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Original article

# Increased number of symptoms during the acute phase of SARS-CoV-2 infection in athletes is associated with prolonged time to return to full sports performance—AWARE VIII

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**Abstract**

*Purpose*: The aim of the study was to identify factors associated with prolonged time to return to full performance (RTFP) in athletes with recent severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection.

*Methods*: Prospective cohort study with cross sectional analysis. A total of 84 athletes with confirmed SARS-CoV-2 infection assessed at a coronavirus disease 2019 recovery clinic gave a history of age, sex, type/level of sport, co-morbidities, pre-infection training hours, and 26 acute SARS-CoV-2 symptoms from 3 categories (“nose and throat”, “chest and neck”, and “whole body”/systemic). Data on days to RTFP were obtained by structured interviews. Factors associated with RTFP were demographics, sport participation, history of co-morbidities, pre-infection training history, and acute symptoms (type, number). Outcomes were: (a) days to RTFP (median, interquartile range (IQR)) in asymptomatic ($n = 7$) and symptomatic athletes ($n = 77$), and (b) hazard ratios (HRs; 95% confidence interval) for symptomatic athletes with *vs*. without a factor (univariate, multiple models). HR $< 1$ was predictive of higher percentage chance of prolonged RTFP. Significance was $p < 0.05$.

*Results*: Days to RTFP were 30 days (IQR: 23−40) for asymptomatic and 64 days (IQR: 42−91) for symptomatic participants ($p > 0.05$). Factors associated with prolonged RTFP (univariate models) were: females (HR = 0.57; $p = 0.014$), endurance athletes (HR = 0.41; $p < 0.0001$), co-morbidity number (HR = 0.75; $p = 0.001$), and respiratory disease history (HR = 0.54; $p = 0.026$). In symptomatic athletes, prolonged RTFP (multiple models) was significantly associated with increased “chest and neck” (HR = 0.85; $p = 0.017$) and “nose and throat” (HR = 0.84; $p = 0.013$) symptoms, but the association was more profound between prolonged RFTP and increased total number of “all symptoms” (HR = 0.91; $p = 0.001$) and “whole body”/systemic (HR = 0.82; $p = 0.007$) symptoms.

*Conclusion*: A larger number of total symptoms and specifically “whole body”/systemic symptoms during the acute phase of SARS-CoV-2 infection in athletes is associated with prolonged RTFP.

**Keywords:** Athletes; COVID-19; Performance; Recovery; Return to play

## 1. Introduction

The potential burden of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection on athletes’ health, especially the cardiopulmonary systems, has been investigated.[1−7] The impact of acute respiratory illness, including SARS-CoV-2, on the short- and longer-term exercise and sports performance parameters was explored in a recent systematic review.[8] Despite the heterogeneity in the results of the reviewed studies, there was a trend towards impairment in both exercise and sports performance outcomes in athletes after a recent acute respiratory infection (ARinf). Specifically, a reduction in sports performance (self-reported training ability and capacity as well as overall training load) was observed in the post-ARinf period.[8]

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The period of inability to train or compete after injury or illness is known as "time loss".[9] After a period of time loss, the process to return to sport is a continuum rather than a single defined end point. This continuum has been described for injuries[10] but also holds for return to sport after ARinf. The return to sport process timeline after ARinf has 2 defined time points. The first time point is when an athlete resumes or starts training (i.e., days to return to training (RTT)). An athlete then progressively increases training load until the final endpoint, when they reach pre-infection levels of sports performance (i.e., days to return to full performance (RTFP)).

The actual days to RTT ranged in previously published data from a median of 14 to 30 days,[11–14] and possible factors associated with days to RTT have been explored.[12–14] Symptom clusters[12,14] or symptoms confined to the lower respiratory tract[13] were associated with prolonged RTT. More recently, reduced training in the 7 days before the infection and number of symptoms during the acute phase of infection were predictive of prolonged RTT.[14] Data on days to RTT and associated factors are limited, and no data are available on the time course (days) or factors associated with RTFP after a recent SARS-CoV-2 or other ARinf.

