COVID-19 Symptoms and Deaths Among Health Care Workers in the United States

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Abstract

Background: While most COVID-19 research has focused on older individuals with multi-comorbidities, few studies have assessed the predictors of fatality among health care workers (HCWs). This study evaluated if demographics and COVID-19 symptomatology predicted COVID-19 fatality and the temporal trends and spatial distribution among HCWs.

Methods: We used a case-control design to compare HCW deaths related to COVID-19 (laboratory-confirmed) with three control groups (i.e., Non-HCW deaths, HCW non-deaths, and non-HCW non-deaths). Patient-level data with 33 variables, including COVID-19 confirmed cases, deaths, demographics, and various specific COVID symptoms reported by all states in the US, have been obtained from the Restricted Access Dataset by the US CDC since January 2020. A logistic regression model was used by regressing the outcome variable against each predictor while controlling for gender, age group, race, and ethnicity.

Results: The percentages of 50-69 years old, Hispanics (8.7%), Black (32%), and Asian (23.1%) in HCW death were significantly higher than in their respective controls. The fatality and all severe indicators were higher among the deaths than non-deaths, but not different for HCWs than non-HCWs. Significantly increased risks for deaths were observed with pre-existing medical conditions (RR: 7.24, 95% CI: 5.40-9.70), shortness of breath (RR: 5.73, 95% CI:4.50-7.31), fever (RR:3.52, 95% CI: 2.71-4.56), cough (RR:2.02, 95% CI: 1.54-2.65), and diarrhea (RR: 1.57, 95% CI:1.20-2.05).

Conclusion: Older and minority HCWs experienced relatively higher COVID-19 fatality. Severe symptoms are similarly prevalent among HCW deaths and non-HCW deaths. Pre-existing medical conditions, shortness of breath and fever symptoms may be critical COVID indicators for HCWs.

Introduction

Since December 2019, a novel coronavirus (COVID-19) has caused large global pandemic in the last century (1). The high transmissibility of this novel virus facilitated its rapid spread across oceans and borders. As of April 14, 2021, more than 31.3 million Americans have contracted COVID-19 (confirmed cases) and more than 560,000 have died as a result of the virus (2, 3). The known risk factors for COVID-19 infection and subsequent death are age, gender, and pre-existing medical conditions. Specifically, multiple prior studies have found that older adults were more likely to contract COVID-19 or suffer severe and critical conditions (4, 5). In addition, people with existing chronic medical conditions, such as diabetes, hypertension, and renal failure, have also been found to be particularly susceptible to COVID-19 infection and mortality (5–7).

Another sub-population that is at higher for contracting COVID-19 is health care workers (HCWs). Reports from the UK at the beginning of the pandemic show that patient-facing HCWs were three times more likely to contract the virus compared to non-patient-facing HCWs (8). In addition, the immediate families of patient-facing HCWs were twice as likely to contract COVID-19 compared to their counterparts (8). This

is significant because an adequate workforce of health care professionals is paramount to defeating this pandemic. Even moderate HCW shortages lead to significantly more COVID-19 deaths (9).

An important reason why HCWs may be more prone to SARS-CoV-2 infection, apart from their close proximity to at-risk patients, is their double responsibility of caring for patients and themselves simultaneously. Additionally, as a high proportion of HCWs identify as one or more racial minorities – 40% of HCWs are people of color including 16% Black, 13% Hispanic, 7% Asian and others (10) – exposure inequality and health risk disparities are timely issues. Kirby(11) opined that doctors from the Black, Asian, and other minority ethnic communities were twice as likely to attend to patients without personal protective equipment (PPE), through coercion, compared to their white colleagues. Available data suggests that non-Hispanic blacks are more likely to hold jobs considered essential (e.g., health care, nurse assistant, food preparation, and home care aids, etc.) compared to their white counterparts. They tend to work in the top nine occupations that are exposed to COVID-19 and, therefore, are at high risk of getting infected (8). However, due to the fear of job loss, they are less likely to publicly express their concerns regarding workplace safety (11).

The initial surge in COVID cases led to a profound increase in HCWs' exposure to the virus. However, what remains unclear is the extent to which this increased level of exposure among HCWs has translated to risk of infection, and which demographic characteristics or symptoms predict increased risk of death among this population. Research is lacking regarding what specific symptoms or severity indicators are associated with deaths among HCWs compared to non-death, as most prior research is limited to cases without appropriate control groups, which could lead to various biases. Additionally, a nation-wide study looking at COVID-19 symptoms and deaths among HCWs is lacking, particularly one considering the 2nd and 3rd COVID-19 surges.

To fill these knowledge gaps, we use CDC COVID-19 surveillance data to compare 1) how COVID-19-related deaths among HCWs differ according to demographic characteristics using three control groups (Non-HCW deaths, HCW non-deaths, Non-HCW non-deaths); 2) symptomatology differences between HCW deaths and controls; and 3) temporal trends and spatial distribution of COVID-19 death in HCWs versus the general US population.

