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Rating of Perceived Exertion Associated With Acute Symptoms in Athletes With Recent SARS-CoV-2 Infection: Athletes With Acute Respiratory InfEction (AWARE) VI Study

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Context: SARS-CoV-2 infection can affect the exercise response in athletes. Factors associated with the exercise response have not been reported.

Objective: To (1) describe heart rate (HR), systolic blood pressure (SBP), and rating of perceived exertion (RPE) responses to exercise in athletes with a recent SARS-CoV-2 infection and (2) identify factors affecting exercise responses.

Design: Cross-sectional, experimental study.

Patients or Other Participants: Male and female athletes (age = 24.2 ± 6.3 years) with a recent (<28 days) SARS-CoV-2 infection (n = 72).

Setting: A COVID-19 Recovery Clinic for athletes.

Main Outcome Measure(s): Heart rate, SBP, and RPE were measured during submaximal exercise (modified Bruce protocol) at 10 to 28 days after SARS-CoV-2 symptom onset. Selected factors (demographics, sport, comorbidities, preinfection training variables, and symptoms during the acute phase of the infection) affecting the exercise response were analyzed using random coefficient (linear mixed) models.

Results: Heart rate, SBP, and RPE increased progressively from rest to stage 5 of the exercise test ($P = .0001$). At stage 5 (10.1 metabolic equivalents), a higher HR and a higher SBP during exercise were associated with younger age ($P = .0007$) and increased body mass index (BMI; $P = .009$), respectively. Higher RPE during exercise was significantly associated with a greater number of whole-body ($P = .006$) and total number ($P = .004$) of symptoms during the acute phase of infection.

Conclusions: A greater number of symptoms during the acute infection was associated with a higher RPE during exercise in athletes at 10 to 28 days after SARS-CoV-2 infection. We recommend measuring RPE during the first exercise challenge after infection, as this may indicate disease severity and be valuable for tracking progress, recovery, and return to sport.

Key Words: exercise, performance, COVID-19, coronavirus, return to sport

Key Points

- In athletes with a recent SARS-CoV-2 infection (10 to 28 days after onset), an expected increase was seen in heart rate, systolic blood pressure, and rating of perceived exertion (RPE) during incremental submaximal exercise.
- Athletes with a greater number of symptoms during the acute phase of the infection had a higher RPE during exercise.
- After acute respiratory infection, we recommend performing an exercise challenge test, including measures of RPE, in keeping with the recently published International Olympic Committee consensus guidelines.

SARS-CoV-2 infection is predominantly a respiratory illness but can have systemic effects, which have been observed in the general population as well as in athletes.[1,2] Younger athletes are relatively protected from severe disease but are not excluded from ongoing medical consequences or postacute sequalae of SARS-CoV-2, despite mild acute illness in most cases.[3–5] In particular, symptoms during exercise post–SARS-CoV-2 infection, including dyspnea and chest pain, have been reported in large cohorts of athletes (4%–8%).[4,5]

The Sport and Exercise Medicine (SEM) clinician is responsible for advising athletes with recent acute respiratory infection, including SARS-CoV-2, on safe return to sport (RTS). To date, RTS guidance post–SARS-CoV-2 infection has been predominantly focused on the detection of inflammatory heart disease, such as myocarditis and pericarditis, and clearing the athlete to resume exercise training.[6,7] In a recent International Olympic Committee consensus statement, an exercise challenge test is recommended as the first step in the RTS process after an acute respiratory infection in athletes.[8] Recommended variables obtained from an exercise challenge test, including heart rate (HR), systolic blood pressure (SBP), and rating of perceived exertion (RPE), can guide the decision to return to training and subsequent decisions to increase the training load until the athlete returns to full performance. However, data are limited on the response to an exercise challenge post–SARS-CoV-2 infection in athletes and factors that may predict an abnormal response to the exercise challenge.

Heart rate and SBP responses during exercise 10 to 34 days postinfection have been reported in small samples of athletes with mixed results. Researchers of some studies reported no differences in peak exercise HR or SBP after infection,[9] although significant differences in HR at the aerobic threshold, anaerobic threshold, and maximal effort have been reported post–SARS-CoV-2 infection.[9] The measurement of the RPE during exercise has not been reported in athletes returning to sport after acute respiratory infection, including SARS-CoV-2.[9] An understanding of the RPE response to exercise postinfection could make a valuable contribution to the decision-making process and implementation of RTS guidance for both athletes and clinicians. Several factors, such as age, sex, history of comorbidities, sporting history, preinfection training history, and severity of the acute infection, may influence the HR, SBP, and RPE responses to an exercise challenge after SARS-CoV-2 infection in athletes, but these variables have not been investigated.

The aim of this study was to (1) describe the HR, SBP, and RPE response to exercise in athletes 10 to 28 days post–SARS-CoV-2 infection and (2) identify factors affecting the exercise responses. Specific factors of interest included demographic variables, sport variables, history of comorbidities, preinfection training variables, and symptoms during the acute phase of the infection.

METHODS

Study Design and Setting

This was a cross-sectional, experimental study in a cohort of athletes. Data were collected in the COVID-19 Recovery Clinic (*the clinic*) research laboratory at the Sport, Exercise Medicine and Lifestyle Institute (SEMLI) in Pretoria, South Africa, between July 20, 2020, and July 20, 2021, during the first (ancestral virus) and second (predominantly β-variant) waves of the COVID-19 pandemic. This study forms part of the Athlete With Acute Respiratory InfEction (AWARE) international, multicenter research study. The Research Ethics Committee of the Faculty of Health Sciences at the University of Pretoria approved the umbrella AWARE study (REC number: 644/2020) as well as this specific study protocol (REC number: 771/2019).

