Evaluation of maximal oxygen uptake pre- and post-COVID-19 in elite footballers in Argentina

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Summary

Introduction and objectives: The SARS-CoV-2 infection appears to cause functional impairment of cardiopulmonary performance in many athletes. We studied the post-COVID-19 impact on the cardiopulmonary system, through the maximal ergospirometry test, in elite professional soccer players.

Material and method: The sample consisted of 10 AFA (Argentine Football Association) first division soccer players, who underwent pre and post COVID-19 infection maximal oxygen uptake (VO_{2max}) tests. The variables analyzed were absolute and relative $VO_{2max,}$ maximal aerobic speed (MAS), first ventilatory threshold (VT1), second ventilatory threshold (VT2), maximal heart rate (HRmax) and respiratory exercise ratio (RER).

Results: The mean age was 22.4 ± 6.9 years, body mass 71.5 ± 7.1 kg and height 176.2 ± 6.9 cm. Post COVID-19 subjects significantly decreased VO_2VT2 by 18% (*P* = 0.028) and RER significantly decreased by 5% (*P* = 0.02). HRmax was the only variable that significantly increased post COVID-19 by 1.8% (*P* = 0.04). No significant changes was observed in body mass 71.5 ± 7.1 vs 73.9 ± 7.4 (*P*< 0.118), VO_{2max} 61.7 ± 5.2 vs 59.0 ± 5.1 ml·kg·min^{-1} (*P*<0,213), MAS 18.7 ± 0.9 vs 18.6 ± 0.5 km·h^{-1} (*P*<0,739), VO_2VT1 39.2 ± 4.0 vs 37.8 ± 4.3 ml·kg·min^{-1} (*P*<0.460), speed al VT1 11.6 ± 0.5 vs 11.8 ± 0.6 (*P* <0.480) and other variables.

Conclusion: It seems reasonable and safe to evaluate athletes after SARS-CoV-2 infection with ergospirometry to ensure health conditions and trainability. In this type of athletes (elite soccer players), the use of the second ventilatory threshold (VT2) can be used as a strategy to observe post-COVID-19 changes. The decrease found may be related more to the cessation of training than to cardiopulmonary damage.

Key words:
COVID-19. Athletic performance. Exercise. Sport medicine. Ventilatory threshold.

Evaluación del consumo máximo de oxígeno pre y post COVID-19 en futbolista de élite en Argentina

Resumen

Introducción y objetivos: La infección por SARS-CoV-2 parece provocar en muchos atletas un deterioro funcional del rendimiento cardiopulmonar. Se estudió el impacto post COVID-19 en el sistema cardiopulmonar, a través del test de ergoespirometría máxima, en futbolistas profesionales elite.

Material y método: La muestra estuvo compuesta por 10 futbolistas de la primera división AFA (Asociación de Fútbol Argentino), a quienes se realizaron test de consumo de oxígeno máximo ($VO_{2máx}$) pre y post infección por COVID-19. Las variables analizadas fueron $VO_{2máx}$ absoluto y relativo, velocidad aeróbica máxima (VAM), primer umbral ventilatorio (VT1), segundo umbral ventilatorio (VT2), frecuencia cardiaca máxima ($FC_{máx}$) y cociente respiratorio (RER).

Resultados: El promedio de la edad fue 22,4 ± 6,9 años, masa corporal 71,5 ± 7,1 kg y estatura 176,2 ± 6,9 cm. Los sujetos post COVID-19 disminuyeron significativamente un 18% el VO_2VT2 (p =0,028) y el RER disminuyó significativamente 5% (p =0,02). La FC_{max}, fue la única variable que post COVID-19 se incrementó significativamente 1,8% (p =0,04). No se observaron cambios significativos en la masa corporal; 71,5 ± 7,1 vs 73,9 ± 7,4 (p <0,118), $VO_{2máx}$ 61,7 ± 5,2 vs 59,0 ± 5,1 ml·kg·min^{-1} (p <0,213), VAM 18,7 ± 0,9 vs 18,6 ± 0,5 km·h^{-1} (p <0,739), VO_2VT1 39,2 ± 4,0 vs 37,8 ± 4,3 ml·kg·min^{-1} (p <0,460), Velocidad al VT1 11,6 ± 0,5 vs 11,8 ± 0,6 (p <0,480) y demás variables.