Methods

Study design and controls: In this study, our population was HCWs in the US. We used a case-control design and compared HCW deaths with three control groups: 1) Non-HCW deaths, 2) HCW non-deaths, and 3) non-HCW non-deaths. A COVID-19 death was defined as a death derived from a laboratory-confirmed COVID-19 case. A dichotomized variable of HCW (Yes/No) was used to separate HCWs from non-HCWs. The purpose of the first control group was to examine demographic and symptom-related differences between HCW deaths and non-HCW deaths. In addition, we used two non-death control groups, non-death among HCWs and non-death among the non-HCW or general population, to identify risk factors and symptomatology of COVID deaths. HCW non-deaths are an ideal reference group to

control for important confounders including occupation, education, and medical knowledge. For the third control group, we used non-deaths among non-HCWs, which represents the general healthy population.

Data acquisition: Information regarding COVID-19 confirmed cases, probable cases, and deaths across the US were obtained from the Restricted Access Dataset operated by the US Centers for Disease Control and Prevention (CDC). This COVID-19 surveillance system database includes patient-level data reported by all US territories and states. COVID-19 was added to the Nationally Notifiable Condition List and classified as “immediately notifiable, urgent (within 24 hours)” by a Council of State and Territorial Epidemiologists (CSTE) Interim Position Statement (Interim-20-ID-01) on 4/5/2020. In January 2020, COVID-19 data collection started, and all states and territories were encouraged to enact laws to submit case notifications to the CDC via jurisdictions. At this time, the CDC also requested that public health departments around the country report all COVID-19 cases to them using the standardized case definitions for lab-confirmed or probable cases. These case reports have been routinely submitted using standardized case report forms ever since. This study covers the timeframe form January 1, 2020 to December 31, 2020.

In this dataset, we obtained demographic and medical information for each record including COVID-19 case status (confirmed or probable case), date of first positive specimen collection, gender, age group, race, ethnicity, county and state of residence, presence of underlying comorbidity or disease, presence of severe COVID-19 symptoms (pneumonia, acute respiratory distress syndrome (ARDS), abnormal chest x-ray, hospitalization status, intensive care unit (ICU) admission status, mechanical ventilation (MV)/intubation status, and death status), and the presence of less severe symptoms: fever, subjective fever, chills, myalgia, rhinorrhea, sore throat, cough, shortness of breath, nausea/vomiting, headache, abdominal pain, and diarrhea. To prevent the release of data that could be used to identify persons, data cells are suppressed by the CDC for low reporting counts (< 5) records, and uncommon combinations of demographic characteristics (sex, age group, race, ethnicity). Suppressed values are re-coded to the *NA* answer option.

Outcomes and predictors: The major health outcome of interested in this study is COVID-19-related deaths. Among all the deaths identified, 97.8% of them were from confirmed COVID-19 cases and 2.2% came from probable cases. While we examined temporal-spatial death trends, the fatality rate by county was defined as the total numbers of COVID-19-related deaths divided by the total numbers of confirmed COVID-19 cases in each county in the US. We used a total of 20 predictors including demographic variables (gender, age group, race, ethnicity, month, and season), severe COVID-19 symptoms (hospitalization, admission to ICU, pneumonia, ARDS, abnormal chest x-ray, received MV/intubation, and death status), and less severe COVID-19-related symptoms, such as fever > 100.4F (38C), chills, muscle aches (myalgia), subjective fever (felt feverish), runny nose (rhinorrhea), sore throat, cough (new onset or worsening of chronic cough), and shortness of breath (dyspnea).

Statistical analysis and confounders: We first compared all 20 predictor variables between the death and control groups using Chi-square tests. We then developed logistic regression models by regressing the

outcome variable against each predictor while controlling for demographic confounders. Demographic confounders in this study included gender, age group, race, and ethnicity. In addition, we examined and compared the temporal trends of confirmed cases and deaths among HCWs and the general population. Finally, we demonstrated the spatial variation in the fatality rate among HCWs across the country. All data cleaning, analysis, and results were accomplished using R 3.5.1 (https://www.r-project.org/).

Results

Among the more than 2 million confirmed COVID-19 cases reported to the CDC from Jan. 1, 2020 to Dec. 31, 2020 in the US, 221,206 cases (10.3%) were HCWs and 1,916,430 cases (89.7%) were non-HCWs. Among these cases, there were 840 HCW deaths (1.5%) and 56,909 non-HCW deaths (98.5%). Table 1 describes the distribution of socioeconomic status among HCW and non-HCWs deaths, respectively. Among HCW death cases and controls, over 80% were female, while only 50% of non-HCW death cases and controls were female. The percentage of individuals in the 50–59 and 60–69 age groups among HCW death cases (28.8% and 36.8%, respectively) were significantly higher than those in HCW controls (18.3% and 8.73%), non-HCW controls (14.7% and 10.15%), and non-HCW cases (7.0% and 15%). The percentage of Hispanics in HCW death cases (8.7%) was higher than in non-HCW death cases (6.4%), while the percentage of Hispanics in HCW controls (6.7%) was lower than that in non-HCW controls (18.5%). Furthermore, the percentages of Black and Asian HCW death cases (Black = 32.0%; Asian = 23.1%) were greater than those in HCW controls (Black = 18.3%; Asian = 7.1%), non-HCW death cases (Black = 13.8%; Asian = 6.5%), and non-HCW controls (Black = 13.9%; Asian = 4.3%).

