Original Research

Obesity, Race, and COVID-19 Mortality: Results from a Large Cohort Early in the Pandemic

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Abstract

Background
Obesity has increased progressively in the United States and is a known risk factor for several diseases such as type 2 diabetes, coronary artery disease, stroke and hypertension. Amid the current pandemic, concerns have been raised about obesity as a risk factor for COVID-19 positive patients. The primary goal of this study was to explore the association between obesity and hospital mortality in COVID-19 patients. Our secondary objective was to explore the relationship between obesity and race on hospital mortality in COVID-19 patients.

Methods
This was a cross-sectional, retrospective analysis using data from 186 hospitals from across the United States and the United Kingdom during the first quarter of 2020. Extraction provided data from 25,894 patients who were tested for COVID-19, of whom 2,977 were positive. Patients were stratified into standard WHO categories for BMI and by race.

Results
Bivariate analysis revealed significant relationships between mortality and sex ($p<0.001$) When BMI was analyzed as a continuous variable, multivariate analysis revealed a significant influence of BMI on mortality (odds ratio=1.291, $p<0.05$)

Conclusion
COVID-19 mortality was significantly related to BMI, age and select co-morbidities, but race/ethnicity was not a predictor of mortality when controlling for other variables.

Keywords
COVID-19; SARS-CoV-2; coronavirus infections; obesity; comorbidity; epidemiologic factors; risk factors; race factors; body mass index; pandemics

Background
The number of overweight and obese adults has increased progressively in the United States (US) over the last four decades. As of 2017 to 2018, 42% of US adults were obese and 9.2% severely obese, with obesity being defined as body mass index (BMI) of greater than or equal to 30 and severe obesity as a BMI of greater than or equal to 40.[1] Obesity is a known risk factor for several diseases including type 2 diabetes, coronary artery disease, stroke and hypertension, and is also associated with an increased likelihood of other risk factors such as elevated blood lipid levels and smoking.[2-5]

Obesity has also consistently shown to be a risk factor for increased morbidity.[6-8] For example, in a large, multicenter study conducted across 24 European countries, obese and very obese patients developed ICU-acquired infections at a higher rate, had increased likelihood of respiratory failure and mechanical ventilation, and had longer ICU and hospital lengths of stay compared to those with a normal BMI.[8] Obesity also places a significant financial burden on the healthcare system, with $187 billion in costs linked to obesity in 2009, up from $78.5 billion in 1998. Individually, medical spending for obese patients was ~42% higher than their non-obese counterparts.[9-10]

Understanding the relationships between obesity and the ability to resist or respond to viral infection is critical for the health care response. The US has one of the highest obesity rates of any country and the highest number of confirmed COVID-19 related deaths, if not the highest death rate, per capita. Subsequently, concerns have been raised about obesity as a risk factor for COVID-19 positive patients.[11] The Centers for Disease Control and Prevention (CDC) has identified "severe obesity" as a risk factor for severe illness and while their statements were qualified with a caveat about limited information, they suggested obese persons with COVID-19 may be at a higher risk for severe illness. Recent studies show that obesity may be linked to COVID-19 outcomes. Tartof et al. reported a 2.68-fold greater risk of death from COVID-19 only in the highest BMI groups (40+).[12] Kass et al. found that younger patients admitted for COVID-19 tended to be obese.[13]

African-American and Hispanic patients have a propensity toward higher BMI and have been reported to have worse outcomes when they are COVID-19 positive.[14] Price-Haywood et al. reported a high proportion (70.4%) of African-American patients in their cohort of 3,481 COVID-19 positive patients from Louisiana.[14] They also found that a high proportion of their COVID-19 positive patients who were admitted and died were African-American. Similarly, Khanna et al. found that COVID-19 detection rates were higher in Hispanic and African-American populations compared to Caucasian non-Hispanic patients.[15] In contrast, Tartof et al. did not find a significant association between race/ethnicity and mortality in their 6,916 patients with COVID-19.[12]

With mixed results prevailing with regard to the effect of and interaction between obesity and race in the course of COVID-19 patients, the primary goal of this study was to explore the association between obesity and hospital mortality in COVID-19 patients. Our secondary objective was to explore the relationship between obesity and race on hospital mortality in COVID-19 patients. Additional demographic variables, health characteristics and health service utilization variables were included to provide further insights into these associations.

