Prevalence and Risk Factors for Long COVID Among California Workers Captured by a Doctor's First Report-Based Surveillance System

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Objective: To understand prevalence and risk factors for long COVID among California workers. **Methods:** Using a cross-sectional study design, we analyzed 4496 Doctor's First Reports of Occupational Injury or Illness (DFRs) used for tracking work-related COVID-19 exposure or illnesses. Logistic regression was used to assess the risk factors. **Results:** With a prevalence of 11%, long COVID cases were slightly higher among male workers, workers aged between 45 and 54 years, and those in essential industries. Over 30 days of lost work was 13 times more prevalent among long COVID cases compared to acute cases. Age, presenting symptoms, and working in mixed essential industries increased long COVID risk. **Conclusion:** These findings highlight long COVID burden on workers' health and productivity. Proactive measures are crucial to safeguard workers' health.

Keywords: long COVID, occupational health, workers, surveillance, post-acute sequalae of SARS-CoV-2

LEARNING OUTCOMES

- Estimate the prevalence of long COVID among California workers who sought medical care for work-related COVID-19 exposure or illness (2020–2025).
- Describe key risk factors associated with developing long COVID among California workers with work-related COVID-19 exposure or illness.

The COVID-19 pandemic continues to create public health challenges globally.[1,2] In California alone, over 11 million COVID-19 cases and over 105,000 deaths were confirmed by December 2023.[3] Although most people appear to recover after the acute phase of COVID-19, some individuals experience lingering symptoms or a series of new symptoms over time, a condition known as long COVID.[4,5] This condition, which can persist for weeks or even months post-infection, is not yet fully understood but is emerging as a significant concern that requires further study. With most workers in California (60%) working in-person in 2020[6] and reported workplace-associated COVID-19 outbreaks within certain industries,[7] the potential burden of long-term COVID-19 effects among workers needs to be examined.

Long COVID can affect multiple-organ systems and presents a diverse range of symptoms including fatigue, cognitive impairment, headaches, myalgia, persistent cough, fever, dizziness, altered smell or taste, and sleep disturbances.[8] In most patients, symptoms can often be exacerbated by physical or mental exertion.[9–15] The persistence of these symptoms is currently unexplained, with hypotheses including residual viral presence in the body, ongoing inflammatory responses, autoimmune reactions, and disruptions in immune regulation.[14]

In the context of occupational health, the implications of long COVID are profound. Workers recovering from COVID-19 may continue to experience symptoms, impacting their ability to perform tasks efficiently and safely.[16,17] Furthermore, the fluctuating nature of the symptoms may require adaptations in the work environment and schedule. Employers and occupational health professionals must be aware of these challenges to provide appropriate support and accommodations for affected workers.[18–20] Therefore, understanding the distribution of long COVID among different industries and occupation groups can uncover the vulnerabilities, inform prevention, and guide rehabilitation of those affected. First, we aimed to establish the prevalence of long COVID and describe long COVID cases by industry and occupation groups. Second, we examined key demographics and aspects of exposure, including industry and occupation, to assess risk factors of developing long COVID.

METHODS

Data Source and Study Design

Our study utilized data from a statewide DFR-based surveillance system for work-related SARS-CoV-2 exposure and COVID-19 illness. In California, physicians are mandated to submit a DFR within 5 days following the examination of a patient with a suspected work-related

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injury or illness, per requirements of the California Department of Industrial Relations.[21] These reports provide a comprehensive snapshot of the worker's demographics, including employer, job title, and a narrative of the incident, objective clinical findings, diagnoses, prescribed treatments, and the resulting work status.

To ensure consistency and depth in our analysis, trained personnel abstracted these reports for work-related acute and long COVID illnesses using a standardized set of variable definitions. Details pertaining to the working conditions, health outcomes, severity of illness, and the duration of work absence were abstracted. The details of this DFR reporting system are further elaborated elsewhere.[22] For long COVID, we adapted this surveillance system to include common long COVID signs and symptoms including fatigue, post-exertion malaise, shortness of breath, chest pain, alopecia, paresthesia, memory loss, brain fog, heart palpitations, and sleep disturbance.

In this study, we adopted a cross-sectional design, with the data extraction completed on May 13, 2025. This approach allowed us to capture a snapshot of the impact of the pandemic on the workforce between January 2020 and May 2025. Reporting of this cross-sectional study was done according to STROBE guidelines (see checklist, Supplemental Digital Content, Supplemental Data 1, http://links.lww.com/JOM/C50).

Case Definition

An acute case of COVID-19 was defined using the following criteria: (1) an individual who developed SARS-CoV-2 symptoms/illness following a direct contact with a confirmed or suspected COVID-19 case at workplace, and (2) an individual who had been diagnosed with COVID-19 (ie, *International Classification of Diseases, Tenth Revision* [*ICD-10*] U07.1) or tested positive for SARS-CoV-2. We established a surveillance case definition for long COVID to align with existing clinical and epidemiological frameworks while maintaining practical relevance in public health surveillance.[8,23,24] A long COVID case was identified when diagnosed by a treating physician, based on *ICD-10* codes (U09.9 or B94.8) or clinical descriptions explicitly referencing these terms: "long COVID," "long hauler," "post-acute sequelae," or "post COVID-19 syndrome." Alternatively, a long COVID case was identified when an individual experienced persistent COVID-19 symptoms lasting more than 4 weeks following exposure or symptom onset.

Variables

The variables included in this study were selected based on their relevance to long COVID outcome as determined through literature review and are specified in this Directed Acyclic Diagram. The demographic variables included calculated or reported age and sex. The DFRs contained the industry and occupation free-text fields that were used by abstractors to assign 2010 Census Industry and Occupation Codes. Industry and occupation codes could not be determined for 1.6% (N = 72) and 18% (N = 822) of reports, respectively.

Exposure variables captured detailed occupational exposure characteristics, including multiple exposures, cluster events, worker proximity, and indoor work settings. Multiple exposures referred to cases where an individual had experienced more than one exposure event or illness. Cluster events were defined as two or more cases occurring at the same worksite within 14 days of the initial report. Worker proximity was categorized into four levels: very close, somewhat close, close, and not close. Indoor/outdoor work settings were classified as follows—primarily indoor and often indoor were grouped as indoor work environments, whereas often outdoor and primarily outdoor were categorized as outdoor work environments. Worker proximity and indoor/outdoor work were classified by linking occupation codes to the Council for State and Territorial Epidemiologists' (CSTE) SARS-CoV-2 Occupational Exposure Matrix.[25] The CSTE Work Group assignment (public facing workers, health care workers, other workers)[26] and the National Institute of Occupational Safety and Health's (NIOSH) Essential Industry designation (essential, mixed [essential/nonessential], and nonessential)[27] were linked to 2010 Census Occupation and 2012 Census Industry codes, respectively, and were also used in statistical models.

