SARS-CoV-2 infection and return to play in junior competitive athletes: is systematic cardiac screening needed?

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ABSTRACT

Background SARS-CoV-2 infection might be associated with cardiac complications in low-risk populations, such as in competitive athletes. However, data obtained in adults cannot be directly transferred to preadolescents and adolescents who are less susceptible to adverse clinical outcomes and are often asymptomatic.

Objectives We conducted this prospective multicentre study to describe the incidence of cardiovascular complications following SARS-CoV-2 infection in a large cohort of junior athletes and to examine the effectiveness of a screening protocol for a safe return to play.

Methods Junior competitive athletes suffering from asymptomatic or mildly symptomatic SARS-CoV-2 infection underwent cardiac screening, including physical examination, 12-lead resting ECG, echocardiogram and exercise ECG testing. Further investigations were performed in cases of abnormal findings.

Results A total of 571 competitive junior athletes (14.3±2.5 years) were evaluated. About half of the population (50.3%) was mildly symptomatic during SARS-CoV-2 infection, and the average duration of symptoms was 4±1 days. Pericardial involvement was found in 3.2% of junior athletes: small pericardial effusion (2.6%), moderate pericardial effusion (0.2%) and pericarditis (0.4%). No relevant arrhythmias or myocardial inflammation was found in subjects with pericardial involvement. Athletes with pericarditis or moderate pericardial effusion were temporarily disqualified, and a gradual return to play was achieved after complete clinical resolution.

Conclusions The prevalence of cardiac involvement was low in junior athletes after asymptomatic or mild SARS-CoV-2 infection. A screening strategy primarily driven by cardiac symptoms should detect cardiac involvement from SARS-CoV-2 infection in most junior athletes. Systematic echocardiographic screening is not recommended in junior athletes.

INTRODUCTION

SARS-CoV-2 is the causative virus responsible for the COVID-19 that rapidly spread worldwide with several implications on public health and in the world of sport concerning the spread of SARS-CoV-2 among athletes and sports teams.[1 2] Initial reports indicate that individuals younger than 18 were considerably less susceptible to becoming infected on exposure to SARS-CoV-2 and that children were largely spared from the most severe symptoms in COVID-19 and often asymptomatic.[1 3] However, cardiac consequences after COVID-19 have been described in adults and young and adolescent individuals.[4 5] SARS-CoV-2 infection-related multisystem inflammatory syndrome in children is a rare but severe hyperimmune response in children and adolescents that occurs days after the acute phase of viral infection, leading to severe cardiac manifestations, such as myocardial dysfunction and pericarditis.[1 6] Therefore, concerns exist regarding young athletes who want to return to play (RTP) after SARS-CoV-2 infection, given that exercise may potentially result in accelerated virus replication, increased inflammation and cellular necrosis with a proarrhythmic myocardial substrate during the acute phase of infection, particularly in the case of concealed cardiac complications.[7] Emerging data show that SARS-CoV-2 infection might also be associated with cardiac complications among young athletes, with a potential risk of myopericardial involvement leading to sport-related arrhythmias.[8 9] Consequently, national and international scientific societies have recommended cardiac screening before the RTP in competitive athletes, even if the protocols differ worldwide.[2 10 11] The absence of robust data, particularly in preadolescent and adolescent athletes, causes uncertainties concerning the optimal approach for appropriate cardiac risk stratification for athletes returning to intensive sport activity after COVID-19 infection.[12] Therefore, we conducted this prospective multicentre study to investigate (1) the prevalence of cardiovascular complications following SARS-CoV-2 infection in a large cohort of junior competitive athletes, and (2) the effectiveness of a cardiac screening protocol for a safe RTP.