Study Cohort

Potential participants for this study were 72 male and female athletes (age = 18 to 65 years) who had a recent SARS-CoV-2 infection and completed at least 10 days of mandatory isolation. Throughout the data collection period for this study, an isolation period of 10 days remained consistent and was mandated by the national government. The SARS-CoV-2 infection was confirmed by either a polymerase chain reaction analysis on a nasopharyngeal or throat swab (n = 70) or a positive IgG antigen test for SARS-CoV-2 taken at the onset of illness (n = 2).[10] At the start of the study, COVID-19 vaccines were not available. In 2021, vaccination became available in a phased rollout, initially only for higher-risk and older individuals. Thus, at the time of closure for participant inclusion for this study (May 2021), no participants were vaccinated.

An *athlete* was defined as someone who "consistently trains in any sport for a minimum of 3 hours per week, competing at varying levels from recreational to elite." Sport disciplines were classified according to their dynamic exercise load, which is associated with the percentage of maximal oxygen uptake (VO_2max) and increased cardiac output.[11] Sports were classified according to their cardiovascular dynamic load as follows: *low*, less than 50% (n = 3); *moderate*, 50% to 75% (n = 19); and *high*, greater than 75% (n = 47) dynamic load.[11] From this classification, the different types of sport within this population were combined for analysis and assigned to a low-moderate dynamic load (<75%) group, including judo, gymnastics, CrossFit, rugby union and rugby, and a high dynamic load (>75%) group, including football, tennis, field hockey, netball, cycling, triathlon, swimming, and running (long distance).[11]

Clinical Assessment Before Exercise Challenge Testing

All athletes provided written informed consent and were assessed by an SEM physician in the clinic before a submaximal exercise challenge test. The initial clinical assessment was conducted between 10 and 28 days postonset of symptoms and included a medical history, clinical assessment, and selected special investigations. All participants completed a previously described online medical questionnaire to provide history related to (1) demographics (age and sex); (2) sport (classification by dynamic load, level of sport, highest level of sport participation, and years of participation in sport); (3) history of comorbidities by organ system, including cardiovascular disease or risk factors; respiratory, nervous system, psychological, gastrointestinal, metabolic, renal or bladder, or immune or blood disorders; and history of cancer; (4) preinfection training variables (hours of training) in 0 to 7 days and 8 to 35 days before the onset of symptoms of acute SARS-CoV-2 infection; and (5) symptoms (number) during the acute phase of the infection that were selected from a list of a maximum of 23 symptoms in 3 anatomical regions (nose and throat, chest and neck, and whole body [systemic]).[12,13] After a clinical assessment, the SEM physician cleared all athletes of any contraindications to a submaximal exercise challenge test.

Measurements

Measurements at Rest. Before commencing exercise, resting measurements were recorded for each athlete. Height (cm) and weight (kg) were measured by a stadiometer (seca 213; Hammer Steindamm) and weight scale (seca 813; Hammer Steindamm), respectively. Heart rate (bpm) was measured by a 12-lead electrocardiogram (custo cardio 110 BT, custo med GmbH) recorded for 30 seconds.[14,15] Systolic

Table 1. Demographics, Sport Variables, History of Comorbidities, Preinfection Training, and Symptoms During the Acute Phase of the Infection in the Study Population (n = 72)

	Mean ± SD	No. (%)
Demographic variables		
Age, y	24.2 ± 6.3	
Male		44 (61)
Female		28 (39)
BMI, kg/m^2	24.2 ± 3.6	
Sport variables		
Classification of sport by dynamic load[a]		
Low-moderate dynamic load (<75%)		22 (32)
High dynamic load (>75%)		47 (68)
Level of sport		
Professional		38 (53)
Amateur		34 (47)
Highest level of sport participation		
International		11 (15)
National		15 (21)
Provincial		23 (32)
Recreational		23 (32)
Athlete experience, y	9.9 ± 6.2	
History of comorbidities		
Pre-existing number of comorbidities	1.0 ± 0.9	
Preinfection training variables		
Hours of training 0–7 days before onset	8.7 ± 6.6	
Hours of training 8–35 days before onset	12.9 ± 8.6	
Training resumed at assessment date		
Yes		26 (36)
No		46 (64)
Detraining days[b]	18.0 ± 9.3	
Symptoms during the acute phase of the infection		
Number of symptoms: nose and throat	3.3 ± 1.9	
Number of symptoms: chest and neck	2.5 ± 1.9	
Number of symptoms: whole body	2.4 ± 2.0	
Total number of symptoms	8.2 ± 4.9	

Abbreviation: BMI, body mass index.
[a] Type of sport indicated as *other* and therefore not classified, n = 3.
[b] Detraining days = number of days between onset of symptoms and return to training.

blood pressure (mm Hg) was measured by a manual Welch Allyn sphygmomanometer, inflatable cuff, and professional stethoscope (Welch Allyn Inc).[14,16]