Conclusión: Parece razonable y seguro evaluar a los atletas después de la infección por SARS-CoV-2 con ergoespirometría para asegurar las condiciones de salud y entrenabilidad. En este tipo de atletas (futbolistas elite), la utilización del segundo umbral ventilatorio (VT2) puede ser utilizado como estrategia para observar cambios pos COVID-19. La disminución hallada, puede estar relacionada más al cese del entrenamiento que al daño cardiopulmonar.

Palabras clave:
COVID-19. Rendimiento deportivo. Ejercicio. Medicina del deporte. Umbral ventilatorio.

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Introduction

Coronavirus disease 2019 (COVID-19) has affected more than 150 million people worldwide[1]. Major sporting events (Olympic Games, world and national championships, etc.) had to be temporarily suspended, meaning that all professional sport had to adapt to the situation[2]. This was mainly because the disease caused by the SARS-CoV-2 virus is, beyond lung involvement, potentially a multi-organ disease. That is to say, it acts by affecting different organs and systems, including the lungs, heart, blood vessels, brain, liver, kidney and intestine[3]. As a result, there has been an increase in people with such sequelae as pulmonary fibrosis, myocarditis, chronic heart failure or chronic kidney disease[4].

In professional athletes affected by COVID-19, there is always doubt about the impact that the virus may have on the body and whether they will return in peak physical condition. Post-COVID-19 assessments are important in general and a comprehensive evaluation of the cardiopulmonary system is especially important[5]. The cardiopulmonary exercise test (CPET) or ergospirometry allows dynamic evaluation of cardiac, respiratory, metabolic and neuromuscular function by analysing the gases breathed during a standardised stress test. It measures oxygen uptake and peak uptake during exercise (VO_{2peak} or VO_{2max}), as well as many other physiological variables and ergospirometric parameters[6].

In the current health context, CPET is included in the list of tests for monitoring patients who have suffered from COVID-19 infection, as reflected in the guidelines published by the European Respiratory Society (ERS)/American Thoracic Society (ATS) task force[7] and the American College of Cardiology[8].

While much remains to be discovered about the long-term impact of COVID-19, cardiopulmonary disturbances and symptoms, such as dyspnoea or fatigue, may persist for months and are possibly related to infection-related pulmonary or interstitial muscle and vascular deconditioning[9,10]. In elite male handball players with a recent history of COVID-19 infection, a significant reduction in VO_{2max}, oxygen pulse and pulmonary ventilation (PV) was evidenced through ergospirometry, opening the way to interpretation that COVID-19 infection leads to a deterioration of cardiopulmonary performance during physical exertion[10]. There are few studies which analyse the impact of COVID-19 on cardiopulmonary variables in elite athletes.

This study aimed to analyse the post-COVID-19 impact on the cardiopulmonary system by means of a maximal ergospirometry test on elite professional footballers. Such an analysis should allow us to better understand how this disease affects highly trained athletes.

Materials and methods

Population and design

The sample consisted of 10 football players from the AFA's (Argentine Football Association) Primera División with the following characteristics; age 22.4 ± 6.9 years old, body mass 71.5 ± 7.1 kg and standing height 176.2 ± 6.9 cm.

The study has an observational design and its level of analysis is relational. The sample was selected intentionally and for convenience. The players had been measured with ergospirometry prior to the COVID-19 disease at the beginning of the 2021 pre-season period as part of a systematic performance evaluation protocol carried out by their club. The players who tested positive for COVID-19 during this period were tested again with ergospirometry on their return to professional sporting activity post-COVID, 10 days after medical discharge. This meant it was possible to compare maximal oxygen uptake before and after infection.

In order to be included, all the players had to test positive for SARS-CoV-2 by a specific RT-PCR using nasopharyngeal swabs. The most frequent symptoms were anosmia, fever, asthenia and adynamia, although 5 subjects were asymptomatic.

