Managing the combined consequences of COVID-19 infection and lock-down policies on athletes: narrative review and guidelines proposal for a safe return to sport

To cite: Fabre J-B, Grelot L, Vanbiervielt W, et al. BMJ Open Sport Exerc Med 2020;0:e000849. doi:10.1136/bmjsem-2020-000849

INTRODUCTION

The SARS-CoV-2 (COVID-19) pandemic is a global health emergency. According to the data available, from the beginning of the epidemic to 23 August 2020, a total of 23,256,567 people were infected, and 805,733 died in 202 countries, as reported by the Coronavirus Resource Centre of the John Hopkins University of Medicine.1 Many research teams proposed that COVID-19 and β-coronaviruses are

What is already known?

► COVID-19 can have a potential effect of the central nervous system and the motor drive. Electromyography, twitch interpolation and evoked potentials may be implemented in athletes who have a history of severe COVID-19 infection and/or demonstrate a slow recovery of force/power production capacity.

What are the findings

► COVID-19 may lead to multiorgan failure, and especially cardiac and vascular injuries. Allowing athletes to return to practice on the sole basis of cardiac assessment may underestimate risks. To have a more global assessment and insights about the severity of the disease, blood- and urine-specific biomarkers are recommended.

► Since COVID-19 is associated with pulmonary complication, athletes could experience a reduction in aerobic exercise capacity. VO2 evaluation is thus recommended to help athletes to improve return to training.

► COVID-19 can have a potential effect of the central nervous system and the motor drive. Electromyography, twitch interpolation and evoked potentials may be implemented in athletes who have a history of severe COVID-19 infection and/or demonstrate a slow recovery of force/power production capacity.

What are the findings

► COVID-19 is currently characterised by influenza-like symptoms and respiratory troubles; in some cases, multiorgan failure may occur and especially cardiac injury. The main difficulty is that symptoms of COVID-19 vary among individuals, and athletes may be affected by no apparent sign of the disease. This could be a real danger for athletes when returning to their usual training and play.

► Isolation could have a significant impact on the physical and mental state of the athletes leading to detraining. A reduction in aerobic capacities, muscular power and flexibility and a diminution of muscle mass are expected.

► Combined effect of detraining and COVID-19 symptoms may influence the arousal of post-viral fatigue syndrome, thus influencing the capacities of athletes to perform exercise and increasing the risk of injury.

ABSTRACT

COVID-19 pandemic is a global health matter. The disease spread rapidly across the globe and brought the world of sports to an unprecedented stoppage. Usual symptoms of the disease are fever, cough, myalgia, fatigue, slight dyspnoea, sore throat and headache. In more severe cases, dyspnoea, hypoxaemia, respiratory failure, shock and multiorgan failure occur. This appears to be a self-limiting phenomenon related to individuals with coexisting medical conditions, such as hypertension, diabetes and cardiovascular disorders. Nevertheless, cases have been reported in professional soccer players in extremely good fitness condition, demonstrating that athletes are not spared by the disease. Despite COVID-19 clinical manifestations are mainly respiratory, major cardiac complications are being reported, leading to acute myocarditis. One difficulty is that symptoms of COVID-19 vary among individuals, with athletes being affected with no apparent sign of the disease. This could be a real danger for amateur or professional athletes when returning to their usual training and thus to play. Another threat is that the lock-down policies did not allow most athletes to follow their usual training routines. There is thus a need for a careful approach by the sports medicine community to ensure safety of all athletes before they return to sport. Here, we propose evaluation guidelines of fitness and health of athletes to (1) reduce any lethal risk of practice, especially myocarditis and sudden cardiac death; (2) evaluate the combined consequences of the disease and detraining on the physical abilities and biological profile of athletes; and (3) monitor postinfection fatigue symptoms.

Jean-Bernard Fabre ©,1 Laurent Grelot,2 William Vanbiervielt,3 Julien Mazerie,1 Raphael Manca,3 Vincent Martin ©4,5

© Author(s) (or their employer(s)) 2020. Re-use permitted under CC BY. Published by BMJ. For numbered affiliations see end of article.

Correspondence to Jean-Bernard Fabre; jb.fabre@humanfab.com

© Author(s) (or their employer(s)) 2020. Re-use permitted under CC BY. Published by BMJ. For numbered affiliations see end of article.

