# Long COVID Among Wisconsin Workers in the Workers' Compensation System

## *Associations With Sociodemographics, Vaccination, and Predominant Variant Period From March 1, 2020 to July 31, 2022*

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**Objective:** This analysis aimed to determine the likelihood of developing long COVID among Wisconsin workers while adjusting for sociodemographics, COVID-19 vaccination, industry, and occupation. **Methods:** This retrospective analysis determined the odds ratios of developing long COVID among Wisconsin workers who were compensated for COVID-19 lost time during March 1, 2020 to July 31, 2022. **Results:** A total of 234 workers (11.7%) were determined to have long COVID. Factors associated with long COVID were age ≥40 years, non-White race, infection occurrence during the initial and Omicron variant dominant periods, and the absence of COVID-19 vaccination. Workers in manufacturing and public administration were more likely to develop long COVID compared with those in health care and social assistance. **Conclusions:** Long COVID disproportionately affects some worker groups. This calls for more worker protection and preventative care to mitigate its impact.

**Keywords:** long COVID, disparities, workers' compensation, SARS-CoV-2, vaccination, occupational health

### LEARNING OUTCOMES

- After reading this article, the authors would like the readers to be able to identify factors associated with long COVID among Wisconsin workers during March 1, 2020 to July 31, 2022.
- The authors of the article would like medical care providers to identify high-risk industry and occupation workers to screen for long COVID symptoms.

After an initial acute SARS-CoV2 infection, an individual's quality of life is more likely to be affected when there are lingering symptoms or the occurrence of new disabling symptoms.[1] Symptoms may include, but are not limited to, unusual fatigue, dyspnea, cough, headache, and impaired cognitive function, which could all have a significant impact on an individual's ability to work.[1,2] According to the Americans with Disabilities Act, long COVID could be considered a disability if it substantially limits one or more major activities.[3] Long COVID seems to affect a high proportion (7.5% to 57%) of persons infected with SARS-CoV-2 with significant variation across studies.[4,5] Considering this relatively high prevalence and the fact that COVID-19 can be an occupational disease, it is estimated that two to four million full-time equivalent American workers (1.8% of the civilian workforce) are likely to be off work due to long COVID, which could contribute to of worker shortages.[6]

Older age (mainly 40 years or older) and female sex are shown to be associated with a higher likelihood of developing long COVID.[7,8] Evidence suggests that preexisting medical conditions such as diabetes, hypertension, asthma, chronic kidney disease, cardiac disease, and autoimmune disorders may increase the risk of long COVID.[1,2,7] Moreover, cases with at least three comorbidities were more likely to develop long COVID—as were hospitalized COVID-19 cases.[9,10] Individuals living in urban and suburban areas were less likely to report persistent symptoms of COVID or develop long COVID.[11]

Worker's compensation (WC) data, by recording the lost time, offer a way to estimate worker's disability period related to COVID-19. Paid claims for lost work time provide a formalized measure of disability through both medical absences (total disability) and diminished on-the-job capacity (partial disabilities). Infectious diseases are not usually compensable for WC purposes because they are considered "ordinary disease(s) of life."[12] However, an exception has been granted

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to COVID-19 that has been recognized as an occupational disease in some cases.[13,14] Epidemiological analyses have shown that certain occupations are at increased risk for infection,[15,16] and some states have passed presumption laws that entitle certain workers to WC benefits.[17] According to the Wisconsin presumption law, COVID-19 infection among first responders is considered work-related unless rebutted by the employer with sufficient proof that the infection occurred outside of work. In the same law, first responders were defined as "an employee of or volunteer for an employer that provides firefighting, law enforcement, or medical treatment of COVID-19, and who has regular, direct contact with, or is regularly in close proximity to, patients or other members of the public requiring emergency services, within the scope of the individual's work for the employer." This law was in effect during March 12 to June 10, 2020.[13] Workers who receive WC benefits for an initial COVID claim are eligible to continue to file for lost work time due to persistent COVID-19 symptoms until further medical evaluation determines that they reached maximum health improvement. These data provide a window into long COVID's impact on the workforce.

This analysis aimed to determine the associations between sociodemographics and the likelihood of developing long COVID among workers in the Wisconsin WC system while controlling for other key factors (ie, geographic factors [urbanicity], industry and occupation, and vaccination status). As such, we are contributing to a growing literature on the risks of long COVID and its impact on the workforce. The long-term health implications of long COVID make it a particularly salient issue for occupational health even in a postpandemic era.