Worker illness data such as preexisting conditions (obesity, hypertension, asthma, diabetes), signs and symptoms in major organ systems (respiratory, nervous system, cardiovascular, mental health or other), number of symptoms (1–4, 5–9, 10 or more), whether hospitalized, the type of health care sought following exposure or symptoms (emergency room, hospital, physician office, telemedicine or other/unknown), vaccination status (unvaccinated/vaccinated), and lost work time (days) were abstracted from all DFRs, if the information was available. Vaccination status was available for 11% (N = 469) of reports. DFRs without vaccine status but with a date of examination, date of injury or illness onset, or test date prior to vaccines availability (December 14, 2020) were coded as unvaccinated (N = 1917). For long COVID DFRs, we also abstracted the type of health care referrals (cardiologist, neurologist, pulmonologist, occupational therapist, physical therapist, psychologist/psychiatrist, other), whether the employee was currently working, and if so, if tasks were modified.

Statistical Methods

We conducted analysis of DFRs by stratifying data on acute COVID-19 exposure or illness and long COVID. Descriptive analyses were generated for demographics, exposure and illness characteristics, and work-related disability. Summary plots of key variables were also created for comparison of acute COVID-19 and long COVID using Wilson confidence intervals.[28] We assessed whether long COVID was associated with particular risk factors, such as sex, age, frequency of exposure, cluster events, worker proximity, hospitalization, worker group, and industry, using a logistic regression model with complete cases in the multivariate model. We estimated both unadjusted (OR) and adjusted odds ratios (aOR), with the latter adjusted for all variables in the model. The results of the final model are presented as aORs and 95% confidence intervals (CIs). All statistical analyses were conducted using R.[29]

RESULTS

Worker Characteristics

Out of the 4496 work-related COVID-19-associated cases reported from February 2020 to May 2025, 11% (N = 503) were long COVID cases (Table 1). Among all long COVID cases, we observed slightly more cases among males (51%, N = 256) than females (47%, N = 238). We found that 63% of the long COVID cases were among the 35- to 54-year age group. In contrast, the 65+-year age group had the smallest proportion of long COVID cases, representing only 3.6% of the total. Few of the COVID-19 cases, 12% (N = 530), were attributed to multiple exposures. Furthermore, only 6% of the long COVID cases were associated with multiple exposures. Over 40% of the long COVID cases were associated with a cluster compared to 75% of the acute COVID-19 cases. Only 7% of all cases reported receiving at least one dose of COVID-19 vaccine, with 89% of vaccine information missing for all cases, and the rest reporting as unvaccinated. Excluding cases before vaccine availability, the proportion of all cases having received at least one dose of COVID-19 vaccine was 14%. While hospital admission following exposure was documented for 3% of all cases, the proportion was three times higher (9%) for long COVID cases. The duration of hospitalization varied in length with equal proportions within 1 to 7 and 8 to 30 days. Although over 59% of acute COVID-19 cases lost work due to illness or quarantine, the proportion was higher (83%) among long COVID cases.

For both acute COVID-19 and long COVID, most cases worked primarily indoors and in very close proximity to others. Health care and social assistance and Public administration industry groups accounted for most of the acute COVID-19 cases at 49% and 34%, respectively. Half of all long COVID cases were from the public administration industry group (Fig. 1). The health care practitioners and

TABLE 1. California Worker Characteristics by Acute COVID-19 Exposure or Illness and Long COVID Based on Doctors First Reports (DFRs), February 2020–May 2025

Variable	Overall (N = 4496)	Acute COVID-19 (N = 3993)	Long COVID (N = 503)
Sex			
Female	2241 (50%)	2003 (50%)	238 (47%)
Male	2112 (47%)	1856 (46%)	256 (51%)
Age group (y)			
18–34	1322 (29%)	1262 (32%)	60 (12%)
35–44	1194 (27%)	1039 (26%)	155 (31%)
45–54	1143 (25%)	984 (25%)	159 (32%)
55–64	654 (15%)	551 (14%)	103 (20%)
65+	132 (2.9%)	114 (2.9%)	18 (3.6%)
Multiple exposures or acute illnesses*	530 (12%)	502 (13%)	28 (5.6%)
Cluster event†	3217 (72%)	2997 (75%)	220 (44%)
Proximity to others			
Not close	205 (4.6%)	172 (4.3%)	33 (6.6%)
Somewhat close	100 (2.2%)	85 (2.1%)	15 (3.0%)
Close	119 (2.6%)	104 (2.6%)	15 (3.0%)
Very close	3238 (72%)	2880 (72%)	358 (71%)
Indoor exposure			
Primarily outdoor	132 (2.9%)	122 (3.1%)	↑
Often outdoor	146 (3.2%)	131 (3.3%)	15 (3.0%)
Often indoor	998 (22%)	845 (21%)	153 (30%)
Primarily indoor	2386 (53%)	2143 (54%)	243 (48%)
Vaccination status			
Fully vaccinated	154 (3.4%)	119 (3.0%)	35 (7.0%)
Partially vaccinated	↑	↑	↑
Vaccinated, doses unspecified	158 (3.5%)	148 (3.7%)	↑
Unvaccinated	163 (3.6%)	144 (3.6%)	19 (3.8%)
Signs or symptoms by organ system			
Respiratory	2510 (56%)	2102 (53%)	408 (81%)
Nervous system	1895 (42%)	1535 (38%)	360 (72%)
Cardiovascular	529 (12%)	333 (8.3%)	196 (39%)
Mental health	178 (4.0%)	76 (1.9%)	102 (20%)
Other symptoms	2094 (47%)	1694 (42%)	400 (80%)
First medical care sought (following exposure)			
Emergency room	784 (17%)	737 (18%)	47 (9.3%)
Hospital admission	124 (2.8%)	81 (2.0%)	43 (8.5%)
Physician office	1828 (41%)	1617 (40%)	211 (42%)
Telemedicine	1169 (26%)	1106 (28%)	63 (13%)
None	↑	↑	↑
Hospitalized	213 (4.7%)	140 (3.5%)	73 (15%)
Days hospitalized			
None	4277 (95%)	3851 (96%)	426 (85%)
1–7 d	64 (1.4%)	42 (1.1%)	22 (4.4%)
8–30 d	59 (1.3%)	40 (1.0%)	19 (3.8%)
>30 d	↑	↑	↑
Unknown days	83 (1.8%)	58 (1.5%)	25 (5.0%)
Lost 1 or more days			
Yes, due to illness	2575 (57%)	2159 (54%)	416 (83%)
Yes, due to quarantine/positive test	209 (4.6%)	208 (5.2%)	↑
Workdays lost			
None	366 (8.1%)	350 (8.8%)	16 (3.2%)
1–7 d	602 (13%)	583 (15%)	19 (3.8%)
8–30 d	1214 (27%)	1080 (27%)	134 (27%)
>30 d	109 (2.4%)	44 (1.1%)	65 (13%)
Unknown days	2198 (49%)	1934 (48%)	264 (52%)
Census occupation major group‡			
Architecture and engineering	12 (0.3%)	↑	↑
Arts, design, entertainment, sports, and media	↑	↑	↑
Building and grounds cleaning and management	79 (1.8%)	72 (1.8%)	↑
Business and financial operations	33 (0.7%)	27 (0.7%)	↑
Community and social service	63 (1.4%)	49 (1.2%)	14 (2.8%)
Computer and math	↑	↑	↑
Construction and extraction	34 (0.8%)	28 (0.7%)	↑
Education, training, and library	182 (4.0%)	171 (4.3%)	11 (2.2%)

