



# Patterns and predictors of depressive and anxiety symptoms within a population-based sample of adults diagnosed with COVID-19 in Michigan

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Received: 14 February 2022 / Accepted: 27 February 2023 / Published online: 14 March 2023  
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## Abstract

**Purpose** The COVID-19 pandemic has had wide-ranging impacts on mental health, however, less is known about predictors of mental health outcomes among adults who have experienced a COVID-19 diagnosis. We examined the intersection of demographic, economic, and illness-related predictors of depressive and anxiety symptoms within a population-based sample of adults diagnosed with COVID-19 in the U.S. state of Michigan early in the pandemic.

**Methods** Data were from a population-based survey of Michigan adults who experienced a COVID-19 diagnosis prior to August 1, 2020 ( $N = 1087$ ). We used weighted prevalence estimates and multinomial logistic regression to examine associations between mental health outcomes (depressive symptoms, anxiety symptoms, and comorbid depressive/anxiety symptoms) and demographic characteristics, pandemic-associated changes in accessing basic needs (accessing food/clean water and paying important bills), self-reported COVID-19 symptom severity, and symptom duration.

**Results** Relative risks for experiencing poor mental health outcomes varied by sex, age, race/ethnicity, and income. In adjusted models, experiencing a change in accessing basic needs associated with the pandemic was associated with higher relative risks for anxiety and comorbid anxiety/depressive symptoms. Worse COVID-19 symptom severity was associated with a higher burden of comorbid depressive/anxiety symptoms. “Long COVID” (symptom duration greater than 60 days) was associated with all outcomes.

**Conclusion** Adults diagnosed with COVID-19 may face overlapping risk factors for poor mental health outcomes, including pandemic-associated disruptions to household and economic wellbeing, as well as factors related to COVID-19 symptom severity and duration. An integrated approach to treating depressive/anxiety symptoms among COVID-19 survivors is warranted.

**Keywords** COVID-19 · Depression · Anxiety · Mental health · Epidemiology

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## Introduction

The COVID-19 pandemic has had far-reaching impacts on mental health [1, 2]. Within the general population, the pandemic has been found to be associated with symptoms of anxiety, depression, stress, sleep problems, substance use, and suicidal ideation [3–7]. However, fewer studies have examined mental health outcomes among adults diagnosed with COVID-19. The relationship between mental health and COVID-19 illness is multi-faceted: individuals with neuropsychiatric disorders (e.g., autism and related developmental disorders, schizophrenia and other forms of severe mental illness) may be at increased risk for COVID-19 infection and severe illness for a variety of reasons, including higher smoking rates or residential instability, which may

impact ability to mitigate exposure risk [8, 9]. In addition, individuals who are diagnosed with COVID-19 face a potential multitude of psychological and functional challenges, including pandemic-associated disruptions to economic wellbeing, as well as acute symptoms, and the potential for neurological and psychiatric sequelae [10–14]. Emerging evidence also suggests that long-term effects of COVID-19 infections among some individuals, or “long COVID,” may manifest in both somatic and mental health symptoms [15–18].

Existing estimates of the burden of mental health disorders among individuals diagnosed with COVID-19 vary widely [19] but tend to suggest high risk of poor mental health outcomes within this population. A meta-analysis based on patient populations in China, Italy, Ecuador, Turkey, and Iran estimated that the prevalence of current depressive symptoms among patients diagnosed with COVID-19 was 45%, and the pooled prevalence of current anxiety symptoms was 47% [19]. Pooled estimates were based primarily on studies that used a range of self-rated questionnaires (e.g., Patient Health Questionnaire depression module-9). In addition, a more recent review estimated that over 30% of patients hospitalized with COVID-19 experienced persistent cognitive impairment, depression, and anxiety, potentially weeks to months following diagnosis [20]. Within the U.S., an analysis of electronic health record (EHR) data found that 33.6% of adults diagnosed with COVID-19 had a recorded neurological or psychiatric disorder within 6 months following diagnosis [21]. Among an internet-based convenience sample of U.S. adults with COVID-19 surveyed an average of 2.7 months following initial symptom onset, 52.4% had symptoms consistent with current major depressive disorder, assessed using the PHQ-9 [22].

