



Swimming competitions in the era of COVID-19: Lessons from successfully hosting the International Swimming League

GÁBOR A. FÜLÖP^{1*†} , ÁLMOS GÓGL^{2†}, BÁLINT LAKATOS¹,
NÓRA SYDÓ¹, EMESE CSULAK¹, BIANKA MESTER³, SZABOLCS TÓTH⁴,
ÁRPÁD PETROV⁵, VIVIEN KLAUDIA NAGY¹, GERGO MERKELY^{4,6‡} and
BÉLA MERKELY^{1‡} 

¹ Heart and Vascular Center, Semmelweis University, Budapest, Hungary

² Szent Rókus Hospital of Semmelweis University, Budapest, Hungary

³ Division of Hospital Hygiene, Semmelweis University, Budapest, Hungary

⁴ Semmelweis University, Budapest, Hungary

⁵ Swimming Academy of Győr, Győr, Hungary

⁶ Orthopedic Department, Brigham and Women's Hospital, Harvard University, Boston, MA, USA

Received: January 28, 2022 • Revised manuscript received: August 8, 2022 • Accepted: September 16, 2022

Published online: December 8, 2022

© 2022 The Author(s)



ABSTRACT

Background: Organization of mass sport events in the COVID-19 era is utterly complicated. Containment measures, required to avoid a virus outbreak, force athletes to compete under circumstances they never experienced before, most likely having a deleterious effect on their performance. *Purpose:* We aimed to design a so-called athlete-friendly bubble system for the International Swimming League 2020 event, which is strict enough to avoid a COVID-19 outbreak, but still provides a supportive environment for the athletes. *Methods:* To avoid the feeling of imprisonment, athletes were permitted to spend a certain amount of time in the parks surrounding the hotels. Such alleviations were possible to apply with strict adherence to the hygienic and social distancing protocols and regular COVID-19 testing. Evaluation of every COVID-19

* Corresponding author. Heart and Vascular Centre, Semmelweis University, Városmajor u. 68, H-1122 Budapest, Hungary. E-mail: fulop.gabor1@med.semmelweis-univ.hu; fulop.gabor.aron@gmail.com

† The first two authors contributed equally to the manuscript.

‡ The last two authors contributed equally to the manuscript.

positive case was key, and if prolonged PCR positivity or false positive PCR result was identified, the unnecessary quarantine was planned to be lifted. Return to play protocol (RTP) was planned, in case of a COVID-19 infection of an athlete inside the bubble. To test, if the athlete-friendly system provided a supportive environment, we evaluated athlete performance. *Results:* 11,480 PCR tests were performed for 1,421 individuals. 63 COVID-19 positive cases were detected, of which 5 turned out to be clinically insignificant, either because of prolonged PCR positivity or because of a false positive result. 93.1% of the positive cases were detected in the local crew, while no athlete got infected inside the bubble, as the two infected athletes were tested positive upon arrival. RTP was provided for two athletes. 85% of the athletes showed improvement during the bubble and 8 world records were broken. *Conclusion:* The applied protocol proved to be effective, as no athlete got infected inside the bubble, moreover, the athlete-friendly system supported the athletes to improve their performance.

KEYWORDS

COVID-19, swimming, competition, bubble

INTRODUCTION

The COVID-19 pandemic affected many parts of our lives, not just having a catastrophic effect on the elderly community [1–3], but also affecting areas such as professional sport, which has been devastated ever since the breakout of the pandemic. Elite athletes were forced to face previously unheard-of challenges, such as lack of competitions, while a number of sports events have been cancelled during the first wave of COVID-19 [4]. In addition, there is limited information about the athlete's physical well-being following COVID-19 infection, which lead to uncertainties regarding the adequate timing of return to training [5]. Some of these concerns were addressed lately, such as thorough protocols have been designed to help return to play [6], but the way to organize COVID-19 safe competitions still represents a matter of debate.

Despite the countless obstacles, several attempts were made to organise major sports events, all utilizing slightly different COVID-protocols [7–9]. Needless to say, that containment measures, such as the bubble system, social distancing and frequent COVID-testing may result in an increased psychological burden in athletes, which can make the circumstances for a successful competition far from optimal [10]. Some sports – just like swimming – were affected not only by the number of cancelled competitions, but also by the lack of training opportunities. Temporarily closed swim clubs and swimming pools made the life of swimmers utterly complicated, leading to predictions that 2020 might be the first year since the 1896 Olympic Games without a world record [11].

Under such circumstances, the International Swimming League (ISL) – an annual invitational short-course team competition – gave a unique opportunity for top-ranking swimmers from around the globe to compete against each other. The ISL in 2020, was organized in Budapest, Hungary between the 16th of October and 22nd of November. Even though, at the time of the competition, Budapest faced the peak of the second wave of COVID-19, the medical team aimed to design a strict, but athlete centered COVID-protocol, providing the most supportive environment possible, in order to decrease the athlete's stress, related to containment measures.



