Received: 16 November 2023 | Revised: 15 February 2024 | Accepted: 19 February 2024

DOI: 10.1002/ajim.23579

RESEARCH ARTICLE

AMERICAN JOURNAL OF INDUSTRIAL MEDICINE WILEY

COVID-19 mortality among Massachusetts workers and the association with telework ability, 2020

Kathleen Fitzsimmons PhD, MPH[1] | Malena Hood MPH[2] | Kathleen Grattan MPH[1] | James Laing[1] | Emily Sparer-Fine ScD, MS[1]

[1]Massachusetts Department of Public Health, Occupational Health Surveillance Program, Boston, USA

[2]Massachusetts Department of Public Health, Special Analytic Projects, Office of Population Health, Boston, USA

Correspondence
Kathleen Fitzsimmons, PhD, MPH, Occupational Health Surveillance Program, Massachusetts Department of Public Health, 250 Washington St., Boston, MA 02108, USA.
Email: kathleen.fitzsimmons@mass.gov

Funding information
CDC-NIOSH, Grant/Award Number: U60OH008490; State Overdose Data to Action cooperative agreement # 6NU17CE925012-01-01

Abstract

Background: Working outside the home put some workers at risk for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) exposure and might partly explain elevated coronavirus disease 2019 (COVID-19) mortality rates in the first months of the pandemic in certain groups of Massachusetts workers. To further investigate this premise, we examined COVID-19 mortality among Massachusetts workers, with a specific focus on telework ability based on occupation.

Methods: COVID-19-associated deaths between January 1 and December 31, 2020 among Massachusetts residents aged 18–64 years were analyzed. Deaths were categorized into occupation-based quadrants (Q) of telework ability. Age-adjusted rates were calculated by key demographics, industry, occupation, and telework quadrant using American Community Survey workforce estimates as denominators. Rate ratios (RRs) and 95% confidence intervals comparing rates for quadrants with workers unlikely able to telework (Q2, Q3, Q4) to that among those likely able to telework (Q1) were calculated.

Results: The overall age-adjusted COVID-19-associated mortality rate was 26.4 deaths per 100,000 workers. Workers who were male, Black non-Hispanic, Hispanic, born outside the US, and with lower than a high school education level experienced the highest rates among their respective demographic groups. The rate varied by industry, occupation and telework quadrant. RRs comparing Q2, Q3, and Q4 to Q1 were 0.99 (95% confidence interval [CI]: 0.8–1.2), 3.2 (95% CI: 2.6–3.8) and 2.5 (95% CI: 2.0–3.0), respectively.

Conclusion: Findings suggest a positive association between working on-site and COVID-19-associated mortality. Work-related factors likely contributed to COVID-19 among Massachusetts workers and should be considered in future studies of COVID-19 and similar diseases.

KEYWORDS
COVID-19, epidemiology, Massachusetts, occupational health, SARS-CoV-2, telework

1 | INTRODUCTION

While the health of many adults has been impacted by the coronavirus disease 2019 (COVID-19) pandemic, certain groups have been disproportionately affected by virtue of their jobs. Work, a core social determinant of health, is a potential risk factor for exposure to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes COVID-19, and has likely contributed to racial and economic inequities in COVID-19 outcomes.[1–12]

Early in the pandemic, workplace outbreaks as well as individual work-related cases of COVID-19 were documented in a variety of industries.[1,7,13–17] Most COVID-19 cases identified in the first 2 weeks of the Massachusetts epidemic were part of a work-related cluster, and 12% of confirmed COVID-19 cases in Utah through early June 2020 were associated with workplace outbreaks.[7,16] In addition, population-based studies have shown differences in risk of infection and mortality by industry and occupation,[18–25] and findings from surveys of infected workers in several US states noted occupational exposures.[5,6] Factors that influence occupational exposure risk to SARS-CoV-2 include those related to the nature of work, such as working indoors or in close proximity to others (e.g., coworkers, patients, clients, customers), as well as access to employer-provided protective measures, and paid sick leave.[1,6,8,11,13,19,25–38]

Throughout the pandemic many workers had to leave home to do their jobs, putting them at risk of infection and of transmitting SARS-CoV-2 to their families and communities. Nationally, just before the pandemic, only an estimated 25% of the US workforce were in jobs that could be done by teleworking, and workers in these jobs earned higher median wages compared to those in jobs that could not be performed remotely.[39] On March 10, 2020, a state of emergency was declared in Massachusetts, and businesses and organizations not deemed to provide "essential services" were ordered to close or transition to remote work 2 weeks later.[40,41] In the early months of the pandemic, studies found higher rates of COVID-19 in Massachusetts communities with greater percentages of workers in essential services, many of whom were likely unable to telework.[42,43] An analysis by Hawkins et al.[22] of Massachusetts death certificate data from March-July 2020 found that COVID-19 age-adjusted mortality rates among workers aged 18-64 years varied by occupation group, with 11 groups having higher than average rates. The authors posited that one potential reason for the elevated rates in some groups was that they were more likely to have to work on-site rather than being able to telework, putting them at risk of occupational exposure.

With the analysis described here, we expanded upon the work of Hawkins et al.[22] in three ways: (1) we included the remaining 5 months of death data for 2020, nearly doubling the number of deaths for analysis; (2) we applied an updated (as of December 22, 2021) surveillance case definition for a COVID-19-associated death[44]; and, (3) we examined the association between COVID-19 mortality and telework ability based on occupation. Our objective was to characterize COVID-19 mortality among working-aged Massachusetts residents in 2020 and identify high-risk groups to highlight potential inequities and inform prevention efforts. We also examined the association between COVID-19 mortality and telework ability based on occupation to understand the potential impact of this work-related factor on COVID-19 risk. We hypothesized that mortality rates would be higher among workers in occupations less suitable for teleworking.

2 | METHODS

The analysis included Massachusetts residents aged 18–64 years who died of COVID-19 between January 1, 2020 and December 31, 2020 and for whom information on occupation was available in the Massachusetts electronic death certificate data. A death was considered to be COVID-19-associated if the decedent was positive for COVID-19 within 30 days of death in the Massachusetts Virtual Epidemiologic Network (MAVEN) infectious disease reporting system or had the International Classification of Diseases, Tenth Revision (ICD-10) code for COVID-19 (U07.1) as the underlying or contributing cause of death in the death certificate data.[44] Information about usual occupation and industry on death certificates was coded according to the 2010 Standard Occupational Classification (SOC) system and 2012 North American Industry Classification System (NAICS), respectively, using the National Institute for Occupational Safety and Health (NIOSH) Industry and Occupation Computerized Coding System (NIOCCS) with additional manual review.[45] All NIOCCS-assigned codes with a probability score (confidence rating generated by NIOCCS) < 0.90 were reviewed. This represented 15.6% of the deaths and ultimately 95 industry codes and 79 occupation codes were changed from the NIOCCS assigned code. The American Community Survey (ACS) 5-Year Public Use Microdata Sample for 2016–2020 was used for civilian workforce estimates.

