directly affected the performance of sports training, as well as

competitions. It is assumed that lack of physical activity is detrimental for sports performance and for general health of the global population and athletes likewise. The state of stress as a consequence from the pandemic and restrictive measures has long-term health effects, with an increased risk of physical and mental disorders affecting athletes[1,2].

COVID-19 is associated with a wide range of clinical morbidities across different physiological systems, most frequently cardiac, pulmonary, hematologic and musculoskeletal system[3], which are directly related to the sports endurance. While many athletes develop only mild symptoms or remain asymptomatic, others experience persistent symptoms following acute illness, which could cause decline of athletic performance[4]. The impact of COVID-19 on physical performance and mental health in professional athletes was a great concern for all sports participants, players, coaches and sport experts.

Many investigations and recommendations regarding athletes' safe return to high intensity training are made and published because of the possible health risk after COVID-19 illness[5,6]. Scientific publications analyzing the sport performance parameters, including physiological and physical parameters, which could be affected by SARS-CoV-2infection, are ambiguous. Some of the studies demonstrated that COVID-19 pandemic has overall detrimental effects on the athletes' fitness and endurance, while others did not show a negative impact.

Athletes with COVID-19 disease display an increased risk of reduced maximal and submaximal performance as a consequence of the major challenge posed to respiratory and circulatory functions[7]. Analysis of aerobic capacity of professional soccer players pre- and post-COVID-19 showed significantly lower running time and oxygen consumption in the post-recovery period[8]. Maximal oxygen consumption ($VO2_{max}$) is an important cardio-physiological parameter that measures general aerobic endurance in sedentary people and athletes. Thus, it can provide an effective value of stamina and it is used as an indicator of cardiorespiratory fitness (CRF). Investigation of aerobic endurance of futsal athletes during COVID-19 pandemic showed decrease in the average $VO2_{max}$ of the athletes after exercising from home[9]. According to a study from Indonesia, the COVID-19 pandemic affected the absolute value of $VO2_{max}$ in futsal players, resulting in a decrease in its value[10]. On the contrary, studies analyzing parameters from elite handball players in Germany[11] and top swimmers from Hungary[12] have not found a statistically significant effect by the SARS-CoV-2 infection on $VO2_{max}$ values. Furthermore, in a sample of professional football players, the motoric skills varied considerably across outcomes before and 8 weeks after SARS-CoV-2 infection[13]. The long quarantine period also impaired some of the physical performance measures compared to regular off-season in soccer players[14]. However, several elite and rather famous professional athletes, like Novak Djokovic and Cristiano Ronaldo, recovered successfully and even recorded peak performance following the infection[15].

The aim of this study was to determine cardio-physiological variables derived from Bruce protocol in a group of soccer players before and after the COVID-19 pandemic, and compare ergometric cardio-physiological parameters between convalescent (infected) and non-infected athletes at two testing points, pre- and post-pandemic.

Materials and methods

We designed a retrospective case-control, open-label, single-center, cohort study. Sixteen (16) male soccer players, aged from18 to 35 years, mean age 25.0 ±5.28 years, height 178.7 ±5.3 cm, weight 76.16 ± 7.5 kg, BMI = 23.8 ± 1.5, from Vardar Football Academy in Skopje, were included. The endurance and fitness level were assessed utilizing the Bruce sub-maximal treadmill test. According to the anamnestic data (COVID-19 questionnaire) players were divided into two subgroups: infected (N=10) and non-infected (N=6). Cardio-

physiological parameters were taken during the pandemic period (May/ June 2021) and one year later (June 2022).

Anthropometric procedure

Participants' height was measured to the nearest 0.1 cm with a fixed stadiometer (Holtain Ltd., Crymych, UK), body weight to the nearest 0.1 kg using the SECA beam balance (Seca, Hamburg, Germany). Personal information of the participants (full name, date of birth, activity record) as well as anthropometric and ergometric data were filled in a special software. $VO2_{max}$ was calculated based on Bruce norms.

Ergometry testing

All participants underwent a standard treadmill exercise testing according to the Bruce protocol, which is a sub-maximal treadmill test, according to the American College of Sports Medicine (ACSM) guidelines. Bruce test consists of multiple stages of progressively increasing workloads, which should be performed until the examinee reaches his/her sub-maximal heart rate. The test includes seven stages, each lasting for three minutes and with each subsequent stage the speed and the inclination of the track is significantly increased. $VO2_{max}$ is calculated from the Bruce nomogram, using the exercise time (ET - duration of the test expressed in minutes) and the gender of the examinee.