METHODS

The study was conducted in non-professional junior competitive athletes (age range: 7–18 years) with previous asymptomatic or mildly symptomatic SARS-CoV-2 infection. Mild symptoms were defined as: non-specific and self-limited fatigue, non-persistent fever, anosmia or ageusia, nausea, vomiting, and/or diarrhoea, asthenia, headache, cough, sore throat and nasopharyngeal congestion. Cardiac symptoms included chest pain, palpitations, exertional dyspnoea and presyncope or syncope. Athletes with severe infection requiring hospitalisation or athletes >18 years of age were excluded from the study. Information about the time elapsing between the negativisation of the nasopharyngeal swab and the screening was also obtained. Athletes evaluated >45 days after the negativisation were excluded from the analysis. The participants were evaluated according to the preparticipation screening protocol recommended by the Italian Federation of Sports Medicine (https://www.fmsi.it/images/img/news/Circolare-idoneit-sportiva-np-covid-13-1-21.pdf) for resuming competitive training after the resolution of SARS-CoV-2 infection. According to the protocol, all competitive athletes were subjected to the following investigations:

- *Personal history and clinical profile*. History of pulmonary or cardiovascular disease, comorbidities, familiar history for sudden cardiac death (SCD) or coronary artery disease, drug therapy, type and duration of symptoms related to SARS-CoV-2 infection or symptoms suggestive of cardiac involvement (ie, palpitations, exertional dyspnoea, syncope, typical or atypical chest pain), type of sport practised (see online supplemental table 1 for the classification of sports disciplines).
- *Twelve-lead resting ECG*. The interpretation of ECG was performed according to the current international criteria for the interpretation of ECG in athletes.[13]
- *Echocardiography*. Biventricular size and function, wall motion abnormalities, the presence of valvular heart disease and pericardial effusion were analysed according to the standardised criteria applied to the general population and competitive athletes.[14 15] The structural or valvular abnormalities incidentally found and unrelated to SARS-CoV-2 infection (ie, bicuspid aortic valve, mitral valve prolapse, etc) were classified as 'other abnormalities'.
- *Exercise test*. All participants underwent an exercise test on a cycle ergometer or step test with a constant load, with ECG continuously monitored and recorded.[16] The presence of supraventricular or ventricular arrhythmias and/or T wave or ST anomalies and symptoms during exercise was analysed for the specific purposes of this study.[17]

The interpretation of the diagnostic examinations was performed by physicians trained in sports cardiology with experience in reading ECG, echocardiography and exercise testing in athletes.

Cardiac complications following SARS-CoV-2 included: reduced left ventricular function with or without segmental or global wall motion abnormality on echocardiography, presence of moderate pericardial effusion, pericarditis, myocarditis and new ventricular arrhythmias at rest or during exercise. Based on the size of the echo-free space seen between the parietal and visceral pericardia at end-diastole, pericardial effusion was classified into: trivial (seen only in systole), small (<10 mm), moderate (10–20 mm) and large (>20 mm).[18] In case of abnormalities identified by transthoracic echocardiography, 12-lead 24-hour ambulatory ECG monitoring, including a training session, and cardiopulmonary exercise testing were performed to evaluate exercise-induced symptoms, cardiopulmonary performance and the occurrence of ventricular arrhythmias at rest and during exercise.[19 20] Given the relevance of the characteristics of ventricular arrhythmias to detect subclinical abnormalities and particularly myocarditis,[21 22] accurate analysis of ventricular arrhythmias was performed: in case of premature ventricular beats with an uncommon morphology, complexity and response to exercise,[22 23] according to the current international guidelines,[19] or in case of suggestive symptoms, cardiac magnetic resonance (CMR) was performed to exclude the presence of myocardial involvement. The diagnosis of pericarditis was based on the presence of at least two of the four following criteria: pericarditic chest pain, pericardial rubs, new widespread ST-elevation or PR depression on ECG and pericardial effusion (new or worsening).[24] The diagnosis of myocarditis was based on the presence of two main features of the updated Lake Louise criteria at CMR: myocardial oedema by elevated T2 signal and myocardial injury by the presence of non-ischaemic late gadolinium enhancement (LGE).[25]

Statistical analysis

The normal distribution of all continuous variables was examined using the Shapiro-Wilk test, and data are presented as mean±SD. Categorical variables are expressed as percentages. According to data distribution, the unpaired t-test and the Mann-Whitney test were used to assess the between-group significance (asymptomatic vs symptomatic and younger vs older athletes). The median value of the age of the overall population was used to distinguish between younger and older athletes. The χ^2 test was used for nominal data. A p value <0.05 was considered statistically significant. Statistics were performed using SPSS V.21.0 (Statistical Package for the Social Sciences).