## METHODS

### Study Design

This was a retrospective analysis to determine the odds of developing long COVID relative to acute COVID among Wisconsin workers in the WC system during March 1, 2020 to July 31, 2022. The initial analysis, which resulted in an unpublished report, was commissioned by the Center for Workers' Compensation Studies.[18] This manuscript expands significantly on that initial analysis. This analysis adheres to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines (Supplemental Digital Content 1, STROBE checklist, http://links.lww.com/JOM/B460).

### Data Sources and Linkages

This analysis is based on data extracted from five different databases (Fig. 1).

Lost time claims from first and subsequent reports of injury were the main data source for this analysis. These claims were evaluated by insurance carriers or some self-insured employers for validity and work-relatedness before being reported to the Wisconsin Department of Workforce Development Workers' Compensation Division.[19]

Race, ethnicity, comorbidities, and death from COVID-19 were extracted from the Wisconsin Electronic Disease Surveillance System (WEDSS) to supplement the WC claim data. These person-level records were matched to the claim data by date of birth and full names by Jaro-Winkler string matching method[20] followed by a manual verification for accuracy to account for name misspelling or nicknames from one database to another.

Wisconsin's WC claim data were lost time only and had no medical claim information. We supplemented this data with the inpatient visits and emergency department data from the hospital discharge data. This approach excluded observation and ambulatory surgery data. We linked our merged dataset to inpatient discharge and emergency department data only using exact date of birth, gender, first name, and last name.

The U.S. Department of Agriculture 2010 primary rural-urban commuting area (RUCA) codes updated in 2020 were linked to the WC data by zip code to obtain geographic variables.[21] All metropolitan areas (core, high and low commuting) were grouped under metropolitan areas; all micropolitan areas (core, high and low commuting) were grouped under micropolitan areas, and small towns (core, high and low commuting) and rural areas were grouped under small and rural areas.

The Wisconsin Immunization Registry (WIR) houses statewide vaccination records including COVID-19 vaccines. WIR includes all vaccination records except those of persons who were vaccinated in Veterans Affairs centers, in pharmacies that are part of the federal retail program, persons who locked their records, or persons who were vaccinated out-of-state unless they reported their vaccination to their medical providers for update. We extracted COVID-19 vaccination records and matched them with the WC data by date of birth and full names by Jaro-Winkler string matching method[20] followed by manual verification. We were interested on the COVID-19 vaccine type (ie, Janssen, Moderna, or Pfizer), vaccination date(s), and vaccination order (that is, first, second, and booster dose).

### Case Identification

We defined a COVID-19 claim[22] as any claim that was coded as "COVID-19" in the detailed claim information nature of injury code and/or "pandemic" as cause of injury code 83. To find additional COVID-19 claims, we conducted a term search in the injury description field for the following terms: "corona," "covid," and "ncov." For

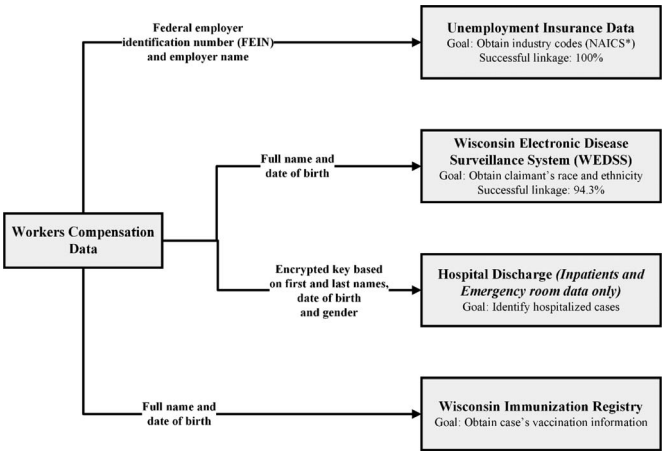


**FIGURE 1.** Data source diagram.

 

claims identified through term search, we conducted a supplementary manual verification for accuracy. We excluded any COVID-19 vaccine-related claims from this dataset.

## Industry and Occupation

We obtained detailed industry codes—2012 North American Industry Classification System (NAICS)—for each claim by linking the claim data to the unemployment insurance data via a unique identifier that was the federal employer identification number. When this initial linkage was not conclusive because of missing federal employer identification numbers or incorrect entries, we matched the claims to the unemployment insurance data by employer name.