Table 1
Descriptive statistics of SES variables for Health care worker deaths

Variables	HCW deaths	non-HCW deaths		HCW non-deaths		non-HCW non-deaths	
		N (%)	P values	N (%)	P values	N (%)	P values
Sex							
Female	541 (64.40)	26691 (46.90)	P < 0.001	181219 (82.24)	P < 0.001	938510 (50.47)	P < 0.001
Male	299 (35.60)	30218 (53.10)		39147 (17.76)		921011 (49.53)	
Age groups							
0–9 Years	0 (0.00)	22 (0.04)	P < 0.001	13 (0.01)	P < 0.001	86401 (4.64)	P < 0.001
10–19 Years	2 (0.24)	85 (0.15)		3437 (1.56)		216722 (11.63)	
20–29 Years	31 (3.69)	278 (0.49)		55334 (25.09)		355796 (19.10)	
30–39 Years	58 (6.90)	651 (1.14)		55131 (25.00)		301208 (16.17)	
40–49 Years	91 (10.83)	1537 (2.70)		45840 (20.79)		282375 (15.16)	
50–59 Years	242 (28.81)	3976 (6.98)		40424 (18.33)		272854 (14.65)	
60–69 Years	309 (36.79)	8570 (15.04)		19250 (8.73)		189070 (10.15)	
70–79 Years	85 (10.12)	13820 (24.25)		1067 (0.48)		99846 (5.36)	
80 + Years	22 (2.62)	28055 (49.22)		20 (0.01)		58526 (3.14)	
Ethnicity							
Hispanic	62 (8.71)	2906 (6.40)	0.016	10673 (6.73)	0.043	224096 (18.48)	P < 0.001
Non-Hispanic	650 (91.29)	42507 (93.60)		147824 (93.27)		988696 (81.52)	
Race							

Variables	HCW deaths	non-HCW deaths		HCW non-deaths		non-HCW non-deaths	
		N (%)	P values	N (%)	P values	N (%)	P values
American Indian/ Alaska Native	0 (0.00)	86 (0.20)	P < 0.001	158 (0.11)	P < 0.001	3887 (0.39)	P < 0.001
Asian	150 (23.08)	2759 (6.49)		10433 (7.06)		42249 (4.27)	
Black	208 (32.00)	5885 (13.84)		27051 (18.30)		136946 (13.85)	
Multiple/Other	16 (2.46)	1985 (4.67)		10297 (6.97)		84483 (8.54)	
Native Hawaiian/ Other Pacific Islander	1 (0.15)	126 (0.30)		471 (0.32)		5590 (0.57)	
White	275 (42.31)	31666 (74.50)		99414 (67.25)		715541 (72.37)	
Month							
1	0 (0.00)	1 (0.00)	P < 0.001	7 (0.00)	P < 0.001	76 (0.00)	P < 0.001
2	0 (0.00)	26 (0.05)		53 (0.03)		341 (0.02)	
3	45 (5.92)	2009 (4.15)		5293 (2.59)		24716 (1.44)	
4	89 (11.71)	8985 (18.55)		16965 (8.30)		65922 (3.83)	
5	89 (11.71)	7033 (14.52)		17224 (8.43)		100404 (5.84)	
6	296 (38.95)	8931 (18.44)		30671 (15.00)		207935 (12.09)	
7	49 (6.45)	4091 (8.45)		20096 (9.83)		206048 (11.98)	
8	36 (4.74)	3425 (7.07)		16604 (8.12)		155678 (9.05)	
9	28 (3.68)	2682 (5.54)		13543 (6.63)		139868 (8.13)	

Variables	HCW deaths	non-HCW deaths		HCW non-deaths		non-HCW non-deaths	
		N (%)	P values	N (%)	P values	N (%)	P values
10	37 (4.87)	3400 (7.02)		21133 (10.34)		212646 (12.36)	
11	57 (7.50)	4683 (9.67)		37684 (18.44)		370037 (21.51)	
12	34 (4.47)	3166 (6.54)		25141 (12.30)		236921 (13.77)	
Season							
Spring	223 (29.34)	18027 (37.22)	P < 0.001	39482 (19.31)	P < 0.001	191042 (11.10)	P < 0.001
Summer	381 (50.13)	16447 (33.96)		67371 (32.96)		569661 (33.11)	
Fall	122 (16.05)	10765 (22.23)		72360 (35.40)		722551 (41.99)	
Winter	34 (4.47)	3193 (6.59)		25201 (12.33)		237338 (13.79)	

