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Determining whether ethnic minorities with severe obesity face a disproportionate risk of serious disease and death from COVID-19: outcomes from a Southern California-based retrospective cohort study

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ABSTRACT

Objective Obesity has been recognised as a risk factor for poor outcomes associated with COVID-19. Ethnic minorities with COVID-19 have been independently found to fare poorly. We aim to determine if ethnic minorities with severe obesity—defined as a body mass index (BMI) above 40 kg/m²—experience higher rates of hospitalisation, invasive ventilation and death.

Design and setting Retrospective cohort study from 1 March 2020 to 28 February 2021 within an integrated healthcare organisation in Southern California.

Participants We identified 373 831 patients by COVID-19 diagnosis code or positive laboratory test.

Methods Multivariable Poisson regression with robust error variance estimated adjusted risks of hospitalisation, invasive ventilator use and death within 30 days. Risks were stratified by ethnicity and BMI.

Results We identified multiple differences in risk of poor outcomes across BMI categories within individual ethnic groups. Hospitalisation risk with a BMI over 45 kg/m² was greater in Asian (RR 2.31, 95% CI 1.53 to 3.49; p<0.001), Hispanic (RR 3.22, 95% CI 2.99 to 3.48; p<0.001) and Pacific Islander (RR 3.79, 95% CI 2.49 to 5.75; p<0.001) patients compared with White (RR 2.04, 95% CI 1.79 to 2.33; p<0.001) and Black (RR 2.00, 95% CI 1.70 to 2.34; p<0.001) patients. A similar trend was observed with invasive ventilation risk. The risk of death was greater in Asian (RR 3.96, 95% CI 1.88 to 8.33; p<0.001), Hispanic (RR 3.03, 95% CI 2.53 to 3.61; p<0.001) and Pacific Islander (RR 4.60, 95% CI 1.42 to 14.92; p=0.011) patients compared with White (RR 1.47, 95% CI 1.13 to 1.91; p=0.005) and Black (RR 2.83, 95% CI 1.99 to 4.02; p<0.001) patients with a BMI over 45 kg/m².

Conclusions Ethnic minorities with severe obesity, particularly Asian, Hispanic and Pacific Islander patients, had a statistically significant higher risk of hospitalisation, invasive ventilator use and death due to COVID-19. Potential explanations include differences in adipose tissue deposition, overall inflammation and ACE-2 receptor expression.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study included a large, diverse cohort from Kaiser Permanente Southern California—an integrated healthcare system where access to care may have been more uniform.

⇒ We accurately obtained information from virtual, outpatient and inpatient care streams through a robust electronic medical record system.

⇒ Our cohort was made up of patients positive for COVID-19 defined as having a diagnosis of COVID-19 or having a positive test processed in our laboratory. Some patients who tested positive outside of Kaiser Permanente Southern California may have been missed.

⇒ Patients with COVID-19 who lack insurance, did not pursue testing or encountered barriers to testing and medical evaluation were not accounted for in this study.

⇒ Some patients who did not have a body mass index on record or were categorised as having 'other' ethnicity were not included. Further, the representation of Pacific Islander patients in our cohort was small.

INTRODUCTION

Out of the world's 535 million reported COVID-19 cases, the USA bares the heaviest burden of disease and death with 85.4 million reported cases and over 1 million deaths as of 12 June 2022. California has reported the highest total cases and deaths in the country due to SARS-CoV-2.[1] Our understanding of unique combinations of risk factors that lead to severe disease and death is incomplete.

Ethnic minorities have been disproportionately affected, with reports from the UK indicating worse outcomes in Black, South Asian and Middle Eastern communities.[2–4] Brazil's Black and Pardo or mixed communities

experienced a higher risk of death.[5] The USA has seen COVID-19 disproportionately affect individuals of Black, Hispanic and Asian descent.[6] In California, members of the Pacific Islander community have died from COVID-19 at a rate that is fourfold their population share.[7]

Societal factors including barriers to timely care, living in crowded conditions and having jobs that cannot be performed remotely have been used to explain this disparity in minority groups.[8 9] Limitations in English proficiency could also contribute to this disparity, particularly in Asian and Hispanic patients.[7 10] Additionally, people of colour may carry a larger burden of comorbidities including obesity, diabetes and cardiovascular disease that could promote poor outcomes in COVID-19.[11 12]

While severe disease has been associated with advanced age and comorbidities such as cardiovascular disease, hypertension and diabetes, obesity has emerged as a strong and independent predictor of unfavourable outcomes.[13–16] This has been attributed to a chronic inflammatory state driven by obesity.[17 18] Severe disease related to COVID-19 has also been associated with an exaggerated inflammatory response triggered by a destructive cytokine storm.[19]

The UK has reported a connection between poor outcomes in ethnic minority groups with obesity.[20] Such an interaction between obesity, ethnicity and severe disease in COVID-19 has not yet been described in depth in the USA.

A better understanding of the association between ethnicity and obesity in COVID-19 and its impact on severe disease (ie, hospitalisation and invasive ventilator use) and mortality has invaluable public health implications aimed at reducing this risk in our most vulnerable communities.