Occupation was coded using the free-text occupation description from the WC data and was supplemented by free-text occupation of cases reported in WEDSS. WEDSS free-text occupation was used when WC occupation was too vague (ie, "health care worker") or missing. NAICS industry codes and free-text occupation were used to derive 2010 Standardized Occupation Codes (SOC) and the system matching probability using the NIOSH (National Institute for Occupational Safety and Health) NIOCCS (Industry and Occupation Computerized Coding System) autocoder.[18,23]

## Operational Definitions

Our operational definitions aligned with previous analyses conducted in the department.[15,18,22]

## Long COVID Case Definition

We adopted the Centers for Disease Control and Prevention (CDC)'s cutoff of 4 weeks in this analysis to distinguish long COVID from acute COVID.[24] We defined a long COVID case as any claimant whose claim period (lost time) was at least 4 weeks. We defined an acute COVID case as any claimant whose claim period was less than 4 weeks.

To operationalize this definition, claims were consolidated into claimants or cases. We defined the claim period, a proxy for disease length, as the period from the injury date to the full return-to-work date, which is the end of the WC lost work time payments. All denied claims were excluded from this case definition because they did not have the full return-to-work date.

## Lost Work Time and Lost Work Time Payments

Lost work time was defined as both temporary total disability and temporary partial disability periods. We also included a specific lost time code for law enforcement called state hazardous pay.

Because there was no permanent disability reported for COVID-19 cases during the data extraction, the WC lost work time defined as the time between the injury date and the full return-to-work date is similar to the claim period. Lost work time payments are provided throughout the length of the claim period.

## Hospitalized COVID-19 Cases

Cases hospitalized for COVID-19 were extracted from the inpatient and emergency department subset of the hospital discharge data and met the following criteria: the hospitalization period had to fall within the claim period; primary or secondary diagnoses had to be a COVID-19–related *International Classification of Diseases* code (Supplemental Digital Content 2, Table 1, http://links.lww.com/JOM/B461); admission date had to be no later than 90 days from the injury date. To identify cases who were intubated or used a ventilator during their hospitalization period, we applied the National Center for Health Statistics' definition based on the *International Classification of Diseases*, *10th Revision*, *Procedure Coding System* procedure codes that are 5A19054 (respiratory ventilation, single, nonmechanical), 5A1935Z (respiratory ventilation, less than 24 consecutive hours), 5A1945Z (respiratory ventilation, 24–96 consecutive hours), or 5A1955Z (respiratory ventilation, greater than 96 consecutive hours).[25]

## Predominant Variant Period or Wave

In the absence of case-level genomic data, we considered the period where the variant was predominant in the United States. Based on the CDC's timeline, the initial variant period was predominant during March 1, 2020–December 28, 2020, the Alpha variant was predominant during December 29, 2020–May 31, 2021, the Delta variant was predominant during June 1, 2021–December 23, 2021, and the Omicron variant was predominant from December 24, 2021 until the end of the study period that was July 31, 2022.[26]

## COVID-19 Vaccination Terms

Vaccination status was assessed based on COVID-19 vaccination records in the WIR relative to the claim period. In this analysis, we defined three categories of vaccination status[18]: (1) unvaccinated, (2) completion of primary series before claim period, and (3) partially vaccinated before claim period. Cases whose vaccination (complete series, partially vaccinated) became effective during the claim period were excluded from the vaccination analysis.

Cases were defined as unvaccinated based on their status by the return-to-work date, since subsequent vaccinations could not affect the amount of lost work time. An unvaccinated case was any COVID-19–positive case for whom WIR had no record of vaccination, a partial primary series effective date was recorded after their return-to-work date, or a first dose of vaccine (messenger ribonucleic acid [mRNA] or Johnson & Johnson) was administered after their return-to-work date.

A complete primary series was defined as having two doses of an mRNA vaccine (Moderna or Pfizer) or one dose of viral vector (Johnson & Johnson) vaccine. We did not distinguish between those who had completed the primary series with or without boosters. Cases who completed their primary series before their claim period are defined as those whose injury date was at least 2 weeks (14 days) after the second dose of mRNA vaccine or first dose of Johnson & Johnson vaccine.

A primary series was defined as partial if the claimant had exactly one dose of mRNA vaccine, with no Johnson and Johnson doses. Partially vaccinated cases were defined as partial primary series (exactly one dose of mRNA vaccine) before the injury date.

## Statistical Analysis

Categorical variables were reported as count and percentage. The percentages of acute and long COVID cases by demographics such as age, sex, race, ethnicity, RUCA code, variant wave, hospitalization, vaccination status, industry, and occupation were reported. A Pearson's chi-squared test was used to test the strength of association with a significance threshold ( $P$ value) of 0.05. A secondary post hoc test (Fisher's exact test) was performed to determine the direction of the association when the initial chi-squared test was significant. Continuous variables such as age were reported as median and range, and a Wilcoxon test was performed to determine the strength of association.