COVID-19 questionnaire

With assistance of a COVID-19 questionnaire, we collected information regarding SARS-CoV-2 infection, confirmed by polymerase chain reaction test (PCR test) or rapid antigen test. Moreover, we noted the vaccination status of the participants. Lastly, the information for post-COVID-19 symptoms was gathered. The participants were fully familiarized with the protocol and gave their written informed consent to participate in this investigation.

Statistical Analyses

Descriptive statistics including minimal, maximal, median and mean values, standard deviation, standard error of the mean and ±95 confidence interval were used for series with numerical attributes. Comparison of means of the heart rate at rest (HR rest), heart rate at recovery (HR recovery), exercise time (ET) and $VO2_{max}$ between the groups was analyzed using the Independent samples t-test, while comparison of these parameters between the groups and relative to the two testing time points was calculated using One-Way Repeated Measures analysis of variance (ANOVA). P-value of <0.05 was considered statistically significant in each of the previous tests. Statistical analyses were performed using IBM SPSS v.19.0 statistical software (SPSS Inc., Chicago, IL, USA).

Results

Sixteen (16) male soccer players, who underwent regular sports medical examination in our Institute in July 2022, were enrolled. Based on their COVID-19 status, they were divided into two groups. The first, referred to as the non-infected group, consisted of six (6) examinees. The second, referred to as the infected group, consisted of ten (10) examinees, out of which seven (7) had infection confirmed by PCR and three (3) had infection confirmed by rapid antigen test. The general characteristics of the cohort are provided in detail in Table 1. The extrapolated data about the most common post-COVID symptoms are presented in absolute numbers and percentages in Table 2. Of the six (6) participants who reported post-COVID-19 symptoms, five (5) were infected with the SARS-CoV-2 virus and one (1) belonged to the non-infected group. Half of the convalescent players did not report any

symptoms in the period after infection. Subjective symptoms like reduced endurance, sleep problems and loss of smell and taste were noted in one athlete each, shortness of breath and muscular pain were detected in two athletes each.

Table 1. Descriptive statistics for anthropometric parameters of soccer players (after pandemic)

	Mean	SD	SEM	Minimum	Median	Maximum	95% CI
Age	25.00	5.28	1.32	18	26	35	22.19 to 27.81
Height (cm)	178.69	5.33	1.33	168	180	188	175.85 to 181.53
Weight (kg)	76.16	7.53	1.88	65.50	74.75	91.50	72.15 to 80.17
BMI (kg/m2)	23.81	1.48	0.37	21.10	23.90	25.90	23.02 to 24.59

RBC-red blood cells, Hb-hemoglobin, BMI-body mass index, SD-standard deviation, SEM-standard error of the mean, CI-confidence interval.

Table 2. Post-COVID-19 symptoms in convalescent soccer players

Symptoms that persisted after the COVID-19 infection. N (number) stands for examinees who had those symptoms.

Symptoms	N (absolute and percentage)
Muscular pain	2 (12.5%)
Loss of smell and taste	1 (6.25%)
Sleep problems	1 (6.25%)
Shortness of breath	2 (12.5%)
Reduced endurance	1 (6.25%)
Palpitations	0
Fatigue	0

Cardio-physiological parameters relative to the athletes' COVID-19 status (infected and non-infected), before and after pandemic, are presented in Table 3. When the soccer team was divided in players who were diagnosed infected or non-infected, the parameter HR rest before pandemic had almost the same mean values in both groups. After the pandemic, non-infected players showed an insignificantly higher heart rate at rest than infected (p=0.69).

