Abnormalities in cardiac and inflammatory biomarkers in ambulatory subjects after COVID-19 infection

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ABSTRACT

Background: Coronavirus-2019 (COVID-19) is known to affect the heart and is associated with a pro-inflammatory state. Most studies to date have focused on clinically sick subjects. Here, we report cardiac and proinflammatory biomarkers levels in ambulatory young adults with asymptomatic or mild COVID-19 infection compared to those without infection 4–8 weeks after severe acute respiratory syndrome coronavirus 2 (SARS-COV-2) testing.

Methods: 131 asymptomatic or mildly symptomatic subjects were enrolled following testing for SARS-COV-2. Fifty subjects tested negative, and 81 subjects tested positive. Serum samples were collected for measurement of C-reactive protein, ferritin, interleukin-6, NT-pro-B-type natriuretic peptide, and cardiac troponin 28–55 days after SARS-COV-2 RT-PCR testing.

Results: Biomarker levels trended higher in SARS-COV-2-positive vs negative subjects, but differences in biomarker levels or proportion of subjects with elevated biomarkers were not statistically significant with respect to SARS-COV-2 status. Among individuals with ≥1 comorbidity, odds of elevated CRP were greater compared to individuals without any comorbidities (odds ratio [OR] = 2.90); this effect size was increased 1.4-fold among SARS-COV-2-positive subjects (OR = 4.03). Similarly, NT-pro-BNP was associated with CVD, with the strongest association in COVID-positive individuals (OR = 16.9).

Conclusions: In a relatively young, healthy adult population, mild COVID-19 infection was associated with mild elevations in cardiac and proinflammatory biomarkers within 4–8 weeks of mild or asymptomatic COVID-19 infection in individuals with preexisting comorbidities, but not among individuals without comorbidities. For the general population of young adults, we did not find evidence of elevation of cardiac or proinflammatory biomarkers 4–8 weeks after COVID-19 infection.

Clinical Perspective: This is a characterization of cardiac and proinflammatory biomarkers in ambulatory subjects following asymptomatic or mild COVID-19 infection. Young, ambulatory individuals did not have cardiac and proinflammatory biomarker elevation 4–8 weeks after mild COVID-19 infection. However, COVID-19 infection was associated with biomarker elevations in select individuals with comorbidities.

Clinical study number: H-47423.
1. Introduction

Coronavirus-19 (COVID-19), the infection caused by the SARS-CoV-2 virus, presents as an upper respiratory tract infection, and can progress to pulmonary infection (i.e., pneumonia), acute respiratory distress syndrome or systemic infection in some subjects [1, 2]. Cardiac involvement in COVID-19 has been documented [3] and can manifest in several ways [4, 5]. Cardiac and inflammatory biomarkers have been reported to be elevated in acute COVID-19 infection, especially among individuals requiring hospitalization and intensive care unit [5, 6]. Elevations in cardiac troponins and NT-pro-B-type natriuretic peptide (BNP) are associated with increased risks of re-hospitalization, CV complications and death after COVID-19 infection [7].

However, most studies of COVID-19 serum biomarkers, particularly cardiac biomarkers, have been reported in hospitalized COVID-19 patients [8]. The role of cardiac biomarkers in young, ambulatory adults following a COVID-19 infection remains unclear. To this end, we compared cardiac and proinflammatory biomarker elevations between 81 COVID-19-positive cases and 50 COVID-19-negative control subjects during an 8-week follow-up period.

2. Methods

2.1. Study population

All studies on human subjects were approved by the Institutional Review Board of Baylor College of Medicine (approval number H-47423). Ambulatory adults (18–49 years of age) who were evaluated at Baylor College of Medicine outpatient clinics or affiliate institutions and had undergone SARS-CoV-2 RT-PCR tests between 18 March and 15 August 2020 were included in the study. Subjects with severe COVID-19 symptoms including those requiring hospitalization were excluded from the study, along with children 17 years of age and younger and pregnant women.

2.2. SARS-CoV2 RT-PCR

Samples for SARS-CoV-2 RT-PCR testing were collected by mid-turbinate or nasopharyngeal swab. Viral RNA was extracted using the Qiagen Viral RNA MiniKit (Qiagen Sciences) and were tested by CDC 2019-novel coronavirus (2019-ncov) Real-Time RT-PCR Diagnostic panel with primers and probes targeting the nucleocapsid genes, N1 and N2, as previously described [9]. Cycle threshold (Ct) values < 40 for both N1 and N2 primers were considered positive for SARS-CoV-2 infection.