Correspondence to Jean-Bernard Fabre; jb.fabre@humanfab.com
from the same family with a 79.0% nucleotide identity to SARS-CoV and 51.8% identity to MERS–coronavirus (MERS). Moreover, research have demonstrated that COVID-19 genome has 96% of similarity with the entire genome of bat coronavirus. The SARS-CoV-2 is predominantly spreading through the respiratory tract and uses the same receptor as SARS-CoV (ACE2). The principal source of contagion is most likely human-to-human aerosol transmission, which happens essentially through contaminated droplets, hands or surfaces. Virus particles present in secretions from an infected person’s respiratory system infect others through direct contact with mucous membranes. Also, the median incubation period is between 2 days and 12 days (median 5.1 days). Thus, based on the data from the previous coronavirus epidemics (SARS-CoV and MERS), COVID-19 has first been described as influenza viral infections and a pathogen that primarily targets the respiratory system (ie, type 2 pneumocytes) with pneumonia and acute respiratory distress syndrome (ARDS) for the most severe cases. After few months and a better understanding of the disease, it appears that COVID-19 also causes direct myocardial injury, disseminated intravascular coagulation and multiorgan failure. One of the main difficulties is that symptoms of COVID-19 vary among individuals, and even young athletes can be infected with no apparent symptom of the disease. This could be a real danger for amateur or professional athletes when returning to their usual training and subsequently when they will return to intensive play. Indeed, as an emerging infectious disease, COVID-19 late effects and sequelae are still unknown for both the moderate and severe forms. The disease spread rapidly across the globe owing to the unique properties of the virus (ie, extraordinary genetic diversity, highly contagious, easy spreading, relative resistance to climatic variations), causing an unprecedented pandemic forcing governments to impose an almost global quarantine. At the beginning of 2020 (January–March), the whole world, including the world of sports, entered an extreme and unknown situation, where, gradually, all sports competitions were postponed and any organised training or practice was banned. In the absence of a vaccination or an antiviral therapy, physical distancing emerged as the key step against COVID-19. Isolation, of course, did not allow athletes to follow their usual training and competitive routines. Regardless of duration, isolation could have a significant impact on the physical and mental state of an athlete. Staying in quarantine can have negative effects on physiological systems, especially aerobic capacities, muscular performance and body composition. This well-known phenomenon is called detraining. After at least 4 weeks of quarantine, depending on country lock-down measures, the rates of new infection begin to plateau and even decline in some countries. This glimmer of hope has created an enthusiasm and a collective euphoria about the resumption of normal sports activity. To reduce injury risk and promote the return of performance, having a better understanding of the combined effect of detraining and COVID-19 infection seems to be relevant. Hence, there is an emergency for a global and purposeful approach to help the sports medicine community to ensure safety and wellness of all athletes before they return to sport. We propose here a global model of evaluation to (1) reduce any lethal risk of practice, especially myocarditis and sudden cardiac death (SCD); (2) evaluate the combined consequences of the disease and detraining on the physical abilities and biological profile of athletes; and (3) monitor postinfection fatigue symptoms.

**COVID-19 SYMPTOMS AND COMPLICATIONS**

Usual symptoms of the disease are fever, cough, myalgia, fatigue, slight dyspnoea, sore throat, headache and conjunctivitis. Gastrointestinal involvement was also reported in a smaller percentage of cases, with diarrhoea, nausea and vomiting. Only around 10% of cases become serious, with dyspnoea, hypoxaemia and an extensive (>50%) destruction of the lung parenchyma leading to fibrosis. In around 5% of cases, the disease evolved in a critical condition, with respiratory failure, pneumonia, shock, multiorgan failure and, in the most serious cases, death, which is almost always caused by progression to ARDS and multiorgan failure. Acute hypoxaemia may cause obstinate dyspnoea with the need for oxygen therapy administration through high-flow nasal oxygen, or through the application of a non-invasive positive pressure (with oronasal or face masks, helmets). Unfortunately, in the case of O₂ saturation worsening, orotracheal intubation and invasive mechanical ventilation are mandatory in intensive care unit. However, SARS-CoV-2 infection does not only affect lungs.