Methods

This was a multicenter, cross-sectional, retrospective review using data from the HCA Healthcare GME Enterprise Data Warehouse, which has de-identified, validated, clinical data from 186 hospitals from across the United States and the United Kingdom. The HCA Healthcare Institutional Review Board approved this study prior to data extraction. The final data set for this study included data from US-based hospitals in 20 states.

The sampling frame included US patients who were tested in the emergency department for COVID-19 at HCA Healthcare facilities during the first quarter of 2020 (n=25,894). All confirmed COVID-19 cases, as of April 20, 2020, were included in the data set (n=2,977). During the time of data collection for this study, COVD-19 testing followed CDC guidelines, which consisted of a Real-Time Reverse Transcriptase PCR panel.

Mortality data (death during hospitalization) was collected on all patients as the primary outcome. Additional variables extracted were: demographics (including sex, race, age and ESRI demographics), health variables (including BMI, vitals, labs and co-morbidities), and health service utilization variables (including ICU admissions/days and ventilator use/days). Any patient listed as "patients under investigation" (PUI) was not included in the final analysis. Subjects' age range was 18–89+ in the data set and for "safe harbor" de-identification, subjects over age 89 were listed as age 90 for descriptive statistics.

As a primary variable of interest, BMI was extracted as a continuous variable. Subsequently, patients were stratified into six (WHO) BMI categories: underweight (BMI <18.5), normal or healthy weight (18.5 –24.9), pre-obesity (25–29.9), obese class I (30–34.9), obese class II (35–39.9) and obese class III (>40). All patients included in the analysis had a BMI above 13.5 and below 75 in order to reduce the potential influence of extremes in body composition that may have been present in a small number of patients.

Statistical analysis was performed using SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). Categorical variables were summarized using frequencies and percentages, while descriptive statistics for continuous variables

included mean, standard deviation, and minimum and maximum values. Initial bivariate statistics were run on categorical variables using cross-tabulations tables and chi-square tests or Fisher's exact tests (as appropriate) and Student's t-tests or Mann-Whitney U tests for continuous variables. The primary outcome variable was mortality. Initial bivariate comparisons of all COVID-19 positive patients who lived versus died was done using all demographic, health characteristics and health service utilization variables. A hierarchical logistic regression analysis was performed using only those variables that were statistically significant from the bivariate analyses: the first step (Model 1) included demographic variables, the second step (Model 2) included health characteristic variables and the third step (Model 3) included the health service utilization variables. All inferential statistical tests were 2-tailed and with a tolerance for nominal type 1 error (alpha) of 0.05.

Results

Demographics

Demographic characteristics of all patients who tested positive for COVID-19 are listed in **Table 1**. A slight majority were male (52.8%) and mortality was significantly higher in males

Table 1. Demographic Characteristics of COVID-19 Positive Patients

Characteristic	All Patients (n=2,977)	Patients Who Died (n=377)	Patients Who Lived (n=2,600)	P value*
Sex, n (%)				**<0.001**
Male	1,573 (52.8)	233 (14.8)	1,340 (85.2)	
Female	1,404 (47.2)	144 (10.3)	1,260 (89.7)	
Race/ethnicity, n (%)				**0.003**
Caucasian	1,075 (36.1)	168 (15.6)	907 (84.4)	
African American	895 (30.1)	110 (12.3)	785 (87.7)	
Hispanic	649 (21.8)	62 (9.6)	587 (90.4)	
Asian	103 (3.5)	12 (11.7)	91 (88.3)	
Other	255 (8.6)	25 (9.8)	230 (90.2)	
Age at index date				
Mean (SD)	59.88 (17.01)	71.98 (14.03)	58.12 (16.69)	
Median (Q1–Q3)	60 (48–73)	74 (64–82.5)	58.5 (46–70.25)	**<0.001**
By age group, n (%)				**<0.001**
18–30y	156 (5.2)	2 (1.3)	154 (98.7)	
31–40y	283 (9.5)	13 (4.6)	270 (95.4)	
41–50y	441 (14.8)	17 (3.9)	424 (96.1)	
51–60y	612 (20.6)	38 (6.2)	574 (93.8)	
61–70y	610 (20.5)	83 (13.6)	527 (86.4)	
71–80y	495 (16.6)	100 (20.2)	395 (79.8)	
81–90y	378 (12.7)	124 (32.8)	254 (67.2)	
ESRI Demographics				0.078
PUC, n (%)	63 (2.1)	3 (4.8)	60 (95.2)	
UP, n (%)	517 (17.4)	77 (14.9)	440 (85.1)	
MC, n (%)	294 (9.9)	34 (11.6)	260 (88.4)	
SP, n (%)	577 (19.4)	57 (9.9)	520 (90.1)	
SR, n (%)	90 (3)	13 (14.4)	77 (85.6)	
R, n (%)	125 (4.2)	16 (12.8)	109 (87.2)	

PUC = principal urban centers; UP = urban periphery; MC = metro cities; SP = suburban periphery; SR = semirural; R = rural.

