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Clinical Research Study

# Postacute Sequelae From SARS-CoV-2 at the University of Illinois Hospital and Clinics: An Examination of the Effects of Long COVID in an Underserved Population Utilizing Manual Extraction of Electronic Health Records

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ABSTRACT

*Background:* Although there has been a steady decrease in morbidity and mortality from the SARS-CoV-2 virus since the 2020-2021 period, thousands of Americans are still infected with the virus daily. Some proportion of these infected individuals will go on to develop postacute sequelae from SARS-CoV-2 (PASC, or Long COVID), manifesting symptoms 4 weeks or more after recovery from COVID-19. PASC and its underlying pathophysiology are still poorly described and understood. Although hundreds of peer-reviewed, published investigations on Long COVID exist, few have focused on underserved urban patient populations. Most of the published research has involved reviews of diagnostic codes from electronic health records, or responses to questionnaires.

*Methods:* We sought to review Long COVID in an underserved population in Chicago, and to go beyond electronic health record reviews of diagnostic codes, utilizing in-depth chart reviews, gleaned via manual extraction, focusing on notations of care providers. We investigated which specific preexisting conditions, if any, might be associated with specific Long COVID symptomatology's, and if any preexisting conditions predicted Long COVID. Study participants included 204 Long COVID patients, 98 COVID-19–positive patients, and 104 healthy (no history of COVID-19 infection) patients from an inner-city health system caring for underserved communities, whose records were reviewed via manual data extraction from electronic health records, focusing on provider notes in patient charts.

*Results:* Our Long COVID symptom frequencies were distinct compared to frequencies from other reviews that did not focus on underserved populations and done with medical records when only diagnostic codes are utilized. Preexisting medical conditions did not predict similar Long COVID symptomologies, save for the significant association between preexisting cough/dyspnea/pulmonary conditions and preexisting migraine/headache and their analogous Long COVID symptoms.

*Conclusions:* The odds of having Long COVID increased comparatively in subjects hospitalized with COVID-19, subjects with BMI >30, and female subjects.

## Background

The SARS-CoV-2 virus was identified in late 2019 and claimed over 1 million lives in the United States in slightly more than 2 years.[1] Awareness, behavior modification, congregant management, and vaccination, as well as less deadly variant forms of the virus, have lowered the mortality of COVID-19. However, infections with SARS-CoV-2 virus continue, and some proportion of these infected individuals will go on to develop postacute sequelae from SARS-CoV-2 (PASC, or Long COVID), manifesting symptoms 4 weeks or more after recovery from COVID-19.[2-5] PASC and its underlying pathophysiology are still poorly understood[6-9] even as considerable marshalling of resources has begun to support their study. Although PASC is being studied internationally and in the United States with well-funded efforts (the RECOVER initiative is a $1.15-billion NIH-funded project that has produced 55 peer-reviewed published articles as of June 1, 2024[10,11]; ORCHESTRA is a similar effort funded by the European Union[12]; nationally funded efforts to study Long COVID are underway in United Kingdom[13] and the Netherlands,[14] as well as in China[15]), many of these studies focus on large regional or national cohorts and do not feature underserved populations,[16] resulting in considerably less knowledge regarding underserved patient populations and Long COVID.[16] Some evidence suggests that Black and Hispanic Americans may be at higher risk for Long COVID than White Americans are.[17-18] Other reviews suggest that Long COVID may affect

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individuals of lower socioeconomic levels with higher frequency than it affects the general population.[19-20] Nearly all Long COVID studies involve reviews of diagnostic codes from electronic health records (EHR), or patient and physician responses to questionnaires, often as part of study protocols, rather than EHR chart reviews, focusing on physician notes to explore the disease's natural history and progression. We sought to observe Long COVID in an underserved, patient population of an academic medical center in Chicago, IL, with only 22.1% of patients carrying private insurance; we utilized EHR and focused on in-depth chart reviews and physician notes from care delivery. This investigation of Long COVID's effects on underserved populations utilizing notational-focused chart reviews of EHR is the first of its kind.

## Objectives

The objective of this study was to utilize clinical data from retrospective and prospective Long COVID patients, COVID-19 patients, and COVID-19–free controls from University of Illinois Hospital and Clinics in Chicago, IL to better describe PASC in an underserved population. The primary exposure of interest was Long COVID.

## Methods

Two hundred and four prospective and retrospective Long COVID patients at University of Illinois Hospital and Clinics in Chicago, IL were reviewed via EHR, from June 2022 through March 2023. Ninety-eight COVID-19 patients with no history of Long COVID were also reviewed during the same time period, as were 104 patients who were never infected with COVID-19. Data on medical history, severity of COVID-19, and Long COVID symptomatology's were extracted manually from EHR.

The review focused on provider notations in patient electronic medical record charts to ascertain both histories and symptomology. Diagnostic coding utilized by care providers was also reviewed.

Long COVID subjects were selected randomly from a list of 500 University of Illinois Hospital and Clinics patients who had any of the following notations in their EHR charts: post COVID; Long COVID; COVID long hauler; postacute sequelae from SARS-CoV-2 or postacute sequelae from COVID; PASC; or ICD10 diagnostic code U09.9. COVID-19–positive subjects were chosen randomly from a list of 500 University of Illinois Hospital and Clinics patients who had an EHR chart reference to COVID-19 positive, Coronavirus positive, or ICD10 code U07.1. These patients' COVID-19 chart notations were contemporaneous with the Long COVID patients' Long COVID chart notations. Healthy patients were chosen randomly from a list of 500 patients who had none of the above-mentioned patients' EMR chart references to Long COVID or COVID-19.