Counts and age-adjusted rates of COVID-19-associated death per 100,000 employed persons (i.e., workers) were calculated by NAICS industry sector, major SOC occupation group, sex (male; female), combined race and Hispanic ethnicity (American Indian/Alaska Native non-Hispanic; Asian/Pacific Islander non-Hispanic; Black non-Hispanic; Hispanic; White non-Hispanic; Other non-Hispanic), nativity (foreign-born; US-born), and education level (less than high school; high school or GED; some college/associate/bachelor's/certificate; master's degree or higher). Rates were age-adjusted to the 2000 US population according to four age groups (18–24, 25–34, 35–44, 45–64 years). Calculations based on counts of 1–4 were suppressed. Analyses were conducted using SAS Studio (version 3.8; SAS Institute Inc.).

2.1 | Assigning exposure: Telework ability

Deaths with occupation information were categorized into four quadrants (Q1–Q4) of telework ability based on six-digit SOC-2010 codes according to Baker,[39] using a detailed table that was requested and received from the author (Marissa Baker, PhD, e-mail communication, November 19, 2021). The four quadrants represent different combinations of the importance of two factors—computer use and interaction with the public (Table 1).

TABLE 1 Description of telework quadrants as defined by Baker.[39,a]

Telework quadrant (Q)	Telework ability	Occupation characteristics	Example occupations
1	Likely able to work from home	Computers important OR very important OR extremely important AND Public interaction not important OR somewhat important	Software developer; Computer programmer; Financial analyst; Accountant; Human resources manager; Marketing manager; Statistician; Editor; Data entry clerk; Medical transcriptionist
2	Not likely able to work from home	Computers important OR very important OR extremely important AND Public interaction important OR very important OR extremely important	Firefighter; Police officer; Paramedic; Airline Pilot; Physician; Dentist; Registered nurse; Pharmacist; Social worker; Retail salesperson; Real estate broker; Elementary school teacher; Librarian; Lawyer; Receptionist
3	Not likely able to work from home	Computers not important OR somewhat important AND Public interaction not important OR somewhat important	Construction laborer; Janitor or cleaner; Landscaper; Agricultural worker; Food production worker; Textile machine operator; Machinery maintenance worker; Ship captain; Rail transportation worker; Freight, stock and material moving worker; Courier; Personal care aide; Nursing assistant
4	Not likely able to work from home	Computers not important OR somewhat important AND Public interaction important OR very important OR extremely important	Bartender, Waiter, Food preparation worker; Hair stylist; Manicurist, Massage therapist; Security guard; Childcare worker, Cashier, Mail carrier; Delivery driver; Flight attendant; Bus driver; Taxi driver; Home health aide

[a]Baker.[39]

Generating workforce estimates by telework quadrant involved cross-walking occupation codes from multiple SOC systems. First, six-digit SOC-P codes from the ACS were match-merged with SOC-2018 codes. Then, using a standard crosswalk, SOC-2018 codes were merged with SOC-2010 codes. The SOC-P/SOC-2010 merges were manually reviewed for alignment across the two classification systems, and this "aligned" file was linked with the Baker file of quadrant-specific SOC-2010 codes to assign quadrants to the ACS data. Decision logic was applied for re-assigning a quadrant when multiple SOC-2010 occupations were linked with only one SOC-P occupation.

Counts and age-adjusted rates of COVID-19-associated death (per 100,000 workers) were calculated for each quadrant. Rate ratios (RRs) and 95% confidence intervals comparing the age-adjusted rate among workers in each quadrant determined by Baker[39] to be unlikely able to work from the home (Q2–Q4) to the age-adjusted rate among those likely able to work from home (Q1) were calculated.

2.2 | Sensitivity analysis

A review of individual occupations classified by Baker[39] as likely able to telework (Q1), revealed that some occupations, particularly those in the 2-digit SOC groups of 49 (Installation, Maintenance, and Repair Occupations), 51 (Production Occupations) and 53 (Transportation and Material Moving Occupations) might have been misclassified as teleworking (i.e., Q1) when they should have been classified as working outside the home (i.e., Q3). All but one occupation of SOC 49, 51, and 53 occupations in Q1 (SOC 51-6092 Fabric and Apparel Patternmakers) were classified as working outside the home by Vergara and Gibb.[33] If these occupations were misclassified and had a higher risk of COVID-19-associated mortality, then the rate in Q1 would be overestimated and the effect of working outside the home on COVID-19-associated mortality would be underestimated (i.e., the RR of Q3 vs. Q1 would be biased toward the null). Additionally, if the deaths in these misclassified occupations were more likely to be among Black Non-Hispanic or Hispanic workers, then the RRs for these workers would be most altered (i.e., most biased to the null). To assess this, a sensitivity analysis was conducted in which all occupations within 2-digit SOC groups 49, 51, and 53 from Q1 (reference) were reclassified to Q3 and the impact on the rates was evaluated.

This study was performed at the Massachusetts Department of Public Health (MDPH). It was conducted within the scope of existing reviewed and approved surveillance activities, did not involve human subjects research, and did not require additional Institutional Review Board review.

3 | RESULTS

Of the 13,756 deaths among Massachusetts residents aged 18–64 years between January 1 and December 31, 2020, 1,366 (9.9%) were COVID-19-associated. Of these, the vast majority (93.7%) were COVID-19-positive within 30 days of death in MAVEN. An additional 86 deaths had COVID-19 as an underlying or contributing cause of

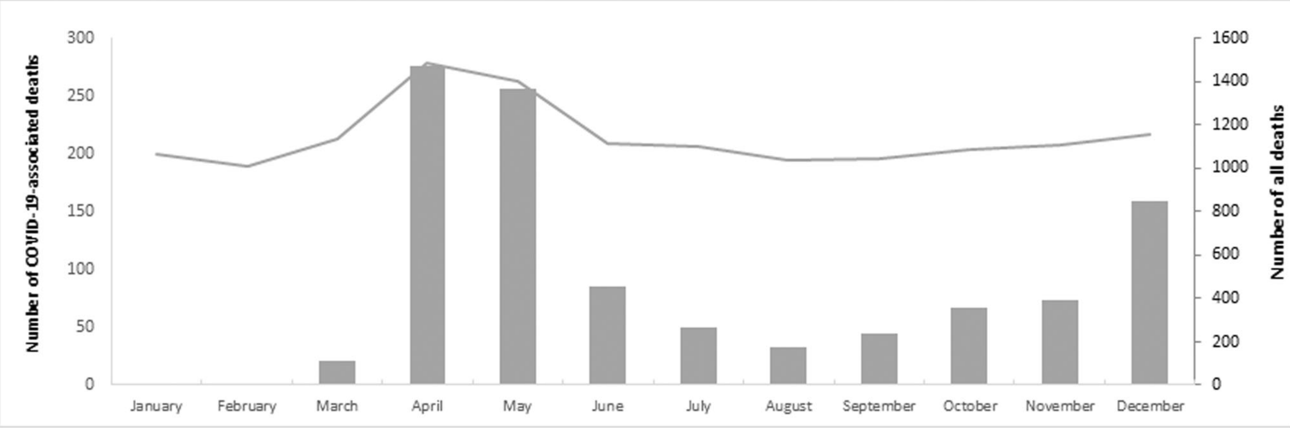

FIGURE 1 Counts of overall and COVID-19-associated deaths among Massachusetts residents aged 18–64 years by month, 2020.

death. Two hundred and 99 deaths were excluded because the death certificate indicated that the decedent was not working/retired/never worked (*n* = 115), a homemaker (*n* = 84), a student (*n* = 3), or had insufficient occupation information (*n* = 97). This resulted in 1067 deaths for the final analysis.

