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# Prevalence and determinants of post-acute sequelae of COVID-19 in Liberia

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## Abstract

**Background:** Evidence from resource-rich settings indicates that many people continue to have persistent symptoms following acute SARS-CoV-2 infection, called post-acute sequelae of COVID-19 (PASC). Only a few studies have described PASC in sub-Saharan Africa (SSA). We aimed to describe PASC in Liberia.

**Methods:** We randomly sampled all people who were reported from the most populous county to the Liberian Ministry of Health (MOH) as having a laboratory-confirmed SARS-CoV-2 infection from June to August 2021. We interviewed individuals by phone 3 to 6 months later. Those with persistence of at least one symptom were considered to have PASC.

**Results:** From among 2848 people reported to the MOH from Montserrado County during the period of interest, we randomly selected 650; of these, 548 (84.3%) were reached and 505 (92.2%) of those who were contacted were interviewed. The median age was 38 years (interquartile range (IQR), 30–49), and 43.6% were female. During acute infection, 40.2% were asymptomatic, 53.9% had mild/moderate disease and 6.9% had severe/critical disease. Among the 59.8% ($n = 302$) who were initially symptomatic, 50.2% ($n = 152$) reported at least one persistent symptom; the most common persistent symptoms were fatigue (21.2%), headache (16.2%) and cough (12.6%); 40.1% reported that PASC significantly affected their daily activities. Being hospitalized with moderate disease [adjusted prevalence ratio (aPR), 2.00 (95% CI, 1.59 to 2.80] or severe/critical disease [aPR, 2.11 (95% CI, 1.59 to 2.80)] was associated with PASC, compared with those not hospitalized. Females were more likely than males to report persistent fatigue [aPR, 1.67 (95% CI, 1.08 to 2.57)].

**Conclusions:** Our findings suggest that persistent symptoms may have affected a large proportion of people with initially symptomatic COVID-19 in west Africa and highlight the need to create awareness among infected people and health care professionals.

**Keywords:** COVID-19, SARS-CoV-2, Africa, post-acute sequelae of COVID-19, long COVID.

**Key Messages**

- Among a random sample of people from Montserrado County reported to the Liberian Ministry of Health with SARS-CoV-2 infection during a 2021 delta-variant surge, half of those who had symptoms during acute infection reported at least one persistent symptom 3–6 months later (defined as post-acute sequelae of COVID-19, or PASC).
- Nearly half of those with PASC reported that symptoms significantly affected activities of daily living.
- Greater severity of acute COVID-19 was independently associated with increased prevalence of at least one persistent symptom.
- Female sex was independently associated with having persistent fatigue.

## Introduction

As of December 2022, more than 600 million people had been infected with SARS-CoV-2, contributing to over 6 million deaths.[1] These figures are likely underestimates, as a lack of testing, surveillance and reporting has made it difficult to determine the actual burden of disease,[2–4] particularly in sub-Saharan Africa (SSA).[5–7] Although most people who have been infected have survived, many continue to experience persistent symptoms, a condition referred to as post-acute sequelae of COVID-19 or 'long COVID'.[8] Since it was initially described in 2020, however, no agreement on the nomenclature, case definition or diagnostic criteria for PASC has been reached.[9,10] In addition, many of the common symptoms associated with PASC are protean (such as fatigue, headache, chest pain and depression) and are not specific to long COVID.[8] However, persistent symptoms may be severe

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enough to impact on a person's quality of life and require them to obtain care and support long after the initial infection.[11] Commonly identified symptoms of PASC include fatigue, headache, chest pain, dyspnoea, cough, joint pain and brain fog or lack of ability to concentrate.[11–13] A large number of less common symptoms has also been reported.[14]

The prevalence and determinants of PASC are not well established, and estimates vary widely by population studied.[12] Acute COVID-19 severity, the presence of one or more comorbid conditions, sex, older age, race and ethnicity have all been found in different studies to be associated with greater risk of developing persistent symptoms.[15–17] Studies from Europe and the USA have found that up to 80% of those who have been discharged from an intensive care unit (ICU) developed PASC,[18,19] in contrast to 13–60% of those with symptomatic but non-severe disease.[20–23] From the few studies of PASC that have been performed from SSA,[15–17,24–26] a wide range in prevalence has also been reported, from as low as 2% to as high as 70%. Some of these differences could be attributed to differences in the populations studied. An evaluation of all hospitalized patients throughout South Africa,[16] as well as one that included only people who were older or who had comorbidities,[25] found a high prevalence of PASC of up to 70%. Two studies that only included outpatients or those without severe disease reported that 2–17% of participants had persistent symptoms.[15,17] To obtain further information on the prevalence of PASC in West Africa, we investigated persistent symptoms in a random sample of individuals who were reported in Liberia as having SARS-CoV-2 infection during a 2021 delta-variant surge.[27]

## Methods

### Overall design

We implemented a cross-sectional survey of a random sample of all individuals from one county in Liberia reported to the Liberian MOH as having a SARS-CoV-2 infection confirmed by polymerase chain reaction (PCR) from June to August 2021. Participants were interviewed by phone. We defined PASC as the persistence of at least one of 18 COVID-19-related symptoms 3–6 months after diagnosis. We evaluated factors associated with persistence of any symptom and with specific symptoms, and asked about the impact of PASC on daily activities.