As such, we aim to describe differences in the risk of hospitalisation, invasive ventilation and death due to COVID-19 among ethnic groups stratified across multiple categories of obesity in patients belonging to a large integrated healthcare system in Southern California.

METHODS
Study design and setting
This was an Institutional Review Board-approved retrospective cohort study of Kaiser Permanente Southern California (KPSC) patients over the age of 18 years diagnosed with COVID-19 by diagnosis code or positive PCR laboratory test from 1 March 2020 to 28 February 2021 (online supplemental eFigure 1, eTable 1). KPSC electronic health records were used to abstract demographic and clinical information including vital signs, healthcare utilisation and mortality data. Non-hospitalised patients were included—particularly when assessing mortality. California State and Social Security Administration Death Master Files were used to identify additional members who died from COVID-19. As of the end of 2019, most of the 4.6 million KPSC members were Hispanic or Latino (43%) and White (35%), followed by Asian or Pacific

Islander (13%) and Black and African American (8%). We included only patients who had continuous enrolment in the health plan for at least 6 months prior to their COVID-19 diagnosis date.

Exposure
The main grouping variables were ethnicity and body mass index (BMI). BMI in the units of kg/m^2 was categorised as less than 25, 25–29.9, 30–34.9, 35–39.9, 40–44.9 and greater than or equal to 45. The adjusted BMI in the units of kg/m^2 with different cut points for Asian patients was categorised as less than 23, 23–27.4, 27.5–32.4, 32.5–37.4, 37.5–42.4 and equal to or greater than 42.5.[21]

Outcomes
The primary outcomes were hospitalisation within 30 days after COVID-19 diagnosis date, invasive ventilator use and death within 30 days of COVID-19 diagnosis date.

Data analysis
Adjusted risk ratios and the 95% CIs were estimated by Poisson regressions with a robust error variance. Statistical control was used to control for confounding. Covariates included in the adjusted models were age, gender, ethnicity, income, date of COVID-19 diagnosis, BMI, smoking status, pregnancy and comorbidities associated with high risk for severe COVID-19 defined by the Centers for Disease Control and Prevention.[22] These underlying conditions included hypertension, heart failure, diabetes, coronary artery disease, atherosclerosis, sleep apnoea, chronic obstructive pulmonary disease, chronic kidney disease, end-stage renal disease, HIV/AIDS, cerebrovascular disease, chronic liver disease, fatty liver, immunosuppressive treatment and malignancy. Interaction terms between both ethnicity and BMI, as well as with adjusted BMI for Asian patients, were explored; covariates in the main models were also used for adjustment. All analyses were conducted by using SAS (V.9.4 for Windows; SAS Institute). Patients without a BMI were excluded from regression analysis. We reanalysed our models to include a missing BMI category to identify any differences in results.

Patient and public involvement
There was no patient or public involvement.

RESULTS
Study population
A total of 373831 patients with a diagnosis of COVID-19 between 1 March 2020 and 28 February 2021 were included; the majority of patients (65.3%) were diagnosed between December 2020 and February 2021 (online supplemental eFigure 1, table 1). Our cohort included 60.2% Hispanic, 20.6% White, 6.5% Asian, 6.0% Black and 0.7% Pacific Islander patients (table 1). The mean age of our cohort was 44.9. Females represented the majority of patients at 54.1%. Mean household median income was $76900 (table 1). The most common comorbidities