In this manuscript, we would like to share our experiences in pursuit of developing an athlete friendly, COVID-19 safe protocol for swimming competitions. In addition, here we also report the effects of COVID-19 restrictions and isolation on the athletes' performance.

METHODS

Structure of the isolation bubble

A common element of sport events organised in the COVID-19 era, is to keep the athletes isolated in a so called bubble [7, 8, 12].

The bubble isolation designed for the ISL had three different layers. The first one served the purpose of protecting the athletes and the team, the second was in favour of the staff required by the competition (mainly from foreign countries) and the third layer was constructed for the Hungarian crew members – e.g. medical staff, hotel workers, bus drivers. Individuals belonging to the first and second layer were living inside the bubble, while those in the third layer, since it was the local crew, were permitted to leave and reenter the bubble on a daily basis. As described below in detail, nobody was allowed to enter the bubble without 2 negative COVID-19 test results. The structure of the bubble is shown in Fig. 1.

The possible deleterious psychological effects of quarantine like isolation are well known [13]. Thus we aimed to design the bubble for ISL in accordance with the needs of the athletes aiming to decrease the psychological burden and help performance.

As the hotels accommodating the individuals in the first layer (athletes, team members etc.) were on the Margaret Island in Budapest, providing a geographical isolation in the middle of the city, the athletes had the opportunity to leave the hotel isolation for up to 1.5 h to take a walk in the parks of the island.

Every athlete and the team members (first layer of the bubble) were housed in single rooms, in order to minimize the number of possible contacts in case of an unlikely outbreak within the bubble.

COVID-19 testing protocol

SARS-CoV-2 RT-PCR is known to be the gold standard test to diagnose COVID-19 [14], albeit multiple reasons can cause false negative results leading to the recommendation of repeated testing [15]. As a result, two negative SARS-CoV-2 PCR tests were required to enter the bubble. In case of foreign nationals arriving with one negative SARS-CoV-2 PCR result, the second testing was carried out upon arrival and they remained quarantined in their hotel rooms until the result of the test arrived (within 12 h). As the median incubation period for COVID-19 is 5 days [16], during the course of the event, every individual within the bubble had to undergo SARS-CoV-2 PCR testing every five days. In addition, SARS-CoV-2 rapid antigen and antibody tests were also used to help further decision making in case of SARS-CoV-2 PCR positivity.

Social distancing and pretriage

Social distancing and the use of face masks were taken seriously in order to minimize the number of possible close contacts in case of an unlikely outbreak. Every individual within the bubble had to wear a face mask outside the pool area and their designated hotel rooms.



Furthermore, to follow the rules of social distancing only single seated tables were available in the dining area, and transport vehicles were assigned and scheduled to limit the number of passengers on board. All of these measures were kept under control with the help of volunteers dedicated to every single team, otherwise known as COVID marshalls.

Every participant within the bubble had to fill out an online questionnaire on a daily basis, in order to monitor their health and any occurring symptoms that might raise the suspicion of a possible COVID-19 infection. Subsequently, answers were forwarded to designated members of the medical team and the symptomatic individual was quarantined until further tests and decision making, as described below.

Protocol in case of COVID-19 positivity

According to the protocol, a SARS-CoV-2 RT-PCR positive individual was quarantined immediately. Every SARS-CoV-2 RT-PCR positive case was reviewed by a board of experts, including infectologists, internists, and sport medicine specialists. In addition to clinical symptoms and medical history, results of repeated RT-PCR tests, SARS-CoV-2 antibody tests and additional SARS-CoV-2 rapid antigen tests were considered to distinguish between infectious COVID-19 positive cases with recent infection/reinfection; and prolonged PCR positive/false positive non-infectious cases.

Infectious COVID-19 positive cases with recent infection/reinfection had to stay quarantined for 14 days, and received regular over-the-phone and personal visits as well with additional blood tests if it was decided to be necessary. Medical visits were performed following COVID-19 protocol appropriately, i.e. the attending doctor was wearing the complete personal protective equipment (PPE). In case of any alarming signs or symptoms, an ambulance – as part of the bubble, operated by the medical staff of the event – was organized to transport the individual to an isolated part of a COVID-19 ward for further examination, observation and therapy if needed. Important to mention that in case of local crew, the SARS-CoV-2 PCR positive individual was banned from the bubble.

Prolonged PCR positive non-infectious cases were those with a SARS-CoV-2 RT-PCR positive test, negative SARS-CoV-2 rapid antigen test, positive SARS-CoV-2 antibody test and a history of previous COVID-19 infection in the past three month [17]. While in case of SARS-CoV-2 RT-PCR positivity in an asymptomatic person with two additional negative SARS-CoV-2 RT-PCR test results and a negative SARS-CoV-2 rapid antigen test our board considered the possibility of a false positive PCR test result [18]. In such a decision, the pre-test probability was taken into consideration [19], as for an asymptomatic individual, isolated in a bubble for weeks, the pre-test probability is low. In both cases the initial quarantine was lifted.