RESULTS

A total of 571 competitive athletes (mean age 14.3±2.5 years) with previous asymptomatic or mildly symptomatic SARS-CoV-2 infection were included in the study. The demographic characteristics of the study population are reported in table 1. Most athletes (61.3%) were males, and most were engaged in mixed sports (ie, soccer, volleyball, basketball). About half of the population (50.3%) was mildly symptomatic, particularly for fever, anosmia and ageusia, with an average duration of symptoms of 4±1 days. Most of the evaluations were performed after 30 days from a negative nasopharyngeal swab for SARS-CoV-2. The main clinical findings are reported in table 2. Resting ECG was normal in all athletes after SARS-CoV-2 infection. ST-T abnormalities were not found during exercise testing, while 4.2% of athletes showed premature ventricular beats with common (infundibular and/or fascicular) morphology and normal response during exercise.

All athletes underwent echocardiography: normal biventricular dimension and function, and no significative valvular regurgitation and/or stenosis was observed in the overall population. The screening allowed to find by chance other abnormalities, the most frequent of which were bicuspid aortic valve and mitral valve prolapse. Pericardial involvement was found in 18 athletes (3.2%) after SARS-CoV-2 infection. In the absence of cardiac symptoms and ECG abnormalities, a small pericardial effusion was found in 15 athletes (2.6%). In one female athlete (0.2%), a moderate pericardial effusion measuring 10 mm in the anterior wall of the right ventricle was found. This athlete was evaluated 15 days after a negative nasopharyngeal swab. Two athletes complained of pericarditic chest pain during the infection, typically sharp, improved by sitting up and leaning forward, associated with small pericardial effusion on echocardiography and was classified as pericarditis (0.4% of the overall population). The characteristics of athletes with pericardial involvement are reported in table 3 (see also online supplemental video). In these subjects, 12-lead resting ECG was normal and normal biventricular function was found by echocardiography. Twelve-lead

Table 1 Demographic characteristics of the study population	
Variables	**n=571**
Age (years)	14.3±2.5
Males, n (%)	350 (61.3)
Caucasian ethnicity, n (%)	559 (97.9)
Asymptomatic, n (%)	284 (49.7)
Mild symptomatic, n (%)	287 (50.3)
Fever, n (%)	183 (63.8)
Cough, n (%)	49 (17.1)
Asthenia, n (%)	70 (24.4)
Ageusia, n (%)	98 (34.1)
Anosmia, n (%)	98 (34.1)
Diarrhoea, n (%)	16 (5.6)
Headache, n (%)	53 (18.5)
Cardiac symptoms	
Chest pain, n (%)	2 (0.4)
Symptom duration (days)	4±1
Evaluation time from negativisation	
<15 days, n (%)	10 (1.7)
16–30 days, n (%)	58 (10.2)
31–45 days, n (%)	503 (88.1)
BSA (m^2)	1.62±0.01
BMI (kg/m^2)	20.9±0.14
Type of sport	
Endurance (%)	4.2
Mixed (%)	87.7
Power (%)	6.9
Skill (%)	1.2

BMI, body mass index; BSA, body surface area.