Table 1 Demographics of patients with COVID-19 by ethnicity

	White (n=76997; 20.6%)	Black (n=22506; 6.0%)	Hispanic (n=225230; 60.2%)	Asian (n=24129; 6.5%)	Pacific Islander (n=2550; 0.7%)	Others (n=22419; 6.0%)	Total (n=373831)
BMI							
Missing	2326 (0%)	459 (0%)	7887 (0%)	781 (0%)	84 (0%)	6663 (0%)	18200 (4.9%)
<25kg/m²	19002 (25.4%)	3729 (16.9%)	33219 (15.3%)	8960 (38.4%)	510 (20.7%)	3767 (23.9%)	69187 (19.5%)
25–29.9kg/m²	23913 (32%)	5814 (26.4%)	68773 (31.6%)	8965 (38.4%)	782 (31.7%)	5097 (32.3%)	113344 (31.9%)
30–34.9kg/m²	16869 (22.6%)	5599 (25.4%)	60478 (27.8%)	3698 (15.8%)	543 (22%)	3821 (24.3%)	91008 (25.6%)
35–39.9kg/m²	8543 (11.4%)	3539 (16.1%)	31873 (14.7%)	1172 (5%)	298 (12.1%)	1777 (11.3%)	47202 (13.3%)
40–44.9kg/m²	3730 (5%)	1863 (8.5%)	13968 (6.4%)	383 (1.6%)	167 (6.8%)	800 (5.1%)	20911 (5.9%)
≥45kg/m²	2614 (3.5%)	1503 (6.8%)	9032 (4.2%)	170 (0.7%)	166 (6.7%)	494 (3.1%)	13979 (3.9%)
Age							
18–30 years	14193 (18.4%)	4331 (19.2%)	57716 (25.6%)	3787 (15.7%)	461 (18.1%)	8059 (35.9%)	88547 (23.7%)
31–40 years	13334 (17.3%)	3965 (17.6%)	47838 (21.2%)	4761 (19.7%)	491 (19.3%)	5905 (26.3%)	76294 (20.4%)
41–50 years	12398 (16.1%)	3899 (17.3%)	45829 (20.3%)	4992 (20.7%)	564 (22.1%)	4007 (17.9%)	71689 (19.2%)
51–60 years	14762 (19.2%)	4553 (20.2%)	39869 (17.7%)	4717 (19.5%)	530 (20.8%)	2743 (12.2%)	67174 (18%)
61–70 years	11649 (15.1%)	3188 (14.2%)	21541 (9.6%)	3572 (14.8%)	314 (12.3%)	1272 (5.7%)	41536 (11.1%)
71–80 years	6601 (8.6%)	1655 (7.4%)	8913 (4%)	1610 (6.7%)	144 (5.6%)	341 (1.5%)	19264 (5.2%)
≥81 years	4060 (5.3%)	915 (4.1%)	3524 (1.6%)	690 (2.9%)	46 (1.8%)	92 (0.4%)	9327 (2.5%)
Mean age (years)	49.5	48.3	43.3	48.2	46.5	38.2	44.9
Gender							
Female	39853 (51.8%)	13444 (59.7%)	125026 (55.5%)	13307 (55.1%)	1302 (51.1%)	9335 (41.6%)	202267 (54.1%)
Male	37142 (48.2%)	9061 (40.3%)	100194 (44.5%)	10821 (44.8%)	1248 (48.9%)	13081 (58.3%)	171547 (45.9%)
Other	1 (0%)	0 (0%)	3 (0%)	1 (0%)	0 (0%)	0 (0%)	5 (0%)
Unknown	1 (0%)	1 (0%)	7 (0%)	0 (0%)	0 (0%)	3 (0%)	12 (0%)
Median household income							
Missing	175 (0%)	64 (0%)	211 (0%)	35 (0%)	6 (0%)	43 (0%)	534
<$40000	2388 (3.1%)	2261 (10.1%)	17365 (7.7%)	755 (3.1%)	77 (3%)	1353 (6%)	24199 (6.5%)
$40000–$74999	23816 (31%)	11301 (50.4%)	121364 (53.9%)	7893 (32.8%)	978 (38.4%)	9836 (44%)	175188 (46.9%)
$75000–$99999	22226 (28.9%)	5234 (23.3%)	58669 (26.1%)	7114 (29.5%)	784 (30.8%)	5991 (26.8%)	100018 (26.8%)
$100000 and above	28392 (37%)	3646 (16.2%)	27621 (12.3%)	8332 (34.6%)	705 (27.7%)	5196 (23.2%)	73892 (19.8%)
Mean median household income	$91405.70	$71638.20	$70762.90	$89551.20	$84424.30	$79557.10	$76896.60
Time of COVID-19 diagnosis							
March 2020 to May 2020	2146 (2.8%)	1018 (4.5%)	7396 (3.3%)	1475 (6.1%)	145 (5.7%)	532 (2.4%)	12712 (3.4%)
June 2020 to August 2020	9673 (12.6%)	3357 (14.9%)	38211 (17%)	2784 (11.5%)	319 (12.5%)	3325 (14.8%)	57669 (15.4%)

