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Justin Catt
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SOCIOECONOMIC CHALLENGES OF LONG COVID

by

JUSTIN CATT

CORA E. LEWIS, COMMITTEE CHAIR
KATIA J. BRUXVOORT
GREGORY PAVELA

A THESIS

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SOCIOECONOMIC CHALLENGES OF LONG COVID

JUSTIN CATT

APPLIED EPIDEMIOLOGY

ABSTRACT

Long COVID, also known as post-acute sequelae of SARS-CoV-2 infection or PASC, is a condition resulting from a SARS-CoV-2 infection characterized by continuing or novel symptoms across multiple organ systems occurring at least four weeks after infection. Symptoms of Long COVID can include cognitive impairment, memory loss, and fatigue. Although associations between COVID-19 and social determinants of health have been studied, noting that disadvantaged socioeconomic or racial groups have higher incidence and mortality rates from COVID-19, the associations between Long COVID and social determinants of health have not been robustly examined. Using data from the Household Pulse Survey in Summer 2022 and Winter 2022, we explored differences and odds in demographics and social determinants of health between those reporting Long COVID and those without Long COVID through descriptive statistics and comparisons, as well as multivariable logistic regression. The odds of Long COVID were further compared between the two survey periods to determine any change in odds over time across demographics and social determinants of health. We found increased odds of Long COVID in participants who were female, of lower educational attainment, of lower income, had experienced a recent loss of work, had recent difficulty with household expenses, had trouble with energy bills within the year, or had recent household food insufficiency. We found no major differences in the odds of Long COVID over time.

However, after controlling for other factors, we found that Black or African American participants had lower odds of reporting Long COVID than White participants, in contrast to existing literature. Our study merits further investigation into Long COVID in at-risk populations to thoroughly examine associations between social determinants of health and Long COVID.

Keywords: Long COVID, Social determinants of health

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ASD   Absolute standardized difference

CI   Confidence interval

COVID-19   Coronavirus disease

OR   Odds ratio

PASC   Post-acute sequelae of SARS-CoV-2 infection

CHAPTER 1

INTRODUCTION

With over 100 million cases recorded in the United States of America and over 750 million cases total, COVID-19 is a highly transmissible disease with repercussions that are still not fully understood.[1] Long COVID, also referred to as post-acute sequelae of SARS-CoV-2 infection (PASC), has become an increasingly serious public health concern.[2-3] The initial focus of the pandemic response was recording and combatting acute disease and deaths; however, Long COVID, a disease characterized by lingering or novel symptoms following a SARS-CoV-2 infection, was quickly recognized as a serious public health concern in its own right.[2-9] Long COVID affects multiple organ systems, including the cardiovascular, respiratory, gastrointestinal, and neurological systems, and the effects of Long COVID can be exacerbated by the presence of comorbidities.[2-9] Though a variety of organ systems may be affected, many individuals who are diagnosed with Long COVID report similar patterns of cognitive and neurological symptoms, including cognitive impairment, memory loss, and fatigue that can last for months.[2-3] Individuals experiencing these symptoms report that they have a significant impact on daily life.

One critical aspect of Long COVID that requires further attention is the relationship between social determinants of health with Long COVID prevalence. This relationship is critical considering the disproportionate impact of COVID-19 on low-

income and marginalized communities.[10-15] For example, studies have found that racial and ethnic minorities including Black and Hispanic people experience a higher incidence and mortality rate from COVID-19, and research suggests that Long COVID has a higher prevalence among racial and ethnic minorities, including Black and Hispanic individuals.[4,9] These data suggests that, as marginalized communities experienced increased risk of infection and death from COVID-19 throughout the course of the pandemic, these same marginalized populations were then placed at an increased risk for Long COVID.[15]

Objectives

Thus, the first objective of this study was to determine differences in demographics or social determinants of health between participants reporting Long COVID and those reporting a history of COVID-19 to explore socioeconomic differences in the Long COVID population to better understand their needs. The second objective of this study is to compare participants reporting Long COVID in Summer 2022 to participants in Winter 2023 to determine if there has been any change in the Long COVID population as SARS-CoV-2 infection rates change and patients become more aware of this novel disease.

CHAPTER 2

METHODOLOGY

We used data available for public use from the United States Census Bureau's Household Pulse Survey, Phase 3.5 and 3.7, (n=382,829, aged 18-89) for this cross-sectional study evaluating the social determinants of health associated with the burden of Long COVID. Phases 3.5 and 3.7 were performed from June 1, 2022 to August 8, 2022 and from December 9, 2022 to February 13, 2023, respectively. The Household Pulse survey has been in use since April 23, 2020 to describe and quantify American household experiences during the COVID-19 pandemic. Household Pulse participants are selected from the Census Bureau's Master Address File to create a sample of individuals above the age of 18 years that comprise a weighted estimate of each state as well as the top 15 metropolitan areas of the United States. Our study examined participants who responded to the survey questions concerning the individual's history with COVID-19 and Long COVID. Participants who did not provide an answer for their COVID-19 history and those who positively indicated a history of COVID-19 but did not provide an answer regarding their Long COVID history were excluded, as shown in Figure 1.

To identify the survey participants' COVID-19 history, we used the question "Have you ever tested (using a rapid point-of-care test, self-test, or laboratory test) positive for COVID-19 or been told by a doctor or other health care provider that you have or had COVID-19?". If the response indicated that the individual has had COVID-

19, we then used the question "Did you have any symptoms lasting 3 months or longer that you did not have prior to having coronavirus or COVID-19?" This question allowed us to identify participants' Long COVID history.