Measurements During the Submaximal Exercise Challenge. Participants completed a submaximal exercise challenge test to measure HR, SBP, and RPE responses to exercise. The modified Bruce treadmill protocol was selected for the submaximal exercise test.[14] The rationale for the selection of this protocol was the consideration of recent SARS-CoV-2 infection and possible resultant exercise intolerance. The modified Bruce protocol allows a slow, gradual progression of exercise intensity (gradient and speed), increasing the likelihood of reaching a steady-state of exercise compared with the common selection of the Bruce protocol that has more aggressive increments in exercise intensity.[17] Participants completed 5 stages of the modified Bruce protocol, starting at 2.3 metabolic equivalents (METs; eg, low-intensity activities of daily living) and ending at 10.1 METs (eg, vigorous jogging, cycling, or swimming),[18] or the test was terminated at 85% HR maximum if this was reached before completion of the fifth stage. Heart rate and SBP were measured using the same apparatus as at rest every 3 minutes (toward the end of each stage), and contraindications to continuing exercise testing were monitored throughout the test by the applied exercise physiologist conducting the tests.[14] The RPE was measured every 3 minutes (in the last 30 seconds of each stage) using a visual chart of the Borg scale ranging from 6 (*no exertion*) to 20 (*maximum exertion*).[18–20]

Factors Affecting the Exercise Response (HR, SBP, and RPE)

The following selected factors that may affect the response to exercise were explored.

Demographic Variables. Demographic variables included age (years), sex (male or female), and body mass index (BMI; kg/m^2).

Sport Variables. Sport variables included the type of sport (low-moderate or high dynamic load), level of sport (professional versus amateur), highest level of sports participation (international, national, provincial, and recreational), and athlete experience (years).

History of Comorbidities. Athletes were grouped as those with and those without a history of pre-existing comorbidities.

Preinfection Training Variables. Preinfection training variables were hours of training at 0 to 7 and 8 to 35 days before the onset of symptoms and detraining days (days between the onset of symptoms and return to training).

Symptoms During the Acute Phase of the Infection. The number (out of a maximum of 23 symptoms) of nose and throat, chest and neck, and whole body symptoms as well as the total number of symptoms during the acute phase of the infection were explored.

Statistical Analyses

Descriptive information was reported as n (%) for categorical variables and mean ± SD for numerical variables. The outcomes (HR, SBP, and RPE) at stage 5 were analyzed, as it represented the highest exercise intensity (10.1 METs) measured across the sample and most realistically represents the exercise intensity at which athletes would return to training. The significance of the factors related to the outcomes at stage 5 was assessed using a linear model, and least square means and standard errors (mean [SEs]) with the χ^2 statistical test (*P* values) were reported.

Linear mixed models with a random intercept and slope were used to investigate the relationship between the outcomes (HR, SBP, and RPE) and the baseline stage to stage 5. The SEs were reported at each stage with the estimated differences (SEs and 95% CIs) from one stage to the next, with *P* values indicating whether the increase at each stage was significant. For the RPE, the interaction of stage × number of total symptoms was analyzed and the results conveyed using a graph. For reporting results, a significance level of 1% was used.

RESULTS

Study Population Characteristics

The cohort consisted of 72 athletes (age = 24.2 ± 6.3 years old; 28 female, 39%; 44 male, 61%) who were assessed 17.5 ± 4.6 days postonset of the SARS-CoV-2 infection. Athletes were assessed between June 2020 and July 2021 in South Africa, and as such, none had been vaccinated for

Table 2. The Heart Rate (HR), Systolic Blood Pressure (SBP), and Rating of Perceived Exertion (RPE) Response From Rest to Stage 5 (10.1 Metabolic Equivalents [METs]) of the Submaximal Exercise Challenge Test

All	HR, bpm				SBP, mmHg				RPE, 6–20			
	Estimate (SE)	Estimated Increase (SE)	LCL–UCL	*P* Value[a]	Estimate (SE)	Estimated Increase (SE)	LCL–UCL	*P* Value[a]	Estimate (SE)	Estimated Increase (SE)	LCL–UCL	*P* Value[a]
Rest	57.3 (1.2)				106.2 (1.0)							
Stage 1 (2.3 METs)	96.8 (2.1)	39.5 (1.5)	36.5–42.6	.0001	110.9 (1.2)	4.8 (0.9)	2.9–6.7	.0001	6.5 (0.12)			
Stage 2 (3.5 METs)	102.4 (2.1)	5.6 (0.6)	4.4–6.8	.0001	118.3 (1.3)	7.3 (0.9)	5.6–9.1	.0001	7.4 (0.20)	0.84 (0.14)	0.56–1.12	.0001
Stage 3 (4.6 METs)	111.3 (2.3)	8.9 (0.8)	7.4–10.4	.0001	123.2 (1.4)	5.9 (0.8)	4.4–7.5	.0001	8.5 (0.25)	1.11 (0.13)	0.86–1.37	.0001
Stage 4 (7.0 METs)	130.1 (2.4)	18.8 (0.7)	17.3–20.2	.0001	134.4 (1.6)	10.2 (1.0)	8.2–12.2	.0001	10.4 (0.31)	1.93 (0.17)	1.59–2.26	.0001
Stage 5 (10.1 METs)	154.4 (2.3)	24.3 (1.0)	22.2–26.4	.0001	148.9 (1.9)	14.5 (1.1)	12.3–16.8	.0001	12.7 (0.30)	2.25 (0.14)	1.96–2.54	.0001

Abbreviations: LCL, lower confidence limit; UCL, upper confidence limit.
[a] *P* values indicate the difference (linear increase) in the estimate (slope) between the stages.

