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RESEARCH ARTICLE

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Risk factors for COVID-19 among Californians working outside the home, November 2020 - May 2021

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Abstract

Background: Higher incidences of COVID-19 mortality and outbreaks have been found in certain industries and occupations. Workplace factors, including working in close proximity to others and contact with the public can facilitate SARS-CoV-2 transmission, especially without appropriate protective measures. Limited information is available about workers at highest risk for SARS-CoV-2 infection.

Methods: A phone-based, nonprobability study was conducted between November 2020 and May 2021 among California workers who were tested for SARS-CoV-2. Participants were asked about demographics and workplace factors, including industry, occupation, and implementation of COVID-19 mitigation measures. Using the SARS-CoV-2 occupational exposure matrix, three exposure metrics and a combination index were used to categorize occupations. We assessed the association between workplace risks and SARS-CoV-2 test positivity using adjusted logistic regression.

Results: We enrolled 451 (13%) of 3475 potentially eligible workers in the study: 212 with positive and 239 with negative SARS-CoV-2 test results. Those working very close to others and with the highest combined exposure index had a positive association with SARS-CoV-2 positivity. Primarily indoor workers had a lower odds of test positivity compared to those with any outdoor work. There was no association between public-facing occupations and test positivity. Participants with employers who implemented mitigation measures in all three control categories—engineering, administrative, and personal protective equipment—had lower odds of test positivity than those with fewer mitigation measures.

Conclusions: Worker groups with higher risk factors should be prioritized for outreach. Assessment of occupational risk factors collectively can provide insight to inform preventative actions for workers, employers, and public health entities.

KEYWORDS
California, COVID-19, mitigation measures, occupational health, SARS-CoV-2, workers

[Correction added on 03 February 2023, after first online publication: The authors have added "November 2020 - May 2021" to the title.]

1 | INTRODUCTION

Since the identification of the first California case of COVID-19 in January 2020, the pandemic has continued to have a profound impact in the state, particularly on workers.[1] While many workers shifted to remote work following the California stay-at-home order on March 19, 2020, essential workers, defined by the Center for Disease Control (CDC) as “those who conduct operations and services in industries that are essential to ensure the continuity of critical functions,” faced risks of SARS-CoV-2 exposure and infection working on-site.[2] In the first 9 months of the pandemic, working-age adults experienced 22% excess mortality compared to prior years.[3] Farming, fishing, and forestry; material moving; and construction and extraction occupational groups experienced more than double the average mortality rates of all workers in California.[4]

During the first 6 months of the pandemic, facilities that employed more on-site staff had larger and longer COVID-19 outbreaks.[5] In this period, workplace outbreaks in Los Angeles (LA) County were concentrated in the manufacturing (26.4%), retail trade (19.4%), and transportation and warehousing (10.5%) industries, making up close to 60% of all their nonhealthcare outbreaks.[5] The most common industries for COVID-19 workplace outbreaks in California were in elementary and secondary schools (26.7%), residential care facilities (16.5%), child day care services (7.4%), skilled nursing facilities (6.6%), and restaurant and other food services (4.5%) industries, between January 1, 2020 and March 4, 2022 based on surveillance.[6]

Several workplace factors facilitating the spread of the virus have been posited, including public-facing work involving numerous contacts, working indoors with poor ventilation, and working in close physical proximity to others. Zhang used COVID-19 case numbers from Washington State and Occupational Information Network (O*NET) data to predict SARS-CoV-2 prevalence rates for detailed occupations based on a series of work factors.[7] Among nonhealthcare occupations, they found that the highest risk of infection was among those working in close direct contact to others, such as flight attendants, barbers, and correctional officers, or in occupations involving direct contact with infected persons, such as ambulance drivers and morticians.[7] Limited information is available on the impact of COVID-19 mitigation measures in combating these workplace risks. Healthcare industries and hospital settings were the earliest to implement mitigation measures and had earlier access to personal protective equipment (PPE), unlike other occupational settings.

Limited research has been conducted to identify workers at highest risk of SARS-CoV-2 infection by industry and occupation outside of health care workers (HCW). HCW were viewed as high-risk and closely monitored over the course of the pandemic.[8,9] The availability of occupational information to assess risk of COVID-19 has been primarily limited to outbreak and mortality surveillance data in California. We launched the California COVID-19 Worker Survey Study to assess workplace risk factors associated with COVID-19 disease among non-healthcare workers during the 2020–2021 pandemic period. This assessment of risk factors can help to identify ways to improve protections for workers and reduce SARS-CoV-2 transmission.

2 | MATERIALS AND METHODS

2.1 | Study design and participants

The study utilized a nonprobability sample of California workers who underwent SARS-CoV-2 polymerase chain reaction testing and were identified in two separate data sources, the California SARS-CoV-2 and Respiratory Virus Sentinel Surveillance System (CalSRVSS) and the Los Angeles Public Health Department's (LAPHD) COVID-19 Case Registry. Among the eight participating CalSRVSS counties, we were able to interview participants from seven (Butte, Humboldt, Imperial, San Diego, Santa Clara, Tulare, and Ventura). CalSRVSS and LAPHD contacts performed an initial screen for ineligible individuals using the details of employment in their data system and provided us weekly line lists of potentially eligible workers to contact.

Between November 2, 2020 and May 30, 2021, trained study interviewers contacted working adults aged 18–64 years old for a phone survey. To be eligible for the study, workers must have been working on-site at their workplace in the 14 days before their SARS-CoV-2 test. Workers in healthcare settings were excluded to focus on workers in other industries and occupations. Test-negative participants with a previous SARS-CoV-2 infection less than 90 days ago were ineligible to account for possible immunity. Potential participants were contacted within three weeks of the test date, and three call attempts were made at different times over the course of a week (i.e., daytime, evening, and weekend) before considering them as unreachable. All interviews were conducted in English or Spanish and interviewers obtained verbal consent before administering the questionnaire.

