

ANTIOXIDANT STATUS AND OXIDATIVE STRESS RESPONSE IN COVID-19-POSITIVE INDIVIDUALS IN SOUTH-WESTERN NIGERIA

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ABSTRACT

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), the etiological agent of COVID-19, remains incompletely characterized regarding oxidative stress and antioxidant defense mechanisms. This study investigated oxidant and antioxidant profiles in COVID-19 patients compared with healthy controls in tertiary hospitals in south-western Nigeria. Nasopharyngeal swabs and plasma samples were obtained from 80 COVID-19 patients and 80 controls at the Lagos State University Teaching Hospital Isolation Centre, Ikeja, Lagos, and the Olabisi Onabanjo Teaching Hospital Isolation Centre, Sagamu, Ogun State. The mean ages (Mean $\pm$ SD) were 51.53 ± 1.86 and 54.21 ± 1.89 , with male-to-female ratios of 46:34 and 28:52, respectively. Serum activities of catalase (CAT), superoxide dismutase (SOD), reduced glutathione (GSH), malondialdehyde (MDA), and total antioxidant capacity (TAC) were quantified using enzyme-linked immunosorbent assay (ELISA). Plasma MDA concentrations were significantly elevated ($p < 0.05$) in COVID-19-positive subjects relative to controls, indicating enhanced lipid peroxidation and oxidative stress. In contrast, SOD and CAT activities, GSH levels, and TAC were significantly reduced ($p < 0.05$), reflecting impaired antioxidant defense. These biochemical perturbations may contribute to disease severity and progression. Interventions aimed at restoring antioxidant capacity and attenuating oxidative damage could be promising therapeutic strategies for managing COVID-19.

Keywords: COVID-19, oxidative stress, antioxidant, TAC, glutathione.

INTRODUCTION

The coronavirus disease-2019 (COVID-19) pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is having a devastating impact on global health. The disease has been reported in 235 countries, with over 138 million infections and over 2.9 million deaths as of April 14, 2021. Although infections have been reported across essentially all demographics, the highest mortality rate is found in patients with comorbidities who are over 60 years old, (Djaharuddin et al., 2021; Wang et al., 2020; Guan et al., 2019; Wu et al., 2020), while in Nigeria, COVID-19 prevalence of 6% has been recorded, according to the Africa Centre for Disease Control (Africa CDC, 2020).

Antioxidant imbalance and oxidative stress have been implicated in the progression of coronavirus disease 2019. Oxidative stress plays an important role in inflammatory processes. Reactive oxygen species (ROS) and peroxides can activate nuclear factor of kappa light chain enhancer in B cells (NF- κ B), thereby triggering

the production of inflammatory cytokines. The pathophysiology of coronavirus disease 2019 is thought to involve oxidative stress and inflammation (Cullen, 2022). Oxidative stress results from the accumulation of free radicals, highly reactive molecules that damage cells, membranes, lipids, proteins, and DNA. Cells in the body make glutathione to protect themselves from oxidative stress. Harmful damage can occur when cells fail to neutralize free radicals, potentially affecting various physiological processes (Premranjan et al., 2021).

Recent studies have revealed that several factors may be responsible for the severity and outcomes of COVID-19, such as hypertension, diabetes, asthma, old age, sex, lifestyle, nutrition, risk behavior, and Body Mass Index (Bai et al., 2020; Cao et al., 2020; Rubin et al., 2021). The complicated mechanisms underlying COVID-19 include the repression of host antiviral immunity, oxidative stress, and inflammation due to excessive cytokine secretion or cytokine storm, which causes acute lung infection, tissue fibrosis, coagulopathy, and pneumonia (Huang et al., 2020; Mehta et al., 2020; Liu et al., 2020; Sette et al., 2021).

Oxidative stress indicators and respiratory viral infections, particularly those caused by RNA viruses, are strongly associated. Some viruses have been shown to alter the redox balance of cells *in vitro* and *in vivo*. The onset of oxidative stress caused by viral infections (such as respiratory syncytial virus) is required for cytokine synthesis and the basal metabolic index to activate innate immunity. Furthermore, several viruses induce oxidative stress, which promotes viral replication within cells. The macrophage respiratory burst in response to COVID-19 infection can generate ROS (Mohammed et al., 2025). ROS/RNS overproduction contributes to lung tissue injury and epithelial barrier dysfunction caused by acute respiratory viral infection. NOX2 (NADPH oxidase 2) plays a crucial role in the formation of reactive oxygen species (ROS), arterial dysfunction, and thrombosis (induced by platelet activation) (Violi et al., 2020). Overactivation of NOX2 has been found in COVID-19 patients (Francesco et al., 2020).