Risk of poor mental health outcomes also varies by both demographic and clinical factors. In the U.S. population generally, pandemic notwithstanding, symptoms of depression and anxiety are more common among younger ages, among women, and among adults with existing medical morbidity [23, 24]. Consistent with this general population distribution, evidence to date suggests that depressive symptoms associated with COVID-19 are more common among younger individuals and individuals with greater symptom severity; however, one study found that depressive symptoms were more common among men than women [22]. Other studies have also reported that symptom severity and stigma associated with COVID-19 illness may be predictive of worse mental health outcomes [11, 25, 26].

While literature on mental health among individuals diagnosed with COVID-19 is growing, most existing studies focus on hospitalized patients, who represent a subset of individuals with particularly severe manifestations of the illness, and who may differ from non-hospitalized individuals in terms of age, comorbidities, and other risk factors

[27, 28]. Examining depressive and anxiety symptoms only among hospitalized patients also precludes opportunities to comprehensively examine the role of illness severity in producing differential patterns of mental health outcomes. In this study, we explored the prevalence of anxiety, depressive, and comorbid depressive/anxiety symptoms within a representative sample of all adults diagnosed with COVID-19 in the U.S. state of Michigan prior to August 1, 2020—an early phase of the pandemic in which Michigan experienced a high volume of COVID-19 cases and deaths [29]. Using detailed questionnaire data, we also examined several predictors of depressive and anxiety symptoms, including sociodemographic characteristics, pandemic-associated economic factors (e.g., experiencing a change in access to food, clean water, and other basic needs), and illness-specific factors (e.g., somatic symptom severity and symptom duration). As our primary research question, we sought to identify which of these factors were independently associated with mental health outcomes among individuals diagnosed with COVID-19, highlighting potential opportunities for targeted interventions to address depressive and anxiety symptoms within this population.

## Methods

### Sample

We used data from the Michigan COVID-19 Recovery Surveillance Study (MI CReSS), a representative survey of adults in Michigan who have experienced a COVID-19 diagnosis. MI CReSS is led by the University of Michigan and the Michigan Department of Health and Human Services. The sampling frame for this study included non-institutionalized Michigan adults (ages 18+) with a recorded positive COVID-19 PCR test in the Michigan Disease Surveillance System (MDSS). Respondents had to be alive at the time of the survey and able to complete the MI CReSS questionnaire either online or over the phone with a trained interviewer in English, Spanish, or Arabic. Adults missing a phone number, or who were missing either zip code or county information in the MDSS, were excluded from the sampling frame.

Individuals were sampled based on timing of illness, as well as geographic strata, which included six public health emergency preparedness regions [30], the counties of Macomb, St. Clair, Washtenaw, Oakland, Monroe, Wayne (excluding the city of Detroit), and the city of Detroit. Timing of illness was based on self-reported symptom onset (if available), the collection date for the first positive COVID-19 test (if available), or, finally, the referral date to MDSS. Three sampling waves were included in this study and encompassed illness onset/test collection/referral dates prior to August 1, 2020. For all three waves, a “base” number of

50–70 individuals was drawn from each geographic region, while the remainder of the sample was drawn proportionally, based on overall case counts within each area.

We excluded respondents with missing covariate or outcome information, with the exception of missing household income information, which was imputed using a hot-deck imputation process. Briefly, we employed the weighted sequential hot-deck (WSHD) method [31] and hot-deck propensity score (HDPS) imputation [32] to impute the income variable under the missing at random assumption. The result was a two-step procedure in which the income imputation is after the auxiliary variables imputation. Auxiliary variables included health status, primary insurance, citizenship, education level, marriage status, employment status, and race/ethnicity, which were imputed univariately using the WSHD method in a sequential order where prior imputed variables were used as predictor variables for subsequent imputations. Income was then imputed using the HDPS approach with 1–1 nearest neighbor matching. The imputation model controlled for respondents' age, sex, and other pre-imputed demographic variables including race, education, marital status, employment status, health status, and citizenship, as well as sampling weights. Weighting was conducted in SAS 9.4 and Stata SE, version 17.

Of the 1212 total respondents in the first 3 MI CReSS waves, 106 were missing outcome or covariate information (aside from household income), including 38 who were missing information on depressive or anxiety symptoms. An additional 19 proxy respondents were also excluded from the analysis. The remaining analytic sample for this study included 1087 respondents. The sample was weighted to the age and sex distribution of the sampling frame within each geographic stratum, and to the geographic distribution of cases in the population. The median time from onset/test collection/referral to survey completion was 20 weeks (IQR = 16–24 weeks), and the response rate was 31.8% (American Association for Public Opinion Research response rate #6) [33]. This secondary analysis of study data was reviewed by the University of Michigan Institutional Review Board and deemed exempt.