2.3. Biomarker quantification

Blood samples were collected during a follow-up visit 28–55 days (median 36 days, interquartile range 14 days) after the SARS-CoV-2 RT-PCR test. All laboratory results were obtained using laboratory analyzers (Vitros S600 and Architect i1000).

2.4. Definition of comorbidities

History of comorbidities were collected by patient survey at the time of study enrollment. Cardiovascular disease (CVD) was captured as a comorbidity if a participant reported history of myocardial infarction, stroke, coronary artery disease, arrhythmia, valvular heart disease and or other cardiovascular disease. Metabolic disease was captured as a comorbidity if a patient reported history of diabetes, pre-diabetes, or impaired glucose tolerance. Lung disease was captured with history of chronic obstructive pulmonary disease or asthma. Other reported comorbidities were categorized as “other.”.

2.5. Definitions of elevated biomarkers

A list of biomarkers tested with normal ranges is shown in Supplementary Table 1. Elevated CRP was defined as greater than or equal to 5.0 mg/L based on the standard reference range for the standard (i.e., not high-sensitivity) CRP assay [10]. Elevated ferritin was defined by conventional clinical cutoffs – greater than 300 ng/mL for males and 200 ng/mL for females [11]. Elevated IL-6 was defined as greater than 25 pg/mL, which has been shown to be an independent risk factor for progression of COVID-19 and in-hospital mortality [12]. Elevated NT-pro-BNP was defined as greater than 125 pg/mL in line with the cutoff used for adults younger than 75 years-old [13]. Elevated troponin was defined as greater than 0.01 ng/mL in accordance with threshold of 99th percentile levels in comparable population studies [14, 15].

2.6. Statistical analyses

Data are represented as percentages or mean ± standard error of the mean (SEM). All statistical analyses were performed using RStudio version 1.4.1717. Two-sample independent t-tests were used to compare quantitative data. Chi-square tests were used to compare qualitative data. Fisher’s exact tests were used in lieu of chi-square tests when expected counts were less than five. Logistic regression was performed using generalized estimating equations to account for confounding variables in testing for the association between predictor variables and a dichotomous outcome variable. All logistic regression analyses were adjusted for age and carried out using the logit link function. For all statistical analyses, two-sided P values < 0.05 were considered statistically significant.

3. Results

3.1. Demographic and clinical characteristics

Demographic and clinical characteristics are shown in Table 1 by SARS-CoV-2 RT-PCR testing status. The overall sample consisted of 131 participants, including 50 SARS-CoV-2 RT-PCR negative controls (mean age 31 years, 52 % female) and 81 SARS-CoV-2 RT-PCR positive cases (mean age 30 years, 58 % female). As shown in Table 1, age (P = 6.86E-03) and race (P = 0.034) were the only demographic characteristics that differed statistically significantly between SARS-CoV-2 RT-PCR positive cases and negative controls. There was a higher representation of White patients in the SARS-CoV-2 RT-PCR negative cohort compared to SARS-CoV-2 RT-PCR positive cohort (80 % versus 57 %), but other race or ethnicity proportions did not differ significantly between SARS-CoV-2 RT-PCR negative and positive cohorts. Presence of any preexisting comorbidity was similar by SARS-CoV-2 RT-PCR negative and positive status (40 % in COVID-19-negative and 34 % in COVID-19-positive).

All cases included in this study were asymptomatic or mildly symptomatic individuals treated as outpatients or discharged from the emergency department and had SARS-CoV-2 RT-PCR positive testing. Controls were asymptomatic or mildly symptomatic individuals that were treated as outpatients or discharged from the emergency department and had SARS-CoV-2 RT-PCR negative testing.

