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RESEARCH LETTER

# COVID-19 Myocardial Pathology Evaluation in Athletes With Cardiac Magnetic Resonance (COMPETE CMR)

Daniel E. Clark, MD, MPH
Amar Parikh, MD
Jeffrey M. Dendy, MD
Alex B. Diamond, DO, MPH
Kristen George-Durrett, BS
Frank A. Fish, MD
James C. Slaughter, DrPH
Warne Fitch, MD
Sean G. Hughes, MD*
Jonathan H. Soslow, MD, MSCI*

Myocarditis is a leading cause of sudden cardiac death among athletes and may occur without antecedent symptoms. Coronavirus disease 2019 (COVID-19)–related cardiac magnetic resonance (CMR) abnormalities have been described in 78% of mostly ambulatory adults,[1] creating concerns over COVID-19–related myocarditis in athletes. A report of 26 COVID-19–positive collegiate athletes revealed late gadolinium enhancement (LGE) in 46%, with 4 (15%) meeting modified Lake Louise criteria for myocarditis.[2,3] However, without an athletic comparator group it is difficult to discern whether LGE represents healing myocarditis or athletic remodeling, because inferoseptal right ventricular insertion LGE is common among athletes.[4] We report the findings of a larger CMR study to evaluate the prevalence and extent of cardiovascular pathology among COVID-19–positive collegiate athletes, with comparison with athletic and healthy control groups.

The data supporting the findings of this study are available from the corresponding author on request. All COVID-19–positive athletes underwent an institutionally mandated cardiovascular screening protocol, including clinical examination, electrocardiography, troponin I, echocardiography with strain, and contrasted CMR with parametric mapping on a 1.5T Siemens Avanto Fit magnet (Siemens Healthcare Sector, Erlangen, Germany). The subjects were retrospectively enrolled. Athletic controls were retrospectively selected from collegiate and tactical athletes (military personnel) referred to our center for clinical CMR before the first reported case of COVID-19 in our region. All athletes in our study participated in ≥6 hours of intense physical exercise weekly. Healthy controls (N=27) similar in age to COVID-19–positive athletes were derived from a cohort of 54 healthy subjects prospectively enrolled for noncontrasted CMR to derive normative T1 and T2 values for our laboratory. The study was approved by the institutional review board with a waiver of consent for retrospective enrollment.

Contrasted studies were performed using 0.15 mmol/kg of gadobutrol. Volumetric and parametric mapping analyses were performed using Qmass and Qmaps (MedisSuite, Leiden, The Netherlands). Punctate inferoseptal right ventricle insertion LGE was not considered a pathological exclusion criterion.[4]

Categorical variables were compared using the chi squared test, and continuous variables were compared using the Wilcoxon rank sum. Statistical analysis was performed using STATA, version 15 (StatCorp LLC, College Station, TX) software.

Fifty-nine COVID-19–positive athletes, 60 athletic controls, and 27 healthy controls were included in our analysis (Table). The COVID-19–positive athletes represented 9 collegiate sports; 63% were female and 15% were non-White, and the median age was 20 years. The median time from severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) detection to CMR was 21.5 days (interquartile range, 13–37; range, 10–162). COVID-19–positive athletes experienced

*Drs Hughes and Soslow contributed equally as co-senior authors.