*Mann-Whitney U was used for all continuous variables with a non-normal distribution. Fisher's exact test was used for bivariate cross-tabulations with a count <5; otherwise Pearson chi-square was used for all other categorical variables.

compared to females with 14.8% of COVID-19 positive male patients dying compared to only 10.3% of COVID-19 positive female patients (p<0.001). Stratified by race, most patients were Caucasian (36.1%). African Americans were over-represented in the COVID-19 positive group, making up 30.1% of the positive tests, but only 14.3% of those tested. There was a similar over-representation of Hispanics, who made up 21.8% of the positive tests, but only 16.3% of total tests. There was a statistically significant relationship between race and mortality in COVID-19 positive patients (p=0.003). (**Table 1**) Of the Caucasian patients, 15.6% died, reflecting the highest percentage across racial categories, followed by African Americans (12.3%). At the index date, the mean age was 59.9 (+17.0) and most patients fell into either the 51–60 (20.6%) or 61–70 (20.5%) age categories. Age was significantly (p<0.001) higher in COVID-19 positive patients who died (mean, 71.98 years) compared to those COVID-19 positive patients who lived (mean, 58.12 years; **Table 1**). With respect to geographic location or level of "rurality," the largest proportion of patients were from suburban areas (19.4%) or urban peripheries (17.4%) (areas between urban centers and suburbs); no statistically significant relationship was found between ESRI categories and mortality (p = 0.078).

Health Characteristics

Table 2 provides health characteristics of all COVID-19 positive patients. The mean BMI for all COVID-positive patients was 31.53 with most patients falling into either the pre-obese (30.2%) or obese I (24.9%) categories. Although those who died had a higher BMI (average 33.25) vs. those who lived (average 31.51), there was no statistically significant difference in mortality between different obesity categories. For patient vitals, the average body temperature (37.16° C), pulse (96.7 bpm) and respiration rate (20.5) were in the normal range, at the high end of normal and elevated, respectively. Of the 11 lab values (indicated as abnormal versus normal), all but one (aspartate aminotransferase) had a statistically significant

Table 2. Health Characteristics of COVID-19 Positive Patients

Characteristic	All Patients (n=2,977)	Patients Who Died (n=377)	Patients Who Lived (n=2,600)	P value*
BMI				
Mean (SD)	31.53 (7.9)	33.25 (9.13)	31.51 (7.72)	
Median (Q1–Q3)	30.18 (26.24–35.41)	30.41 (25.5–35.26)	30.17 (26.41–35.47)	0.696
By category, n (%)				0.086
Underweight	39 (1.3)	9 (23.1)	30 (76.9)	
Normal weight	506 (17)	73 (14.4)	433 (85.6)	
Pre-obese	898 (30.2)	97 (10.8)	801 (89.2)	
Obese I	741 (24.9)	96 (13)	645 (87)	
Obese II	410 (13.8)	47 (11.5)	363 (88.5)	
Obese III	383 (12.9)	55 (14.4)	328 (12.2)	
Vitals				
Temp (Celsius)				
Mean (SD)	37.16 (0.74)	37.08 (1.25)	37.18 (.67)	
Median (Q1–Q3)	37 (36.7–37.5)	37 (36.5–37.7)	37 (36.8–37.5)	0.075
Pulse				
Mean (SD)	96.7 (18.83)	99.73 (23.42)	96.19 (18.23)	
Median (Q1–Q3)	96 (84–109)	99 (84–114)	96 (83–108)	**0.003**
Respiration rate				
Mean (SD)	20.5 (5.36)	23.6 (8.17)	20.06 (4.68)	
Median (Q1–Q3)	18 (18–22)	20 (18–26)	18 (18–22)	**<0.001**

ALT = alanine aminotransferase; AST = aspartate aminotransferase; BMI = body mass index; CK = creatine kinase; COPD = chronic obstructive pulmonary disease; HCT = hematocrit; HGB = hemoglobin; HIV = human immunodeficiency virus; RBC = red blood cell; WBC = white blood cell

* Mann-Whitney U was used for all continuous variables with a non-normal distribution. Fisher's exact test was used for bivariate cross-tabulations with a count <5; otherwise Pearson chi-square was used for all other categorical variables.