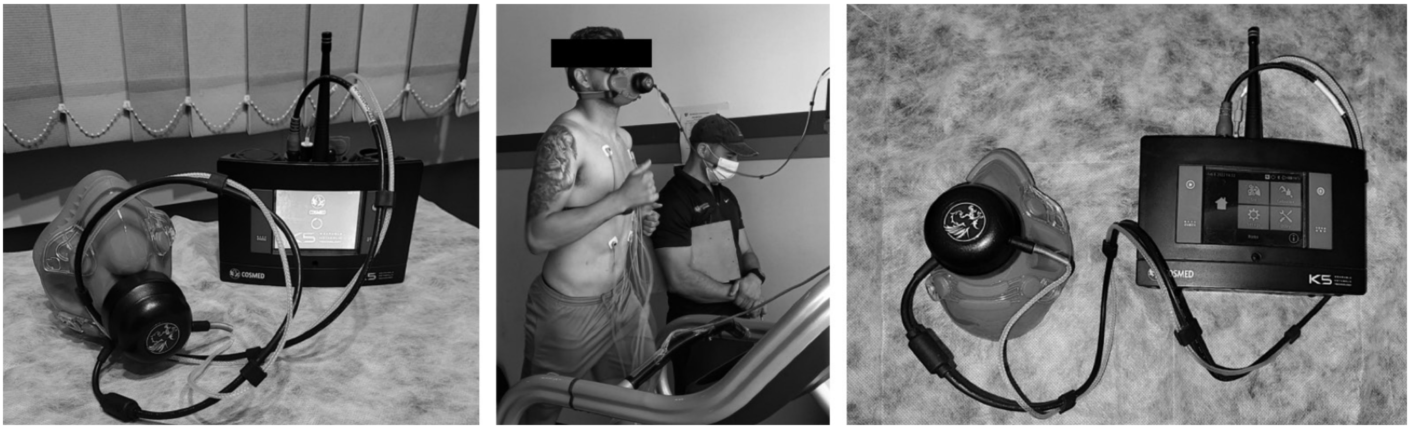
The study was carried out in accordance with the Declaration of Helsinki, and respecting Resolution 1480/11 of the Argentine Ministry of Public Health, Guide for Research with Human Beings. The data from the evaluations that football players usually undergo in their sports career were used. Participation in this study was voluntary and the players were explained beforehand what the measurements consisted of and that their data would always be kept anonymous. Informed consent was obtained from all the players taking part.

Cardiopulmonary exercise test (CPET)

In the lab test, the players did a 3-minute warm-up. The test was incremental, starting at 8 $km \cdot h^{-1}$ and increasing the speed by 1 $km \cdot h^{-1}$ every 1 minute until exhaustion, with a fixed slope at 1%[12]. The mean temperature during the test ranged from 22 to 24°C. The players' body mass and height were also measured. The COSMED® model K5 gas analyser was used on the treadmill (Figure 1). It has linear and fast-response sensors[12]. The flow meter is a digital turbine with a flow range of 0.08 -16 l/s, an accuracy of ±2% or 50 ml/s and a resistance of <0.6 cmH_2O s/l up to 14 l/s. The O_2 sensor is a gas flow controller (GFC) with a range of 0 - 100%, an accuracy of ±0.02% and a response time of ~120 ms. The CO_2 sensor is a non-dispersive infrared (NDIR) sensor with a range of 0 - -10%, an accuracy of ±0.02% and a response time of ~100 ms. This type of evaluation has been described in the literature to measure professional footballers[13].

Gas exchange was measured with dynamic micro mixing chamber. The data processing software was OMNIA® PC. Oxygen uptake (VO_2), carbon dioxide production (VCO_2) and heart rate (HR) were measured. Gas exchange was quantified with the dynamic micro mixing (DMM) chamber mode in which proportional fractions of exhaled gas are sampled from several breaths within a small chamber of approximately 2 ml[15]. Maximal aerobic speed (MAS) was measured. Relative VO_2 and CO_2 were calculated in $ml \cdot kg \cdot min^{-1}$ and as % predicted, the first (VT1) and second ventilatory thresholds (VT2) were calculated in $ml \cdot kg \cdot min^{-1}$,

Figure 1. Portable gas analyser used in the study.



HR was calculated at VT2 and as a % of VO_{2max}, and the speeds at which the thresholds were reached and the respiratory exchange ratio (RER) were also determined. Prior to the CPET, a resting electrocardiogram and colour doppler echocardiogram were performed on all the players, with no abnormalities found in any of them. No arrhythmias were observed during the stress test.