2.2 | Survey instrument and variables

The 48-item questionnaire was developed in partnership with the National Institute for Occupational Safety and Health (NIOSH) as part of a multistate project.[10] Race and ethnicity were collected during the survey and all participants who reported their ethnicity as Hispanic or Latino were categorized as Hispanic/Latino for the race/ethnicity variable. American Indian, Alaska Native, Native Hawaiian, and other Pacific Islanders were grouped as “other race” for analyses. Living arrangement captured whether participants lived in a home or apartment they owned or rented, temporary housing by their employer, did not have reliable housing, or other.

The industry and occupation of participants were collected as free text fields. The free responses were coded based on the 2012 US Census Occupation and Industry Classification System, using the NIOSH Industry and Occupation Computerized Coding System (NIOCCS) and additional manual review.[11] Participants who reported having more than one job were asked the same set of work-related questions for each job they held, with a maximum of three jobs recorded. For this reason, the unit of analysis for all work-related characteristics and factors is job. The data within the unit of analysis (job) may be correlated since persons with more than one job are included in the analyses more than once. Given the small proportion of study participants (4%) who reported more than one job, we ignored these correlations for analysis. Following Census coding, industry and occupation were categorized from detailed titles to larger subgroups. During the pandemic, the Occupational Safety and Health Administration (OSHA) defined exposure risk of SARS-CoV-2 into occupational groups based on the types and number of contacts with others suspected or known to be infected.[12,13] Groups with presumed lower SARS-CoV-2 exposure relative to the others, occupations with the ability to work at distances or without many coworkers/clients present at the time of the survey as defined by OSHA, were combined into an occupation reference category for regression models.[12,13] The occupation reference category included art, design, entertainment, sports, and media; architecture and engineering; business and financial operations; computer and mathematical; and life, physical, and social science. Using a similar approach to identify work environments involving less frequent close contact with others, seven subgroups comprised the industry reference category. These industries were real estate and rental and leasing; arts, entertainment, and recreation; professional, scientific, and technical services; educational services; information; utilities; and finance and insurance.

We chose to use the Council of State and Territorial Epidemiologists SARS-CoV-2 Occupational Exposure Matrix (SOEM), developed using data from the O*NET national database and the input of occupational health and safety experts, to classify nonhealthcare worker occupations into exposure categories for three workplace exposure metrics.[14] These metrics were whether the occupation was public facing, the extent of working indoors or outdoors (primarily indoors, mixed: often indoor, mixed: often outdoor, or primarily outdoors), and physical proximity to others while working (very close, somewhat close, close, or not close). The SOEM matrix provided a combined exposure metric index level for each occupation based on the three metrics mentioned. High-risk exposure for the index included occupations with the highest exposure level for at least two metrics, low exposure included occupations designated as not public facing and not close physical proximity to others, and medium exposure included occupations in all remaining exposure combinations.[14] We used binary exposure metrics by designating exposed as primarily indoors, very close, or high index to ensure sufficient sample size in the category groups for analysis.

Interviewers asked participants whether their employer had implemented 15 different types of COVID-19 mitigation measures. We categorized these mitigation measures into three groups of controls: engineering, administrative, and PPE. We considered mitigation measures to be higher if a participant indicated “yes” to at least one mitigation measure in each of the three groups of controls.

Among the demographic characteristics, age, gender, race/ethnicity, education, income, county of SARS-CoV-2 test, and living arrangements were included as covariates in the logistic regression models. There were three work-related covariates (work transportation, work contact, and contact with a COVID-19 case at work) included. The work transportation variable captured whether the transportation used to commute to and from work and on the job involved potential contact with the general public or other coworkers (yes/no). Participants who reported riding in a private vehicle with others, rideshare, public transportation, or airplane were categorized as “yes,” while all other transportation options including riding in a private vehicle, walking or biking were categorized as “no.” We created a work contact variable which combined information on the number of coworkers/customers (0, 1–9, 10 or more) with whom a participant came into contact (within 6 feet for 15 min or more) each day and the percentage of coworkers/customers (0%, <10%, 10%–49%, 50%–99%, and 100%) who were wearing a face mask. Participants with the highest number of daily close contacts (10 or more coworkers/customers) and reported less than 10% of contacts wore masks were categorized as having high work contact. Participants who had 1–9 daily close contacts or reported that 10%–49% of these contacts wore masks were categorized as having medium work contact. All other combinations were considered low work contact.

2.3 | Data analysis

We assessed the demographic and occupational characteristics of participants, compared with SARS-CoV-2 test result. The DAGGity tool[15] was used to generate directed acyclic graphs (DAGs) that visualized causal pathways and identified potential sources of bias. The DAGs were used to determine the set of covariates to adjust for in our regression models. The DAG for the combined exposure and SARS-CoV-2 test result can be found here. The association between occupational exposures—industry, occupation, employer-implemented mitigation measures, and SOEM exposure metrics—and SARS-CoV-2 test positivity were assessed by logistic regression models. We calculated crude and adjusted odds ratio (OR) and the 95% confidence intervals (95% CI). Results from industries (agriculture, forestry, fishing, and hunting; management, administrative, support, and waste management services) and occupations (farming, fishing, and forestry; installation, maintenance, and repair; personal care services) with cell sizes under five were suppressed from results.

Our nonprobability approach for study recruitment likely introduced selection bias, as participants may have differed systematically from those who were eligible but did not participate. Using county lists of potentially eligible workers ($n = 3475$) with occupation information (41.2%), we assessed selection bias using several explicit assumptions (Supporting Information: Table 1).