**CARDIOVASCULAR COMPLICATION OF COVID-19**

Despite COVID-19 clinical manifestations are essentially respiratory, major cardiac and vascular (ie, vasculitis) complications are being reported. One of the proposed mechanisms of myocardial injury includes a cytokine storm that develops during severe COVID-19 illness. This may lead to decrements in cardiac function, similar to those seen in other forms of sepsis, with features that overlap with classic forms of ‘stress’ or catecholamine-induced cardiomyopathy. To date, this appears to be a self-limiting phenomenon confined to the severe phases of the illness in individuals with coexisting medical conditions, such as hypertension, type 2 diabetes and cardiovascular disorders. Alternatively, COVID-19 may directly infect myocardial cells, thereby leading to myocarditis with lymphocyte-rich inflammatory histology, acute impairment of cardiac muscle function and potentially residual chronic scars with increased vulnerability to malignant ventricular arrhythmias. Importantly, myocarditis has recently been reported in patients who did not present symptoms, such as fever or respiratory difficulties. One of the major difficulties is that...
symptoms of COVID-19 vary among individuals.¹⁸ Lavezzo and colleagues (unpublished data, 2020) reported in a cohort study conducted in the town of Vo Euganeo in Italy that around 30–75% of individuals with positive RT-PCR throat swab results remain asymptomatic, while others develop mild influenza-like symptoms. It is therefore difficult to differentiate COVID-19 from other respiratory diseases,²⁶ ²⁷ which may be a real threat. Interestingly, many professional team sport players in extremely good fitness condition have been infected (unpublished data, French Soccer Federation, 2020), demonstrating that athletes are not spared by the disease. Although definite evidence is lacking, athletes may bear higher risk of developing myocarditis than the general population. Sports activity can influence the susceptibility to infections, depending on the intensity and duration of the physical exercise.²⁸ While moderate physical activity may improve immunological defences,²⁹ ³⁰ intense and prolonged training or competition lower the immunity by reducing salivary secretory IgA, lactoferrin and lysozyme altering the T-cell response.³¹ All mechanisms may increase the vulnerability of athletes to viral infections.²⁹ ³⁰ The myocarditis associated with COVID-19 may be an additional threat since acute cardiac injury is observed in almost one-fifth of patients, with a 50% survival rate.³¹ Myocarditis has been traditionally considered as the cause of life-threatening ventricular arrhythmias and SCD in athletes. The prevalence and acute and delayed clinical implications among infected people who experience mild illness or who remain asymptomatic remain completely unknown. Also unknown is the incidence of silent myocardial inflammation that lingers long after the resolution of typical COVID-19 symptoms, a form of disease that may uniquely affect athletes during resumption of training and competition.

This could be a real danger for amateur or professional athletes. There is a need to prevent lethal risk, especially myocarditis and SCD risk, prior to any practice.

CARDIAC TESTING IN ATHLETES PREVIOUSLY INFECTED WITH COVID-19

From the perspective of heart health, the preparticipation evaluation (PPE) is traditionally considered as a tool to screen for occult cardiovascular diseases that predispose the athlete to SCD.³² In the context of COVID-19, it would be prudent to adopt a broader approach of the cardiovascular PPE. In addition to using the PPE to search for rare genetic and congenital conditions, it is recommended to look for cardiovascular sequelae of COVID-19 to ensure a safe return to sport. Though imperfect, medical history and physical examination are valuable tools for identifying athletes with underlying myocardial inflammation and/or overt myocarditis. The use of 12-lead ECG is crucial in the initial evaluation of athletes. Specialist must seek patterns that reflect myocardial inflammation such as T-wave inversions and new ST segment changes.³³ Repolarisation abnormalities are the most common alterations in acute myocarditis, being detected in 40% of the patients. The most notable ECG feature of early repolarisation is ST segment elevation, which may vary in terms of morphology, location and degree. T-wave inversion can also be observed particularly in black athletes but confined to leads V1–V4.³⁴ For more details about acute myocarditis and ECG evaluation, readers should refer to the excellent review of Vio and colleagues.³⁵

However, as failure to identify athletes with myocarditis by preparticipation screening ECG has been reported before,³⁶ blood sampling as a complementary approach during the PPE is recommended.³⁷ ³⁸ Biomarkers indicative of myocardial injury are indeed elevated in myocarditis. In a recent meta-analysis review about the effects of COVID-19 on cardiac biomarkers, Li and colleagues³⁹ found troponin I significantly increased in patients with COVID-19 with severe disease compared with those with milder infection. Increases in troponin I, creatine kinase (CK-MB) and N-terminal pro b-type natriuretic peptide (NT-pro BNP) are indicators of possible cardiac damage during COVID-19 infection, and three case reports have found fulminant myocarditis³⁹ ⁴⁰ and cardiac tamponade⁴¹ after COVID-19 infection. We then suggest that troponin I, CK-MB and NT-pro BNP must be routinely measured in infected athletes before they return to play.

This will help to identify those infected athletes that may require additional testing and medical care prior to return to play. However, allowing athletes to return to practice on the sole basis of cardiological assessment may underestimate risks since the COVID-19 can lead to multiorgan failure. There is thus a need for a broader monitoring prior to return to practice.