### Study population

In Liberia, all SARS-CoV-2 infections detected by PCR were reported to the MOH on a weekly basis, along with name, age, sex, mobile number, address and next of kin. Rapid antigen-based testing, either self-administered or laboratory-based, was not available at the time of the study. From March 2020 through August 2021, 80% of all infections were reported from residents of Montserrado County, the most populous county in Liberia (Figure 1). We restricted our sampling frame to the 2729 people reported to the MOH from this county between June and August 2021, during which time a surge of infections occurred, mainly attributed to the delta-variant.[27] Both minors and adults were included in our sample. Among these, we selected a random sample of 650 people using the RAND function in Microsoft Excel version 16.71 (23031200). We conducted a phone survey from December 2021 through January 2022, which corresponded to 3 to 6 months following report of infection. Five people were interviewed 6.5 months after infection. Four district health supervisors called each person by phone up to three times on different days and times; if the person could not be reached, a call was made to the next of kin in an attempt to reach them and determine vital status. Once a potential participant was reached, the study was explained and verbal informed consent obtained. Verbal assent was obtained from minors aged 15 to <18 years, as well as consent from one parent or guardian; parental consent was obtained for children <15 years of age. Parents assisted minors and children in answering the survey. The study was conducted as part of the Liberian MOH's COVID-19 surveillance effort. Surveillance is classified as not being human subjects research, consistent with the US *2018 Revised CommonRule,*[28] criteria also used by the Liberian MOH.

### Measurements

A survey was administered by phone and lasted about 10 min. It included questions about age, sex, marital status, level of education, employment and whether the participant had had diabetes, hypertension, heart failure, chronic renal or liver disease, cancer or HIV infection within the previous 6 months. Other questions included reasons for obtaining a COVID-19 test (feeling sick, exposure to a case, travel, job or other reason), and if they had experienced any of 18 possible COVID-related symptoms at the time of infection. The 18 symptoms were based on the most common symptoms reported on MOH COVID-19 case report forms, according to the district health officers and the supervisor for Montserrado County. (The questionnaire is included in Supplementary data, available at *IJE* online) If participants reported a symptom during acute infection, they were asked if they still had that symptom at the time of the interview. We asked about hospitalization during acute illness and duration of hospital stay. Those who required oxygen and/or ventilatory support were categorized as having had severe/critical disease; those with symptoms but who did not require oxygen or ventilation were categorized as having mild/moderate disease. Participants were asked about the extent to which persistent symptoms affected their day-to-day activities (not at all, a little bit, somewhat, quite a bit, very much and don't know). Participants were also asked if and when they had received a COVID-19 vaccine.

### Statistical analyses

We calculated the frequency distribution of sociodemographic characteristics, presence of comorbid conditions, hospitalization during acute infection and reason for being tested, stratified by severity of initial infection (asymptomatic, mild/moderate disease, severe/critical disease). We determined the distribution of individual symptoms, and at least one systemic, respiratory, gastrointestinal or neurological symptom, at the time of infection and at the time of the interview. Among those with at least one persistent symptom, we calculated the reported impact of PASC on day-to-day activities, stratified by number of symptoms.

We used univariate and multivariable logistic regression models to evaluate the association of factors with several different outcomes. Our primary outcome was the persistence of at least one COVID-19-related symptom. Additional outcomes included each of the three symptoms most frequently reported by participants, as well having at least one

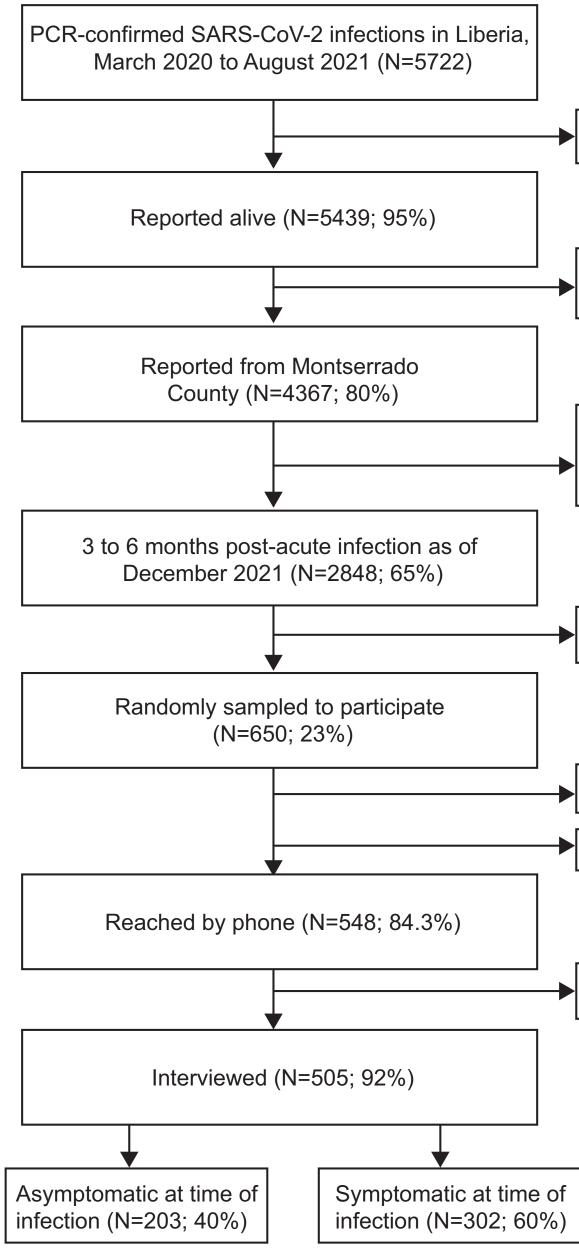


**Figure 1.** Assembly of a random sample of residents of Montserrado County, Liberia, who were reported with SARS-CoV-2 infection from June to August 2021, and who were interviewed 3 to 6 months later. PCR, polymerase chain reaction

respiratory, gastrointestinal or neurological symptom. We developed separate regression models for each of these outcomes.

We identified age, sex, presence of a comorbidity and severity of acute disease as potential determinants or confounders of PASC, based on a review of the literature and the construction of a directed acyclic graph (DAG) (not shown) used to determine the minimal adjustment sets. Socioeconomic status (SES), body mass index (BMI), COVID-19 variant and vaccination were not completely measured, therefore we did not include them in the analysis.

All variables were retained in the multivariable models. We used the cubic spline of age to adjust for age and to model it as a primary predictor.[29] We performed a parametric g-computation, then used the margins command in Stata to calculate marginal unadjusted and adjusted prevalence ratios[30] and unadjusted and adjusted prevalence differences, with 95% confidence intervals (CIs). This method predicted the counterfactual outcomes for each observation under each exposure.[31] All analyses were performed using Stata (Version 17.0 SE, College Station, TX).