The hypothesis of this study is that an increase in the number of symptoms during the acute phase will be associated with prolonged time to RTFP. However, to date no data are available on days to RTFP or factors influencing these timelines. Therefore, the aim of this study was to report the number of days from the onset of symptoms/positive test to RTFP and to identify factors associated with a prolonged time (days) to RTFP in a cohort of athletes with a recent SARS-CoV-2 infection.

## 2. Methods

### 2.1. Study design and setting

This was a descriptive cross-sectional analysis of data collected in a prospective cohort study, which is part of the multi-centered Athletes With Acute Respiratory InfEctions (AWARE) research program conducted by the Sport, Exercise Medicine and Lifestyle Institute (SEMLI) at the University of Pretoria in South Africa. The most predominant SARS-CoV-2 variants during the recruitment phase were the Ancestral virus and Beta and Delta variants, and varying degrees of restrictions on human movement and sporting events were in place. Governmental authorities stipulated that an individual with a positive Coronavirus disease 2019 (COVID-19) test should isolate at home for a period of 14 days. However, at the time of this study, no specific guidelines on RTT were available. Vaccination only became available in South Africa in a phased roll out in early 2021 and was not readily available to most participants. The study followed the Code of Ethics according to the Declaration of Helsinki,[15] and all participants gave written informed consent. Ethical approval for the project was obtained from the Research Ethics Committee of the Faculty of Health Sciences at the University of Pretoria (REC 409/2020 and REC 751/2019).

### 2.2. Participants and data collection

Participants were deemed eligible if they: (a) were athletes aged 18−60 years, (b) were training >3 h a week, (c) had a recent SARS-CoV-2 infection confirmed by polymerase chain reaction or antigen testing, (d) completed the online questionnaire, and (e) consented to partake in the study. Data collection was in 2 phases.

#### 2.2.1. Data collection: Phase 1

The first phase of the study was conducted over a 15-month period, between July 1, 2020, and September 30, 2021. During this period, 105 participants were recruited and clinically assessed in the SEMLI's "COVID-19 recovery clinic" before exercise was resumed. The first assessment in the clinic was at a median of 17 days (interquartile range (IQR): 14−21) after the onset of acute symptoms (for symptomatic participants) or positive COVID-19 test (for asymptomatic participants). Participants completed an online questionnaire[12] that was hosted on the Research Electronic Data Capture (REDCap) platform[16] and contained the following sections: (a) demographics (age, body mass index, and sex); (b) sport participation (level/type of sport);[17] (c) allergies, history of comorbidities (by 10 organ systems: cardiovascular disease, cardiovascular disease risk factors, respiratory, nervous and psychological, gastrointestinal, endocrine, kidney/bladder, immune/blood system disorders, and cancer); (d) 26 symptoms[18] during the acute phase of SARS-CoV-2 infection (presence, number, duration, and severity) per anatomical region "nose and throat", "chest and neck", and "whole body"/systemic, and (e) training history (weekly training 2−5 weeks prior to onset of symptoms (h/week). Acute symptoms were reported on a scale of 1−7 (adapted from the validated Wisconsin Upper Respiratory Symptom Survey) and scored as "mild" (1−3), "moderate" (4−5), or "severe" (6−7) as described in a previous study.[12] This online questionnaire (including the symptoms) was completed before the participant's first assessment. To minimize recall bias, all the clinical information from the questionnaire was verified by the principal investigator (CS) during the first assessment. During this assessment, the investigator assessed participants based on their history of chronic diseases and medication use, acute symptoms, as well as the clinical findings upon physical examination and the results of special investigations (including electrocardiogram, troponin-T, and echocardiogram). Once the investigator evaluated all the outcomes, the participant was cleared to resume exercise. The actual day of the first training session was recorded by the investigator as the date for RTT. Due to the lack of scientific guidelines on RTT at the time of this study, each participant was assessed and advised individually. Participants were followed up with clinically at regular intervals over a period of 3 months. The total number of participants for Phase 1 of the study was 105 (Supplementary Fig. 1).