Subjects were defined as Long COVID patients if their health care provider utilized ICD10 diagnostic code UO9.9, or if the provider noted "Long COVID," "Post Acute Sequelae from COVID/SARS-CoV-2," "PASC," "COVID Long Hauler," "Post-Covid," "Post-Acute COVID," or similar in the subject's EHR. Subjects needed at least two diagnoses of Long COVID or similar (ICD10 diagnostic code U09.9, "Long COVID," "Post Acute Sequelae from COVID/SARS-CoV-2," "PASC," "COVID Long Hauler," "Post-Covid," "Post-Acute COVID," or similar), each with at least one associated symptom, specified by health care providers. Both diagnoses must have occurred at least 30 days from the abatement of COVID-19 symptoms, or at least 30 days after a negative COVID-19 test, with a provider referencing the patient's survivorship from COVID-19 temporally. The diagnoses must also have occurred at least 30 days from each other, so that the subject had documentation of Long COVID symptoms at least 60 days post recovery from COVID-19. Subjects were considered to be COVID-19 positive if their medical records showed a positive PCR test for the SARS-CoV-2 virus or, in the absence of a positive PCR test, a provider referencing a COVID-19 infection during a specific time period. Subjects were considered healthy" if there was no mention of COVID-19 infection in their medical records.

Subjects were grouped into clusters based on medical history, referencing preexisting comorbid conditions. These included a pulmonary group (history of asthma or pulmonary disease, including history of cough or dyspnea), a cardiovascular disease group (prior cardiovascular event, including stroke, myocardial infarction, or cardiac procedure [surgical or interventional], or history of angina or cerebrovascular event), a metabolic group (history of hypertension and type 1 or 2 diabetes mellitus), a mental health group (history of anxiety and/or depression), a musculoskeletal group (history of osteoarthritis or rheumatoid arthritis, myalgia, arthralgia, or myalgic encephalopathy chronic fatigue syndrome), a group with syncope/orthostasis/POTS, a migraine/headache group, a group with a history of hospitalization from COVID-19, a SARS-CoV-2 vaccinated group, a group with body mass index (BMI) greater than 30, and a group with "breakthrough" COVID-19 history (infection with SARS-CoV-2 post vaccination). Long COVID symptomologies were likewise grouped into clusters reflecting related symptoms. These clusters included breakthrough PASC, a pulmonary group (dyspnea/cough/pulmonary referral for Long COVID symptoms), a headache/migraine group, an anxiety/depression/mental health group, a brain fog/memory group, a fatigue group, an orthostasis group (syncope/dizzy/balance/orthostasis), a weakness group, a cardiac group (chest pain/palpitations/myocarditis), a neuropathy group (neuropathy/neurology referral for Long COVID symptoms), an arthralgia/myalgia group, and an anosmia group. Demographic variables (age, sex, race, and ethnicity) and vaccination status were also assessed descriptively.

Characteristics of subjects were assessed descriptively, and associations between preexisting medical conditions and Long COVID symptoms and between preexisting medical conditions and patient group (Long COVID patients, COVID-19 patients, and COVID-19–free controls) were assessed using Chi-square tests, independent group t-tests, and logistic regression models. The logistic regression analysis served as the sensitivity analysis for the Chi-square and t-test associations. Demographic variables (age, sex, race, ethnicity) and vaccination status were also analyzed statistically as well as controlled for in the Chi-square, independent group t-tests, and logistic regression models (Tables 1–6).

## Results

The frequencies of various Long COVID symptoms in this study were distinct from Long COVID symptom frequencies reported by other investigators (Table 4).[3,21]

The most frequently reported Long COVID symptom at University of Illinois Hospital and Clinics was dyspnea/cough, reported by 66.18% of Long COVID patients (Table 4). Next, fatigue was reported by 29.41% of Long COVID patients; palpitations/chest pain/myocarditis was reported by 23.04% of Long COVID patients; brain fog/memory was reported by 21.08% of Long COVID patients. No other symptoms were reported by more than 20% of Long COVID patients. The odds of having Long COVID increased comparatively in subjects hospitalized with COVID-19, subjects with BMI >30, and female subjects, in comparison to COVID-19–positive subjects; the odds of having Long COVID increased comparatively in subjects with BMI >30 and female subjects in comparison with healthy (no COVID-19) patients.

As shown in Table 6, among Long COVID subjects, only the preexisting conditions of dyspnea/cough/pulmonary and anxiety/depression predicted similar Long COVID symptoms (see Tables 5 and 6). Among Long COVID subjects, a history of dyspnea/cough was associated with increased odds for dyspnea/cough as Long COVID symptoms (crude OR = 2.02, 95%CI 1.05-4.0; OR = 2.02*, 95% CI 1.01-4.0; OR = 2.03**, 95% CI 1.01-4.0) (*Adjusted for age, sex, and race; **Adjusted for age, sex, race, and vaccination except when age, sex, or race are in model, where adjustment is for other two variables plus vaccination.) Among Long COVID subjects, a history of anxiety/depression was associated with increased odds for anxiety/depression as Long COVID symptoms (crude OR = 5.25; 95% CI 1.10-17.0; OR = 5.10*, 95% CI 1.45-

**Table 1**
Characteristics of Population and Association With Patient Group at the University of Illinois Hospital and Clinics from January 1, 2022 to March 31, 2023.