As shown in Figure 1, half (49.9%, *n* = 533) of these deaths occurred in April and May of 2020, and then the monthly count declined for several months and increased again in December. Of the 1067 deaths, 90% (*n* = 956) occurred among those aged 45–64 years. The age-adjusted COVID-19-associated death rate was 26.4 deaths per 100,000 workers (Table 2). The rate was higher for male compared to female workers, Black non-Hispanic and Hispanic workers compared to any other race/ethnicity group examined, those who were born outside the US compared to those born in the United States, and those with lower than a high school level of education compared to any other education level. Black non-Hispanic and Hispanic workers had rates more than three times the rate for White non-Hispanic workers (74.4 and 65.2, respectively vs. 18.8 per 100,000 workers).

As shown in Figure 2, the greatest number of COVID-19-associated deaths was in the Health care and social assistance (*n* = 180) industry group followed by Manufacturing (*n* = 131) and Construction (*n* = 125). Age-adjusted COVID-19-associated mortality rates were highest in the following industry groups: Agriculture, forestry, fishing and hunting (118.3 deaths per 100,000); Accommodation and food services (52.7); Construction (47.7); Transportation and warehousing (42.1); and Administrative and support and waste management and remediation (40.5). Figure 3 presents COVID-19-associated mortality findings by occupation group. The greatest number of COVID-19-associated deaths was among workers in Transportation and material moving (*n* = 118) occupations followed by Construction and extraction (*n* = 113) and Office and administrative support (*n* = 100) occupations. The highest age-adjusted rates were in the following occupation groups: Construction and extraction (60.3 per 100,000); Installation, maintenance, and repair (56.3); Transportation and material moving (54.6); Food preparation and serving (48.5); and Personal care and service occupations (48.0).

Table 3 shows the counts and age-adjusted rates of COVID-19-associated death by telework quadrant (Q) overall and by demographic characteristics. Overall, rates were 17.6 per 100,000 (95% CI: 15.1–20.2) for Q1, 17.4 (95% CI: 15.5–19.3) for Q2, 56.0 (95% CI: 49.8–62.2) for Q3 and 43.1 (95% CI: 37.6–48.5) for Q4. Because the rates across quadrants 2, 3, and 4 varied, we compared them separately to the reference group (Q1) rather than collapsing into a single "work outside the home" group. As shown in Table 4, compared to the rate for Q1 ("likely able to work from home"), the rate for Q2 was similar (RR = 0.99; 95% CI: 0.8–1.2), the rate for Q3 was three times higher (RR = 3.2; 95% CI: 2.6–3.8), and the rate for Q4 was 2.5 times higher (RR = 2.5; 95% CI: 2.0–3.0). The findings for Q2 were fairly consistent across all demographic strata, and those for Q3 and Q4 were fairly consistent across strata of sex and nativity. There was effect measure modification by race/ethnicity and education, although some estimates were imprecise as evidenced by the wide confidence intervals. By race/ethnicity, the effect was strongest for Asian/Pacific Islander non-Hispanic and White non-Hispanic workers. By education, the effect was strongest for those with the highest level of education (some college/associate/bachelor's degree/certificate).

The results of the sensitivity analysis are presented in Table 5. Overall, this reclassification resulted in 39 decedents and an estimated 81,386 workers being shifted from Q1 to Q3. Across race/ethnicity groups, it resulted in a decrease in age-adjusted rates in Q1, but had little impact on the rates in Q3 and did not change our conclusions.

4 | DISCUSSION

We examined the distribution of COVID-19-associated deaths among working-aged (i.e., 18–64 years) Massachusetts residents in 2020 by industry, occupation and other key demographic factors, as

TABLE 2 Counts and age-adjusted rates of COVID-19-associated death by demographic characteristics, Massachusetts workers aged 18–64 years, 2020.

Characteristic	COVID-19-associated deaths *n* (%)	Rate per 100,000 workers (95% CI)
All workers	1067	26.4 (24.8–28.0)
Age groups (years)		
18–24	7 (0.7%)	1.7 (0.2–5.0)
25–34	32 (3.0%)	4.0 (1.1–8.7)
35–44	72 (6.7%)	10.4 (5.1–17.6)
45–54	225 (21.1%)	30.2 (26.3–34.2)
55–64	731 (68.5%)	112.4 (104.2–120.5)
Sex		
Male	736 (69.0%)	35.9 (33.3–38.5)
Female	331 (31.0%)	16.6 (14.8–18.3)
Race/ethnicity		
American Indian/Alaska Native Non-Hispanic	4 (0.4%)	–
Asian/Pacific Islander non-Hispanic	37 (3.5%)	18.2 (10.8–27.4)
Black non-Hispanic	172 (16.1%)	74.4 (63.3–85.6)
Hispanic	214 (20.1%)	65.2 (56.5–73.9)
White Non-Hispanic	619 (58.0%)	18.8 (17.3–20.3)
Other Non-Hispanic	18 (1.7%)	31.6 (21.5–43.5)
Nativity		
Foreign-born	310 (29.1%)	39.0 (34.7–43.4)
US-born	753 (70.6%)	23.1 (21.5–24.8)
Education		
Less than high school	137 (12.8%)	126.3 (105.1–147.4)
High school or GED	544 (51.0%)	52.9 (48.4–57.3)
Some College/Associate/Bachelor's/Certificate	324 (30.4%)	15.9 (14.2–17.7)
Master's degree or higher	39 (3.7%)	8.9 (4.1–15.7)

Note: Rate denominator: Estimated average annual number of workers ages 18–64 in Massachusetts, American Community Survey, PUMS 2016–2020. For age groups, rates are age-stratum specific rates. All other rates are age-adjusted to the 2000 US population. Rates based on counts of 1–4 are suppressed. Sex is noted on the death certificate as male, female, unknown. There were no deaths with "unknown" sex in the final analytic data set.

well as the association with telework ability. Deaths from COVID-19 comprised 9.9% of all deaths among this age group in 2020. Counts were highest in the early months during the first wave of the pandemic and again in late 2020 during the start of the second wave. We identified 689 COVID-19-associated deaths from March to July, which was greater than the number analyzed by Hawkins et al.[22] ($n = 555$) for the same time period. Including deaths from the remainder of 2020 brought the total number included in this study to 1067, nearly double the number from the prior study.[22] Along with the additional 5 months of mortality data used in our study, the updated, more sensitive definition of COVID-19-associated death might account for this difference.[44] The overall age-adjusted rate of 26.4 COVID-19-associated deaths per 100,000 workers (95% confidence interval [CI]: 25.1–27.8) in Massachusetts was slightly lower than the rates reported for workers in California (30.0 per 100,000 workers, 95% CI: 29.3–30.8) and the US (28.6, 95% CI: 28.2–29.0) in 2020.[23,24] Worth noting, differences in denominator sources and a slight difference in the age range in the United States study (i.e., 16–64 years) might partly account for these differences in rates.

Stratified analyses highlight the importance of considering intersecting identities when examining rates of COVID-19 mortality.