## Results

### Characteristics of the study population

From March 2020 (when the first case of COVID-19 was identified in Liberia) through August 2021, the MOH recorded 5439 cases and 283 deaths nationwide (Figure 1); 4367 were reported from Montserrado County, accounting for 80% of all cases. From June to August 2021, 2848 cases were reported from this county, from which we randomly selected 650 potential participants. We reached 548 (84.3%) of the 650 by phone; two of the 650 (0.3%) were reported by next of kin or friends as having died; the cause could not be determined. Among the 548 reached, 505 (92.2%) consented to and completed the interview. The median length of time between date of infection and the interview was 22 weeks [interquartile range (IQR), 18–24] (data not shown). Slightly more than half of participants (56.4%) were male; the median age was 38 years (IQR, 30–49); 3.2% were <18 years old and nearly a quarter (21.0%) were older than 50 years; 53.3% had at least some college education, and 57.8% were employed (Table 1). Only a small proportion ($n = 47$, 9.3%) had one or more comorbid conditions, of which hypertension and diabetes were the most prevalent. The most frequently reported reasons for seeking testing were travel requirements (38.8%) and feeling ill (27.3%). By the time of interview, the majority ($n = 313$, 62.0%) had received at least one dose of vaccine, primarily Ad26.COV2.S (Johnson & Johnson/Jensen) (212/313, 67.7%) or AZD1222 (AstraZeneca) (96/313, 30.7%) (data not shown). However, most participants could not accurately recall the date of vaccination or whether they had received a vaccine before or after infection; therefore, we did not include vaccination in our regression analyses. At the time of infection, 203 participants (40.2%) reported no symptoms, 272 (53.9%) had mild/moderate disease and 30 (5.9%) had severe/critical disease. The majority of those with severe/critical disease were >50 years old (70.1%) and more likely to have diabetes (38.9%) or hypertension (50.0%) compared with those who were asymptomatic or who had mild/moderate disease. All those with severe/critical disease, and 24% of those with mild/moderate disease, had been hospitalized.

### Acute and post-acute symptoms

The most common reported acute symptoms were systemic (88.4%) and respiratory (88.1%) (Table 2). Cough (76.8%), fatigue (67.5%), fever (63.2%) and headache (60.6%) were the most frequent individual symptoms; fewer respondents reported brain fog (8.3%), difficulty breathing (21.2%) or chest pain (21.5%). The median number of symptoms among those who reported at least one symptom was six (IQR, 3–9) (data not shown). Among the 302 who had acute symptoms, 50.2% had persistent symptoms, the most frequent of which were systemic (62.5%) and neurological (49.3%). The most common individual persistent symptoms were fatigue (42.1%), headache (32.2%) and cough (25.0%); only 10% reported brain fog and 4.0% continued to have difficulty breathing.

### Effect of symptoms on daily activities

Among the 152 participants with PASC, 46.7% reported one persistent symptom, 38.8% reported two and 14.5% reported three or more (Table 3). More than a third (37.5%) reported that persistent symptoms affected their daily activities ‘somewhat’, and 40.1% said that PASC affected them ‘quite a bit/very much’. Among people reporting three or more symptoms, 95.4% indicated that the impact on daily living was ‘quite a bit/very much’, higher than among those with two persistent symptoms (52.5%) or one persistent symptom (12.7%).

### Determinants of PASC

The estimated prevalence of having at least one persistent symptom did not differ between males and females; those who were older were more likely to report PASC, although this did not reach statistical significance (Table 4a). People hospitalized with mild/moderate acute disease and those with severe acute disease were 2.00 (95% CI, 1.60 to 2.51) and 2.11 (95% CI, 1.59 to 2.80) times as likely to have any persistent symptoms, respectively, compared with those who were not hospitalized (Table 4a). Having been hospitalized with mild/moderate disease or having severe disease during acute infection was also independently associated with a greater prevalence of fatigue (Table 4b) and cough (Table 4d); having severe disease was independently associated with persistent headache [aPR, 2.29 (95% CI, 1.08 to 4.85)] (Table 4c). Women were 1.67 times more likely to have fatigue (95% CI, 1.08 to 2.57) than men (Table 4b). The prevalence of cough among people with diabetes was 2.40 (95% CI, 2.05 to 5.49) times as high as among those without diabetes (Table 4d). Compared with those who were not hospitalized, people with severe disease and those hospitalized with mild/moderate disease were 1.89 (95% CI, 1.09 to 3.30) and 2.54 (95% CI, 1.80 to 3.58) times as likely to have systemic symptoms, respectively (Supplementary Table S1a, available as Supplementary data at *IJE* online). The prevalence of respiratory symptoms among people hospitalized with mild/moderate disease and those with severe disease was 4.53 (95% CI, 2.15 to 9.53) and 4.07 (95% CI, 2.24 to 7.41) times as high as among those who were not hospitalized, respectively (Supplementary Table S1b, available as Supplementary data at *IJE* online). None of the variables assessed were associated with having persistent gastrointestinal symptoms (Supplementary Table S1c, available as Supplementary data at *IJE* online). The severity of acute disease was associated with having at least one neurological symptom (Supplementary Table S1d, available as Supplementary data at *IJE* online).

## Discussion

In this study of a random sample of Liberians from the most populous county reported to the MOH during a surge of infections in 2021, we found that half of those with acute symptoms had PASC 3 to 6 months following diagnosis. Nearly 80% of those who were hospitalized reported persistent symptoms, twice the number of those with milder initial disease. Among those with at least one persistent symptom, 40% indicated that sequelae significantly affected their daily functioning. Our findings suggest that the long-term health impact of COVID-19 in people infected during this period of the pandemic in SSA could be more significant than previously recognized.