| | | Long COVID Patients (n = 204) | | COVID-Positive Patients (n = 98) | | Healthy Patient Controls (n = 104) | | Total (n = 406) | | P Value |
|---|---|---|---|---|---|---|---|---|---|---|
| Characteristic | | n | % | n | % | n | % | n | % | |
| Sex | | | | | | | | | | **0.0367** |
| | Male | 45 | 22.06 | 34 | 34.69 | 33 | 32.04 | 112 | 27.65 | |
| | Female | 159 | 77.94 | 64 | 65.31 | 70 | 67.96 | 293 | 72.35 | |
| | Missing | | | | | | | | | |
| Race | | | | | | | | | | 0.8523 |
| | Asian, Other, or Unknown | 11 | 5.39 | 8 | 8.16 | 7 | 6.73 | 26 | 6.40 | |
| | Black/African American | 95 | 46.57 | 46 | 46.94 | 46 | 44.23 | 187 | 46.06 | |
| | Hispanic | 57 | 27.94 | 30 | 30.61 | 29 | 27.88 | 116 | 28.57 | |
| | White | 41 | 20.10 | 14 | 14.29 | 22 | 21.15 | 77 | 18.97 | |
| Age (Continuous) [Mean, SD] | | | | | | | | 49.22 (15.26) | | 0.3283 |
| Age (Categorical) | | | | | | | | | | 0.0526 |
| | Less than 65 | 174 | 85.29 | 80 | 82.47 | 77 | 74.04 | 331 | 81.73 | |
| | 65 and older | 30 | 14.71 | 17 | 17.53 | 27 | 25.96 | 74 | 18.27 | |
| | Missing | | | | | | | 1 | | |
| BMI >30 | | | | | | | | | | **0.0028** |
| | Less than 30 | 86 | 41.67 | 55 | 56.12 | 63 | 60.58 | 203 | 50.00 | |
| | 30 or more | 119 | 58.33 | 43 | 43.88 | 41 | 39.42 | 203 | 50.00 | |
| Vaccination Status | | | | | | | | | | |
| | Vaccinated | 164 | 80.39 | 75 | 76.53 | 78 | 75.00 | 317 | 78.08 | |
| | Unvaccinated | 40 | 19.61 | 23 | 23.47 | 26 | 25.00 | 89 | 21.92 | |

P values are from Chi-square tests, except for the associations between age and patient group, where the P value is from an ANOVA test.
**Bold** = significant association at alpha = 0.05.

**Table 2**
Association Between Preexisting Conditions and Patient Group.

| | | | Long COVID Patients (N=204) | | COVID-Positive Patients (N=99) | | Healthy Patient Controls (N=104) | | Total (N=407) | | P Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Symptom | | | n | % | n | % | n | % | n | % | |
| **PRE-EXISTING CONDITIONS** | **Pulmonary Hx** | | | | | | | | | | 0.0896 |
| | | Yes | 64 | 31.37 | 22 | 22.45 | 22 | 21.15 | 108 | 26.6 | |
| | | No | 140 | 68.63 | 76 | 77.55 | 82 | 78.85 | 298 | 73.4 | |
| | **Migraine/Headache** | | | | | | | | | | 0.8911 |
| | | Yes | 37 | 18.14 | 16 | 16.33 | 17 | 16.35 | 70 | 17.24 | |
| | | No | 167 | 81.86 | 82 | 83.67 | 87 | 83.65 | 336 | 82.76 | |
| | **Anxiety/Depression/Psych HX** | | | | | | | | | | |
| | | Yes | 76 | 37.25 | 30 | 30.61 | 35 | 33.65 | 141 | 34.73 | |
| | | No | 128 | 62.75 | 68 | 69.39 | 69 | 66.35 | 265 | 65.27 | |
| | **Hypertension/CKD** | | | | | | | | | | 0.0696 |
| | | Yes | 113 | 55.39 | 62 | 63.27 | 55 | 52.88 | 182 | 44.83 | |
| | | No | 91 | 44.61 | 36 | 36.73 | 49 | 47.12 | 224 | 55.17 | |
| | **DM** | | | | | | | | | | 0.2940 |
| | | Yes | 57 | 27.94 | 36 | 36.73 | 31 | 29.81 | 124 | 30.54 | |
| | | No | 147 | 72.06 | 62 | 63.27 | 73 | 70.19 | 282 | 69.46 | |
| | **Hypertension/CKD/DM** | | | | | | | | | | 0.3978 |
| | | Yes | 52 | 25.49 | 32 | 32.65 | 27 | 25.96 | 111 | 27.34 | |
| | | No | 152 | 74.51 | 66 | 67.35 | 77 | 74.04 | 295 | 72.66 | |
| | **Hyperlipidemia** | | | | | | | | | | 0.1776 |
| | | Yes | 82 | 40.20 | 48 | 48.98 | 38 | 36.54 | 168 | 41.38 | |
| | | No | 122 | 59.80 | 50 | 51.02 | 66 | 63.46 | 238 | 58.62 | |
| | **Cardiovascular Disease** | | | | | | | | | | 0.0503 |
| | | Yes | 44 | 21.57 | 29 | 29.59 | 16 | 15.38 | 89 | 21.92 | |
| | | No | 160 | 78.43 | 69 | 70.41 | 88 | 84.62 | 317 | 78.08 | |
| | **Orthostasis/Syncope/POTS** | | | | | | | | | | 0.2103 |
| | | Yes | 10 | 4.90 | 9 | 9.18 | 10 | 9.62 | 29 | 7.14 | |
| | | No | 194 | 95.10 | 89 | 90.82 | 94 | 90.38 | 377 | 92.86 | |
| | **Osteoarthritis/Rheumatoid Arthritis/Myalgia** | | | | | | | | | | 0.4903 |
| | | Yes | 47 | 23.04 | 17 | 17.35 | 24 | 23.08 | 88 | 21.67 | |
| | | No | 157 | 76.98 | 81 | 82.65 | 80 | 76.92 | 318 | 78.33 | |
| | **Breakthrough COVID** | | | | | | | | | | 0.2943 |
| | | Yes | 45 | 22.06 | 27 | 27.55 | N/A | N/A | 72 | 23.84 | |
| | | No | 159 | 77.94 | 71 | 72.45 | N/A | N/A | 230 | 76.16 | |
| | **Hospitalized for COVID-19** | | | | | | | | | | **0.0098** |
| | | Yes | 46 | 22.55 | 10 | 10.20 | N/A | N/A | 56 | 18.54 | |
| | | No | 158 | 77.45 | 88 | 89.80 | N/A | N/A | 246 | 81.46 | |