In human alveolar type 2-like epithelial cells and small airway epithelial cells, viruses can reduce the activity of antioxidant systems, including superoxide dismutase, glutathione S-transferase, catalase, and glutathione peroxidase (Zhu et al., 2019). Although significant levels of antioxidant enzymes were found, this could be a protective strategy against oxidative stress, as free radicals such as ROS and RNS are known to be neutralized, in large part, by catalase and superoxide dismutase (Livan, 2020). In a study by Zhu et al. (2019), individuals had

elevated levels of inflammatory markers, including erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP). Individuals with COVID-19 are known to have decreased oxygen delivery to tissues, disseminated intravascular coagulation, and sepsis. Hypoxia can generate reactive species, such as superoxide and peroxides, which can increase the expression of inflammatory cytokines (Zhu et al., 2019). In COVID-19 patients, interactions between oxidative stress and inflammatory cytokines can lead to multiple organ failures, exacerbating the illness, and a "cytokine storm" has been reported (Livan, 2020).

MATERIALS AND METHODS

Study design and participant recruitment

This case-control study was conducted at the COVID-19 Isolation Center, Lagos State University Teaching Hospital, Ikeja, Lagos, Nigeria, and Ogun State University Teaching Hospital, Sagamu, Ogun State, between January 15th, 2021, and January 14th, 2022.

Sample Size Calculation :

This was calculated using the sample sizes for the comparison groups (as cited in Armitage and Berry, 1994).

Sample size $N = 2Z^2 p (1-p)/D^2$

$Z =$ the standard normal deviate, usually 1.96 (At 95% confidence Level)

$P =$ prevalence of condition; 6%, (Africa CDC, 2020)

$D =$ margin of unacceptable error or measure of precision = 0.05

Type of test: two-sided test.

$N = 2(1.96)^2 \times 0.06(1-0.06) / 0.05 \times 0.05 = 86.63$

The study group included 80 patients diagnosed with COVID-19 and 80 healthy controls (COVID-19-negative). Nasopharyngeal swabs were collected from suspected patients admitted to the isolation centres at the Lagos State University Teaching Hospital and the Olabisi Onabanjo University Teaching Hospital (OSUTH) for SARS-CoV-2 infection and tested using reverse transcription polymerase chain reaction (RT-PCR). Laboratory test results were compared between groups that tested positive and healthy subjects (healthy controls).

Study Population: Healthy Controls

The inclusion criteria were as follows: baseline oxidative stress and antioxidant status; age- and sex-matched healthy controls with no record of dyslipidemia, diabetes, hypertension, or cardiovascular disease at the Lagos State University Teaching Hospital, Ikeja, Lagos, and Olabisi Onabanjo University, Ogun State, Nigeria, were recruited from the local community/hospital staff during the same study period. Individuals receiving antioxidant therapy, including vitamins, zinc, folate, glutathione, folic acid, and selenium, were excluded from the study. Control samples were individuals who tested negative for SARS-CoV-2 by Real-Time Reverse Transcription-Polymerase Chain Reaction (rRT-PCR) at the time of enrollment.

Exclusion Criteria

Individuals meeting any of the following criteria were excluded from the control group to prevent confounding of oxidative stress: Chronic Comorbidities: Any established medical history of metabolic disorders (Type 1 or Type 2 Diabetes Mellitus), cardiovascular diseases (Hypertension, Coronary Artery Disease), chronic kidney disease, chronic obstructive pulmonary disease (COPD), or active malignancies. Inflammatory and Autoimmune

Conditions: Documented history of autoimmune disorders or chronic inflammatory conditions. Medication and Supplementation: Current use of systemically active medications or regular intake of antioxidant supplements (e.g., Vitamin C, Vitamin E, Zinc, Selenium) within 2 weeks or 1 month before blood sampling.

Lifestyle Factors: Individuals with heavy smoking or significant alcohol intake are independently excluded.

Verification of "Healthy" State

The controls were free of hidden metabolic or physiological confounders; all potential candidates underwent a standardized clinical screening protocol before blood collection.

Medical History and Physical Examination: A trained healthcare professional administered a detailed questionnaire and clinical examination to verify the medical history, calculate Body Mass Index (BMI), and measure resting blood pressure. Normal blood pressure was defined as systolic blood pressure <120 mm Hg and diastolic blood pressure <80 mm Hg.