MULTIORGAN THREAT AND GLOBAL ASSESSMENT FOR INFECTED ATHLETES

In about 5% of the cases, SARS-CoV-2 infection does not only affect lungs and heart. As commonly observed in sepsis, liver and kidney alterations might occur.⁴² Hepatocytes degenerate, liver sinusoids are hyperaemic with microthrombi and can lead to a metabolic disorder. So far, these complications are reported only in severe forms, but less is known about athletes infected with milder symptoms and the potential detrimental effect on liver and kidney of an early return to sport, which would result in misadapted physiological responses to exercise. We then suggest adding specific blood and urine biomarkers to the PPE to help understand the severity of the infection in athletes before a return to sport. Recent work reported that C reactive protein (CRP) levels are increased in patients with COVID-19, and it has been shown that median CRP values are strongly correlated with disease severity and prognosis.⁴³ Based on a global review of laboratory markers, complete blood count, interleukin 6, alanine aminotransferase, aspartate aminotransferase, albumin, CRP, lactate dehydrogenase, procalcitonin, ferritin,⁴⁴ troponin I, CK-MB and NT-pro BNP can be relevant to explore the level of severity of COVID-19 in patients.⁴⁵ ⁴⁶ ⁴⁷ ⁴⁸ ⁴⁹ To prevent asymptomatic acute kidney injury that may result from COVID-19 infection, we recommend assessment of traditional urine biomarkers such as the glomerular filtration rate of the kidney,
creatine, albumin urea, cystatin C, beta-trace protein, beta-2 microglobulin and fatty acid-binding proteins. For a better understanding, biomarkers are presented in Table 1. During the first month of practice, tracking the evolution of kidney and liver biomarkers could be of great help to understand the consequences of the viral infection and prevent a putative worsening due to a too rapid and/or too high energy expenditure. In that perspective, oxygen consumption (VO2) evaluation could be an additional valuable approach.

**VO2 EVALUATION FOR ATHLETES INFECTED WITH RESPIRATORY SYNDROME**

The data obtained from various groups worldwide and the 31 provinces of China suggest that the clinical symptoms of COVID-19 are more or less similar to that of SARS-CoV infection. SARS is associated with pulmonary complications in the form of pulmonary fibrosis and bronchiectasis. A reduction in aerobic exercise capacity 3 months after hospital discharge has been reported in some adult survivors of the SARS-CoV. This reduction could last up to 12 months after the onset of the illness. Such impairment was consistently shown to be at variance with the expected VO2max test. In more severe cases, a follow-up of the peak VO2 and ventilatory threshold as indicator of improving aerobic capacity could be useful, as recommended in patients infected with SARS-CoV.

COVID-19 could also have an impact on metabolic adaptation during exercise. The evaluation of the respiratory exchange ratio could help to understand the effect of the disease on metabolic adaptations to exercise in athletes with moderate symptoms or asymptomatic. In the case of athletes who recovered from a severe infection, complementary measurement should be proposed. Lipid profile assessment before and after exercise and glycaemia measurements during the incremental VO2 test are currently performed on patients suffering from metabolic disorder to exercise. This approach could be proposed to get insights into the consequences of the viral infection on metabolic adaptations to exercise, together with an evaluation of other performance determinants.

### Table 1 Biomarker assessment recommendation for athletes infected with COVID-19

| Haematological parameters | Organ | References |
|---------------------------|-------|------------|
| Interleukin 6             | Inflammatory | 13 14 |
| Complete base compte      | Inflammatory | 13 14 |
| Albumin                   | Liver | 13 14 36 |
| Alanine aminotransferase  | Liver | 13 14 |
| Aspartate aminotransferase| Liver | 13 14 |
| C reactive protein        | Inflammatory | 13 14 16 19 24 36 39 |
| Serum creatinine          | Kidney | 13 14 |
| Lactate dehydrogenase     | Liver | 16 19 24 |
| Procalciton               | Liver | 48 |
| Ferritin                  | Liver | 45 |
| Troponin I                | Heart | 48 |
| Creatine kinase-MB        | Heart | 41 48 |
| N-terminal pro b-type natriuretic peptide | Heart | 41 48 |

| Urine markers             | Organ | References |
|---------------------------|-------|------------|
| Glomerular filtration rate| Kidney | 51 52 |
| Creatinine                | Kidney | 51 52 |
| Albumine urea             | Kidney | 51 52 |
| Cystatin C                | Kidney | 51 |
| Beta-trace protein        | Kidney | 51 |
| Beta-2 microglobulin      | Kidney | 51 |
| Fatty acid-binding proteins| Kidney | 51 |