Table 2 Clinical findings at first-line evaluation in asymptomatic or mildly symptomatic SARS-CoV-2-positive junior athletes	
Variables	**n=571**
Resting and exercise ECG	
Resting HR (bpm)	78±15
PR interval (ms)	143±22.6
First-degree atrioventricular block, n (%)	4 (0.7)
QRS interval (ms)	84±9
QRS axis (°)	67±18
Incomplete RBBB, n (%)	90 (15.7)
Complete RBBB, n (%)	6 (1)
QTc duration (ms)	388±30
Pathological T wave inversion, n (%)	0 (0)
Abnormal resting ECG, n (%)	0 (0)
Athletes with common PVBs during exercise testing, n (%)	24 (4.2)
Athletes with uncommon PVBs during exercise testing, n (%)	0 (0)
ST-T abnormalities during exercise, n (%)	0 (0)
Echocardiography	
LV EDD (mm)	45.9±5.0
LV ESD (mm)	27.6±4.5
IVST (mm)	7.8±1.2
PWT (mm)	7.7±1.2
LV EF (%)	63.5±4.7
LV wall motion abnormalities, n (%)	0 (0)
Aortic root (mm)	27.1±3.7
Ascending aorta (mm)	25.0±3.6
Aortic arch (mm)	21.3±2.9
LA area (cm^2)	16.1±4.5
LA volume (mL)	29.5±9.8
LA volume index (mL/m^2)	18.2±5.3
Mid-cavity RV diameter (mm)	28.2±7.2
TAPSE (mm)	24.2±3.1
s′ velocity (m/s)	0.14±0.02
RV wall motion abnormalities, n (%)	0 (0)
IVC diameter (mm)	16.6±4.5
Pericardial involvement, n (%)	18 (3.2)
Small pericardial effusion, n (%)	15 (2.6)
Moderate pericardial effusion, n (%)	1 (0.2)
Small pericardial effusion with a final diagnosis of pericarditis, n (%)	2 (0.4)
Other abnormalities	
Bicuspid aortic valve	6 (1.1)
Mitral valve prolapse	5 (0.9)
Atrial septal defect	1 (0.2)
Patent foramen ovale	4 (0.7)
Patent ductus arteriosus	1 (0.2)

IVC; inferior vena cava.EDD, end-diastolic diameter; EF, ejection fraction; ESD, end-systolic diameter; HR, heart rate; IVST, interventricular septum thickness; LA, left atrial; LV, left ventricular; PVB, premature ventricular beats; PWT, posterior wall thickness; RBBB, right bundle branch block; RV, right ventricular; TAPSE, tricuspid annular plane systolic excursion.

ambulatory ECG monitoring, including a training session and exercise testing, did not show frequent or uncommon ventricular arrhythmias or ST-T abnormalities.

Three athletes (two athletes with pericarditis and the athlete with moderate pericardial effusion) underwent CMR that demonstrated normal biventricular function and absence of myocardial oedema or LGE. Blood testing demonstrated a small rise in C-reactive protein (CRP) in athletes with final diagnosis of pericarditis, while the CRP was within the normal limits in the athlete with moderate pericardial effusion.

In athletes with asymptomatic small pericardial effusion and negative findings at additional investigations, a gradual RTP was allowed, while the two athletes with pericarditis and the athlete with moderate pericardial effusion were temporarily disqualified. In these three athletes, during the follow-up, there were no major cardiac events, including the absence of complex ventricular arrhythmias or relevant symptoms. An almost complete spontaneous regression of the pericardial involvement and no inducible arrhythmias on exercise testing were found after 2 months from the first echocardiographic investigation, that is, 3 months after the resolution of the acute infection. In the complete absence of symptoms and/or arrhythmias, a gradual RTP was also allowed for these three athletes.

When athletes with mild COVID-19-related symptoms were compared with asymptomatic subjects, irrespective of cardiac symptoms, they more frequently showed pericardial involvement (4.9% vs 1.4%, p=0.017). The median age of the study population was 14 years: when children >14 years were compared with children <14 years of age, there was no difference in the prevalence of pericardial involvement (3.9% vs 2.4%, p=0.31) (see table 4).

Figure 1 summarises the main results of this study.

DISCUSSION

This study investigated the prevalence of cardiac complications after SARS-CoV-2 infection in junior athletes screened before their RTP. An extensive clinical screening was conducted including physical examination, personal and family history, 12-lead resting ECG, exercise testing and echocardiography. The main findings of this multicentre study are: (1) cardiac complications in junior athletes recovering from SARS-CoV-2 infection are uncommon and not associated with malignant ventricular arrhythmias; (2) systematic cardiac screening with

Table 3 Characteristics of competitive athletes with pericardial involvement after SARS-CoV-2 infection