Continued

Table 1 Continued

	White (n=76997; 20.6%)	Black (n=22506; 6.0%)	Hispanic (n=225230; 60.2%)	Asian (n=24129; 6.5%)	Pacific Islander (n=2550; 0.7%)	Others (n=22419; 6.0%)	Total (n=373831)
September 2020 to November 2020	13254 (17.2%)	3270 (14.5%)	35440 (15.7%)	3303 (13.7%)	366 (14.4%)	3556 (15.9%)	59189 (15.8%)
December 2020 to February 2021	51924 (67.4%)	14861 (66%)	144183 (64%)	16567 (68.7%)	1720 (67.5%)	15006 (66.9%)	244261 (65.3%)
Smoking history							
Ever	23392 (30.4%)	5575 (24.8%)	44229 (19.6%)	5263 (21.8%)	712 (27.9%)	3464 (15.5%)	82635 (22.1%)
Never	51190 (66.5%)	16450 (73.1%)	172922 (76.8%)	18088 (75%)	1738 (68.2%)	13055 (58.2%)	273443 (73.1%)
Unknown	2415 (3.1%)	481 (2.1%)	8079 (3.6%)	778 (3.2%)	100 (3.9%)	5900 (26.3%)	17753 (4.7%)
Comorbidities							
Obesity (BMI ≥30 kg/m²)	31756 (41.2%)	12504 (55.6%)	115351 (51.2%)	5423 (22.5%)	1174 (46.0%)	6892 (30.7%)	173100 (46.3%)
Pregnant	1211 (1.6%)	441 (2%)	5313 (2.4%)	477 (2%)	47 (1.8%)	160 (0.7%)	7649 (2%)
Hypertension	15467 (20.1%)	6572 (29.2%)	31926 (14.2%)	5230 (21.7%)	615 (24.1%)	1565 (7%)	61375 (16.4%)
Heart failure	2360 (3.1%)	900 (4%)	2438 (1.1%)	409 (1.7%)	55 (2.2%)	84 (0.4%)	6246 (1.7%)
Diabetes	8676 (11.3%)	4228 (18.8%)	32337 (14.4%)	4215 (17.5%)	555 (21.8%)	1259 (5.6%)	51270 (13.7%)
Coronary artery disease	2842 (3.7%)	699 (3.1%)	2924 (1.3%)	648 (2.7%)	64 (2.5%)	132 (0.6%)	7309 (2%)
Atherosclerosis	5187 (6.7%)	1369 (6.1%)	6149 (2.7%)	1242 (5.1%)	100 (3.9%)	183 (0.8%)	14230 (3.8%)
Sleep apnoea	3545 (4.6%)	969 (4.3%)	5302 (2.4%)	622 (2.6%)	129 (5.1%)	301 (1.3%)	10868 (2.9%)
Chronic obstructive pulmonary disease	7373 (9.6%)	2711 (12%)	13120 (5.8%)	1545 (6.4%)	205 (8%)	846 (3.8%)	25800 (6.9%)
Chronic kidney disease	3273 (4.3%)	1104 (4.9%)	3769 (1.7%)	785 (3.3%)	106 (4.2%)	142 (0.6%)	9179 (2.5%)
End-stage renal disease	264 (0.3%)	320 (1.4%)	1107 (0.5%)	187 (0.8%)	27 (1.1%)	8 (0%)	1913 (0.5%)
HIV	252 (0.3%)	115 (0.5%)	594 (0.3%)	46 (0.2%)	6 (0.2%)	41 (0.2%)	1054 (0.3%)
Cerebrovascular disease	1811 (2.4%)	656 (2.9%)	2040 (0.9%)	370 (1.5%)	36 (1.4%)	84 (0.4%)	4997 (1.3%)
Chronic liver disease	372 (0.5%)	96 (0.4%)	963 (0.4%)	71 (0.3%)	7 (0.3%)	22 (0.1%)	1531 (0.4%)
Fatty liver	822 (1.1%)	209 (0.9%)	3434 (1.5%)	313 (1.3%)	35 (1.4%)	133 (0.6%)	4946 (1.3%)
Immunosuppressive treatment	3 (0%)	1 (0%)	7 (0%)	2 (0%)	0 (0%)	0 (0%)	13 (0%)
Malignancy	2072 (2.7%)	650 (2.9%)	2917 (1.3%)	458 (1.9%)	46 (1.8%)	103 (0.5%)	6246 (1.7%)

BMI, body mass index

were obesity (46.3%), hypertension (16.4%) and diabetes (13.7%) (table 1).

Overall analyses of risk

The overall risk of hospitalisation, invasive ventilation and death due to COVID-19 was lower under the age of 51 and higher over the age of 60 compared with patients between the ages of 51 and 60. Those over the age of 81 had a 4.4 times higher risk of hospitalisation (RR 4.44, 95% CI 4.23 to 4.66; p<0.001), 4.2 times higher risk of invasive ventilation (RR 4.22, 95% CI 3.66 to 4.88; p<0.001) and 14.9 times higher risk of death compared with the reference group of patients aged 51–60 years (RR 14.87, 95% CI 13.31 to 16.62; p<0.001) (online supplemental eFigures 2–4).

Females had a lower risk of hospitalisation (RR 0.63, 95% CI 0.62 to 0.65; p<0.001), invasive ventilation (RR 0.42, 95% CI 0.39 to 0.45; p<0.001) and death (RR 0.53, 95% CI 0.50 to 0.56; p<0.001) due to COVID-19 compared with males (online supplemental eFigures 2–4).

Patients earning over \$100 000 had a lower risk of hospitalisation (RR 0.91, 95% CI 0.87 to 0.96; p<0.001) and death (RR 0.78, 95% CI 0.70 to 0.87; p<0.001) compared with those with an income under \$40 000 (online supplemental eFigures 2 and 4). A significant difference in risk of invasive ventilation (RR 0.99, 95% CI 0.86 to 1.14; p=0.893) was not observed (online supplemental eFigure 3).

Patients with diabetes had a higher risk of hospitalisation (RR 1.41, 95% CI 1.37 to 1.45; p<0.001), invasive ventilation (RR 1.62, 95% CI 1.51 to 1.75; p<0.001) and death (RR 1.39, 95% CI 1.31 to 1.47; p<0.001) (online supplemental eFigures 2–4).