Biochemical Screening: Fasting blood glucose (FBG) testing was performed to rule out undiagnosed diabetes or prediabetes. Participants were confirmed as "healthy" only if their FBG was within the normal reference range (<100 mg/dL or <5.6 mmol/L). Routine laboratory parameters, including complete blood counts (CBC), liver function tests (ALT/AST), and renal function tests (creatinine), were within normal physiological limits.

Ethical Approval

The study protocol was reviewed and approved by the Health Research and Ethics Committee of the Lagos State University Teaching Hospital, Ikeja, Lagos, Nigeria. Reference number LREC/06/10/1474.

Administration of Questionnaire

Structured questionnaires were administered to obtain demographic information. The research team administered the questionnaire. The questionnaire was divided into sections A, B, C, D, and E and adapted from a previous study by Obinna et al. (2020). Section A covers demographic questions such as age and gender. It also includes baseline information. Section B includes symptoms and exposure history. Section C includes medical and vaccination History, while Section D includes consent and terms of consent (confirmation of having read and agreed to the terms of consent). Section E includes the laboratory and biochemical parameters filled out by the research team and healthcare workers. The questionnaire was designed and used to collect demographic, clinical, and exposure data from COVID-19 patients and healthy individuals (controls). It was also used to assess recent symptoms, risk factors, and preexisting medical conditions.

Sample Collection

A nasopharyngeal swab was collected using a sterile flocked swab stick in viral transport medium (VTM). Five milliliters (5 mL) were collected via venipuncture from the antecubital fossa under aseptic conditions in a plain bottle from all subjects at the isolation center and sent to the molecular laboratory. Samples were obtained after blood pressure measurements, with the participants relaxed. The samples were used to determine the serum activities of catalase and superoxide dismutase, and the levels of reduced glutathione and malondialdehyde. The total antioxidant capacity was measured using enzyme-linked immunosorbent assay (ELISA) in all participants.

Sample Preparation And Laboratory Analysis

Ribonucleic Acid (RNA) was extracted from nasopharyngeal swabs, and COVID-19 was detected using Real-time Polymerase Chain Reaction (RT-PCR). The presence of SARS-CoV-2 in nasopharyngeal swabs was identified with Real-Time (RT-PCR) Amplification using the GeneFinder COVID-19 PLUS RealAmp Kit (OSANG Healthcare Co., Ltd., Korea) on the ELITE InGenius platform (ELITech Group, Puteaux, France), which integrates extraction and amplification. The real-time PCR kit simultaneously detects three SARS-CoV-2 targets: the envelope (E) and nucleocapsid (N) proteins, and the RNA-dependent RNA polymerase (RdRp) gene. An internal control based on amplification of the human beta-globin gene was used to confirm the quality of the extracted sample material and test performance.

Biochemical Analysis

Biochemical parameters such as plasma catalase, superoxide dismutase, reduced glutathione, malondialdehyde, and total antioxidant capacity were measured using the Enzyme-linked immunosorbent assay (ELISA). We purchased the kit from ElabScience (Beijing, China).

METHOD

The standards, samples, and the biotinylated antibody reagent were added to designated wells coated with Streptavidin. Endogenous analytes (CAT, SOD, GSH, MDA, and total TAC) in the patient's plasma bind to the antigenic site of the biotinylated Anti-CAT antibody. Simultaneously, the biotinylated antibody was immobilized onto the wells through the high-affinity Streptavidin-Biotin interaction. Unbound protein and excess biotin-conjugated antibody were washed off with wash buffer. After adding a Peroxidase (HRP)-conjugated antibody reagent, a sandwich complex formed, with the analytes of interest (CAT, SOD, GSH, MDA, and total TAC) located between the two highly specific antibodies labelled with Biotin and HRP. Excess unbound protein from the enzyme-conjugated antibody reagent was removed by washing with wash buffer. Upon addition of the substrate, the intensity of the developed color was directly proportional to the concentrations of the analytes (CAT, SOD, GSH, MDA, and total TAC) in the samples. A standard curve was prepared to relate color intensity to the concentrations of the analytes (CAT, SOD, GSH, MDA, and total TAC).

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 23. Mean values were compared across different groups using Student's t-test and analysis of variance (ANOVA). Differences were considered statistically significant where $p < 0.05$.