Table 2. Cont'd.

Characteristic	All Patients (n=2,977)	Patients Who Died (n=377)	Patients Who Lived (n=2,600)	P value*
Labs, n (%)				
ALT (abnormal)	743 (25.3)	93 (12.5)	650 (87.5)	0.872
ALT (normal)	2,234 (74.7)	280 (12.7)	1,917 (87.3)	
AST (abnormal)	1,603 (53.8)	275 (17.2)	1,328 (82.8)	**<0.001**
AST (normal)	1,374 (46.2)	102 (7.4)	1,272 (92.6)	
CK (abnormal)	309 (37.4)	97 (31.4)	212 (68.6)	**<0.001**
CK (normal)	2,668 (62.6)	85 (16.4)	432 (83.6)	
Creatinine (abnormal)	1,029 (34.6)	243 (23.6)	786 (76.4)	**<0.001**
Creatinine (normal)	1,948 (65.4)	134 (6.9)	1,814 (93.1)	
HCT (abnormal)	516 (30.7)	118 (22.9)	398 (77.1)	**<0.001**
HCT (normal)	2,461 (69.3)	127 (10.9)	1,037 (89.1)	
HGB (abnormal)	977 (32.8)	191 (19.5)	786 (80.5)	**<0.001**
HGB (normal)	2,000 (67.2)	186 (9.3)	1,814 (90.7)	
Platelet (abnormal)	723 (24.3)	132 (18.3)	591 (81.7)	**<0.001**
Platelet (normal)	2,254 (75.7)	245 (10.9)	2,009 (89.1)	
WBC (abnormal)	561 (28.1)	96 (17.1)	465 (82.9)	**0.001**
WBC (normal)	2,416 (71.9)	162 (11.3)	1,279 (88.7)	
Lactate (abnormal)	515 (22.4)	157 (30.5)	358 (69.5)	**<0.001**
Lactate (normal)	2,462 (77.6)	187 (10.5)	1,595 (89.5)	
Troponin (abnormal)	340 (17.8)	137 (40.3)	203 (59.7)	**<0.001**
Troponin (normal)	2,637 (82.2)	157 (10.0)	1,416 (90.0)	
Comorbidities				
Asthma (present)	254 (8.5)	21 (8.3)	233 (91.7)	**0.028**
Asthma (absent)	2,723 (91.5)	356 (13.1)	2,367 (86.9)	
Hypertension (present)	1,180 (39.6)	133 (11.3)	1,047 (88.7)	0.064
Hypertension (absent)	1,797 (60.4)	244 (13.6)	1,553 (86.4)	
COPD (present)	272 (9.1)	68 (25.0)	204 (75.0)	**<0.001**
COPD (absent)	2,705 (90.9)	309 (11.4)	2,396 (88.6)	
Diabetes (present)	1,000 (33.6)	201 (20.1)	799 (79.9)	**<0.001**
Diabetes (absent)	1,977 (66.4)	176 (8.9)	1,801 (91.1)	
Stroke (present)	6 (0.2)	1 (16.7)	5 (83.3)	0.557
Stroke (absent)	2,971 (99.8)	376 (12.7)	2,595 (87.3)	
HIV (present)	16 (0.5)	3 (18.8)	13 (81.3)	0.444
HIV (absent)	2,961 (9.5)	374 (12.6)	2,587 (87.4)	
Sleep apnea (present)	131 (4.4)	28 (21.4)	103 (78.6)	**0.002**
Sleep apnea (absent)	2,846 (95.6)	349 (12.3)	2,497 (87.7)	
Any cancer (present)	22 (0.7)	8 (36.4)	14 (63.6)	**0.004**
Any cancer (absent)	2,955 (99.3)	369 (12.5)	2,586 (87.5)	
Smoking Status				**<0.001**
Never smoked, n (%)	1,899 (63.8)	158 (8.3)	1,741 (91.7)	
Former smoker, n (%)	525 (17.6)	84 (16)	441 (84.0)	
Current smoker, n (%)	185 (6.2)	16 (8.6)	169 (91.4)	
Unknown, n (%)	368 (12.4)	119 (32.3)	249 (67.7)	