Hispanic and White patients represented the majority of patients who were hospitalised (55.4%, 23.6%), invasively ventilated (64.6%, 15.9%) and who died (49.5%, 29.2%) because of COVID-19. Compared with White patients, Asian and Pacific Islander patients had higher rates of hospitalisation (Asian: RR 1.56, 95% CI 1.49 to 1.63, p<0.001; Pacific Islander: RR 1.59, 95% CI 1.42 to 1.77, p<0.001), invasive ventilator use (Asian: RR 2.91, 95% CI 2.56 to 3.30, p<0.001; Pacific Islander: RR 2.60, 95% CI 1.94 to 3.47, p<0.001) and death (Asian: RR 1.35, 95% CI 1.23 to 1.49, p<0.001; Pacific Islander: RR 1.56, 95% CI 1.21 to 2.02, p<0.001) (online supplemental eFigures 2–4).

There was a trend towards higher risk of hospitalisation, invasive ventilation and death with increasing BMI. There was a 2.8 times higher risk of hospitalisation (RR 2.76, 95% CI 2.60 to 2.94; p<0.001), a 6.0 times greater risk of invasive ventilation (RR 6.03, 95% CI 5.16 to 7.05; p<0.001) and a 2.4 times higher risk of death (RR 2.41, 95% CI 2.11 to 2.76; p<0.001) in patients with a BMI greater than or equal to 45 kg/m² (online supplemental eFigures 2–4).

Interaction of ethnicity and BMI

We identified differences in the distribution of BMI categories across ethnic groups which were more evident at higher BMI categories. For example, 1.6% of Asian patients had a BMI between 40 and 44.9 kg/m² compared with 8.5% of Black and 6.4% of Hispanic patients (table 1).

We detected multiple differences when we analysed the risk of hospitalisation, invasive ventilation and death among patients with different BMI categories compared with normal BMI under 25 kg/m² within their individual ethnic groups.

At BMIs greater than or equal to 45 kg/m², the risk of hospitalisation was higher in Hispanics (RR 3.22, 95% CI 2.99 to 3.48; p<0.001), Pacific Islanders (RR 3.79, 95% CI 2.49 to 5.75; p<0.001) and in Asian (RR 2.31, 95% CI 1.53 to 3.49; p<0.001) patients. Comparatively, the risk at this BMI category was not as high in Black (RR 2.00, 95% CI 1.70 to 2.34; p<0.001) and White patients (RR 2.04, 95% CI 1.79 to 2.33; p<0.001) (figure 1).

Differences in the risk of invasive ventilation were higher in Hispanic (RR 3.71, 95% CI 3.07 to 4.49; p<0.001), Asian (RR 4.50, 95% CI 2.43 to 8.30; p<0.001) and Pacific Islander (RR 4.40, 95% CI 1.36 to 14.31; p=0.014) patients compared with Black (RR 2.78, 95% CI 1.76 to 4.37; p<0.001) and White (RR 2.92, 95% CI 2.03 to 4.20; p<0.001) patients at BMIs of 40–44.9 kg/m² (figure 2).

Less difference in the risk of invasive ventilation was observed at BMIs greater than or equal to 45 kg/m² for all ethnic groups compared with their counterparts with normal BMI (Asian: RR 5.66, 95% CI 2.68 to 11.96, p<0.001; Black: RR 4.88, 95% CI 3.10 to 7.67, p<0.001; Hispanic: RR 5.96, 95% CI 4.89 to 7.27, p<0.001; Pacific Islander: RR 6.34, 95% CI 1.91 to 21.01, p=0.003; White: RR 5.55, 95% CI 3.92 to 7.84, p<0.001) (figure 2).

White patients at every BMI category between 25 and 40 kg/m² experienced less risk of death compared with White patients with a normal BMI (BMI 25–29.9 kg/m²: RR 0.65, 95% CI 0.58 to 0.73, p<0.001; BMI 30–34.9 kg/m²: RR 0.67, 95% CI 0.58 to 0.76, p<0.001; BMI 35–39.9 kg/m²: RR 0.81, 95% CI 0.69 to 0.96, p=0.017) (figure 3). Black patients at BMI categories between 30 and 44.9 kg/m² had no significant difference in risk of death compared with those with a normal BMI (BMI 30–34.9 kg/m²: RR 0.98, 95% CI 0.77 to 1.23, p=0.834; BMI 35–39.9 kg/m²: RR 1.09, 95% CI 0.83 to 1.44, p=0.535; BMI 40–44.9 kg/m²: RR 1.06, 95% CI 0.71 to 1.58, p=0.778) (figure 3). The risk of death rose as BMI increased in Asian (BMI 35–39.9 kg/m²: RR 2.08, 95% CI 1.46 to 2.96, p<0.001; BMI 40–44.9 kg/m²: RR 3.09, 95% CI 1.74 to 5.47, p<0.001), Hispanic (BMI 35–39.9 kg/m²: RR 1.31, 95% CI 1.15 to 1.49, p<0.001; BMI 40–44.9 kg/m²: RR 2.00, 95% CI 1.70 to 2.34, p<0.001) and Pacific Islander patients (BMI 30–34.9 kg/m²: RR 2.35, 95% CI 1.13 to 4.92, p=0.023; BMI 40–44.9 kg/m²: RR 4.47, 95% CI 1.63 to 12.25, p=0.004) (figure 3).