Patient No	COVID symptoms	Cardiac symptoms	Evaluation time from negative swab (days)	Resting ECG	Echocardiography	PVBs at ambulatory ECG monitoring	PVB during exercise testing	Final diagnosis	Eligibility to sports competitions	Follow-up
1	Asthenia	Pericarditic chest pain	>30≤45	Normal	Small pericardial effusion	No	No	Pericarditis	No	Regression after 2 months and gradual RTP
2	No	Pericarditic chest pain	>30≤45	Normal	Small pericardial effusion	No	No	Pericarditis	No	Regression after 2 months and gradual RTP
3	Fever	No	>15<30	Normal	Moderate pericardial effusion	No	No	Pericardial effusion	No	Regression after 2 months and gradual RTP
4	Fever Cough	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
5	No	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
6	Asthenia	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
7	Fever Ageusia Anosmia	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
8	Cough Asthenia	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
9	No	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
10	Fever Cough	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
11	No	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
12	Fever Asthenia	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
13	Fever	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
14	No	No	>15<30	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
15	Fever Asthenia	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
16	Anosmia	No	>15<30	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
17	Ageusia	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	
18	Asthenia	No	>30≤45	Normal	Small pericardial effusion	No	No	Small pericardial effusion	RTP	

PVB, premature ventricular beats; RTP, return to play.;

Table 4 Results of return-to-play screening in junior competitive athletes after SARS-CoV-2 infection: data are presented according to different age groups

Variables	<14 years (n=290)	≥14 years (n=281)	Overall P value
Asymptomatic during COVID-19, n (%)	162 (55.8)	188 (66.9)	0.002
Symptom duration (days)	4.1±8.4	3.2±8.0	0.56
Resting HR (bpm)	81±15	75±14	<0.0001
Echocardiography			
LV EDD (mm)	43.9±4.5	48.0±4.5	<0.0001
LV ESD (mm)	25.9±4.2	29.5±4.1	<0.0001
LV EF (%)	63.8±4.9	63.2±4.5	0.14
Mid-cavity RV diameter (mm)	27.2±6.6	29.3±7.7	0.01
s′ velocity (m/s)	0.14±0.02	0.14±0.02	0.71
Aortic root (mm)	25.6±3.3	28.6±3.6	<0.0001
Ascending aorta (mm)	23.6±3.1	26.5±3.4	<0.0001
Aortic arch (mm)	19.9±2.9	22.6±2.2	<0.0001
Pericardial involvement, n (%)	7 (2.4)	11 (3.9)	0.31
Pericarditis, n (%)	0 (0)	2 (0.7)	0.98

HR, heart rate; LV, left ventricular; EDD, end-diastolic diameter; ESD, end-systolic diameter; EF, ejection fraction; RV, right ventricular.

echocardiography seems unnecessary in junior athletes after SARS-CoV-2 infection who are asymptomatic or mildly asymptomatic; and (3) the presence of cardiac symptoms, or ECG abnormalities and uncommon arrhythmias at rest or during exercise found on routine cardiac screening should drive additional diagnostic investigations.

Prior studies show that SARS-CoV-2 infection can be associated with cardiac complications, and high rates of cardiac injury in hospitalised patients were recognised early in the COVID-19 pandemic.[26 27] Pericardial disease, including acute pericarditis and pericardial effusion, appear to be common manifestations of COVID-19-mediated cardiac injury.[28 29] CMR studies have demonstrated cardiac involvement in up to 78% of patients with recent COVID-19 illness, with myocardial inflammation and pericardial enhancement detected in 60% and 22% of patients, respectively.[28] Cardiac complications after SARS-CoV-2 infection have also been demonstrated among young athletes, with a potential risk of myopericardial involvement leading to sport-related arrhythmias.[8 9] One single-centre study demonstrated that more than one in three previously healthy college athletes recovering from COVID-19 infection showed imaging features of a resolving pericardial inflammation, with 39.5% showing late pericardial enhancement with associated pericardial effusion detected by CMR.[9]

Larger cohorts of competitive athletes have demonstrated lower rates of cardiac involvement after SARS-CoV-2 infection. A low prevalence of cardiac involvement (0.6%) was demonstrated in 789 professional athletes (mean age: 25±3 years) who were evaluated using troponin testing, 12-lead resting ECG and resting echocardiography, followed by clinically indicated CMR.[12] Using the same screening for the RTP, a low prevalence (0.5%–3.0%) of definite, probable or possible SARS-CoV-2 cardiac involvement and a low risk of adverse cardiac events during short-term follow-up were found among 2820 athletes (mean age: 20 years) with prior SARS-CoV-2 infection.[30] The

