COMPREHENSIVE MEDICAL CARE OF ELITE SWIMMERS: SCREENING, PERFORMANCE AND COMPETITIONS DURING THE COVID ERA

PhD thesis

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1. Introduction

The pandemic of the Coronavirus disease 2019 (COVID-19) has influenced various aspects of society, including high-level athletes. It has changed the world of sports, including the medical care of athletes. Besides the respiratory consequences of the infection, COVID-19 enhanced the risk of myocarditis and thromboembolism, increasing the likelihood of sudden cardiac death. Therefore, comprehensive post-COVID cardiovascular screening of athletes was crucial during the initial phase of the pandemic. The fact that athletes were at a higher cardiovascular risk following the COVID-19 infection brought new challenges to the sports cardiology screenings. It raised several questions about the safe return-to-play. Recommendations for return-to-play have been continuously updated along with the latest evidence of the disease. Early identification of the virus and its consequences, along with vaccination, helped reduce disease progression and prevent unexpected events, allowing athletes to train and compete with minimized health risks. During the pandemic, healthcare services were mainly focused on COVID-19-related issues, and in parallel, the focus of competition was distracted as the events were postponed. Aquatic athletes were particularly affected by the closure of swimming pools, which forced them to maintain their sports adaptation through land-based training. Performance assessment tests were also de-emphasized, especially cardiopulmonary exercise testing (CPET), due to the higher risk of airborne transmission. However, routine performance diagnostics are crucial for optimizing training programs and monitoring sport adaptation, especially since COVID-19 also impacted athletes' preparation.

2. Objectives

- Our primary aim was to assess how the COVID-19 pandemic affected elite swimmers' physiological adaptation and sports performance, preparing for the Tokyo Olympics. To evaluate the impact of COVID-19 infection on their Olympic preparation and to compare the performance parameters of those who had been infected with those who had not, we compared the two annual detailed sports cardiology screenings of the Hungarian National Swim Team.
- Our secondary aim was to more precisely investigate the effects of COVID-19 in a multinational cohort of aquatic athletes during the 19th AQUA World Championship.
- Our third aim was to examine, in detail, the COVID-19 and non-COVID-19-related medical services during the 19th AQUA World Championship.
- Lastly, we aimed to survey, through a questionnaire-based study, the COVID-19 experience of the multinational cohort of elite aquatic athletes competing in the first global sports event without an isolation "bubble." We assessed the infection rate, disease course, symptoms, vaccination experiences, and psychological well-being of the athletes participating in the 19th AQUA World Championship.

3. Methods

3.1. Sports cardiology screening and COVID-19 infection of elite swimmers

In our observational study related to the Hungarian National Swim Team, detailed sports cardiology screening was performed in 2019 and 2021. Sports cardiology screening included: sport-specific questionnaire, resting electrocardiogram (ECG), blood test, echocardiography, body composition

analysis, and CPET. Personal and family history, as well as symptoms, were assessed using the sport-specific questionnaire. Routine blood tests were supplemented with an iron panel and vitamin D levels, and, in 2021, a COVID-19 spike-protein antibody assay. The swimming performance of individuals was evaluated using AQUA time-ranking points. These points are assigned based on time-ranking scores to measure and compare swimming performance across events. Swimmers have been instructed to report any signs of infection during the pandemic. If COVID-19 symptoms appeared, a polymerase chain reaction (PCR) test and an antigen test were immediately conducted. A post-COVID cardiology assessment was necessary after the quarantine period to resume training. The baseline examination consisted of the following: patient history, sport- and COVID-19-specific questionnaires, physical examination, blood test, resting ECG, body composition, and echocardiography. The clinical characteristics of the infection were evaluated through a COVID-specific questionnaire. The blood test used during the sports cardiology screening was supplemented with a highly sensitive troponin T and D-dimer test. If abnormalities or prolonged symptoms occurred, additional tests were performed.

3.2. Sport event medical services during the COVID era

Semmelweis University provided medical services at several AQUA events, including the 19th AQUA World Championship in Budapest from June 13 to July 13, 2022. Medical services were provided at all venues by experienced staff, with protocols in place to minimize COVID-19 risk through a semi-bubble structure, along with vaccination recommendations and testing requirements. Participants had to present a negative PCR or antigen test result, along with a statement confirming their previous COVID-