Among every ethnic group, the risk of death was highest when the BMI was greater than or equal to 45
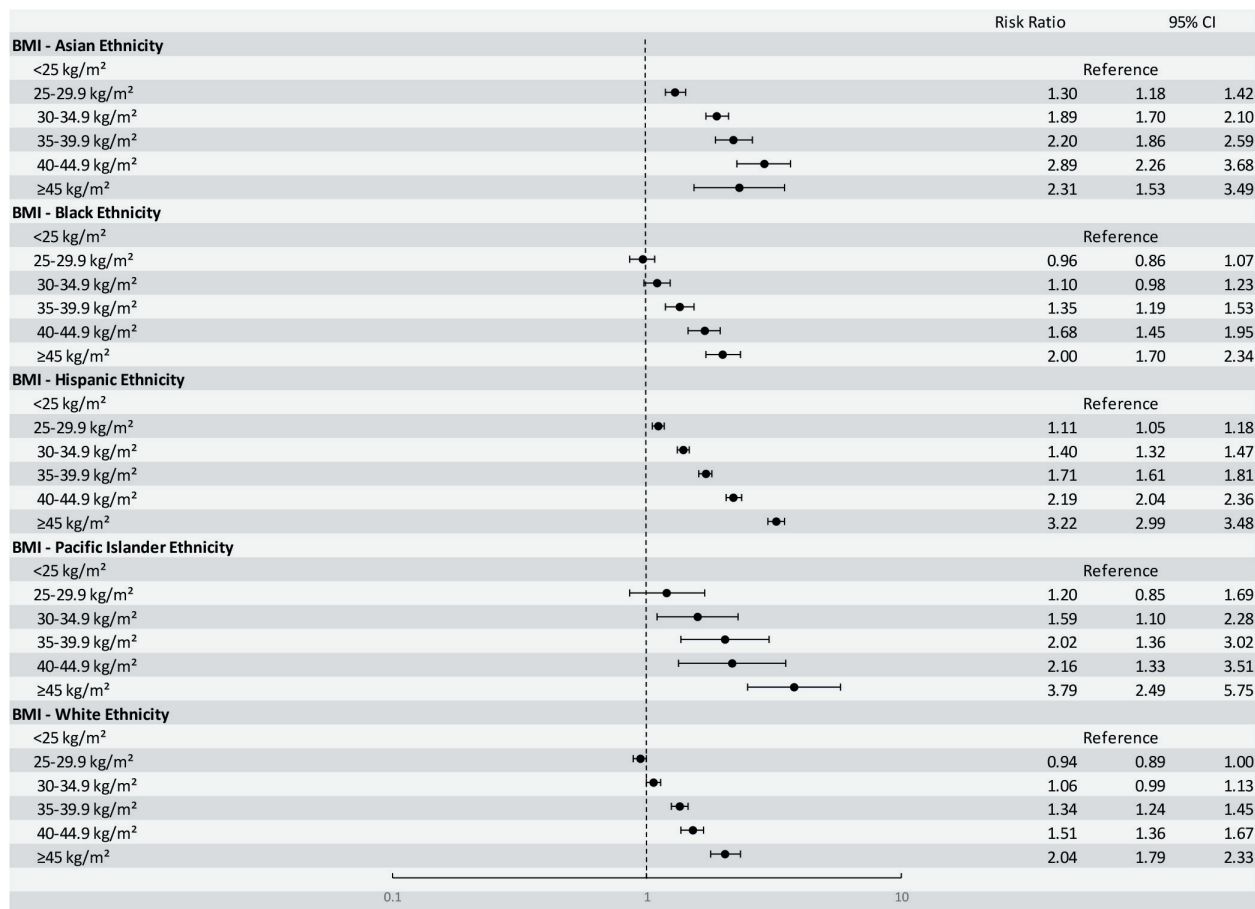
Figure 1 Forest plots of adjusted risk ratios of body mass index for hospitalisation stratified by ethnicity (n=25 970). Models were adjusted for ethnicity, age, gender, income, smoking history, pregnancy, hypertension, heart failure, diabetes, coronary artery disease, atherosclerosis, sleep apnoea, chronic obstructive pulmonary disease, chronic kidney disease, end-stage renal disease, HIV, cerebrovascular disease, chronic liver disease, fatty liver, immunosuppressive treatment and malignancy. BMI, body mass index.

kg/m². While White patients had a 1.5 times higher risk (RR 1.47, 95% CI 1.13 to 1.91; p=0.005), the risk was higher by 2.8 times in Black patients (RR 2.83, 95% CI 1.99 to 4.02; p<0.001), 3.0 times in Hispanic patients (RR 3.03, 95% CI 2.53 to 3.61; p<0.001), 4.0 in Asian patients (RR 3.96, 95% CI 1.88 to 8.33; p<0.001) and 4.6 in Pacific Islander patients (RR 4.60, 95% CI 1.42 to 14.92; p=0.011) (figure 3).