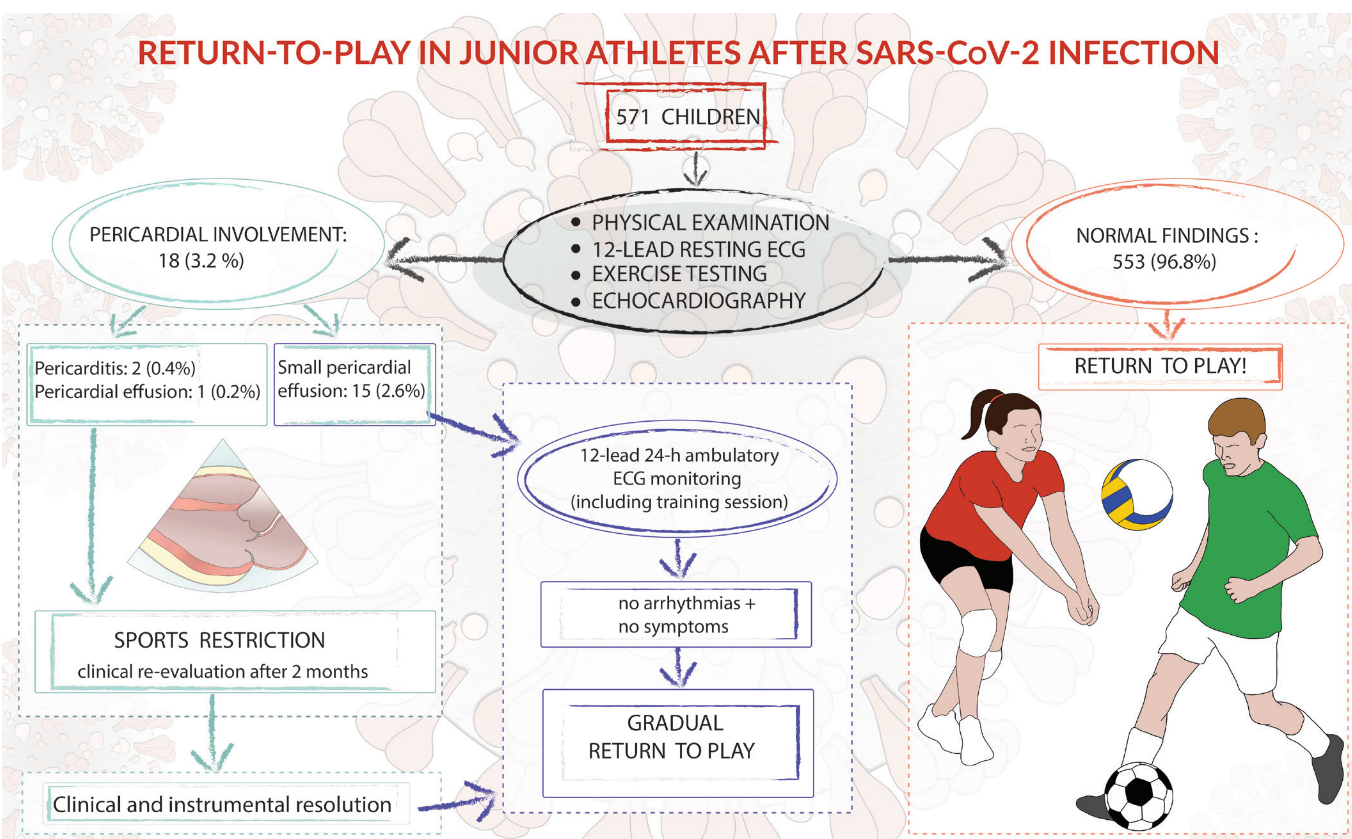

Figure 1 Central illustration summarising the main findings of the study.

present study demonstrated for the first time in a large cohort of junior athletes (age range: 7–18 years) that pericardial involvement was found in 3.2% of the cases, with cardiac complications requiring a delay in the RTP being very rare, that is, moderate pericardial effusion (0.2%) and pericarditis (0.4%). Notably, none of these athletes with pericardial involvement demonstrated complex or potentially life-threatening ventricular arrhythmias at exercise testing and 24-hour ambulatory ECG monitoring including a training session, and CMR was normal without findings of myocardial involvement in the three athletes temporarily restricted from sport.