COVID-19 at the time of infection or assessment. Most athletes (n = 46; 64%) had not resumed training postonset of symptoms at the time of assessment, and for those who had resumed training, 18.0 ± 9.3 days passed between the onset of symptoms and the resumption of training.

All demographic variables, sport variables, history of comorbidities, preinfection training, and symptoms during the acute phase of the infection are presented in Table 1.

The HR, SBP, and RPE Response to the Exercise Challenge

The HR, SBP, and RPE response to the exercise challenge from rest to the completion of stage 5 (10.1 METs) of the submaximal exercise test is reported in Table 2. A significant increase was found from rest (HR and SBP) through all 5 stages of exercise (HR, SBP, and RPE; $P < .0001$). The largest increase in HR (39.5 bpm) was from baseline to stage 1. The largest increase in SBP (14.5 mmHg) and RPE (2.3) was from stage 4 to stage 5.

Factors Associated With the HR Response During Exercise

Factors potentially associated with the HR response at stage 5 (10.1 METs) of the submaximal exercise test are reported in Table 3. Younger age was significantly associated with a higher HR ($P = .0007$) with an average decrease in HR of 12 bpm for every 10-year increase in age. All other demographic, sport, or training variables and symptoms during the acute phase of the infection were not associated with the HR response.

Factors Associated With the SBP Response During Exercise

Factors potentially associated with the SBP response at stage 5 (10.1 METs) of the submaximal exercise test are reported in Table 4. Age, sex, all sport variables, comorbidities, preinfection training variables, and symptoms during the acute phase of infection were not significantly associated with the SBP response. The only demographic variable that was associated with higher SBP at stage 5 was a higher BMI ($P = .009$) with an average of 1.5 mmHg increase in SBP for every 1 kg/m^2 increase in BMI.

Factors Associated With the RPE Response During Exercise

Factors potentially associated with the RPE response at stage 5 (10.1 METs) of the submaximal exercise test are reported in Table 5. Demographics, sport variables, history of comorbidities, and preinfection training variables were not significantly associated with the RPE response at stage 5. A greater number of whole-body symptoms ($P = .006$) and the total number of symptoms ($P = .004$) were significantly associated with a higher RPE at stage 5. For every increase of 4 total number of symptoms, the RPE increased by 0.7 (SE = 0.23).

The relationship between the RPE response from stage 1 to stage 5 and the total number of symptoms is depicted in the Figure. An increase was seen in the RPE with increasing stages as well as a steeper increase with an increasing number of symptoms ($P = .024$ for interaction).

Table 3. Factors Associated With the Heart Rate (HR) Response During Exercise (10.1 Metabolic Equivalents [METs])

	Variable Estimates	HR (bpm) at 10.1 METs, Mean ± SE	Chi-Square	*P* Value[a]
Demographic variables				
Age, y	20	159.4 ± 2.6	11.6	**.0007**
	30	147.4 ± 2.9		
	40	135.4 ± 5.7		
Sex	Male	152.8 ± 3.0	0.62	.43
	Female	156.6 ± 3.7		
BMI, kg/m^2	20	153.9 ± 3.6	0.02	.891
	22	154.1 ± 2.8		
	26	154.4 ± 2.6		
Sport variables				
Classification of sport by dynamic load	Low-moderate (<75%)	161.2 ± 4.1	4.4	.036
	High (>75%)	150.0 ± 2.8		
Level of sport	Professional	153.1 ± 3.3	0.26	.609
	Amateur	155.5 ± 3.3		
Highest level of sport participation	International	140.4 ± 5.8	8.55	.036
	National	153.7 ± 4.9		
	Provincial	161.3 ± 3.8		
	Recreational	153.6 ± 3.8		
Athlete experience, y	20	157.8 ± 3.3	2.82	.093
	30	156.5 ± 2.8		
	40	153.9 ± 2.3		
History of comorbidities				
Comorbidities	Yes	148.7 ± 3.1	6.2	.013
	No	160.1 ± 3.2		
Preinfection training variables				
Training 0–7 days before onset, h	4	157.2 ± 2.8	3.3	.069
	6	155.9 ± 2.5		
	11	152.7 ± 2.4		
Training 8–35 days before onset, h	6	154.7 ± 3.0	0.06	.806
	10	154.4 ± 2.5		
	18	153.9 ± 2.7		
Detraining days[b]	12	151.5 ± 2.7	3.36	.067
	15	152.9 ± 2.4		
	22	156.1 ± 2.5		
Symptoms during the acute phase of the infection				
Number of symptoms: nose and throat	2	153.2 ± 2.8	0.44	.506
	3	154.0 ± 2.3		
	4	154.9 ± 2.5		
Number of symptoms: chest and neck	2	154.4 ± 2.4	0.06	.811
	3	154.1 ± 2.4		
	4	153.8 ± 3.0		
Number of symptoms: whole body	2	154.0 ± 2.4	0.3	.586
	3	154.6 ± 2.4		
	4	155.3 ± 3.0		
Total number of symptoms	4	153.5 ± 3.1	0.15	.699
	8	154.2 ± 2.3		
	10	154.6 ± 2.5		

Abbreviation: BMI, body mass index.
[a] Bold values are statistically significant.
[b] Detraining days = number of days between onset of symptoms and return to training.