Table 2 shows multivariable analysis for HCW deaths and the three control groups separated by severity indicators and COVID-19 related symptoms. All severity indicators for COVID-19 were statistically significantly higher among HCW death cases compared to non-death controls (HCW non-deaths and Non-HCW non-deaths, RR range = 1.11-286.03). However, we found that there were no significant differences in the most severe indicators between HCW deaths and non-HCW deaths, except for ICU and MV, which were significantly higher among HCW deaths. In addition, compared with the control groups, we observed significantly increased risks for multiple COVID-19 related symptoms among HCW deaths. The top five symptoms significantly associated with COVID-19 deaths (showed the highest RRs here while comparing with the multiple controls) include pre-existing medical conditions (RR: 7.24, 95% CI: 5.40–9.70), shortness of breath (RR: 5.73, 95% CI:4.50–7.31), fever (RR:3.52, 95% CI: 2.71–4.56), cough (RR:2.02, 95% CI: 1.54–2.65), and diarrhea (RR: 1.57, 95% CI:1.20–2.05).

Table 2
Multivariable analysis* for HCW deaths compared with three control groups

Variables	HCW deaths	non-HCW deaths		HCW non-deaths		non-HCW non-deaths	
	N (%)	N (%)	RR (95%CI)	N (%)	RR (95%CI)	N (%)	RR (95%CI)
Hospitalized	642 (81.78)	39710 (76.91)	0.96 (0.77, 1.20)	11381 (6.64)	49.81 (40.20, 61.72)	128167 (7.77)	47.18 (38.17, 58.32)
Admitted ICU	381 (73.69)	15871 (61.23)	1.28 (1.01, 1.63)	1040 (1.60)	132.95 (103.51, 170.77)	15852 (2.69)	99.49 (78.74, 125.71)
Had pneumonia	176 (61.54)	8453 (62.91)	0.98 (0.74, 1.31)	2618 (3.89)	31.98 (24.17, 42.31)	28615 (4.38)	31.74 (24.15, 41.72)
Abnormal X-ray	127 (61.35)	5088 (64.18)	0.73 (0.52, 1.03)	1710 (4.61)	24.30 (17.50, 33.73)	19328 (6.42)	18.50 (13.39, 25.56)
ARDS	78 (44.32)	4456 (38.36)	1.11 (0.78, 1.57)	744 (1.12)	63.79 (44.61, 91.20)	6634 (1.03)	73.79 (52.41, 103.89)
MV/ Intubation	231 (62.60)	6066 (39.90)	1.48 (1.15, 1.90)	274 (0.47)	286.03 (214.46, 381.47)	3541 (0.70)	202.21 (158.43, 258.10)
Fever	226 (67.87)	11120 (63.26)	1.16 (0.88, 1.53)	32261 (43.71)	2.89 (2.22, 3.77)	250837 (39.67)	3.52 (2.71, 4.56)
Subjective fever	104 (53.61)	4185 (37.52)	1.44 (1.04, 2.01)	28821 (40.21)	1.82 (1.33, 2.50)	250426 (37.07)	2.07 (1.51, 2.84)
Chills	145 (48.17)	4047 (28.42)	1.67 (1.28, 2.18)	37475 (44.22)	1.16 (0.90, 1.50)	291051 (38.58)	1.34 (1.05, 1.72)
Myalgia	171 (54.81)	4887 (32.99)	1.92 (1.48, 2.50)	54028 (60.46)	0.91 (0.71, 1.17)	412885 (51.74)	1.11 (0.87, 1.43)
Rhinorrhea	42 (29.37)	1306 (17.39)	1.28 (0.83, 1.97)	25362 (45.67)	0.53 (0.35, 0.80)	177684 (41.89)	0.52 (0.35, 0.78)
Sore throat	81 (27.46)	1975 (14.16)	1.76 (1.30, 2.38)	34032 (39.76)	0.72 (0.54, 0.96)	272736 (35.37)	0.78 (0.59, 1.04)

*Controlled for gender, age group, race, and ethnicity

Variables	HCW deaths	non-HCW deaths		HCW non-deaths		non-HCW non-deaths	
	N (%)	N (%)	RR (95%CI)	N (%)	RR (95%CI)	N (%)	RR (95%CI)
Cough	289 (77.90)	12620 (64.80)	1.61 (1.21, 2.14)	60107 (65.58)	1.95 (1.48, 2.57)	496345 (60.14)	2.02 (1.54, 2.65)
Dyspnea	257 (68.35)	12551 (65.07)	0.94 (0.73, 1.22)	27620 (32.27)	5.15 (4.02, 6.58)	191677 (25.06)	5.73 (4.50, 7.31)
Nausea/ Vomiting	80 (25.16)	2641 (16.76)	1.15 (0.86, 1.55)	19903 (22.92)	1.28 (0.97, 1.71)	127355 (16.67)	1.43 (1.08, 1.90)
Headache	126 (41.86)	3022 (21.20)	1.46 (1.11, 1.92)	59612 (66.12)	0.44 (0.34, 0.57)	465703 (57.72)	0.47 (0.36, 0.61)
Abdominal pain	41 (15.83)	1112 (9.89)	1.12 (0.75, 1.68)	9508 (14.07)	1.21 (0.83, 1.77)	66084 (11.77)	1.27 (0.87, 1.85)
Diarrhea	115 (36.86)	3652 (23.52)	1.57 (1.20, 2.05)	26305 (31.05)	1.46 (1.13, 1.88)	204892 (26.92)	1.50 (1.17, 1.93)
Pre-existing medical conditions	437 (86.88)	27347 (93.92)	0.58 (0.42, 0.79)	54220 (47.22)	7.24 (5.40, 9.70)	405353 (46.34)	6.75 (5.03, 9.06)
*Controlled for gender, age group, race, and ethnicity							