Although the bubble and all social distancing measures were designed precisely in favour of avoiding close contacts, still, following a detection of every real COVID-19 positive case, thorough contact tracing was planned to be carried out, and if close contacts were to be identified [20], they had to be quarantined and tested as well. Close contacts were to be tested on the 4th and 6th day after the contact and quarantine could only be lifted in possession of two negative SARS-CoV-2 PCR test results.

Return to play protocol (RTP)

Several reports have been published about the possible cardiorespiratory complications of COVID-19 in athletes [21–24] emphasizing the importance of a thorough return to play



examination protocol [6, 25]. As the duration of the competition was planned to last for 6 weeks, the medical team agreed to provide the possibility of returning to the competition to those athletes who tested positive while inside the bubble. Ten days after a positive test result 2 SARS-CoV-2 PCR tests were performed 48 h apart for those who had been asymptomatic for at least three days. In case of negative results, examinations started according to the most recent return to play guidelines available [6, 25]. Physical examination, echocardiography, chest X-ray, lab tests and ECG was performed with MRI evaluation if necessary.

Assessment of athlete performance

Official Omega timing results were analyzed day to day of every race to measure athletes' performance during the competition, which we used as a marker for wellbeing inside the bubble. Achieved results were compared to a swimmers' personal best time in each swimming stroke and personal improvement was notified if a swimmer improved his or her times during the series. Those swimmers who only swam once or twice in a particular race were excluded from the analyses. Relay lap and the special skins race performances were excluded due to their unofficial character. Registered world records were also considered as improvement of athletes' performance.

Ethical approval

The study was approved by the institutional review board and the local ethics committee (SE RKEB: 32/2021).

RESULTS

A total of 1,421 individuals entered the bubble. The participants were aged 16–74 years, with the median age of 38.6 years and 62.6% were male. The overall population in the bubble consisted of 296 (20.83%) athletes, 149 (10.48%) team members (e.g. physiotherapist, coach), 214 (15.05%) ISL officials and technical staff, while more than half of the study population, 762 (53.62%) participants were part of the local crew (e.g. hotel staff, security, janitors) as shown in Fig. 1. Foreign participants arrived from 5 continents and 40 different countries, mostly United States of America (27.9%), United Kingdom (13.0%), Japan (6.6%), France (6.0%), Russia (5.9%), Brazil (5.5%), Italy (4.6%) and Germany (4.6%).

Test results in the studied population

Altogether, 11,480 SARS-CoV-2 RT-PCR tests were performed and positivity was detected in 67 tests (0.58%). Sixty-three of the 1,421 participants turned out to be positive, resulting in a 4.43% positivity rate. According to the protocol, further examinations were initiated in these subjects. In 5 cases, the PCR positivity was considered to be clinically insignificant by the medical board: 4 of them were prolonged PCR positivity, while 1 was a false positive result (0.04% and 0.01% of all PCR tests, respectively), as in that case, repeated PCR tests did not confirm COVID-19 infection. Most of the 58 true positive cases were detected in the local crew, while only three athletes and 1 ISL technical staff member were infected (93.1%, 5.17% and 1.72% of all positive cases respectively). None of the athletes got infected while staying within the bubble.