RESULTS AND DISCUSSION

Table 1: COVID-19-infected subjects show significantly decreased antioxidant enzymes (SOD, GSH) and total antioxidant capacity (TAC). They also show significantly increased oxidative damage, as indicated by higher MDA levels. Catalase levels tend to be lower in these cases, but the difference is not statistically significant.

TABLE 1: ANTIOXIDANT AND OXIDATIVE STRESS BIOMARKERS IN COVID-19-INFECTED AND CONTROL SUBJECTS

Biomarkers	Case N = 80	Control N= 80	P value
SOD (u/mL)	0.385±0.126	2.85±0.19	0.000*
CAT(ng/mL)	0.0079±0.0056	0.018±0.00 17	0.063
GSH (mmol/L)	0.028±0.0015	0.04±0.003 5	0.005*
MDA (nmol/mL)	3.39±0.168	2.54±0.20	0.002*
TAC (u/mL)	0.72±0.105	1.25±0.196	0.020*

Statistically significant at $p < 0.05$

Table Legend:

N: Number of samples. NS: not significant; S*: statistically significant. Values are given as mean + standard deviation. Values are expressed as Mean ± standard Deviation (SD) and are statistically significant at $p < 0.05$. SOD = Superoxide dismutase, CAT = Catalase, GSH = Reduced Glutathione, TAC = Total antioxidant capacity.

Table 2: The antioxidant status of COVID-19-infected subjects was assessed across different age groups (15-34, 35-54, 55-64, and 65-94 years) using various biomarkers: SOD, CAT, GSH, MDA, and TAC. SOD levels showed a rising trend with age, from 0.009±0.003 u/mL in the youngest group to 0.840±0.003 u/mL in the oldest, but this difference was not statistically significant ($F=1.587$, $p=0.199$). CAT concentrations varied irregularly among groups, ranging from 0.0006 to 0.03 ng/mL, with no significant differences ($F=1.392$, $p=0.252$). GSH levels were similar across ages, with a slight increase with age but not significant ($F=0.659$, $p=0.580$). MDA levels, an oxidative stress marker, were comparable across groups, hovering around 2.85 to 3.58 nmol/mL ($F=0.694$, $p=0.559$). TAC values also showed no significant variation with age, ranging from 0.56 to 0.87 u/mL ($F=0.535$, $p=0.660$). Overall, none of the antioxidant biomarkers differed significantly between age groups in COVID-19-infected subjects ($p > 0.05$).

TABLE 2: ANTIOXIDANT STATUS IN COVID-19-INFECTED SUBJECTS ACROSS DIFFERENT AGE GROUPS

Biomarkers	15-34 Years N = 12	35-54 Years N = 34	55-64 Years N = 16	65-94 Years N = 18	p
SOD (u/mL)	0.009±0.003	0.34±0.1 8	0.239± 0.23	0.840 ±0.00 3	0.199
CAT (ng/mL)	0.004±0.0003	0.002±0. 007	0.03±0 .002	0.000 6±0.0 06	0.252
GSH (mmol/L)	0.026±0.003	0.028±0. 001	0.033± 0.005	0.033 ±0.00 5	0.580
MDA (nmol/mL)	2.85±0.41	3.58±0.3 0	3.43±0 .30	3.34± 0.26	0.559
TAC (u/mL)	0.57±0.10	0.87±0.2 2	0.56±0 .078	0.70± 0.19	0.660

Statistically significant at $p < 0.05$.

TABLE 3: Correlation Pair: Malondialdehyde and Catalase, $r = 0.255$. Weak positive correlation. As MDA levels increased, CAT levels tended to increase slightly. $p = 0.023$ * Statistically significant ($p < 0.05$). This relationship is unlikely to be due to chance. Higher levels of malondialdehyde (MDA) are markers of oxidative stress. This correlates with increased levels of catalase (CAT), an antioxidant enzyme. This may reflect the body's compensatory antioxidant response to oxidative damage in patients with COVID-19.

Higher malondialdehyde (MDA, an oxidative stress marker) correlates with increased catalase (CAT, an antioxidant enzyme). This may reflect the body's compensatory antioxidant response to oxidative damage in patients with COVID-19.

Strong Evidence of a True Relationship. The positive correlation between catalase (CAT) and glutathione (GSH) suggests a coordinated activity between these antioxidants. In COVID-19, this may indicate a synergistic defence mechanism against virus-induced oxidative stress. **r**: Pearson correlation coefficient (measures strength/direction of the linear relationship). Range: -1 to +1. **P**: p-value (measures statistical significance). Lower values indicate stronger evidence against the null hypothesis of no correlation. *: Significance notation ($* = p < 0.05$, $** = p < 0.001$). The positive correlation between catalase (CAT) and glutathione (GSH) suggests coordinated activity between these antioxidants. In COVID-19, this may indicate a synergistic defence mechanism against virus-induced oxidative stress.