Continued next page

TABLE 1. *(Continued)*

Variable	Overall (*N* = 4496)	Acute COVID-19 (*N* = 3993)	Long COVID (*N* = 503)
Farming, fishing, and forestry	30 (0.7%)	27 (0.7%)	↑
Food preparation and serving related	50 (1.1%)	42 (1.1%)	↑
Health care practitioners and technical	1159 (26%)	1060 (27%)	99 (20%)
Health care support	289 (6.4%)	274 (6.9%)	15 (3.0%)
Installation, maintenance, and repair	50 (1.1%)	43 (1.1%)	↑
Legal	↑	↑	↑
Life, physical, and social science	13 (0.3%)	12 (0.3%)	↑
Management	90 (2.0%)	80 (2.0%)	↑
Military	↑	↑	-
Office and administrative support	297 (6.6%)	267 (6.7%)	30 (6.0%)
Personal care and service	13 (0.3%)	11 (0.3%)	↑
Production	46 (1.0%)	37 (0.9%)	↑
Protective service	1145 (25%)	971 (24%)	174 (35%)
Sales and related	18 (0.4%)	↑	↑
Transportation and material moving	57 (1.3%)	42 (1.1%)	15 (3.0%)
CSTE worker group assignment[§]			
Health care worker	1493 (33%)	1381 (35%)	112 (22%)
Public pacing	1528 (34%)	1312 (33%)	216 (43%)
Other	641 (14%)	548 (14%)	93 (18%)
Census industry major group			
Accommodation and food services	18 (0.4%)	16 (0.4%)	↑
Administration and support and waste management services	55 (1.2%)	37 (0.9%)	18 (3.6%)
Agriculture, forestry, fishing, and hunting	119 (2.6%)	107 (2.7%)	12 (2.4%)
Arts, entertainment, and recreation	↑	↑	↑
Construction	13 (0.3%)	↑	↑
Educational services	300 (6.7%)	292 (7.3%)	↑
Finance and insurance	↑	↑	↑
Health care and social assistance	2058 (46%)	1951 (49%)	107 (21%)
Information	↑	↑	-
Management of companies and enterprises	↑	↑	-
Manufacturing	26 (0.6%)	14 (0.4%)	12 (2.4%)
Military	↑	↑	-
Mining, quarrying, and oil and gas extraction	↑	-	-
Other services, except public administration	↑	↑	↑
Professional, scientific, and tech services	14 (0.3%)	↑	↑
Public administration	1604 (36%)	1349 (34%)	255 (51%)
Real estate and rental and leasing	17 (0.4%)	16 (0.4%)	↑
Retail trade	48 (1.1%)	37 (0.9%)	11 (2.2%)
Transportation and warehousing	35 (0.8%)	22 (0.6%)	13 (2.6%)
Utilities	78 (1.7%)	65 (1.6%)	13 (2.6%)
Wholesale trade	↑	↑	↑
NIOSH Industry Designation[‖]			
Essential	4343 (97%)	3894 (98%)	449 (89%)
Mixed	66 (1.5%)	46 (1.2%)	20 (4.0%)
Nonessential	14 (0.3%)	↑	↑

‡Finance and insurance; information; military; mining, quarrying, and oil and gas extraction industries; arts, design, entertainment, sports, and media; legal; and military occupations with less than 5 DFRs are not shown.

*Multiple exposure was defined as more than one exposure event of Acute SARS-CoV-2 or COVID-19 illness (More than 1 DFR).

†If two or more cases involved the same employer and were within 14 days of each other, they were ascribed to a single event (cluster).

§CSTE worker group assignment—The Council for State and Territorial Epidemiologists' (CSTE) worker group assignment categorize occupations as public facing workers, health care workers, and other workers.

‖NIOSH industry designation—National Institute of Occupational Safety and Health's (NIOSH) industry designation categorize industry as essential, mixed, and nonessential.

Cells with less than 11 DFRs are suppressed. Cells with 0 DFRs (NA) are displayed as "—."

technical occupational group, mainly comprising registered nurses, accounted for 27% of all acute COVID-19 cases, whereas protective service occupations accounted for 35% of all long COVID cases driven by these detailed occupations: bailiffs, correctional officers, and jailers (see chart, Supplemental Digital Content, Supplemental Fig. 1, http://links.lww.com/JOM/C51). Although registered nurses constituted a majority of both acute COVID-19 and long COVID cases (>55% and >45%, respectively), health practitioner support technologists and technicians made up 21% of the long COVID cases (see chart, Supplemental Digital Content, Supplemental Fig. 1, http://links.lww.com/JOM/C51). By worker group assignment, 33% of all cases were health care workers and 34% were public facing workers.

Although missing for 64% of long COVID cases, 36% reported at least one preexisting condition primarily captured through encounters at a physician's office (69%) and telemedicine appointments (24%). The most prevalent preexisting conditions were obesity, hypertension, asthma, and diabetes among all cases (see fig., Supplemental Digital Content, Supplemental Fig. 2, http://links.lww.com/JOM/C52). About half of all long COVID cases (49%) sought additional care from specialists including cardiologists (10%), neurologists (10%),