In addition to participants' COVID and Long COVID history, we collected survey data to examine factors of interest that illustrated the impact of sociodemographic factors. Specific factors of interest in this study included: age, gender assigned at birth, race, Hispanic origin, marital status, household makeup, educational attainment, income, sector of employment, and health insurance, as well as other indicators of economic stress detailed below. Participants were asked to identify their race as: "White, alone," "Black, alone," "Asian, alone," or "Any other race alone, or race in combination," as well as identifying their origin as "Hispanic" or "non-Hispanic." Marital status was categorized as "Now Married," "Never Married," or "Widowed, Divorced, or Separated." Household makeup was categorized into a binary variable indicating whether the household included children under 18 years of age. Educational attainment was categorized as "High school graduate equivalent or less," "Some college education," "Associate degree," "Bachelor's degree," or "Graduate degree," while sector of employment was categorized as "Government," "Private company," "Non-profit organization," "Self-employed," or "Working in a family business." Health insurance was categorized as "Private health insurance," "Public health insurance," "Both," or "Neither."

Binary variables for indicators of economic stress included a loss of work in the previous four weeks and received unemployment insurance benefits in the previous six to nine months. Categorical variables for indicators of economic stress included difficulty with expenses in the previous seven days, ownership of current housing, trouble paying

an energy bill in the previous year, household food sufficiency in the previous seven days, and food insufficiency for children in the household in the previous seven days due to cost. Difficulty with expenses in the previous seven days was categorized as "Not at all difficult," "A little difficult," "Somewhat difficult," and "Very difficult." Ownership of current housing was categorized as "Owned with no mortgage or loan," "Owned with a mortgage or loan," "Renting," or "Occupying without rental payment." Trouble paying an energy bill in the previous year was categorized as "Almost every month," "Some months," "1 or 2 months," or "Never." Household food sufficiency in the previous seven days was categorized as "Enough desired food," "Enough food," "Sometimes not enough," and "Often not enough," and food insufficiency for children in the household in the previous seven days due to cost was categorized as "Often," "Sometimes," or "Never."

The sample was weighted using the personal level weights provided by the U.S. Census Bureau that were included in the public use datasets, with the variance estimated using the balanced repeated replication method with $\epsilon = 0.5$. Characteristics of the sample by Long COVID status were described using frequencies and percentages for categorical variables and means and standard deviations for continuous variables. T-tests and Chi-square tests were used to compare the distribution of characteristics by Long COVID status. Logistic regression models were used to identify individual factors associated with Long COVID status, identified by P value <0.05 and an absolute standard difference >0.1, with adjustment for potential confounders as determined by literature review. The survey phase was used as an indication of time, and a binary variable was created to identify the survey phase. Long COVID status was modeled as a function of the survey

phase. Through backward selection, a multivariable model of the significant factors with p<0.05 and an absolute standard difference >0.1 was used to identify independent factors associated with Long COVID status. Statistical analyses were conducted using SAS 9.4 (Cary, NC) using a significance level of α=0.05.
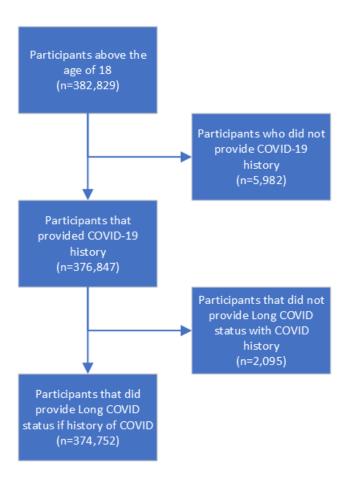

Figure 1. CONSORT diagram for analysis, with total number of participants included from both Phase 3.5 and Phase 3.7 of the Household Pulse Survey.

CHAPTER 3

RESULTS

Demographic and socioeconomic characteristics of the total population sampled by the Household Pulse Survey for Phases 3.5 (weeks 46-48) and 3.7 (weeks 52-54) are described in Table 1. This sample included 374,752 participants ≥18 years old. A minority of participants reported a history of COVID-19 (n=175,799, 46.91%) and Long COVID (n=50,074, 13.36%), with more participants in Phase 3.7 reporting COVID-19 (52.84%) and slightly more participants reporting Long COVID (14.06%). The average age of the participants was in their fifties (53.03 ± 15.98 and 51.96 ± 15.88). Most of the sample were female (59.17% and 57.11%), White (81.99% and 82.01%), of non-Hispanic origin (91.35% and 91.19%), married (56.60% and 57.03%), and without children (68.25% and 65.61%). Most participants had attained a bachelor's degree (28.74% and 28.49%) or greater (26.85% and 25.83%).

The majority of the total sample population worked in private companies (56.47% and 56.67%) with a majority of participants earning under $100,000 (60.24% and 59.19%) with private health insurance (54.74% and 57.45%), no loss of work (90.46% and 91.36%), and no unemployment benefits received within the last six to nine months (98.67% and 98.52%). Many participants reported no difficulty paying weekly expenses (44.74% vs 39.64%), owned their home with a mortgage or loan (45.96% vs 48.81%),

and reported having sufficient desired food in their house in the previous seven days

(68.92% vs 63.90%).

Table 1

Unweighted demographic and economic characteristics of participants by survey phase.