**Key Words:** athletes ■ cardiac magnetic resonance imaging ■ COVID-19 ■ myocarditis



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CORRESPONDENCE

**Table. Demographics, Echocardiography, and Cardiovascular Magnetic Resonance Results**

| | COVID-19–positive athletes (N=59)*† | Healthy controls (N=27)* | Athletic controls (N=60)† | *P* value* | *P* value† |
|---|---|---|---|---|---|
| Age, median (IQR), y | 20 (19–21) | 30 (27–34) | 25 (22–27) | <0.001 | <0.001 |
| Height, cm | 173 (164–188) | 173 (164–183) | 175 (173–185) | 0.50 | 0.17 |
| Weight, kg | 67 (59–91) | 73 (66–86) | 85 (72–95) | 0.46 | 0.01 |
| Body surface area, kg/m$^2$ | 1.8 (1.6–2.2) | 1.9 (1.7–2.0) | 2.1 (1.9–2.2) | 0.85 | 0.03 |
| Race: non-White, N (%) | 6 (15%)‡ | 3 (13%)§ | 3 (21%)‖ | 0.81 | 0.55 |
| Ethnicity: non-Hispanic, N (%) | 36 (95)¶ | 22 (88)# | 13 (87)** | 0.33 | 0.32 |
| Gender: Female, N (%) | 37 (63)†† | 10 (37)‡‡ | 7 (12)§§ | 0.04 | <0.001 |
| Echocardiography | | | | | |
| LVEF, % | 61 (57–66) | NA | 60 (58–61)‖‖ | | 0.24 |
| GLS, % | –18.6 (–20.1 to –17.4)¶¶ | NA | NA | | |
| CMR | | | | | |
| Volumetrics | | | | | |
| LVEF, median (IQR), % | 60 (56–63) | 60 (57–64) | 58 (56–60) | 0.46 | 0.03 |
| LVEDV, mL | 160 (143–213) | 164 (138–210) | 195 (167–235) | 0.61 | 0.02 |
| LVEDVi, mL/m$^2$ | 93 (84–100) | 88 (78–99) | 95 (86–111) | 0.12 | 0.37 |
| LVESV, mL | 68 (58–84) | 64 (55–83) | 84 (66–97) | 0.32 | 0.007 |
| LVESVi, mL/m$^2$ | 37 (34–43) | 35 (31–41) | 40 (35–47) | 0.21 | 0.08 |
| LV mass, g | 112 (88–147) | 71 (57–96) | 117 (105–143) | <0.001 | 0.26 |
| LV mass index, g/m$^2$ | 60 (52–71) | 41 (32–48) | 59 (53–67) | <0.001 | 0.48 |
| RVEF, % | 53 (50–56) | 58 (55–60) | 53 (51–57) | <0.001 | 0.53 |
| RVEDV, mL | 184 (153–240) | 166 (136–210) | 201 (170–241) | 0.08 | 0.19 |
| RVEDVi, mL/m$^2$ | 100 (91–115) | 89 (78–104) | 99 (87–117) | 0.004 | 0.61 |
| RVESV, mL | 86 (70–117) | 67 (58–86) | 94 (73–116) | 0.002 | 0.46 |
| RVESVi, mL/m$^2$ | 48 (42–55) | 36 (32–45) | 45 (40–55) | <0.001 | 0.53 |
| Parametric mapping and LGE | | | | | |
| T1, median (IQR), ms | | | | | |
| Basal septum | 992 (970–1007) | 988 (972–1000) | 990 (973–1003)## | 0.44 | 0.64 |
| Basal lateral | 972 (952–995) | 958 (945–983) | 966 (954–993)## | 0.13 | 0.91 |
| Mid septum | 988 (973–1013) | 979 (963–1000) | 982 (960–997)*** | 0.15 | 0.12 |
| Mid lateral | 984 (951–996) | 965 (947–975) | 965 (948–987)*** | 0.06 | 0.07 |
| T2, ms | | | | | |
| Basal septum | 44.3 (42.8–46.2) | 42.8 (41.7–43.6) | 43.2 (42.4–44.2)††† | 0.001 | 0.28 |
| Basal lateral | 45.4 (44.1–46.6) | 44.2 (43.0–44.6) | 44.2 (43.2–45.3)††† | <0.001 | 0.25 |
| Mid-septum | 46.8 (44.9–48.4) | 44.7 (43.3–46.1) | 44.9 (43.9–46.4)‡‡‡ | <0.001 | 0.02 |
| Mid-lateral | 47.0 (44.9–47.9) | 44.4 (42.6–45.5) | 45.6 (44.0–46.9)‡‡‡ | <0.001 | 0.21 |
| ECV, % | | | | | |
| Basal septum | 24.6 (22.8–25.9)‡‡‡ | NA | 22.9 (20.8–26.3)††† | | 0.54 |
| Basal lateral | 22.5 (20.7–24.2)‡‡‡ | NA | 23.9 (20.8–25.8)††† | | 0.42 |
| Mid-septum | 25.6 (23.9–27.7)§§§ | NA | 22.7 (21.6–24.3)‖‖‖ | | 0.006 |
| Mid-lateral | 23.9 (21.6–25.6)§§§ | NA | 20.8 (19.9–24.8)‖‖‖ | | 0.05 |
| LGE (any), N (%) | 16 (27%) | 0 | 10 (24%)¶¶¶ | | 0.56 |
| Mid-inferior RV septal insertion site (without myocarditis) | 13 (22%) | 0 | 10 (24%)¶¶¶ | | 0.69 |
| Meeting modified Lake Louise criteria | 2 (3%) | 0 | 0 | | |

(*Continued*)

**Table. Continued**

| | COVID-19–positive athletes (N=59)*† | Healthy controls (N=27)* | Athletic controls (N=60)† | *P* value* | *P* value† |
|---|---|---|---|---|---|
| Other myocardial | 1 (2%) | 0 | 0 | | |
| Pericardial | 1 (2%) | 0 | 0 | | |

Four regions of interest (ROIs) in the left ventricle from short axis views were obtained for native T1, T2, and ECV. Healthy controls underwent CMR without contrast and therefore do not have ECV or LGE assessments. CMR indicates cardiac magnetic resonance; COVID-19, coronavirus disease 2019; ECV, extracellular volume; GLS, global longitudinal strain; IQR, interquartile range; LGE, late gadolinium enhancement; LV, left ventricle; LVEDV, left ventricular end-diastolic volume; LVEDVi, left ventricular end-diastolic volume index; LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; LVESVi, left ventricular end-systolic volume index; NA, not available; RV, right ventricle; RVEDV, right ventricular end-diastolic volume; RVEDVi, right ventricular end-diastolic volume index; RVEF, right ventricular ejection fraction; RVESV, right ventricular end-systolic volume; and RVESVi, right ventricular end-systolic volume index.