Figure 1 describes the temporal patterns of lab-confirmed infections and deaths of HCWs compared to the general population. In general, three peaks of COVID-19 infections and deaths occurred in the US around April 2020, July 2020, and December 2020. The temporal pattern of confirmed infections among HCWs was similar to that among the general population. However, the temporal pattern of deaths among HCWs remained flat after the first peak when fatality rates among the general population increased.

Figure 2 shows the geographic distribution of fatality rate among HCW cases by county in the US. Ohio had the greatest number of counties with a high fatality rate. 19 counties had a fatality rate above the median among all counties with non-zero HCW cases (i.e. 5/1000), seven of which were above the 75th percentile rate (i.e. 10/1000). North Carolina (with ten counties > median and six > 75th percentile), New Jersey (with nine counties > median and three > 75th percentile), Illinois, and Tennessee (both with eight counties > median and five > 75th percentile) were among the states with the largest number of high fatality counties in the US.

Discussion

Demographic characteristics of COVID-19 deaths among HCWs

Compared to the controls, this study found some unique demographic characteristics among HCWs with COVID-19 deaths in the US, including older age (50–69 years old), high proportions of female, Hispanic, African American, and Asian individuals, and increased cases from March to June.

More specifically, we found that HCWs had significantly higher proportion of 50–69 years old compared to all three control groups. Consistent with our findings, previous research has found that older age groups are more vulnerable to COVID-19 infection and death compared to other age groups due to the prevalence of multiple pre-existing medical conditions and lower immunity against viral infection (12).

This study also found that female deaths were significantly higher among HCWs than Non-HCW cases and Non-HCW controls. This could be attributed to common characteristics of HCWs, i.e., women make up the majority of most types of health care occupations including registered nurses, home health aides, medical assistants, and physician assistants. In a retrospective cohort study, 2,842 HCW patients were recruited from a large academic medical center emergency department (ED) in NYS. Kim et al (13) found that HCWs were more likely to be female compared with not HCWs and the general population. Using non-HCW cases as a comparison group, Diez-Manglano, et al. (14) also found that HCW female cases were more likely to be affected compared to males in Spain and explained that this difference is due to the higher proportion of females in health care professions. In other words, the findings regarding non-HCW controls could be confounded by different gender compositions between HCWs and non-HCW populations. Therefore, the use of non-HCWs as a control group may lead to biased results regarding gender differences due to occupational confounders. Our findings support this interpretation as we found significantly fewer female HCW deaths compared to HCW non-deaths. Worldwide, men were more likely to be infected by COVID-19 or to suffer more severe symptoms compared to women, which is consistent with our findings of twice the rate of male HCW deaths as male HCW non-deaths.

Our findings regarding the increased risk of COVID-19 deaths among minority populations agrees with numerous findings from prior research. For instance, studies conducted by Rogers et al. (15) and Kirby (11) reported increased risk of COVID-19 mortality among non-Hispanic African American and Hispanic minority populations. In addition, researchers at the New York's Furman Center found that COVID-19 infection and death is strongly linked with factors associated with overcrowded neighborhoods, especially those with dense populations of African Americans, Hispanics, and residents with no college degree ((16). Our study also reported a significantly higher risk of COVID-19 deaths (3–5 fold increase) among Asian HCWs compared to all three control groups. Sze et al (17) conducted a comprehensive literature review of 50 studies that included 18,728,893 COVID patients from the US and the UK. They found that African American and Asian individuals were at an increased risk of COVID-19 infection compared to White individuals (pooled adjusted RRs: 2.02, 95% CI:1.67–2.44 for African American; and RRs: 1.50, 95% CI:1.24–1.83 for Asian, respectively). While higher risk of COVID-19 infection and death have been noted among African American and Hispanic individuals, few studies have reported that

Asians are also at higher risk. While some believe Asian individuals are at lower risk of contracting COVID-19 due to genetic protection, our results completely contradict this notion. Therefore, these findings are of critical public health importance in terms of communicating true information to specific racial/ethnic minority groups to reduce COVID-19-related morbidity and mortality.

Most HCW cases in the US occurred between March and June 2020 during the initial COVID-19 peak in the US. The initial surge in COVID cases led to a profound increase in HCWs' exposure to the virus. This was likely due to inadequate ICU and hospital beds; insufficient PPE quality and supply; inadequate training and experience among HCWs; and heavy workloads due to a large and rapid influx of patients. Other similar studies agree with this interpretation of our findings (18). Nguyen et al. (18) also suggested that HCWs with inadequate access to PPE were at increased risk of SARS-CoV-2 infection compared to those with adequate PPE access.