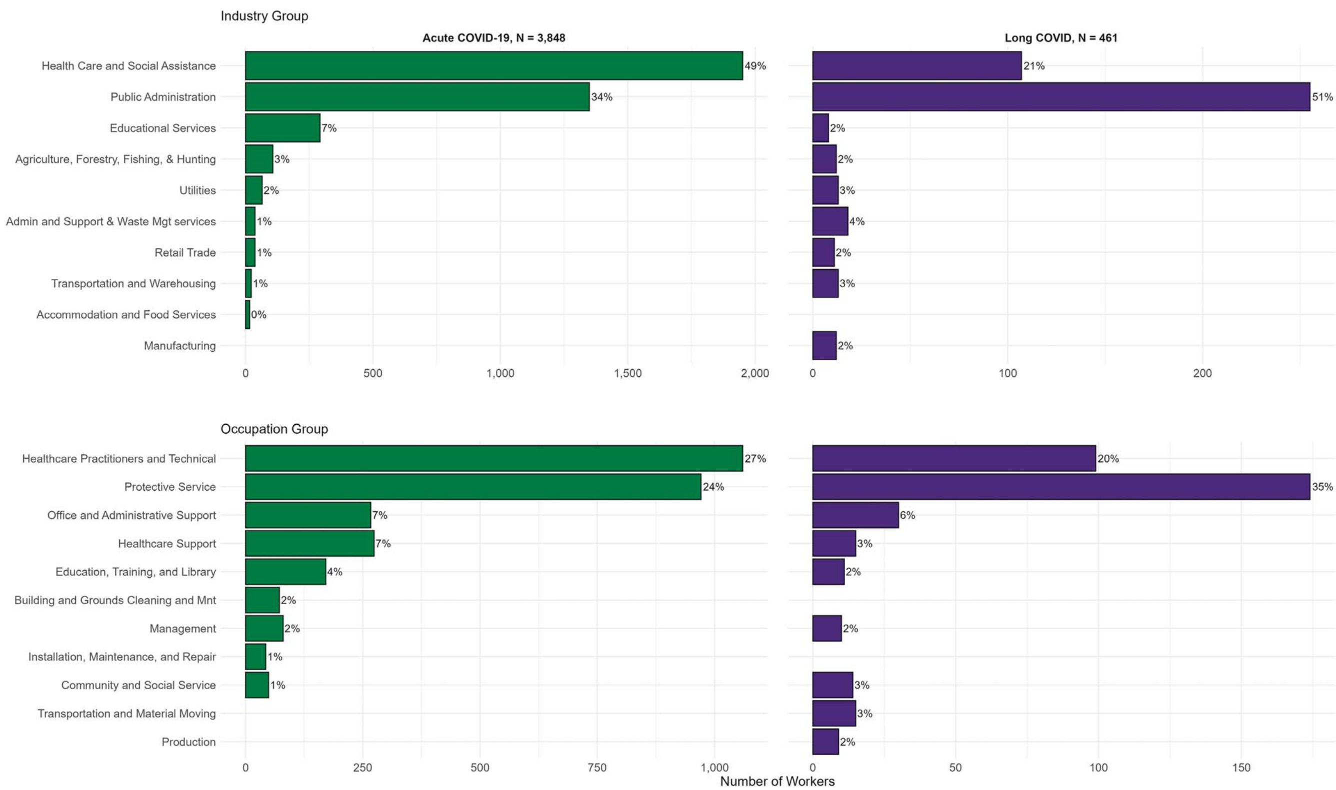

FIGURE 1. Prevalence of acute COVID-19 exposure or illness and long COVID by major industry and occupation group based on doctors first reports (DFRs), February 2020–May 2025.

pulmonologists (19%), and other specialists (16%). Approximately 43% ($N = 214$) of workers with long COVID reported they were actively working at the time they sought care. Among these, 21% indicated that their work duties were modified, or tasks had been changed. We observed stark disparity in work disruption, measured as more than 30 lost workdays, between workers long COVID cases (13%, $N = 65$) and acute COVID-19 cases (1.1%, $N = 44$).

The DFRs captured 70% of the workers presenting with at least one sign or symptom as displayed by organ system in Figure 2. The most common signs/symptoms among both acute and long COVID cases were in the respiratory and the nervous systems. Among acute cases, cough (32%, $N = 1258$) and muscle pain (22%, $N = 883$) were the most common symptoms overall, whereas dyspnea (62%, $N = 313$), fatigue (57%, $N = 285$), cough (50%, $N = 249$), and muscle pain (45%, $N = 225$) were most common symptoms among long COVID cases. Less prevalent cardiovascular symptoms, such as chest tightness, high arterial blood pressure, palpitations, and tachycardia, were notably more frequent among long COVID cases compared to acute cases. Additionally, cognitive-specific symptoms including confusion and memory loss or ‘brain fog' were also more prevalent among long COVID patients. When we examined risk factors in relation to developing respiratory, nervous system, cardiovascular, mental health, and other signs or symptoms, the age, hospitalization, and vaccination odds ratios increased risk across all symptoms (Table 2). In contrast, being part of a cluster event was associated with lower odds for all organ symptoms.

Risk Factors for Long COVID

Using logistic regression analysis, we found that the aORs for long COVID increased with age; for example, workers aged 45 to 54 years had the highest aOR of long COVID (2.36, 95% CI: 1.44–3.88) compared to those aged between 18 and 34 years, as shown in Figure 3. In our workplace risk factors assessment, we found an inverse association of cluster events with long COVID (aOR: 0.34, 95% CI: 0.23–0.49). We did not detect any exposure response pattern when examining proximity or indoor risk factors in relation to long COVID, which were about the null. The number of symptoms was strongly associated with long COVID. For example, having 10 or more symptoms increased the odds of long COVID by a factor of 7 (aOR: 7.38, 95% CI: 4.04–13.46), whereas those who had 5 to 9 symptoms increased the odds by a factor of 2 (aOR: 2.43, 95% CI: 1.66–3.55) (Fig. 3). Working in an industry classified as mixed, ie, industries carrying out essential and nonessential services or work, increased the odds of long COVID compared to essential industry groups (aOR: 9.90, 95% CI: 1.59–61.65).

DISCUSSION

Our findings revealed that long COVID constituted 11% of all COVID-19 exposure and illness cases among workers who sought medical care as captured by DFRs. Long COVID cases predominantly involved male workers, with the highest incidence observed in the public administration and health care and social assistance industry groups The acute work-related COVID-19 cases were more common among younger workers aged 18 to 34 years, whereas long COVID cases were more frequently reported among workers aged 45 to 54 years. We that found over half of workers with long COVID were not actively working at the time care was sought. We found positive associations of long COVID among older age, workers presenting with symptoms, and workers from mixed essential/nonessential industries. However, we found inverse associations of long COVID among workers involved with worksite clusters in our exploration of workplace exposure risk factors. These findings highlight which workers may be at a higher risk of long-term sequelae of a COVID infection impacting their health and their ability to earn a living.

Although most of our knowledge about long COVID stems from general population studies, worker population studies of long COVID are emerging.[9,10,12,30,31] The prevalence of long COVID was slightly lower than 14% reported by Zhang et al.[32] We found that most