The layers of the ISL bubble

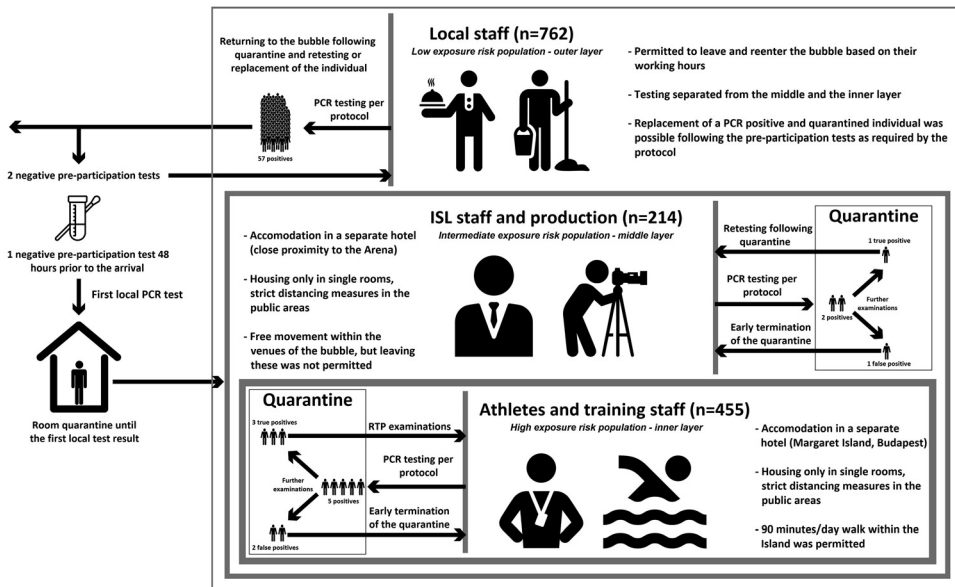


Fig. 1. The structure of the intelligent bubble. While the general rules of social distancing, hygiene and the 5 days testing schedule did not differ between the participants, the COVID-bubble of the event consisted of three different layers based on their risk profile. The high exposure risk individuals (inner layer), such as athletes and the training staff could not constantly maintain every measures (e.g. not wearing a mask during training, possible direct physical contact). The intermediate exposure risk participants (middle layer), such as the ISL staff and the production team was able to maintain every preventive measure, however, they encountered with the athletes and the training team closer and also more frequently. The local staff was considered to have a low exposure risk (outer layer), as they rarely had close proximity to the former two group. Certain PCR testing and quarantine rules varied between the layers in order to promote the maximal safety of the event, but also the comfort of the attendants

Twenty-one out of 296 (7.1%) athletes reported previous COVID-19 infection, of which 13 (61.9%) had a positive antibody test upon arrival. Information about previous PCR positivity was not collected from the local crew.

Quarantine, medical visits and return to play

During the course of the competition 37 foreign participants (5.6% of all foreigners) reported symptoms to the medical team, of which 4 (10.8%) were ISL officials, 2 (5.4%) team members, and 31 athletes (83.8%). 18.9% of symptomatic cases did not raise suspicion of COVID-19 based on symptoms, such as eye infection and ear ache. Other cases with symptoms similar to COVID-19 required quarantine and further COVID-19 testing, according to the protocol. As several cases turned out to be non-COVID, such as GI infections, further quarantine was not required. Thus, the average quarantine time was 2.8 days, although it was longer in the case of confirmed COVID-19 infection (average 14 days).



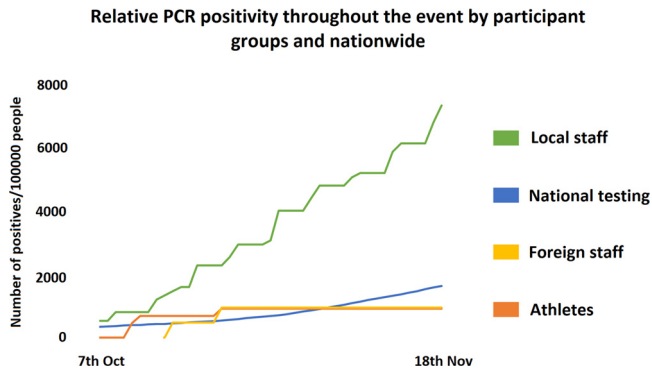


Fig. 2. Relative PCR positivity of the participant groups and Hungary. Relative PCR positivity of the participant groups and Hungary. Following the arrival of the athletes and the foreign crew, positive individuals were detected and quarantined after their first PCR result. The latter positive cases were proven to be false positives. On the other hand, in parallel with the nationwide increase of the cases the incidence of PCR positivity steadily increased in the local crew as well. Regular mandatory testing of this population yielded a ≈ 4.5 -fold higher incidence of COVID-19 compared to the general population

The medical team performed 83 in-room visits, most of which were according to the COVID-19 protocol (84.33%). In overall, four athletes required hospitalization: two athletes due to anaphylactic reaction treated on site for further monitoring, one athlete due to clinical suspicion of appendicitis for an abdominal ultrasound, and one athlete required hospitalization at a COVID-19 ward because of COVID-19-infection related leukopenia. The average hospital stay was 1.5 days.

RTP was performed for two athletes due to COVID-19 infection before reentering the competition. The RTP showed no pathological changes in either of the cases, although one athlete felt chest discomfort upon reentering the competition, thus a cardiac MRI was performed, which showed no signs of myocardial involvement and the athlete could continue competing.

Performance of the athletes during the competition

We assessed the results of 296 swimmers in 1,030 races with 3,732 time results. Out of the 296 swimmers 176 (59%) improved his or her personal best results, while 252 swimmers (85%) improved during the bubble. 160 swimmers (54%) improved both his or her personal best and in bubble times. Furthermore 8 world records were broken during the final and semi-final stages of the competition.

DISCUSSION

In this manuscript we present a detailed description of the COVID-19 protocol applied for the International Swimming League 2020 event, which was organized in Budapest, Hungary. During the entire course of the event, the SARS-CoV-2 infection numbers rapidly increased nationwide, reaching more than 1,600 infected/100,000 persons according to the National



COVID Testing Database. In the case of the athletes and the foreign staff, true positive individuals were found only at arrival, while the latter cases were proven to be false positive results. On the other hand, the relative positivity rate of the local staff markedly exceeded the official national numbers (7,218 infected/100,000 person). Therefore, the regular testing of the local staff detected ≈ 4.5 -fold more COVID-19 positive individuals compared to the nationwide results, as shown on Fig. 2.