Severity indicators among HCWs

This study found that the death rate among HCW COVID-19 cases was higher than those among non-HCW cases in the US. In addition, we found that there were no significant differences between HCW deaths and non-HCW deaths with regard to the most severe indicators, except for ICU and MV. More ICU and MV use among the HCWs could be due to better accessibility to these facilities. This study identified that the order or power of the severity indicators to predict COVID-19 related death among HCWs are MV, ICU, ARDS, hospitalization, pneumonia, and abnormal chest X-ray, which is consistent while comparing with both non-death control groups. Unfortunately, there is a general paucity of literature regarding the severity of indicators for COVID-19 mortality and morbidity for comparison with our study.

Symptoms among HCWs compared to controls

COVID-19 deaths among HCWs represented increased proportions of pre-existing conditions (19), shortness of breath, fever, cough, diarrhea and vomiting, but decreased proportions of all other symptoms compared to the controls. One interesting finding was that fever exceeding 100.4□F even subjective fever (felt feverish) was consistently more common among HCW deaths compared to the three control groups, indicating that fever may be an early indicator of disease severity. Another finding worth mentioning is that multiple gastrointestinal (GI) symptoms (diarrhea, nausea, vomiting, abdominal pain) were reported for HCW deaths, but not in controls. This could be because most people ignore GI symptoms as they relate to COVID-19, believing they are unrelated matters, while HCWs are likely more knowledgeable about health issues. Few or no studies have examined symptoms among COVID deaths, especially among HCWs, and therefore, no literature can be compared with.

Symptoms indicators identification

While we re-examined all symptom indicators among HCWs, we found that pre-existing conditions were the most important indicator for COVID-19 death, followed by shortness of breath, fever, cough, diarrhea, and nausea/vomiting. On the other hand, runny nose, sore throat, cough, and headache were the least important indicators.

Temporal and spatial patterns of infection and death

Temporal trend

The US CDC data showed that COVID-19 infections among HCWs grew quickly in March, faster than the national average, and peaked in April 2020. After that, the temporal trend of COVID-19 infections among HCWs followed the same temporal trend in the US, peaking again in the summer of 2020 and once again after Thanksgiving and Christmas 2020. However, while COVID infection and fatality trends in the US experienced these three distinct peaks, fatality among HCWs went down after April 2020 and remained low for a year. This finding is consistent with the CDC data and other studies conducted in the US (2). The flatter COVID-19 fatality trend among HCWs may indicate improved self-protection or PPE (20, 21), better access to health care facilities such as MV or ICU, and early detection and treatment. These trends also illustrate how quickly the COVID-19 epidemic among the general public spread to HCWs who took care of the most deadly cases (13).

Spatial pattern

The states with the high fatality rates among HCWs include western Washington, central and southern California, northeast Illinois, Ohio, New Jersey, Massachusetts, and some scattered areas in Michigan, North Carolina, and Arkansas. Some states had multiple counties with high COVID fatality among HCWs, such as Ohio, North Carolina, New Jersey, Illinois, and California. This spatial distribution agrees with the ecological mortality analysis by Zhang and Schwartz (22) which established that large metropolitan areas in Northeast (Boston to Washington DC) and Midwest (Detroit, Chicago, and New Orleans) account for the highest coronavirus mortality. Their analysis also demonstrated that high case fatality was not unique to large metropolitan areas, but also disproportionately affected small metropolitan areas and nonmetropolitan counties such as areas in Albany, GA, Saginaw, MI, and Flagstaff, AZ. Fatima et al. (23) examined spatial data from Colorado and was able to demonstrate that poverty and unemployment were the key determinants of high COVID-19 mortality in rural and urban areas. The main drivers were population density and asthma.

Strengths And Limitations

This is one of the few COVID-19 studies that has used multiple control groups to avoid different biases, as almost all published literature analyzing HCWs deaths used non-HCW deaths as the only comparison group. By using our three unique control groups, we were able to not only evaluate how COVID-19 deaths differed among HCWs who had similar exposure opportunities and SES background, but also examine how fatality differed between HCWs and the general population. Different from most prior studies, which limited their analysis to one hospital or one location and used case data only, our study used nation-wide, dynamic data for both deaths and non-deaths with good representation of the entire country. Another strength of this project is the utilization of CDC surveillance data. Using this objective source reduces reporting bias which is typically a major concern in previous studies relying on surveys or questionnaires.

In addition to using three control groups, we controlled for several known risk factors for COVID-19, including age (seniors), sex (male), race (African American), and ethnicity (Hispanic). Finally, this study used timely data that is collected constantly and reported every two weeks. On the other hand, the ecological fallacy may be a major concern for our analyses using this national dataset based on county or state level. However, all variables used in this paper, except for geographic location (county and state level), were reported at individual-level which reduces the ecological bias.