Utilisation of adjusted BMI categories in Asian patients

In the analysis of adjusted BMI categories, Asian patients with an adjusted BMI of 37.5–42.4 kg/m² had a 6.6 times higher risk of invasive ventilation compared with Asian patients with a BMI under 23 kg/m² (RR 6.55, 95% CI 3.98 to 10.77; p<0.001) (online supplemental eTable 2). Patients with a BMI greater than or equal to 42.5 kg/m² had a 6.4 times higher risk of invasive ventilation (RR 6.36, 95% CI 3.16 to 12.79; p<0.001) (online supplemental eTable 2). The risk of death was 3.0 times for Asian patients with an adjusted BMI greater than or equal to 42.5 kg/m² (RR 3.04, 95% CI 1.64 to 5.66; p<0.001) (online supplemental eTable 2).

Missing data

BMI was missing in 5% of patients in our study. The differences were small when we ran sensitivity analysis comparing model results with and without patients missing a BMI.

DISCUSSION

In this ethnically diverse Southern California-based managed care cohort, the risk of hospitalisation, invasive ventilation and death was higher in Asian, Hispanic and Pacific Islander patients with severe obesity compared with Black and White patients with severe obesity. The study took place between 1 March 2020 and 28 February 2021—a time when the COVID-19 vaccine was not readily available in the USA. Lineages B.1.429 and B.1.427 of the Epsilon variant became the dominant strain of SARS-CoV-2 during a winter surge between November 2020 and March 2021 in Southern California.[23]

The acceleration in risk of hospitalisation with increasing BMI was less striking in Black and White patients compared with other ethnic groups. At BMIs
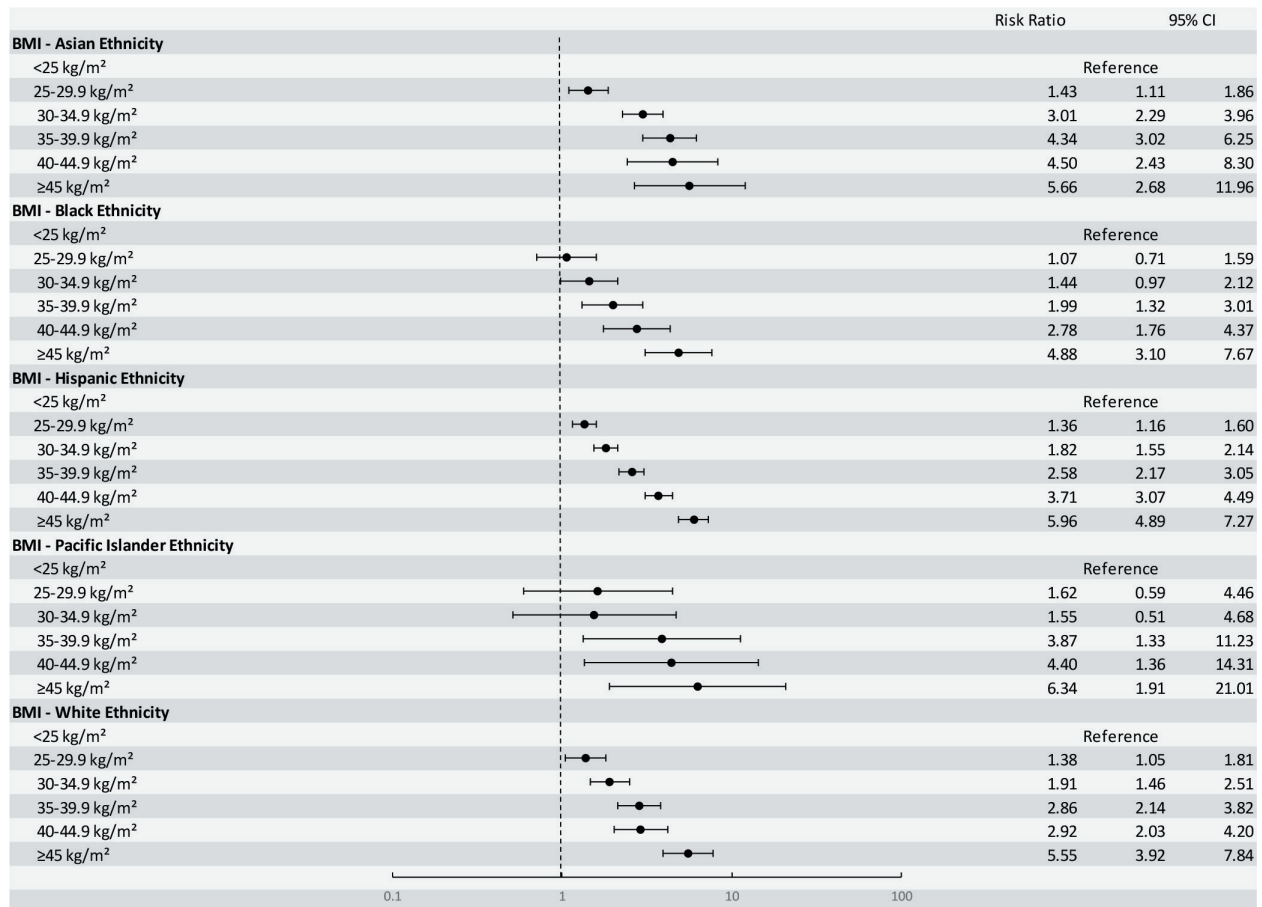
	Risk Ratio	95% CI	
BMI - Asian Ethnicity			
<25 kg/m²	Reference		
25-29.9 kg/m²	1.43	1.11	1.86
30-34.9 kg/m²	3.01	2.29	3.96
35-39.9 kg/m²	4.34	3.02	6.25
40-44.9 kg/m²	4.50	2.43	8.30
≥45 kg/m²	5.66	2.68	11.96
BMI - Black Ethnicity			
<25 kg/m²	Reference		
25-29.9 kg/m²	1.07	0.71	1.59
30-34.9 kg/m²	1.44	0.97	2.12
35-39.9 kg/m²	1.99	1.32	3.01
40-44.9 kg/m²	2.78	1.76	4.37
≥45 kg/m²	4.88	3.10	7.67
BMI - Hispanic Ethnicity			
<25 kg/m²	Reference		
25-29.9 kg/m²	1.36	1.16	1.60
30-34.9 kg/m²	1.82	1.55	2.14
35-39.9 kg/m²	2.58	2.17	3.05
40-44.9 kg/m²	3.71	3.07	4.49
≥45 kg/m²	5.96	4.89	7.27
BMI - Pacific Islander Ethnicity			
<25 kg/m²	Reference		
25-29.9 kg/m²	1.62	0.59	4.46
30-34.9 kg/m²	1.55	0.51	4.68
35-39.9 kg/m²	3.87	1.33	11.23
40-44.9 kg/m²	4.40	1.36	14.31
≥45 kg/m²	6.34	1.91	21.01
BMI - White Ethnicity			
<25 kg/m²	Reference		
25-29.9 kg/m²	1.38	1.05	1.81
30-34.9 kg/m²	1.91	1.46	2.51
35-39.9 kg/m²	2.86	2.14	3.82
40-44.9 kg/m²	2.92	2.03	4.20
≥45 kg/m²	5.55	3.92	7.84