All data were analyzed using R version 4.0.2. Selection bias was assessed using R package episensr and intervals were generated with bootstrapping methods.[16,17]

3 | RESULTS

From November 2, 2020 to May 30, 2021, we contacted 3475 California workers. Among the 451 workers enrolled, 47% had SARS-CoV-2 positive results and 53% had SARS-CoV-2 negative results, with response rates of 22.9% and 9.4%, respectively (Figure 1). In the study, 304 (67.4%) workers were from LA, 69 (15.3%) were from Santa Clara, and 78 (17.3%) belonged to the other six counties. More than half of the participants were between 18 and 39 years old (57.9%), male (54.7%), and identified as Hispanic/Latino (59%) (Table 1). Four percent of participants reported having additional job(s) that met our study criteria and these jobs were included in the analyses. Compared with test-negative, test-positive participants more often identified as Hispanic/Latino (79.6% vs. 40.4%), lacked health insurance (22.9% vs. 9.6%), received less education (high school or less) (52.1% vs. 25.1%), and reported lower household annual income (≤$61,000) (73.8% vs. 43.9%). Spanish was the primary language of 16% of participants.

The most common industries reported among test-positive participants were transportation and warehousing (18.4%), retail trade (16.6%), and accommodation and food services (12.4%); while among test-negative participants these were information (15.1%), retail trade (11.6%), and educational services (11.6%). Test-positive participants were most represented in sales and related (16.6%), office and administrative support (15.7%), and material moving and transportation (14.6%) occupations, whereas test-negative participants were most represented in office and administrative support (14.9%); arts, design, entertainment, sports, and media (10.4%); and management (8.8%) occupations. Among the industry groups, transportation and warehousing, wholesale trade, and public administration had the highest ORs when compared with the industry reference group, although with wide confidence intervals (Table 2). Participants with sales and related, management, and protective services occupations had the highest ORs when compared with the occupation reference group.

Some mitigation measures were more commonly reported by test-negative than test-positive participants (Figure 2). More test-negative than test-positive participants reported changes or improvements to workplace ventilation (52.9% vs. 30.4%), worker reassignments (44.4% vs. 27.2%), and COVID-19 screening of customers (53.9% vs. 31.5%). For the provision of PPE, including face masks (not respirators) and hand sanitizer, the proportions were similar among test-negative and test-positive participants. A new question was

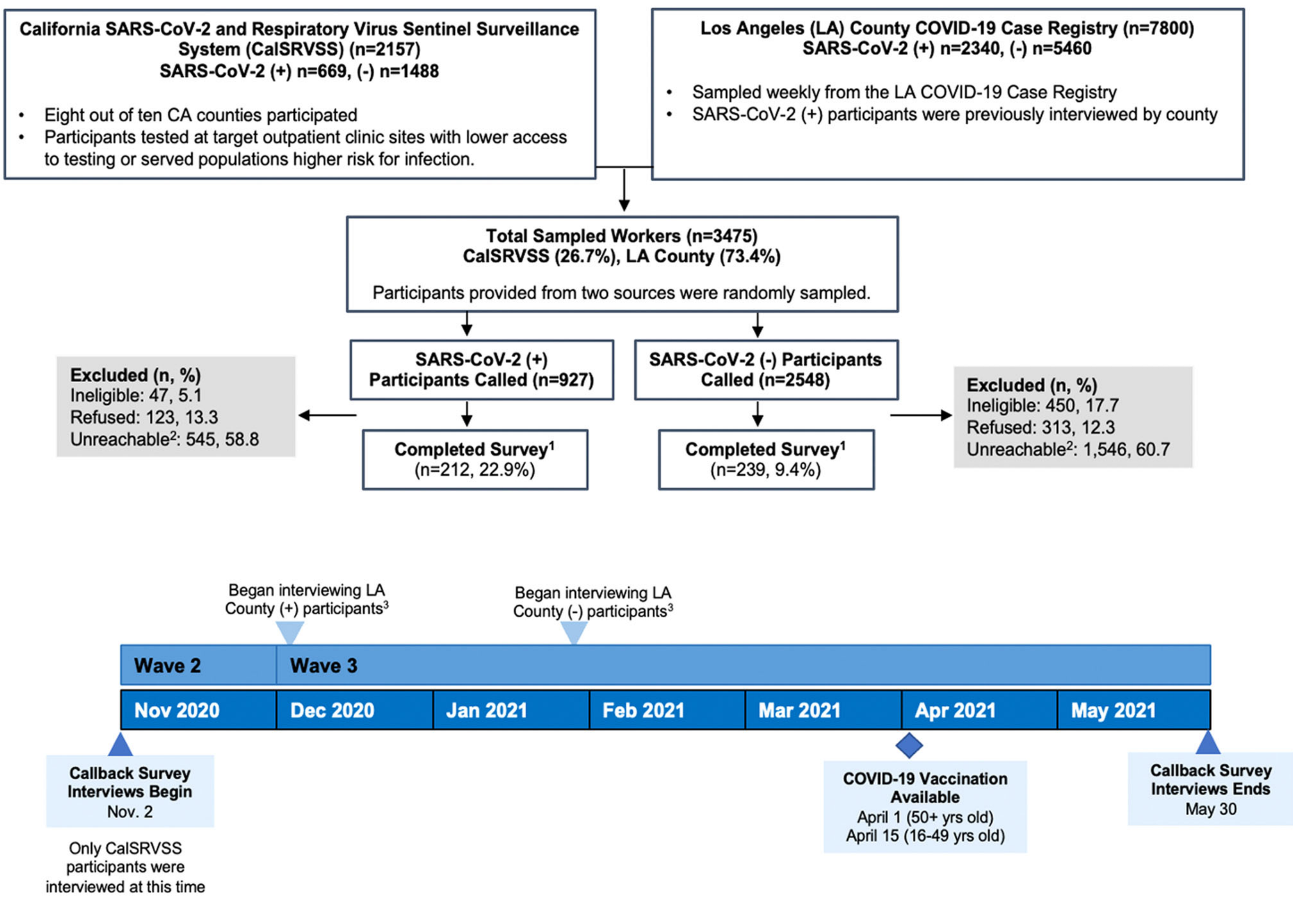

FIGURE 1 California COVID-19 worker survey population flowchart and timeline, November–May 2021. [1]Five SARS-CoV-2 test-negative and one test-positive participant did not finish completing the whole survey. [2]Ineligible participants were those who (1) did not work during 14 days before test, (2) fully teleworked or worked remotely from home, or (3) worked in a healthcare setting or as a healthcare worker. [3]LA county's participation in the Callback Survey began in December. Initially, only SARS-CoV-2 positive participants were provided (December) and later SARS-CoV-2 negative participants (January). CalSRVSS; California SARS-CoV-2 and Respiratory Virus Sentinel Surveillance System; LA, Los Angeles.