Moreover as reported previously, sharing household, just like living in the same hotel, as the athletes during the competition, helps the virus to spread more easily [26]. The transmission is also affected by respiration rates, which is approximately $0.5 \text{ m}^3 \text{ h}^{-1}$ under normal circumstances, but might be 3 fold higher during physical activities, such as swimming [27]. The size of the room, or sports arena also affects the spreading of the virus [26]. From this perspective, the size of the arena where the ISL competition was organized was big enough to decrease the chance of transmission, on the other hand using the same corridors in the arena or in the hotel can increase the chance of infection. Humidity might be also an important factor in the case of swimming, although reports are controversial about the role of it in disease transmission [26, 28].

Despite the close proximity of such an infection cluster, and the numerous above mentioned factors affecting the transmission of the virus, due to the applied COVID-19 protocol inside the bubble, none of the athletes got infected. Additionally, as indicated by the large number of improved personal best times and a handful of new world records, the COVID-19-related restrictions did not have deleterious effect on the performance of the athletes. To our knowledge this is the first report of a COVID-19 bubble, in which the balance between the safety of the event and the comfort and performance of the participants were also of crucial interest.

The successful prevention of the virus outbreak inside the bubble could be attributed to multiple factors. First and foremost, the required repeated SARS-CoV-2 PCR testing prior to entering the bubble was essential, since we detected three athletes with COVID-19 infection upon arrival, who tested negative on the first PCR test before travelling. Second, mandatory PCR testing every five days for all the individuals inside the bubble proved to be sufficient to separate every positive case before the spread of the infection. Nevertheless, the importance of applied social distancing measures in order to decrease the number of possible contacts is also far from negligible. Important to underline, that local staff left and reentered the bubble on a daily basis, therefore – although solely based on our experience - it appears that such a testing schedule may be sufficient for further competitions, without the need to house the staff inside the bubble.

As the number of infections are still steadily increasing worldwide, the possibility of a previously infected athlete to attend a competition is high. Although early reinfections are constantly reported in the literature [29,30], there is a considerable chance of prolonged PCR positivity without infectious potential. As discussed above, we applied SARS-CoV-2 antigen rapid tests and SARS-CoV-2 antibody tests as well in such cases to determine whether the PCR positive individual is still infectious. Based on the test results, the medical board of the competition discussed these cases and lifted the quarantine of two athletes and two foreign staff members. We acknowledge the sensitive nature of this topic; however, we believe that an unnecessary quarantine or even a ban from a competition could seriously impact an athletic carrier in both short and long term. Moreover, competitions that require similarly high or even higher number of PCR testing as the ISL, have an inherited increased chance of false-positive PCR result as well [18]. In our example, this meant one false positive result for the 11,480 SARS-CoV-2 PCR tests. In case of the athlete with the false positive result, the quarantine was lifted.



The negative psychological impact of being isolated in quarantine is robustly established. It may lead to exhaustion, anxiety, impaired work performance or even suicide in the general population [13]. However, very few reports have focused on how athletes are affected by COVID-19 related separation. A study from South Africa showed that athletes suffered from altered sleep patterns, lack of motivation, worsening nutrition and even depression mainly driven by the uncertainties regarding RTP [10].

Motivation is key for success in athletes, and as discussed by one of the most widely used motivational theory, the self-determination theory (SDT), basic psychological needs (BPNs) have a huge impact on intrinsic motivation [31]. According to SDT, autonomy, competence and relatedness are the three BPNs, which play a key role in motivation and well-being. Studies conducted with Portuguese athletes showed that autonomy satisfaction and frustration were the most reliable predictors of motivation [32,33], while in terms of coaching, autonomy-supportive behavior proved to be effective in satisfying young swimmers physiological needs [34]. As a result, it can be hypothesized that restricting autonomy in a bubble structure with strict COVID-19 related containment measures might negatively affect an athlete's motivation and consequently, the performance of the given athlete. Therefore, we have designed the bubble for the ISL competition together with ISL athletes. One key element of the athlete-friendly system was the possibility to leave the bubble in order to spend time outside, considering that it is associated with identical, or even lower risk of infection compared to the stricter approach [35]. Dining was also not restricted to the rooms, but it was enabled in a common dining area with adequate social distancing measures as it may carry an acceptably low risk of infection [36]. As 85% of the athletes improved either their personal best or their best time in the bubble during isolation, including 8 world records, our COVID-19 bubble seems to be successful in decreasing the mental health burden on the athletes with the necessary isolation and restrictions.

Based on our experience, if the competition is long enough, return to play protocol should be provided to athletes who were diagnosed with COVID-19 infection inside the bubble. In contrast with previous reports [23], the prevalence of inflammatory heart disease seems to be low among post-COVID athletes [37], on the other hand, an undiagnosed myocarditis might have serious complications [38, 39]. Until there is no clear data about the possible consequences of intense physical activity after a COVID-19 infection, return to play protocols should be used. To underline the importance of RTP and making it possible for the athletes to reenter the competition, we must mention that one of the athletes, who underwent our RTP examination protocol and reentered the competition swam his personal best.