ALT = alanine aminotransferase; AST = aspartate aminotransferase; BMI = body mass index; CK = creatine kinase; COPD = chronic obstructive pulmonary disease; HCT = hematocrit; HGB = hemoglobin; HIV = human immunodeficiency virus; RBC = red blood cell; WBC = white blood cell

* Mann-Whitney U was used for all continuous variables with a non-normal distribution. Fisher's exact test was used for bivariate cross-tabulations with a count <5; otherwise Pearson chi-square was used for all other categorical variables.

Table 3. Health Service Utilization of COVID-19 Positive Patients

Characteristic	All Patients (n=2,977)	Patients Who Died (n=377)	Patients Who Lived (n=2,600)	P value*
ICU				
Admission (yes), n (%)	871 (29.3)	281 (32.3)	590 (67.7)	**<0.001**
Admission (no), n (%)	2,106 (70.7)	96 (4.6)	2,010 (95.4)	
Length of stay (days)				
Mean (SD)	5.85 (4.87)	7.49 (4.94)	5.42 (4.84)	
Median (Q1–Q3)	4.59 (2.24–8.02)	5.68 (3.19–9.39)	3.83 (1.95–7.41)	**<0.001**
Ventilator				
Use (yes), n (%)	468 (15.7)	242 (51.7)	226 (48.3)	**<0.001**
Use (no), n (%)	2,509 (84.3)	135 (5.4)	2,374 (94.6)	
Number of days				
Mean (SD)	1.80 (0.63)	1.86 (0.61)	1.77 (.64)	
Median (Q1–Q3)	1.92 (1.61–2.19)	1.94 (1.62–2.24)	1.90 (1.57–2.12)	0.169

* Mann-Whitney U was used for all continuous variables with a non-normal distribution. Fisher's exact test was used for bivariate cross-tabulations with a count <5; otherwise Pearson chi-square was used for all other variables.

relationship with mortality, such that a greater percentage of patients with abnormal values died. The most prevalent comorbidities were hypertension (39.6%) and diabetes (33.6%). Of the comorbidities included, mortality was significantly higher in patients with COPD (p<0.001), diabetes (p<0.001), sleep apnea (p= 0.002) and any cancer (p=0.004). Finally, the majority of the sample self-reported as "never smoked" (63.8%), but smoking status had a statistically significant effect on mortality with those of unknown status having the highest mortality rate (32.3%) compared to all other smoking categories.

Health Service Utilization

Table 3 provides details on health service utilization of all COVID-19 positive patients. Of those who tested positive, 871 (29.3%) were admitted to the ICU and the average length of stay was 5.85 days. Only 468 patients (15.7%) became ventilator dependent and the average length was 1.8 days. Chi-squared tests showed a statistically significant relationship between both ICU admission and ventilator use and mortality (p<0.001 for both variables). Statistical significance was corroborated by Mann-Whitney U tests for number of days in ICU (p <0.001) but not number of days on a ventilator (p =0.169).

Hierarchical Logistic Regression Analysis

Table 4 provides a summary of the three logistic regression models. In Model 1, which only included demographic variables, males were 1.66 times more likely to die compared to females (p<0.001), and for every 1-year increase in age, patients were 1.06 times more likely to die (p<0.001). There were no significant differences based on race.

In Model 2, all of the demographic and health characteristic variables were included. Age was the only demographic variable that retained statistical significance. Of the health characteristic variables, BMI was statistically significant with every 1-point increase in BMI increasing the odds of dying by 1.07 times (p=0.008). Of the lab data, abnormal lactate was the only statistically significant variable with the odds of dying increased over 8 times (p <0.001). Of the comorbidities, only diabetes was statistically significant with the odds of dying increased over 3.6 times (p=0.003)

Table 4. Summary of Hierarchical Regression Analysis for Variables Predicting Death of COVID-19 Positive Patients