Table 3. Descriptive statistics of cardio-physiological parameters and significance regarding COVID-19 status (infected and non-infected) before and after pandemic

COVID-19 status	Non-infected		Infected		Significance		
Parameters	Mean	Std. Dev.	N	Mean	Std. Dev.	N	p
HR rest before COVID-19 (bpm)	81.17	16.56	6	82.20	15.01	10	p=0.8996
HR rest after COVID-19 (bpm)	77.17	15.64	6	74.70	9.40	10	p=0.6968
HR recovery before COVID-19 (bpm)	102.83	7.25	6	107.90	12.11	10	p=0.3719
HR recovery after COVID-19 (bpm)	100.83	15.26	6	103.60	12.06	10	p=0.6930
ET before COVID-19 (minutes)	12.59	1.99	6	13.55	1.46	10	p=0.2860
ET after COVID-19 (minutes)	13.90	2.03	6	13.88	1.46	10	p=0.9835
$VO2_{max}$ before COVID-19 (ml/kg/min)	45.00	5.21	6	46.70	4.40	10	p=0.4957
$VO2_{max}$ after COVID-19 (ml/kg/min)	48.33	4.63	6	48.20	3.26	10	p=0.9469

HR- heart rate; bpm - beats per minute; ET- exercise time; VO2 max- maximal oxygen consumption; N- number

Heart rate at recovery period (three minutes after the test is finished) at pre-pandemic and post-pandemic period was slightly higher in athletes who became infected (p=0.37). Before the pandemic, exercise time and oxygen consumption (which is calculated from ET) were insignificantly longer and higher in the infected soccer players (not yet infected at that point), while after pandemic, both groups had almost the same ET and$VO2_{max}$ (p=0.49; p=0.95).

The mean values of cardio-physiological parameters for the whole team (infected plus non-infected) regarding the two testing time points, before and after pandemic, are displayed in Table 4. The mean values of all cardio-physiological parameters were better after the pandemic, compared to the values recorded before it, but with no statistical significance. The only significantly different parameter was maximal oxygen consumption, which was better at the second testing point, i.e., after pandemic. At this point, the mean value of $VO2_{max}$ was 48.27 mL/kg/min versus 45.85 mL/kg/min before the pandemic (p=0.040).

Table 4. Mean values of cardio-physiological parameters for the whole team (infected plus non-infected) regarding the two testing time points

Parameters	Before COVID19	After COVID19	Significance
HR rest (bpm)	81.68	75.93	p=0.161
HR recovery (bpm)	105.37	102.22	p=0.365
ET (minutes)	13.07	13.89	p=0.075
VO2 max (ml/kg/min)	45.85	48.27	p=0.040

HR- heart rate; bpm - beats per minute; ET- exercise time; VO2 max- maximal oxygen consumption

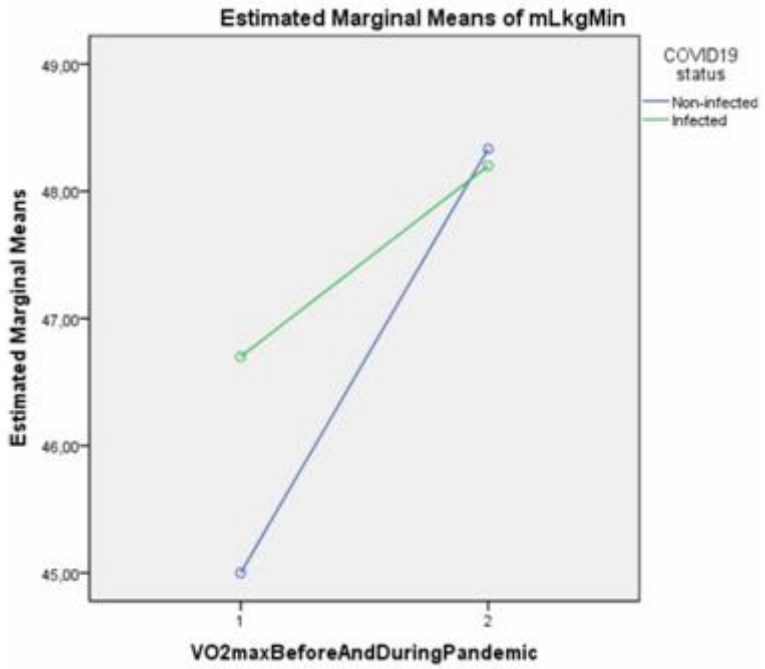

Fig. 1. Graph that correlates ET values with the two testing time points. The blue line represents the non-infected participant's group and the infected participant's line is shown with the green color

ET values with the two testing time points are shown in Figure 1. The infected participants' line (green color) illustrates a more gradual incline compared to the non-infected participants' line (blue color), resulting in a lower mean of ET expressed in minutes. Figure 2 presents the comparison of$VO2_{max}$ values with the two testing time points. The non-infected

participants' line (blue color) shows a steeper incline compared to the infected participants' line (green color), resulting in even higher mean of $VO2_{max}$ expressed in mL/kg/min. A statistical significance was obtained between $VO2_{max}$ values before and during the pandemic (p=0,040) with the latter mean values being higher by 2.42 mL/kg/min.