DISCUSSION

This study aimed to describe the HR, SBP, and RPE response to exercise and investigate the factors associated with the HR, SBP, and RPE response to submaximal exercise in athletes with a recent SARS-CoV-2 infection. The main findings of this study are as follows: (1) HR, SBP, and RPE significantly increased from rest to stage 5 of the exercise test; (2) higher exercise HR was significantly associated with younger age; (3) SBP at stage 5 was not associated with any factor; and (4) the most significant clinical finding was that the RPE at stage 5 was significantly associated with symptoms during the acute phase of infection.

The HR and SBP Response to an Exercise Challenge Post–SARS-CoV-2 Infection in Athletes

The first main finding of this study is an expected HR and SBP response[14,18,20] to an exercise challenge test in athletes less than 28 days post–SARS-CoV-2 infection. Previous researchers have not described the HR and SBP response throughout the exercise challenge test but did report findings of resting HR, peak HR, and peak SBP without abnormality or significant difference to controls.[21–23] Thus, our findings are in keeping with those in previous reports.[9] For the clinician planning safe RTS in athletes after SARS-CoV-2 infection, this

Table 4. Factors Associated With the Systolic Blood Pressure (SBP) Response During Exercise (10.1 Metabolic Equivalents [METs])

	Variable Estimates	SBP (mmHg) at 10.1 METs, Mean ± SE	Chi-Square	*P* Value[a]
Demographic variables				
Age, y	20	148.2 ± 2.4	0.06	.814
	30	149.0 ± 2.8		
	40	149.8 ± 5.6		
Sex	Male	151.7 ± 2.4	4.51	.034
	Female	143.2 ± 3.1		
BMI, kg/m^2	20	142.4 ± 3.0	6.78	**.009**
	22	145.4 ± 2.2		
	26	151.5 ± 2.2		
Sport variables				
Classification of sport by dynamic load	Low-moderate (<75%)	147.8 ± 3.5	0.130	.716
	High (>75%)	149.4 ± 2.4		
Level of sport	Professional	145.7 ± 2.6	2.56	.11
	Amateur	151.9 ± 2.8		
Highest level of sport participation	International	138.8 ± 4.9	4.68	.197
	National	149.4 ± 4.1		
	Provincial	151.0 ± 3.4		
	Recreational	150.3 ± 3.4		
Athlete experience, y	20	150.9 ± 2.8	1.51	.219
	30	150.0 ± 2.4		
	40	148.1 ± 2.0		
History of comorbidities				
Comorbidities	Yes	149.6 ± 2.8	0.28	.599
	No	147.5 ± 2.8		
Preinfection training variables				
Training 0–7 days before onset, h	4	149.1 ± 2.4	0.17	.677
	6	148.9 ± 2.1		
	11	148.3 ± 2.1		
Training 8–35 days before onset, h	6	148.2 ± 2.5	0.06	.813
	10	148.4 ± 2.1		
	18	148.8 ± 2.3		
Detraining days[b]	12	147.3 ± 2.3	1.06	.304
	15	148.0 ± 2.0		
	22	149.8 ± 2.3		
Symptoms during the acute phase of the infection				
Number of symptoms: nose and throat	2	148.7 ± 2.3	0.01	.928
	3	148.6 ± 2.0		
	4	148.5 ± 2.2		
Number of symptoms: chest and neck	2	148.4 ± 2.0	0.23	.630
	3	148.9 ± 2.1		
	4	149.4 ± 2.6		
Number of symptoms: whole body	2	148.5 ± 2.0	0.04	.850
	3	148.7 ± 2.1		
	4	148.9 ± 2.7		
Total number of symptoms	4	148.2 ± 2.5	0.05	.815
	8	148.6 ± 2.0		
	10	148.8 ± 2.2		

Abbreviation: BMI, body mass index.
[a] Bold values are statistically significant.
[b] Detraining days = number of days between onset of symptoms and return to training.

finding is reassuring because athletes returning to sport after SARS-CoV-2 infection may present unique clinical scenarios that can raise concern and uncertainty for the attending SEM physician, clinician, and athlete.[5]

A second main finding from our study is the association between a higher HR and younger age. This finding was expected and can be explained by the widely documented finding that maximum exercise HR decreases with age.[24] We also show that SBP was not associated with any variables that we explored. Changes in HR and SBP during recovery from SARS-CoV-2 infection require further investigation.

RPE During an Exercise Challenge Post–SARS-CoV-2 Infection in Athletes

A third and novel aspect of our study was to measure the RPE during an exercise challenge test in athletes at 10 to 28 days post–SARS-CoV-2 infection. The RPE response to exercise post–SARS-CoV-2, or any other acute respiratory infection, has not previously been reported, and we cannot compare our findings to those of previous research studies. The RPE response during exercise can provide valuable insight about the multisystem response to exercise[18,20,25,26] and provides a recognized measure of effort and relative fatigue during exercise, indicating intensity and homeostatic

Table 5. Factors Associated With the Rating of Perceived Exertion (RPE) Response During Exercise (10.1 Metabolic Equivalents [METs])