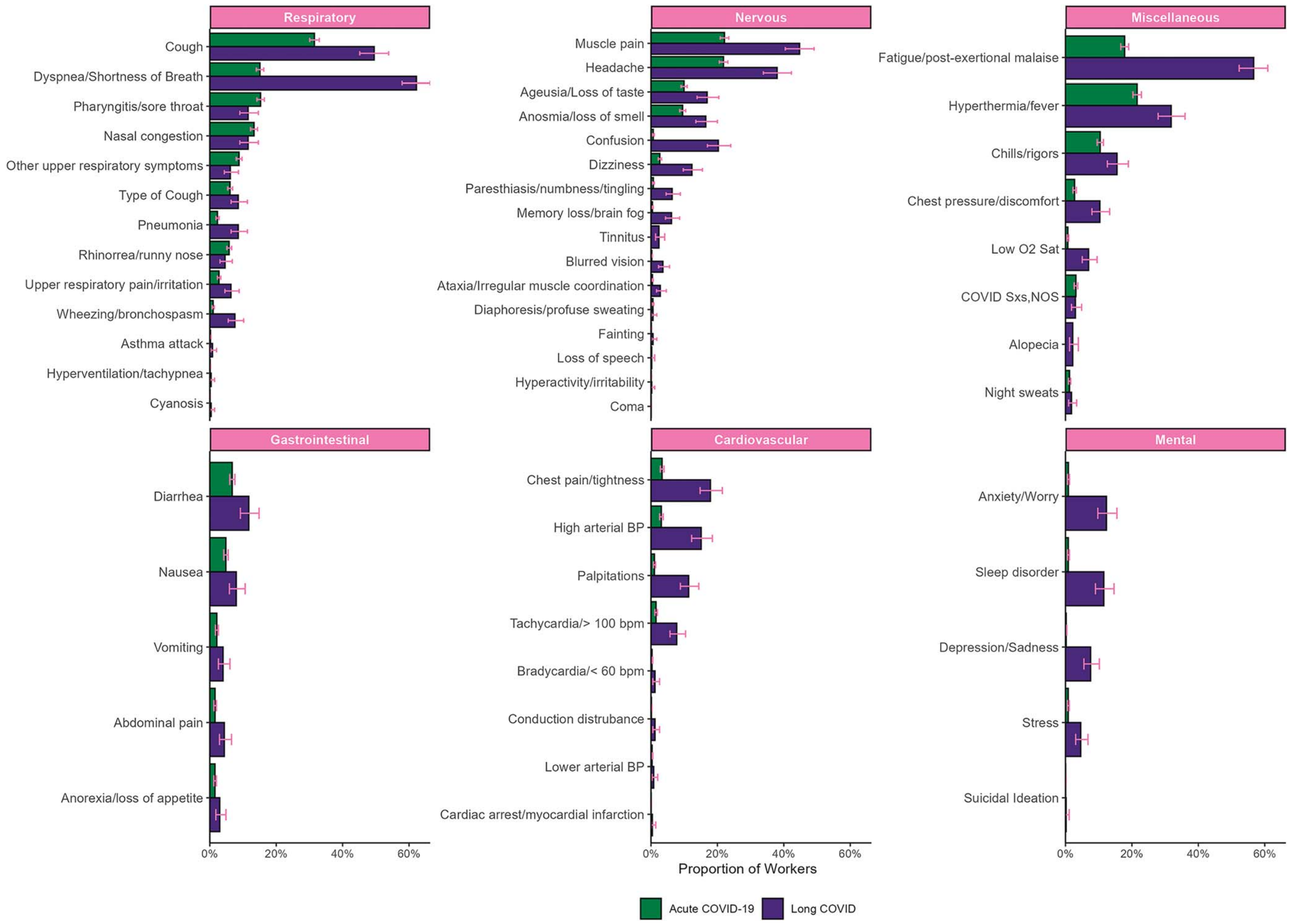

FIGURE 2. Prevalence of signs and symptoms of acute COVID-19 exposure or illness and long COVID by organ system based on doctors first reports (DFRs), February 2020–May 2025.

of the long COVID cases were among workers covered by California COVID-19 presumptions—namely, first responders, including health care providers and police officers[33] who worked primarily indoors and in close contact with other.

Our study underscores the profound impact of long COVID on workers, extending beyond health care to affect quality of life, productivity, and economic stability.[17,34–37] We observed a wide range of persistent signs and symptoms across various organ systems, including fatigue/malaise, memory loss, and brain fog. Workers experiencing long COVID may face significant challenges in performing their duties, potentially requiring workplace accommodation and facing job limitations.[38] The economic strain is also considerable, with increased health care utilization and potential for long-term disability.[39] Our results also highlighted substantial lost workdays, particularly among long COVID cases, leading to a 13-fold (1.1% among acute cases vs 13% among long COVID cases) increase in workers losing over 30 workdays. This loss directly impacts productivity; exacerbates labor shortages, particularly in critical sectors; and increases medical costs, as noted by Cutler.[16] Therefore, our findings emphasize the socioeconomic importance of understanding and addressing the long-term effects of COVID-19 among workers, highlighting the real-world implications of our research and the urgent need for supportive interventions.

In our examination, COVID-19 among workers based on DFRs, age was a risk factor for long COVID as found in other studies.[40–43] However, in a meta-analysis of long COVID among adults older than 18 years that assessed risk factors, age was identified as a risk factor for the presence of more symptoms rather than for long COVID.[42] Our finding of an inverse association for cluster event and long COVID may be due to interventions implemented across workplaces in California.[44] The highest outbreak-associated cases in California between January 2020 and August 2021 were among the health care sector, a group for which we observed the second highest prevalence of long COVID DFRs.[45] The 2009 California Division of Occupational Safety and Health (Cal/OSHA) Aerosol Transmissible Disease Standard required employers in health care and congregate living settings to assess and control risk of exposure to aerosol transmissible pathogens, including novel pathogens like SARS-CoV-2.[46] For the retail sectors, manufacturing and food services sectors that experience outbreaks,[45] the potential for exposure might have encouraged employers to provide sick time, to require use of personal protective equipment, and to encourage uptake of vaccinations. Although we did not detect any impacts of vaccination on the risk of long COVID, others have identified vaccines as critical in prevention of long COVID.[47–49] The association between number of symptoms and increased odds of long COVID is well documented.[41,50] Symptom count reflects the extent of systemic involvement, multiple-organ involvement, infection severity, or inflammatory response levels, which could increase the likelihood of lingering effects and increased risk of long COVID.[51] Employment in mixed essential industries was another potential risk factor for long COVID when compared to essential only industries. As previously noted, health care workers were protected through the ATD and were under health care orders to receive a

TABLE 2. Logistic Regression of Risk Factors for Long COVID Major Organ System Signs or Symptoms Based on Doctors First Reports (DFRs), February 2020–May 2025

Variable	Category	Respiratory Symptoms	Nervous System Symptoms	Cardiovascular Symptoms	Mental Health Symptoms	Other Symptoms
Sex	Female		Ref	Ref	Ref	Ref
	Male	1.05 (0.72–1.54)	0.91 (0.61–1.37)	1.50 (0.86–2.64)	0.53 (0.24–1.16)	0.99 (0.67–1.45)
Age (y)	18–34		Ref	Ref	Ref	Ref
	35–44	1.90 (1.13–3.24)	1.75 (1.00–3.11)	2.61 (1.12–6.81)	3.95 (1.37–14.32)	1.81 (1.07–3.11)
	45–54	2.48 (1.51–4.18)	2.48 (1.47–4.31)	2.73 (1.17–7.15)	2.74 (0.88–10.30)	2.45 (1.48–4.14)
	55–64	2.09 (1.16–3.77)	1.81 (0.96–3.42)	4.74 (1.99–12.55)	2.11 (0.58–8.63)	2.20 (1.23–3.96)
	65+	1.97 (0.55–5.57)	1.68 (0.38–5.28)	3.07 (0.43–13.92)	—	1.80 (0.49–5.16)
Multiple exposure*	No		Ref	Ref	Ref	Ref
	Yes	0.64 (0.30–1.22)	0.58 (0.25–1.17)	0.97 (0.33–2.33)	2.85 (0.95–7.46)	0.80 (0.40–1.47)
Cluster event†	No		Ref	Ref	Ref	Ref
	Yes	0.28 (0.20–0.40)	0.32 (0.22–0.47)	0.24 (0.14–0.41)	0.10 (0.04–0.22)	0.28 (0.19–0.40)
Proximity to others	Not close		Ref	Ref	Ref	Ref
	Somewhat close	0.63 (0.18–1.91)	0.56 (0.14–1.87)	2.78 (0.75–10.46)	0.71 (0.03–6.18)	0.45 (0.11–1.50)
	Close	0.65 (0.19–1.90)	0.83 (0.24–2.47)	2.61 (0.67–9.84)	2.33 (0.37–14.16)	1.01 (0.35–2.75)
	Very close	0.79 (0.42–1.57)	1.04 (0.52–2.19)	1.23 (0.49–3.60)	1.54 (0.45–6.86)	0.88 (0.46–1.77)
Indoor exposure	No		Ref	Ref	Ref	Ref
	Yes	0.91 (0.62–1.32)	0.85 (0.57–1.28)	1.14 (0.65–2.05)	1.26 (0.57–2.97)	0.84 (0.57–1.22)
Hospitalized	No		Ref	Ref	Ref	Ref
	Yes	2.33 (1.29–4.08)	2.06 (1.08–3.78)	2.88 (1.35–5.84)	2.48 (0.80–6.67)	2.29 (1.25–4.06)
Vaccination status	Unvaccinated		Ref	Ref	Ref	Ref
	Vaccinated	1.76 (1.13–2.70)	1.97 (1.24–3.06)	1.53 (0.76–2.91)	3.72 (1.65–8.10)	2.21 (1.43–3.36)
CSTE worker group assignment	Health care worker		Ref	Ref	Ref	Ref
	Public facing	1.59 (1.01–2.52)	1.80 (1.10–2.99)	1.05 (0.51–2.16)	1.02 (0.39–2.69)	1.31 (0.83–2.09)
	Other	1.47 (0.83–2.57)	2.25 (1.24–4.05)	1.85 (0.85–3.97)	2.00 (0.71–5.56)	1.55 (0.88–2.67)
NIOSH industry designation§	Essential		Ref	Ref	Ref	Ref
	Mixed	4.74 (1.20–17.78)	6.51 (1.68–24.08)	0.58 (0.03–4.67)	5.30 (0.55–30.63)	7.72 (2.07–29.63)
	Nonessential	1.71 (0.22–9.81)	1.91 (0.25–10.76)	1.45 (0.07–10.49)	6.51 (0.76–46.03)	3.36 (0.57–19.78)