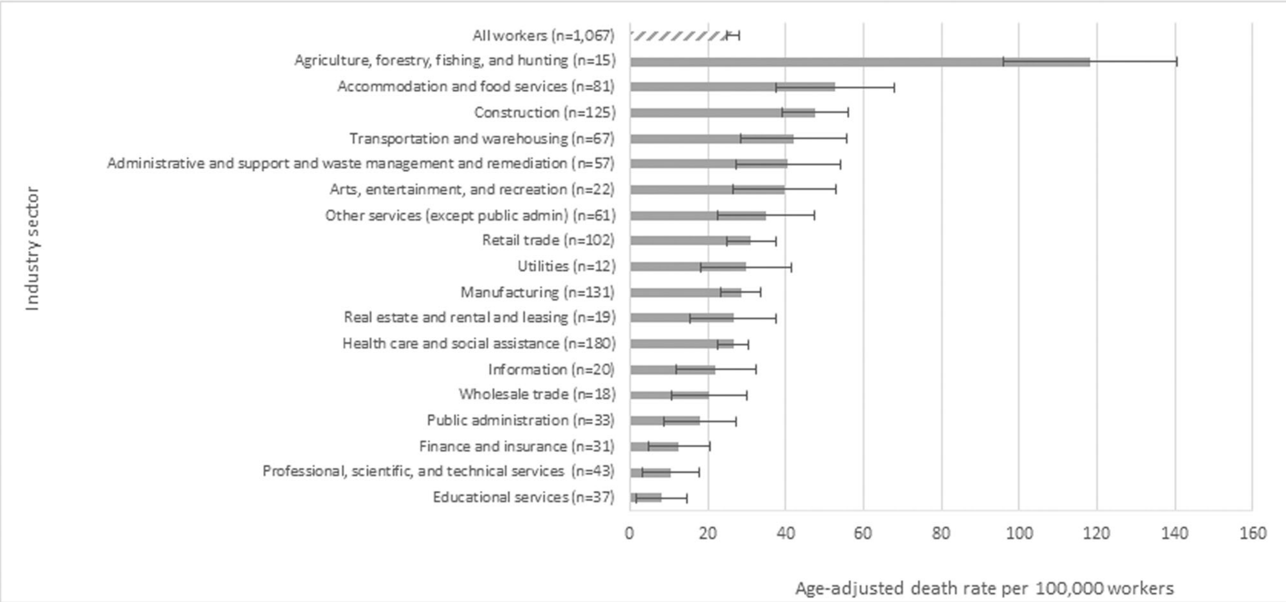

FIGURE 2 Age-adjusted rates of COVID-19-associated death by industry, Massachusetts workers aged 18–64 years, 2020, *n* = 1067*. *This figure excluded 13 deaths among those working in the military industries due to lack of denominator information or because the death certificates did not contain sufficient information to code industry. Age adjusted to the 2000 US population. Denominator source: American Community Survey, 2016–2020.

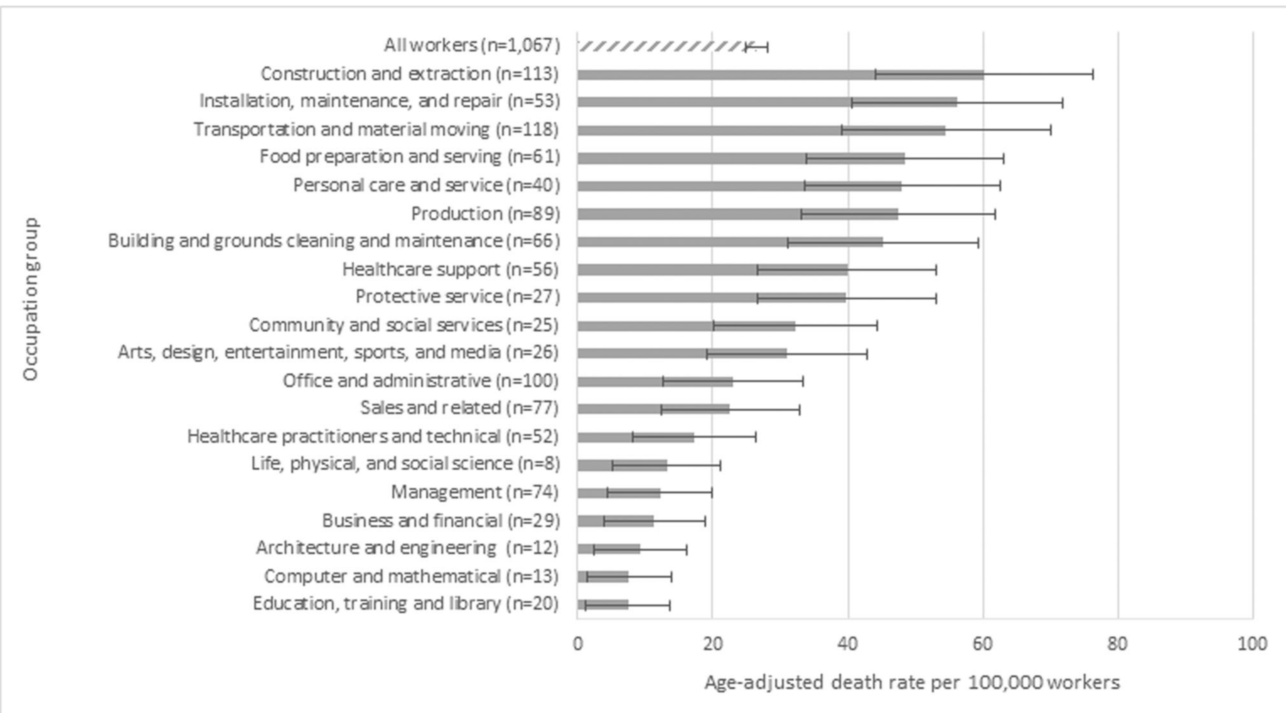

FIGURE 3 Age-adjusted rates of COVID-19-associated death by occupation, Massachusetts workers aged 18–64 years, 2020, *n* = 1,067*. *Age adjusted to the 2000 US population. Rates for Farming, Fishing, and Forestry occupations (SOC 45-0000, *n* = 4) and Legal occupations (SOC 23-0000, *n* = 4) were suppressed. Denominator source: American Community Survey, 2016–2020.

TABLE 3 Counts and age-adjusted rates of COVID-19-associated death by telework quadrant and demographic characteristics, Massachusetts workers aged 18–64 years, 2020.