**ATHLETES INFECTED WITH COVID-19, LOCK-DOWN AND PHYSICAL PERFORMANCE DETERMINANT**

Athletes are used to reduced activity periods throughout their sport careers, usually coinciding with the end of their competition period, illness, injury or other factors. Nevertheless, infected athletes are facing the cumulative effects of the illness and detraining on their physical performance. Because COVID-19 is a new type of coronavirus (SARS-CoV-2) that shares 96% of his genotype with the SARS-CoV of 2002, one can speculate that they share the same effect on muscles. So and colleagues reported loss of muscle mass in patients infected with mild and severe form of SARS-CoV. They concluded that it can affect force production and locomotion. Ong and colleagues suggested that the reduced exercise capacity was probably related to myalgia. Additionally, the reduction in physical activity due to lockdown policies may also have affected muscle mass, and more generally, body composition. We then suggest that the recovery of muscle mass with training may be longer in athletes previously infected with COVID-19. To improve return to practice and follow the effect of training on muscle mass, periodic evaluation of body composition and force production capacity is recommended.

Patients infected with COVID-19 also present central nervous system alterations. Excepted for asymptomatic,
dysgeusia, described as an highly frequent early or lone symptom of COVID-19, and hyposmia or anosmia have been reported, even by professional (basketball) athletes with mild symptoms. However, the neuroinvasive potential of COVID-19 remains poorly understood, and the impact on neuromuscular function warrants further investigation. From a practical point of view, it may specifically affect power and force production through modulation of the neural drive. The countermovement jump (CMJ) is one of the most popular tests to monitor an athlete’s muscle power of the lower extremities. An athlete’s CMJ performance is relevant in a variety of sports and commonly quantified by jump height or flight time, which have been considered as indicators of vertical jump performance and used to measure training adaptations. The standardised drop vertical jump (DJ) from 30 cm height as a screening tool for evaluation of deceleration activities, eccentric strength, has also largely been reported in the literature. To the best of our knowledge, there is no information about the impact of COVID-19 infection on neuromuscular performance in the literature. Given its potential effects of the central nervous system, evaluating muscle strength and power using simple and classical field-tests could be clinically relevant as a first intention. To get further insights into the effects of COVID-19 on the motor drive, electromyography, twitch interpolation and evoked potentials may be implemented in athletes who have a history of severe COVID-19 infection and/or demonstrate a slow recovery of force/power production capacity.

Moreover, extra attention should be given to the possible post-viral fatigue syndrome, which may also generate neuromuscular fatigue. The use of CMJ and DJ in isolation as a global indicator of muscle power of the lower limb muscles does not inform about the specific effect of neuromuscular fatigue on sports performance. Neuromuscular fatigue arises not only because of peripheral changes at the level of the muscle but also because the central nervous system fails to drive the motoneurons adequately. Appropriate screening methods, combining stimulation methods, dynamometry and electromyography may be used to identify and evaluate the relative contributions of central and peripheral factors to peripheral fatigue. That could help to prescribe exercise modalities adapted to the level of fatigue and propose countermeasures, such as nutritional and/or specific training regimens, to help athlete to regain performance faster.

Finally, the fatigue reported by patients with COVID-19 may have affected their flexibility. Indeed, fatigue leads to inactivity, which in turn may decrease flexibility. Inactivity affects different muscles and muscle chains depending on whether they are tonic or phasic, causing muscle shortening and/or hypertonia or laxity and/or hypotonia depending on the muscle type. The ‘Y Balance Test’ is an easy and reproducible method to assess the flexibility of hip and leg muscles. Including flexibility evaluation in the PPE would give insight into the flexibility status of athletes with COVID-19 and may ensure a safe return to activity. Managing the combined consequences of COVID-19 infection and lock-down policies on athletes is represented in figure 1. This combined approach based

![Figure 1](https://example.com/figure1.png)

Figure 1  Guidelines for athletes infected with COVID-19 before returning to sport. ICU, intensive care unit; VO₂, oxygen consumption.
on the physical performance determinant and medical assessment has a dual interest for the sports medicine community, ensuring a return to practice without risk and advising athletes to accelerate their return to performance.

CONCLUSION
The COVID-19 infection is characterised by influenza-like symptoms, respiratory troubles, and in some cases, multi-organ failure may occur. These effects may combine with the detrimental effects of detraining induced by the lockdown policies. In the context of sport, this may translate into potential alterations of the cardiorespiratory, metabolic and neuromuscular responses to exercise. The present guidelines aim to propose a framework for an easy and accessible assessment of athletes to ensure a safe return to practice and optimise a quick recovery of performance. However, our knowledge of the effects of COVID-19 infection on physiological responses to exercise is very scarce. Research in this field will have to be carried to document this issue and update the proposed framework.