Concerns exist regarding young athletes returning to sports practice and competitions after SARS-CoV-2 infection, given that exercise may result in accelerated virus replication with a proarrhythmic myocardial substrate during the acute phase, particularly in case of concealed cardiac complications.[7] Consequently, national and international scientific societies have recommended cardiac screening before the RTP in competitive athletes to identify cardiac complications after SARS-CoV-2 infection, even if the protocols differ worldwide.[10 11 29 31 32] Indeed, while some experts do not advocate cardiovascular risk stratification in asymptomatic or mildly symptomatic athletes after SARS-CoV-2 infection, others suggest a more extensive evaluation by 12-lead resting ECG and/or echocardiography and/or maximal exercise testing, reserving further investigations (eg, CMR) in case of abnormal findings. Robust data on the population of preadolescent and adolescent athletes are missing, even though they represent a large proportion of the athletic population.

This study fills an important knowledge gap regarding the role and diagnostic yield of cardiac screening in preadolescent and adolescent athletes after SARS-CoV-2 infection. Prior data found in adult athletes have been applied to junior athletes without validation. Indeed, it has been shown that individuals younger than 18 years of age were considerably less susceptible to becoming infected on exposure to SARS-CoV-2, that children were largely spared from the most severe symptoms in COVID-19, and were often asymptomatic.[1 3] Indeed, half of the population (49.7%) of our study was completely asymptomatic. In agreement with other studies, the most described symptom in the paediatric population enrolled in this study was fever (63.8%), and contrary to adults with COVID-19, children were more likely to present with extrarespiratory symptoms (eg, diarrhoea).[33] Moreover, children showed short-lived symptoms with an average duration of symptoms of 4±1 days, compared with the duration of the disease described in non-athlete adults (ie, 11.5±5.7 days).[34] As a consequence, some authors consider cardiovascular risk stratification unnecessary for athletes younger than 15 years of age, in the absence of systemic or cardiovascular symptoms, emphasising the low prevalence of cardiac involvement and the absence of adverse events during short-term clinical surveillance related to SARS-CoV-2 asymptomatic and mild infections.[10 30] However, they recommend a cardiovascular risk stratification in junior athletes in case of systemic or cardiovascular symptoms during or after the infection.[10] The present study demonstrates that a small pericardial effusion may be occasionally found in asymptomatic children after SARS-CoV-2 infection, even when not associated with arrhythmias at rest or during exercise and in absence of ECG abnormalities. Conversely, the diagnosis of pericarditis in 0.4% of the study population was mainly driven by typical cardiovascular symptoms, that is, pericarditic chest pain, that could be detected during a new clinical reassessment that would have required an evaluation by echocardiography and additional examinations. A study in college athletes also found that cardiac involvement after SARS-CoV-2 infection was more likely in the presence of cardiopulmonary symptoms, specifically exertional chest pain.[35] Similarly, a study in competitive athletes demonstrated that cardiac consequences (and particularly myocarditis) after SARS-CoV-2 infection should be based on the detection of uncommon arrhythmias and cardiac symptoms.[36] Preparticipation evaluation (PPE) is traditionally viewed as a tool to screen for unknown cardiovascular diseases that predispose the athletes to sudden cardiac death. Before the COVID-19 pandemic, myopericardial involvement was routinely diagnosed among competitive athletes presenting with postviral cardiovascular symptoms and possibly ECG abnormalities or malignant arrhythmias at rest and during exercise, and ultimately demonstrated by imaging techniques.[30] The present findings demonstrate that a systematic screening by echocardiography seems unnecessary in junior athletes after SARS-CoV-2 infection, in the absence of cardiac symptoms, as the most important cardiovascular complication identified was symptomatic pericarditis (in the absence of arrhythmias), and this condition would have been suspected during the clinical evaluation. Only one case in our population had isolated pericardial effusion without symptoms that would not have been detected without echocardiography. However, this condition was not associated with arrhythmias or other pathological findings and presented a spontaneous resolution during the follow-up, questioning the true risk of this condition. Notably, systematic echocardiographic screening identified previously unknown and not negligible cardiac conditions, unrelated to SARS-CoV-2 infection and not detectable by a PPE based on physical examination and 12-lead resting ECG, such as bicuspid aortic valve and mitral valve prolapse, in agreement with its use in the everyday clinical practice.[37]