Since the COVID-19 case surveillance system is passive, the data we used may underestimate the true number of cases because of misdiagnosis and underreporting, even though reporting all COVID-19 cases to the CDC is mandated by federal law. Completeness of reporting may be influenced by the availability of diagnostic testing, resources, and the priorities of health officials. Although the case report form captures several outcomes, including hospitalization, ICU admission, and death, these data may be incomplete because outcomes are not yet known at the time of reporting. To address this concern, we conducted a sensitivity analysis three months after the initial analyses were conducted by adding all updated data and we still found similar results. Another limitation is the limited number of variables available from this surveillance dataset. However, this list of variables is adequate for the purposes of this descriptive epidemiologic study. Finally, the non-death control groups in this dataset may include more suspected cases or people with COVID symptoms who took a COVID test. In other words, these non-death controls may not totally represent a normal or healthy population, and therefore, the associations we examined may be underestimated.

Conclusion

We found that older, Hispanic, African American, and Asian HCWs experienced a higher fatality rate due to COVID-19. HCW cases had reduced fatality rates and lower prevalence of all severe indicators compared to non-HCW cases in the US. We also found that the pre-existing conditions, shortness of breath, fever, cough, diarrhea, and nausea/vomiting were the most important indicators for COVID-related death. Fever and GI symptoms may be important COVID death indicators for HCWs, but runny nose, sore throat, and headache may not be major indicators for COVID-19 related death.

Abbreviations

HCW: Health Care Worker

RR: Relative Risk

CDC: Centers for Disease Control and Prevention

CSTE: Council of State and Territorial Epidemiologists

ARDS: Acute Respiratory Distress Syndrome

ICU: Intensive Care Unit

MV: Mechanical Ventilation

Declarations

Ethics approval and consent to participate:

Not applicable

Consent for publication:

Not applicable

Availability of data and materials:

The data that support the findings of this study are available from CDC but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of CDC.

Competing interests:

The authors declare that they have no competing interests

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Authors' contributions:

SL contributed to the conception and design of the work, interpretation of data, and drafted the work and revised it; XD and WZ contributed to the acquisition, analysis, drafted the work. IR, KZ, EO, DB, and BS were major contributors in revising the manuscript. All authors read and approved the final manuscript.