A major strength of our study was the random sampling of people reported with an infection during a SARS-CoV-2 delta-surge. Our sample does not represent everyone in the population who was infected because of limited availability and/or uptake of testing in Liberia. Assembling a representative sample of everyone who is infected would be very challenging; probability sampling and testing of the general population are extremely difficult and time-consuming to perform.[32] Regardless, our sample is likely to be representative of all those from Montserrado County identified as being infected; infections from this county identified through PCR comprised 80% of all reported cases in the country. Apart from one research study, PCR testing performed at the National Reference Laboratory was the only method of detection used in Liberia, and reporting of positive results to the MOH was mandated. Rapid antigen testing was not available

**Table 1.** Sociodemographic and clinical characteristics of a random sample of people from Montserrado County, Liberia, reported to have a SARS-CoV-2 infection from June to August 2021

| Characteristic | Disease severity at time of infection: Asymptomatic (*n*=203) *n* | % | Mild/moderate[a] (*n*=272) *n* | % | Severe/critical[b] (*n*=30) *n* | % | All (*n*=505) *n* | % |
|---|---|---|---|---|---|---|---|---|
| Sex | | | | | | | | |
| Men | 114 | 56.2 | 155 | 57.0 | 16 | 53.3 | 285 | 56.4 |
| Women | 89 | 43.8 | 117 | 43.0 | 14 | 47.7 | 220 | 43.6 |
| Age, years | | | | | | | | |
| <18 | 11 | 5.4 | 4 | 1.5 | 1 | 3.3 | 16 | 3.2 |
| 18–35 | 84 | 41.4 | 108 | 39.7 | 4 | 13.3 | 196 | 38.8 |
| 36–50 | 77 | 37.9 | 106 | 39.0 | 4 | 13.3 | 187 | 37.0 |
| 51–65 | 26 | 12.8 | 45 | 16.5 | 14 | 46.7 | 85 | 16.8 |
| ≥65 | 5 | 2.5 | 9 | 3.3 | 7 | 23.4 | 21 | 4.2 |
| Marital status | | | | | | | | |
| Single | 100 | 49.2 | 125 | 46.0 | 5 | 16.7 | 230 | 45.5 |
| Married | 91 | 44.8 | 129 | 47.4 | 18 | 60.0 | 238 | 47.1 |
| Divorced/separated | 7 | 3.5 | 9 | 3.3 | 5 | 16.7 | 21 | 4.2 |
| Widow/widower | 5 | 2.5 | 9 | 3.3 | 2 | 6.6 | 16 | 3.2 |
| Education, highest completed | | | | | | | | |
| None | 1 | 0.5 | 4 | 1.5 | 2 | 6.7 | 7 | 1.4 |
| Primary, at least some | 13 | 6.4 | 15 | 5.5 | 5 | 16.7 | 33 | 6.5 |
| Secondary, at least some | 75 | 37.0 | 118 | 43.4 | 3 | 10.0 | 196 | 38.8 |
| University, at least some | 114 | 56.1 | 135 | 49.6 | 20 | 66.6 | 269 | 53.3 |
| Employment | | | | | | | | |
| Unemployed | 28 | 13.8 | 52 | 19.1 | 7 | 23.3 | 87 | 17.2 |
| Employed | 120 | 59.1 | 156 | 57.4 | 16 | 53.3 | 292 | 57.8 |
| Retired | 4 | 2.0 | 5 | 1.8 | 4 | 10.0 | 13 | 2.6 |
| Student | 51 | 25.1 | 59 | 21.7 | 3 | 13.4 | 113 | 22.4 |
| Comorbid conditions[c] | | | | | | | | |
| Hypertension | 2 | 0.99 | 16 | 5.9 | 9 | 30.0 | 27 | 5.3 |
| Diabetes | 1 | 0.49 | 7 | 2.5 | 7 | 23.3 | 15 | 2.9 |
| Asthma | — | — | 4 | 1.5 | — | — | 4 | 0.79 |
| Chronic liver disease | 1 | 0.49 | 2 | 0.74 | — | — | 3 | 0.59 |
| Other | 1 | 0.49 | 1 | 0.37 | 2 | 6.7 | 4 | 0.79 |
| Any comorbid condition | | | | | | | | |
| None | 198 | 97.5 | 244 | 89.7 | 16 | 53.3 | 458 | 90.7 |
| 1 comorbidity | 5 | 2.5 | 26 | 9.6 | 10 | 33.3 | 41 | 8.1 |
| >1 comorbidity | 0 | — | 2 | 0.7 | 4 | 13.3 | 6 | 1.2 |
| Reason for COVID-19 testing | | | | | | | | |
| Symptomatic | 0 | — | 118 | 43.4 | 20 | 66.7 | 138 | 27.3 |
| Exposure to case | 55 | 27.1 | 60 | 22.1 | 3 | 10.0 | 118 | 23.4 |
| Travel requirement | 108 | 53.2 | 82 | 30.1 | 6 | 20.0 | 196 | 38.8 |
| Employment requirement | 22 | 10.8 | 8 | 2.9 | 1 | 3.3 | 31 | 6.1 |
| Voluntary | 18 | 8.9 | 4 | 1.5 | 0 | 0.0 | 22 | 4.3 |
| Hospitalized for COVID-19 | 0 | — | 64 | 23.5 | 30 | 100.0 | 94 | 18.7 |

[a] Symptomatic during acute COVID-19 infection but did not require supplemental oxygen or ventilation.
[b] Symptomatic during acute COVID-19 infection and required supplemental oxygen or ventilation.
[c] Proportions do not add up to 100% as conditions are not mutually exclusive.

at the time of the study.[33] Therefore, we are unlikely to have missed people from this county who had a positive PCR test result. Finally, more than 90% of those who were contacted responded to the survey; this level of participation is higher than in other studies of PASC from SSA.[15–17,24–26]