P values are from Chi-square tests.
**Bold** = significant association at alpha = 0.05.

**Table 3a**
Logistic Regression to Assess the Association Between Pre-Existing Conditions and Patient Groups.

| | | Long COVID Patients vs COVID Positive Patients | | | | | |
|---|---|---|---|---|---|---|---|
| | | Crude | | Adjusted* | | Adjusted** | |
| | | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI |
| **PRE-EXISTING CONDITIONS·** | **Orthostasis/Syncope/POTS** | 0.51 | (0.20-1.30) | 0.48 | (0.18-1.25) | 0.46 | (0.18-1.22) |
| | **Breakthrough COVID** | 0.74 | (0.43-1.29) | 0.71 | (0.40-1.24) | 0.63✦ | (0.35-1.15)✦ |
| | Vaccinated | N/A | N/A | N/A | N/A | N/A | N/A |
| | Unvaccinated | N/A | N/A | N/A | N/A | N/A | N/A |
| | BMI Less than 30 | N/A | N/A | N/A | N/A | 1.44 | (0.59-3.52) |
| | BMI 30 or more | N/A | N/A | N/A | N/A | **0.29** | **(0.13-0.68)** |
| | **Hospitalized for COVID-19** | **2.56** | **(1.23-5.33)** | **2.86** | **(1.34-6.12)** | **2.96** | **(1.38-6.37)** |
| | **BMI>30** | **1.79** | **(1.10-2.91)** | **1.76** | **(1.05-2.94)** | **1.75** | **(1.05-2.92)** |
| | **Sex** | **1.88** | **(1.10-3.19)** | **2.06** | **(1.19-3.56)** | **2.07** | **(1.20-3.58)** |

* Adjusted for age, sex and race.

** Adjusted for age, sex, race, and vaccination (except when age, sex or race are in model, where adjustment is for other 2 variables plus vaccination).**Bold** = significant association at alpha = 0.05.

✦ = significant interaction by vaccination status, BMI, categorical age, sex, or race.*Italicized* = Results from Firth's Logistic Regression.

· REF = Not having pre-existing condition, male sex, and White race.NULL = Model failed to converge.N/A = Non-applicable.

**Table 3b**
Logistic Regression to Assess the Association Between Pre-Existing Conditions and Patient Groups.

| | | Long COVID Patients vs Healthy Patient Controls | | | | | |
|---|---|---|---|---|---|---|---|
| | | Crude | | Adjusted* | | Adjusted** | |
| | | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI |
| **PRE-EXISTING CONDITIONS·** | **Orthostasis/Syncope/POTS** | 0.49 | (0.20-1.20) | 0.58 | (0.22-1.51) | 0.50 | (0.19-1.29) |
| | **Breakthrough COVID** | N/A | N/A | N/A | N/A | N/A | N/A |
| | Vaccinated | N/A | N/A | N/A | N/A | N/A | N/A |
| | Unvaccinated | N/A | N/A | N/A | N/A | N/A | N/A |
| | BMI Less than 30 | N/A | N/A | N/A | N/A | N/A | N/A |
| | BMI 30 or more | N/A | N/A | N/A | N/A | N/A | N/A |
| | **Hospitalized for COVID-19** | N/A | N/A | N/A | N/A | N/A | N/A |
| | **BMI>30** | **2.15** | **(1.33-3.48)** | **2.19** | **(1.31-3.67)** | **2.16** | **(1.28-3.62)** |
| | **Sex** | 1.67 | (0.98-2.83) P-Value: 0.0591 | 1.65 | (0.96-2.81) P-Value: 0.0687 | 1.64 | (0.96-2.81) P-Value: 0.0701 |

* Adjusted for age, sex and race.

** Adjusted for age, sex, race, and vaccination (except when age, sex or race are in model, where adjustment is for other 2 variables plus vaccination).**Bold** = significant association at alpha = 0.05.

✦= significant interaction by vaccination status, BMI, categorical age, sex, or race.

*Italicized* = Results from Firth's Logistic Regression.

· REF = Not having pre-existing condition, male sex, and White race.NULL = Model failed to converge.