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Figures

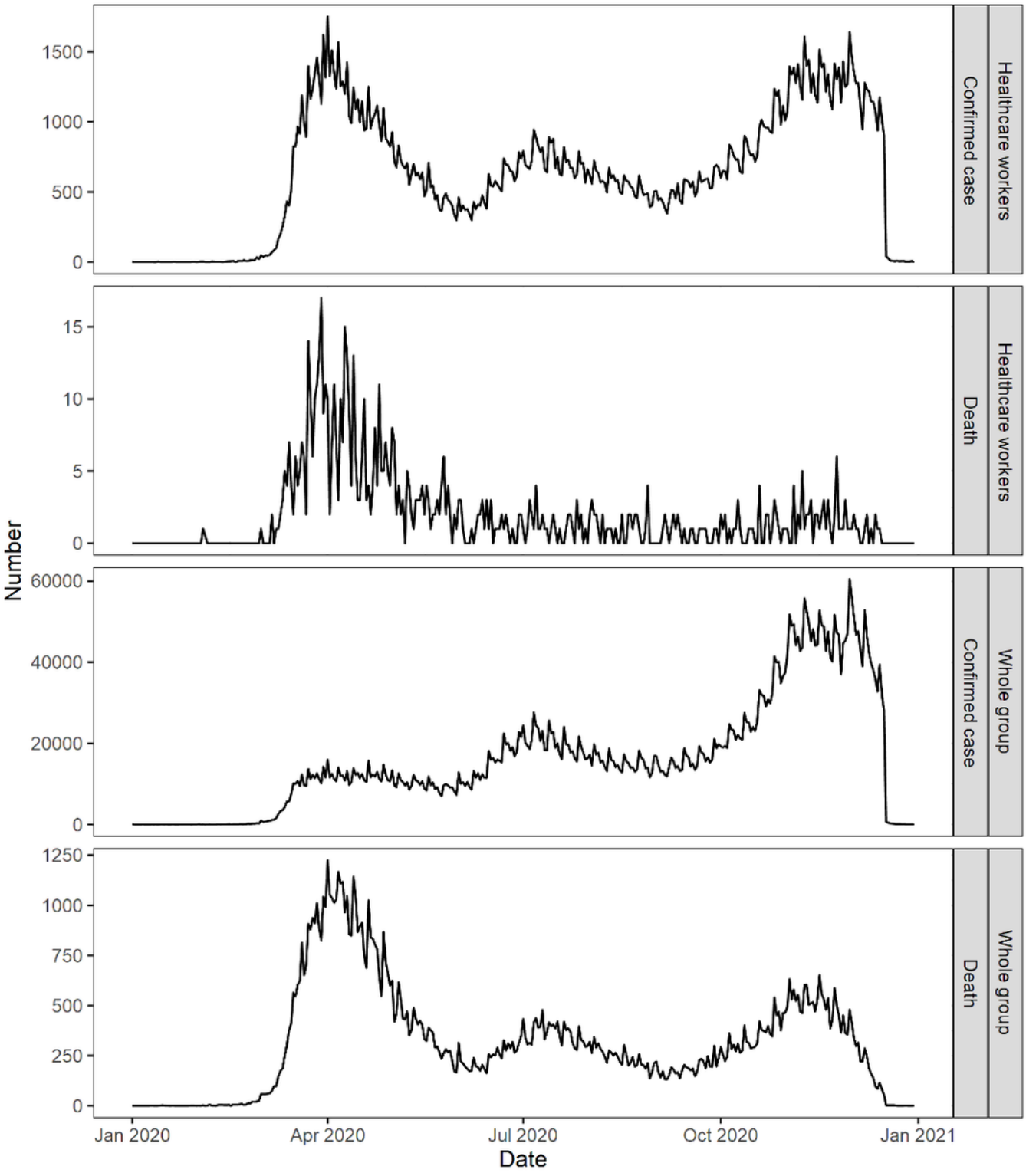

Figure 1

Comparing COVID-cases and deaths between HCWs and general population in US

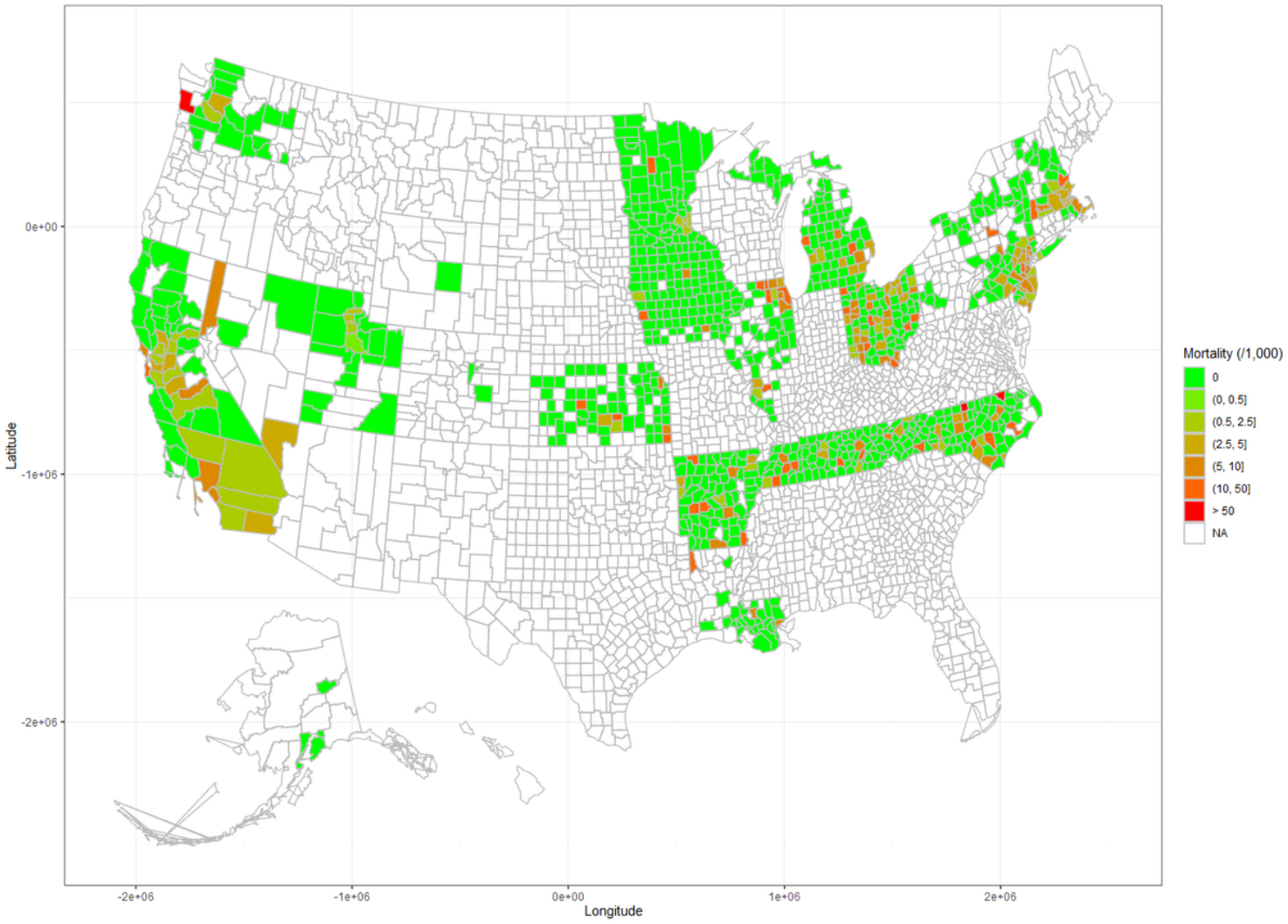

Figure 2

COVID19 Fatality rate among HCW cases in the US Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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- GraphicalAbstract.png