	Quadrant 1		Quadrant 2		Quadrant 3		Quadrant 4	
Demographics	*n*	Rate per 100,000 workers (95% CI)	*n*	Rate per 100,000 workers (95% CI)	*n*	Rate per 100,000 workers (95% CI)	*n*	Rate per 100,000 workers (95% CI)
All workers	181	17.6 (15.1–20.2)	330	17.4 (15.5–19.3)	314	56.0 (49.8–62.2)	242	43.1 (37.6–48.5)
Race/ethnicity								
Asian/Pacific Islander non-Hispanic	10	13.5 (7.3–21.7)	10	14.2 (7.8–22.5)	10	37.6 (26.6–50.6)	7	19.8 (12.1–29.5)
Black non-Hispanic	26	76.5 (60.4–94.6)	57	59.6 (45.4–75.6)	49	100.3 (81.6–120.8)	40	78.4 (62–96.7)
Hispanic	28	59.0 (44.9–75)	37	33.8 (23.4–46.1)	74	90.4 (72.7–110)	75	79.3 (62.8–97.6)
White Non-Hispanic	112	12.6 (10.3–14.9)	223	13.9 (12–15.7)	172	42.8 (36.4–49.3)	112	29.9 (24.4–35.4)
American Indian/Alaska Native Non-Hispanic/ Other Non-Hispanic	3	–	3	–	8	48.1 (35.5–62.6)	8	43.4 (31.5–57.3)
Sex								
Male	130	23.1 (19.1–27.1)	192	23.4 (20.1–26.7)	236	64.5 (56.2–72.7)	178	58.5 (49.9–67.1)
Female	51	10.9 (5.4–18.3)	138	12.8 (10.7–14.9)	78	39.6 (28.2–52.8)	64	24.8 (16–35.5)
Nativity								
Foreign-born	46	26.5 (17.4–37.5)	64	24.0 (15.3–34.5)	106	66.2 (53.6–78.8)	94	49.4 (36.6–64)
US-born	135	15.9 (13.2–18.6)	265	16.3 (14.3–18.2)	206	51.1 (44.1–58.1)	147	40.0 (33.6–46.5)
Education								
Less high school	20	192.6 (166.3–220.7)	12	87.0 (69.7–106.2)	62	147.9 (125–172.7)	43	103.2 (84.2–124)
High school or GED	77	45.5 (33.3–59.7)	130	47.6 (39.4–55.8)	183	61.7 (52.8–70.7)	154	53.5 (45.1–62)
Some College/Associate/ Bachelor's degree/ Certificate	72	12.1 (6.3–19.9)	158	15.2 (12.9–17.6)	57	29.0 (19.4–40.5)	37	17.3 (10.2–26.4)
Master's degree or higher	10	4.1 (1.1–8.9)	25	4.1 (1.2–9.0)	4	–	0	0.0

Note: Telework quadrant 1 = "likely able to work from home" and quadrants 2–4 = "likely need to work outside the home." Rate denominator: Estimated average annual number of workers ages 18–64 in Massachusetts, by Occupation (SOC 2010), ACS PUMS 2016–2020. Age-adjusted to the 2000 US population. Rates based on counts of 1–4 are suppressed. Sex is noted on the death certificate as male, female, unknown. There were no deaths with "unknown" sex in the final analytic data set.

The finding that males had a substantially higher rate compared to females was consistent with previous reports.[22,23,46] Also consistent with prior studies, findings indicated profound racial/ethnic disparities in mortality rates among workers.[22,23] Rates for Hispanic and Black non-Hispanic workers were two to three times higher than those for the other racial/ethnic groups examined. Additionally, the rate was markedly higher for foreign-born individuals than their US-born counterparts. Structural racism and systemic oppression results in workers of color and immigrant workers being disproportionately employed in jobs with low wages, hazardous working conditions, and inadequate employment-related resources, and underpins the observed disparities in COVID-19 outcomes.[8,42,47–49]

We found differences in age-adjusted mortality rates across industry and occupation groups. To specifically assess the relationship between teleworking ability and COVID-19-associated mortality, we compared rates among workers in occupation-based quadrants determined by Baker[39] to be most likely to work outside the home to the rate among those most likely able to telework. Rather than dichotomizing exposure, we compared each of the rates in the "work outside the home" quadrants (Q2, Q3, Q4) to the rate in the "work from home" quadrant (Q1). Rates among those workers in Q3 and Q4 were notably higher than the rate for Q1, whereas the rate for those in Q2 did not differ from the reference group. Workers in Q3 had the highest rates across nearly all strata of demographics. We discuss a few potential reasons for these findings below.

First, differences in factors related to the nature of work (e.g., working in close proximity to others, working indoors) and workplace prevention measures (e.g., ventilation, physical distancing, or personal protective equipment) might have altered on-the-job SARS-CoV-2 exposure risk. Prior studies have suggested that occupational exposure risk varied by income and that workers in low-wage jobs were at increased risk.[34,38] According to Baker,[39] US workers in

TABLE 4 Rate ratios comparing the age-adjusted rate of COVID-19-associated death in each telework quadrant 2–4 ("likely to work outside the home") to the rate in quadrant 1 ("likely able to work from home") by demographic characteristics, Massachusetts workers aged 18–64 years, 2020.

Characteristic	Quadrant 2	Quadrant 3	Quadrant 4
All workers	0.99 (0.8–1.2)	3.2 (2.6–3.8)	2.5 (2.0–3.0)
Race/ethnicity			
Asian/Pacific Islander non-Hispanic	1.0 (0.4–2.6)	2.8 (1.1–6.9)	1.5 (0.6–3.99)
Black non-Hispanic	0.8 (0.5–1.2)	1.3 (0.8–2.1)	1.0 (0.6–1.7)
Hispanic	0.6 (0.3–0.9)	1.5 (0.99–2.4)	1.3 (0.9–2.1)
White non-Hispanic	1.1 (0.9–1.4)	3.4 (2.7–4.3)	2.4 (1.8–3.1)
Sex			
Male	1.0 (0.8–1.3)	2.8 (2.2–3.5)	2.5 (2.0–3.2
Female	1.2 (0.8–1.6)	3.6 (2.5–5.2)	2.3 (1.6–3.3)
Nativity			
Foreign-born	0.9 (0.6–1.3)	2.5 (1.8–3.5)	1.9(1.3–2.7)
US-born	1.0 (0.8–1.3)	3.2 (2.6–4.0)	2.5 (2.0–3.2)
Education			
Less high school	0.5 (0.2–0.9)	0.8 (0.5–1.3)	0.5 (0.3–0.9)
High school or GED	1.0 (0.8–1.4)	1.4 (1.0–1.8)	1.2 (0.9–1.6)
Some college/ associate/ bachelor's degree/certificate	1.3 (0.9–1.7)	2.4 (1.7–3.4)	1.4 (0.9–2.1)
Master's degree or higher	1.0(0.5–2.1)	5.2 (1.6–16.9)	–

Note: Rate ratios are not calculated if either rate is suppressed (i.e., count 1–4).

TABLE 5 Sensitivity analysis: Counts and age-adjusted rates of COVID-19-associated death for reclassified telework quadrants 1 and 3 by race/ethnicity, Massachusetts workers aged 18-64 years, 2020.

	Quadrant 1		Quadrant 3	
Race/ Ethnicity	*n*	Rate per 100,000 workers (95% CI)	*n*	Rate per 100,000 workers (95% CI)
Asian/PI non-Hispanic	8	11.7 (5.0–23.0)	12	36.9 (19.1–64.5)
Black non-Hispanic	18	60.8 (36.0–96.1)	57	106.7 (80.8–138.2)
Hispanic	21	54.4 (33.7–83.2)	81	89.5 (71.1–111.2)
White non-Hispanic	91	11.3 (9.1–13.8)	193	40.3 (34.4–46.3)
All	142	15.2 (12.7–17.8)	353	53.9 (48.1–59.7)

Note: Rates based on 1–4 counts are suppressed.

quadrants 3 and 4 had lower median wages, on average, compared to those in quadrants 1 and 2. It is well documented that low-wage workers, who in the United States are disproportionately female, Black non-Hispanic, Hispanic, foreign-born, and have lower educational attainment, experience disparities in a wide range of health outcomes, including work-related illness.[47] An analysis of the June 2020 SummerStyles survey found that among frontline (i.e., primarily worked outside the home), nonhealthcare workers in the United States, those with lower incomes were more likely to report being unable to access occupational hazard controls or being prohibited from using them by their employers.[38] Inadequate protections might also have differentially affected lower-wage frontline health care workers, namely those in health care support occupations. In our study, the two largest groups of health care support occupations (i.e., nursing assistants and home health aides) were in Q3 and Q4, respectively. In contrast, nearly all workers in higher-wage health diagnosis and treating occupations (e.g., physicians and nurses) were in Q2.[39] Although all frontline health care workers working with infected patients were at particularly high baseline risk for occupational SARS-CoV-2 exposure, better access to workplace protective measures might have helped to reduce infection risk for those in Q2 relative to those in Q3 and Q4.[11,25,50]