	Model 1			Model 2			Model 3		
Variable	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Sex (ref=female)	1.664	1.318–2.101	<0.001	0.914	0.390–2.141	0.835	12.339	0.692–219.96	0.087
Race (ref=White)									
African American	1.307	0.988–1.729	0.06	1.109	0.421–2.926	0.834	0.636	0.061–6.617	0.705
Hispanic	1.073	0.769–1.496	0.680	0.851	0.206–3.518	0.824	1.451	0.068–31.167	0.812
Asian	0.784	0.411–1.495	0.460						
Other	0.931	0.583–1.487	0.766	1.255	0.242–6.496	0.786			
Age	1.062	1.053–1.071	<0.001	1.075	1.035–1.116	<0.001	1.069	0.953–1.200	0.254
BMI				1.074	1.018–1.132	0.008	1.291	1.019–1.635	**0.034**
Vitals									
Pulse				1.011	0.989–1.033	0.334	1.029	0.971–1.092	0.332
Respiration rate				0.992	0.929–1.060	0.810	0.938	0.811–1.085	0.389
Labs									
AST				1.640	0.638–4.215	0.305	2.614	0.250–27.365	0.423
RBC				1.139	0.362–3.587	0.824	2.132	0.105–43.336	0.622
CK				2.131	0.892–5.091	0.089	0.204	0.022–1.883	0.161
Creatinine				0.763	0.301–1.937	0.570	0.336	0.024–4.777	0.420
HCT				0.732	0.249–2.153	0.570	2.523	0.120–52.997	0.551
HGB				0.606	0.183–2.004	0.411	0.138	0.008–2.501	0.180
Platelet				1.105	0.455–2.682	0.825	3.283	0.385–27.986	0.277
WBC				1.053	0.421–2.635	0.912	0.696	0.055–8.860	0.780
Lactate				8.040	3.233–19.99	<0.001	32.023	1.86–549.56	**0.017**
Troponin				2.187	0.863–5.547	0.099	3.026	0.282–32.461	0.360
Comorbidities									
Asthma				0.988	0.247–3.954	0.987	1.734	0.022–138.86	0.806
COPD				1.898	0.630–5.718	0.255	4.307	0.160–116.01	0.385
Diabetes				3.652	1.550–8.606	0.003	16.828	1.41–201.45	0.026
Sleep apnea				1.957	0.540–7.090	0.307			
Any cancer				45.427	0.731–223.301	0.070			
ICU (length of stay, days)							0.913	0.685–1.216	0.534
Ventilator (no. of days)							1.055	0.039–28.363	0.975
Chi-square test of model coefficients	263.37***			121.97***			57.79***		

Hierarchical logistic regression analysis using only those variables that were statistically significant from the bivariate analyses: the first step (Model 1) included demographic variables, the second step (Model 2) included health characteristic variables, and the third step (Model 3) included the health service utilization variables. Parameters unable to be estimated in the model are represented with dashes. Chi-square test of model coefficients: ***p<0.001.

Lastly, Model 3 included all variables from Models 1 and 2 as well as the health service utilization variables. None of the demographic variables retained statistical significance. Of the health characteristic variables, BMI retained statistical significance with every 1-point increase in BMI increasing the odds of dying by 1.3 times (p=0.034). Of the lab data, having an abnormal lactate test retained statistical significance with the odds of dying increased over 32 times (p=0.017). Similarly, of the comorbidities, having diabetes retained statistical significance with the odds of dying increased nearly 17 times (p=0.026). Neither admittance to the ICU nor being on a ventilator (number of days) were statistically significant.

Discussion

Obesity continues to be a major global public health issue, with its prevalence increasing progressively over the past four decades and therefore increasing the prevalence of associated comorbidities, morbidity and mortality.[1,16] With the COVID-19 pandemic, insights from large, national datasets to explore the complex associations between obesity, race and other pertinent variables are needed. In our study, data on all patients tested for COVID-19 across 186 HCA hospitals in the first quarter of 2020 were analyzed with the main goal of examining relationships between BMI and COVID-19 mortality.

Although a bivariate analysis of BMI and mortality showed no statistical significance, COVID-19 patients with a higher BMI had a statistically significant higher rate of mortality when controlling for other demographic variables, health characteristic variables and health service utilization variables in the logistic regression models. With every 1-point increase in BMI there was an increase in the odds of dying by 1.07 times or 1.3 times (Model 2, Model 3 respectively; **Table 4**). This discrepancy between the bivariate and regression analyses may indicate that other confounding variables (such as age, lactate and/or diabetes—all statistically significant in the regression models) are contributing to the impact of BMI on mortality.