19 infection and vaccination status. Furthermore, an on-site entry PCR and an antigen test were required before obtaining accreditation. In case of negative results, masks were no longer mandatory. For vaccinated participants, no additional exams were necessary. For unvaccinated participants, an additional antigen test was performed on the 5th day. Symptomatic cases and contacts were tested immediately. For COVID-positive participants, isolation was required, lasting 6 days for vaccinated and 10 days for non-vaccinated individuals. Negative antigen tests allowed athletes to return to competition, with the requirement of wearing masks for an additional 5 days. Medical encounters during the Championship were recorded in an application developed by our team. Treatments were categorized based on whether they were related to COVID-19 or non-COVID-19 issues. The non-COVID problems were divided by major medical specialties into nine categories: (1) acute trauma or injury, (2) chronic orthopedic conditions, (3) upper respiratory tract infection; ear, nose, and ophthalmology issues, (4) dental problems, (5) headaches, (6) neurology or psychiatric issues, (7) dermatology, (8) gastroenterology, and (9) urology problems.

3.3. COVID-specific questionnaire research

A collaboration between AQUA and Semmelweis University led to the development of an anonymized COVID-19 questionnaire, which was completed voluntarily by participating aquatic athletes during the 19th World Championship. This survey gathered demographic data, sports activity, infection and vaccination history, and psychological factors related to the pandemic. It began with sociodemographic data: age, sex, nationality, aquatic discipline, training hours, and experience. Then, it covered COVID-

19 clinical details: disease course, severity, and timing, noting when athletes contracted the virus within six-month periods. Vaccination status and psychological perceptions were also collected. Athletes were grouped according to their symptoms. The severity levels were categorized as follows: asymptomatic (1), mild (2), moderate (3), and severe (4). Mild symptoms included disturbances in smell or taste, cough, fever, headache, fatigue, notable weakness, palpitations, eye pain, muscle or joint pain, and runny nose. Moderate symptoms were shortness of breath, chest pain, and loss of consciousness without requiring hospitalization. Hospitalization was classified as a severe disease course, regardless of symptoms. An ordinal variable with seven levels was created to quantify symptom duration. Missed training sessions were grouped into six categories: no missed days (1), 1–3 days (2), 4–6 days (3), 1–2 weeks (4), 3–4 weeks (5), or over 4 weeks of missed training (6). Symptoms persisting for over 4 weeks following infection are categorized as long COVID symptoms. Additional questions focused on overall well-being, mood shifts, perceived decline in performance, and the need for psychological support.

4. Results

4.1. Participants

Swimmers of the Hungarian National Team

In 2019 and 2021, a total of 46 swimmers from the Hungarian National Swim Team underwent detailed sports cardiology screening. During both years, their training schedules were similar, and the main goal of the Hungarian Championships in both seasons was to qualify for major international competitions, requiring all swimmers to be in comparable preparation phases for both screenings. The average training volume exceeded 20 hours per

week for at least 13 years. Between March 2020 and April 2021, 14 athletes contracted the COVID-19 virus. No significant differences were found between COVID and non-COVID swimmers regarding age, experience, or training hours before and after infection. The average training loss was 18.6 ± 4.3 days.

Participants at the 19th AQUA World Championship

The 19th AQUA World Championship in Budapest hosted 9631 accredited participants, including 2097 athletes (21.8%) from 181 countries. Out of them, 907 completed the COVID-19 questionnaire, and 812 response sheets (39%) were used for analysis. The athletes had an average age of 22.7 ± 5.9 years, with 57.5% being female. They trained an average of 22.7 ± 10.1 hours weekly, with a training history of 14.6 ± 5.8 years. Most participants were swimmers (41%), followed by artistic swimmers (20%), water polo players (16.4%), divers (15.3%), and open water swimmers (7.4%).

4.2. Sports cardiology screening and COVID-19 infection of elite swimmers

Most findings from the sports cardiology screening were identified in 2019. The athletes had no family history or risk factors for cardiovascular diseases. During the initial screening, three athletes underwent 24-hour ambulatory blood pressure monitoring; one was diagnosed with hypertension and started on medication. No abnormalities appeared on the resting ECG. A pulmonology exam was required for 10 swimmers during the initial screening; in seven cases, previous asthma treatments were adjusted, and two athletes were newly diagnosed with asthma. Due to the high incidence of asthma among swimmers, pulmonary screening for all athletes was arranged in 2021. Laboratory, echocardiography, and body composition results were

analyzed based on COVID status. Basic laboratory parameters showed no major changes or significant differences between COVID and non-COVID athletes. The COVID group had more frequent low vitamin D levels (64% vs. 50%) and significantly lower levels (37.8 ± 11.0 ng/mL vs. 47.7 ± 11.0 ng/mL, $p < 0.05$). Echocardiography showed improvements in left ventricular wall thickness and ejection fraction across all groups, with no significant COVID-related differences. Left ventricular end-diastolic diameters decreased, while right ventricular diameters increased in all groups. No significant differences in muscle or fat mass were found between female and male athletes, regardless of COVID status. During CPET, no clinically significant pathological changes were identified. The CPET findings aligned with those typically observed in elite swimmers. An increasing trend in maximal aerobic capacity was seen in female non-COVID and male COVID athletes. Otherwise, as shown in Table 1, there were no notable differences between COVID and non-COVID athletes from 2019 to 2021.