	Variable Estimates	RPE (6–20) at 10.1 METs, Mean ± SD	Chi-Square	*P* Value[a]
Demographic variables				
Age, y	20	12.7 ± 0.3	1.78	.182
	30	12.1 ± 0.4		
	40	11.4 ± 0.8		
Sex	Male	12.0 ± 0.4	4.78	.029
	Female	13.3 ± 0.5		
BMI, kg/m^2	20	12.8 ± 0.5	1.00	.317
	22	12.7 ± 0.3		
	26	12.3 ± 0.3		
Sport variables				
Classification of sport by dynamic load	Low-moderate (<75%)	11.4 ± 0.5	6.39	.012
	High (>75%)	13.0 ± 0.3		
Level of sport	Professional	12.3 ± 0.4	0.37	.545
	Amateur	12.7 ± 0.4		
Highest level of sport participation	International	12.3 ± 0.7	0.91	.824
	National	12.7 ± 0.6		
	Provincial	12.8 ± 0.5		
	Recreational	12.1 ± 0.5		
Athlete experience, y	20	12.6 ± 0.4	0.13	.719
	30	12.5 ± 0.4		
	40	12.4 ± 0.3		
History of comorbidities				
Comorbidities	Yes	12.5 ± 0.4		
	No	12.4 ± 0.4	0.06	.811
Preinfection training variables				
Training 0–7 days before onset, h	4	12.6 ± 0.4	0.39	.535
	6	12.6 ± 0.3		
	11	12.4 ± 0.3		
Training 8–35 days before onset, h	6	12.7 ± 0.4	1.06	.303
	10	12.6 ± 0.3		
	18	12.3 ± 0.3		
Detraining days[b]	12	12.3 ± 0.34	0.92	.338
	15	12.4 ± 0.30		
	22	12.6 ± 0.34		
Symptoms during the acute phase of the infection				
Number of symptoms: nose and throat	2	12.1 ± 0.3	4.82	.028
	3	12.4 ± 0.3		
	4	12.8 ± 0.3		
Number of symptoms: chest and neck	2	12.4 ± 0.3	5.34	.021
	3	12.7 ± 0.3		
	4	13.0 ± 0.4		
Number of symptoms: whole body	2	12.4 ± 0.3	7.5	**.006**
	3	12.8 ± 0.3		
	4	13.2 ± 0.4		
Total number of symptoms	4	11.8 ± 0.3	8.46	**.004**
	8	12.5 ± 0.3		
	10	12.9 ± 0.3		

Abbreviation: BMI, body mass index.
[a] Bold values are statistically significant.
[b] Detraining days = number of days between onset of symptoms and return to training.

disturbance.[18,20,25,26] The RPE is an integration of various symptoms from a number of organ systems including, but not limited to, working muscles, cardiovascular and pulmonary systems, joints, and those responsible for sweating, possible pain, and dizziness.[19,27] Of particular practical clinical value, measuring the RPE during exercise does not require any equipment and can be measured not only by the clinician but also by the athlete or coach.

The most significant finding of this study was the association between a higher RPE and a greater number of symptoms during the acute phase of the infection. Athletes with a greater number of acute symptoms reported a higher RPE during exercise at the same workload than those with fewer symptoms (an RPE of 13 that is "somewhat hard" versus an RPE of 11 that is "fairly light," respectively). In previously published studies reporting exercise tests in athletes with a recent SARS-CoV-2 infection, HR and BP variables have been reported, but not the RPE.[21–23,28] We suggest that measuring the RPE can be a valuable practical clinical tool to assess the multiorgan response to exercise in the setting of athletes with recent acute respiratory infection. We recently showed that a greater number of total symptoms is associated with prolonged return to training post–SARS-CoV-2 infection in athletes.[12] Prolonged symptoms beyond

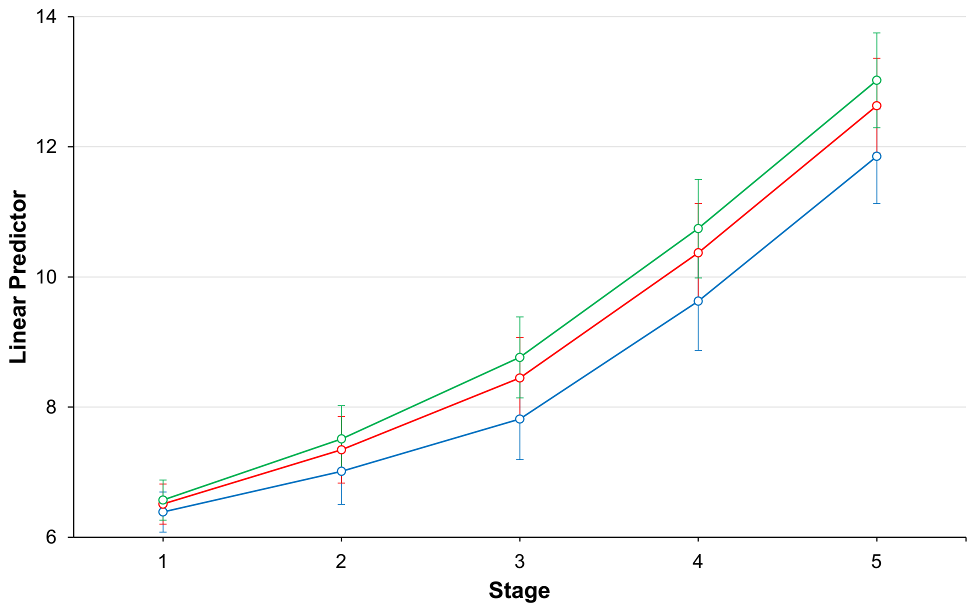

Figure. The relationship between the rating of perceived exertion (6–20) response to submaximal exercise from stage 1 to 5 and total number of symptoms (estimated for 4, 8, and 10 symptoms).