Variables	Phase 3.5 (1 June 2022 – 8 Aug 2022) N=164,860 (43.99%)	Phase 3.7 (9 Dec 2022 – 13 Feb 2023) N=209,892 (56.01%)
History of COVID-19	64,894 (39.36%)	110,905 (52.84%)
History of Long COVID	20,557 (12.47%)	29,517 (14.06%)
Age (Years)	53.03 ± 15.98	51.96 ± 15.89
Gender assigned at birth		
Male	67,311 (40.83%)	90,015 (42.89%)
Female	97,549 (59.17%)	119,877 (57.11%)
Race		
White	135,162 (81.99%)	172,140 (82.01%)
Black	13,087 (7.94%)	16,962 (8.08%)
Asian	8,530 (5.17%)	10,314 (4.91%)
Any other race, or race in combination	8,081 (4.90%)	10,476 (4.99%)
Hispanic origin		
Yes	14,268 (8.65%)	18,483 (8.81%)
No	150,592 (91.35%)	191,409 (91.19%)
Marital status		
Now married	92.873 (56.60%)	119,275 (57.03%)
Never married	32,740 (19.95%)	42,999 (20.56%)
Widowed, divorced, or separated	38,473 (23.45%)	46,877 (22.41%)
Children under 18 years in the household		
Present	52,350 (31.75%)	72,188 (34.39%)
Not present	112,510 (68.25%)	137,704 (65.61%)
Educational attainment		
High school graduate or less	22,625 (13.72%)	30,094 (14.34%)
Some college education	33,697 (20.44%)	44,098 (21.01%)
Associate degree	16,898 (10.25%)	21,687 (10.33%)
Bachelor's degree	47,376 (28.74%)	59,793 (28.49%)
Graduate degree	44,264 (26.85%)	54,220 (25.83%)
Sector of employment		
Government	14,970 (15.87%)	22,124 (17.08%)
Private company	53,277 (56.47%)	73,409 (56.67%)
Non-profit organization	12,439 (13.18%)	17,052 (13.16%)
Self-employment	11,728 (12.43%)	14,479 (11.18%)
Working in a family business	1,936 (2.05%)	2,480 (1.91%)
Income		
Less than $25,000	14,329 (10.83%)	17,427 (9.97%)
$25,000 to $34,999	11,411 (8.63%)	14,317 (8.19%)
$35,000 to $49,999	13,770 (10.41%)	18,353 (10.50%)
$50,000 to $74,999	21,809 (16.49%)	28,937 (16.56%)
$75,000 to $99,999	18,362 (13.88%)	24,416 (13.97%)
$100,000 to $149,999	23,850 (18.03%)	31,774 (18.18%)
$150,000 to $199,999	12,620 (9.54%)	17,319 (9.91%)
$200,000 and above	16,143 (12.20%)	22,247 (12.73%)
Health insurance		
Private health insurance	78,434 (54.74%)	106,319 (57.45%)
Public health insurance	25,707 (17.94%)	30,745 (16.61%)

Both	32,646 (22.78%)	39,789 (21.50%)
Neither	6,499 (4.54%)	8,206 (4.43%)
Loss of work in the previous 4 weeks		
Yes	15,588 (9.54%)	17,965 (8.64%)
No	147,851 (90.46%)	190,014 (91.36%)
Unemployment insurance benefits received in the previous 6-9 months		
Yes	2,129 (1.33%)	3,022 (1.48%)
No	157,939 (98.67%)	201,122 (98.52%)
Difficulty paying expenses in the previous 7 days		
Not at all difficult	70,152 (44.74%)	79,369 (39.64%)
A little difficult	38,991 (24.87%)	57,181 (28.56%)
Somewhat difficult	27,480 (17.52%)	37,121 (18.54%)
Very difficult	20,187 (12.87%)	26,576 (13.27%)
Ownership of current housing		
Owned with no mortgage or loan	39,386 (28.32%)	46,590 (25.75%)
Owned with a mortgage or loan	63,918 (45.96%)	88,331 (48.81%)
Renting	33,908 (24.38%)	43,732 (24.17%)
Occupying without rental payment	1,846 (1.33%)	2,308 (1.28%)
Trouble paying an energy bill in the previous year		
Almost every month	9,789 (7.11%)	13,191 (7.36%)
Some months	13,888 (10.09%)	18,601 (10.37%)
1 or 2 months	10,290 (7.48%)	14,326 (7.99%)
Never	103,644 (75.32%)	133,170 (74.28%)
Household food sufficiency in the previous 7 days		
Enough desired food	101,997 (68.92%)	125,945 (63.90%)
Enough food	35,501 (23.99%)	56,406 (28.62%)
Sometimes not enough	7,998 (5.40%)	11,072 (5.62%)
Often not enough	2,497 (1.69%)	3,674 (1.86%)
Food insufficiency for children in the household due to cost in the previous 7 days		
Often	908 (5.38%)	1,276 (4.97%)
Sometimes	3,973 (23.53%)	4,809 (18.73%)
Never	12,006 (71.10%)	19,584 (76.29%)

Notes. This table shows the unweighted frequencies of COVID-19 and Long COVID histories, demographic characteristics, and socioeconomic characteristics of all included participants by survey phase (N=374,752).

Analyses of the weighted samples of participants showed significant differences between those with a history of COVID-19 reporting Long COVID and those without Long COVID, as shown in Table 2. While many of these differences appear statistically significant due to the sample size, certain variables do not show a large effect size as the absolute standardized difference (ASD) does not meet the cutoff threshold. Among the participants with a history of COVID-19, participants from Phase 3.5 were more likely to

report Long COVID (34.15%) than those in Phase 3.7 (27.96%, p<0.0001, ASD=0.1447). Compared to the participants without Long COVID, participants who reported Long COVID were more likely to be female (36.13% vs 24.56% for male, p<0.0001, ASD=0.1219), Black or another race or a combination of races (32.00% or 36.51%, respectively, vs 30.65% for White or 22.83% for Asian, p<0.0001, ASD=0.1219). Participants who reported Long COVID were more likely to be widowed, divorced, or separated (37.95% vs 28.41% for now married, p<0.0001, ASD=0.1456). Those who reported Long COVID were more likely to have a lower educational attainment (34.57% for high school graduate vs 22.03% for graduate degree, p<0.0001, ASD=0.2610). When comparing age, there was no statistically significant difference between the ages of those who reported Long COVID and those who did not report Long COVID (p=0.1426, ASD=0.0006). Although there were statistically significant differences, there were no standardized differences found in participants with respect to their Hispanic origin (p<0.0001, ASD=0.0959) or the presence of children in the household (p<0.0001, ASD=0.0512).