In addition, especially for those working outside the home, having access to adequate paid sick leave would have been important for the infected individual as well as for preventing workplace transmission.[13,26,27,37,51,52] A recent systematic review of the literature by Vander Weerdt et al.[26] concluded based on the evidence that paid sick leave is associated with reduced presenteeism and workplace transmission of illness, and increased worker satisfaction and retention. It should be noted however, that findings from a 2020 survey of Massachusetts residents found wide variation in access to paid sick leave (and workplace COVID-19 protections) across demographic and occupational subgroups of respondents working outside the home.[53] While there is evidence that the federal emergency sick leave policy enacted during the pandemic was effective in reducing COVID-19 spread, further research found disparate awareness and use of this benefit among US workers, particularly indicating unaddressed need among female and foreign-born workers.[51,52]

Another consideration for the differences in rates across the three "work outside the home" quadrants is whether workers in certain quadrants were more likely to experience job loss, either temporarily or permanently during the pandemic, due to, for example, businesses closing or furloughing of staff. Among workers in Q2, this job loss might have been greater in retail salespersons, tour guides, hotel desk clerks and concierges more than others, such as those in education and health care who were largely considered essential. It might also explain the weaker effect in Q4 relative to that in Q3.[39,49] While there is consistency across our study and others[33,54] about which occupations primarily offer no opportunity to telework (i.e., are captured in Q3 and Q4), occupations in Q4 (e.g., waiters, bartenders, hair stylists, manicurists, flight attendants, cashiers, and childcare workers) might have been more likely to be laid off or leave work due to the pandemic (temporarily or permanently). Therefore, we might have overestimated the denominator (i.e., number of workers at risk) for these groups, and likewise underestimated the rates. Importantly, this might have varied across demographic subgroups of Massachusetts workers, and therefore partly explain differences in the relative effect across subgroups in our study.[55]

Misclassification of telework ability might explain some of the differences in the effect across quadrants. We used the Baker[39] assignment as a proxy for telework, but it is possible that workers in certain occupations assigned to one of the three "work outside the home" quadrants actually worked from home during the pandemic and that occupations assigned to the "work from home" reference group (Q1) worked outside the home. For instance, the relatively low rate in Q2 might in part reflect the fact that this quadrant included workers in many health care and education occupations who may have had the ability to work from home during 2020, and were therefore at lower risk of work-related SARS-CoV-2 exposure.[33,50,54,56] In their study, Yuan et al.[56] found that, overall, working in frontline essential occupations was positively associated with COVID-19 incidence, hospitalization and mortality, but closer examination of occupation groups revealed a negative association among education, training and library occupations (essential), which in our analysis were largely included in Q2. The authors speculated that online teaching technology might have allowed for remote learning, thereby reducing the risk of occupational exposure for workers in education. For health care occupations, Massachusetts survey findings showed large variation across health care industry subgroups in the percentage of workers who reported working from home, ranging from 47% in ambulatory services to 32% in hospitals to just 11% in nursing and residential care facilities.[50] Additionally, results from our sensitivity analysis examining the potential impact of misclassification of workers in select occupation groups as working from home suggest that our RRs based on Baker[39] quadrants are likely conservative estimates of the effect of working outside the home.

Finally, it is worth noting that additional factors not assessed in this study might also have contributed to the observed elevated rates and account for variability in the relative effect of telework ability among demographic subgroups. Health outcomes related to COVID-19 (e.g., infection, hospitalization, death) for many workers likely involved a complex interaction of occupational and nonoccupational risk factors at the personal and community level.[47] These include pre-existing health conditions,[10,20,46,55,57–59] inadequate health care access,[4,48,55,60] and crowded living conditions.[10,13,35,46,55,61]

There are several potential limitations to note. First, we do not know whether a decedent's infection resulted from occupational exposure. As previously noted, death certificates record the usual occupation (and industry), or the job in which the decedent spent most of their working life, which might not necessarily mean that the decedent was working at the time of their death. Even if the employment information was current at the time of their death, there was no indicator of work-relatedness in the data used for this study. Second, there is no information on teleworking status or ability in the death certificate data, and we therefore used a proxy measure of telework ability based on occupation. As previously discussed, this might have resulted in some misclassification of exposure. Next, monthly workforce changes due to the pandemic might have affected denominators for rates, and these likely varied by industry and occupation. Therefore, rates for certain groups or quadrants might have been over or underestimated and the extent may have varied. Since we used 5-year average annual workforce estimates we were not able to assess this, but the impact of these changes should be assessed in future studies. Next, it is possible that we missed some COVID-19-associated deaths among workers that were not recognized and appropriately coded, particularly early in the pandemic, and therefore underestimated the burden. Lastly, deaths among Hispanic and Native American residents are known to be undercounted due to misclassification of race or ethnicity recorded in death certificates.[62] Therefore, relevant estimates of COVID-19 mortality and associated inequities presented here should be regarded as conservative.

In conclusion, findings suggest that work-related factors contributed to COVID-19 risk. COVID-19-associated mortality rates varied by industry and occupation, and were two to three times higher among those workers most likely to work outside the home (Q3 and Q4) compared to those most likely able to telework (Q1). The effect varied somewhat by demographic characteristics likely reflecting the complex intersections of occupational and nonoccupational risk factors. While we examined COVID-19-associated mortality, many additional workers likely experienced short and long-term consequences of occupational SARS-CoV-2 infection. Understanding the role of work in driving transmission of SARS-CoV-2 and similar infections deserves ongoing attention, as does the impact of work on noninfectious disease and injury risk. It is the responsibility of the employer to provide a workplace free of recognized hazards. Employer efforts should include measures to minimize work-related exposure to hazards, including infectious diseases, as well as those to support workers who become ill. Finally, the application of occupational exposure matrices to examine associations between work-related factors and health outcomes may be useful in assessing the potential impacts of emerging infectious diseases and climate-related factors.

AUTHOR CONTRIBUTIONS

Kathleen Fitzsimmons conceived the study. Kathleen Fitzsimmons, Malena Hood, Kathleen Grattan, James Laing and Emily Sparer-Fine designed the study. Kathleen Fitzsimmons, Malena Hood and Kathleen Grattan acquired data. James Laing cleaned and coded data for analysis. Malena Hood and Kathleen Grattan analyzed data and prepared tables and figures. Kathleen Fitzsimmons wrote the manuscript. Kathleen Fitzsimmons, Malena Hood, Kathleen Grattan, James Laing and Emily Sparer-Fine interpreted data findings and revised the manuscript. All authors approve this version of the manuscript and agree to be accountable for all aspects of the work.

ACKNOWLEDGMENTS

The authors would like to acknowledge Marissa Baker, PhD from the University of Washington for sharing supporting data on occupation assignments to telework ability quadrants that were critical for this study. The authors would also like to acknowledge Shauna Onofrey, MPH and Catherine Brown, DVM from the MDPH Bureau of Infectious Disease and Laboratory Sciences for providing data and reviewing the manuscript. This work was supported in part by grant sponsor: CDC-NIOSH under grant number: U60OH008490.