## Outcome measures

We assessed current depressive symptoms based on responses to the Patient Health Questionnaire two-item survey (PHQ-2), which asks respondents over the last 2 weeks, “how often have you been bothered by having little interest or pleasure in doing things?” and “how often have you been bothered by feeling down, depressed or hopeless?” [34] Presence of current anxiety symptoms was assessed using the two-item Generalized Anxiety Disorder survey (GAD-2), which asks respondents over the last two weeks, “how often have you been bothered by feeling nervous, anxious

or on edge?” and “how often have you been bothered by not being able to stop or control worrying?” [35] Responses to each item were measured using a four-point Likert scale, with options including “Never,” “For several days”, “For more than half the days”, and “Nearly every day.” Responses were assigned numerical values ranging from 0 (“Never”) to 3 (“Nearly every day”) and these values were summed within each 2-item construct. In line with prior literature, a cut-off score of 3+ was used to indicate the presence of depressive symptoms or anxiety symptoms [34]. Using these thresholds, we created a four-level variable indexing: (1) no anxiety or depressive symptoms (reference group), (2) depressive symptoms only, (3) anxiety symptoms only, and (4) comorbid depressive and anxiety symptoms.

## Predictor variables

We examined associations between mental health and a range of predictors including sociodemographic characteristics and aspects of the pandemic and COVID-19 infection. Sociodemographic predictors included sex at birth (male, female); age (18–34, 35–54, 55–64, 65+); race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, non-Hispanic adults of another race/ethnicity, including multi-racial); and past-year annual household income (<\$35K, \$35K–\$74,999, \$75K+). We included an indicator variable representing whether the respondent reported any pre-existing chronic disease (excluding a psychological or psychiatric condition), and an indicator variable representing a pre-existing psychological or psychiatric condition. These variables were derived from a question which asked respondents about pre-existing health conditions they had before being diagnosed with COVID-19 (“Have you ever been told by a doctor or other health professional that you have had any of the following conditions?”). Response options included emphysema or COPD, asthma, diabetes, heart disease or other cardiovascular disease, high blood pressure, liver disease, kidney disease, stroke or other cerebrovascular disease, cancer, immunosuppressive condition, autoimmune condition, physical disability, psychological/psychiatric condition, or any other condition. We included a single binary predictor variable indicating whether the respondent reported a change in accessing at least one basic need during the pandemic, based on the question, “Since the COVID-19 pandemic began, what has changed for you and your family?”, with the following response options: “You or your family were unable to get enough food or healthy food,” “You or your family were unable to access clean water,” and “You or your family were unable to pay important bills like mortgage, rent, or utilities.” Finally, we examined factors related to COVID-19 illness, including self-reported symptom severity (mild/asymptomatic, moderate, severe, very severe), and a binary variable representing whether the

respondent reported somatic symptom duration consistent with “Long COVID” [36], which we defined as self-reported symptoms lasting at least 60 days [37]. All adjusted models also adjusted for survey type (phone versus online) and survey wave.

## Statistical analysis

We first estimated the prevalence of depressive symptoms, anxiety symptoms, and comorbid depressive/anxiety symptoms within the sample as a whole and across categories of predictor variables. We then conducted a multinomial logistic regression analysis to estimate bivariate and adjusted relative risk ratio associations [38] between predictor variables and the four-level outcome variable. For adjusted models, we included all sociodemographic variables, as well as pandemic- and illness-associated variables that we hypothesized could be associated with mental health outcomes. Results from these models provide insight into the extent to which pandemic- and illness-related factors independently predict mental health symptoms, after accounting for differences in sociodemographic characteristics. Finally, we conducted a post hoc sensitivity analysis to examine the potential impact of using imputed income information on our results by re-estimating adjusted models excluding individuals with missing income data.

All statistical analyses were conducted using Stata v. 17 and incorporated sampling strata parameters and survey weights for both point and variance estimation.

## Results

### Descriptive characteristics

Descriptive statistics for the analytic sample are included in Table 1. The majority of the sample was female (56.1%) and non-Hispanic White (52.1%). Since the pandemic began, 26.6% reported experiencing a change in accessing at least one basic need. Over 50% of the analytic sample reported that their COVID-19 symptoms were “severe” or “very severe,” and 31.1% reported symptoms that lasted at least 60 days (i.e., Long COVID). Approximately one in four respondents were currently experiencing depressive or anxiety symptoms, with 6.7% reporting depressive symptoms only, 8.0% reporting anxiety symptoms only, and 11.6% reporting both.