REFERENCES
1. Coronavirus Resource Center of the John Hopkins University of Medicine, COVID-19 Pandemic, 2020.
2. Pascarella G, Strumia A, Piliego C, et al. COVID-19 diagnosis and management: a comprehensive review. J Intern Med 2020, Aug;288:192–206. Epub 2020 May 13. PMID: 32348588.
3. Liu J, Zheng X, Tong Q, et al. Overlapping and discrete aspects of the pathology and pathogenesis of the emerging human pathogenic coronaviruses SARS-CoV, MERS-CoV, and 2019-nCoV. J Med Virol 2020;92:491–4.
4. Ren LL, Wang YM, Wu QZ, et al. Identification of a novel coronavirus causing severe pneumonia in humans: a descriptive study. Chin Med J 2020;1.
5. Zhuo P, Yang XL, Wang XG. A pneumonia outbreak associated with a new coronavirus of probable bat origin. Nature 2020.
6. Adhikari SP, Meng S, Wu YJ et al. Epidemiology, clinical manifestation and diagnosis, prevention and control of coronavirus disease (COVID-19) during the early outbreak. Infect Dis Poverty.
7. Kaiszek TG, Erdman D, Goldsmith CS, et al. A novel coronavirus associated with severe acute respiratory syndrome. N Engl J Med 2003;348:1953–66.
8. Tan W, Aboulhosn J. The cardiovascular burden of coronavirus disease 2019 (COVID-19) with a focus on congenital heart disease. Int J Cardiol 2020;309:70–7.
9. Zang J, Lu D, Xu A. The interaction of circRNAs and RNA binding proteins: an important part of circRNA maintenance and function. J Neurosci Res 2020;98:87–97.
10. Mackenzie JS, Smith DW, COVID-19 a novel zoonotic disease caused by a coronavirus from China: what we know and what we don’t. Microbiol Sci 2020.
11. Corsini A, Bisciotti GN, Eirale C, et al. Football cannot restart soon during the COVID-19 emergency. A critical perspective from the Italian experience and a call for action. Br J Sports Med 2020.
12. Mujika I, Padilla S. Detraining: loss of training-induced physiological and performance adaptations. Part I. Sports Med 2000;30:79–87.
13. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet 2020;395:507–13.
14. Chen L, Liu HG, Liu W, et al. Analysis of clinical features of 29 patients with 2019 novel coronavirus pneumonia. Zhonghua Jie He Hu Xi Za Zhi – Zhonghua Jiehe He Huxi Zazhi = Chin J Tuberculosis Respir Dis 2020;43:E005–E005.
15. Yang X, Yu Y, Xu J, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. Lancet Respir Med 2020;8:475–81.
16. Li L, Huang T, Wang Y, et al. COVID-19 patients’ clinical characteristics, discharge rate, and fatality rate of meta-analysis. J Med Virol 2020;92:577–83.
17. Pascarella G, Strumia A, Piliego C, et al. COVID-19 diagnosis and management: a comprehensive review. J Intern Med 2020.
18. He F, Deng Y, Li W. Coronavirus disease 2019: what we know? J Med Virol 2020;92:719–25.
19. Wu C, Chen X, Cai Y, et al. Risk factors associated with acute respiratory distress syndrome and death in patients with coronavirus disease 2019 pneumonia in Wuhan, China. JAMA Intern Med 2020;180:934.
20. Xu Z, Shi L, Wang Y, et al. Pathological findings of COVID-19 associated with acute respiratory distress syndrome. Lancet Respir Med 2020;8:420–2.
21. Guan W, Ni Z, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med 2020;382:1708–20.
22. Ding L, Wang L, Ma W, Ding L, Wang L, Ma W, et al. Efficacy and safety of early positive positioning combined with HFNC or NIV in moderate to severe ARDS: a multi-center prospective cohort study. Crit Care 2020;24:28.
23. Clerkin KJ, Fried JA, Raikhelkar J, et al. Coronavirus disease 2019 (COVID-19) and cardiovascular disease. Circulation 2020.
24. Li YY, Wang WN, Lei Y, et al. Comparison of the clinical characteristics between RNA positive and negative patients clinically diagnosed with 2019 novel coronavirus pneumonia. Zhonghua Jie He Hu Xi Za Zhi – Zhonghua Jiehe He Huxi Zazhi = Chin J Tuberculosis Respir Dis 2020;43:E023–E023.
25. Paul J, Charles P, Richaud C, et al. Coronavirus disease 2019 (COVID-19) and cardiovascular disease. Circulation 2020.
26. Li Y-C, Bai W-Z, Hashikawa T. The neuroinvasive potential of SARS-CoV2 may play a role in the respiratory failure of COVID-19 patients. Zhi= Zhonghua Jie He Hu Xi Za Zhi= Chin J Tuberculosis Respir Dis 2020;41:45–50.
27. Li Y-C, Bai W-Z, Hashikawa T. The neuroinvasive potential of SARS-CoV2 may play a role in the respiratory failure of COVID-19 patients. Zhi= Zhonghua Jie He Hu Xi Za Zhi= Chin J Tuberculosis Respir Dis 2020;41:45–50.
28. Li Y-C, Bai W-Z, Hashikawa T. The neuroinvasive potential of SARS-CoV2 may play a role in the respiratory failure of COVID-19 patients. Zhi= Zhonghua Jie He Hu Xi Za Zhi= Chin J Tuberculosis Respir Dis 2020;41:45–50.
29. Brolinson P, Elliott D. Exercise and the immune system. J Appl Physiol 2008;104:187–98.
30. Nieman DC. Nutrition, exercise, and immune system function. Br J Sports Med 2007;41:537–40.
31. Doyen D, Moceri P, Ducreux D, et al. Myocarditis in a patient with COVID-19: a cause of raised troponin and ECG changes. Lancet 2020;395:1516.
Fabre J-B, et al. BMJ Open Sp Ex Med 2020;6:000849. doi:10.1136/bmjsem-2020-000849