Our study had several additional strengths, including evaluation of both people who were hospitalized and outpatients, inclusion of all age groups and analysis of determinants of PASC. We found that the severity of initial infection was the only independent factor associated with having at least one persistent symptom. Among those who required hospitalization, more than 80% had PASC, twice the rate among those who had milder acute disease. These results are comparable to a study from South Africa that found 67% of hospitalized COVID-19 patients developed PASC.[16] Studies from elsewhere have also reported that up to 93% of those with severe initial disease developed PASC.[18,34–36] It is difficult, however, to determine the long-term impact of severe SARS-CoV-2 infection independent of being hospitalized in an ICU. People requiring critical care, regardless of the underlying medical condition, generally have poorer outcomes and greater morbidity than non-ICU hospitalized patients.[37] We found that among those who were not hospitalized, about 37% reported at least one persistent symptom, similar to a South African study of outpatients.[26]

Overall, direct comparisons with other studies are difficult, because of heterogeneity in study design and target population, the period during the pandemic in which studies were conducted, lack of comparator groups and different definitions of PASC.[14,22,23,38,39] Unsurprisingly, therefore, the reported prevalence of long-COVID has varied widely. Meta-analysis or systematic reviews, although attempted, are

**Table 2.** Self-reported symptoms at the time of SARS-CoV-2 infection and 3 to 6 months later

| Symptoms | Time of infection | | | | 3–6 months after infection | | | |
|---|---|---|---|---|---|---|---|---|
| | All (*n*=505) | | ≥1 initial symptom (*n*=302) | | ≥1 initial symptom (*n*=302) | | ≥1 persistent symptom (*n*=152) | |
| | *n* | % | *n* | % | *n* | % | *n* | % |
| Any symptom | 302 | 59.8 | — | — | 152 | 50.3 | — | — |
| Systemic | | | | | | | | |
| Fever | 191 | 37.8 | 191 | 63.2 | 7 | 2.3 | 7 | 4.6 |
| Fatigue | 204 | 40.4 | 204 | 67.5 | 64 | 21.2 | 64 | 42.1 |
| Body aches | 130 | 25.7 | 130 | 43.0 | 5 | 1.7 | 5 | 3.3 |
| Chills | 73 | 14.5 | 73 | 24.2 | 1 | 0.3 | 1 | 0.7 |
| Joint pains | 74 | 14.7 | 74 | 24.5 | 9 | 3.0 | 9 | 5.9 |
| Difficulty sleeping | 89 | 17.6 | 89 | 29.5 | 32 | 10.6 | 32 | 21.1 |
| ≥1 systemic symptom | 267 | 52.9 | 267 | 88.4 | 95 | 31.5 | 95 | 62.5 |
| Respiratory | | | | | | | | |
| Cough | 232 | 45.9 | 232 | 76.8 | 38 | 12.6 | 38 | 25.0 |
| Chest pain | 65 | 12.9 | 65 | 21.5 | 2 | 0.7 | 2 | 1.3 |
| Difficulty breathing | 64 | 12.7 | 64 | 21.2 | 6 | 2.0 | 6 | 4.0 |
| Runny nose/congestion | 114 | 22.6 | 114 | 37.8 | 11 | 3.6 | 11 | 7.2 |
| Sore throat | 117 | 23.2 | 117 | 38.7 | 0 | — | 0 | — |
| ≥1 respiratory symptom | 266 | 52.7 | 266 | 88.1 | 51 | 16.9 | 51 | 33.6 |
| Gastrointestinal | | | | | | | | |
| Loss of appetite | 108 | 21.4 | 108 | 35.8 | 9 | 3.0 | 9 | 5.9 |
| Vomiting | 12 | 2.4 | 12 | 4.0 | 0 | — | 0 | — |
| Stomach pain | 36 | 7.1 | 36 | 11.9 | 1 | 0.3 | 1 | 0.7 |
| ≥1 gastrointestinal symptom | 123 | 24.4 | 123 | 40.7 | 10 | 3.3 | 10 | 6.6 |
| Neurological | | | | | | | | |
| Headache | 183 | 36.2 | 183 | 60.6 | 49 | 16.2 | 49 | 32.2 |
| Brain fog | 25 | 5.0 | 25 | 8.3 | 15 | 5.0 | 15 | 10.0 |
| Altered smell | 104 | 20.6 | 104 | 34.4 | 4 | 1.3 | 4 | 2.6 |
| Altered taste | 28 | 5.5 | 28 | 9.3 | 10 | 3.3 | 10 | 6.6 |
| ≥1 neurological symptom | 227 | 45.0 | 227 | 75.2 | 75 | 24.8 | 75 | 49.3 |

**Table 3.** Effect of persistent symptoms on daily activities 3–6 months after initial SARS-CoV-2 infection

| Effect on daily activities | Number of persistent symptoms | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 (*n*=71) | | 2 (*n*=59) | | ≥3 (*n*=22) | | All (*n*=152) | |
| | *n* | % | *n* | % | *n* | % | *n* | % |
| Not at all/a little bit | 29 | 40.8 | 5 | 8.5 | 0 | — | 34 | 22.4 |
| Somewhat | 33 | 46.5 | 23 | 39.0 | 1 | 4.6 | 57 | 37.5 |
| Quite a bit/very much | 9 | 12.7 | 31 | 52.5 | 21 | 95.4 | 61 | 40.1 |

problematic for the same reasons.[40] A standardized definition of PASC would greatly aid in understanding its frequency and impact.

We assessed the relationship of participant characteristics with multiple different outcomes, including the persistence of any symptom, of cough, headache and fatigue, and of any systemic, respiratory, neurological or gastrointestinal complaint. Greater severity of initial disease was the only factor associated with a higher prevalence of almost all outcomes; of those who were hospitalized, about 80% complained of persistent symptoms, twice the number of those who had milder initial disease. Older age has been found to be associated with greater risk of PASC in many studies.[14,16,23] In our study, however, those who were older had a greater estimated prevalence of any persistent symptom, fatigue or cough, but age was not independently associated with these outcomes. We found that twice as many women as men were likely to report ongoing fatigue. Differences between men and women in presentation of PASC have been reported, with women more likely to experience continued fatigue and musculoskeletal and respiratory symptoms.[23,41] Only a small proportion of people in our sample, less than 10%, reported having comorbidities, the most common of which were hypertension and diabetes. We did not find these to be independently associated with any of our outcomes, with the exception that diabetes was associated with a greater prevalence of cough. People who are obese have been found to have worse outcomes[16] of COVID-19, but as we did not measure BMI, we could not evaluate it in our analysis.