Table 1. Cardiopulmonary exercise testing results in swimmers.

	Non-COVID Swimmers			Covid Swimmers			2019 vs. 2019	2021 vs. 2021
	2019	2021	p	2019	2021	p	p	p
Resting HR (bpm)	68.4 ± 13.4	62.0 ± 11	0.06	69.0 ± 15	72.4 ± 17	0.61	0.90	0.024 *
Peak HR (bpm)	190.0 ± 10.3	190.5 ± 11.5	0.88	191.2 ± 9.1	188.0 ± 11	0.44	0.74	0.53
HR recovery (1/min)	32.3 ± 10.8	22.0 (20.0 – 32.0)	0.03 *	33.1 ± 13.9	23.5 (19.7 – 31.2)	0.32	0.85	0.78
RER	1.15 ± 0.05	1.17 ± 0.08	0.28	1.15 ± 0.07	1.17 ± 0.07	0.38	0.81	0.94

Treadmill time (min)	M	16.0 (13.0 – 16.5)	14.5 ± 2.7	0.12	14.5 ± 1.3	15.0 (13.7 – 15.0)	1.0	0.73	0.40
	F	13.2 ± 2.8	12.9 ± 1.6	0.80	14.4 ± 2.0	13.5 ± 2.0	0.45	0.35	0.55
Max load (Watt)	M	432.6 ± 74.0	402.9 ± 60.8	0.25	464.3 ± 25.8	458.0 ± 31.0	0.75	0.42	0.052
	F	294.0 ± 50.4	270.4 ± 41.3	0.32	311.4 ± 61.7	283.3 ± 41.5	0.37	0.52	0.59
VO_2 max (L/min)	M	4.7 (4.5 – 5)	4.6 ± 0.7	0.89	4.7 ± 0.4	5.2 ± 0.6	0.14	0.89	0.08
	F	2.9 ± 0.3	3.1 ± 0.4	0.48	3.3 ± 0.5	3.2 ± 0.4	0.82	0.10	0.47
VO_2 max (mL/min/kg)	M	56.7 ± 4.7	55.5 ± 4.5	0.49	55 ± 3.8	56.5 ± 4.9	0.53	0.41	0.20
	F	49.6 ± 3	50.7 ± 2.6	0.47	53.1 ± 5.5	52.9 ± 4.1	0.97	0.12	0.76
O_2 pulse (mL/bpm)	M	25.0 ± 1.9	24.0 ± 1.8	0.23	25.6 ± 2.1	26.4 ± 2.4	0.58	0.58	0.03 *
	F	15.0 (13.7 – 17.9)	16.2 ± 2.1	0.64	17.8 ± 2.8	18.2 ± 2.7	0.82	0.06	0.18
VE (L/min)	M	158.0 ± 33.0	159.0 ± 31.5	0.95	153.0 ± 9.5	178.0 ± 16.6	0.03 *	0.74	0.19
	F	114.0 ± 17.0	109.0 ± 25.0	0.64	118.0 ± 10.4	111.0 ± 12.4	0.28	0.60	0.90
VE/VCO_2	M	25.0 ± 2.2	29.4 ± 3.9	0.70	28.5 ± 2.2	28.9 ± 3.5	0.86	0.88	0.78
	F	32.9 ± 2	31.0 ± 2.9	0.12	31.5 ± 2.2	30.2 ± 1.6	0.32	0.17	0.58
Peak lactate (mmol/L)	M	7.6 ± 2.5	7.8 ± 3.1	0.88	9.7 ± 4.1	9.5 ± 2.1	0.95	0.22	0.23
	F	8.5 ± 2.5	9.1 ± 2.2	0.58	8.4 ± 1.9	6.6 ± 1.7	0.09	0.99	0.04

Legend: Data are presented as mean ± SD or median (IQR), stratified by sex. P-values in the central columns refer to within-group comparisons between 2019 and 2021, while the rightmost columns indicate between-group comparisons (COVID vs. non-COVID) for 2019 and 2021, respectively. Significance level: * $p < 0.05$. Abbreviation: M—male, F—female, HR—heart rate, BPM—beats per minute, RER—respiratory exchange ratio, VE—ventilation, MIN—minute.