#### 2.2.2. Data collection: Phase 2

In Phase 2 of the study (January−March 2022), 94 participants were interviewed by a structured in-person or telephonic interview. Eleven participants could not be contacted (Supplementary Fig. 1). Participants were asked to report the days to RTFP as follows: "On which day were you back to your pre-COVID-19 sports performance level?" Subsequently, they were asked if they had "no symptoms or health concerns but other factors that prevented you from the first training session to return to the pre-illness level of performance, e.g., work/travel/training venue access restrictions". If participants answered "yes" to this question, their data were excluded from the analysis, as the factors influencing RTFP were not considered to be SARS-CoV-2 related. A total of 10 participants reported that factors such as work/travel/training venue access restrictions affected days to RTFP, and they were excluded from the analysis. The number of remaining participants was 84. Two participants had a re-infection of SARS-CoV-2 (2 and 12 months after the initial infection, respectively). Data from both assessments were included, however demographic information was not duplicated. A total of 7 participants were asymptomatic. In data analysis exploring symptoms during the acute phase of infection as factors influencing time to RTFP, these 7 participants were thus excluded. Thus, for analyses related to symptoms, only 79 assessments were included (Supplementary Fig. 1).

### 2.3. *Patient and public involvement*

Athletes with a recent ARinf and medical practitioners involved in athletes' treatment provided feedback on the questionnaire during the developmental stages.

### 2.4. *Measures of outcome*

The main aim was to identify factors associated with a prolonged time (day) to RTFP in a cohort of athletes with a recent SARS-CoV-2 infection. Specific factors include the following: demographics (age, sex, and body mass index); sport participation (level and type of sport); history of co-morbidities (number and type); allergies; pre-infection training history; the presence and number of all symptoms; and symptoms by anatomical region during the acute phase of infection. The days (median; IQR) from the onset of symptoms to RTFP as well as symptom characteristics (number (%), duration (day) (median; IQR), and severity (mild *vs*. moderate/severe)) by anatomical region are also reported.

### 2.5. *Statistical analysis of data*

Demographics, sport participation, and history of co-morbidities in participants were described using *n* (%) or mean ± SD for all participants (*n* = 84) and for symptomatic participants (*n* = 77). The number of asymptomatic (*n* = 7) participants was too small to compare statistically with the symptomatic group. Two participants had a re-infection, thus 79 assessments on symptomatic participants and their pre-infection training history were described. The responses to the 26 SARS-CoV-2 symptoms (8 "nose and throat", 8 "chest and neck", and 10 "whole body"/systemic) were described as: (a) the presence of symptoms (number of athletes (*n*, %)), (b) the duration in days (median; IQR), and (c) the severity (number (%) of mild and moderate/severe). Days to RTT and RTFP were reported as median (IQR) for symptomatic and asymptomatic participant assessments, but RTFP analyses were performed on only the symptomatic participant assessments (*n* = 79). One participant did not RTFP during the study period and was censored in the analysis.

Cox regression was used to model the factors associated with RTFP. Hazard ratios (HRs; 95% confidence interval (95%CI)) were reported with $\chi^2$ ($p$ values) (type 3 test) for significance ($p < 0.05$) for: demographics, sport participation, history of co-morbidities, and pre-infection training for symptomatic participant assessments (*n* = 79), as well as 26 SARS-CoV-2 symptoms (individual and by anatomical region ("nose and throat", "chest and neck", "whole body", and "all symptoms")). Four multiple regression models for factors associated with RTFP were done—one for each anatomical region. Significant confounder variables with $p < 0.01$ were included in the initial models. A stepwise approach was used to configure the final multiple models. All models were adjusted for type of sport and RTT days. The HR (95%CI) was reported with $\chi^2$ ($p$ values) (type 3 test) for significance ($p < 0.05$).

## 3. Results

### 3.1. *Demographics, sport participation, history of co-morbidities, and pre-infection training*

The demographics, sport participation (level and type), history of co-morbidities, and pre-infection training history of all participants (*n* = 84) and symptomatic (*n* = 77) participants are shown in Supplementary Table 1.