Few data on the determinants of PASC in SSA are available for comparison.[15–17] The study from South Africa by Dryden *et al.*, which was based on a large random sample of all hospitalized patients throughout the country, found older age, female sex, mixed race, obesity and severity of initial infection to be determinants of PASC.[16] The other two studies from the region that evaluated factors associated with PASC did not find that women or people of older age were more likely to develop persistent symptoms.[15,17] Understanding the overall impact of PASC in SSA is also constrained by limited data on the actual burden of SARS-CoV-2 infection in

**Table 4.** Association between sociodemographic and clinical characteristics and post-acute sequelae of COVID-19 among those who had at least one COVID-19 related symptom at the time of infection ($n = 302$)

| | All | | Prevalence ratio | | Prevalence difference | |
|---|---|---|---|---|---|---|
| Characteristics | *n* | Prevalence % (95% CI) | Unadjusted (95% CI) | Adjusted[a] (95% CI) | Unadjusted (95% CI) | Adjusted[a] (95% CI) |
| **a) At least one persistent symptom** | | | | | | |
| Sex | | | | | | |
| Male | 171 | 46.8% (39.3% to 54.3%) | Ref. | Ref. | Ref. | Ref. |
| Female | 131 | 55.0% (46.4% to 63.5%) | 1.17 (0.94 to 1.47) | 1.11 (0.90 to 1.37) | 0.08 (–0.03 to 0.20) | 0.05 (–0.05 to 0.16) |
| Age, years[b] | | | | | | |
| 20 | — | 43.5% (28.8% to 58.1%) | Ref. | Ref. | Ref. | Ref. |
| 40 | — | 45.0% (37.0% to 52.9%) | 1.03 (0.69 to 1.55) | 1.07 (0.74 to 1.53) | 0.02 (–0.16 to 0.19) | 0.03 (–0.14 to 0.19) |
| 50 | — | 53.3% (45.5% to 61.2%) | 1.23 (0.81 to 1.85) | 1.17 (0.80 to 1.71) | 0.10 (–0.09 to 0.29) | 0.08 (–0.10 to 0.26) |
| 60 | — | 65.6% (55.8% to 75.5%) | **1.51 (1.04 to 2.19)** | 1.32 (0.92 to 1.91) | **0.22 (0.04 to 0.40)** | 0.15 (–0.04 to 0.33) |
| Acute COVID-19 severity | | | | | | |
| Mild/moderate non-hospitalized | 203 | 36.5% (29.8% to 43.1%) | Ref. | Ref. | Ref. | Ref. |
| Mild/moderate hospitalized | 69 | 76.8% (66.9% to 86.8%) | **2.11 (1.69 to 2.63)** | **2.00 (1.60 to 2.51)** | **0.40 (0.28 to 0.52)** | **0.38 (0.25 to 0.50)** |
| Severe/critical | 30 | 83.3% (70.0% to 96.7%) | **2.29 (1.80 to 2.91)** | **2.11 (1.59 to 2.80)** | **0.47 (0.32 to 0.62)** | **0.42 (0.24 to 0.60)** |
| Hypertension | | | | | | |
| No | 277 | 49.1% (43.2% to 55.0%) | Ref. | Ref. | Ref. | Ref. |
| Yes | 25 | 64.0% (45.2% to 82.8%) | 1.30 (0.95 to 1.79) | 0.87 (0.54 to 1.41) | 0.15 (–0.05 0.35) | –0.07 (–0.28 to 0.15) |
| Diabetes | | | | | | |
| No | 288 | 49.3% (43.5% to 55.1%) | Ref. | Ref. | Ref. | Ref. |
| Yes | 14 | 71.4% (47.8% to 95.1%) | **1.45 (1.02 to 2.06)** | 1.00 (0.57 to 1.77) | 0.22 (–0.02 to 0.46) | 0.001 (–0.29 to 0.29) |
| **b) Fatigue** | | | | | | |
| Sex | | | | | | |
| Men | 171 | 15.2% (9.8% to 20.6%) | Ref. | Ref. | Ref. | Ref. |
| Women | 131 | 29.0% (21.4% to 36.8%) | **1.91 (1.22 to 2.97)** | **1.67 (1.08 to 2.57)** | **0.14 (0.04 to 0.23)** | **0.11 (0.02 to 0.20)** |
| Age, years[b] | | | | | | |
| 20 | — | 16.9% (6.1% to 27.8%) | Ref. | Ref. | Ref. | Ref. |
| 40 | — | 18.9% (12.9% to 24.9%) | 1.12 (0.52 to 2.37) | 1.12 (0.57 to 2.22) | 0.02 (–0.11 to 0.15) | 0.02 (–0.11 to 0.15) |
| 50 | — | 22.5% (15.8% to 29.1%) | 1.33 (0.60 to 2.95) | 1.19 (0.57 to 2.47) | 0.06 (–0.09 to 0.20) | 0.03 (–0.11 to 0.18) |
| 60 | — | 28.3% (19.6% to 36.9%) | 1.67 (0.80 to 3.48) | 1.26 (0.61 to 2.58) | 0.11 (–0.03 to 0.26) | 0.05 (–0.10 to 0.19) |
| Acute COVID-19 severity | | | | | | |
| Mild/moderate non-hospitalized | 203 | 11.8% (7.4% to 16.3%) | Ref. | Ref. | Ref. | Ref. |
| Mild/moderate hospitalized | 69 | 39.1% (27.6% to 50.6%) | **3.31 (2.05 to 5.33)** | **2.96 (1.83 to 4.80)** | **0.27 (0.15 to 0.40)** | **0.25 (0.13 to 0.37)** |
| Severe/critical | 30 | 43.3% (25.6% to 61.1%) | **3.67 (2.10 to 6.39)** | **2.93 (1.53 to 5.63)** | **0.32 (0.13 to 0.50)** | **0.24 (0.05 to 0.44)** |
| Hypertension | | | | | | |
| No | 277 | 20.0% (15.2% to 24.6%) | Ref. | Ref. | Ref. | Ref. |
| Yes | 25 | 36.0% (17.2% to 54.8%) | **1.81 (1.02 to 3.22)** | 1.18 (0.59 to 2.36) | 0.16 (–0.03 to 0.36) | 0.04 (–0.13 to 0.20) |
| Diabetes | | | | | | |
| No | 288 | 19.8% (15.2% to 24.4%) | Ref. | Ref. | Ref. | Ref. |
| Yes | 14 | 50.0% (23.8% to 76.2%) | **2.53 (1.42 to 4.48)** | 1.50 (0.71 to 3.19) | **0.30 (0.04 to 0.57)** | 0.10 (–0.12 to 0.33) |
| **c) Headache** | | | | | | |
| Sex | | | | | | |
| Male | 171 | 15.8% (10.3% to 21.3%) | Ref. | Ref. | Ref. | Ref. |
| Female | 131 | 16.8% (10.4% to 23.2%) | 1.06 (0.64 to 1.78) | 1.03 (0.61 to 1.75) | 0.01 (–0.07 to 0.09) | 0.01 (–0.08 to 0.09) |
| Age, years[b] | | | | | | |
| 20 | — | 17.8% (6.5% to 29.1%) | Ref. | Ref. | Ref. | Ref. |
| 40 | — | 15.2% (9.6% to 20.8%) | 0.85 (0.39 to 1.86) | 0.89 (0.41 to 1.93) | –0.03 (–0.16 to 0.11) | –0.02 (–0.16 to 0.12) |
| 50 | — | 15.6% (10.0% to 21.2%) | 0.88 (0.38 to 2.01) | 0.86 (0.38 to 1.98) | –0.02 (–0.16 to 0.12) | –0.02 (–0.17 to 0.12) |