TABLE 1 Demographic and work-related factors crude and adjusted odds ratio in the logistic regression between the SOEM combined exposure index and SARS-CoV-2 test result, California COVID-19 worker survey (n = 451)

	Positive, *n* (%)	Negative, *n* (%)	Crude, OR (95% CI)	Adjusted OR[4,5] (95% CI)
Demographic covariates[1]	*n* = 212	*n* = 239		
Age (years)				
18–29	67 (31.6)	76 (31.8)	–	–
30–39	65 (30.7)	53 (22.2)	1.32 (0.82, 2.14)	1.73 (0.89, 3.42)
40–49	33 (15.6)	37 (15.5)	0.97 (0.55, 1.69)	1.88 (0.82, 4.41)
50–59	35 (16.5)	48 (20.1)	0.77 (0.55, 1.69)	1.61 (0.76, 3.45)
60–65	12 (5.7)	25 (10.5)	0.55 (0.25, 1.15)	0.99 (0.34, 2.82)
Gender[2]				
Female	87 (41.2)	116 (48.9)	0.72 (0.50, 1.04)	0.94 (0.54, 1.63)
Male	124 (58.8)	121 (51.1)	–	–
Race/ethnicity[3]				
Hispanic/Latino	168 (79.6)	95 (40.4)	8.35 (4.92, 14.8)	4.65 (2.12, 10.6)
Asian	8 (3.8)	24 (10.2)	1.54 (0.58, 3.82)	1.45 (0.45, 4.41)
Black/African American	10 (4.7)	11 (4.7)	4.55 (1.68, 12.3)	2.22 (0.62, 7.82)
Other race/multirace	6 (2.8)	15 (6.4)	2.33 (0.80, 6.37)	2.04 (0.57, 6.93)
White	19 (9.0)	90 (38.3)	–	–
Education				
<High school (HS)	35 (16.6)	10 (4.3)	10.3 (4.81, 23.9)	2.84 (0.89, 9.61)
HS or equivalent	75 (35.5)	48 (20.8)	4.48 (2.69, 7.57)	2.01 (0.90, 4.50)
Some college/associate degree	64 (30.3)	69 (29.9)	2.60 (1.59, 4.30)	1.11 (0.55, 2.23)
Bachelor's degree or higher	37 (17.5)	104 (45.0)	–	–
Household annual income				
$0–20,000	36 (18.8)	15 (7.3)	5.9 (3.03, 12.0)	–
$21,000–40,000	67 (35.1)	51 (24.9)	3.18 (1.97, 5.17)	–
$41–60,000	38 (19.9)	24 (11.7)	3.69 (1.97, 5.17)	–
$61,000 or more	50 (26.2)	115 (56.1)	–	–
Living arrangement				
House/apartment they owned or rented	206 (97.6)	220 (94.8)	–	–
Employer provided housing/No reliable housing/Other	5 (2.4)	12 (5.2)	0.44 (0.16, 1.11)	0.47 (0.12, 1.63)
Worked-related covariates	*n* = 217	*n* = 254		
Contact with COVID-19 case at work				
Close contact with case	44 (20.4)	23 (9.2)	2.52 (1.48, 4.40)	2.13 (1.02, 4.54)
No close contact with case	172 (79.6)	227 (90.8)	–	–
Work close contact (# of customers/coworkers in contact and % of them wearing masks)				
High work contact	63 (29.2)	82 (32.5)	0.85 (0.57, 1.27)	0.73 (0.41, 1.28)
Low/medium work contact	153 (70.8)	170 (67.5)	–	–

(Continues)

TABLE 1 (Continued)

	Positive, *n* (%)	Negative, *n* (%)	Crude, OR (95% CI)	Adjusted OR[4,5] (95% CI)
Type of work transportation (whether transportation involved potential contact with others (i.e., public transit, carpool, transit with co-workers)				
Contact with others	47 (21.8)	39 (15.4)	1.53 (0.95, 2.45)	1.10 (0.56, 2.18)
No contact with others	169 (78.2)	214 (84.6)	–	–

Abbreviations: CI, confidence interval; OR, odds ratio; SOEM, SARS-CoV-2 occupational exposure matrix.

[1]The *n* displayed for demographic covariates reflect the number of participants. For the analyses (crude and adjusted), the unit of analysis was job and there were (4%) of participants who held more than one job.

[2]One SARS-CoV-2 negative worker reported neither female nor male gender and was not included here.

[3]All workers who reported their ethnicity as Hispanic/Latino were categorized as Hispanic/Latino for race/ethnicity. Other race includes American Indian/Alaska Native and Native Hawaiian/Other Pacific Islander. Workers who selected more than one race were categorized as multirace.

[4]California county of SARS-CoV-2 test variable was adjusted for in the analysis but results are not displayed.

[5]The adjusted ORs for the model with the combined exposure index and SARS-CoV-2 test result are displayed here. Household annual income was not adjusted for in the model.