Table 2 includes prevalence estimates for mental health outcomes across all predictor variables. Just over 30% of females reported depressive and/or anxiety symptoms, compared to just over 20% of males. Respondents with lower household incomes were more likely to report any symptoms compared to respondents with higher household incomes,

**Table 1** Descriptive characteristics of MI CReSS analytic sample ( $N=1087$ )

Variable	<i>N</i>	Weighted %
Sex		
Male	439	43.9
Female	648	56.1
Age category		
18–34	268	26.4
35–44	175	17.5
45–54	232	22.4
55–64	231	20.1
65+	181	13.6
Race/ethnicity		
Non-Hispanic White	659	52.1
Non-Hispanic Black	213	24.6
Hispanic	107	11.4
Another race/ethnicity	108	12.0
Income		
< \$35 K	349	33.4
\$35–\$74,999	329	29.2
> \$75 K	409	37.4
Any pre-existing condition (excluding psychiatric)	639	56.6
Prior psychiatric condition	126	11.3
Experienced change in access to basic needs <sup>a</sup>	273	26.6
Self-reported symptom severity		
Mild/asymptomatic	252	23.4
Moderate	283	24.7
Severe	324	30.5
Very severe	228	21.4
Long COVID <sup>b</sup>	346	31.1
No depressive or anxiety symptoms	805	73.7
Depressive symptoms only	68	6.7
Anxiety symptoms only	93	8.0
Depressive and anxiety symptoms	121	11.6

<sup>a</sup>Defined as inability to access enough food or healthy food, inability to access clean water, or inability to pay important bills (including rent and utilities)

<sup>b</sup>Self-reported symptom length of at least 60 days

and younger respondents were more likely to report anxiety symptoms, or combined depressive and anxiety symptoms, compared to older respondents. Approximately 40% of respondents reporting a change in access to basic needs, “very severe” COVID-19 symptoms, or Long COVID reported depressive and/or anxiety symptoms.

### Regression modeling results

Table 3 includes results from bivariate and adjusted multinomial logistic regression models. In both bivariate and adjusted models, demographic patterns of depressive and anxiety symptoms largely reflected descriptive

**Table 2** Weighted prevalence of depressive symptoms only, anxiety symptoms only, and combined depressive and anxiety symptoms across predictor variables. MI CReSS. *N* = 1087

	No depressive or anxiety symptoms (%)	Depressive symptoms only (%)	Anxiety symptoms only (%)	Combined depressive & anxiety symptoms (%)
<b>Sex</b>				
Female	69.3	6.0	10.8	13.9
Male	79.2	7.6	4.5	8.6
<b>Age</b>				
18–34	71.1	3.3	13.2	12.4
35–44	72.1	2.7	9.3	15.8
45–54	66.9	12.0	7.4	13.7
55–64	77.8	9.0	5.0	8.2
65+	85.7	6.3	2.0	6.0
<b>Race/ethnicity</b>				
Non-Hispanic White	74.6	4.8	7.9	12.7
Non-Hispanic Black	72.2	7.3	9.3	11.3
Hispanic	69.7	14.5	8.0	7.8
Another race/ethnicity	76.4	6.4	6.1	11.1
<b>Income</b>				
< \$35K	64.2	8.9	10.6	16.3
\$35K–\$74,999	75.9	6.1	7.5	10.5
\$75K+	80.3	5.2	6.2	8.2
<b>Any pre-existing condition (excluding psychiatric)</b>				
Yes	70.5	8.8	6.6	14.0
No	77.8	3.9	9.9	8.4
<b>Prior psychiatric condition</b>				
Yes	39.6	12.2	14.6	33.6
No	78.0	6.0	7.2	8.8
<b>Experienced change in access to basic needs<sup>a</sup></b>				
Yes	58.1	10.4	12.9	18.6
No	79.3	5.4	6.3	9.0
<b>Symptom severity</b>				
Mild/asymptomatic	83.2	3.5	6.1	7.1
Moderate	74.8	5.7	8.6	10.9
Severe	72.9	7.9	8.1	11.2
Very Severe	63.1	9.6	9.5	17.8
<b>Long COVID<sup>b</sup></b>				
Yes	61.0	11.2	10.4	17.5
No	79.4	4.7	7.0	8.9