Several regression models were developed to determine the best covariates including sociodemographics and variant wave predictors in the analysis. The model with the lowest Akaike information criterion was retained and included age, sex, race, ethnicity, RUCA code, and variant wave (Supplemental Digital Content 3, Table 2, http://links.lww.com/JOM/B462). A multivariate binomial logistic regression based on these variables was conducted to determine the unadjusted odds ratios (ORs) and adjusted odds ratio (aORs) of developing long COVID relative to acute COVID. Odds ratios were generated with their 95% confidence intervals (CIs).

Statistical tests were two-sided and performed at an alpha level of 0.05. Data were cleaned, processed, visualized, and analyzed in R 4.0.5 (R Foundation for Statistical Computing, Vienna, Austria).

 

## RESULTS

During our study period, 2001 workers (35.6% of claimants) were compensated for lost work time due to COVID-19, out of whom 234 workers (11.7%) (Fig. 2) were identified as long COVID cases (ie, had four or more weeks of lost work time). Most long COVID cases (70.8%, n = 182) were able to return to work within 59 days after the injury date, and 7.4% of long COVID cases (n = 19) had at least 6 months of lost time.

Age and race were found to be associated with the occurrence of long COVID. Workers with long COVID were older than those with acute COVID (Table 1, median age of 48 vs 39 years, respectively, $P < 0.001$). The odds of developing long COVID for cases who were at least 40 years old was 2.35 times higher (Table 2; 95% CI, 1.72–3.24; $P < 0.001$) than that of cases who were younger. Non-White workers represented a higher proportion of long COVID cases than of acute cases (Table 1, 23.1% vs 14.4%, chi-squared, $P < 0.001$). The odds of developing long COVID among non-White workers was 1.75 times higher than that of White workers (Table 2; 95% CI, 1.22–2.50; $P = 0.002$). Although there was no statistically significant association between the geographic location captured by the RUCA code and the occurrence of long COVID when the chi-squared analysis was conducted (Table 1), the multivariate results showed that odds of developing long COVID for cases who resided in metropole was 1.75 times higher than that of cases who resided in small and rural areas (Table 2; 95% CI, 1.15–3.59; $P = 0.019$).

There was a statistically significant difference between the distributions of cases by dominant variant wave. There was a higher proportion of long COVID cases during the initial strain dominant period as opposed to a higher proportion of acute COVID cases during the other variants (Alpha, Delta, and Omicron) dominant periods (Table 1). The odds of developing long COVID was much lower for cases who occurred during the Alpha (Table 3; aOR, 0.3; 95% CI, 0.12–0.65; $P < 0.001$) and Delta (Table 3; aOR, 0.39; 95% CI, 0.22–0.64; $P < 0.001$, respectively) strain dominant periods. However, the difference for the Omicron dominant period did not quite reach significance (Table 3; 95% CI, 0.04–0.89; $P = 0.07$).

Hospitalization for COVID-19 was significantly associated with long COVID, and 21.8% of long COVID cases were hospitalized versus 4.3% for acute COVID cases (Table 1, chi-squared, $P < 0.001$). Of 127 hospitalized cases, 3.1% (4 cases) were intubated or used a ventilator during their hospital stay. The unadjusted and adjusted odds of developing long COVID was respectively 6.2 times (Table 3; 95% CI, 4.20–9.10; $P < 0.001$) and 5.16 times (Table 3; 95% CI, 3.37–7.87; $P < 0.001$) higher for hospitalized cases than nonhospitalized cases.

During our study period, 13.3% of our cases completed their primary series before the onset of COVID-19 (date of injury), and there was a statistically significant association between long COVID and vaccination status (Table 1, chi-squared, $P < 0.001$). Cases who completed their primary series were less likely to develop long COVID. The adjusted odds of developing long COVID was 3.4 times higher (Table 3; 95% CI, 1.29–9.65; $P = 0.015$) for unvaccinated cases and 4.24 times higher (Table 3; 95% CI, 1.25–14.2; $P = 0.018$) for partially vaccinated cases.

There was no initial association between industry and occupation and the occurrence of long COVID. After adjustment for sociodemographics, two industry sectors had significantly elevated odds of long COVID. Using healthcare and social assistance industry as reference, the adjusted odds of developing long COVID was 2.13 times higher for public administration industry workers (Table 3; 95% CI, 1.11–3.94; $P = 0.018$) and 2.44 times higher for those in the manufacturing industry (Table 3; 95% CI, 1.08–5.19; $P = 0.025$).