**Table 4**
Long COVID Symptoms Frequencies.

| Symptom | No | | Yes | |
|---|---|---|---|---|
| | n | % | n | % |
| **Breakthrough PASC** | 162 | 79.41 | 42 | 20.59 |
| **Dyspnea/Cough** | 69 | 33.82 | 135 | 66.18 |
| **Headache** | 166 | 81.37 | 38 | 18.63 |
| **Brain Fog Memory** | 161 | 78.92 | 43 | 21.08 |
| **Anxiety/Depression/Psych History** | 189 | 92.65 | 15 | 7.35 |
| **Fatigue** | 144 | 70.59 | 60 | 29.41 |
| **Syncope/Dizziness/POTS** | 182 | 89.22 | 22 | 10.78 |
| **Chest Pain/Myocarditis/Palpitations** | 157 | 76.96 | 47 | 23.04 |
| **Weakness** | 190 | 93.14 | 14 | 6.86 |
| **Neurology Referral/Neuropathy** | 168 | 82.35 | 36 | 17.65 |
| **Myalgia/Arthralgia** | 185 | 90.69 | 19 | 9.31 |
| **Anosmia** | 190 | 93.14 | 14 | 6.86 |

17.0; OR = 5.95**, 95% CI 1.6-22.17)(*Adjusted for age, sex, and race; **Adjusted for age, sex, race, and vaccination, except when age, sex, or race are in model, where adjustment is for other two variables plus vaccination.)

All other Long COVID symptoms were not predicted by similar preexisting conditions. Long COVID subjects who were hospitalized for COVID-19 had more than two times greater odds of having dyspnea/cough/pulmonary as Long COVID symptoms (crude OR = 2.15, 95% CI 0.99-4.64; OR = 2.28*, 95% CI 1.03-5.01; OR = 2.26**, 95% CI 1.02-5.02) (*Adjusted for age, sex, and race; **Adjusted for age, sex, race, and vaccination, except when age, sex, or race are in model, where adjustment is for other two variables plus vaccination.) Subjects who were vaccinated against COVID-19 had 82% lower odds of having anosmia (crude OR = 0.21, 95% CI 0.07-0.5; OR = 0.18*, 95% CI 0.05-0.5) (*adjusted for age, sex, and race).

Subjects aged 65 years or greater had borderline significant associations with chest pain/palpitations/myocarditis as Long COVID symptoms (crude OR = .97, 95% CI 0.95-1.0; OR = 0.97*, 95% CI 0.94-1.0; OR = 0.97**, 95% CI 0.94-1.0) (*Adjusted for age, sex, and race; **Adjusted for age, sex, race, and vaccination, except when age, sex, or race are in model, where adjustment is for other two variables plus vaccination.)

Counterintuitively, among Long COVID patients, those with a history of migraine/headache had 63% lower odds of having cough/dyspnea/pulmonary history as Long COVID symptoms (adjusted OR = 0.37, 95% CI 0.18-0.79) after adjusting for age, sex, race, and vaccination. This association was modified by sex; in stratified analysis, females who had a history of migraine/headache/ had 75% lower odds of having cough/dyspnea/pulmonary as Long COVID symptoms (adjusted OR = 0.25, 95% CI = 0.11-0.59) after adjusting for age, race, and vaccination, and there was no association found among males.

**Table 5a**
Association Between Pre-Existing Conditions and Long COVID Symptoms.

| | | LONG COVID SYMPTOMS | | | | | |
|---|---|---|---|---|---|---|---|
| | | Breakthrough PASC | Dyspnea/Cough | Headache | Brain Fog FFoFog FoFog Fog Memory | Anxiety/Depression /Psych HX | Fatigue |
| **PRE-EXISTING CONDITIONS** | **Pulmonary History** | 0.7586 | **0.0340** | 0.2575 | 0.5814 | 0.8650 | 0.5459 |
| | **Migraine/Headache** | 0.7814 | **0.0127** | 0.6051 | 0.9287 | 0.6159 | 0.7249 |
| | **Anxiety/Depression/Psych HX** | 0.2298 | 0.3133 | 0.7538 | 0.1576 | **0.0027** | 0.6007 |
| | **Hypertension/CKD** | 0.9265 | 0.3377 | 0.2700 | 0.9501 | 0.2128 | 0.9420 |
| | **DM** | 0.1495 | 0.1581 | 0.5168 | 0.4476 | 0.4764 | 0.3438 |
| | **Hypertension/CKD/DM** | 0.2823 | 0.2230 | 0.1282 | 0.9877 | 0.2617 | 0.2455 |
| | **Cardiovascular Disease** | 0.4138 | 0.9662 | 0.6010 | 0.7620 | 0.4204 | 0.7251 |
| | **Orthostasis/Syncope/POTS** | 0.9624 | 0.3434 | 0.9090 | 0.1325 | 0.3610 | 0.5030 |
| | **Osteoarthritis/Rheumatoid Arthritis/Myalgia** | 0.4906 | 0.1493 | 0.9166 | 0.9697 | 0.3253 | 0.9487 |
| | **Breakthrough COVID** | **<.0001** | 0.9372 | 0.3015 | 0.0633 | 0.1353 | 0.4075 |
| | **Hospitalized for COVID-19** | 0.5263 | **0.0490** | 0.2690 | 0.0537 | 0.8061 | 0.1944 |
| | **BMI>30** | 0.3799 | 0.7075 | 0.4293 | 0.4682 | 0.6832 | 0.7553 |
| | **Age** | 0.8333 | 0.6718 | 0.9202 | 0.2771 | 0.9475 | 0.4933 |
| | **Sex** | 0.7588 | 0.5254 | 0.2563 | 0.8408 | 0.3971 | 0.4075 |
| | **Race** | 0.5159 | 0.8503 | 0.2130 | 0.8128 | 0.2393 | 0.0846 |
| | **Vaccination** | **0.0003** | 0.5686 | 0.5110 | 0.8520 | 0.9683 | 0.3870 |

P-values are from Chi-Square tests, except for associations between age and long COVID symptoms, where the P-values are from independent group t-tests.
**Bold** = significant association at alpha = 0.05.