<sup>a</sup>Defined as inability to access enough food or healthy food, inability to access clean water, or inability to pay important bills (including rent and utilities)

<sup>b</sup>Self-reported symptom length of at least 60 days

patterns observed in Table 2. In adjusted models, females had higher relative risks (RRs) of experiencing anxiety symptoms (adjusted relative risk ratio (aRRR) = 2.37, 95% confidence interval (CI) = 1.28, 4.38), compared to males, and age was inversely associated with poor mental health outcomes. Respondents ages 18–54 had a higher RR of anxiety symptoms (aRRR for 18–34 = 14.06, 95% CI = 3.58, 55.20; aRRR for 35–44 = 7.88; 95% CI = 1.93, 32.21; aRRR for 45–54 = 6.99, 95% CI = 1.76, 27.86) and

a higher RR of comorbid depressive/anxiety symptoms (aRRR for 18–34 = 3.95, 95% CI = 1.62, 9.65; aRRR for 35–44 = 4.37, 95% CI = 1.77, 10.77; aRRR for 45–54 = 3.73, 95% CI = 1.52, 9.15), compared to respondents ages 65+. Respondents of age 45–54 also had a higher RR of reporting depressive symptoms only, compared to individuals ages 65+ (aRRR = 2.86, 95% CI = 1.22, 6.71). Race/ethnicity was generally not associated with mental health outcomes, with the exception that Hispanic respondents had higher RRs

**Table 3** Relative risk ratios for depressive symptoms only, anxiety symptoms only and combined depressive and anxiety symptoms associated with predictor variables, from bivariate and adjusted multino-mial logistic regression models, with “no depressive or anxiety symptoms” as the baseline category. MI CRESS.  $N = 1087^{a,b}$ 