TABLE 2 Crude and adjusted odds ratios for occupational risk factors (SOEM, employer mitigation, industry, and occupation) and SARS-CoV-2 test result, California COVID-19 worker survey ($n = 451$)

	Positive, *n* (%) (*n* = 217)	Negative, *n* (%) (*n* = 254)	Crude OR (95% CI)	Adjusted OR (95% CI)
SOEM measures				
Close physical proximity[1]				
Very close	170 (78.3)	134 (53.8)	3.10 (2.08, 4.70)	1.70 (0.84, 3.44)
Not very close	47 (21.7)	115 (46.2)	–	–
Public facing[1]				
Public facing	81 (37.3)	84 (33.7)	1.17 (0.80, 1.71)	1.04 (0.47, 2.29)
Not public facing	136 (62.7)	165 (66.3)	–	–
Indoor/outdoor[1]				
Working primarily indoors	131 (60.4)	204 (81.9)	0.34 (0.22, 0.51)	0.41 (0.17, 0.99)
Working in any outdoor capacity	86 (39.6)	45 (18.1)	–	–
Combined exposure index[2]				
High exposure	126 (58.1)	127 (51.0)	1.33 (0.92, 1.92)	1.36 (0.67, 2.77)
Low/medium exposure	91 (41.9)	122 (49.0)	–	–
Employer mitigation measure level[3]				
High mitigation	114 (53.5)	162 (64.3)	0.64 (0.44, 0.93)	0.83 (0.48, 1.43)
Low/medium mitigation	99 (46.5)	90 (35.7)	–	–
Industry major groups[4]				
Industry ref group	24 (11.1)	101 (40.2)	–	–
Accommodation and food services	27 (12.4)	22 (8.8)	5.16 (2.54, 10.7)	2.88 (0.78, 11.0)
Construction	22 (10.1)	13 (5.2)	7.12 (3.20, 16.5)	2.40 (0.55, 10.3)
Health care and social assistance	5 (2.3)	13 (5.2)	1.62 (0.48, 4.76)	1.19 (0.28, 4.50)
Manufacturing	17 (7.8)	18 (7.2)	3.97 (1.79, 8.91)	2.38 (0.79, 7.20)
Other services	9 (4.1)	14 (5.6)	2.71 (1.02, 6.94)	1.31 (0.41, 4.14)
Public administration	13 (6.0)	14 (5.6)	3.91 (1.62, 9.47)	3.29 (0.84, 12.4)
Retail trade	36 (16.6)	29 (11.6)	5.22 (2.72, 10.3)	1.99 (0.71, 5.56)

TABLE 2 (Continued)

	Positive, *n* (%) (*n* = 217)	Negative, *n* (%) (*n* = 254)	Crude OR (95% CI)	Adjusted OR (95% CI)
Transportation and warehousing	40 (18.4)	14 (5.6)	12.0 (5.79, 26.3)	5.55 (2.05, 15.6)
Wholesale trade	7 (3.2)	6 (2.4)	4.91 (1.50, 16.6)	3.41 (0.82, 15.0)
Occupation major groups[5]				
Occ ref group	12 (5.5)	67 (26.9)	–	–
Building, grounds cleaning, and maintenance	14 (6.5)	8 (3.2)	9.77 (3.47, 29.7)	1.54 (0.34, 7.19)
Construction and extraction	16 (6.9)	5 (2.0)	17.9 (5.86, 63.7)	2.68 (0.57, 14.2)
Food preparation and serving related	20 (9.2)	21 (8.4)	5.32 (2.27, 13.0)	1.56 (0.47, 5.26)
Management	12 (5.5)	22 (8.8)	3.05 (1.19, 7.85)	3.46 (1.04, 11.5)
Material moving and transportation	32 (14.7)	16 (6.4)	11.2 (4.87, 27.3)	2.08 (0.69, 6.42)
Office and administrative support	34 (15.7)	37 (14.9)	5.13 (2.43, 11.5)	2.43 (0.95, 6.44)
Production	11 (5.1)	8 (3.2)	7.68 (2.61, 23.9)	2.72 (0.58, 13.7)
Protective service	14 (6.5)	11 (4.4)	7.11 (2.66, 19.9)	2.74 (0.77, 10.1)
Sales and related	36 (16.6)	21 (8.4)	9.57 (4.34, 22.4)	6.17 (2.11, 18.9)

Abbreviations: CI, confidence interval; OR, odds ratio; SOEM, SARS-CoV-2 occupational exposure matrix.

[1]Models adjusted with age, education, living arrangement (not adjusted in the public facing model), employer safety mitigations, industry, occupation, race/ethnicity, California county of SARS-CoV-2 test, gender, work. transportation, and work contact, COVID-19 work known exposure, public facing index, working indoor/outdoor index, and close physical proximity index.

[2]Model adjusted with age, education, living arrangement, employer safety mitigations, industry, occupation, race/ethnicity, California county of SARS-CoV-2 test, gender, work transportation, work contact, and COVID-19 work known exposure.

[3]Model adjusted with age, education, industry, occupation, race/ethnicity, California county of SARS-CoV-2 test, gender, work transportation, work contact, COVID-19 work known exposure, and the combined SOEM exposure index.

[4]Two industry groups (agriculture, forestry, fishing, and hunting; management, administrative, support and waste management services) with cell sizes <5 were excluded from the table. The reference group for industry combined real estate and rental and leasing; arts, entertainment, and recreation; professional, scientific, and technical services; educational services; information; utilities; and finance and insurance. The model adjusted for age, education, mitigation measures, occupation, race/ethnicity, California county of test, gender, work transportation, work close contact, and work-known exposure to COVID-19.

[5]Three occupation groups (farming, fishing, and forestry; installation, maintenance, and repair; personal care services) with cell sizes <5 were excluded from the table. The reference group for occupation combined art, design, entertainment, sports, and media; architecture and engineering; business and financial operations; computer and mathematical; and life, physical, and social sciences. The model adjusted for age, education, mitigation measures, race/ethnicity, county of test, gender, living arrangements, household income, work transportation, work close contact, and work-known exposure to COVID-19.

added on February 22, 2021 to assess perceptions about the feasibility of social distancing at work in a subset of 229 jobs; in 77.8% of the jobs, the participants reported being able to almost always maintain physical distance from others while working. This result was lower than the percentage of participants who reported their employers implemented safe distancing (88.2%). A lower proportion of test-positive participants (53.5%) met the definition of higher level COVID-19 mitigations compared with test-negative participants (64.3%). Among participants who reported higher level of mitigation measures, 91.7% (253/276) agreed with the statement that protecting employees from exposure to COVID-19 was a high priority with management where they worked, while 83.1% (157/189) agreed among those with lower levels of mitigation measures.