**Table 5b**
Association Between Pre-Existing Conditions and Long COVID Symptoms.

| | | LONG COVID SYMPTOMS | | | | | |
|---|---|---|---|---|---|---|---|
| | | Syncope/Dizziness /POTS | Chest Pain /Myocarditis /Palpitations | Weakness | Neuro Referral referral/Neuropathy | Myalgia/Arthralgia | Anosmia |
| **PRE-EXISTING CONDITIONS** | **Pulmonary History** | 0.3074 | 0.5318 | 0.3373 | 0.2842 | 0.9838 | 0.1534 |
| | **Migraine/Headache** | 0.9954 | 0.1283 | 0.6984 | 0.8008 | 0.3659 | 0.077 |
| | **Anxiety/Depression/Psych HX** | 0.9271 | 0.8608 | 0.9017 | 0.5463 | 0.5910 | 0.4862 |
| | **Hypertension/CKD** | 0.3208 | 0.3101 | 0.6741 | 0.7280 | 0.7993 | 0.6741 |
| | **DM** | 0.1512 | 0.7478 | 0.5018 | 0.1067 | 0.4822 | 0.5018 |
| | **Hypertension/CKD/DM** | 0.2154 | 0.6973 | 0.7840 | 0.7286 | 0.6412 | 0.7840 |
| | **Cardiovascular Disease** | 0.8887 | 0.2472 | 0.5092 | 0.9163 | 0.9542 | 0.9895 |
| | **Orthostasis/Syncope/POTS** | 0.3353 | 0.3153 | 0.3787 | 0.0572 | 0.9390 | 0.3787 |
| | **Osteoarthritis/Rheumatoid Arthritis/Myalgia** | 0.5668 | 0.6436 | 0.2432 | 0.8979 | 0.4307 | 0.8821 |
| | **Breakthrough COVID** | 0.3131 | 0.3424 | 0.5426 | 0.9792 | 0.4889 | **0.0392** |
| | **Hospitalized for COVID-19** | 0.5746 | 0.1523 | 0.2219 | 0.3520 | 0.4591 | 0.4433 |
| | **BMI>30** | 0.5932 | 0.3836 | 0.0753 | 0.0625 | 0.5965 | 0.5122 |
| | **Age** | 0.9755 | **0.0166** | 0.1835 | 0.6211 | 0.2518 | 0.1924 |
| | **Sex** | 0.9362 | 0.5127 | 0.5426 | 0.3618 | 0.9116 | 0.1631 |
| | **Race** | 0.5742 | 0.1343 | 0.2851 | 0.6628 | 0.7667 | 0.9447 |
| | **Vaccination** | 0.1884 | 0.7426 | 0.1158 | 0.1571 | 0.4393 | **0.0030** |

P-values are from Chi-Square tests, except for associations between age and long COVID symptoms, where the P-values are from independent group t-tests.
**Bold** = significant association at alpha = 0.05.

## Discussion

Our review found distinct frequencies of Long COVID symptoms in Long COVID patients in an underserved urban patient population, but with familiar comorbidity predictors of Long COVID risk. Our review also found a lack of association between preexisting conditions and analogous Long COVID symptoms, save for migraine and cough/dyspnea/pulmonary comorbidities.

Our focus on an underserved patient population is in contrast to Long COVID research to date. University of Illinois Hospital and Clinics has a payer base that is 21.3% private payer, 45.7% Medicaid, and 1.5% charitable (https://healthcarereportcard.illinois.gov/hospital/101228). Our Long COVID patients were 47.6% Black and 27.9% Hispanic. This is in comparison to the RECOVER Long COVID cohort with 15% Black and 16.5% Hispanic subjects.[3] Our review features a patient population distinct from existent Long COVID research.

Our report is based on chart notes by providers, listing Long COVID symptoms reported directly to providers by patients (i.e., no patient surveys and no total reliance on diagnostic codes). Our reported Long COVID symptom frequencies varied from Long COVID symptom frequencies reported by other authors who relied solely on diagnostic codes or patient surveys. The most current comprehensive symptom frequency review was that of the RECOVER group's 2023 publication describing Long COVID utilizing patient surveys. There the following symptom frequencies were reported: malaise/fatigue 86%; brain fog 64%; dizziness 62%; weakness 42%; shortness of breath 36%; cough 33%.[3] Other authors have reported varying frequencies of Long COVID symptoms.[22] Long COVID symptom frequency has been described as varying widely among centers and studies.[22] Our symptom frequencies (dyspnea/cough at 66%; fatigue at 29%; no other symptoms above 23%) contrast with Long COVID symptoms reported in other, larger, multicenter reviews of patient surveys or EMR reviews of diagnostic codes. Although the existing data and peer-reviewed publications on Long COVID featured some representation of nonwhite, underinsured, underserved Long COVID patients, our review has a higher share of these patients, who are underrepresented in the literature.[23]