We acknowledge that our study has certain limitations. First, the appearance and spread of new COVID-19 variants, since the ISL competition markedly changed the landscape of defence against SARS-CoV-2 [40]. Some of these variants seem to have a significantly increased transmissibility [41, 42], which might require a modified COVID-19 PCR testing schedule to prevent a rapid increase in active cases. Second, although the ISL is a team swimming competition, from the infectological perspective it substantially differs from a team sport. Due to these differences, we propose that each sport should have its own specific bubble system and COVID-19 protocol for competitions. Third, at the time of the ISL competition vaccination was not available yet. Organisers for competitions in the future must consider how to deal with vaccinated athletes. Since there is a chance of infection even after vaccination regardless of the vaccine type, moreover, there is no robust evidence of the immunity provided against new COVID-19 variants yet, this topic must be further discussed.



PERSPECTIVE

The world of professional sports has gone through major changes due to the COVID-19 pandemic. The uncertainties regarding the possible deleterious effects of a COVID-19 infection on the athlete's health is just one side of the coin, as strict containment measures, applied at competitions, aiming to prevent a COVID-19 outbreak put an extra mental burden on athletes, which might affect their performance. Consequently, when designing the ISL COVID-19 protocol, we aimed to develop a system, which is strict enough to prevent a virus outbreak, but still not overly restrictive for the athletes. Although the competition took place during the second wave of COVID-19 in Budapest, Hungary, we successfully avoided a virus outbreak inside the bubble, moreover the excellent athlete performances proved the athlete-friendly system to be effective. We believe that our system can be used as a base for further athlete-friendly COVID-19 bubbles, although it is important to underline that each sport should design its own specific protocol, as there are major differences between sports regarding the infectiological perspective. Finally, as the outbreak of such pandemics in the upcoming decades cannot be excluded, an ongoing discussion about the future of mass sport events seems to be inevitable.

FUNDING

Project no. NVKP_16-1-2016-0017 ('National Heart Program') has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the NVKP_16 funding scheme.

The research was financed by the Thematic Excellence Programme (2020-4.1.1.-TKP2020) of the Ministry for Innovation and Technology in Hungary, within the framework of the Therapeutic Development and Bioimaging thematic programmes of the Semmelweis University.

This project was supported by grants from the National Research, Development and Innovation Office (NKFIH) of Hungary (K120277 and K135076 to B.M).

REFERENCES

1. Kemenesi G, Kornya L, Toth GE, Kurucz K, Zeghib S, Somogyi BA, et al. Nursing homes and the elderly regarding the COVID-19 pandemic: situation report from Hungary. *Geroscience* 2020; 1-7. <https://doi.org/10.1007/s11357-020-00195-z>.
2. Moccia F, Gerbino A, Lionetti V, Miragoli M, Munaron LM, Pagliaro P, et al. COVID-19-associated cardiovascular morbidity in older adults: a position paper from the Italian Society of Cardiovascular Researches. *Geroscience* 2020; 42(4): 1021-49. <https://doi.org/10.1007/s11357-020-00198-w>.
3. Nikolich-Zugich J, Knox KS, Rios CT, Natt B, Bhattacharya D, Fain MJ. SARS-CoV-2 and COVID-19 in older adults: what we may expect regarding pathogenesis, immune responses, and outcomes. *Geroscience* 2020; 42(2): 505-14. <https://doi.org/10.1007/s11357-020-00186-0>.
4. Sridhar S. Impact of COVID-19 pandemic on sports events around the world | Reuters. Available from: <https://www.reuters.com/article/health-coronavirus-sport/factbox-impact-of-covid-19-pandemic-on-sports-events-around-the-world-idUKL5N2CG73V> [Accessed 9 Jan 2021].