the acute phase of infection have been reported in athletes including fatigue, shortness of breath, and headache,[3,4,29] and the regression of cardiopulmonary endurance parameters as a consequence of detraining has been questioned.[29] Evidence suggests that a greater number of symptoms during the acute phase of the SARS-CoV-2 infection in nonathletes is associated with multiorgan involvement and prolonged recovery.[30] We therefore hypothesize that multiorgan system involvement could be the main mechanism responsible for the increased RPE response we observed in athletes with a greater number of acute symptoms. We also suggest that monitoring the RPE during exercise in the recovery from infection can be valuable to track progress, recovery, and RTS. We do acknowledge that although the RPE scale is subjective, it has advantages because it is validated, reliable, easy to understand, simple to use, and gives data that are easy to interpret.[19,20] Further studies are needed to (1) explore the relationship between a higher RPE during an exercise challenge test and prolonged RTS in athletes post–SARS-CoV-2 infection, (2) track changes in the RPE during the recovery from infection over time, (3) explore other possible reasons for the higher RPE in athletes with a greater number of acute symptoms, and (4) investigate if findings are applicable to an athletic population vaccinated against the SARS-CoV-2 infection.

The strengths of this study include its relatively larger sample size than that of similar studies, the assessment of athletes at 10 to 28 days post–SARS-CoV-2 infection, and the fact that the RPE was measured during the exercise challenge test. Limitations to the study include the nature of RPE measurement and the limited training data available. The RPE is a subjective measure that requires time for the athlete to understand and interpret the sensitivity of the scale. Furthermore, the significant association between the RPE and number of acute symptoms was observed at submaximal intensities of exercise with a maximum RPE of 13 ("somewhat hard"). However, it would be expected for athletes to exceed an RPE of 13 during training, which limits the generalizability of the results. Thus, it would be beneficial to understand the exercise response at higher intensities of exercise and higher RPE ratings. Available training data preinfection were limited, and additional variables such as intensity and type of training could have strengthened the covariate analysis.

CONCLUSIONS

In summary, in this study, we report the response to an exercise challenge test in athletes with a recent (<28 days postonset of symptoms) SARS-CoV-2 infection. Based on the results of this study, we confirm the value of performing an exercise challenge test postacute respiratory infection, which is the recommendation from recently published International Olympic Committee consensus guidelines.[8] We also suggest that the RPE be documented during exercise, in addition to other parameters that include HR and SBP. Symptoms during exercise also need to be monitored during follow-up exercise challenges as new exertional symptoms can be unmasked as training progresses.[29]

REFERENCES

1. Thakur V, Ratho RK, Kumar P, et al. Multi-organ involvement in COVID-19: beyond pulmonary manifestations. *J Clin Med*. 2021;10(3): 446. doi:10.3390/jcm10030446
2. Wiersinga WJ, Rhodes A, Cheng AC, Peacock SJ, Prescott HC. Pathophysiology, transmission, diagnosis, and treatment of coronavirus disease 2019 (COVID-19): a review. *JAMA*. 2020;324(8):782–793. doi:10.1001/jama.2020.12839
3. Hull JH, Wootten M, Moghal M, et al. Clinical patterns, recovery time and prolonged impact of COVID-19 illness in international athletes: the UK experience. *Br J Sports Med*. 2022;56(1):4–11. doi:10.1136/bjsports-2021-104392
4. Krzywański J, Mikulski T, Krysztofiak H, et al. Elite athletes with COVID-19—predictors of the course of disease. *J Sci Med Sport*. 2022;25(1):9–14. doi:10.1016/j.jsams.2021.07.003