3.2. Correlation of elevated biomarkers with recent SARS-CoV-2 infection

As shown in Fig. 1, SARS-CoV-2 RT-PCR positive subjects tended to have higher biomarker levels compared to SARS-CoV-2 RT-PCR negative subjects. However, no differences reached statistical significance. In total, 46 subjects had elevated CRP (Fig. 1A). Thirty-one of 81 (38.3 %) SARS-CoV-2 RT-PCR positive and 15 of 50 (30.0 %) SARS-CoV-2 RT-PCR negative subjects (P = 0.35 for difference in proportion) had elevated CRP levels during the 8-week follow-up visit (Table 2). In total, five subjects had elevated ferritin levels (Fig. 1B); all these subjects were male and of the White race, with one being Hispanic ethnicity. Three of...
had elevated troponin levels (Fig. 1). Thirteen of 81 (16 %) SARS-CoV-2 RT-PCR positive test. Three (out of nine) subjects with elevated the nine (88.9 %) subjects with elevated NT-pro-BNP levels were female; lung disease, one of which was SARS-CoV-2 RT-PCR positive. Eight of the nine (88.9 %) subjects with elevated NT-pro-BNP levels were female; seven (out of nine) of the patients with elevated NT-pro-BNP had SARS-CoV-2 RT-PCR positive test. (0.41 – 0.31).

Table 2

| Characteristic | SARS-CoV-2 RT-PCR positive (n = 50) | SARS-CoV-2 RT-PCR negative (n = 81) | P value |
|---------------|-----------------------------------|-----------------------------------|---------|
| Age (years)   | 31.0 ± 6.1                        | 34.5 ± 8.3                        | 6.86E-03 |
| Female, n (%) | 26 (52 %)                         | 47 (58 %)                         | 0.41    |
| Race          |                                   |                                   | 0.034   |
| Asian, n (%)  | 4 (8 %)                           | 11 (14 %)                         |         |
| Black/African | 5 (10 %)                          | 10 (12 %)                         |         |
| American, n (%) |                                |                                   |         |
| Declined to answer, n (%) | 0 (0 %)   | 5 (6.2 %)                         |         |
| Other, n (%)  | 1 (2.0 %)                         | 5 (6.2 %)                         |         |
| White, n (%)  | 40 (88 %)                         | 46 (57 %)                         |         |
| Ethnicity     |                                   |                                   |         |
| Hispanic, n (%) |                                | 14 (28 %)                         | 0.28    |
| Comorbidities |                                   |                                   |         |
| Any, n (%)    | 20 (40 %)                         | 26 (34 %)                         | 0.22    |
| CVD, n (%)    | 6 (12 %)                          | 9 (11 %)                          | 0.28    |
| Lung disease, n (%) | 4 (8.0 %)   | 9 (11 %)                          | 0.22    |
| Metabolic disease*, n (%) | 1 (2.0 %)   | 6 (7.4 %)                         | 0.10    |
| Metabolic disease**, n (%) |                |                                   |         |
| Metabolic disease***, n (%) |                |                                   |         |

Biomarkers###

Table 2

| Biomarkers | SARS-CoV-2 RT-PCR positive (n = 50) | SARS-CoV-2 RT-PCR negative (n = 81) | OR (95 % CI) | P value |
|------------|-----------------------------------|-----------------------------------|--------------|---------|
| CRP        | 31 (38.3 %)                       | 15 (30.0 %)                       | 1.44         | 0.35    |
| Ferritin   | 3 (3.7 %)                         | 2 (4.0 %)                         | 0.924        | 1.00    |
| IL-6       | 11 (13.6 %)                       | 7 (14.0 %)                        | 0.966        | 0.00012 |
| NT-pro-BNP | 7 (8.6 %)                         | 2 (4.0 %)                         | 2.26         | 0.48    |
| Troponin   | 13 (16.0 %)                       | 4 (8.0 %)                         | 2.14         | 0.28    |

Values are reported as n (%). Cutoffs as defined in methods. BNP, B-type natriuretic peptide; CRP, C-reactive protein; IL-6, interleukin-6; OR, odds ratio.

3.3. Correlation of elevated biomarkers with the presence of comorbidities

Multivariate logistic regression was conducted to look for an association between the presence of ≥1 comorbidity (composite of CVD, lung disease, and metabolic disease) and elevated biomarkers. Presence of any comorbidity was used as the dichotomous predictor, and elevated biomarker was used as the dichotomous outcome. Analyses were adjusted for age. ORs are reported for the overall sample as well as in strata defined by SARS-CoV-2 RT-PCR status. Results are shown in Fig. 2. Higher CRP was positively associated with comorbidities in the overall sample (OR = 2.89, 95 % confidence interval [CI] 1.27–6.75, P = 0.0121) and among SARS-CoV-2 RT-PCR positive subjects (OR = 4.03, 95 % CI 1.32–13.2, P = 0.0163) but not SARS-CoV-2 RT-PCR negative subjects (P = 0.245). No other biomarkers were statistically significantly associated with presence of ≥ 1 comorbidity.