Athletes' overall performance, measured by time ranking points, increased by 54.8% from 2019 to 2021, regardless of COVID-19 status. COVID athletes improved their AQUA points by 55.6%, while non-COVID athletes saw a 54.5% rise. There was no significant difference between the groups ($p = 0.75$). Most athletes experienced (86%) COVID symptoms, mainly fatigue (64%), fever (50%), muscle pain (43%), dyspnea (43%), headache (36%), runny nose (36%), sleep issues (36%), cough (21%), anosmia and ageusia (21%), sore throat (21%), and palpitations (7%). Laboratory testing revealed elevated highly sensitive Troponin T levels (16 ng/L and 30 ng/L) in two

athletes; however, cardiac MRI results were normal in both cases. Other tests showed no abnormal findings. All swimmers successfully resumed training.

4.3. Medical Service at the 19th AQUA World Championship

During the event, there were 830 medical issues: 427 hotel, 373 on-site, and 67 emergency department visits, involving 418 participants. Almost half of the medical care (n=404, 49%) was provided to athletes, affecting 205 (10%) of them. Athletes' medical treatments were associated with 13.8% (n=61) of water polo players, 12.1% (n=41) of artistic swimmers, 9.9% (n=20) of open water swimmers, 8.2% (n=19) of divers, and 6.5% (n=64) of swimmers. In terms of visit frequency, swimming had the highest number of control visits, while water polo had the most treated athletes. Trauma and injury were the most common non-COVID-related illnesses, followed by upper respiratory tract infections, ear-nose-throat issues, and eye problems. Among sports, water polo players experienced the highest injury rate at 43%. Out of 404 medical encounters related to athletes, 226 (56%) were associated with COVID-19 infection. Participants with mild symptoms received only on-site treatment (n = 32). A total of 192 hotel visits were made, and two athletes were treated in the emergency department. A total of 616 exams (12.2% of all tests) were performed for symptomatic participants. Overall, there were 104 confirmed positive cases during the competition, with 47% involving athletes. Of these, 29% were detected through entry testing, 53% due to symptoms, and 18% were linked to close contacts. On the fifth day of testing non-vaccinated participants, no COVID-19 infections were detected. Among participants with acute infection, 34% of the 104 COVID-positive cases had no symptoms. The most common symptoms in the remaining cases included

cough (30%), fever (29%), sore throat (28%), runny nose (15%), headache (15%), and fatigue (12%). No patients exhibited major COVID-19 symptoms, and no hospitalizations were required. Regarding COVID-19 vaccination, 2.3% of participants were non-vaccinated, including nearly half (n=105) of them being athletes. However, 99% of those infected had received the vaccine.

4.4. Findings of the COVID-19 Questionnaire

Regarding the incidence of COVID-19 among aquatic athletes who participated in the 19th AQUA World Championship and completed the COVID-19 questionnaire, 398 (49%) were affected at least once, while an additional 52 athletes (13%) had a COVID-19 infection twice (Figure 2).

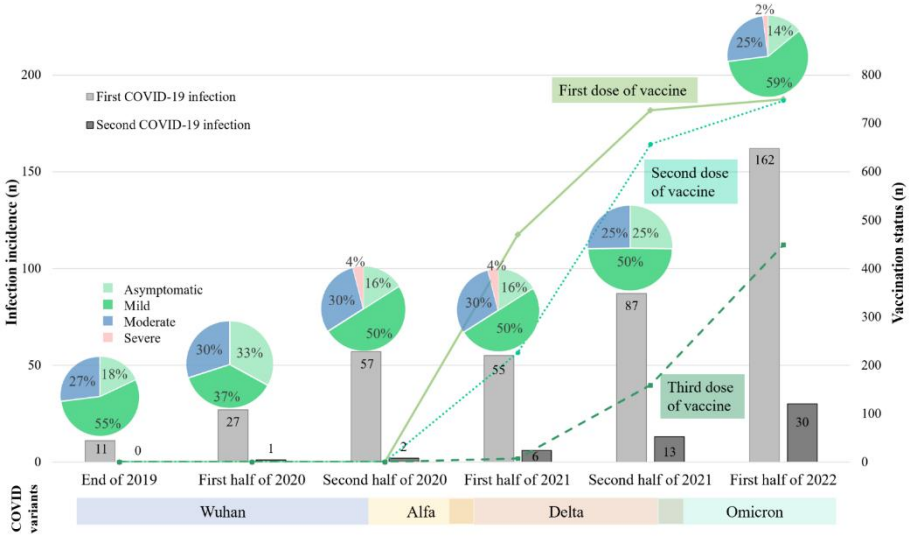

Figure 2. COVID-19 infection incidence and vaccination status over time

Legend: The diagram illustrates the incidence of first and second infections in half-year intervals, the severity distribution of symptoms for first infections (shown in pie charts), and the number of vaccinations. COVID variants are also displayed along the timeline at the bottom of the figure. Most athletes experienced asymptomatic, mild, or moderate symptoms. The highest case numbers, including