TABLE 3: Correlation Pair

Correlation pair	r	p-value
MDA vs. CAT	0.255	0.023*
CAT vs. GSH	0.395	0.000**

Key Parameters

- **r**: Pearson correlation coefficient (measures strength/direction of the linear relationship). Range: -1 to +1.
- **P**: p-value (measures statistical significance). Lower values indicate stronger evidence of a correlation.

* Significance notation ($* = p < 0.05$, $** = p < 0.001$).

DISCUSSION

The findings in Table 1 demonstrate a marked disruption in redox homeostasis in individuals infected with SARS-CoV-2. Specifically, the data reveal significantly elevated plasma malondialdehyde (MDA) levels alongside reduced activities of key antioxidant defenses (SOD, GSH, and TAC) in COVID-19 patients compared with healthy controls. These patterns emphasize that acute viral infection triggers severe systemic oxidative stress, coupled with the exhaustion of both enzymatic and non-enzymatic antioxidant reserves.

These findings align strongly with other regional investigations across Nigeria and broader African populations. For instance, a cross-sectional comparative study conducted in North-Western Nigeria by Muhammad et al. (2021) similarly observed marked antioxidant depletion and heightened oxidative stress biomarkers among hospitalized COVID-19 patients (Muhammad et al., 2021). The overutilization of endogenous antioxidants to neutralize reactive oxygen species (ROS) produced during the

hyperinflammatory phase of viral pathogenesis explains the systemic decrease in levels of parameters such as glutathione and superoxide dismutase (Muhammad et al., 2021).

Globally, these results mirror international clinical trends regarding the pathophysiology of SARS-CoV-2. The significant increase in MDA (3.39 ± 0.168 nmol/mL vs. 2.54 ± 0.20 nmol/mL, $p = 0.002$), which signifies excessive lipid peroxidation, is consistent with comprehensive global systematic reviews and meta-analyses highlighting oxidant-antioxidant imbalances as major drivers of acute respiratory distress syndrome (ARDS) and multi-organ damage in severe COVID-19 cases (Alam, 2026).

Furthermore, global evaluations of total antioxidant capacity (TAC) and enzymatic activities consistently report reductions similar to those observed in this study's cohort (0.72 ± 0.105 u/mL vs. 1.25 ± 0.1 u/mL, $p = 0.020$) (Golabi et al., 2022). While catalase (CAT) activity showed a downward trend in patients (0.0079 vs. 0.018 ng/mL) that approached marginal significance ($p = 0.063$), discrepancies in individual enzyme responses compared to global cohorts often stem from variations in disease severity, viral variants, and patient nutritional status at admission.

Ultimately, the profound oxidant-antioxidant imbalance shown in Table 1 supports the integration of supportive antioxidant therapies (such as glutathione precursors or targeted micronutrient supplementation) to mitigate cellular injury and enhance clinical outcomes in COVID-19 management.

Age is an independent factor widely associated with dynamic trends in biomarkers, such as body fat, glucose and body mass index (BMI), as well as lifestyle habits, including alcohol consumption and smoking. Free radicals can damage cellular components, with lipid peroxidation, protein oxidation, and DNA damage among the most critical effects. Antioxidant systems play vital roles in neutralizing free radicals in the body. The non-enzymatic antioxidant system protects cells from oxidative damage by scavenging free radicals. Another key function of non-enzymatic antioxidants is to enable endogenous enzymatic antioxidants to scavenge reactive free radicals throughout the system. This collaborative action helps to maintain cellular integrity and function in the face of oxidative stress (Phaniendra et al., 2015).

The results of this study demonstrated no significant changes ($p > 0.05$) in plasma total antioxidant capacity (TAC), superoxide dismutase (SOD), catalase, glutathione (GSH), and malondialdehyde (MDA) concentrations across different age groups. The observed age-related variations in biochemical parameters among COVID-19 patients are likely attributable to changes in the body's immune response capabilities (Khalid Hassan Abdalruda, 2022).