5. Petek BJ, Moulson N, Baggish AL, et al; ORCCA Investigators. Prevalence and clinical implications of persistent or exertional cardiopulmonary symptoms following SARS-CoV-2 infection in 3597 collegiate athletes: a study from the Outcomes Registry for Cardiac Conditions in Athletes (ORCCA). *Br J Sports Med*. 2022;56(16):913–918. doi:10.1136/bjsports-2021-104644
6. Casasco M, Iellamo F, Scorcu M, et al. Return to play after SARS-CoV-2 infection in competitive athletes of distinct sport disciplines in Italy: a FMSI (Italian Federation of Sports Medicine) study. *J Cardiovasc Dev Dis*. 2022;9(2):59. doi:10.3390/jcdd9020059
7. McKinney J, Connelly KA, Dorian P, et al. COVID-19-myocarditis and return to play: reflections and recommendations from a Canadian working group. *Can J Cardiol*. 2021;37(8):1165–1174. doi:10.1016/j.cjca.2020.11.007
8. Schwellnus M, Adami PE, Bougault V, et al. International Olympic Committee (IOC) consensus statement on acute respiratory illness in athletes part 1: acute respiratory infections. *Br J Sports Med.* Published online July 21, 2022. doi:10.1136/bjsports-2022-105759
9. Kaulback K, Pyne DB, Hull JH, Snyders C, Sewry N, Schwellnus M. The effects of acute respiratory illness on exercise and sports performance outcomes in athletes—a systematic review by a subgroup of the IOC consensus group on "Acute respiratory illness in the athlete." *Eur J Sport Sci.* 2023;23(7):1356–1374. doi:10.1080/17461391.2022.2089914
10. Borges do Nascimento IJ, Cacic N, Abdulazeem HM, et al. Novel coronavirus infection (COVID-19) in humans: a scoping review and meta-analysis. *J Clin Med*. 2020;9(4):941. doi:10.3390/jcm9040941
11. Levine BD, Baggish AL, Kovacs RJ, Link MS, Maron MS, Mitchell JH; American Heart Association Electrocardiography and Arrhythmias Committee of Council on Clinical Cardiology, Council on Cardiovascular Disease in Young, Council on Cardiovascular and Stroke Nursing, Council on Functional Genomics and Translational Biology, and American College of Cardiology. Eligibility and disqualification recommendations for competitive athletes with cardiovascular abnormalities: Task Force 1: classification of sports: dynamic, static, and impact: a scientific statement from the American Heart Association and American College of Cardiology. *Circulation*. 2015;132(22):e262–e266. doi:10.1161/CIR.0000000000000237
12. Schwellnus M, Sewry N, Snyders C, et al. Symptom cluster is associated with prolonged return-to-play in symptomatic athletes with acute respiratory illness (including COVID-19): a cross-sectional study-AWARE study I. *Br J Sports Med*. 2021;55(20):1144–1152. doi:10.1136/bjsports-2020-103782
13. Snyders C, Schwellnus M, Sewry N, et al. Symptom number and reduced pre-infection training predict prolonged return to training after SARS-CoV-2 in athletes: AWARE IV. *Med Sci Sports Exerc*. 2023;55(1):1–8. doi:10.1249/MSS.0000000000003027
14. Fletcher GF, Ades PA, Kligfield P, et al; American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee of the Council on Clinical Cardiology, Council on Nutrition, Physical Activity and Metabolism, Council on Cardiovascular and Stroke Nursing, and Council on Epidemiology and Prevention. Exercise standards for testing and training: a scientific statement from the American Heart Association. *Circulation*. 2013;128(8):873–934. doi:10.1161/CIR.0b013e31829b5b44
15. Vaidya GN. Application of exercise ECG stress test in the current high cost modern-era healthcare system. *Indian Heart J*. 2017;69(4):551–555. doi:10.1016/j.ihj.2017.06.004
16. Muntner P, Shimbo D, Carey RM, et al. Measurement of blood pressure in humans: a scientific statement from the American Heart Association. *Hypertension*. 2019;73(5):e35–e66. doi:10.1161/hyp.0000000000000087
17. Badawy MM, Muaidi QI. Cardio respiratory response: validation of new modifications of Bruce protocol for exercise testing and training in elite Saudi triathlon and soccer players. *Saudi J Biol Sci*. 2019;26(1):105–111. doi:10.1016/j.sjbs.2017.05.009
18. Fletcher GF, Balady GJ, Amsterdam EA, et al. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. *Circulation*. 2001;104(14):1694–1740. doi:10.1161/hc3901.095960
19. Borg E, Kaijser L. A comparison between three rating scales for perceived exertion and two different work tests. *Scand J Med Sci Sports*. 2006;16(1):57–69. doi:10.1111/j.1600-0838.2005.00448.x
20. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*. 10th ed. Wolters Kluwer; 2018.
21. Costello BT, Climie RE, Wright L, et al. Athletes with mild COVID-19 illness demonstrate subtle imaging abnormalities without exercise impairment or arrhythmias. *Eur J Prev Cardiol*. 2022;29(6):e220–e223. doi:10.1093/eurjpc/zwab166
22. Csulak E, Petrov Á, Kováts T, et al. The impact of COVID-19 on the preparation for the Tokyo Olympics: a comprehensive performance assessment of top swimmers. *Int J Environ Res Public Health*. 2021;18(18):9770. doi:10.3390/ijerph18189770
23. Komici K, Bianco A, Perrotta F, et al. Clinical characteristics, exercise capacity and pulmonary function in post-COVID-19 competitive athletes. *J Clin Med*. 2021;10(14):3053. doi:10.3390/jcm10143053
24. Ozemek C, Whaley MH, Finch WH, Kaminsky LA. Maximal heart rate declines linearly with age independent of cardiorespiratory fitness levels. *Eur J Sport Sci.* 2017;17(5):563–570. doi:10.1080/17461391.2016.1275042
25. Eston R. Use of ratings of perceived exertion in sports. *Int J Sports Physiol Perform*. 2012;7(2):175–182. doi:10.1123/ijspp.7.2.175
26. Williams N. The Borg Rating of Perceived Exertion (RPE) scale. *Occup Med (Lond)*. 2017;67(5):404–405. doi:10.1093/occmed/kqx063
27. Borg E, Borg G, Larsson K, Letzter M, Sundblad BM. An index for breathlessness and leg fatigue. *Scand J Med Sci Sports.* 2010;20(4):644–650. doi:10.1111/j.1600-0838.2009.00985.x
28. Fikenzer S, Kogel A, Pietsch C, et al. SARS-CoV2 infection: functional and morphological cardiopulmonary changes in elite handball players. *Sci Rep*. 2021;11(1):17798. doi:10.1038/s41598-021-97120-x
29. Moulson N, Gustus SK, Scirica C, et al. Diagnostic evaluation and cardiopulmonary exercise test findings in young athletes with persistent symptoms following COVID-19. *Br J Sports Med.* Published online May 18, 2022. doi:10.1136/bjsports-2021-105157
30. Fernández-Lázaro D, Sánchez-Serrano N, Mielgo-Ayuso J, García-Hernández JL, González-Bernal JJ, Seco-Calvo J. Long COVID a new derivative in the chaos of SARS-CoV-2 infection: the emergent pandemic? *J Clin Med*. 2021;10(24):5799. doi:10.3390/jcm10245799

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