32 Drezner JA, O’Connor FG, Harmon KG, et al. AMSSM position statement on cardiovascular preparticipation screening in athletes: current evidence, knowledge gaps, recommendations and future directions. Br J Sports Med 2017;51:153–67.

33 Drezner JA, Sharma S, Baggish A, et al. International criteria for electrocardiographic interpretation in athletes: consensus statement. Br J Sports Med 2017;51:704–31.

34 Calore C, Zorzi A, Sheikh N, et al. Electrocardiographic anterior T-wave inversion in athletes of different ethnicities: differential diagnosis between athlete’s heart and cardiomyopathy. Eur Heart J 2016;37:2515–27.

35 Vio R, Zorzi A, Corrado D. Myocarditis in the athlete: arrhythmogenic substrates, clinical manifestations, management, and eligibility decisions. J Cardiovasc Transl Res 2020;1–12.

36 Corrado D, Brmso C, Parrei A, et al. Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program. JAMA Cardiol 2020;5:819.

37 Halle M, Binzenhofer L, Mehrhold H, et al. Myocarditis in athletes: a clinical perspective. Eur J Prev Cardiol 2020.

38 Pelliccia A, Solberg EE, Papadakis M, et al. Recommendations for participation in competitive and leisure time sport in athletes with cardiomyopathies, myocarditis, and pericarditis: position statement of the sport cardiology section of the European Association of Preventive Cardiology (EAPC). Eur Heart J 2019;40:19–33.

39 Hu H, Ma F, Wei X, et al. Coronavirus fulminant myocarditis treated with glucocorticoid and human immunoglobulin. Eur Heart J 2020.

40 Inciardi RM, Lupi L, Zaccone G, et al. Cardiac involvement in a patient with coronavirus disease 2019 (COVID-19). JAMA Cardiol 2020;5:819.

41 Hua A, O’Gallagher K, Sado D, et al. Life-threatening cardiac tamponade complicating myo-pericarditis in COVID-19. Eur Heart J 2020;41:2130–31.

42 Zhang C, Shi L, Yang F-S. Liver injury in COVID-19: Management and challenges. Lancet Gastroenterol Hepatol 2020;5:428–30.

43 Ruan Q, Yang K, Wang W, et al. Clinical predictors of mortality due to COVID-19 based on an analysis of data of 150 patients from Wuhan, China. Intensive Care Med 2020;1–3.

44 Mehta P, McAuley DF, Brown M, et al. COVID-19: the effects of an emerging infectious disease on factors that influence organ function and failure. Lancet 2020;395:1033–42.

45 Velavan TP, Meyer CG. Mild versus severe COVID-19: laboratory markers. Int J Infect Dis 2020;95:304–7.

46 Gao Y, Li T, Han M, et al. Diagnostic utility of clinical laboratory data determinations for patients with the severe COVID-19. J Med Virol 2020.