5. Jorstad HT, van den Aardweg JG. Balancing act: when is an elite athlete who has had COVID-19 safe to return to play? When does prudent investigation go offside into overmedicalising? *Br J Sports Med* 2020; 54(19): 1134–5. <https://doi.org/10.1136/bjsports-2020-103259>.
6. Wilson MG, Hull JH, Rogers J, Pollock N, Dodd M, Haines J, et al. Cardiorespiratory considerations for return-to-play in elite athletes after COVID-19 infection: a practical guide for sport and exercise medicine physicians. *Br J Sports Med* 2020; 54(19): 1157–61. <https://doi.org/10.1136/bjsports-2020-102710>.
7. Bontemps T. NBA outlines COVID-19 safety protocols in 134-page guide. Available from: https://www.espn.com/nba/story/_/id/30406725/nba-outlines-covid-19-safety-protocols-134-page-guide [Accessed 31 Jan 2021].
8. Baldwin A. Bubbles within bubbles as F1 teams gear up for season start - Eurosport. Available from: https://www.eurosport.com/formula-1/bubbles-within-bubbles-as-f1-teams-gear-up-for-season-start_story.shtml [Accessed 31 Jan 2021].
9. Kristina SG. Mladenovic fumes at “abominable” treatment under US open covid protocols | sport | the guardian. Available from: <https://www.theguardian.com/sport/2020/sep/03/kristina-mladenovic-fumes-at-abominable-treatment-under-us-open-covid-protocols> [Accessed 30 Jan 2021].
10. Pillay L, Janse van Rensburg DCC, Jansen van Rensburg A, Ramagole DA, Holtzhausen L, Dijkstra HP, et al. Nowhere to hide: the significant impact of coronavirus disease 2019 (COVID-19) measures on elite and semi-elite South African athletes. *J Sci Med Sport* 2020; 23(7): 670–9. <https://doi.org/10.1016/j.jsams.2020.05.016>.
11. Lord C. Will 2020 Be the first year without world swimming records since 1896? - swimming world news. Available from: <https://www.swimmingworldmagazine.com/news/will-2020-be-the-first-year-without-world-swimming-records-since-1896/> [Accessed 9 Feb 2021].
12. Hagemann G, Hu C, Al Hassani N, Kahil N. Infographic. Successful hosting of a mass sporting event during the COVID-19 pandemic. *Br J Sports Med* 2020. <https://doi.org/10.1136/bjsports-2020-103511>.
13. Brooks SK, Webster RK, Smith LE, Woodland L, Wessely S, Greenberg N, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *Lancet* 2020; 395(10227): 912–20. [https://doi.org/10.1016/S0140-6736\(20\)30460-8](https://doi.org/10.1016/S0140-6736(20)30460-8).
14. Udugama B, Kadhiresan P, Kozlowski HN, Malekjhani A, Osborne M, Li VYC, et al. Diagnosing COVID-19: the disease and tools for detection. *ACS Nano* 2020; 14(4): 3822–35. <https://doi.org/10.1021/acsnano.0c02624>.
15. Arevalo-Rodriguez I, Buitrago-Garcia D, Simancas-Racines D, Zambrano-Achig P, Del Campo R, Ciapponi A, et al. False-negative results of initial RT-PCR assays for COVID-19: a systematic review. *PLoS One* 2020; 15(12): e0242958. <https://doi.org/10.1371/journal.pone.0242958>.
16. Lauer SA, Grantz KH, Bi Q, Jones FK, Zheng Q, Meredith HR, et al. The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: estimation and application. *Ann Intern Med* 2020; 172(9): 577–82. <https://doi.org/10.7326/M20-0504>.
17. Hong K, Cao W, Liu Z, Lin L, Zhou X, Zeng Y, et al. Prolonged presence of viral nucleic acid in clinically recovered COVID-19 patients was not associated with effective infectiousness. *Emerg Microbes Infect* 2020; 9(1): 2315–21. <https://doi.org/10.1080/22221751.2020.1827983>.
18. Surkova E, Nikolayevskyy V, Drobniowski F. False-positive COVID-19 results: hidden problems and costs. *Lancet Respir Med* 2020; 8(12): 1167–8. [https://doi.org/10.1016/S2213-2600\(20\)30453-7](https://doi.org/10.1016/S2213-2600(20)30453-7).
19. Watson J, Whiting PF, Brush JE. Interpreting a covid-19 test result. *BMJ* 2020; 369: m1808. <https://doi.org/10.1136/bmj.m1808>.
20. WHO. Contact tracing in the context of COVID-19. Available from: <https://www.who.int/publications/i/item/contact-tracing-in-the-context-of-covid-19> [Accessed 9 May 2021].
21. Starekova J, Bluemke DA, Bradham WS, Eckhardt LL, Grist TM, Kusmirek JE, et al. Evaluation for myocarditis in competitive student athletes recovering from coronavirus disease 2019 with cardiac magnetic resonance imaging. *JAMA Cardiol* 2021. <https://doi.org/10.1001/jamacardio.2020.7444>.