The symptomatic study population (*n* = 77) had a mean age of 25 years. The majority were males (61%), 51% were professional, and 50% were endurance athletes. A history of co-morbidity was reported by 51%, respiratory disease by 30%, asthma by 20%, hay fever by 16%, and allergies by 30%. In participants reporting a history of asthma, 18% used an inhaled corticosteroid and 24% used a short-acting beta-2 agonist only. Six (7%) of all the study participants were vaccinated. The demographics of the total study population were very similar to those of the symptomatic participants. No athletes were hospitalized during the acute phase of infection.

### 3.2. *Time course (day) from onset of symptoms to RTFP*

#### 3.2.1. *Asymptomatic participant subgroup*

For asymptomatic participants (*n* = 7), the median days from the positive SARS-CoV-2 test to RTT was 13 days (IQR: 11−24) and days to RTFP was 30 days (IQR: 23−40). Limited statistical power prevented comparison of RTT and RTFP days between asymptomatic and symptomatic subgroups.

#### 3.2.2. *Symptomatic participant subgroup*

For symptomatic participants (*n* = 79), the median days for onset of symptoms of SARS-CoV-2 infection to RTT was

16 days (IQR: 12−24), with a maximum of 90 days. The median days for onset of symptoms to RTFP was 64 days (IQR: 42−91), with a maximum of 415 days (Supplementary Fig. 2). In the subgroup of symptomatic participants, 47 (59%) reported they had ongoing symptoms after the initial acute phase of infection for variable durations, and 12 (15%) participants reported symptoms after a period of 3 months.[19] In 8 (10%) participants, the duration of symptoms could not be determined as they did not attend all the scheduled visits during the 3-month follow-up period. As symptoms seem to play an important role in the timeline to RTFP, all subsequent analyses were performed on the symptomatic participant assessments.

### *3.3. Characteristics of symptoms of SARS-CoV-2 infection per anatomical region during the acute phase of infection in the symptomatic subgroup assessments (n = 79)*

The presence (*n* (%)), duration (median: IQR) and severity (*n* (%) of mild and moderate/severe) of symptoms during the acute phase of infection for the 79 participant assessments are summarized according to anatomical regions in Supplementary Table 2. Symptoms in the "nose and throat" region were reported by 79 (100%) participants, 68 (86%) indicated they had at least 1 symptom in the "chest and neck" region, and 63 (80%) had "whole body"/systemic symptoms.

### *3.4. Factors associated with the time course (day) from onset of symptoms to RTFP (univariate model)*

#### *3.4.1. RTFP and demographics, sport participation/type, history of co-morbidities, and pre-infection training history (univariate model)*

The HRs (95%CI) for the associations between time to RTFP and demographics, sport participation, and history of co-morbidities for symptomatic participants ($n = 77$) are shown in Table 1. An HR < 1 indicates a higher chance (%) of prolonged RTFP after the onset of the infection.

Demographic factors associated with prolonged time to RTFP for symptomatic participants were: female sex ($p = 0.014$), endurance sport ($p < 0.0001$), number of co-morbidities ($p = 0.001$), history of a respiratory disease ($p = 0.026$), and days to RTT ($p = 0.007$).

#### *3.4.2. RTFP and presence of symptoms by anatomical region and specific symptoms (univariate model)*

The HRs (95%CI) for the association between time to RTFP and the presence of symptoms by anatomical region and specific symptoms during the acute infection are shown in Supplementary Table 3.

Significant associations between presence of symptoms by anatomical region and prolonged RTFP (% higher chance) is as follows: any "chest and neck" symptoms (65%; $p = 0.0005$) and any "whole body" symptoms (60%; $p = 0.004$). None of

Table 1
The HRs (95%CI) for RTFP by demographics, sport participation, history of co-morbidities, and pre-infection training history as possible factors associated with time to RTFP for symptomatic participants ($n = 77$) (univariate model).