**Table 6a**
Logistic Regression to Assess the Association Between Pre-Existing Conditions and Long COVID Symptoms.

| | | LONG COVID SYMPTOMS | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Breakthrough PASC | | | | | | Dyspnea/Cough | | | | | | Anxiety/Depression/Psych HX | | | | | |
| | | Crude | | Adjusted* | | Adjusted** | | Crude | | Adjusted* | | Adjusted** | | Crude | | Adjusted* | | Adjusted** | |
| | | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI |
| **PRE-EXISTING CONDITIONS*** | **Pulmonary Hx** | N/A | N/A | N/A | N/A | N/A | N/A | **2.05** | **(1.05-4.01)** | **2.02** | **(1.01-4.04)** | **2.03** | **(1.01-4.06)** | N/A | N/A | N/A | N/A | N/A | N/A |
| | **Migraine/Headache** | N/A | N/A | N/A | N/A | N/A | N/A | **0.41** | **(0.20-0.84)** | **0.37** | **(0.17-0.78)** | **0.37✦** | **(0.18-0.79)✦** | N/A | N/A | N/A | N/A | N/A | N/A |
| | *Male* | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 3.27 | (0.29-36.64) | N/A | N/A | N/A | N/A | N/A | N/A |
| | *Female* | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | **0.25** | **(0.11-0.59)** | N/A | N/A | N/A | N/A | N/A | N/A |
| | **Anxiety/Depression /Psych HX** | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | **5.25** | **(1.61-17.13)** | **5.10** | **(1.45-17.86)** | **5.95** | **(1.60-22.17)** |
| | **Hospitalized for COVID-19** | N/A | N/A | N/A | N/A | N/A | N/A | 2.15 | (0.99-4.64) | **2.28** | **(1.03-5.05)** | **2.26** | **(1.02-5.02)** | N/A | N/A | N/A | N/A | N/A | N/A |
| | **Vaccination** | ***28.11*** | ***(1.63-483.79)*** | ***26.98*** | ***(1.71-425.26)*** | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

* Adjusted for age, sex and race (except when age, sex or race are in model, where adjustment is for other 2 variables).
** Adjusted for age, sex, race, and vaccination (except when age, sex or race are in model, where adjustment is for other 2 variables plus vaccination).**Bold** = significant association at alpha = 0.05.
✦ = significant interaction by vaccination status, BMI, categorical age, sex, or race.*Italicized* = Results from Firth's Logistic Regression.
* REF = Not having pre-existing condition, male sex, and White race; Null = Model failed to converge; N/A Not Applicable.

**Table 6b**
Logistic Regression to Assess the Association Between Pre-Existing Conditions and Long COVID Symptoms.

| | | LONG COVID SYMPTOMS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Chest Pain/Myocarditis/Palpitations | | | | | | Anosmia | | | | | |
| | | Crude | | Adjusted* | | Adjusted** | | Crude | | Adjusted* | | Adjusted** | |
| | | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI | Odds Ratio | 95%CI |
| **PRE-EXISTING CONDITIONS·** | **Breakthrough COVID** | N/A | N/A | N/A | N/A | N/A | N/A | *0.11* | *(0.01-1.94)* | *0.10* | *(0.01-1.46)* | *0.15* | *(0.01-2.22)* |
| | **Age** | **0.97** | **(0.95-1.00)** | **0.97** | **(0.94-1.00)** | **0.97** | **(0.94-1.00)** | N/A | N/A | N/A | N/A | N/A | N/A |
| | **Race** | | | | | | | N/A | N/A | N/A | N/A | N/A | N/A |
| | Asian, Other, or Unknown vs White | 3.33 | (0.74-14.98) | 2.89 | (0.62-13.42) | 2.88 | (0.62-13.40) | N/A | N/A | N/A | N/A | N/A | N/A |
| | Black/African American vs White | 1.46 | (0.54-3.97) | 1.83 | (0.65-5.16) | 1.82 | (0.64-5.15) | N/A | N/A | N/A | N/A | N/A | N/A |
| | Hispanic vs White | 2.69 | (0.96-7.55) | 3.36 | (1.15-9.80) | **3.34** | **(1.14-9.78)** | N/A | N/A | N/A | N/A | N/A | N/A |
| | **Vaccination** | N/A | N/A | N/A | N/A | N/A | N/A | **0.21** | **(0.07-0.64)** | **0.18** | **(0.05-0.59)** | N/A | N/A |

* Adjusted for age, sex and race (except when age, sex or race are in model, where adjustment is for other 2 variables).
** Adjusted for age, sex, race, and vaccination (except when age, sex or race are in model, where adjustment is for other 2 variables plus vaccination).**Bold** = significant association at alpha = 0.05.✦ = significant interaction by vaccination status, BMI, categorical age, sex, or race.*Italicized* = Results from Firth's Logistic Regression.
· REF = Not having pre-existing condition, male sex, and White race.NULL = Model failed to converge.N/A = Not Applicable.

Beyond the patient mix, our data were extracted directly from EHR documentation of providers' notes and charting, without the use of machine learning or natural language processing. It is understood that there are many hurdles associated with utilization of ICD10 coding to ascertain Long COVID (and other disease state) symptomologies. Indeed, in a study of 300 Long COVID patients (randomly sampled from Beth Israel Deaconess Medical Center, University of Pittsburgh Medical Center, and national US Veterans Health Administration), utilizing a parallel manual chart review rather than reliance solely on diagnostic codes, The Consortium for Clinical Characterization of COVID-19 by EHR commented.

When we examined the data capture of symptoms by ICD-10 codes and natural language processing of clinical narratives, such as clinician notes and discharge summaries, we found that the incorporation of narrative data significantly improved identification of symptoms, compared to using diagnosis codes alone.

…we identified 3 major challenges in using real world data to study long COVID: ambiguity and heterogeneity in clinical coding of long COVID; inadequacy of diagnostic codes in capturing the constellation of symptoms; and biases in EHR data arising from variability in the number and kind of contacts with the healthcare system.

A comparison of real-world EHR and administrative data with manually extracted clinical information (obtained through chart review of patients with the U09.9 code) found that functional definitions of long COVID varied widely by provider, which led to inconsistencies in coding practice and adherence to clinical definitions.