Workers with employers who implemented a higher level of mitigation measures had lower adjusted odds of testing positive for SARS-CoV-2 than those in lower levels (OR = 0.83, 95% CI: 0.48–1.43). Those in very close physical proximity to others (OR = 1.70, 95% CI: 0.84–3.44) and those with the highest combined exposure metric index (OR = 1.36, 95% CI: 0.67–2.77) had higher ORs, compared with those not working in very close proximity to others and in the lower exposure index, respectively (Table 2). We did not observe an association between public-facing occupations and test positivity (OR = 1.04, 95% CI: 0.47–2.29). Primarily indoor workers had a 59% lower adjusted odds of test positivity than those with any outdoor work (95% CI 0.17–0.99). Primarily indoor workers reported smaller average household size (2.5 [*SD* = 1.8] versus 3.2 [*SD* = 1.8]) and less exposure to a COVID-19 positive person(s) outside of work (8.6% vs. 29.9%) than those with any outdoor work.

In our assessment of selection bias, we detected differences between unadjusted estimates of participants and screened participants. Adjusting for selection bias based on nonparticipants who were screened, we found the crude association between the close physical proximity measure and SARS-CoV-2 test positivity remained

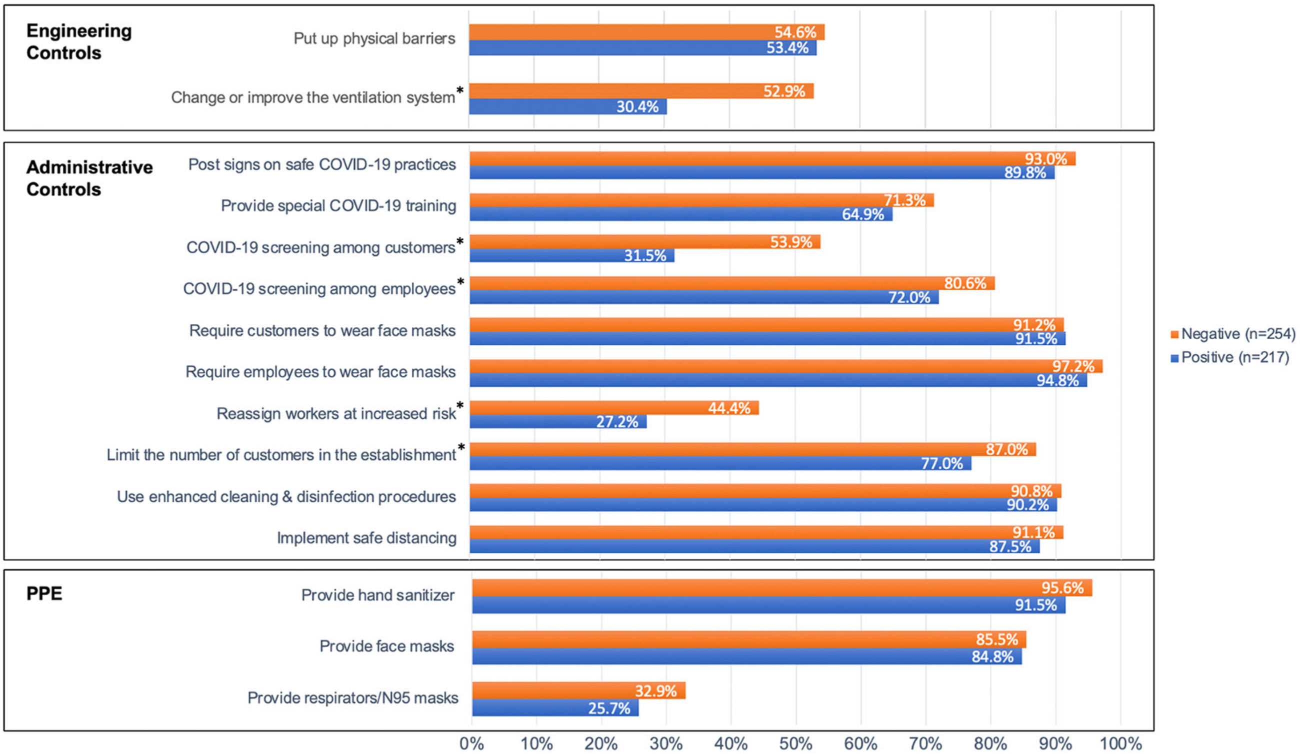

FIGURE 2 COVID-19 mitigation measures implemented by employers as reported by workers, California COVID-19 worker survey ($n = 471$); the unit of analysis is jobs. Workers had more than one job (4%) were asked the mitigation measures questions for each job reported (up to three jobs). *$p < 0.05$ for the χ^2 test comparing the mitigation measures implemented between test-positive and test-negative SARS-CoV-2 participants. PPE, personal protective equipment.

higher than the null (OR = 1.45, 95% CI: 0.95–2.17) (Supporting Information: Table 1).