| Variable | HR[a] (95%CI) | $\chi^2$ | *p* |
|---|---|---|---|
| Symptomatic participants ($n = 77$) | | | |
| Demographics | | | |
| Age (year)[b] | 0.98 (0.95−1.01) | 2.10 | 0.148 |
| Females (*vs*. males) | 0.57 (0.37−0.89) | 6.03 | **0.014** |
| BMI (kg/m$^2$)[b] | 1.10 (1.00−1.14) | 3.80 | 0.051 |
| Sport participation | | | |
| Level of sport participation | | | |
| Professional (*vs*. amateur) | 0.65 (0.41−1.03) | 3.42 | 0.065 |
| Type of sport | | | |
| Endurance (*vs*. mixed) | 0.41 (0.28−0.60) | 21.19 | **<0.0001** |
| History of co-morbidities | | | |
| Number of co-morbidities per participant[b] | 0.75 (0.60−0.93) | 6.72 | **0.001** |
| Any co-morbidity (yes *vs*. no) | 0.64 (0.42−1.0) | 3.89 | **0.049** |
| Respiratory (yes *vs*. no)[c] | 0.54 (0.31−0.93) | 4.93 | **0.026** |
| Allergies (yes *vs*. no) | 0.63 (0.38−1.03) | 3.44 | 0.064 |
| Symptomatic participant assessments ($n = 79$)[d] | | | |
| Pre-infection training history | | | |
| Training 7 days prior to onset of symptoms (h/week)[b] | 1.02 (0.99−1.05) | 1.64 | 0.201 |
| Weekly training 2−5 weeks prior to onset of symptoms (h/week)[b] | 1.02 (1.00−1.04) | 2.66 | 0.103 |
| Days to RTT[b] | 0.97 (0.95−0.99) | 7.38 | **0.007** |

Note: Bold type indicates statistical significance ($p < 0.05$).
[a] HR of an individual with the co-variate compared to the reference factor.
[b] Continuous variables.
[c] Numbers on other co-morbidities (including cardiovascular, gastrointestinal, and nervous systems) were too few to calculate HR.
[d] Training history is reported for 79 assessments (2 athletes had re-infections).
Abbreviations: 95%CI = 95% confidence interval; BMI = body mass index; HR = hazard ratio; RTFP = return to full performance; RTT = return to training.

the individual "nose and throat" symptoms were associated with prolonged RTFP.

*3.4.3. RTFP and number of symptoms per anatomical region during acute phase of infection (univariate model)*

The HRs (95%CI) for the association between time to RTFP and the number of symptoms during the acute infection by anatomical region are shown in Table 2.

The association between number of symptoms by anatomical region and prolonged RTFP (% higher chance) is as follows: "nose and throat" (15%; $p = 0.025$), "chest and neck" (21%; $p < 0.0001$), "whole body" (26%; $p < 0.0001$), and "all symptoms" (12%; $p < 0.0001$).

### *3.5. Factors associated with the time course (day) from onset of symptoms to RTFP after recent SARS-CoV-2 infection (multiple models)*

In the multiple models, significant covariates with $p < 0.01$ (type of sport, number of co-morbidities, and number of days to RTT) were included. Only type of sport and days to RTT remained significant. Therefore, in the multiple models we adjusted for type of sport and days to RTT. The adjusted HRs (95%CI) for number of symptoms per anatomical region as well as total number of all symptoms associated with RTFP are reported in Table 3.

In the multiple models, prolonged time to RTFP (higher % chance) was significantly associated with an increase in the number of symptoms in each of the anatomical regions: "nose and throat" (16%; $p = 0.013$); "chest and neck" (15%; $p = 0.017$), "whole body" (18%; $p = 0.007$), and "all symptoms" (9%; $p = 0.001$).

The relationship between days from the onset of symptoms to RTFP (horizontal axis) and the probability of survival (not RTFP) (vertical axis) for "total all acute symptoms" at Q1 (5 symptoms), median (8 symptoms), and Q3 (11 symptoms) is shown in Fig. 1.

The graph shows that the group with 11 symptoms took longer (more days) to RTFP compared to the groups with 8 and 5 acute symptoms.