## DISCUSSION

This analysis showed the likelihood and distribution of acute versus long COVID among Wisconsin workers with a paid WC claim. More than one in ten (11.7%) workers in our dataset met the criteria for a long COVID claim. Of those, 70.8% were able to return to work within 2 months, with approximately one in six (17.5%) losing three or more months of work due to long COVID. Our findings were similar to those of some large studies conducted by the Workers Compensation Research Institute and the New York Insurance Fund.[27,28] In the latter, the proportion of long COVID among workers who received lost time compensation was 10.7% and exceeded 30% when accounting for medical-only claims.[27] In addition, CDC estimated that 15.2% of the workforce (31 million workers) may have developed long COVID.[29] An economic assessment of long COVID in the United States suggests that long COVID may be responsible for as much as 15% of the labor shortage and an estimated $170 billion of annual lost wage costs.[6] As such, our study may underestimate the real burden that is still unknown given that some cases may be qualified as beyond medical improvement, have gone into early retirement, or have requested workplace accommodations.[30]

Our analysis showed that age (OR, 2.35), previous hospitalization for COVID-19 (aOR, 5.16), and race (OR, 1.75) were risk factors for long COVID. Older workers were more likely to develop long COVID compared with acute COVID. A systematic review and meta-analysis of 41 studies including more than 800,000 patients found similar findings with ORs of 1.21 for adults aged 40 years or more and

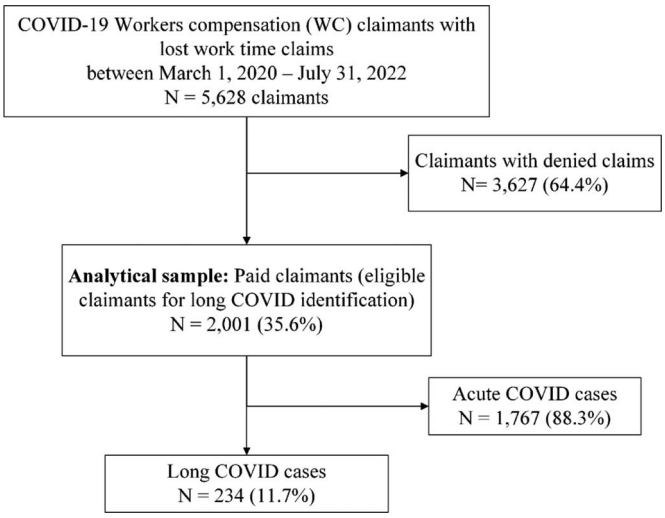


**FIGURE 2.** Long COVID case identification flowchart.

**TABLE 1.** Characteristics of Individuals With Acute COVID Versus Long COVID—Wisconsin Workers Compensation Data March 1, 2020–July 31, 2022