	Depressive symptoms only		Anxiety symptoms only		Combined depressive and anxiety symptoms	
	Bivariate	Adjusted	Bivariate	Adjusted	Bivariate	Adjusted
Sex (Male ref.)						
Female	0.90 (0.52, 1.55)	0.84 (0.47, 1.49)	<b>2.71 (1.56, 4.71)</b>	<b>2.37 (1.28, 4.38)</b>	<b>1.83 (1.16, 2.90)</b>	1.49 (0.91, 2.43)
Age (65 + ref.)						
18–34	0.64 (0.21, 1.91)	1.01 (0.32, 3.17)	<b>8.08 (2.43, 26.94)</b>	<b>14.06 (3.58, 55.20)</b>	<b>2.48 (1.18, 5.25)</b>	<b>3.95 (1.62, 9.65)</b>
35–44	0.52 (0.14, 1.90)	0.59 (0.16, 2.15)	<b>5.64 (1.58, 20.16)</b>	<b>7.88 (1.93, 32.21)</b>	<b>3.13 (1.44, 6.78)</b>	<b>4.37 (1.77, 10.77)</b>
45–54	<b>2.45 (1.03, 5.82)</b>	<b>2.86 (1.22, 6.71)</b>	<b>4.82 (1.37, 16.87)</b>	<b>6.99 (1.76, 27.86)</b>	<b>2.91 (1.35, 6.31)</b>	<b>3.73 (1.52, 9.15)</b>
55–64	1.57 (0.64, 3.85)	1.54 (0.64, 3.71)	2.83 (0.76, 10.51)	3.11 (0.78, 12.34)	1.51 (0.67, 3.39)	1.65 (0.67, 4.09)
Race/ethnicity (Non-Hispanic White ref.)						
Non-Hispanic Black	1.56 (0.78, 3.12)	1.15 (0.54, 2.47)	1.22 (0.68, 2.17)	0.90 (0.46, 1.74)	0.92 (0.54, 1.55)	0.88 (0.47, 1.67)
Hispanic	<b>3.24 (1.57, 6.69)</b>	<b>2.81 (1.19, 6.67)</b>	1.08 (0.47, 2.47)	0.53 (0.18, 1.51)	0.66 (0.29, 1.48)	0.51 (0.22, 1.21)
Another race/ethnicity	1.31 (0.50, 3.38)	1.13 (0.41, 3.10)	0.76 (0.32, 1.79)	0.43 (0.17, 1.09)	0.85 (0.42, 1.75)	0.73 (0.34, 1.58)
Income (\$75 K + ref.)						
< \$35 K	<b>2.12 (1.12, 4.04)</b>	1.39 (0.67, 2.88)	<b>2.13 (1.17, 3.86)</b>	1.72 (0.87, 3.42)	<b>2.48 (1.49, 4.11)</b>	<b>2.18 (1.17, 4.09)</b>
\$35 K–\$74,999	1.22 (0.59, 2.53)	1.00 (0.46, 2.17)	1.28 (0.68, 2.41)	1.08 (0.54, 2.18)	1.36 (0.78, 2.37)	1.24 (0.67, 2.29)
Any pre-existing condition, excluding psychiatric (None ref.)						
Yes	<b>2.47 (1.32, 4.62)</b>	1.70 (0.77, 3.76)	0.74 (0.46, 1.21)	0.84 (0.46, 1.53)	<b>1.84 (1.19, 2.84)</b>	<b>1.84 (1.09, 3.11)</b>
Prior psychiatric condition (None ref.)						
Yes	<b>3.99 (1.96, 8.12)</b>	<b>3.95 (1.82, 8.61)</b>	<b>3.99 (2.14, 7.45)</b>	<b>3.10 (1.60, 6.01)</b>	<b>7.52 (4.44, 12.73)</b>	<b>4.83 (2.65, 8.80)</b>
Experienced change in access to basic needs <sup>c</sup> (No change ref.)						
Yes	<b>2.65 (1.50, 4.69)</b>	1.67 (0.87, 3.18)	<b>2.79 (1.69, 4.61)</b>	<b>1.99 (1.13, 3.53)</b>	<b>2.82 (1.82, 4.37)</b>	<b>1.81 (1.03, 3.18)</b>
Symptom severity (Mild/asymptomatic ref.)						
Moderate	1.79 (0.65, 4.90)	1.35 (0.50, 3.68)	1.56 (0.76, 3.22)	1.36 (0.60, 3.08)	1.71 (0.85, 3.45)	1.56 (0.75, 3.28)
Severe	2.56 (0.97, 6.75)	1.63 (0.61, 4.33)	1.50 (0.75, 3.02)	1.22 (0.56, 2.64)	1.79 (0.92, 3.47)	1.54 (0.73, 3.25)
Very Severe	<b>3.57 (1.33, 9.56)</b>	1.39 (0.48, 4.02)	2.04 (0.98, 4.24)	1.52 (0.63, 3.67)	<b>3.30 (1.69, 6.43)</b>	<b>2.81 (1.28, 6.15)</b>
Long COVID <sup>d</sup> (None ref.)						
Yes	<b>3.13 (1.80, 5.46)</b>	<b>2.19 (1.10, 4.37)</b>	<b>1.93 (1.16, 3.19)</b>	<b>2.03 (1.09, 3.76)</b>	<b>2.54 (1.66, 3.89)</b>	<b>1.88 (1.14, 3.11)</b>

<sup>a</sup>Bold indicates statistical significance at 0.05 level<sup>b</sup>Adjusted models control for all variables in table, as well as survey type (phone versus online) and survey wave<sup>c</sup>Defined as inability to access enough food or healthy food, inability to access clean water, or inability to pay important bills (including rent and utilities)<sup>d</sup>Self-reported symptom length of at least 60 days

of depressive symptoms compared to non-Hispanic White respondents (aRRR = 2.81, 95% CI = 1.19, 6.67). Respondents with annual household income less than \$35,000 had higher RRs of experiencing combined depressive/anxiety symptoms (aRRR = 2.18, 95% CI = 1.17, 4.09), compared to respondents with higher income levels. Reporting a pre-existing condition (excluding psychological/psychiatric conditions) was associated with combined depressive/anxiety

symptoms (aRRR = 1.84; 95% CI = 1.09, 3.11), while reporting a prior psychiatric condition was strongly associated with all levels of the outcome variable.

Beyond sociodemographic characteristics and comorbidities, experiencing a change in access to basic needs was associated with an elevated RR of anxiety symptoms (aRRR = 1.99; 95% CI = 1.13, 3.53), as well as comorbid depressive/anxiety symptoms (aRRR = 1.81; 95% CI = 1.03,

3.18). Individuals who reported experiencing “very severe” COVID-19 symptoms had a higher RR of experiencing combined depressive/anxiety symptoms (aRRR = 2.81; 95% CI 1.28, 6.15), compared to those with milder symptoms. Finally, Long COVID was associated with depressive symptoms (aRRR = 2.19, 95% CI = 1.10, 4.37), anxiety symptoms (aRRR = 2.03, 95% CI = 1.09, 3.76), and comorbid depressive/anxiety symptoms (aRRR = 1.88, 95% CI = 1.14, 3.11).