In addition, there were several non-significant associations between comorbidities and biomarker elevations. Two (out of 18) subjects with elevated IL-6 had metabolic disease, both of which were SARS-CoV-2 RT-PCR positive. Two (out of 18) subjects with elevated IL-6 also had lung disease, one of which was SARS-CoV-2 RT-PCR positive. Eight of the nine (88.9 %) subjects with elevated NT-pro-BNP levels were female; seven (out of nine) of the patients with elevated NT-pro-BNP had SARS-CoV-2 RT-PCR positive test. Three (out of nine) subjects with elevated higher CRP was positively associated with comorbidities in the overall sample (OR = 2.89, 95 % confidence interval [CI] 1.27–6.75, P = 0.0121) and among SARS-CoV-2 RT-PCR positive subjects (OR = 4.03, 95 % CI 1.32–13.2, P = 0.0163) but not SARS-CoV-2 RT-PCR negative subjects (P = 0.245). No other biomarkers were statistically significantly associated with presence of ≥ 1 comorbidity.

Values are reported as n (%). Cutoffs as defined in methods. BNP, B-type natriuretic peptide; CRP, C-reactive protein; IL-6, interleukin-6; OR, odds ratio.

Fig. 1. Biomarker levels by COVID-19 status. Serum levels of CRP (A), ferritin (B), IL-6 (C), NT-pro-BNP (D), and cardiac troponin (E) in COVID-negative (blue) and COVID-positive (red) individuals. Error bars denote mean +/- SEM. Blue line denotes upper limit of normal (see methods). BNP, B-type natriuretic peptide; CRP, C-reactive protein; IL-6, interleukin 6; SEM, standard error of the mean. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
NT-pro-BNP had a history of CVD, and one patient also had elevated troponins. Regarding troponins, CVD was the only comorbidity present among subjects with elevated troponins—present in two of the SARS-CoV-2 RT-PCR positive and one of the SARS-CoV-2 RT-PCR negative subjects.

3.4. Correlation of CVD, lung, and metabolic disease with elevated cardiac biomarkers

To tease apart differential associations of biomarkers with specific comorbidities, multivariate logistic regression was conducted for each biomarker against a history of CVD, lung disease, and metabolic disease. Comorbidity was used as the dichotomous outcome, and elevated biomarker level was used as the dichotomous predictor. Analyses were adjusted for age. ORs are reported for the overall sample as well as in strata defined by SARS-CoV-2 RT-PCR status. Odds of metabolic disease were greater in individuals with elevated CRP. This effect was accentuated in SARS-CoV-2 RT-PCR positive individuals (OR = 13.1, 95% CI 1.86–265, P = 0.025) compared to the overall sample (OR = 5.42, 95% CI 1.06–40.4, P = 0.055) and SARS-CoV-2 RT-PCR negative subjects (OR = 0.50, 95% CI 0.034–735, P = 0.99; Fig. 3A). Similarly, the proportion of individuals with elevated biomarkers did not differ between SARS-CoV-2 RT-PCR positive versus SARS-CoV-2 RT-PCR negative subjects, although odds of elevations in CRP, NT-pro-BNP, and troponin were greater among SARS-CoV-2 RT-PCR positive subjects (Table 2). Our results are consistent with a prior study demonstrating that statistically significant biomarker elevations only predicted risk of mortality [8]. Our study population of young, mostly healthy adults with low CoronaHeart Risk Scores [16] likely had a minimal risk of mortality due to a COVID-19 infection, and our study was not powered to examine mortality.

Post-COVID-19 syndrome can occur up to six months after COVID-19 infection and is characterized by cardiac complications such as atrial fibrillation and heart failure, as well as vascular complications such as venous thromboembolism [17]. While less common, children who suffer COVID-19 infection also exhibit post-COVID-19 cardiac dysfunction in up to one-third patients, characterized by left ventricular hypokinesia and dilatation, coronary artery aneurysm, and electrocardiographic abnormalities [18]. Elevated troponin levels are seen in 76% of patients