reinfections, were observed in the first half of 2022. Although case numbers increased over time, the spread of vaccination and the emergence of the Omicron variant were associated with overall milder clinical outcomes.

COVID-19 infection was detected in 68% of athletes due to symptoms, in 24% without symptoms during routine screening, and in 8% during competition screening. Aquatic team sports had the highest infection rates, with 67% in water polo and 61% in artistic swimming, while open water swimmers had the lowest incidence at 24% ($p < 0.0001$).

A logistic regression model predicted COVID-19 incidence based on biological plausibility. Older age (OR 1.04, CI 1.01–1.06) and team sports participation (OR 2.18, CI 1.58–3.00) were independent predictors. The highest incidence was 40.2% in late 2022. No significant change in symptom severity occurred across the 6-month periods. Overall, 83% of athletes had COVID-19 symptoms, with 2% severe requiring hospitalization. Over half (54%) had mild, 27% moderate, and 17% asymptomatic cases. The reinfection rate was 13% (n=52), mostly among females (n=28) and team athletes (n=26), mainly in late 2021 and early 2022. Symptom count, symptom severity, and missed training time were significantly lower during the second infection. The median number of symptoms was 3 (IQR 1-4) for the first infection and 1 (IQR 0-3) for the second infection ($p < 0.0001$). The median missed training time was 1-2 weeks (IQR 3-4) during the first infection and 4-6 days (IQR 2-4) during the second infection ($p = 0.0001$).

Long COVID syndrome developed in 40 athletes (10%) after the initial infection and was more prevalent in females (n=25). Fatigue (65%), shortness of breath (48%), cough (35%), and concentration problems (28%) were the most common symptoms. Independent predictors of long COVID

were identified using a multivariate logistic regression (AUC 0.76, CI 0.72–0.80, $p < 0.0001$), revealing that the number of symptoms during the acute phase was a reliable predictor (OR 1.4, CI 1.18-1.7).

Regarding the COVID-19 vaccination status of athletes, 94% ($n = 769$) received one dose, 92% received two doses, and 55% received three doses of the vaccine. Psychological support was needed by 36% of athletes, but nearly half did not get help. The median well-being score during the pandemic was 6 (IQR 4-7), mood changes 6 (IQR 4–8), and subjective performance decline 5 (IQR 3–7). Female athletes showed more mood changes (median 7 vs. 6, $p = 0.0002$). Well-being correlated with mood changes ($r = 0.617$, $p < 0.0001$), performance decline ($r = 0.466$, $p < 0.0001$), and initial infection severity ($r = 0.146$, $p = 0.004$).

5. Conclusions

The COVID-19 pandemic has significantly impacted the sports world, presenting unique challenges for athletes and professionals, while highlighting the importance of sports cardiology screening. It has become essential to rule out COVID-related cardiac consequences and return-to-play decisions. However, the emerging evidence and the appearance of milder variants did not indicate an increased cardiac risk; however, the detailed screening programs provided a good practice for safer sport eligibility decisions. Our research reveals a high rate of COVID-19 infection among aquatic athletes, with most experiencing mild to moderate symptoms and a low rate of complications. Furthermore, elite swimmers preparing for the Tokyo Olympics maintained their performance levels. Higher transmission rates were observed in team sports, highlighting the importance of

implementing effective preventive measures. Vaccination acceptance was high among aquatic athletes, with mostly mild side effects, emphasizing the importance of encouraging vaccination within sports communities for a safer environment. The increased awareness and hygiene practices from the pandemic may continue to help athletes by reducing infections. Psychological factors significantly affected athletes' experiences, emphasizing the need for ongoing mental health support. After the quarantine era, mass competitions could be safely and successfully organized without complications and relevant transmission of the COVID-19 infection, as Hungary outlined with the first organized World Championship without strict preventive countermeasures. Overall, our findings highlight the importance of adaptable training, targeted medical monitoring, mental health support, and evidence-based organizational strategies in protecting athlete health and maintaining competitive sports during future public health crises.

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