47 Mo P, Xing Y, Xiao Y, et al. Clinical characteristics of refractory COVID-19 pneumonia in Wuhan, China. Clinical Infectious Diseases 2020.

48 Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. JAMA 2020;323:1239–42.

49 Liu Y, Yang Y, Zhang C, et al. Clinical and biochemical indexes from 2019-ncov infected patients linked to viral loads and lung injury. Sci China Life Sci 2020;63:364–74.

50 Luft FC. Biomarkers and predicting acute kidney injury. Acta Physiol 2020.

51 den Bakker E, Gemke RJ, Bökenkamp A. Endogenous markers for kidney function in children: a review. Curr Rev Clin Lab Sci 2018;55:163–83.

52 Guan WJ, Ní ZY, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med 2020;28.

53 Michael DC, Susan MP, Mona RL, et al. Severe acute respiratory syndrome. Clin Infect Dis 2004;38:1407–20.

54 Peiris JSM, Chu C-M, Cheng V-C-C, et al. Clinical progression and viral load in a community outbreak of coronavirus-associated SARS pneumonia: a prospective study. Lancet 2003;361:1767–72.

55 Ong SWX, Tan YK, Chia PY, et al. Air, surface environmental, and personal protective equipment contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from a symptomatic patient. JAMA 2020;323:1610–12.

56 Hui DS, Joynut GM, Wong KT, et al. Impact of severe acute respiratory syndrome (SARS) on pulmonary function, functional capacity and quality of life in a cohort of survivors. Thorax 2005;60:401–9.

57 Wu CCW, Li AM, So RC, et al. Longer term follow-up of aerobic capacity in children affected by severe acute respiratory syndrome (SARS). Thorax 2006;61:240–6.

58 Narici M, De Vito G, Franchi M, et al. Impact of sedentarism due to the COVID-19 home confinement on neuromuscular, cardiovascular and metabolic health: physiological and pathophysiologic implications and recommendations for physical and nutritional countermeasures. Eur J Sport Sci 2020;1–22.

59 Fittipaldi EO da S, Dornelas de Andrade A, Santos ACO, et al. Cardiorespiratory performance and acute effect of high-intensity exercise on lipid profile in hypertensive sedentary older adults with and without diabetes mellitus. Arch Gerontol Geriatr 2020;89:104061.

60 So RC, Ko J, Yuan YW, et al. Severe acute respiratory syndrome and sport. Sports Med 2004;34:1023–33.

61 Ong KC, Ng A-K, Lee L-U, et al. Pulmonary function and exercise capacity in survivors of severe acute respiratory syndrome. Respir J 2004;24:436–42.

62 Hortobágyi T, Houmard JA, Stevenson JR, et al. The effects of detraining on power athletes. Med Sci Sports Exerc 1993;25:929–35.

63 Vanezis A, Lees A. A biomechanical analysis of good and poor performers of the vertical jump. J Strength Conditioning Res 2004;18:27–39.

64 Silva JR, Magalhães JF, Ascensão AA, et al. Drop jump landing knee valgus angle; normative data in a physically active population. J Strength Conditioning Res 2011;25:2729–39.

65 Thorpe R, Strudwick A, Buchheit M, et al. The effects of detraining and sprint training on sprint performance and indices of explosive power and anaerobic capacity in survivors of severe acute respiratory syndrome. J Strength Conditioning Res 2015;29:619–29.

66 Herrington L, Munro A. Drop jump landing knee valgus angle; normative data in a physically active population. J Strength Conditioning Res 2011;25:2729–39.

67 Boden BP, Griffin LY, Garretti JWE. Etiology and prevention of noncontact ACL injury. Phys Sportsmed 2000;28:53–60.

68 Laffaye G, Wagner PP, Tombokos TIL. Countermovement jump height: effects of countermovement depth and countermovement duration on jump height. Phys Ther Sport 2010;11:56–8.

69 Gandevia SC. Spinal and supraspinal factors in human muscle fatigue. J Neurol Neurosurg Psychiatry 2020;89:100849.

70 Pickering C, Grgic J. Caffeine and exercise: what next? Br J Sports Med 2020;54:230–6.

71 Caldewell BP, Peters DM. Seasonal variation in physiological fitness of a semiprofessional soccer team. J Strength Conditioning Res 2009;23:1370–7.

72 Overmoyer GV, Reiser RF. Relationships between low-extremity flexibility, asymmetries, and the Y balance test. J Strength Conditioning Res 2015;29:1240–7.