Compared to participants without Long COVID, those with Long COVID were more likely to have a lower income (43.73% for <$25,000 vs 17.29% for >$200,000, p<0.0001, ASD=0.3543), and public health insurance (38.22% vs 27.90% for private health insurance, p<0.0001, ASD=0.2103). Additionally, participants with Long COVID were more likely to rent their homes (35.49% vs 27.96% for owned with no mortgage or loan, p<0.0001, ASD=0.1341), report a recent loss of work (42.78% vs 28.80% for no loss, p<0.0001, ASD=0.2169), experience difficulty paying recent expenses (46.25% for very difficult vs 19.14% for not at all difficult, p<0.0001, ASD=0.4539), and experience

difficulty paying energy bills within the last year (47.87% for almost every month vs 24.52% for never, p<0.0001, ASD=0.4253) when compared to those without Long COVID. The same participants who reported Long COVID were also more likely to report some level of household food insufficiency (53.58% for often not enough vs 23.26% enough desired food, p<0.0001, ASD=0.4284) or food insufficiency for children in the household in the previous seven days (53.04% for often vs 39.16% for never, p<0.0001, ASD=0.1515) when compared to those without Long COVID. No difference was found in receipt of unemployment benefits within the last six to nine months between participants who reported Long COVID and those who did not (p=0.1410, ASD=0.0176).

Table 2

Long COVID status by demographic and economic characteristics of participants with a history of COVID-19.

Variables	Long COVID N=50,074 (28.48%)	No Long COVID N=125,725 (71.52%)	p-values	Absolute Standardized Difference
Survey Phase			<0.0001	0.1447
3.5 (1 June 2022 – 8 Aug 2022)	17,869,644 (34.15%)	34,455,161 (65.85%)		
3.7 (9 Dec 2022 – 13 Feb 2023)	18,076,294 (27.96%)	46,582,616 (72.04%)		
Age (Years)	45.82 ± 0.12	46.07 ± 0.09	0.1426	0.0006
Gender assigned at birth			<0.0001	0.2750
Male	13,424,994 (24.56%)	41,229,172 (75.44%)		
Female	22,520,944 (36.13%)	39,808,606 (63.87%)		
Race			<0.0001	0.1219
White	27,819,755 (30.65%)	62,951,415 (69.35%)		
Black	3,913,324 (32.00%)	8,316,059 (68.00%)		
Asian	1,489,355 (22.83%)	5,034,316 (77.17%)		
Any other race, or race in combination	2,723,504 (36.51%)	4,735,988 (63.49%)		
Hispanic origin			<0.0001	0.0959
Yes	7,873,424 (34.97%)	14,644,608 (65.04%)		
No	28,072,514 (29.72%)	66,393,169 (70.28%)		
Marital status			<0.0001	0.1456
Now married	18,966,983 (28.41%)	47,787,189 (71.59%)		
Never married	9,629,411 (31.11%)	21,325,394 (68.89%)		
Widowed, divorced, or separated	7,134,327 (37.95%)	11,667,174 (62.05%)		

Children under 18 years in the household			<0.0001	0.0512
Present	15,984,814 (31.99%)	33,981,739 (68.01%)		
Not present	19,961,124 (29.79%)	47,056,038 (70.21%)		
Educational attainment			<0.0001	0.2610
High school graduate or less	14,186,707 (34.57%)	26,856,832 (65.44%)		
Some college education	8,540,755 (34.22%)	16,416,906 (65.78%)		
Associate degree	3,964,262 (35.00%)	7,362,496 (65.00%)		
Bachelor's degree	5,414,361 (24.36%)	16,813,470 (75.64%)		
Graduate degree	3,839,852 (22.03%)	13,588,073 (77.97%)		
Sector of employment			<0.0001	0.0478
Government	3,233,540 (30.44%)	7,390,004 (69.56%)		
Private company	13,152,992 (28.41%)	33,141,438 (71.59%)		
Non-profit organization	2,189,601 (28.64%)	5,456,337 (71.36%)		
Self-employment	2,412,257 (32.27%)	5,062,766 (67.73%)		
Working in a family business	532,598 (27.91%)	1,375,549 (72.09%)		
Income			<0.0001	0.3543
Less than $25,000	4,318,065 (43.72%)	5,557,540 (56.28%)		
$25,000 to $34,999	3,379,179 (38.71%)	5,351,426 (61.30%)		
$35,000 to $49,999	3,908,290 (36.66%)	6,753,867 (63.34%)		
$50,000 to $74,999	4,943,922 (32.20%)	10,412,223 (67.80%)		
$75,000 to $99,999	3,595,729 (29.98%)	8,398,435 (70.02%)		
$100,000 to $149,999	4,057,036 (26.73%)	11,119,710 (73.27%)		
$150,000 to $199,999	1,772,760 (22.98%)	5,940,897 (77.02%)		
$200,000 and above	1,606,395 (17.29%)	7,682,079 (82.71%)		
Health insurance			<0.0001	0.2103
Private health insurance	16,021,126 (27.90%)	41,394,853 (72.10%)		
Public health insurance	5,942,583 (38.22%)	9,607,143 (61.78%)		
Both	5,443,411 (32.38%)	11,370,236 (67.63%)		
Neither	2,775,650 (38.77%)	4,383,049 (61.23%)		
Loss of work in the previous 4 weeks			<0.0001	0.2169
Yes	6,714,658 (42.78%)	8,980,162 (57.22%)		
No	28,747,723 (28.80%)	71,076,472 (71.20%)		
Unemployment insurance benefits received in the previous 6-9 months			0.1410	0.0176
Yes	730,570 (33.38%)	1,458,007 (66.62%)		
No	33,677,950 (30.64%)	76,232,074 (69.36%)		
Difficulty with expenses in the previous 7 days			<0.0001	0.4539
Not at all difficult	6,449,049 (19.14%)	27,242,056 (80.86%)		
A little difficult	8,927,006 (28.78%)	22,095,503 (71.22%)		
Somewhat difficult	8,935,089 (36.79%)	15,351,015 (63.21%)		
Very difficult	9,091,505 (46.25%)	10,566,054 (53.75%)		
Ownership of current housing			<0.0001	0.1341
Owned with no mortgage or loan	5,469,608 (27.96%)	14,094,615 (72.04%)		
Owned with a mortgage or loan	13,282,444 (29.58%)	31,622,970 (70.42%)		
Renting	9,834,227 (35.49%)	17,873,734 (64.51%)		
Occupying without rental payment	493,814 (35.67%)	890,735 (64.33%)		
Trouble paying an energy bill in the previous year			<0.0001	0.4253
Almost every month	4,536,814 (47.87%)	4,940,681 (52.13%)		