… *the ICD-10 code is an unreliable surrogate of long COVID disease status in research.*[24,25]

We grouped symptoms and preexisting conditions together, as has been done in other Long COVID investigations, to reflect generally linked disease states.[21] The World Health Organization has defined long COVID as having over 200 possible symptoms.[26] Gross and Lo Re, in commenting on one of the initial RECOVER publications, described Long COVID with the phrase "*e unabus pluram*" (from one, many).[27] Long COVID has been previously described as a heterogenous symptom syndrome.[28,29] It was thought that the grouping of like comorbidities, and like symptoms, as with other Long COVID investigations, might better elucidate associations between preexisting conditions and the likelihood of Long COVID, as well as associations between preexisting conditions and Long COVID symptoms.

Lastly, our review mirrored results of other Long COVID reviews in that female patients, patients with BMI >30, and patients hospitalized due to COVID-19 all had higher odds of being Long COVID patients.[30] However, our review of possible associations between specific preexisting conditions and analogous Long COVID symptomologies appears to have few precedents in the Long COVID literature.

Although several studies have focused on specific preexisting conditions and their prediction of Long COVID risk generally, a symptom-for-symptom comparison (between pre–Long COVID comorbidities and Long COVID symptoms) has perhaps not yet been attempted. Our results here are somewhat surprising in that only dyspnea/cough/pulmonary and headache/migraine predicted similar Long COVID symptoms while preexisting musculoskeletal infirmities such as osteoarthritis, rheumatoid arthritis, chronic fatigue, or even generalized weakness had no analogs in Long COVID symptomologies. Similar findings occurred for preexisting neurologic disorders and any neurologic Long COVID symptomologies, including brain fog. Our review describes a randomness of association between preexisting conditions and analogous Long COVID symptoms.

Our review utilized logistic regression applied to a multitude of both preexisting conditions and Long COVID symptoms, extracted manually from EHR chart reviews. The extraction required significant time to complete. To our knowledge, only one previous review of Long COVID has relied on manual extraction of EHR chart notations (Appendix A). Our results suggest that this type of review may be better understood with larger databases utilized, but the detail required to extract the data needed for such a review is not easily realized. Our results may also be helpful to clinicians who are treating Long COVID and who may be expecting some association of the Long COVID symptoms with pre–SARS-CoV-2 infection histories. This expectation may not be useful for most Long COVID symptoms, save pulmonary and migraine.

Our results may describe a tendency for Long COVID in an underserved population to be underdiagnosed and underreported, and for the most obvious COVID-19 symptom (cough/dyspnea) to predominate in the symptom diagnoses of Long COVID patients. It is possible that providers may not be sufficiently prepared to diagnose patients with Long COVID.

One of the strengths of our review is that we likely captured incidental Long COVID patients and could manually extract all chart notations

describing the subjects' progression from COVID-19 to Long COVID. This contrasts with other reviews that have not captured the natural history of Long COVID with this level of detail. Another strength is our ability to examine Long COVID in an underserved patient population, in contrast to most previous research on Long COVID (Appendix B).

This review has several limitations. With sample sizes of 204 Long COVID cases, 98 controls with COVID-19, and 100 controls without COVID-19, our statistical power and generalizability was limited. The sample sizes reflect the focus on chart notations by health care providers, and the time required to manually extract the notations. The level of detail we sought came at the cost of larger sample sizes. Our hope is that our analysis will prompt more investigation of Long COVID's effects on underserved populations and spur further research utilizing chart notations to better gauge the natural history of Long COVID, possibly with language-model data science.

Our review began shortly after the ICD10 diagnostic code U09.9 was designated for Long COVID, and shortly after University of Illinois Hospital and Clinics opened its Long COVID Clinic. Diagnosing and treating Long COVID, while garnering attention in national media, was still in its clinical infancy during our data collection. It is possible that some Long COVID patients and symptoms were missed, whether due to patients not reporting symptoms to providers or providers not assigning the patient's symptoms to Long COVID. In the same vein, our controls may not have accurately communicated their status as not having experienced Long COVID symptoms or not having been infected by SARS-CoV-2 to their health care providers.

While our subjects represent a random sample of cases and controls from the University of Illinois Hospital and Clinics, the novel nature of Long COVID means our cases may not be reflective of Long COVID patients in the general population, or even of Long COVID patients in the underserved populations on which we wished to focus. While we controlled for age, gender, race, and vaccination status, the broad scope of the comorbidities reviewed comes with confounding risk. Also, because not all comorbidities that may increase the likelihood of Long COVID are known, there is the potential for residual confounding.

## Conclusions

Our review showed that Long COVID in an underserved population, studied via manually extracted EHR chart data, was predicted by hospitalization from COVID-19, BMI >30, and female gender. Associations between preexisting medical conditions and those conditions' analogous to Long COVID symptoms were random, save for migraine/headache and cough/dyspnea/pulmonary. Symptom frequency, reported directly by patients to providers in a clinic setting, varied from other symptom frequency reports (indeed, several symptoms that were more widely reported in other data were absent or nearly so in our data).

## Authorship

All authors had access to the data, but only the first author had a role in writing this manuscript; the second author had a role in review and editing.

## Declaration of competing interest

None.

## CRediT authorship contribution statement

**John Musachia:** Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Jon Radosta:** Writing – review & editing, Supervision, Project administration. **Dirin Ukwade:** Validation. **Shahrukh Rizvi:** Validation. **Romani Wahba:** Validation.

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