*Comparison of COVID-19–positive athletes with healthy controls.

†Comparison of COVID-19–positive athletes with athletic controls.

‡N=41.

§N=24.

‖N=14.

¶N=38.

#N=25.

**N=15.

††N=59.

‡‡N=27.

§§N=60.

‖‖N=30.

¶¶N=49.

##N=28.

***N=55.

†††N=4.

‡‡‡N=15.

§§§N=57.

‖‖‖N=11.

¶¶¶N=41 who received gadolinium.

mild illness (N=46 [78%]) or were asymptomatic (N=13 [22%]).

Two asymptomatic COVID-19–positive athletes (3%) met criteria for myocarditis[2]; 1 athlete had pericarditis. These athletes had normal electrocardiograms, troponin I, and echocardiograms with strain. Both athletes with myocarditis had normal left ventricular ejection fraction by initial CMR; however, 1 athlete developed new left ventricle dysfunction (left ventricular ejection fraction, 45%) on a follow-up echocardiogram performed for worsening dyspnea.

COVID-19–positive athletes had increased volumes and mass when compared with healthy controls, consistent with athletic remodeling. Most standard CMR parameters were similar between COVID-19–positive athletes and athletic controls. Focal LGE isolated to the inferoseptal right ventricle insertion was present in 22% of COVID-19–positive athletes, compared with an identical LGE pattern in 24% of athletic controls.

COVID-19–positive athletes had elevated myocardial T2 relaxation times in all myocardial segments compared with healthy controls; however, only the midseptal T2 was significantly elevated compared with athletic controls. Similarly, midseptal extracellular volume was elevated in COVID-19–positive athletes compared with athletic controls. Mild segmental increases in T1, T2, or extracellular volume were found in 39% of COVID-19–positive athletes, 13% of athletic controls, and 8% of healthy controls compared with our laboratory-specific normative values.

The prevalence of myocarditis in collegiate athletes after COVID-19 is modest (3%) but may be missed by conventional screening without CMR. Although the long-term significance of myocarditis detectable only by CMR remains unclear, 1 athlete with myocarditis did develop left ventricle dysfunction on subsequent echocardiography. Future investigations are necessary to follow COVID-19–positive athletes for long-term complications.

Our findings confirm that focal inferoseptal right ventricle insertion LGE is common in athletes, may represent remodeling from athletic training, and should not be conflated with myocarditis. Disparities in volumetrics and LGE prevalence between the COVID-19–positive athletes and healthy controls were diminished when using athletic controls as the comparator. This highlights the importance of utilizing athletic controls when interpreting CMR findings in COVID-19–positive athletes.[5]

There are limitations to our study. Athletic controls were preferentially matched by athletic training, not age or sex, which could contribute to differences between groups. Not all CMR were performed at a uniform time and myocardial strain was assessed only with echocardiography.

CMR with parametric mapping detects myocardial inflammation with high sensitivity. Clinical judgment

remains imperative when contextualizing abnormal CMR findings in the adjudication of a safe return to athletic competition. Ongoing investigations of the short- and long-term cardiovascular manifestations of COVID-19 are necessary to inform the optimal care of athletes recovering from infection.

## ARTICLE INFORMATION

Data sharing: The data that support the findings of this study and research materials, as well as experimental procedures and protocols, are available from the corresponding author upon reasonable request.

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### Correspondence

Daniel E. Clark, MD, MPH, 2220 Pierce Ave, 383 Preston Research Building, Nashville, TN 37237. Email Daniel.e.clark@vumc.org

### Affiliations

Department of Internal Medicine, Division of Cardiovascular Medicine (D.E.C., A.P., J.M.D., F.A.F., S.G.H.), Department of Orthopaedic Surgery and Sports Medicine (A.B.D., W.F.), and Department of Biostatistics (J.C.S.), Vanderbilt University Medical Center, Nashville, TN. Department of Pediatrics, Thomas P. Graham Division of Pediatric Cardiology, Monroe Carell Jr. Children's Hospital at Vanderbilt, Nashville, TN (K.G-D., F.A.F., J.H.S.).

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### Disclosures

None.

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