Some months	5,684,524 (42.93%)	7,557,850 (57.07%)		
1 or 2 months	3,484,631 (40.22%)	5,178,801 (59.78%)		
Never	14,890,907 (24.52%)	45,828,032 (75.48%)		
Household food sufficiency in the previous 7 days			<0.0001	0.4284
Enough desired food	13,745,439 (23.26%)	45,339,245 (76.74%)		
Enough food	12,751,518 (38.26%)	20,461,875 (61.61%)		
Sometimes not enough	4,031,773 (46.47%)	4,643,430 (53.53%)		
Often not enough	1,469,326 (53.58%)	1,273,089 (46.42%)		
Food insufficiency for children in the household due to cost in the previous 7 days			<0.0001	0.1515
Often	648,811 (53.04%)	574,534 (46.96%)		
Sometimes	2,133,472 (45.06%)	2,601,714 (54.94%)		
Never	5,609,830 (39.16%)	8,715,479 (60.84%)		

Notes. This table shows the T test and Chi-square tests comparing participants with a reported case of COVID-19 (N=175,799) on survey phase, demographic characteristics, and socioeconomic characteristics by history of Long COVID.

*The absolute standardized difference is an index used to compare distribution of characteristics between groups, with a cutoff value of >0.1 for significant differences.

Odds ratios of selected factors not excluded due to p-value or the absolute standardized difference were used in logistic regression analyses of the weighted sample and are shown fully in Table 3. After controlling for other factors, the odds of reporting Long COVID are lower for the later survey phase 3.7 (0.772, 95% CI: 0.730 to 0.815) when compared to the earlier survey phase. Additionally, after controlling for other factors, the odds of reporting Long COVID are higher for females (1.641, 95% CI: 1.565 to 1.719) compared to males, lower for Black (0.793, 95% CI: 0.725 to 0.868) and Asian (0.731, 95% CI: 0.636-0.840) participants compared to White participants, and lower for those with a university degree (Bachelor's: 0.817, 95% CI: 0.763 to 0.876, Graduate: 0.775, 95% CI: 0.716 to 0.838). Those with the lowest income have higher odds of reporting Long COVID (<$25,000: 1.119, 95% CI: 1.017 to 1.230), while those with the

highest income have higher odds of reporting Long COVID (>$200,000: 0.871, 95% CI: 0.787-0.963) compared to the average income of $50,000-$75,000 when controlling other factors. Each variable measuring economic stress showed a significant increase in the odds of reporting Long COVID when controlling other variables: with 25% increase for loss of work (95% CI: 1.163 to 1.335) compared to no loss, up to a 73% increase for having difficulties with expenses (95% CI: 1.581 to 1.889) compared to no difficulty, up to a 50% increase for monthly difficult paying an energy bill (95% CI: 1.377 to 1.635) compared to no troubles, and up to 75% increase for often not having enough food for the household (95% CI: 1.474 to 2.066) compared to having enough desired food. There was no statistical difference between any marital status compared to being currently married when controlling for other variables, although the crude odds show an increase for both being never married (1.138, 95% CI: 1.082 to 1.196) and widowed, divorced, or separated (1.541, 95% CI: 1.455 to 1.631).

Table 3

Independent factors associated with Long COVID status in participants with a history of COVID-19.

Variables	Long COVID	
	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Survey Phase		
3.5 (1 June 2022 – 8 Aug 2022)	ref	ref
3.7 (9 Dec 2022 – 13 Feb 2023)	0.748 (0.717-0.780)	0.772 (0.730-0.815)
Gender assigned at birth		
Male	ref	ref
Female	1.737 (1.674-1.802)	1.641 (1.565-1.719)
Race		
White	ref	ref
Black	1.065 (0.989-1.146)	0.793 (0.725-0.868)
Asian	0.670 (0.595-0.754)	0.731 (0.636-0.840)
Any other race, or race in combination	1.301 (1.188-1.426)	1.069 (0.972-1.176)
Marital status		
Now married	ref	ref
Never married	1.138 (1.082-1.196)	0.980 (0.922-1.041)
Widowed, divorced, or separated	1.541 (1.455-1.631)	1.097 (1.028-1.171)