Results from analyses excluding individuals with missing information on income were largely similar to the primary analysis in direction and statistical significance, except that the association between age (ages 45–54) and experiencing depressive symptoms became marginally non-significant (Supplemental Table 1).

## Discussion

Within a population-based sample of adults in Michigan who experienced a COVID-19 diagnosis prior to August 2020, approximately one-quarter reported recent symptoms of depression and/or anxiety. This estimate is lower than in some prior studies. For example, a meta-analysis of mental health outcomes among people diagnosed with COVID-19 estimated a pooled prevalence of 45% for current depressive symptoms and 47% for anxiety symptoms [19], while another review suggested that 30% of hospitalized COVID-19 patients may experience persistent cognitive impairment, depression, or anxiety, potentially months following diagnosis [20]. The lower prevalence of poor mental health outcomes in this study may stem in part from the population surveyed. Many studies of adults with COVID-19 have focused on hospitalized patient populations, who represent a subset of individuals with severe illness. However, we analyzed a probability sample of all recorded cases in the Michigan Disease Surveillance System, including hospitalized (21%) and non-hospitalized (79%) individuals. Consequently, we characterized depressive and anxiety symptoms across a spectrum of COVID-19 symptom severity levels. In our study, nearly 40% of those who had experienced “very severe symptoms” of acute COVID-19 illness reported at least some depressive and/or anxiety symptoms, compared to less than 20% among individuals with mild/asymptomatic acute illness. Likewise, 39% of individuals who experienced Long COVID reported recent depressive and/or anxiety symptoms, compared to 20.6% among those who did not experience Long COVID. Differences between our analysis and prior studies may also be due to the limited time period of the mental health assessment (e.g., past 2 weeks) as well as the timing of the survey relative to illness onset, as interviews were conducted several months after the acute phase of COVID-19 infection.

We found that mental health outcomes differed across sociodemographic groups and were generally consistent with patterns of mental health outcomes observed in the broader population, including patterns observed during the COVID-19 pandemic [6, 39]. For example, a survey of the U.S. population in an early phase of the pandemic (June 2020) found that younger adults (ages 18–24) were more likely to report worse mental health outcomes compared to older adults [6]. Likewise, Hispanic respondents had a higher prevalence of anxiety and depressive symptoms, compared to respondents in other racial/ethnic groups [6]. We also found a higher likelihood of anxiety and combined anxiety/depressive symptoms among younger respondents in our sample. Compared to other racial/ethnic groups, Hispanic respondents had a higher likelihood of depressive only symptoms in our sample, however, this pattern was not observed for other outcomes. In contrast to a prior study of mental health outcomes among adults diagnosed with COVID-19 [22], we found that females were more likely to report symptoms of poor mental health, compared to males. Building on prior literature, these findings shed light on groups that may be at particularly high risk for depressive or anxiety symptoms associated with a COVID-19 infection as well as those that may be at dual risk for both COVID-19 infections and subsequent poor mental health outcomes. For example, adults with lower SES may be more susceptible to COVID-19 infections due to employment, neighborhood, and housing environments [40, 41]; in our study, adults with lower income also experienced a higher prevalence of comorbid depressive/anxiety symptoms following a COVID-19 diagnosis.

We also examined the extent to which pandemic- and illness-related factors were independently associated with depressive and anxiety symptoms, after adjusting for demographic characteristics and pre-existing conditions. Our results are in line with prior studies that have found that severity of COVID-19 illness is associated with poor mental health outcomes [11, 22, 25, 26]. In our sample, individuals diagnosed with COVID-19 faced multiple, overlapping risk factors for poor mental health outcomes, including both physical symptoms associated with COVID-19 and economic disruptions due to the pandemic. We found that self-reported symptom severity, Long COVID, and experiencing a change in ability to access basic needs were all independently associated with poor mental health outcomes in adjusted models. Moreover, these factors were highly prevalent in our sample. Over 30% of respondents reported symptoms lasting more than 60 days and over 50% reported a change in access to basic needs associated with the pandemic, including a change in access to enough or healthy food, access to clean water, or the ability to pay important bills. These results imply that addressing the mental health burden associated with COVID-19 will likely require a multi-faceted response that acknowledges long-term

symptom burden as well as the impact of the pandemic on other aspects of wellbeing.