The impact of obesity on mortality found in this study are similar to what was found during the H1N1 influenza virus outbreak of 2009–2010 in California.[11] During that outbreak, 66% of patients with obesity also had multiple comorbidities, such as COPD, diabetes and coronary artery disease, which lead to higher need for hospitalization, mechanical ventilation and a higher rate of mortality. The effect of obesity on mortality is not surprising, given that obesity is associated with decreased expiratory reserve volume, functional capacity and reduced respiratory system compliance.[11] Furthermore, it has been shown that adipose tissue allows persistence of other viral infections such as HIV, influenza A and cytomegalovirus, in addition to exacerbating pro-inflammatory responses and contributing to anti-infectious immune responses.[16] Such effects of obesity on the body also help to explain why there was a significantly higher mortality when associated with comorbidities, which we found to be significant for COPD, diabetes, sleep apnea and any type of cancer. (**Table 2**) A recent meta-analysis review has also shown significant increased mortality risks associated with COVID-19 in patients with obesity.[17]

In our study, African-American and Hispanic patients were overrepresented in the COVID-19 positive group, making up 30.1% and 21.8% of the positive tests, respectively, but only 14.3% and 16.3% of those tested. In the bivariate analysis, (**Table 1**) race was statistically significant; however, based on the regression models, there was no significant relationship between mortality and race. (**Table 4**) Similarly, Tartof et al. found no evidence of a race/mortality effect in a sample of COVID-19 positive patients in southern California.[12] Price-Haywood et al., on the other hand, reported high proportions of African-Americans (70+%) in their patient population who tested positive, were admitted and who died.[14] Obesity rates tend to be higher in African-American and Hispanic populations but these differences did not influence mortality in our sample when controlling for other variables.[21]

Our bivariate and regression analyses also showed that age was significantly higher in COVID-19 positive patients who died (**Table 1**; **Table 2**: Models 1 and 2). A similar relationship between age and mortality was found for patients dying in relation to COVID-19 in Italy. Onder et al. reported a higher rate of mortality in patients 70 years or older.[18] In the current

study, COVID-19 positive patients who died were older (mean 71.98 years) compared to those COVID-19 positive patients who survived (mean 58.12 years, **Table 1**). These age-related findings may be secondary to the multiple physiologic changes related to aging that lead to redistribution of fat from subcutaneous to abdominal depots and to the liver, muscles and other ectopic sites that can affect organic failure through lipotoxicity.[19] Age-related mortality may also be linked to higher pro-inflammatory states in the elderly, as well as insulin resistance, both of which help explain how select comorbidities were linked to COVID-19 mortality and obesity.[20]

As a retrospective study, our results should be considered within the context of several limitations. First, the data are limited to US patients tested for COVID-19 during the first quarter of 2020; therefore, our findings are subject to early stages of knowledge and action in terms of identification and treatment of COVID-19. Second, the majority of patient encounters were in the states of Texas (n=47 hospitals) and Florida (n=46 hospitals), with an additional 34 hospitals in South Carolina, Georgia, Louisiana and Tennessee. Thus, while the HCA Healthcare system has hospitals in a broad geographic range (e.g., California, New Hampshire, Indiana, Kentucky, Idaho and Missouri), our population demographics are geographically disproportionate to the Southwestern and Southeastern regions of the US given the predominate hospital locations of this particular data set. There is increased prevalence of obesity in these regions and the overall BMI of patients in our sample is higher than the average American BMI, which could have influenced our results. Third, COVID-19 testing was done in hospital emergency rooms. Consequently, our sample may reflect patients who were sicker than the general population and may have been more likely to test positive.

Conclusion

Controlling for other variables in our regression analysis, obesity was associated with a significantly higher risk of mortality in patients with COVID-19. However, in these models, race was not significantly related to mortality in COVID-19 positive patients. Age and diabetes were significantly related to mortality. This study adds to the continuing efforts to better understand the complexities of the COVID-19 pandemic and suggests that greater vigilance and higher rate of testing for this at-risk population that includes older patients, patients who are obese, patients with diabetes and other select co-morbid conditions is warranted.

Conflicts of Interest

The authors declare they have no conflicts of interest.

Drs. Ferez-Pinzon, Mabe, Senkowski and Shaw are employees of Memorial Health University Medical Center, a hospital affiliated with the journal's publisher.

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