Educational attainment		
High school graduate or less	ref	ref
Some college education	0.985 (0.931-1.042)	1.020 (0.957-1.087)
Associate degree	1.019 (0.948-1.097)	1.071 (0.989-1.161)
Bachelor's degree	0.610 (0.577-0.644)	0.817 (0.763-0.876)
Graduate degree	0.535 (0.505-0.567)	0.775 (0.716-0.838)
Income		
Less than $25,000	1.636 (1.502-1.783)	1.119 (1.017-1.230)
$25,000 to $34,999	1.330 (1.199-1.476)	1.015 (0.909-1.133)
$35,000 to $49,999	1.219 (1.128-1.317)	1.046 (0.961-1.138)
$50,000 to $74,999	ref	ref
$75,000 to $99,999	0.902 (0.843-0.965)	1.042 (0.967-1.122)
$100,000 to $149,999	0.768 (0.715-0.826)	1.072 (0.996-1.154)
$150,000 to $199,999	0.628 (0.583-0.677)	1.038 (0.952-1.133)
$200,000 and above	0.440 (0.404-0.480)	0.871 (0.787-0.963)
Loss of work in the previous 4 weeks		
Yes	1.849 (1.737-1.968)	1.246 (1.163-1.335)
No	ref	ref
Difficulty with expenses in the previous 7 days		
Not at all difficult	ref	ref
A little difficult	1.707 (1.617-1.801)	1.319 (1.240-1.403)
Somewhat difficult	2.459 (2.325-2.601)	1.576 (1.470-1.690)
Very difficult	3.635 (3.420-3.862)	1.728 (1.581-1.889)
Trouble paying an energy bill in the previous year		
Almost every month	2.826 (2.613-3.056)	1.500 (1.377-1.635)
Some months	2.315 (2.173-2.466)	1.405 (1.303-1.515)
1 or 2 months	2.071 (1.911-2.244)	1.374 (1.259-1.499)
Never	ref	ref
Household food sufficiency in the previous 7 days		
Enough desired food	ref	ref
Enough food	2.056 (1.961-2.155)	1.328 (1.245-1.416)
Sometimes not enough	2.864 (2.655-3.089	1.426 (1.282-1.588)
Often not enough	3.807 (3.229-4.488)	1.745 (1.474-2.066)

Notes. This table shows the unadjusted and adjusted odds ratios for survey phase, demographic, and socioeconomic characteristics of the multivariable logistic regression model for history of Long COVID in participants with a reported case of COVID-19 (N=175,799).

OR: Odds Ratio, CI: Confidence Interval, ref: Reference value

Odds ratios of the same factors were used in logistic regression analyses of the weighted samples separated by the survey phase, and adjusted odds ratios are shown in Table 4 with unadjusted odds ratios shown in Supplementary Table 1. After controlling for other factors, the odds of reporting Long COVID are lower for participants with a Graduate degree during survey phase 3.5 (0.678, 95% CI: 0.603 to 0.762) compared to the later survey phase 3.7 (0.862, 95% CI: 0.780 to 0.951). Other variables showed no

statistically significant difference between the two survey phases. However, there were variables that were not statistically significant in one survey phase but were significant in another phase. After controlling for other factors, during the earlier survey phase 3.5 the odds of reporting Long COVID were 25% lower for participants with an income above $200,000 compared to those with an income of $50,000 to $75,000 (95% CI: 0.636 to 0.893), while the odds of this same group were not statistically significant during the latter survey phase. After controlling for other factors, the odds of reporting Long COVID during the latter survey phase 3.7 are 11% higher for participants of another race or a combination of races when compared to white participants (95% CI: 1.001 to 1.228), and higher for participants earning less than $25,000 in income (1.250, 95% CI: 1.091 to 1.433), and higher for participants earning between $100,000 and $149,999 in income (1.114, 95% CI: 1.011 to 1.228). When controlling for other variables, no statistical difference was found in the odds of reporting Long COVID between the two survey phases for gender at birth, marital status, loss of work in the previous four weeks, difficulty with expenses in the previous seven days, trouble paying an energy bill in the previous year, or having sufficient household food in the previous seven days.

Table 4

Independent factors associated with Long COVID status in participants with a history of COVID-19 by survey phase.

Variables	Long COVID	
	Phase 3.5 (1 June 2022 – 8 Aug 2022)	Phase 3.7 (9 Dec 2022 – 13 Feb 2023)
	Adjusted OR (95% CI)	Adjusted OR (95% CI)
Gender assigned at birth		
Male	ref	ref
Female	1.657 (1.541-1.782)	1.626 (1.513-1.747)
Race		
White	ref	ref

Black	0.769 (0.667-0.888)	0.810 (0.726-0.904)
Asian	0.677 (0.545-0.840)	0.770 (0.643-0.921)
Any other race, or race in combination	1.026 (0.870-1.210)	1.109 (1.001-1.228)
Marital status		
Now married	ref	ref
Never married	0.945 (0.852-1.047)	1.013 (0.927-1.106)
Widowed, divorced, or separated	1.101 (0.999-1.213)	1.093 (1.000-1.195)
Educational attainment		
High school graduate or less	ref	ref
Some college education	0.969 (0.881-1.066)	1.068 (0.973-1.172)
Associate degree	1.038 (0.921-1.171)	1.098 (0.994-1.214)
Bachelor's degree	0.752 (0.676-0.837)	0.878 (0.804-0.958)
Graduate degree	0.678 (0.603-0.762)	0.862 (0.780-0.951)
Income		
Less than $25,000	1.078 (0.921-1.262)	1.148 (1.013-1.301)
$25,000 to $34,999	0.934 (0.815-1.071)	1.091 (0.950-1.254)
$35,000 to $49,999	1.026 (0.894-1.179)	1.062 (0.943-1.196)
$50,000 to $74,999	ref	ref
$75,000 to $99,999	1.002 (0.878-1.144)	1.076 (0.971-1.193)
$100,000 to $149,999	1.025 (0.891-1.180)	1.114 (1.011-1.228)
$150,000 to $199,999	1.032 (0.885-1.204)	1.047 (0.946-1.158)
$200,000 and above	0.754 (0.636-0.893)	0.968 (0.864-1.085)
Loss of work in the previous 4 weeks		
Yes	1.222 (1.104-1.353)	1.273 (1.167-1.388)
No	ref	ref
Difficulty with expenses in the previous 7 days		
Not at all difficult	ref	ref
A little difficult	1.251 (1.123-1.395)	1.388 (1.292-1.491)
Somewhat difficult	1.525 (1.367-1.700)	1.642 (1.494-1.803)
Very difficult	1.706 (1.484-1.962)	1.772 (1.593-1.971)
Trouble paying an energy bill in the previous year		
Almost every month	1.421 (1.222-1.651)	1.569 (1.415-1.739)
Some months	1.363 (1.186-1.565)	1.433 (1.309-1.568)
1 or 2 months	1.391 (1.201-1.611)	1.352 (1.217-1.502)
Never	ref	ref
Household food sufficiency in the previous 7 days		
Enough desired food	ref	ref
Enough food	1.306 (1.183-1.443)	1.347 (1.250-1.451)
Sometimes not enough	1.497 (1.247-1.796)	1.366 (1.208-1.544)
Often not enough	1.591 (1.201-2.107)	1.897 (1.553-2.317)

Notes. This table shows the adjusted odds ratios for demographic and socioeconomic characteristics by survey phase of the multivariable logistic regression model for history of Long COVID in participants with a reported case of COVID-19 (N=175,799).