4. Discussion

In this study, we demonstrate that asymptomatic or mild SARS-CoV-2 RT-PCR positive infection in young, ambulatory adults may be associated with biomarker elevations 4–8 weeks after SARS-CoV-2 RT-PCR positivity in individuals with history of comorbidities but not in the general population of young healthy individuals or in individuals without comorbidities. While serum levels of all measured biomarkers trended higher in SARS-CoV-2 RT-PCR positive compared to SARS-CoV-2 RT-PCR negative subjects, these results did not reach statistical significance (Table 1, Fig. 1). Similarly, the proportion of individuals with elevated biomarkers did not differ between SARS-CoV-2 RT-PCR positive versus SARS-CoV-2 RT-PCR negative subjects, although odds of elevations in CRP, NT-pro-BNP, and troponin were greater among SARS-CoV-2 RT-PCR positive subjects (Table 2). Our results are consistent with a prior study demonstrating that statistically significant biomarker elevations only predicted risk of mortality [8]. Our study population of young, mostly healthy adults with low CoronaHeart Risk Scores [16] likely had a minimal risk of mortality due to a COVID-19 infection, and our study was not powered to examine mortality.

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Fig. 2. Odds ratios of elevated biomarkers among individuals with comorbidities. Odds of elevated CRP, ferritin, IL-6, NT-pro-BNP, and troponin among individuals with ≥1 comorbidity. ORs are derived from logistic regression adjusted for age and plotted along with 95% confidence intervals. BNP, B-type natriuretic peptide; CRP, C-reactive protein; OR, odds ratio.

Fig. 3. Odds ratios of CVD and metabolic disease in individuals with elevated CRP or NT-pro-BNP levels. Odds of metabolic disease in individuals with elevated CRP (A) and CVD in individuals with elevated NT-pro-BNP (B) Both analyses were conducted in the overall sample and strata defined by COVID-19 status. ORs are derived from logistic regression adjusted for age and plotted along with 95% confidence intervals. BNP, B-type natriuretic peptide; CVD, cardiovascular disease; CRP, C-reactive protein; OR, odds ratio.
up to two months after COVID-19 infection despite normal heart function [19]. Moreover, echocardiographic evidence of reduced global longitudinal strain despite preserved ejection fraction has been reported among COVID-19 patients, indicating the presence of subclinical cardiac damage [20]. Myocardial damage can occur after COVID-19 infection due to several reasons: microthrombus formation, persistent systemic inflammation, cytokine-mediated pathologic cardiac hypertrophy [21], and direct viral infection. A study of induced pluripotent stem cell (iPSC)-derived cardiomyocytes demonstrated that troponin release is greatest when iPSC-derived cardiomyocytes are infected with COVID-19 in the presence versus absence of IL-6 and IL-1β [22]. The percentage of infected cells remained constant at 35% regardless of the presence of ILs, indicating that direct infection likely does play a key role in myocardial damage relative to cytokine-mediated damage. Interestingly, however, autopsies performed in ten patients who died of COVID-19 infection failed to demonstrate appreciable evidence of lymphocytic myocarditis, but rather showed diffuse alveolar hemorrhage with microthrombi [23]. It is important to note that these patients had severe (i.e., fatal) COVID-19 infection and may not be representative of the mildly symptomatic and/or asymptomatic patients in our study cohort. Altogether, it seems likely that direct COVID-19 infection of cardiomyocytes plays a key role in COVID-19-related myocardial damage, but whether there is persistent viral infection within the myocardium remains elusive.

Nonetheless, we did observe statistically significant associations among individuals with comorbidities. CRP was statistically significantly associated with the presence of one or more comorbidities (Fig. 2) as well as metabolic disease in SARS-COV-2 RT-PCR positive subjects (Fig. 3A). Indeed, post-COVID-19 CRP elevation have been reportedly to be greater in diabetics compared to non-diabetics [24]. The degree of CRP elevation has also been shown to predict COVID-19 outcomes [25]. However, it is important to note, due to small sample size, the single CRP cutoff of 5.0 mg/L used in this study was not adjusted for the potential confounding effects of sex (higher CRP in females), race (higher CRP in African Americans), and body mass index (higher in obese individuals) on CRP levels [26].