Statistical analysis

The data were analysed using the IBM SPSS Statistics V22.0 package, The sample was described, indicating mean and standard deviation. Prior to analysis, the Shapiro-Wilk normality test with a significance level (α=0.05) was performed, indicating that the variables behaving normally are all except ($p < 0.05$): post-VO_2VT2, post-MAS, pre-SpeedVT1, post-SpeedVT1, pre-SpeedVT2 and post-SpeedVT2. Accordingly, testing for related samples (before-after design) was carried out using the t-test and the non-parametric Wilcoxon test. Differences were interpreted with the size effect using Cohen's method; <0.5 (small), 0.5 to 0.8 (medium), >0.8 (large)[16].

Results

The ranges obtained for the variables measured pre-COVID-19 were as follows: absolute VO_{2max} between 3,768 and 4,917 ml·min^{-1}; relative VO_{2max} between 54.6 and 68.3 ml·kg·min^{-1}; MAS between 17 and 20 km·h^{-1}; RER between 1.12 and 1.29; METs between 15.6 and 19.5 kcal/min; VT1 between 32.6 and 44.5 ml·kg·min^{-1}; VT2 between 44.2 and 57.8 ml·kg·min^{-1}; HR_{max} between 179 and 189 beats·min^{-1}, SpeedVT1 between 11 and 12 km·h^{-1}; SpeedVT2 between 14 and 16 km·h^{-1} and %VO_2VT2 between 76% and 88%.

The ranges obtained for the variables measured post-COVID-19 were as follows: absolute VO_{2max} between 3,533 and 5,094 ml·min^{-1}; relative VO_{2max} between 52.3 and 68.2 ml·kg·min^{-1}; MAS between 18 and 19 km·h^{-1}; RER between 1.10 and 1.22; METs between 15.0 and 19.5 kcal/

Table 1. Description of the variables measured pre- and post-COVID-19.

Variables (n=10)	Pre-COVID-19 (Mean ± SD)	Post-COVID-19 (Mean ± SD)	Diff (post-pre)	p<	Cohen's *d*
Body mass (kg)	71.5 ± 7.1	73. 9± 7.4	2.41	0.118	0.55 *(medium)*
VO_{2max} (ml·min^{-1})	4,402.5 ± 387.4	4,362.4 ± 528.4	40.10	0.686	0.13 *(small)*
VO_{2max} (ml·kg·min^{-1})	61.7 ± 5.2	59.0 ± 5.1	2.75	0.213	0.42 *(small)*
MAS (km·h^{-1})	18.7 ± 0.9	18.6 ± 0.5	0.10	0.739	0.10 *(small)*
HR_{max} (beats·min^{-1})	185.4 ± 6.1	188.8 ± 5.4	3.40	0.040	0.76 *(medium)*
METs (kcal/min)	17.6 ± 1.5	16.8 ± 1.5	0.78	0.222	0.42 *(small)*
RER (VCO_2/VO_2)	1.2 ± 0.1	1.1 ± 0.1	0.06	0.024	0.86 *(large)*
VO_2VT1 (ml·kg·min^{-1})	39.2 ± 4.0	37.8 ± 4.3	1.38	0.460	0.24 *(small)*
VO_2VT2 (ml·kg·min^{-1})	50.7 ± 4.4	45.6 ± 4.1	5.10	0.028	0.83 *(large)*
SpeedVT1 (km·h^{-1})	11.6 ± 0.5	11.8 ± 0.6	0.20	0.480	0.22 *(small)*
SpeedVT2 (km·h^{-1})	14.8 ± 0.6	14.6 ± 0.5	0.20	0.419	0.25 *(small)*
VO_2VT2 (%VO_{2max})	82.3 ± 3.4	77.5 ± 5.1	4.80	0.670	0.66 *(medium)*

VO_{2max}: maximal oxygen uptake; METs: metabolic equivalent of task; RER: respiratory exchange ratio; VO_2: oxygen uptake; MAS: maximal aerobic speed; HR_{max}, maximal heart rate; VO_2VT1: oxygen uptake at first ventilatory threshold; VT2: second ventilatory threshold; HR: heart rate.

min; VT1 between 32.3 and 44.9 ml·kg·min^{-1}; VT2 between 41.3 and 53.1 ml·kg·min^{-1}; HR_{max} between 179 and 195 beats·min^{-1}, SpeedVT1 between 11 and 13 km·h^{-1}; SpeedVT2 between 14 and 15 km·h^{-1} and %VO_2VT2 between 67% and 83%.