## 4. Discussion

The first finding of this study was that in univariate analyses we identified factors associated with prolonged RTFP in symptomatic participants, including: females ($p = 0.014$), endurance sport ($p < 0.0001$), number of co-morbidities ($p = 0.001$), history of respiratory disease ($p = 0.026$), and days to RTT ($p = 0.007$). The presence of symptoms by anatomical regions "whole body"/systemic (specifically excessive fatigue, loss of appetite, nausea, fever, chills, and general muscle aches) and "chest and neck" (chest pain/pressure, headache, and chest tightness) were also significantly associated with prolonged RTFP. Our second main finding was that the total number of symptoms and the number of symptoms per anatomical region remained significantly associated with prolonged RTFP when adjusted for type of sport and days to RTT in multiple models.

Table 2
The HR (95%CI) for RTFP and number of symptoms during the acute phase of infection by anatomical region for symptomatic participant assessments ($n = 79$) (univariate model).

| Number of symptoms[a] by anatomical region | Q1; median; Q3 | HR (95%CI)[b] | $\chi^2$ | $p$ |
|---|---|---|---|---|
| Nose and throat | 2; 3; 4 | 0.85 (0.73−0.98) | 5.04 | **0.0250** |
| Chest and neck | 1; 2; 3 | 0.79 (0.72−0.87) | 22.79 | **<0.0001** |
| Whole body | 1; 2; 4 | 0.74 (0.65−0.83) | 23.37 | **<0.0001** |
| All symptoms | 5; 8; 11 | 0.88 (0.83−0.92) | 26.00 | **<0.0001** |

Note: Bold type indicates statistical significance ($p < 0.05$).
[a] For number of symptoms, the HR indicates the change in risk for 1 more symptom.
[b] HR of the hazard of RTFP for an individual with an increased number of symptoms in each anatomical region. HR < 1 indicates a higher chance of RTFP after the onset of infection.
Abbreviations: 95%CI = 95% confidence interval; HR = hazard ratio; RTFP = return to full performance.

Table 3
The HR (95%CI) for RTFP and number of symptoms during acute phase of infection by anatomical region (adjusted for type of sport and days to RTT) for symptomatic participant assessments ($n = 79$) (multiple models).

| Number of symptoms by anatomical region | Q1; median; Q3 | HR (95%CI)[a] | $\chi^2$ | $p$ |
|---|---|---|---|---|
| Nose and throat | 2; 3; 4 | 0.84 (0.74−0.97) | 6.14 | **0.013** |
| Chest and neck | 1; 2; 3 | 0.85 (0.74−0.97) | 5.70 | **0.017** |
| Whole body | 1; 2; 4 | 0.82 (0.70−0.95) | 7.28 | **0.007** |
| All symptoms | 5; 8; 11 | 0.91 (0.86−0.96) | 10.55 | **0.001** |

Note: Bold type indicates statistical significance ($p < 0.05$).
[a] HR of the hazard of RTFP for an individual with an increased number of symptoms in each anatomical region. An HR < 1 indicates a higher chance of prolonged RTFP after the onset of infection.
Abbreviations: 95%CI = 95% confidence interval; HR = hazard ratio; RTFP = return to full performance; RTT = return to training.

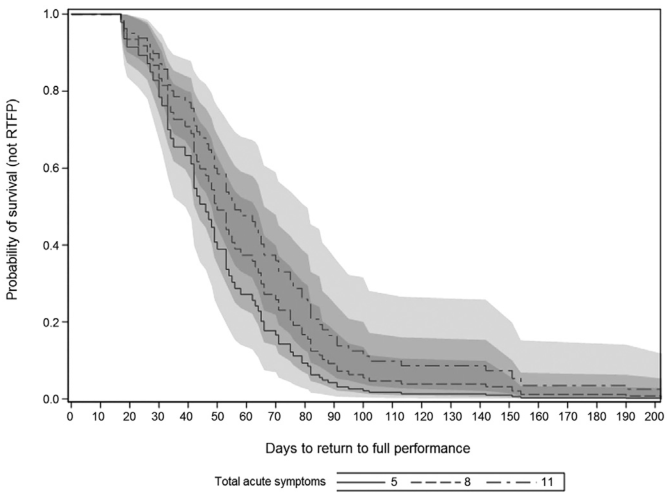


Fig. 1. The relationship between days from the onset of symptoms to RTFP (horizontal axis) and the probability of survival (not RTFP) (vertical axis) for "total all acute symptoms" at Q1 (5 symptoms), median (8 symptoms), and Q3 (11 symptoms) (shaded areas are 95%CIs). 95%CI = 95% confidence interval; RTFP = return to full performance.