(continued)

**Table 4.** (continued)

| Characteristics | *n* | All | Prevalence ratio | | Prevalence difference | |
|---|---|---|---|---|---|---|
| | | Prevalence % (95% CI) | Unadjusted (95% CI) | Adjusted[a] (95% CI) | Unadjusted (95% CI) | Adjusted[a] (95% CI) |
| 60 | — | 17.0% (9.8% to 24.2%) | 0.95 (0.43 to 2.10) | 0.85 (0.37 to 1.96) | –0.01 (–0.15 to 0.13) | –0.03 (–0.17 to 0.12) |
| Acute COVID-19 severity | | | | | | |
| Mild/moderate non-hospitalized | 203 | 13.3% (8.6% to 18.0%) | Ref. | Ref. | Ref. | Ref. |
| Mild/moderate hospitalized | 69 | 20.3% (10.8% to 30.0%) | 1.53 (0.85 to 2.74) | 1.56 (0.86 to 2.82) | 0.07 (–0.04 to 0.18) | 0.07 (–0.03 to 0.18) |
| Severe/critical | 30 | 26.7% (10.8% to 42.5%) | **2.01 (1.01 to 4.0)** | **2.29 (1.08 to 4.85)** | 0.13 (–0.03 to 0.30) | 0.17 (–0.03 to 0.37) |
| Hypertension | | | | | | |
| No | 277 | 16.2% (11.9% to 20.6%) | Ref. | Ref. | Ref. | Ref. |
| Yes | 25 | 16.0% (1.6% to 30.4%) | 0.98 (0.39 to 2.51) | 0.82 (0.28 to 2.39) | –0.003 (–0.15 to 0.15) | –0.03 (–0.18 to 0.12) |
| Diabetes | | | | | | |
| No | 288 | 16.3% (12.1% to 20.6%) | Ref. | Ref. | Ref. | Ref. |
| Yes | 14 | 14.3% (-4.0% to 32.6%) | 0.88 (0.24 to 3.24) | 0.62 (0.15 to 2.63) | –0.02 (–0.21 to 0.17) | –0.06 (–0.22 to 0.09) |
| **d) Cough** | | | | | | |
| Sex | | | | | | |
| Male | 171 | 9.9% (5.5% to 14.4%) | Ref. | Ref. | Ref. | Ref. |
| Female | 131 | 16.0% (9.7% to 22.3%) | 1.06 (0.64 to 1.78) | 1.24 (0.70 to 2.23) | 0.01 (–0.07 to 0.09) | 0.03 (–0.05 to 0.10) |
| Age, years[b] | | | | | | |
| 20 | — | 10.7% to (1.7% to 19.6%) | Ref. | Ref. | Ref. | Ref. |
| 40 | — | 11.1% (6.3% to 15.9%) | 1.05 (0.39 to 2.82) | 0.96 (0.40 to 2.30) | 0.00 (–0.10 to 0.11) | –0.01 (–0.12 to 0.11) |
| 50 | — | 13.1% (7.7% to 18.4%) | 1.23 (0.42 to 3.53) | 0.97 (0.38 to 2.47) | 0.02 (–0.10 to 0.14) | –0.00 (–0.12 to 0.12) |
| 60 | — | 16.4% (9.4% to 23.4%) | 1.54 (0.58 to 4.11) | 0.99 (0.40 to 2.48) | 0.06 (–0.06 to 0.18) | –0.00 (–0.12 to 0.12) |
| Acute COVID-19 severity | | | | | | |
| Mild/moderate non-hospitalized | 203 | 4.9% (2.0% to 7.9%) | Ref. | Ref. | Ref. | Ref. |
| Mild/moderate hospitalized | 69 | 27.5% (17.0% to 38.1%) | **5.59 (2.73 to 11.43)** | **5.19 (2.51 to 10.70)** | **0.23 (0.12 to 0.34)** | **0.22 (0.11 to 0.33)** |
| Severe/critical | 30 | 30.0% (13.6% to 46.4%) | **6.09 (2.70 to 13.76)** | **5.01 (1.93 to 13.01)** | **0.25 (0.08 to 0.42)** | **0.21 (0.02 to 0.39)** |
| Hypertension | | | | | | |
| No | 277 | 12.3% (8.4% to 16.1%) | Ref. | Ref. | Ref. | Ref. |
| Yes | 25 | 16.0% (1.6% to 30.4%) | 1.30 (0.50 to 3.38) | 0.78 (0.27 to 2.21) | 0.04 (–0.11 to 0.19) | –0.03 (–0.14 to 0.08) |
| Diabetes | | | | | | |
| No | 288 | 11.1% (7.5% to 14.7%) | Ref. | Ref. | Ref. | Ref. |
| Yes | 14 | 42.9% (16.9% to 68.8%) | **3.86 (1.94 to 7.67)** | **2.40 (1.05 to 5.49)** | **0.32 (0.06 to 0.58)** | 0.16 (–0.05 to 0.37) |