22. Brito D, Meester S, Yanamala N, Patel HB, Balcik BJ, Casaclang-Verzosa G, et al. High prevalence of pericardial involvement in college student athletes recovering from COVID-19. *JACC Cardiovasc Imaging* 2021; 14(3): 541–55. <https://doi.org/10.1016/j.jcmg.2020.10.023>.
23. Rajpal S, Tong MS, Borchers J, Zareba KM, Obarski TP, Simonetti OP, et al. Cardiovascular magnetic resonance findings in competitive athletes recovering from COVID-19 infection. *JAMA Cardiol* 2021; 6(1): 116–8. <https://doi.org/10.1001/jamacardio.2020.4916>.
24. Hull JH, Loosemore M, Schweltnus M. Respiratory health in athletes: facing the COVID-19 challenge. *Lancet Respir Med* 2020; 8(6): 557–8. [https://doi.org/10.1016/S2213-2600\(20\)30175-2](https://doi.org/10.1016/S2213-2600(20)30175-2).
25. Kim JH, Levine BD, Phelan D, Emery MS, Martinez MW, Chung EH, et al. Coronavirus disease 2019 and the athletic heart: emerging perspectives on pathology, risks, and return to play. *JAMA Cardiol* 2021; 6(2): 219–27. <https://doi.org/10.1001/jamacardio.2020.5890>.
26. Phucharoen C, Sangkaew N, Stosic K. The characteristics of COVID-19 transmission from case to high-risk contact, a statistical analysis from contact tracing data. *EClinicalMedicine* 2020; 27: 100543. <https://doi.org/10.1016/j.eclinm.2020.100543>.
27. Bazant MZ, Bush JWM. A guideline to limit indoor airborne transmission of COVID-19. *Proc Natl Acad Sci USA* 2021; 118(17). <https://doi.org/10.1073/pnas.2018995118>.
28. Mecenas P, Bastos R, Vallinoto ACR, Normando D. Effects of temperature and humidity on the spread of COVID-19: a systematic review. *PLoS One* 2020; 15(9): e0238339. <https://doi.org/10.1371/journal.pone.0238339>.
29. Tillett RL, Sevinsky JR, Hartley PD, Kerwin H, Crawford N, Gorzalski A, et al. Genomic evidence for reinfection with SARS-CoV-2: a case study. *Lancet Infect Dis* 2021; 21(1): 52–8. [https://doi.org/10.1016/S1473-3099\(20\)30764-7](https://doi.org/10.1016/S1473-3099(20)30764-7).
30. Van Elslande J, Vermeersch P, Vandervoort K, Wawina-Bokalanga T, Vanmechelen B, Wollants E, et al. Symptomatic SARS-CoV-2 reinfection by a phylogenetically distinct strain. *Clin Infect Dis* 2020. <https://doi.org/10.1093/cid/ciaa1330>.
31. Ryan RM, Deci EL. *Self-determination theory: basic psychological needs in motivation, development, and wellness*: Guilford Publications; 2018.
32. Monteiro D, Teixeira DS, Vitorino A, Moutao J, Rodrigues F, Machado S, et al. Behavioral regulation sport questionnaire: gender and sport invariance in Portuguese athletes. *Percept Mot Skills* 2019; 126(2): 323–41. <https://doi.org/10.1177/0031512519825700>.
33. Monteiro D, Cid L, Teixeira DS, Fonseca T, Duarte-Mendes P, Silva LM, et al. Understanding needs satisfaction and frustration in young athletes: factor structure and invariance analysis. *Int J Environ Res Public Health* 2020; 17(11). <https://doi.org/10.3390/ijerph17114046>.
34. Coatsworth JD, Conroy DE. The effects of autonomy-supportive coaching, need satisfaction, and self-perceptions on initiative and identity in youth swimmers. *Dev Psychol* 2009; 45(2): 320–8. <https://doi.org/10.1037/a0014027>.
35. The Lancet Respiratory M. COVID-19 transmission-up in the air. *Lancet Respir Med* 2020; 8(12): 1159. [https://doi.org/10.1016/S2213-2600\(20\)30514-2](https://doi.org/10.1016/S2213-2600(20)30514-2).
36. Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schunemann HJ, et al. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. *Lancet* 2020; 395(10242): 1973–87. [https://doi.org/10.1016/S0140-6736\(20\)31142-9](https://doi.org/10.1016/S0140-6736(20)31142-9).
37. Martinez MW, Tucker AM, Bloom OJ, Green G, DiFiori JP, Solomon G, et al. Prevalence of inflammatory heart disease among professional athletes with prior COVID-19 infection who received systematic return-to-play cardiac screening. *JAMA Cardiol* 2021. <https://doi.org/10.1001/jamacardio.2021.0565>.
38. Siripanthong B, Nazarian S, Muser D, Deo R, Santangeli P, Khanji MY, et al. Recognizing COVID-19-related myocarditis: the possible pathophysiology and proposed guideline for diagnosis and management. *Heart Rhythm* 2020; 17(9): 1463–71. <https://doi.org/10.1016/j.hrthm.2020.05.001>.



39. Kim IC, Kim JY, Kim HA, Han S. COVID-19-related myocarditis in a 21-year-old female patient. *Eur Heart J* 2020; 41(19): 1859. <https://doi.org/10.1093/eurheartj/ehaa288>.
40. Jewell BL. Monitoring differences between the SARS-CoV-2 B.1.1.7 variant and other lineages. *Lancet Public Health* 2021; 6(5): e267-8. [https://doi.org/10.1016/S2468-2667\(21\)00073-6](https://doi.org/10.1016/S2468-2667(21)00073-6).
41. Davies NG, Abbott S, Barnard RC, Jarvis CI, Kucharski AJ, Munday JD, et al. Estimated transmissibility and impact of SARS-CoV-2 lineage B.1.1.7 in England. *Science* 2021; 372(6538). <https://doi.org/10.1126/science.abg3055>.
42. Pearson CAB, Russell WT, Davies NG, Kucharski AJ, CMMID Working Group, Edmunds WJ, Eggo RM. Estimates of severity and transmissibility of novel South Africa SARS-CoV-2 variant 501Y.V2. Preprint. 2021.

Open Access. This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited, a link to the CC License is provided, and changes - if any - are indicated. (SID_1)