Strengths of this study include the use of a population-based sample, representative of all recorded cases of COVID-19 in Michigan's disease tracking system. The use of a probability sample mitigates concerns about internal and external validity in highly selected patient populations, and provides estimates of rates and associations that are relevant for an entire population of COVID-19 survivors in the US State of Michigan. We constructed weights to account for non-response. Our survey tool covered a wide range of topics, which enabled us to explore predictors of mental health outcomes across demographic, physical, and economic domains.

Our study also had several limitations. Interviews were conducted several months after infection, so we were not able to assess mental health during the acute phase of COVID-19 illness, or trajectories of mental health outcomes over time [42, 43]. Likewise, our analysis was cross-sectional, and the validity of information was subject to respondent recall and reporting. Our sample is representative only of the subset of all individuals with COVID-19 who received a positive PCR test and were recorded in the MDSS with non-missing address and phone number information. It is likely that a substantial number of cases went undetected, particularly in the early phases of the pandemic, due to limitations on testing eligibility and access. Likewise, 5–18% of the potentially eligible sample in each wave was missing phone number or address information, which could lead to selection bias. Our outcome measure was based on two-item screener questions for depressive and anxiety symptoms, which do not represent clinical diagnoses. The goals of our study were primarily descriptive, and not causal. Patterns of depressive/anxiety symptoms observed in this study may help guide future research into the potential for targeted mental health interventions among highly impacted population subgroups, as well as potential causal mechanisms linking factors (e.g., somatic symptoms associated with Long COVID) to mental health outcomes. It is possible that some associations explored in our study reflect temporal ambiguity, in which pre-existing (undiagnosed or unreported) depressive and anxiety symptoms preceded the “predictive” factors explored in this analysis (e.g., changes in access to basic needs during the pandemic). Because we did not sample individuals without a COVID-19 diagnosis, we were unable to compare the prevalence of anxiety and/or depressive symptoms within our sample to individuals without a documented positive COVID-19 PCR test. Finally, our study focused on the state of Michigan, early in the pandemic. COVID-19-related policies that were in place in Michigan through the end of the study period included a mask order (beginning April 27, 2020) and restaurant and bar closures (beginning March 16, 2020). A stay-at-home

order was also in place from March 24, 2020 through June 1, 2020 [44]. While this policy environment was largely in line with many other U.S. states early in the pandemic, [44] we cannot guarantee that results from this study are generalizable to other geographical contexts, or other stages of the pandemic.

Among a probability sample of adults who had been diagnosed with COVID-19 in Michigan, we found that approximately one in four reported experiencing depressive and/or anxiety symptoms in the months following diagnosis. By highlighting differential patterns of mental health outcomes, the results of this study shed light on high-risk groups that may benefit from supportive mental health interventions, including individuals who have experienced pandemic-related disruptions to economic wellbeing, and those who have experienced particularly severe or long-lasting symptoms. Pandemic- and illness-specific risk factors identified in this study underscore the need for a robust and integrative clinical and public health response to address the potential for depressive and anxiety symptoms among individuals diagnosed with COVID-19.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s00127-023-02453-9>.

**Acknowledgements** We would like to thank the Michigan COVID-19 Recovery Surveillance Study participants and interviewers for making this study possible. We would also like to acknowledge Yanmei Xie for her assistance with imputation.

**Funding** The Michigan COVID-19 Recovery Surveillance Study has received funding from the Michigan Department of Health and Human Services, the Michigan Public Health Institute, the University of Michigan Institute for Data Science, the University of Michigan Rogel Cancer Center, and the University of Michigan Epidemiology Department. This manuscript is supported by the Centers for Disease Control and Prevention of the U.S. Department of Health and Human Services (HHS) funded by CDC/HHS through grant number 6 NU50CK000510-02-04. The contents are those of the authors and do not necessarily represent the official views of, nor an endorsement, by CDC/HHS, or the U.S. Government. Andrea R. Titus was supported by the Agency for Health Care Research and Quality (Grant No.: T32HS026120).

**Data availability** Although the dataset used in this study is not currently available to others, we are in the process of making a de-identified dataset and data dictionary available.

## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

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