To the best of our knowledge, there are no other data on both the time to RTFP (median of 64 days for symptomatic participants) and factors associated with prolonged time to RTFP in athletes after ARinf. Days to RTT in our study (median of 16 days) were comparable with previous studies.[11,13,14] Factors associated with RTT in athletes after ARinf have also been reported.[12–14] Symptom clusters of mainly systemic ("whole body") or chest related-symptoms ("chest and neck"), including excessive fatigue, fever, loss of appetite, altered/loss sense of smell, headache, chest pain/pressure, and difficulty breathing, were significantly associated with prolonged RTT.[12] In another study, dyspnea, chest pain, cough, and fever were associated with prolonged time loss (relative risk of 2.1).[13] Our study shows that symptoms in these 2 anatomical regions also have a significant impact on prolonged RTFP.

Acute SARS-CoV-2 symptoms can persist after the initial infection.[11] Long COVID has been defined by the World Health Organization (WHO) as "continuation or development of new symptoms 3 months after the initial SARS-CoV-2 infection, with these symptoms lasting for at least 2 months with no other explanation". In our study, 15% of participants reported symptoms after a period of 3 months. Athletes with persistent symptoms should be appropriately investigated and treatment should be considered so that these athletes can reach pre-infection level of performance sooner.

Total number of acute symptoms and number of acute symptoms in each anatomical region have previously been associated with prolonged RTT.[14] Our study shows that these 2 parameters are also associated with prolonged RTFP. We have no data from other studies in athletes with which we can compare our findings, but we note with interest that studies in the general population showed that ≥5 acute symptoms is associated with a higher risk of prolonged duration of symptoms after SARS-CoV-2 infection.[20,21] Although intuitively expected, these emerging data suggest that a greater number of acute symptoms may indicate more severe COVID-19, resulting in prolonged recovery. We recognize that our findings need to be replicated in other populations and with larger sample sizes and other respiratory pathogens.

From our univariate analysis we show that female athletes had longer duration to RTFP. Although this finding is to some extent supported by data from 2 studies where females had a greater number of acute SARS-CoV-2 symptoms[13] and where female athletes had a longer period to RTT[14] compared to males, the results of univariate analysis should be interpreted with caution. In the univariate analysis we also show that endurance athletes had prolonged RTFP. In 1 study, endurance athletes returned to training quicker,[14] but the time to reach the full pre-infection performance level was not reported. A prolonged adaptation to training, once training after SARS-CoV-2 infection in endurance athletes resumes, may be a reason for this observation, but further investigation is required.

Finally, in the univariate analysis we show that a history of co-morbidities, specifically respiratory co-morbidities (mostly asthma) were associated with prolonged RTFP. In the general population, several co-morbidities have been associated with poorer clinical outcomes of SARS-CoV-2 infections.[22] We also show that the presence of dry cough and chest tightness were associated with prolonged RTFP. Therefore, at the time of the first clinical assessment, athletes with a history of underlying respiratory disease should be identified as being at higher risk for prolonged RTFP, and appropriate use of medication for chronic conditions (e.g., inhaled corticosteroids as a first-line treatment for asthma) should also be evaluated. We suggest that these athletes be monitored once training resumes. New and persistent exertional symptoms should also be investigated appropriately.[11]