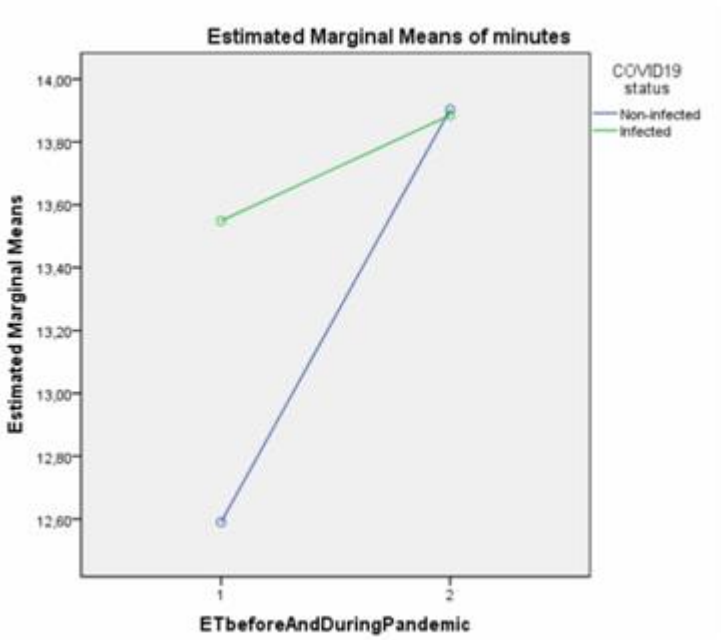

Fig. 2. Graph that compares VO2 max values with the two testing time points. The blue line represents the non-infected participant's group and the infected participant's line is shown with the green color.

Discussion

For the first time in our country, our study analyzed the possible influence of the SARS-CoV-2 infection on the aerobic capacity of soccer players. We hypothesized that COVID-19 illness might diminish cardiovascular and respiratory functions of the infected athletes. The cardio-physiological parameters obtained with Bruce ergometry do not allude to decreased aerobic capacity after the pandemic.

The published data regarding the impact of COVID-19 disease on sport performance are insufficient and long-term data are still not available. The infection rate among professional soccer players is consistent with that of the general population and most of them are asymptomatic[16]. A small percentage of athletes experienced persistent or serious symptoms while recovering from the infection, which were mostly mild in nature, but could affect return-to-play decisions and timing[17]. In our investigation only two (2/16) soccer players reported shortness of breath and muscular pain. Subjective feeling of reduced endurance, sleep problems and loss of smell and taste were reported by one athlete each. None of the participants had complaints of palpitations or fatigue.

The heart rate before, during and after ergometry are indicators of the capacity of the cardiovascular system to adapt to physical strain, and successful adaptation means that a subject can endure longer and greater physical activity. The comparison of the cardio-physiological parameters related to the COVID-19 pandemic, showed that heart rate at rest and heart rate at recovery were insignificantly lower after the pandemic in both groups, infected and non-infected. Lower heart rates at the beginning of the ergometry could be an indicator of better endurance in athletes[18]. During recovery period, three minutes after submaximal effort, when the cardiovascular system passes from very high physical exertion

to resting state, the best adaptation is significant lowering of the heart rate. Regardless of the COVID-19 status, our participants showed better cardio-physiological parameters after the period of the previous testing (ergometry).

Steeper decrease in heart rate values at rest were observed in the infected group (mean from 82.20 to 74.70 beats per minute) compared to the non-infected group (mean from 81.17 to 77.16 bpm). Only one participant who belonged to the non-infected group showed value (HR rest=56 bpm) that can be described as sport's bradycardia. Heart rate at recovery is a parameter that is estimated three minutes after the workload ceases. Decreasing trend of HR recovery was sharper in the infected soccer players (mean from 107.90 to 103.60 bpm) compared to the non-infected (mean from 102.83 to 100.83 bpm). It has to be pointed out that the variations in these two ergometric parameters (HR rest and HR recovery) were not statistically significant, therefore, possible causal effect by the SARS-CoV-2 infection was difficult to extrapolate based on this study alone.