Therefore, according to the present findings, screening echocardiography before the RTP in junior athletes after SARS-CoV-2 infection should not be recommended given the relatively low prevalence of cardiac complications. Conversely, echocardiography and additional tests, such as ambulatory 24-hour ECG monitoring, exercise testing and CMR, should be reserved for young athletes with a more severe clinical course and with cardiopulmonary symptoms, such as chest pain, shortness of breath, palpitations or exercise intolerance, or demonstration of uncommon ventricular arrhythmias that may raise the suspicion of underlying myocardial involvement.

Limitations

Junior athletes enrolled in this study were evaluated annually according to the Italian national protocol of PPE established for competitive athletes. However, the PPE does not include echocardiography. Therefore, a previous echocardiographic evaluation is not available, and the presence of small pericardial effusion cannot be attributed with certainty to COVID-19. However, in junior athletes with moderate pericardial effusion and pericarditis, this study demonstrated a resolution of symptoms and echocardiographic findings during follow-up, suggesting the causative role of SARS-CoV-2.

The time elapsed from the negativisation of the nasopharyngeal swab to the clinical evaluation has likely influenced the rate of cardiac complications. However, the design of this study reflects the current rules applied to clinical centres in Italy in which the patient is usually evaluated after the negativisation of the nasopharyngeal swab. In this study, most of the athletes were evaluated between 30 and 45 days after the negativisation with only a minority (1.7%) evaluated a few days after the negativisation. Thus, some cases of cardiac involvement could have resolved prior to the cardiac evaluation performed. Notably, the presentation of cardiac consequences of COVID-19 can be delayed and not present when the evaluation is performed only a few days after infection resolution.[38] Given the possibility of a delayed presentation of cardiac complications, our study supports that the absence of clinical complications can be reasonably excluded in adolescent athletes within the return-to-sport timeline and regulations required in Italy.

CMR is usually recommended as the gold-standard non-invasive technique to diagnose myocarditis. However, in the present study, only a minority of participants underwent CMR. Indeed, an extensive screening including CMR is neither feasible nor cost-effective, particularly if applied to all competitive athletes after SARS-CoV-2 infection. Accordingly, in this study, CMR was performed in agreement with the current guidelines and was driven by clinical data, particularly symptoms and uncommon ventricular arrhythmias. The theoretical application of CMR to the entire population, although not clinically indicated, would have likely increased the number of junior athletes with cardiac involvement that the present study may underestimate.

Finally, although short-term follow-up was available for children with cardiac involvement and no adverse events were recorded, long-term follow-up is needed to further inform the clinical outcomes of junior athletes experiencing SARS-CoV-2 infection.

CONCLUSIONS

The prevalence of pericardial involvement was low in young competitive athletes after asymptomatic or mildly symptomatic SARS-CoV-2 infection. Cardiac complications requiring a delay in the RTP were rare, that is, moderate pericardial effusion (0.2%) and pericarditis (0.4%). Cardiac screening driven by cardiopulmonary symptoms should detect cardiac involvement in most junior athletes after SARS-CoV-2 infection and facilitate a safe RTP. Systematic screening with echocardiography is not recommended in junior athletes after asymptomatic or mildly symptomatic SARS-CoV-2 infection and should be reserved for children with cardiopulmonary symptoms, ECG abnormalities and arrhythmias found on routine screening at rest or during exercise.

What are the findings?

- Pericardial involvement was found in 3.2% of junior athletes after asymptomatic or mildly symptomatic SARS-CoV-2 infection.
- Pericarditis was found in 0.4% of junior athletes following SARS-CoV-2 infection.
- No myocardial involvement or complex arrhythmias were found in junior athletes with pericardial involvement.

How might it impact on clinical practice in the future?

- A systematic screening strategy with echocardiography is not recommended in junior competitive athletes after asymptomatic or mildly symptomatic SARS-CoV-2 infection and should be reserved for children with cardiopulmonary symptoms, such as chest pain, palpitations or exertional fatigue, or in the presence of arrhythmias.

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