4 | DISCUSSION

In this nonprobability worker survey, working in very close physical proximity and the highest exposure metric index were positively associated with test positivity after accounting for other factors. Zhang 2020 found occupations at the highest risk of COVID-19 infection were those involving close direct contact with others.[7] Workers in close proximity to others on a frequent or prolonged basis may be vulnerable to SARS-CoV-2 exposure, particularly if there were challenges with implementing mitigations such as physical distancing. Contrary to expected, working primarily indoors appeared protective against test positivity. Selection bias may explain some of this association, but not all. Indoor workers may have taken additional precautions to protect themselves and their employers may have enforced mitigation measures more intently, knowing dilution ventilation is not possible in their work setting. Primarily indoor workers lived in smaller households and were less exposed to infected persons outside of work compared with outdoor workers, which may have been factors outside of work affecting test positivity. There was no association between public-facing occupations and SARS-CoV-2 test positivity in our study. However, previous studies have found increased risk to SARS-COV-2 among workers in customer-facing positions and in direct customer exposure.[9,18]

Participants in the transportation and warehousing industry and the sales and related occupation groups had the highest ORs in relation to SARS-CoV-2 test positivity. The wide confidence intervals around the risk estimates could reflect either a lack of association or truly elevated risk in the context of small-size subgroups by industry and occupation. The findings of prior studies are consistent with elevated risk. Material moving and transportation workers have been found to have one of the highest COVID-19 mortality rates in California[4] and higher risk for severe COVID-19 in a United Kingdom study.[8] Customer facing jobs, commonly in the sales and related occupation sector, were found to have higher risk of SARS-CoV-2 than noncustomer facing ones.[18]

Participants who reported that their employers implemented more mitigation measures had lower odds of test positivity than those with fewer mitigation measures. However, some mitigation measures may not be easily implemented. Participants who reported safe distancing measures at work also reported often being unable to stay 6 feet apart. Understanding of the mitigation measures asked, including distinguishing between different type of face masks (i.e., N95, surgical mask), could have potentially affected participants' self-reporting. Higher than expected percentages were reported among those who were provided respirator masks such as N95s by their employer, during a period of time when N95 availability and access was limited to health care workers.[19,20]

A majority (79.6%) of the SARS-CoV-2 test-positive participants in the study identified as Hispanic/Latino, which was considerably larger than the 37.7% estimate reported among the 2020 California workforce by the US Bureau of Labor Statistics.[21] Both of our sample sources had higher percentages of Hispanic/Latinos. Cooksey et al. noted overrepresentation of Latino workers in the CalSRVSS study population and 49.1% of LA County's population identified as Hispanic/Latino according to the US Census Bureau.[22,23] Socio-economic differences, in particular education and household income, were observed between SARS-CoV-2 test-positive and test-negative participants. Those with lower education and household annual income appeared to experience higher burdens of COVID-19. This observation is consistent with other data/studies that found socio-demographic factors associated with higher incidences and death rates.[24,25]

The study's small sample size introduced wide confidence intervals and restricted our ability to assess COVID-19 risk by industries and occupations. The nonprobability sampling of study participants also introduced nondifferential selection bias to specific industries or occupations. A high proportion of test-negative participants were in the educational services (schools) and information (motion pictures and video, broadcasting) industries, but the least frequent among test-positive participants. Participants from these industries reported periodic SARS-CoV-2 testing as part of a routine work requirement. Industries with routine testing increased the likelihood for participant selection into the study and as test-negatives. Regionally, certain predominant industries may shape the work culture and workplace risks for workers. All 35 jobs within the frequently SARS-CoV-2 screened film and motion pictures industry were from LA County. We explored the possibility of selection bias introduced by nonparticipants and with the potential recall bias from self-reporting, the SOEM provided an *a priori* approach to identify higher exposed occupations albeit likely introducing some degree of exposure misclassification. The study findings may not be representative of all workers in California, as only a subset of all counties was included and participants recruited were predominately from one county (LA) through convenience sampling.

Our study captured workplace exposures and risk factors of California workers in different industry sectors and occupational groups during a highly consequential period of the pandemic when vaccines were not widely available for nonhealthcare workers. Few studies have examined the impact of COVID-19 on different occupational groups outside of healthcare, despite high concentrations of mortality and outbreaks seen distributed in several groups.[3–6] Our study provided a detailed comparison of occupational differences found between SARS-CoV-2 test-positive and test-negative workers. Further assessment of employer mitigation measures provided an added layer of insight into the frequency of the implementation and the protective effect to SARS-CoV-2 test positivity.

The COVID-19 pandemic exposed major gaps in the assessment of factors affecting exposure and morbidity among on-site workers outside of healthcare. Industry and occupational groups identified here and elsewhere as higher risk, such as material moving and warehouse industry settings and sales and related workers, could be further prioritized in preventive efforts, including vaccination outreach. Our collective assessment of occupational risk factors and workplace mitigation measures aimed to provide insight to potential reasons for higher COVID-19 workplace transmissions. Identification of these risks can inform which mitigation measures could help prevent infections; our study identified lower odds of SARS-CoV-2 positivity among workers who reported higher levels of mitigation. COVID-19 work factors and conditions continually change and this study provides essential information to capture shifts, as we see in worker perceptions and public health guidelines.

AUTHOR CONTRIBUTIONS

Kristin Cummings, MD, MPH and Ximena Vergara, PhD, MPH conceptualized the study design and analysis plan. Jessie Wong, MPH, Kathryn Gibb, MPH, Andrea Rodriguez, MPH acquired the data. Jessie Wong and Ximena Vergara analyzed the data. Jessie Wong, Kristin Cummings, Kathryn Gibb, Amy Heinzerling, Ximena Vergara interpreted the results. Jessie Wong, MPH, Kristin Cummings, MD, MPH, and Ximena Vergara, PhD, MPH drafted the manuscript. All authors reviewed, revised, and approved the manuscript. Jessie Wong, MPH agrees to be accountable for investigating and resolving questions related to the accuracy and integrity of the work.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

DATA AVAILABILITY STATEMENT

Research data are not shared.

ETHICS APPROVAL AND INFORMED CONSENT

The California Health and Human Services Agency's Committee for the Protection of Human Subjects determined that this project was exempt from review because the activities involved public health practice/surveillance. Verbal informed consent was received from study participants.