CONFLICT OF INTEREST STATEMENT

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

The data in this report are publicly available data and can be obtained by making a data request to the Massachusetts Department of Public Health.

ETHICS APPROVAL AND INFORMED CONSENT

This study was performed at the Massachusetts Department of Public Health (MDPH). It was conducted within the scope of existing reviewed and approved surveillance activities, did not involve human subjects research, and did not require additional Institutional Review Board review.

REFERENCES

1. 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(13):6307. doi:10.3390/ijerph20136307
2. Hawkins D. The other side of the balance sheet: work as a fundamental determinant of health. *Am J Public Health*. 2023;113(6):631-633. doi:10.2105/AJPH.2023.307300
3. Ahonen EQ, Fujishiro K, Cunningham T, Flynn M. Work as an inclusive part of population health inequities research and prevention. *Am J Public Health*. 2018;108(3):306-311. doi:10.2105/AJPH.2017.304214
4. Hawkins D. Social determinants of COVID-19 in massachusetts, United States: an ecological study. *J Prev Med Public Health*. 2020;53(4):220-227. doi:10.3961/jpmph.20.256
5. Laskaris Z, Hirschtick JL, Xie Y, McKane P, Fleischer NL. COVID-19 in the workplace: self-reported source of exposure and availability of personal protective equipment by industry and occupation in michigan. *Am J Ind Med*. 2022;65(12):994-1005. doi:10.1002/ajim.23430
6. Free H, Luckhaupt SE, Billock RM, et al. Reported exposures among In-Person workers with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection in 6 states, September 2020-June 2021. *Clin Infect Dis*. 2022;75(suppl 2):S216-S224. doi:10.1093/cid/ciac486
7. Bui DP, McCaffrey K, Friedrichs M, et al. Racial and ethnic disparities among COVID-19 cases in workplace outbreaks by industry sector—utah, March 6-June 5, 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(33):1133-1138. doi:10.15585/mmwr.mm6933e3
8. Côté D, Durant S, MacEachen E, et al. A rapid scoping review of COVID-19 and vulnerable workers: intersecting occupational and public health issues. *Am J Ind Med*. 2021;64(7):551-566. doi:10.1002/ajim.23256
9. Lan FY, Wei CF, Hsu YT, Christiani DC, Kales SN. Work-related COVID-19 transmission in six Asian countries/areas: A follow-up study. *PLoS One*. 2020;15(5):e0233588. doi:10.1371/journal.pone.0233588
10. Selden TM, Berdahl TA. COVID-19 and Racial/Ethnic disparities in health risk, employment, and household composition. *Health Aff*. 2020;39(9):1624-1632. doi:10.1377/hlthaff.2020.00897
11. Goldman N, Pebley AR, Lee K, Andrasfay T, Pratt B. Racial and ethnic differentials in COVID-19-related job exposures by occupational standing in the US. *PLoS One*. 2021;16(9):e0256085. doi:10.1371/journal.pone.0256085
12. Centers for Disease Control and Prevention. National Center for Immunization and Respiratory Diseases (U.S.). Division of Viral Diseases. Health equity considerations and racial and ethnic minority groups. July 24, 2020. Accessed May 24, 2023. https://stacks.cdc.gov/view/cdc/91049
13. Dyal JW, Grant MP, Broadwater K, et al. COVID-19 among workers in meat and poultry processing facilities—19 states, April 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(18):557-561. doi:10.15585/mmwr.mm6918e3
14. Waltenburg MA, Victoroff T, Rose CE, et al. Update: COVID-19 among workers in meat and poultry processing facilities - United States, April-May 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(27):887-892. doi:10.15585/mmwr.mm6927e2
15. Mosites E, Parker EM, Clarke KEN, et al. Assessment of SARS-CoV-2 infection prevalence in homeless shelters—four U.S. cities, March 27–April 15, 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(17):521-522. doi:10.15585/mmwr.mm6917e1
16. Massachusetts Department of Public Health. Coronavirus Disease 2019 (COVID-19) Cases in MA. Accessed March 7, 2023. https://www.mass.gov/info-details/archive-of-covid-19-cases-2020-2021#march-2020
17. 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(33):1052-1056. doi:10.15585/mmwr.mm7133a4
18. Gaffney A, Himmelstein DU, McCormick D, Woolhandler S. COVID-19 risk by workers' occupation and industry in the United States, 2020–2021. *Am J Public Health*. 2023;113(6):647-656. doi:10.2105/AJPH.2023.307249
19. 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
20. Cox-Ganser JM, Henneberger PK, Weissman DN, Guthrie G, Groth CP. COVID-19 test positivity by occupation using the delphi US COVID-19 trends and impact survey, September-November 2020. *Am J Ind Med*. 2022;65(9):721-730. doi:10.1002/ajim.23410
21. Groenewold MR, Billock R, Free H, et al. Excess risk of SARS-CoV-2 infection among in-person nonhealthcare workers in six states, September 2020-June 2021 [published online ahead of print]. *Am J Ind Med*. 2023;66(7):587-600. doi:10.1002/ajim.23487
22. Hawkins D, Davis L, Kriebel D. COVID-19 deaths by occupation, Massachusetts, March 1-July 31, 2020. *Am J Ind Med*. 2021;64(4):238-244. doi:10.1002/ajim.23227
23. 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
24. Billock RM, Steege AL, Miniño A. COVID-19 mortality by usual occupation and industry: 46 states and New York city, United States, 2020. *Natl Vital Stat Rep*. 2022;71(6):1-33.
25. Nguyen LH, Drew DA, Graham MS, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. *Lancet Pub Health*. 2020;5(9):e475-e483. doi:10.1016/S2468-2667(20)30164-X