### *4.1. Limitations of the study*

In our study, participants were self-selected, and this limits the generalizability of our findings to other populations of athletes with SARS-CoV-2 infection. The number of asymptomatic participants was small, so days for this group's RTFP could not be adjusted for possible confounders and could not be compared to the symptomatic group of participants. We also recognize that RTT and RTFP dates were self-reported. The date a participant resumed exercise during the 3-month follow up period was recorded by the investigator as the date for RTT. RTFP data were collected during a structured interview by the principal investigator (CS) as part of following-up with the cohort after the 3-month period—hence, they were based on recall. Our population of athletes was interviewed during the COVID-19 pandemic, which was a time when the significant impact of SARS-CoV-2 on their well-being and sport opportunities made athletes more aware of their performance and timelines to full recovery. Data were collected during the dominance of specific SARS-CoV-2 variants, and 93% of participants were unvaccinated. Our findings were not compared to different SARS-CoV-2 variants, vaccinated individuals, or other pathogens causing ARinf and so may not be applicable in these study populations. Sports performance is multi-factorial, and we acknowledge that the time to RTFP could not solely be attributed to the effects of

SARS-CoV-2 infection. Additional factors (e.g., the novelty of the COVID-19 virus, the impact of the isolation during acute infection, fear of physical harm during exercise post infection, multiple psychological factors, unavailability of scientifically proven RTT or RTFP guidelines, and lack of motivation to train when competitions were limited during the pandemic) could also have influenced time to RTFP. Finally, our study design was cross-sectional, and although significant associations with prolonged RTFP were shown, these do not infer a cause-and-effect relationship.

### *4.2. Clinical implications*

Knowledge of the expected time to RTFP as well as identifying factors associated with prolonged RTFP can assist the athlete, coach, and medical staff in planning training schedules to reach set goals to RTFP after an infection. For the medical staff attending to athletes with SARS-CoV-2 infection, a history on the symptoms experienced during the acute phase of infection is of value as an increased number of acute symptoms, specifically "whole body"/systemic symptoms ($p < 0.01$), may indicate a longer time to RTFP. These athletes warrant a detailed history, possible further investigations, appropriate management, and closer monitoring once exercise resumes. Knowledge of the number of symptoms and specific symptoms during the acute phase of SARS-CoV-2 infection may also assist the sport and exercise medicine (SEM) physician with RTFP timelines.

### *4.3. Summary*

Female and endurance athletes with SARS-CoV-2 infection, and those with more co-morbidities and a history of respiratory disease, may have a prolonged RTFP. In athletes with SARS-CoV-2 infection, presence of acute symptoms in both the "whole body" and "chest and neck" regions can prolong RTFP. In athletes with SARS-CoV-2 infection, both the total number of acute symptoms and the number of acute symptoms in each anatomical region (especially "whole body"/systemic) are associated with prolonged RTFP. Future studies are needed to determine time to RTFP and associated factors in larger cohorts of athletes, vaccinated athletes, and for other SARS-CoV-2 variants and non-SARS-CoV-2 ARinf. Research to determine factors influencing the time to RTT and RTFP after ARinf is also suggested.

## 5. Conclusion

Our study is novel and, as far as we are aware, it is the only study reporting the days to RTFP and factors affecting the time course to RTFP. Knowledge related to the time course to RTFP can assist in the planning for athletes to achieve peak performance at sporting events. The treating physician should monitor athletes' progress after SARS-CoV-2 infection to RTFP especially in the following groups: females, endurance athletes, athletes with a history of respiratory disease, and athletes presenting with many symptoms during the acute phase of infection. Persistent symptoms may influence time to RTFP, and if athletes report these, they should be investigated and managed appropriately. Underlying co-morbidities should also be identified.

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## Authors' contributions

CS was involved in study planning, data collection, data interpretation, manuscript writing (first draft), and manuscript editing; EJ and MD were involved in data cleaning, data management, data analysis (including statistical analysis), data interpretation, and manuscript editing. NS was involved in study planning, data interpretation, manuscript writing (first draft), and manuscript editing; MS was responsible for the overall content (as guarantor), study concept, study planning, data collection, data interpretation, manuscript editing, and facilitating funding. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

## Competing interests

The authors declare that they have no competing interests.

## Supplementary materials

Supplementary materials associated with this article can be found in the online version at doi:10.1016/j.jshs.2023.10.005.

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