Presented as odds ratios and 95% confidence intervals.

*Multiple exposure was defined as more than one exposure event of acute SARS-CoV-2 or COVID-19 illness (more than 1 DFR).

†If two or more cases involved the same employer and were within 14 days of each other, they were ascribed to a single event (cluster).

‡CSTE worker group assignment—The Council for State and Territorial Epidemiologists' (CSTE) worker group assignment categorize occupations as public facing workers, health care workers, and other workers.

§NIOSH industry designation—National Institute of Occupational Safety and Health's (NIOSH) industry designation categorize industry as essential, mixed, and nonessential.

COVID vaccine,[46,52] which might explain our strong association for mixed essential. Many public-facing workers can also work in mixed essential industries, like those in retail, and may often lack workplace protections or accommodations, such as paid time off for vaccinations. In summary, the rationale for our observed pattern of long COVID is complex and the untangling each of these potential risk factors in an adequately powered study would be needed.

This study was subject to several limitations affecting the interpretation of our findings. Primarily, our data were contingent on physician reporting through DFRs, which may introduce a bias as most occupational COVID-19 cases are likely unreported, thus skewing our estimates.[53] To be identified as an occupational COVID-19 or long COVID case through a DFR, a worker must have access to and seek medical care following an illness, the attending physician must recognize the illness as work-related, and the physician must be aware of the DFR reporting requirements. Moreover, patterns of COVID-19 medical care access may be driven by presumptions, severity of illness, or both. The fear of workplace retribution often discourages workers from reporting, and research suggests that up to two-thirds of occupational illnesses may go unreported.[54] Lack of sufficient data to code for industry and occupation information could have biased the rate estimates for these categories. The combination of these mechanisms may have led to underreporting of occupational COVID. Second, we devised an approach to classify cases of long COVID that could differ from other studies and affect the calculation of the prevalence. Third, the cross-sectional nature of the analysis restricted our understanding of the temporal relationship between workplace risk factors, health status, and long COVID. Finally, the extent to which vaccination prevents long COVID is unclear; some studies indicate no improvement in resolving persistent symptoms,[55–58] whereas others indicate prevention or improvement.[47–49] Due to lack of vaccination information on the DFRs, we could not adequately examine the effect of vaccination on risk of long COVID. We had no data to assess race/ethnicity and other socioeconomic data in the development of long COVID among workers. For DFRs that captured workplace accommodation or task changes, the specific details on the types of changes were limited. Owing to a lack of complete reporting, barriers for workers to seek care for a work-related illness, and limited volume of DFRs, the generalizability of our findings is limited to workers who sought medical care for an exposure to SARS-CoV-2, acute COVID-19 illness, or long COVID illness.

Despite the limitations, the surveillance system had several strengths. First, DFRs are timely accounts from medical professionals while incorporating workers' perspectives on COVID-19 exposure or illness. This dual reporting ensures both clinical accuracy and first-hand descriptions of workplace exposures, enhancing data reliability. Understanding the worker's account provides critical insight into potential transmission dynamics, workplace risks, and gaps in occupational protections. Second, unlike many other data sources, DFRs capture detailed industry and occupational information, providing valuable context for understanding work-related COVID-19 exposures, illness not available in many data sources, or both. Lastly, the surveillance system attempted to capture lost work time, highlighting the economic impact of COVID-19 on workers. By tracking the duration of work absence, the occupational COVID-19 surveillance system contributes to knowledge on the broader economic consequences of long COVID on the workforce as highlighted by other studies.[16,30,36,59,60]