The variables measured pre- and post-COVID are presented in Table 1.

A significant decrease in VO_2VT2 by 18% (p =0.028) was observed in the post-COVID-19 subjects. RER also fell significantly by 5% (p = 0.02). HR_{max} was the only variable that increased significantly after COVID-19, by 1.8% (p = 0.04). As shown in Table 1, no significant changes were observed in the other variables measured.

Discussion

The main result of this study was that in elite professional footballers who were measured before and after COVID-19 with a maximal ergospirometry test, differences were observed in the variables VO_2VT2 (p =0.028), HR_{max} (p =0.04) and RER (p =0.02).

The post-COVID-19 respiratory quotient was lower (Table 1), but although this difference can be interpreted as significant, its importance is low because in both cases the values exceeded 1.1, revealing that significant work intensities were achieved. The heart rate increased (Table 1), which should be interpreted with caution, because while this might indicate greater exertion, the differences were small. Oxygen uptake at the first ventilatory threshold (VO_2VT2) was lower in the post-COVID-19 evaluation (Table 1). The decrease of VO_2 at VT2 in the post-COVID-19 evaluations demonstrates the impact of detraining during the weeks of isolation and the convalescent stage even though they were all mild cases.

These results coincide with two recently published studies, although it should be clarified that these were carried out in other sporting populations[11,17]. Fikenzer *et al*.[11] tried to characterise the early effects of SARS-CoV-2 infections on myocardial morphology and cardiopulmonary function in 8 elite male handball players (27 ± 3.5 years old) compared to 4 uninfected teammates (22 ± 2.6 years old). The infected athletes were examined 19 ± 7 days after first testing positive by PCR. Ergospirometry analysis showed a significant reduction in VO_{2max} (-292 ml/min, -7.0%, p =0.03), oxygen pulse (-2.4 ml/beat, p = 0.015, -10.4%) and minute ventilation (VE) (-18.9 l/min, -13.8%) in those athletes with a history of infection (p <0.05, respectively). The maximal heart rate was seven beats/min higher (+3.7%, p =0.038). The authors suggest that a possible explanation for the changes observed could be the prevalence of pulmonary thrombosis and microembolism, contributing to reduced oxygen uptake, decreased O_2 pulse, and increased heart rate, albeit without clinical evidence of pulmonary thrombosis or embolism. The lung changes only occurred at peak load, indicating a more pronounced functional effect of SARS-CoV-2 infection on the heart. Similarly, Sliz *et al.* observed pre- and post-COVID-19 changes in 45 recreational and professional endurance athletes of both sexes. The evaluations were carried out with direct measurement and the device used was a treadmill or cycle ergometer depending on the competitive discipline[17]. Unlike our study, the authors reported a significant 6% decrease in VO_{2max}. They did, however, observe a 7% decrease in VO_2 at the anaerobic threshold and reported no differences in HRmax or maximal aerobic speed, coinciding with our study[17].

To date, we have not found scientific evidence from tests carried out on elite footballers. For this reason, this study provides important evidence which should be taken into consideration in post-COVID-19 sports training planning. We were obliged to compare our results with studies focusing on different sports disciplines[11,17]. Although this can be interpreted as a limitation, it is extremely difficult to evaluate athletes of this kind due to the complexity of the sports calendar and the availability of VO_{2max} measured with a gas analyser before and after COVID-19 for later comparison. The results point to the importance of carrying out evaluations of this kind on elite athletes for monitoring.

Conclusions

SARS-CoV2 infection causes functional impairment of cardiopulmonary performance in many athletes. It seems reasonable and safe to test athletes after SARS-CoV2 infection with ergospirometry to ensure health and trainability conditions. Detecting the decrease of the second ventilatory threshold (VT2) post-COVID-19 allows us to interpret the relevance of detraining in elite footballers. It is very important to demonstrate in this group of professional elite athletes without pre-existing diseases that the greatest impact of this disease is generated in a variable related more to halting training than to cardiopulmonary damage. Knowledge of their limitations can help the adaptation processes for recovery to pre-COVID-19 performance levels, stressing these physiological variables.

Conflict of interest

The authors declare that they are not subject to any type of conflict of interest.

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