The difference in proportion of SARS-COV-2-positive vs SARS-COV-2-negative individuals with elevated ferritin did not reach statistical significance (Table 2). Like CRP, ferritin is an acute phase reactant that reflects the degree of acute and chronic inflammation as well as monocyte/macrophage activation [27]. Studies have shown ferritin to be an independent predictor of COVID-19 severity [28] and a marker of COVID-19 renal involvement [29] and thromboembolism [30]. Our study demonstrates that the odds of elevated ferritin did not differ by COVID-19 status when measured 4–8 weeks after detection of COVID-19. This could have been because the individuals in our study had mild COVID-19 infection and ferritin may be associated with severe COVID-19 infection [28]. Alternatively, ferritin, is an acute phase reactant and may have decreased back to normal levels by the time of sera collection 4–8 weeks later.

In our study, the percent of individuals with elevated IL-6 did not differ between COVID-19 patients and controls. While higher IL-6 has been shown to predict risk of mortality from acute COVID-19 infection [8], it is important to note that contrary to our subjects with mild disease, the subjects in former studies reporting this association were very sick (i.e., hospitalized, requiring ICU stay). Furthermore, like ferritin, IL-6 may have been elevated at the time of infection but may have had decreased back to normal by the time of sera collection 4–8 weeks post-infection. Indeed, IL-6 is secreted by macrophages at sites of infection and, like CRP and other acute phase reactants, decreases back to normal levels around one week after infection [31]. Our study used a cutoff of 25 pg/mL, which has been shown to have prognostic value for mortality and intensive care unit admission in subjects with COVID-19 pneumonia [32]. In the same study, mild COVID-19 pneumonia had mean IL-6 of 7.7 pg/ml, moderate 35.5 pg/ml, and severe 321 pg/ml [32]. Thus, a cutoff of 25 pg/mL in a young, healthy adult population may have excluded some individuals with greater-than-normal IL-6 levels.

Among the biomarkers tested in this study, NT-pro-BNP was associated with history of CVD in SARS-COV-2-positive subjects (P = 0.026, Fig. 3B). Interestingly, troponin was not associated with CVD in the overall sample nor COVID-positive subjects. We used a cutoff of 0.01 ng/mL (rather than the clinical cutoff for myocardial ischemia of 0.03 ng/mL) for troponin based on population-based screening studies [14]. It is important to note that other studies of COVID-19-related cardiac injury may have used the high-sensitivity, rather than standard, troponin assay, to predict myocardial damage [33]. Nonetheless, we did not find troponin elevations in young, healthy adults, 4–8 weeks after asymptomatic or mild COVID-19 infection, even in those with pre-existing CVD. Elevations in troponin and NT-pro-BNP have been associated with COVID-19 mRNA vaccination-related myocarditis [34]. However, the time frame of our study (latter half of 2020) makes it unlikely that study subjects had received the Pfizer-BioNTech or Moderna vaccines, which were approved by the FDA on August 31, 2021 [35] and January 31, 2022 [36], respectively.

Our study has several limitations. First, sera samples were collected 4–8 weeks after SARS-Cov-2 RT-PCR test. While we still found evidence of some biomarker elevations, these and other biomarkers could have been elevated had the sera been collected closer to the time of COVID-19 infection. Our ability to detect differences in proportion of elevated biomarkers by COVID-19 status was also likely hindered by the small sample sizes in our study, particularly the small proportion of individuals with elevated biomarkers, which is to be expected among young, healthy adults. Nevertheless, the biomarker elevations we did find to be elevated are likely true positives considering the relatively long time between COVID-19 testing and biomarker quantification. Second, our study was cross-sectional. A longitudinal study comparing biomarkers before and after COVID-19 infection would have helped account for the large inter-individual variation in circulating biomarker levels. Third, levels of cardiac troponin and CRP were not assessed using high sensitivity assays. Use of high sensitivity troponin portends greater prognostic utility compared to the conventional cardiac troponin assay [37,38]. Data is mixed for high sensitivity compared to standard CRP [39,40]. Nevertheless, use of standard assays may have precluded detection of more subtle increases in biomarkers below the limit of detection of conventional assays that may be more likely in a population of young, healthy adults. Finally, different cut-offs in biomarker levels, specific for sex, race, age could have resulted in different findings. Given the small sample size, we used a single cut-off for the biomarkers, which is another limitation of our study.

5. Conclusions

Our study provides evidence that proinflammatory and cardiac biomarkers are not elevated in young, ambulatory adults 4–8 weeks following mild or asymptomatic SARS-CoV-2 infection. SARS-CoV-2 infection is associated with higher biomarker elevations among individuals with pre-existing comorbidities. Future longitudinal studies are needed to explore the utility of biomarkers in young adults after SARS-CoV-2 infection.

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