26. Vander Weerdt C, Stoddard-Dare P, DeRigne L. Is paid sick leave bad for business? A systematic review. *Am J Ind Med*. 2023;66(6): 429-440. doi:10.1002/ajim.23469
27. Michaels D, Wagner GR. Occupational safety and health administration (OSHA) and worker safety during the COVID-19 pandemic. *JAMA*. 2020;324(14):1389-1390. doi:10.1001/jama.2020.16343
28. Cox-Ganser JM, Henneberger PK. Occupations by proximity and Indoor/Outdoor work: relevance to COVID-19 in all workers and Black/Hispanic workers. *Am J Prev Med*. 2021;60(5):621-628. doi:10.1016/j.amepre.2020.12.016
29. European Centre for Disease Prevention and Control. COVID-19 Clusters and Outbreaks in Occupational Settings in the EU/EEA and the UK. 11 August 2020. Accessed March 24, 2023. https://www.ecdc.europa.eu/sites/default/files/documents/COVID-19-in-occupational-settings.pdf
30. Rao CY, Robinson T, Huster K, et al. Occupational exposures and mitigation strategies among homeless shelter workers at risk of COVID-19. *PLoS One*. 2021;16(11):e0253108. doi:10.1371/journal.pone.0253108
31. Kahlert CR, Persi R, Güsewell S, et al. Non-occupational and occupational factors associated with specific SARS-CoV-2 antibodies among hospital workers—a multicentre cross-sectional study. *Clin Microbiol Infect*. 2021;27(9):1336-1344. doi:10.1016/j.cmi.2021.05.014
32. Lan F-Y, 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*. 2020;78: 237-243.
33. Vergara XP, Gibb K. Close physical proximity on the job-an exposure matrix. *Am J Ind Med*. 2022;65(7):537-547. doi:10.1002/ajim.23396
34. McNamara CL, McKee M, Stuckler D. Precarious employment and health in the context of COVID-19: a rapid scoping umbrella review. *Eur J Pub Health*. 2021;31(suppl ment_4):iv40-iv49. doi:10.1093/eurpub/ckab159
35. Carlsten C, Gulati M, Hines S, et al. COVID-19 as an occupational disease. *Am J Ind Med*. 2021;64(4):227-237. doi:10.1002/ajim.23222
36. Centers for Disease Control and Prevention. Guidance for businesses and employers responding to coronavirus disease 2019 (COVID-19). Atlanta, GA: US Department of Health and Human Services, CDC. 2020. Accessed May 24, 2023. https://stacks.cdc.gov/view/cdc/85488
37. Occupational Safety and Health Administration. Guidance on preparing workplaces for COVID-19. Washington, DC: US Department of Labor, Occupational Safety and Health Administration. 2020. Accessed February 13, 2022. https://www.osha.gov/Publications/OSHA3990.pdf
38. Billock RM, Groenewold MR, Free H, Haring Sweeney M, Luckhaupt SE. Required and voluntary occupational use of hazard controls for COVID-19 prevention in Non-Health care workplaces—United States, June 2020. *MMWR Morb Mortal Wkly Rep*. 2021;70(7):250-253. doi:10.15585/mmwr.mm7007a5
39. Baker MG. Nonrelocatable occupations at increased risk during pandemics: United States, 2018. *Am J Public Health*. 2020;110: 1126-1132. doi:10.2105/AJPH.2020.305738
40. Commonwealth of Massachusetts 2020A. Covid-19 Order No. 13. 2020. Accessed March 7, 2023. https://www.mass.gov/doc/march-23-2020-essential-services-and-revised-gatherings-order/download
41. Commonwealth of Massachusetts. Massachusetts COVID-19 Essential Services. March 23, 2020. Accessed June 13, 2023. https://www.mass.gov/doc/covid-19-essential-services/download
42. Hawkins D. Differential occupational risk for COVID-19 and other infection exposure according to race and ethnicity. *Am J Ind Med*. 2020;63(9):817-820. doi:10.1002/ajim.23145
43. Haley BM, Patil P, Levy JI, et al. Evaluating COVID-19 risk to essential workers by occupational group: A case study in Massachusetts. *J Community Health*. 2024;49:91-99. doi:10.1007/s10900-023-01249-x
44. Council of State and Territorial Epidemiologists. Interim Guidance for Public Health Surveillance Programs for Classification of COVID-19-associated Deaths among COVID-19 Cases. Accessed June 13, 2023. https://cdn.ymaws.com/www.cste.org/resource/resmgr/pdfs/pdfs2/20211222_interim-guidance.pdf
45. National Institute for Occupational Safety and Health. NIOSH Industry and Occupation Computerized Coding System (NIOCCS). U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluation and Field Studies, Surveillance Branch. 2018. Accessed February 13, 2022. https://www.cdc.gov/niosh/topics/coding/overview.html
46. Zsichla L, Müller V. Risk factors of severe COVID-19: A review of host, viral and environmental factors. *Viruses*. 2023;15(1):175. doi:10.3390/v15010175
47. Baron SL, Beard S, Davis LK, et al. Promoting integrated approaches to reducing health inequities among low-income workers: applying a social ecological framework. *Am J Ind Med*. 2014;57(5):539-556. doi:10.1002/ajim.22174
48. Horner KM, Wrigley-Field E, Leider JP. A first look: disparities in COVID-19 mortality among US-Born and Foreign-Born minnesota residents. *Popul Res Policy Rev*. 2022;41(2):465-478. doi:10.1007/s11113-021-09668-1
49. Sönmez S, Apostolopoulos Y, Lemke MK, Hsieh YC. Understanding the effects of COVID-19 on the health and safety of immigrant hospitality workers in the United States. *Touri Manage Perspect*. 2020;35:100717. doi:10.1016/j.tmp.2020.100717
50. Massachusetts Department of Public Health. COVID-19 Frontline Healthcare Worker Study: Legislative Report. January 2023. Accessed August 16, 2023. https://www.mass.gov/doc/covid-19-frontline-healthcare-worker-study/download
51. Pichler S, Wen K, Ziebarth NR. COVID-19 emergency sick leave has helped flatten the curve in the United States. *Health Aff*. 2020;39(12):2197-2204. doi:10.1377/hlthaff.2020.00863
52. Jelliffe E, Pangburn P, Pichler S, Ziebarth NR. Awareness and use of (emergency) sick leave: US employees' unaddressed sick leave needs in a global pandemic. *Proc Nati Acad Sci*. 2021;118(29):e2107670118. doi:10.1073/pnas.2107670118
53. Massachusetts Department of Public Health. COVID-19 Community Impact Survey (CCIS) Spotlight: Employment. June 2021. Accessed June 16, 2023. https://www.mass.gov/info-details/ccis-spotlight-employment
54. Dingel JI, Neiman B. How many jobs can be done at home? *J Public Econ*. 2020;189:104235.
55. Economic Policy Institute. Black workers face two of the most lethal preexisting conditions for coronavirus—racism and economic inequality [online]. 2020. Accessed June 12, 2023 https://www.epi.org/publication/blackworkers-covid
56. Yuan B, Lan J, Li J. Disparity in occupational health risk during the pandemic: potential misestimation and its implications for health policies. *J Occupat Environm Med*. 2022;64(10):809-814. doi:10.1097/JOM.0000000000002563
57. O'Connor LF, Madden GR, Stone D, Classen DC, Eby JC. Risk factors for severe COVID-19 among health care workers. *J Occupat Environm Med*. 2023;65(6):529-532. doi:10.1097/JOM.0000000000002843
58. Wiemers EE, Abrahams S, AlFakhri M, Hotz VJ, Schoeni RF, Seltzer JA. Disparities in vulnerability to complications from COVID-19 arising from disparities in preexisting conditions in the

United States. *Res Soc Stratif Mobi*. 2020;69:100553. doi:10.1016/j.rssm.2020.100553

59. Raifman MA, Raifman JR. Disparities in the population at risk of severe illness from COVID-19 by Race/Ethnicity and income. *Am J Prev Med*. 2020;59(1):137-139. doi:10.1016/j.amepre.2020.04.003
60. Boal WL, Li J, Silver SR. Health care access among essential critical infrastructure workers, 31 states, 2017-2018. *Public Health Rep*. 2022;137(2):301-309. doi:10.1177/0033354921996688
61. Emeruwa UN, Ona S, Shaman JL, et al. Associations between built environment, neighborhood socioeconomic status, and SARS-CoV-2 infection among pregnant women in New York city. *JAMA*. 2020;324(4):390-392. doi:10.1001/jama.2020.11370
62. Arias E, Heron M, Hakes J, National Center for Health Statistics, US Census Bureau. The validity of race and hispanic-origin reporting on death certificates in the United States: an update. *Vital Health Stat 2*. Vol 172, 2016:1-21.

How to cite this article: Fitzsimmons K, Hood M, Grattan K, Laing J, Sparer-Fine E. COVID-19 mortality among Massachusetts workers and the association with telework ability, 2020. *Am J Ind Med*. 2024;1-12. doi:10.1002/ajim.23579