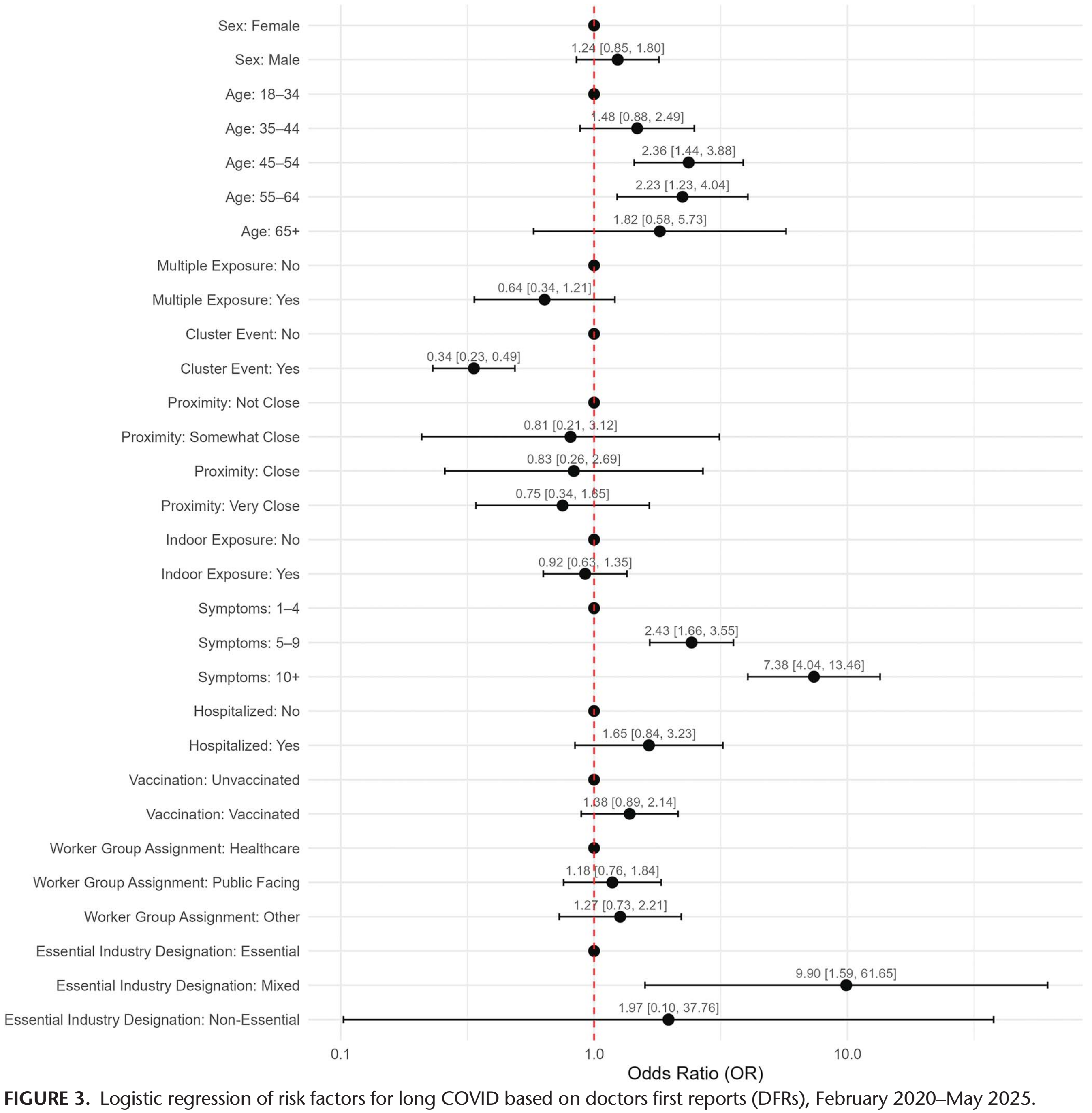

FIGURE 3. Logistic regression of risk factors for long COVID based on doctors first reports (DFRs), February 2020–May 2025.

In conclusion, our study characterized the burden of long COVID among California workers using Doctor's First Reports, emphasizing the significance of lost work time as an indicator of economic impact. The findings reveal an elevated risk of long COVID among older workers, workers presenting with symptoms, and workers in industries classified as mixed essential/nonessential. In particular, health care and protective service workers who sought medical care for workplace exposures emerge as key populations for targeted interventions. Given the prolonged recovery trajectories associated with long COVID, further research is warranted to assess its long-term impact on worker disability, labor market participation, and overall economic impacts. Additionally, examining the role of vaccination in mitigating post-COVID complications remains a critical avenue for public health inquiry.

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REFERENCES

1. Martín Sánchez FJ, Martínez-Sellés M, Molero García JM, et al. Insights for COVID-19 in 2023. *Rev Esp Quimioter* 2023;36:114–124.
2. The Lancet. The COVID-19 pandemic in 2023: far From over. *Lancet* 2023;401:79.
3. State of California—COVID-19 Time-Series Metrics by County and State (ARCHIVED). Available at: https://data.gov. Accessed August 12, 2024.
4. WHO. Coronavirus disease (COVID-19): post COVID-19 condition. Available at: https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-(covid-19)-post-covid-19-condition. Accessed July 31, 2023