| | Acute COVID (N = 1767) | Long COVID (N = 234) | P | Fisher P |
|---|---|---|---|---|
| Age | | | | |
| Median [min, max] | 39 [16.0, 83.0] | 48 [20.0, 75.0] | *<0.001* | *NA* |
| Age category | | | | |
| 40 years or younger* | 956 (54.1%) | 77 (32.9%) | *<0.001* | *<0.001* |
| Older than 40 years* | 810 (45.8%) | 157 (67.1%) | | *<0.001* |
| Sex | | | | |
| Female | 1322 (74.8%) | 173 (73.9%) | *0.895* | *NA* |
| Male | 342 (19.4%) | 43 (18.4%) | | *NA* |
| Missing | 103 (5.8%) | 18 (7.7%) | | *NA* |
| Race category | | | | |
| White* | 1285 (72.7%) | 153 (65.4%) | *<0.001* | *0.003* |
| Non-White* | 254 (14.4%) | 54 (23.1%) | | *0.003* |
| Missing | 228 (12.9%) | 27 (11.5%) | | *1* |
| Ethnicity | | | | |
| Hispanic or Latino | 102 (5.8%) | 10 (4.3%) | | |
| Not Hispanic or not Latino | 1463 (82.8%) | 194 (82.9%) | *0.46* | *NA* |
| Missing | 202 (11.4%) | 30 (12.8%) | | *NA* |
| Rural-urban commuting area (RUCA) | | | | |
| Small and rural | 247 (14.0%) | 20 (8.5%) | 0.07 | *NA* |
| Micropolitan areas | 182 (10.3%) | 26 (11.1%) | | *NA* |
| Metropolitan areas | 1278 (72.3%) | 180 (76.9%) | | *NA* |
| Missing | 60 (3.4%) | 8 (3.4%) | | *NA* |
| SARS-CoV2 variant wave | | | | |
| Initial strain* | 1207 (68.3%) | 200 (85.5%) | <0.001 | <0.001 |
| Alpha variant | 150 (8.5%) | 9 (3.8%) | | 0.03 |
| Delta variant* | 341 (19.3%) | 23 (9.8%) | | <0.001 |
| Omicron variant | 69 (3.9%) | 2 (0.9%) | | 0.03 |
| Hospitalization for COVID-19 | | | | |
| Not hospitalized* | 1691 (95.7%) | 183 (78.2%) | <0.001 | <0.001 |
| Hospitalized* | 76 (4.3%) | 51 (21.8%) | | <0.001 |
| COVID-19 vaccination before claim period | | | | |
| Completed primary series* | 253 (14.3%) | 7 (3.2%) | <0.001 | <0.001 |
| Partially vaccinated | 45 (2.5%) | 8 (3.7%) | | 0.37 |
| Unvaccinated* | 1467 (83.1%) | 202 (93.1%) | | <0.001 |
| Industry sector (NAICS) | | | | |
| Health care and social assistance | 1416 (80.1%) | 178 (76.1%) | 0.14 | NA |
| Public administration | 97 (5.5%) | 18 (7.7%) | | NA |
| Manufacturing | 66 (3.7%) | 14 (6.0%) | | NA |
| Management of companies and enterprises | 48 (2.7%) | 9 (3.8%) | | NA |
| Administrative and support and waste management and remediation services | 76 (4.3%) | 5 (2.1%) | | NA |
| Other | 64 (3.6%) | 10 (4.3%) | | NA |
| Major occupation (SOC) | | | | |
| Healthcare practitioners and technical occupations | 898 (50.9%) | 100 (46.1%) | 0.54 | NA |
| Healthcare support occupations | 289 (16.4%) | 43 (19.8%) | | NA |
| Personal care and service occupations | 84 (4.8%) | 12 (5.5%) | | NA |
| Production occupations | 47 (2.7%) | 7 (3.2%) | | NA |
| Protective service occupations | 71 (4.0%) | 15 (6.9%) | | NA |
| Transportation and material moving occupations | 24 (1.4%) | 3 (1.4%) | | NA |
| Other | 352 (19.9%) | 37 (17.1%) | | NA |

*Statistically significant ( $P < 0.05$) difference between acute COVID and long COVID.

2.48 for previous hospitalization or intensive care unit admission.[31] This risk may be confounded by comorbidities or preexisting conditions that are also prevalent with age.[32] Such findings call for more targeted prevention for older workers and individuals with preexisting conditions.

Race was another sociodemographic factor associated with long COVID, with non-White workers experiencing greater risk. This also aligns with previous findings. A large-scale analysis in the United Kingdom identified race as a risk factor.[7] Other large studies also show racial and ethnic disparities in long COVID with elevated risks for Black and Hispanic Americans.[33,34] This aligns with a long-standing issue in the U.S. workforce where minorities suffer an inequitable disease burden in workplaces.[35]

Urbanicity was a risk factor in our analysis as cases who resided in metropoles were at higher risk than those in small and rural areas. A nationwide survey of approximately 16,000 COVID-19 cases showed the opposite risk association with cases who lived in urban areas less likely to develop long COVID compared with cases who lived in rural areas.[11] This difference could be explained by the difference in the demographics within state and between states, with other confounding exposures such as air quality, access to care, behavioral attitudes toward COVID-19 in terms of disease denial, vaccine hesitancy, and disease reporting. Also, the nationwide survey is not based on WC data. People who live in cities could be more likely to file claims than their

 

**TABLE 2.** Multivariate Logistic Regression Analysis of Demographic Factors Associated With Long COVID-19, Wisconsin Workers Compensation Data March 1, 2020–July 31, 2022

| | Odds Ratio (95% CI) | Odds Ratio *P* |
|---|---|---|
| Age category | | |
| 40 years or younger | — | |
| Older than 40 years* | 2.35 (1.72, 3.24) | <0.001 |
| Sex | | |
| Female | — | |
| Male | 0.93 (0.63, 1.35) | 0.5 |
| Missing | *NA* | *NA* |
| Race category | | |
| White | — | |
| Non-White* | 1.75 (1.22, 2.50) | 0.002 |
| Missing | *NA* | *NA* |
| Ethnicity | | |
| Hispanic or Latino | — | — |
| Not Hispanic or not Latino | 0.9 (0.52, 2.10) | >0.9 |
| Missing | *NA* | *NA* |
| Rural-urban commuting area (RUCA) | | |
| Small and rural | — | — |
| Micropolitan areas | 1.99 (0.97, 4.15) | 0.061 |
| Metropolitan areas* | 1.97 (1.15, 3.59) | 0.019 |
| Missing | *NA* | *NA* |

CI, confidence interval.
*Statistically significance difference ( $P < 0.05$)

rural counterparts, and this could be related to their job, level of education, sense of job security, or relation to their employer.