[a] All variables retained in multivariable model.
[b] Cubic spline of age.

the subcontinent, largely due to lack of surveillance, reporting and testing.[6] By the end of 2021, at the time of our study, only 7.1 million infections had been reported to the WHO from the African region, but several epidemic models estimated that up to 500 million infections had occurred during 2021; if these models are accurate, it is likely that only a small proportion of actual infections have been identified and/or reported.[6,42]

Because many of the symptoms of COVID-19 are non-specific and may be due to existing conditions or the constraints of the pandemic on mental health, jobs and lifestyle, the inclusion of comparator groups of uninfected individuals is important to determine whether symptoms can be attributed to infection.[14,22,23,39,43–46] A population-based study from The Netherlands used a case-control design and corrected for symptoms before SARS-CoV-2 infection; the authors found that 21% of people had symptoms 3 to 6 months later, but only 13% had symptoms that could be attributed to COVID-19.[22] Other similar studies of outpatients performed in the USA, Norway and Denmark, and which included an uninfected comparator group, reported that up to 18% had persistent symptoms that could be attributed to COVID-19.[14,22,23,39,43,46] Unfortunately, our study did not include an uninfected group, so we cannot be certain whether reported symptoms were solely related to COVID-19.

We evaluated people infected during a COVID-19 surge that was primarily due to the delta-variant[27]; this variant has been associated with more severe symptoms than the currently widely circulating omicron sub-variants.[47] Therefore, it is uncertain whether our findings will pertain to people who have been more recently infected and who are more likely to be vaccinated, or whether results can be generalized to other resource-limited settings with different distributions of age, comorbidities and sociodemographic characteristics.

Our study had several limitations in addition to those mentioned above. First, although we asked about symptoms of initial infection which were still being experienced at the time of the survey, we did not obtain information about the duration of those symptoms or their frequency. We also did not enquire about any new symptoms that may have arisen. Symptoms possibly attributable to SARS-CoV-2 infection can develop later, even if not experienced during acute infection.[38] Second, we evaluated 18 commonly reported COVID-19-associated symptoms, but did not specifically enquire about symptoms that have since been recognized as associated with PASC and/or that are less frequent, such as tachycardia, orthostasis, skin conditions or hair loss, among others.[14,48] Third, participants may have over-reported their symptoms in the hope of receiving economic support. In Liberia at the beginning of the pandemic, funds were provided by governmental and non-governmental organizations to infected people who had a limited income. In an effort to reduce reporting bias, interviewers made clear that our study was not linked to any support services. Fourth, although we asked about COVID-19 vaccination, most respondents could not remember the date of vaccination, and therefore we did not include this variable in our analysis. Vaccination before infection has been shown to reduce the severity of acute disease, which in turn impacts on PASC[49]; vaccination after infection may also diminish the occurrence and severity of long-term sequelae.[50] Fifth, we only evaluated infections from Montserrado County, the general population of which has higher levels of income and education than the rest of the country.[51] Higher SES could influence awareness of COVID-19 and greater likelihood of seeking testing. About 60% of participants reported they had symptoms during acute infection, even though only 27% sought testing because of symptoms. It is possible that even if people were tested for reasons other than feeling ill (such as travel or exposure), they could have gone on to develop symptoms shortly thereafter. The Liberian government emphasized testing of travellers into and out of the country in an effort to reduce introduction of infections, regardless of whether this was an effective public health approach in the face of limited testing capacity.

**Conclusion**

Despite these limitations, our findings highlight the need to create greater awareness of PASC in resource-limited settings. Few people and health care providers in lower-income countries may be aware that SARS-CoV-2 infection can have long-term sequelae; as a result, patients may not present for care or have their symptoms taken seriously. Relying solely on the findings from resource-rich settings may be misleading. Given that PASC constitutes a family of disorders,[8] the pathophysiology of the disorder and the effectiveness of therapy among those living in lower-income countries, particularly in SSA, still need to be investigated. A better understanding of the burden and characteristics of PASC would be greatly enhanced by well-designed, longitudinal cohort studies that include uninfected comparator groups, and by the development of standardized definitions.

## Ethics approval

Analysis was conducted using de-identified data abstracted from the Montserrado County Health Team COVID-19 public health surveillance effort, and therefore was not considered human subjects research. The classification of surveillance as not being human subjects research is consistent with the US *2018 Revised CommonRule,*,[28] which is the basis on which the UCSF Office of Human Subjects Protection classifies surveillance.

## Data availability

The data for this article cannot be shared publicly because they are the property of the Liberian Ministry of Health.

## Supplementary data

Supplementary data are available at *IJE* online.

## Author contributions

C.G., J.M., C.L. and M.B. conceived and designed the study. C.G., Y.S-W. and M.B. participated in data collection. C.G . performed the data analysis with input from D.G., M.B., C. L. and J.M. All authors contributed to interpretation of data. C.G., .JM. and C.L. were primarily responsible for writing the paper. All authors reviewed the manuscript, provided edits and approved the final submission.

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## Conflict of interest

None declared.

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