OR: Odds Ratio, CI: Confidence Interval, ref: Reference value

CHAPTER 4

DISCUSSION

The findings of this study do show differences in the odds of reporting Long

COVID with regards to social determinants of health and time, with an increase in self-

reported Long COVID over time in both the unweighted and weighted frequencies.

However, the odds of reporting Long COVID were lower for participants in the later

survey phase both in the unadjusted and adjusted odds ratios. Across both survey phases,

participants who were Black or Asian or male had lower odds for reporting Long COVID

in the unadjusted and adjusted results when compared to their respective reference

groups. Conversely, both unadjusted and adjusted results for both phases show a higher

educational attainment through achieving a bachelor's or graduate degree is associated

with lower odds for reporting Long COVID when compared to those with a high school

education or less. Participants with a lower economic position as measured through

income, difficulty with expenses, and housing, were more likely to report Long COVID

when compared to the respective reference groups. However, when examining the social

determinants of health between survey phases, there was little difference in the odds of

reporting Long COVID, other than higher odds for participants with a graduate degree

during the later phase.

Crude results show that the later survey phase had more participants reporting a

history of COVID-19 as well as more participants with a history of Long COVID,

because of more COVID-19 cases. Further, the crude results reflect the association of the social determinants of health with Long COVID. More participants that are female, Black, or of another race or races report a history of Long COVID in the crude results. Many of the variables selected to measure socioeconomic position including income, receipt of unemployment benefits, loss of work, ownership of current housing, difficulty with expenses, trouble with bills, and food insufficiency suggest that these markers of lower socioeconomic position are more at risk for Long COVID as each respective percentage in the sample reporting a history of Long COVID is larger than that of the corresponding higher socioeconomic position markers.

The unadjusted and adjusted odds ratios show that female participants have higher odds of reporting a Long COVID diagnosis when compared to male participants, which agrees with previous studies (3). In the unadjusted odds ratios, only Asian and Hispanic participants show lower odds for reporting Long COVID when compared to White participants. However, Black, Asian, and non-Hispanic participants had lower adjusted odds for reporting Long COVID when compared to White participants. These second results stand in contrast to findings of previous studies that found that minority participants were more likely to become infected with COVID-19 and more likely to develop Long COVID (3). This difference in results for minority participants could be due to the adjustments made in this study with regards to the other social determinants of health. Additionally, these differences could be due to undiagnosed cases or a lack of outreach to minority groups to diagnose cases. Further, the differences in symptoms and severity between minority groups could lead to undiagnosed or false negative cases among these groups (3, 8). While the Household Pulse Survey asks questions concerning

symptoms and severity, these aspects are beyond the scope of this study and are difficult to measure due to changing questions and values within the survey.

Participants reporting the lowest income and those reporting difficulty with expenses had higher adjusted odds of reporting a Long COVID diagnosis when compared to the median income and those without expense difficulties, respectively. These results highlight that the communities at-risk for Long COVID are those with the least means to be able to manage the doctor's appointments, medications, and lifestyle changes to treat the disease. Additionally, participants that reported having no health insurance or both public and private health insurance were more likely to report having Long COVID. These groups without health insurance stand an even greater chance of being undiagnosed due to the high cost of healthcare in the United States.

The decrease in the weighted percentage and the decrease in the odds ratio of participants reporting a history of Long COVID between the two phases of the study could be a result of the waves of SARS-CoV-2 that occurred prior to the survey. Phase 3.5 occurred during the summer of 2022 while 3.7 was during the winter of 2022-23. Prior to Phase 3.5 was the spike in cases in early 2022 due to the first omicron variants, BA.1.1.519, BA.1.1, and BA.2 (19). This large surge in cases would have naturally caused a greater number of new Long COVID diagnoses several months afterwards. These Long COVID cases could have resolved by the time of Phase 3.7 or the Long COVID cases could be associated with a specific variant of SARS-CoV-2 that became less predominant. This distinction would require further investigation and viral sequencing to better determine the cause, which is beyond the scope of this study and this data source.

Strengths and Limitations

One of the strengths of this study is the large sample size from multiple weeks of representative sampling. The Household Pulse Survey attempts to sample and weight the results to have a representative sample of the entire adult population of the United States. By utilizing responses from nearly 400,000 individuals across 2 survey phases, this study can offer robust data about a novel disease to gain a greater understanding of the populations affected by the disease.

One of the limitations in this study on the social determinants of health and Long COVID is that the Household Pulse Survey is a self-reported survey. As the data is self-reported, this could include incorrect responses to certain questions, particularly clinical questions concerning their COVID-19 history and their Long COVID status, or participants may avoid questions concerning socioeconomic position like job loss or receipt of unemployment benefits. While the survey questions were thorough, there is still room for a mistake or misunderstanding on the respondent's part. Further, other data concerning the socioeconomic position of the participants could be incorrectly reported. Participants may not accurately report income due a misunderstanding on their own part about their total household income, or participants' personal understanding of having difficulties with expenses or what food sufficiency is may differ, resulting in incorrect categorization of a participant. While these inaccuracies are concerning, the benefit of such a large representative sample is that this can mitigate these individual level inaccuracies across the whole survey sample.