Vaccination has been a protective factor against the course of the disease. Our findings showed that cases who completed their primary series before the infection were less likely to develop long COVID. In our analysis, workers who completed their primary series before the infection had the shortest claim length and thus were less likely to develop long COVID compared with unvaccinated or partially vaccinated workers. Several large-scale analyses have demonstrated the protective effect of vaccination against long COVID, even for partially vaccinated individuals.[36–38]

The predominant variant period was significantly associated with the likelihood of developing long COVID. Cases infected during the Alpha- and Delta-dominant periods were less likely to develop long COVID than those infected during the initial strain. There was no difference between the initial strain and Omicron strain in the odds of developing long COVID. This finding is similar to that of Durstenfeld et al.[39] However, it is important to temper that finding because the Delta variant was known to be more lethal,[40] thus significantly reducing the survival rate and the likelihood of developing long COVID. The higher odds of developing long COVID during the initial strain may also reflect the increased amount of time that those cases have had to manifest long COVID symptoms and process a WC claim for long COVID, relative to those who were more recently infected in subsequent strains. At the same time, there is reason to believe that different strains imply differential risks of long COVID. A systematic review and meta-analysis found significantly different manifestations of long COVID by variant types.[41] This is a call for more prevention and surveillance despite being in the postpandemic era.

The majority of acute COVID (80.1%) and long COVID (76.1%) claims in our analysis are from those in the health care and social assistance industries. As has been reported elsewhere, healthcare

**TABLE 3.** Multivariate Logistic Regression Analysis of Characteristics Associated With Long COVID-19—Wisconsin Workers Compensation Data March 1, 2020–July 31, 2022

| | Unadjusted | | | Adjusted[a] | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | *P* | aOR | 95% CI | *P* |
| SARS-CoV2–variant wave | | | | | | |
| Initial strain | — | — | | — | — | |
| Alpha variant* | 0.36 | 0.17, 0.68 | 0.004 | 0.3 | 0.12, 0.65 | 0.005 |
| Delta variant* | 0.41 | 0.25, 0.62 | <0.001 | 0.39 | 0.22, 0.64 | <0.001 |
| Omicron variant | 0.17 | 0.03, 0.56 | 0.016 | 0.27 | 0.04, 0.89 | 0.07 |
| Hospitalization for COVID-19 | | | | | | |
| Not hospitalized | — | — | | — | — | |
| Hospitalized* | 6.20 | 4.20, 9.10 | <0.001 | 5.16 | 3.37, 7.87 | <0.001 |
| COVID-19 vaccination before claim period | | | | | | |
| Completed primary series | — | — | | — | — | |
| Partially vaccinated* | 6.43 | 2.20, 19.2 | <0.001 | 4.24 | 1.25, 14.2 | 0.018 |
| Unvaccinated* | 4.98 | 2.50, 11.8 | <0.001 | 3.4 | 1.29, 9.65 | 0.015 |
| Industry sector (NAICS) | | | | | | |
| Health care and social assistance | — | — | | — | — | |
| Public administration* | 1.25 | 0.90, 1.73 | 0.2 | 2.13 | 1.11, 3.94 | 0.018 |
| Manufacturing* | 1.69 | 0.89, 2.98 | 0.086 | 2.44 | 1.08, 5.19 | 0.025 |
| Management of companies and enterprises | 1.49 | 0.67, 2.95 | 0.3 | 1.05 | 0.38, 2.41 | >0.9 |
| Administrative and support and waste management and remediation services | 0.52 | 0.18, 1.19 | 0.2 | 0.66 | 0.16, 1.90 | 0.5 |
| Other | 1.24 | 0.59, 2.36 | 0.5 | 1.92 | 0.79, 4.18 | 0.12 |
| Major occupation (SOC) | | | | | | |
| Healthcare practitioners and technical occupations | — | — | | — | — | |
| Healthcare support occupations* | 1.26 | 0.86, 1.82 | 0.2 | 1.2 | 0.78, 1.82 | 0.4 |
| Personal care and service occupations* | 1.16 | 0.58, 2.11 | 0.7 | 1.16 | 0.55, 2.25 | 0.7 |
| Production occupations | 1.21 | 0.49, 2.57 | 0.7 | 1.22 | 0.43, 3.03 | 0.7 |
| Protective service occupations | 1.71 | 0.92, 3.01 | 0.075 | 1.9 | 0.92, 3.75 | 0.072 |
| Transportation and material moving occupations | 1.01 | 0.24, 2.96 | >0.9 | 1.15 | 0.17, 4.61 | 0.9 |
| Other | 0.94 | 0.64, 1.36 | 0.8 | 0.69 | 0.61, 1.47 | 0.8 |