Table 2 illustrates the distribution of antioxidant enzymes (SOD, CAT), non-enzymatic antioxidants (GSH), lipid peroxidation end-products (MDA), and total antioxidant capacity (TAC) across various age cohorts (15–34, 35–54, 55–64, and 65–94 years) among COVID-19-infected subjects. Interestingly, despite the physiological decline in basal metabolic and antioxidant functions typically observed with advanced age, the differences across these age brackets were not statistically significant ($p > 0.05$ for all tested parameters).

When contextualized within regional data from Nigeria and other sub-Saharan African countries, age-stratified analyses of oxidative stress in viral respiratory infections often present complex patterns. While studies like those by Muhammad et al. (2021) in north-western Nigeria confirm a profound overall redox imbalance in cohorts of mixed ages, isolating specific age-dependent deviations

often yields non-uniform statistical outcomes due to sample-size distributions across older age groups (Muhammad et al., 2021). Furthermore, African clinical cohorts frequently feature younger median patient ages than Western cohorts, which can compress the variance between age groups.

Globally, the relationship between age and oxidative stress during SARS-CoV-2 infection is well-documented, yet individual biomarker responses across chronological age brackets remain debated. While advanced age is universally recognized as a major independent risk factor for severe COVID-19 outcomes—largely driven by baseline immunosenescence (Cecerska-Heryć et al., 2025)—cellular biomarkers such as SOD, CAT, and TAC do not always exhibit a linear, age-dependent collapse during acute systemic inflammation.

For instance, findings by Bastin et al. (2023) evaluating redox parameters across varying COVID-19 clinical severities noted that disease staging and acute inflammatory surges (cytokine storms) often override baseline age-related protective reserves, leading to generalized systemic oxidant accumulation (such as elevated MDA values ranging between 2.85 and 3.58 nmol/mL across brackets) regardless of whether the patient is young or elderly (Bastin et al., 2023). The lack of statistically significant differences ($p = 0.559$ for MDA; $p = 0.580$ for GSH) across the age groups in Table 2 suggests that acute SARS-CoV-2 infection imposes an overwhelming oxidative burden that heavily strains antioxidant defences uniformly across all adult age strata, rather than sparing younger cohorts.

Conclusion

This study demonstrates that COVID-19 infection is associated with increased oxidative stress, as evidenced by significantly elevated plasma malondialdehyde (MDA) levels in infected subjects compared to healthy controls. Concurrently, the activities of the key antioxidant enzymes superoxide dismutase (SOD) and catalase were significantly reduced, indicating impaired enzymatic antioxidant defense. Although reduced glutathione levels and total antioxidant capacity also decreased in COVID-19 patients, these changes were not significant. These findings suggest that oxidative imbalance plays a role in the pathophysiology of COVID-19 and may contribute to disease severity.

Recommendations

Based on the findings derived from the study conducted.

The following recommendations were made:

Serum Malondialdehyde (MDA) and Total Antioxidant Capacity (TAC) should be integrated into routine clinical monitoring alongside traditional inflammatory markers (such as CRP and Ferritin). Measuring baseline MDA and TAC can help clinicians assess the extent of cellular membrane damage and systemic buffer exhaustion, thereby identifying patients at higher risk of respiratory decompensation.

Future studies in Nigeria and broader African populations should focus trial stratification on clinical disease severity (mild vs. moderate vs. severe/ICU) or inflammatory staging rather than age alone, as SARS-CoV-2 acts as an age-independent systemic redox equalizer.

Longitudinal follow-up studies should evaluate whether persistent lipid peroxidation (MDA) contributes to long-term post-viral fatigue, vascular inflammation, and organ dysfunction. Extended oral antioxidant regimens (e.g., N-Acetylcysteine, Vitamin E, Selenium) should be evaluated in clinical trials for post-acute symptom

resolution.

Account for Sub-Saharan Baseline Confounders: Researchers conducting oxidative stress studies in West Africa should measure baseline nutritional status and evaluate endemic co-infections (such as asymptomatic malaria or HIV) better to contextualize variability in baseline catalase and thiol levels.

A limitation of this study is the potential for unmeasured confounding factors from underlying comorbidities (such as metabolic or cardiovascular disorders), which are known to influence systemic oxidative stress. While controls were strictly matched for age and sex, unadjusted differences in baseline health status could have introduced selection bias.

Author Contributions

S.A. A. participated in the design of the experimental protocol, sample collection, as well as in the biochemical assay, data analysis and writing the manuscript. O. O. carried out sample collection, supervised each step of the experimental process and the preparation of the manuscript, and monitored all stages of the study. S.A.A., O.W., O.O.O., and N.P. performed an intensive and comprehensive review of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

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