Another limitation of this study is that the Household Pulse Survey does not include any clinical data from the participants. This lack of clinical data severely limits our understanding of their precise Long COVID status or their COVID-19 status, which limits the impact of this study. Additionally, there are no variables to determine severity of Long COVID symptoms or the length or type of persistent symptoms. Without clinical data and without specifics on the symptoms, the respondent's assertion of having persistent symptoms must be assumed true, which could be including false positives in with the Long COVID cases. This limitation and bias from available data could limit the applicability of this study for the individual, while allowing us to understand the greater trends of Long COVID on the American adult population.

Conclusions

This study finds that there are associations between Long COVID and demographic and socioeconomic characteristics of at-risk communities. Although the number of Long COVID cases continue to increase, while the adjusted odds of reporting Long COVID cases appears to decrease, which merits further investigation into the causes of these decreased odds. Further research into the association between Long COVID and the social determinants of health would help understand the needs of the affected communities. To better understand this association within these vulnerable communities, questions concerning COVID-19 and Long COVID should be added to other national health or census surveys to explore these diseases more robustly, with additional clinical questions concerning symptoms and severity. These clinical questions

should be included in the Household Pulse Survey to link these data to demographic and

socioeconomic data for further analysis.

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APPENDIX A

SUPPLEMENTARY TABLE

APPENDIX A

SUPPLEMENTARY TABLE

Supplementary Table 1

Unadjusted independent factors associated with Long COVID status in participants with a history of COVID-19 by survey phase.

Variables	Long COVID	
	Phase 3.5 (1 June 2022 – 8 Aug 2022) Unadjusted OR (95% CI)	Phase 3.7 (9 Dec 2022 – 13 Feb 2023) Unadjusted OR (95% CI)
Gender assigned at birth		
Male	ref	ref
Female	1.733 (1.615-1.862)	1.737 (1.626-1.855)
Race		
White	ref	ref
Black	1.050 (0.917-1.203)	1.059 (0.956-1.173)
Asian	0.586 (0.482-0.713)	0.680 (0.574-0.805)
Any other race, or race in combination	1.275 (1.096-1.483)	1.336 (1.211-1.473)
Marital status		
Now married	ref	ref
Never married	1.134 (1.035-1.242)	1.207 (1.116-1.306)
Widowed, divorced, or separated	1.552 (1.421-1.694)	1.500 (1.387-1.621)
Educational attainment		
High school graduate or less	ref	ref
Some college education	0.890 (0.815-0.917)	0.992 (0.913-1.077)
Associate degree	0.962 (0.861-1.075)	1.014 (0.927-1.109)
Bachelor's degree	0.542 (0.494-0.595)	0.619 (0.573-0.668)
Graduate degree	0.439 (0.398-0.486)	0.553 (0.509-0.600)
Income		
Less than $25,000	1.619 (1.426-1.840)	1.636 (1.450-1.844)
$25,000 to $34,999	1.260 (1.107-1.434)	1.401 (1.225-1.601)
$35,000 to $49,999	1.226 (1.082-1.389)	1.208 (1.085-1.345)
$50,000 to $74,999	ref	ref
$75,000 to $99,999	0.866 (0.765-0.981)	0.928 (0.839-1.027)
$100,000 to $149,999	0.735 (0.649-0.834)	0.806 (0.732-0.888)
$150,000 to $199,999	0.623 (0.545-0.712)	0.640 (0.579-0.707)
$200,000 and above	0.389 (0.334-0.453)	0.494 (0.443-0.551)
Loss of work in the previous 4 weeks		
Yes	1.879 (1.701-2.076)	1.847 (1.699-2.008)
No	ref	ref
Difficulty with expenses in the previous 7 days		
Not at all difficult	ref	ref
A little difficult	1.654 (1.498-1.827)	1.813 (1.694-1.940)
Somewhat difficult	2.505 (2.271-2.764)	2.603 (2.395-2.829)

Very difficult	3.635 (3.227-4.093)	3.804 (3.523-4.107)
Trouble paying an energy bill in the previous year		
Almost every month	2.805 (2.453-3.208)	2.869 (2.648-3.107)
Some months	2.305 (2.035-2.612)	2.300 (2.132-2.481)
1 or 2 months	2.115 (1.837-2.436)	1.993 (1.813-2.190)
Never	ref	ref
Household food sufficiency in the previous 7 days		
Enough desired food	ref	ref
Enough food	2.106 (1.945-2.280)	2.153 (2.033-2.281)
Sometimes not enough	3.133 (2.769-3.545)	2.858 (2.563-3.186)
Often not enough	3.564 (2.685-4.729)	4.338 (3.562-5.282)

Notes. This table shows the unadjusted odds ratios for demographic and socioeconomic

characteristics by survey phase of the multivariable logistic regression model for history

of Long COVID in participants with a reported case of COVID-19 (N=175,799).

OR: Odds Ratio, CI: Confidence Interval, ref: Reference value

APPENDIX B

IRB APPROVAL

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Office of the Institutional Review Board for Human Use

NHSR
DETERMINATION

TO: Catt, Justin

FROM: University of Alabama at Birmingham Institutional Review Board
Federalwide Assurance # FWA00005960
IORG Registration # IRB00000196 (IRB 01)
IORG Registration # IRB00000726 (IRB 02)
IORG Registration # IRB00012550 (IRB 03)

DATE: 06-Jul-2023

RE: IRB-300011173
Socioeconomic challenges of long Covid

The Office of the IRB has reviewed your Application for Not Human Subjects Research Designation for the above referenced project.

The reviewer has determined this project is not subject to FDA regulations and is not Human Subjects Research. Note that any changes to the project should be resubmitted to the Office of the IRB for determination.

if you have questions or concerns, please contact the Office of the IRB at 205-934-3789.

Additional Comments:

De-identified publicly available data from United States Census Bureau's Household Pulse Survey, Phase 3.5 and 3.7