DISCLAIMER

The findings and conclusions in this article are those of the authors and do not necessarily represent the views or opinions of the California Department of Public Health or the California Health and Human Services Agency.

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REFERENCES

1. 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. doi:10.1513/AnnalsATS.202112-1334VP
2. Centers for Disease Control and Prevention. Categories of Essential Workers: COVID-19 Vaccination. CDC; 2022. https://www.cdc.gov/vaccines/covid-19/categories-essential-workers.html
3. Chen YH, Glymour M, Riley A, et al. Excess mortality associated with the COVID-19 pandemic among Californians 18–65 years of age, by occupational sector and occupation: March through November 2020. *PLoS One*. 2021;16(6):e0252454. doi:10.1371/journal.pone.0252454
4. Cummings KJ, Beckman J, Frederick M, et al. Disparities in COVID-19 fatalities among working Californians. *PLoS One*. 2022;17(3):e0266058. doi:10.1371/journal.pone.0266058
5. Contreras Z, Ngo V, Pulido M, et al. Industry sectors highly affected by worksite outbreaks of coronavirus disease, Los Angeles county, California, USA, March 19–September 30, 2020. *Emerging Infect Dis*. 2021;27(7):1769-1775. doi:10.3201/eid2707.210425
6. California Department of Public Health. COVID-19 outbreak data. Accessed March 22, 2020. https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/COVID-19-Outbreak-Data.aspx
7. Zhang M. Estimation of differential occupational risk of COVID-19 by comparing risk factors with case data by occupational group. *Am J Ind Med*. 2021;64(1):39-47. doi:10.1002/ajim.23199
8. Mutambudzi M, Niedzwiedz C, Macdonald EB, et al. Occupation and risk of severe COVID-19: prospective cohort study of 120 075 UK Biobank participants. *Occup Environ Med*. 2021;78(5):307-314. doi:10.1136/oemed-2020-106731
9. Lan FY, Suharlim C, Kales SN, Yang J. Association between SARS-CoV-2 infection, exposure risk and mental health among a cohort of essential retail workers in the USA. *Occup Environ Med*. 2021;78(4):237-243. doi:10.1136/oemed-2020-106774
10. Free H, Luckhaupt SE, Billock RM, et al. Reported exposures among in-person workers with SARS-CoV-2 infection in 6 states, September 2020-June 2021. *Clin Infect Dis*. 2022;75:S216-S224.
11. Centers for Disease Control and Prevention. NIOSH Industry and Occupation Computerized Coding System (NIOCCS); 2018. Accessed March 22, 2022. https://csams.cdc.gov/nioccs
12. The Occupational Safety and Health Administration. Guidance on preparing workplaces for COVID-19. https://www.osha.gov/sites/default/files/publications/OSHA3990.pdf
13. COVID-19 - Hazard Recognition, Occupational Safety and Health Administration. United States Department of Labor. Accessed April 24, 2022. https://www.osha.gov/coronavirus/hazards
14. Council of State and Territorial Epidemiologists Occupational Health Subcommittee. Characterizing the risk of exposure to SARS-CoV-2 among non-health care occupations based on three workplace risk factors: public facing work, working indoors, and working in close physical proximity to others. https://cdn.ymaws.com/www.cste.org/resource/resmgr/occupationalhealth/publications/SOEM.zip
15. Textor J, van der Zander B, Gilthorpe MS, Liśkiewicz M, Ellison GTH. Robust causal inference using directed acyclic graphs: the R package 'dagitty'. *Int J Epidemiol*. 2017;45(6):1887-1894. doi:10.1093/ije/dyw341
16. Lash TL, Fink AK, Fox MP. Selection bias. In: *Applying Quantitative Bias Analysis to Epidemiologic Data*. Springer Science and Business Media, LLC; 2009:43-57.
17. Haine D. Episensr: basic sensitivity analysis of epidemiological results. https://cran.r-project.org/web/packages/episensr/episensr.pdf
18. Wei CF, Lan FY, Hsu YT, et al. Risk of SARS-CoV-2 infection among essential workers in a community-based cohort in the United States. *Front Public Health*. 2022;10:878208. doi:10.3389/fpubh.2022.878208
19. Contrera J. N95 masks save lives. So why are they still hard to get this far into a pandemic? *Washington Post*, Accessed May 9, 2022. https://www.washingtonpost.com/graphics/2020/local/news/n-95-shortage-covid/
20. Noguchi Y. Why N95 masks are still in short supply in the U.S. *NPR*. Published January 27, 2021, Accessed May 9, 2022. https://www.npr.org/sections/health-shots/2021/01/27/960336778/why-n95-masks-are-still-in-short-supply-in-the-u-s.
21. The Economics Daily: U.S. Bureau of Labor Statistics. Hispanics or Latinos made up over one-fourth of the labor force in six states in 2020. Accessed March 22, 2022. https://www.bls.gov/opub/ted/2021/hispanics-or-latinos-made-up-over-one-fourth-of-the-labor-force-in-six-states-in-2020.htm
22. Cooksey GLS, Morales C, Linde L, et al. Severe acute respiratory syndrome coronavirus 2 and respiratory virus sentinel surveillance, California, USA, May 10, 2020-June 12, 2021. *Emerging Infect Dis*. 2022;28(1):9-20. doi:10.3201/eid2801.211682
23. U.S. Census Bureau QuickFacts: Los Angeles County, California. Accessed December 4, 2022. https://www.census.gov/quickfacts/fact/table/losangelescountycalifornia/RHI725221
24. Karmakar M, Lantz PM, Tipirneni R. Association of social and demographic factors with COVID-19 incidence and death rates in the US. *JAMA Network Open*. 2021;4(1):e2036462. doi:10.1001/jamanetworkopen.2020.36462
25. St-Denis X. Sociodemographic determinants of occupational risks of exposure to COVID-19 in Canada. *Can Rev Sociol/Revue canadienne de sociologie*. 2020;57(3):399-452. doi:10.1111/cars.12288

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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