Exercise time parameter represents the amount of time each examinee spends on the treadmill during Bruce test until reaching individual submaximal heart rate. The maximal oxygen consumption is calculated indirectly, with nomogram using exercise time duration. Both groups, infected and non-infected, achieved longer ET at post-pandemic testing compared to pre-pandemic results. Post-pandemic ergometry results were almost the same in both groups. A gradual incline was observed of the trend line in the infected group compared to the non-infected steeper increase of the line resulting in even higher ET expressed in minutes (mean from 13.55 to 13.88 for the infected group; mean from 12.59 to 13.90 for the non-infected group).

The maximal oxygen consumption is impaired after reduction of physical activity and decrease of training regime, which is additionally aggravated in athletes that have undergone SARS-CoV-2 infection[7,19]. In our study, the comparison of $VO2_{max}$ in both groups, infected and non-infected, showed improvement at the second testing (after the pandemic). The comparison of the whole team, all 16 players, before and after the pandemic, showed significant improvement in oxygen consumption ($p=0.040$).

Examinations whether infected soccer players have residual cardiorespiratory complications and impact on the endurance and strength are scarce. Reports from SARS patients in 2003 suggest the possibility of cardiorespiratory impairments in athletes even 24 months after SARS onset[20]. The observational study of aerobic capacity of professional players pre- and post-COVID-19 disease demonstrated that infected players had significantly lower $VO2_{max}$ after 60 days recovery period, which could indicate that at two months post-COVID-19, players did not reach full recovery[8].

Our results are opposite to those published in a paper from Indonesia, showing a decrease in the absolute number of $VO2_{max}$ values in futsal players[9]. Additionally, Ariestika *et al*. described a COVID-19 influence on the categorization of athletes, based on the $VO2_{max}$ parameter[10]. On the contrary, our findings are in line with studies analyzing ergometry variables from elite handball players in Germany[11] and top swimmers from Hungary[12], that have not found a statistically significant effect by the SARS-CoV-2 infection on $VO2_{max}$ values.

The resistance of elite athletes to serious adverse outcomes from SARS-CoV-2 and their ability to sustain peak performance both in the short and long-term post-infection emphasizes the importance of practicing regular physical activity and maintaining optimal body composition and overall fitness of the general health[15]. The soccer players in our study did not show a significant difference in cardio-physiological parameters after the pandemic, both in infected and non-infected players. These results indicate that pandemic conditions, lockdowns, training deficit and possible infection did not alter ergometry results. The general

improvement of oxygen uptake could be a result of improvement of the general endurance due to the longer training history of soccer players.

Apropos limitations, our study is composed of a small cohort sample, therefore the results obtained cannot be related to the entire population. On one hand, we face with financial difficulties in our small country, thus we do not have technological support to conduct a detailed analysis. Due to the pandemic, we could not perform the spirometry, because of the very infectious transmission of SARS-CoV-2 virus and the risky conditions of performing the procedure. On the other hand, this type of study lacks randomization and blinding. Also, it can be difficult to establish a causal effect of the infection. Ideally, comparison of the ergometry results should be matched with the convalescent period, physical and sport anamnesis, period of inactivity, COVID-19 and post-COVID-19 symptoms.

Conclusion

The soccer players reported only mild post-COVID-19 symptoms, which did not affect the cardiovascular adaptation during the ergometric test. Cardio-physiological parameters analyzed with Bruce protocol following SARS-CoV-2 infection in male soccer players manifested no difference in the heart rate values (HR rest, HR recovery), exercise time duration (ET) and $VO2_{max}$ compared to non-infected participants from the same team. The general oxygen consumption ($VO2_{max}$ of the whole team, regardless of the COVID-19 status) was higher at post-pandemic testing, which could be a result of the improvement in the training regime. Our soccer players were young, healthy, physically active people, who had asymptomatic or mild form of the disease, without significant influence on the sport's performance.

Conflict of interest statement. None declared.

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