OR, unadjusted odds ratio; aOR, adjusted odds ratio; CI, confidence interval.
*Statistically significance difference ( $P < 0.05$)
[a] The odds ratio was adjusted for age, sex, race, ethnicity, rural-urban commuting area (RUCA) code, and variant wave.

workers made up the bulk of Wisconsin's COVID-19 claims, a fact that was likely shaped by both their COVID risk and their inclusion in Wisconsin's short-lived rebuttable presumption for work-related COVID-19.[22] After adjustment for sociodemographics, public administration and manufacturing workers were at higher risk of developing long COVID compared with health care and social assistance industry workers. Other industry groups were at the same risk as healthcare and social assistance industry workers. There were no risk differences between occupation groups. A COVID-19 work-related risk analysis in Wisconsin showed that other workers in nonhealthcare industry (warehousing) or occupations (protective services, childcare, food, and beverage service) were at high risk, as well as healthcare workers.[15] Notably, many of those groups were considered "essential workers" during the pandemic and nationally have relatively high proportions of non-White workers,[42] reflecting long-standing racial disparities in blue collar and service jobs,[35] along with the attendant health risks and lower pay. This finding is nonetheless surprising and interesting because several COVID analyses showed higher risk of COVID for healthcare workers and nonhealthcare industries have less rigorous testing and reporting requirements, which led to under-representation of these groups in COVID-19 data. Such retrospective findings could contribute to future vaccination prioritization to prevent the spread of aerosolized or airborne infectious diseases in workplaces and community spillover effects.

This study has several limitations. First, it is based on paid WC claims and therefore only reflects claims that were reported to the WC division by insurance companies and were awarded their lost time benefits throughout the course of the disease. As discussed previously, such claims largely represent healthcare workers and offer fewer data points to assess risk to other parts of the workforce, although our results do point toward risks outside of healthcare. In Wisconsin, the Worker's Compensation Act covers most workers except employees of federal government, interstate railroad workers, seamen, and many other worker groups as defined by the Wisconsin state statutes Wis. Stats 102.7, who could be high-risk group of COVID-19.[43] In addition, WC laws and data vary across states, which tend to limit the generalizability of findings. However, on several issues, findings converge. Second, the present dataset can only speak to lost work time rather than to the types and extent of medical manifestations of long COVID. Third, the data lack the power to differentiate the post–intensive care syndrome during hospitalization and/or intensive care from long COVID. However, we found that a very few cases were intubated or used a ventilator in our analysis, implying that post–intensive care syndrome was not likely the main driver of most of our cases.[44] In addition, this is a known issue in defining long COVID that could be addressed with large clinical data.

This study draws from many strengths. First, it directly examines the functional impact of long COVID on the workforce by using lost work time data to explore the amount of work time lost to long COVID. Second, it incorporates additional data sources such as vaccination and hospitalization data to help account for the relative impact of these factors. Third, it accounts for different risks during different periods of the pandemic by incorporating a temporal variable related to the dominant viral strain. Fourth, it brings together both demographic and occupational data to provide a more complete picture of the long COVID affected workforce, as represented through WC claims. Fifth, this analysis' use of data from five databases demonstrates the value of such linkages and the need for greater collaboration, data sharing, and data collection uniformity across data sources, as currently exists in many Scandinavian, Middle Eastern, and European nations.

## CONCLUSIONS

This is one of the first studies to use WC data to examine long COVID in the workforce. The findings add to a growing body of research indicating that the burden of long COVID—as with acute COVID infections—fall disproportionately on people of color, and that long COVID poses more of a risk to unvaccinated individuals and those who have been hospitalized with a COVID infection. The prevalence of long COVID in our study aligns with the emerging literature. The implication that long COVID is adversely impacting the health and work lives of over 10% of infected workers has enormous implications for the economy and the workforce. The impact of this level of disability is likely to reverberate through the workforce for years to come.

This study has significant clinical and policy implications. High-risk workers, as well as their employers and providers, should remain attentive to the possibility of long COVID and the potential need for work adjustments or accommodations. Importantly, future vaccination efforts must consider the possibility that some nonhealthcare workers may be at equal or even higher risk of infection and long-term sequelae than healthcare workers. Lastly, the inclusion of industry and occupation data, as promoted by National Institute for Occupational Safety and Health, is key to this and other occupational health surveillance activities.

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