5. California Department of Public Health (CDPH). Post-COVID conditions (Long COVID). Available at: https://covid19.ca.gov/long-covid/. Accessed July 31, 2023.
6. Alamo C. COVID-19 and the labor market: who are California's frontline and remote workers? December 8, 2020. Available at: https://lao.ca.gov/LAOEconTax/Article/Detail/593. Accessed April 4, 2024.
7. Heinzerling A, Vergara XP, Gebreegziabher E, et al. COVID-19 outbreaks and mortality among public transportation workers—California, January 2020–May 2022. *MMWR Morb Mortal Wkly Rep* 2022;71:1052–1056.
8. Fernández-de-las-Peñas C, Palacios-Ceña D, Gómez-Mayordomo V, Cuadrado ML, Florencio LL. Defining post-COVID symptoms (post-acute COVID, long COVID, persistent post-COVID): an integrative classification. *Int J Environ Res Public Health* 2021;18:2621.
9. Ali ST, Kang AK, Patel TR, et al. Evolution of neurologic symptoms in non-hospitalized COVID-19 "long haulers.". *Ann Clin Transl Neurol* 2022;9:950–961.
10. Cabrera Martimbianco AL, Pacheco RL, Bagattini ÂM, Riera R. Frequency, signs and symptoms, and criteria adopted for long COVID-19: a systematic review. *Int J Clin Pract* 2021;75:e14357.
11. Koc HC, Xiao J, Liu W, Li Y, Chen G. Long COVID and its management. *Int J Biol Sci* 2022;18:4768–4780.
12. Yong SJ. Long COVID or post–COVID-19 syndrome: putative pathophysiology, risk factors, and treatments. *Infect Dis Lond Engl* 2021;53:737–754.
13. Davis HE, McCorkell L, Vogel JM, Topol EJ. Long COVID: major findings, mechanisms and recommendations. *Nat Rev Microbiol* 2023;21:133–146.
14. Castanares-Zapatero D, Chalon P, Kohn L, et al. Pathophysiology and mechanism of long COVID: a comprehensive review. *Ann Med* 2022;54:1473–1487.
15. Goërtz YMJ, Van Herck M, Delbressine JM, et al. Persistent symptoms 3 months after a SARS-CoV-2 infection: the post–COVID-19 syndrome? *ERJ Open Res* 2020;6:00542–02020.
16. Cutler DM. The costs of long COVID. *JAMA Health Forum* 2022;3:e221809.
17. Reuschke D, Houston D, Sissons P. Impacts of long COVID on workers: a longitudinal study of employment exit, work hours and mental health in the UK. *PLoS One* 2024;19:e0306122.
18. DeMars J, Durand-Moreau Q, Branton E, Nowrouzi-Kia B, Gross DP. On behalf of participants of the 2024 Canadian Symposium on Long COVID Return to Work Session. Improving occupational rehabilitation for people living with long COVID. *J Occup Rehabil* 2025;35:1–3.
19. O'Connor RJ, Parkin A, Mir G, et al. Work and vocational rehabilitation for people living with long covid. *BMJ* 2024;385:e076508.
20. Vyas L. "New normal" at work in a post-COVID world: work–life balance and labor markets. *Policy Soc* 2022;41:155–167.
21. DIR. DWC Electronic Reporting System for Doctor's First Report of Injury. Available at: https://www.dir.ca.gov/dwc/Electronic-Reporting-System-for-DFR/Index.htm. Accessed August 4, 2023.
22. Bui DP, Gibb K, Fiellin M, et al. Occupational COVID-19 exposures and illnesses among workers in California—analysis of a new occupational COVID-19 surveillance system. *Int J Environ Res Public Health* 2023;20:6307.
23. National Academies of Sciences, Engineering, and Medicine; Health and Medicine Division; Board on Global Health; Board on Health Sciences Policy, et al. Defining long COVID. In: *A Long COVID Definition: A Chronic, Systemic Disease State With Profound Consequences*. Washington, DC: National Academies Press (US); 2024: Available at: https://www.ncbi.nlm.nih.gov/books/NBK605682/. Accessed May 29, 2025.
24. Alwan NA, Johnson L. Defining long COVID: going back to the start. *Med N Y N* 2021;2:501–504.
25. SARS-CoV-2 Occupational Exposure Risk Matrix or SOEM using O*NET. *CSTE* Available at: https://resources.cste.org/soem-documents/SOEM%20Appendix%201.%20SOEM%20-%20SOC%20and%20COC%20-%208.18.21%20Final.xlsx. Accessed April 5, 2024.
26. Occupational Health Subcommittee Epidemiological Classification of COVID-19 Work-Relatedness and Documentation of Public-Facing Occupations. Available at: https://www.cste.org/page/OHPublications. Accessed March 29, 2024.
27. About the Essential Worker Code Set | NIOSH | CDC. December 19, 2022. Available at: https://www.cdc.gov/niosh/topics/coding/essentialworkers/about.html. Accessed April 4, 2024.
28. Brown LD, Cai TT, DasGupta A. Interval estimation for a binomial proportion. *Stat Sci*. 2001;16:101–117.
29. R Core Team. R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing; 2023.
30. Leitner M, Pötz G, Berger M, Fellner M, Spat S, Koini M. Characteristics and burden of acute COVID-19 and long-COVID: demographic, physical, mental health, and economic perspectives. *PLoS One* 2024;19:e0297207.
31. Al-Oraibi A, Naidu JS, Chaka A, et al. Prevalence of long COVID-19 among healthcare workers: a systematic review and meta-analysis protocol. *BMJ Open* 2022;12:e065234.
32. Zhang J, Yu Y, Chen L. Long COVID in the California Workers' Compensation System - 2024 Update. WCIRB California 2024;1–46. Available at: https://www.wcirb.com/sites/default/files/2024-09/long_covid_in_the_california_workers_compensation_system_-_2024_update_-_2024-09-30.pdf. Accessed July 15, 2025.
33. Division of Workers' Compensation-Disability Evaluation. SB-1159 Workers' Compensation: COVID-19: Critical Workers.; 2020. Available at: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB1159. Accessed April 4, 2024.
34. Líška D, Liptaková E, Babičová A, Batalik L, Baňárová PS, Dobrodenková S. What is the quality of life in patients with long COVID compared to a healthy control group? *Front Public Health* 2022;10:975992.
35. Sun C, Liu Z, Li S, Wang Y, Liu G. Impact of long COVID on health-related quality of life among patients after acute COVID-19 infection: a cross-sectional study. *Inquiry* 2024;61:469580241246461.
36. Kwon J, Milne R, Rayner C, et al. Impact of long COVID on productivity and informal caregiving. *Eur J Health Econ* 2024;25:1095–1115.
37. Valdivieso-Martínez B, Sauri I, Philibert J, et al. Impact of long-COVID on health care burden: a case-control study. *J Clin Med* 2023;12:5768.
38. Gallegos M, Morgan ML, Burgos-Videla C, Caycho-Rodríguez T, Martino P, Cervigni M. The impact of long COVID on people's capacity to work. *Ann Work Expo Health* 2023;67:801–804.
39. Nehme M, Braillard O, Chappuis F, Guessous I. The chronification of post-COVID condition associated with neurocognitive symptoms, functional impairment and increased healthcare utilization. *Sci Rep* 2022;12:14505.
40. Righi E, Mirandola M, Mazzaferri F, et al. Determinants of persistence of symptoms and impact on physical and mental wellbeing in long COVID: a prospective cohort study. *J Infect* 2022;84:566–572.
41. Subramanian A, Nirantharakumar K, Hughes S, et al. Symptoms and risk factors for long COVID in non-hospitalized adults. *Nat Med* 2022;28:1706–1714.
42. Notarte KI, de Oliveira s, Peligro PJ, et al. Age, sex and previous comorbidities as risk factors not associated with SARS-CoV-2 infection for long COVID-19: a systematic review and meta-analysis. *J Clin Med* 2022;11:7314.
43. Thompson EJ, Williams DM, Walker AJ, et al. Long COVID burden and risk factors in 10 UK longitudinal studies and electronic health records. *Nat Commun* 2022;13:3528.
44. Cummings KJ, Materna BL, Vergara X, Beckman J, Espineli C, Harrison R. COVID-19 in the workplace: the view from California. *Ann Am Thorac Soc* 2022;19:1260–1264.
45. Heinzerling A, Nguyen A, Frederick M, et al. Workplaces most affected by COVID-19 outbreaks in California, January 2020–August 2021. *Am J Public Health* 2022;112:1180–1190.
46. California Code of Regulations, Title 8, Section 5199. Aerosol Transmissible Diseases. Available at: https://www.dir.ca.gov/title8/5199.html. Accessed June 20, 2025.
47. Scherlinger M, Pijnenburg L, Chatelus E, et al. Effect of SARS-CoV-2 vaccination on symptoms from post-acute sequelae of COVID-19: results from the nationwide VAXILONG study. *Vaccines (Basel)* 2021;10:46.
48. Tran VT, Perrodeau E, Saldanha J, Pane I, Ravaud P. Efficacy of first dose of COVID-19 vaccine versus no vaccination on symptoms of patients with long COVID: target trial emulation based on ComPaRe e-cohort. *BMJ Med* 2023;2:e000229.
49. Marra AR, Kobayashi T, Suzuki H, et al. The effectiveness of coronavirus disease 2019 (COVID-19) vaccine in the prevention of post–COVID-19 conditions: a systematic literature review and meta-analysis. *Antimicrob Steward Healthc Epidemiol ASHE* 2022;2:e192.
50. Lopez-Leon S, Wegman-Ostrosky T, Perelman C, et al. More than 50 long-term effects of COVID-19: a systematic review and meta-analysis. *Sci Rep* 2021;11:16144.
51. O'Mahoney LL, Routen A, Gillies C, et al. The risk of long COVID symptoms: a systematic review and meta-analysis of controlled studies. *Nat Commun* 2025;16:4249.
52. Order of the State Public Health Officer Health Care Worker Vaccine Requirement. Available at: https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/Order-of-the-State-Public-Health-Officer-Health-Care-Worker-Vaccine-Requirement.aspx. Accessed April 8, 2024.
53. Azaroff LS, Levenstein C, Wegman DH. Occupational injury and illness surveillance: conceptual filters explain underreporting. *Am J Public Health* 2002;92:1421–1429.
54. Reinisch F, Harrison RJ, Cussler S, et al. Physician reports of work-related asthma in California, 1993–1996*. *Am J Ind Med* 2001;39:72–83.
55. Murphy WJ, Longo DL. A possible role for anti-idiotype antibodies in SARS-CoV-2 infection and vaccination. *N Engl J Med* 2022;386:394–396.
56. Couzin-Frankel J, Vogel G. Vaccines may cause rare, long COVID-like symptoms. *Science* 2022;375:364–366.
57. Kreye J, Reincke SM, Kornau HC, et al. A therapeutic non–self-reactive SARS-CoV-2 antibody protects from lung pathology in a COVID-19 hamster model. *Cell* 2020;183:1058–1069.e19.
58. Arjun MC, Singh AK, Pal D, et al. Characteristics and predictors of long COVID among diagnosed cases of COVID-19. *PLoS One* 2022;17:e0278825.
59. Sweis JJG, Alnaimat F, Esparza V, et al. From acute infection to prolonged health consequences: understanding health disparities and economic implications in long COVID worldwide. *Int J Environ Res Public Health* 2024;21:325.
60. Kim J, Lee S, Weir P. Long-COVID is associated with increased absenteeism from work. *PLoS One* 2025;20:e0325280.