Figure 2 Forest plots of adjusted risk ratios of body mass index for invasive ventilation stratified by ethnicity (n=4051). Models were adjusted for ethnicity, age, gender, income, smoking history, pregnancy, hypertension, heart failure, diabetes, coronary artery disease, atherosclerosis, sleep apnoea, chronic obstructive pulmonary disease, chronic kidney disease, end-stage renal disease, HIV, cerebrovascular disease, chronic liver disease, fatty liver, immunosuppressive treatment and malignancy. BMI, body mass index.

of 40–44.9 kg/m², the risk of hospitalisation was higher by 1.5 times in White patients and 1.7 times in Black patients, but 2.9 times in Asian patients, and 2.2 times in Hispanic and Pacific Islander patients (figure 1). Risk of invasive ventilation in those with a BMI of 40–44.9 kg/m² was higher by 4.5 times in Asian patients, 4.4 times in Pacific Islander patients and 3.7 times in Hispanic patients. This compares to a higher risk of 2.8 times in Black patients and 2.9 times in White patients (figure 2). At BMIs greater than or equal to 45 kg/m² though, the risk of invasive ventilation became less different across all ethnicities.

A protection from death was only largely observed in White patients with BMIs between 30 and 39.9 kg/m² (figure 3). An obesity or BMI paradox has associated severe obesity with lower mortality rates in patients with acute respiratory distress syndrome (ARDS).[24 25] Excess fat may create an advantageous environment of caloric reserves for patients in intensive care settings.[26] Black patients saw no significantly higher risk of mortality at BMIs between 30 and 44.9 kg/m² (figure 3). The risk of death disproportionately trended up as BMI increased in Asian, Hispanic and Pacific Islander patients (figure 3).

While we observed White patients were protected from death at BMI categories under 45 kg/m², reports have indicated that the BMI paradox does not apply to COVID-19 which in severe cases can also lead to ARDS.[27]

In our study, a BMI paradox was not observed in any ethnicity with a BMI greater than or equal to 45 kg/m². Risk of death at the highest BMI category was disproportionately elevated in minority ethnic groups—2.8 times greater in Black patients, 3.0 times greater in Hispanic patients, 4.0 times greater in Asian patients and 4.6 times greater in Pacific Islander patients compared with a 1.5 times greater risk in White patients who had a BMI greater than or equal to 45 kg/m² (figure 3). Further, reports have identified fundamental flaws including collider bias and reverse causality that compromise the validity of a BMI paradox.[28–31]

While further investigation is needed to explain these differences, our findings could potentially be explained by variability in adipose tissue deposition and inflammatory markers. Subcutaneous adipose tissue (SAT) is elevated in Black patients and may have a protective function because of its association with reduced triglycerides and increased high-density lipoprotein.[32–34]
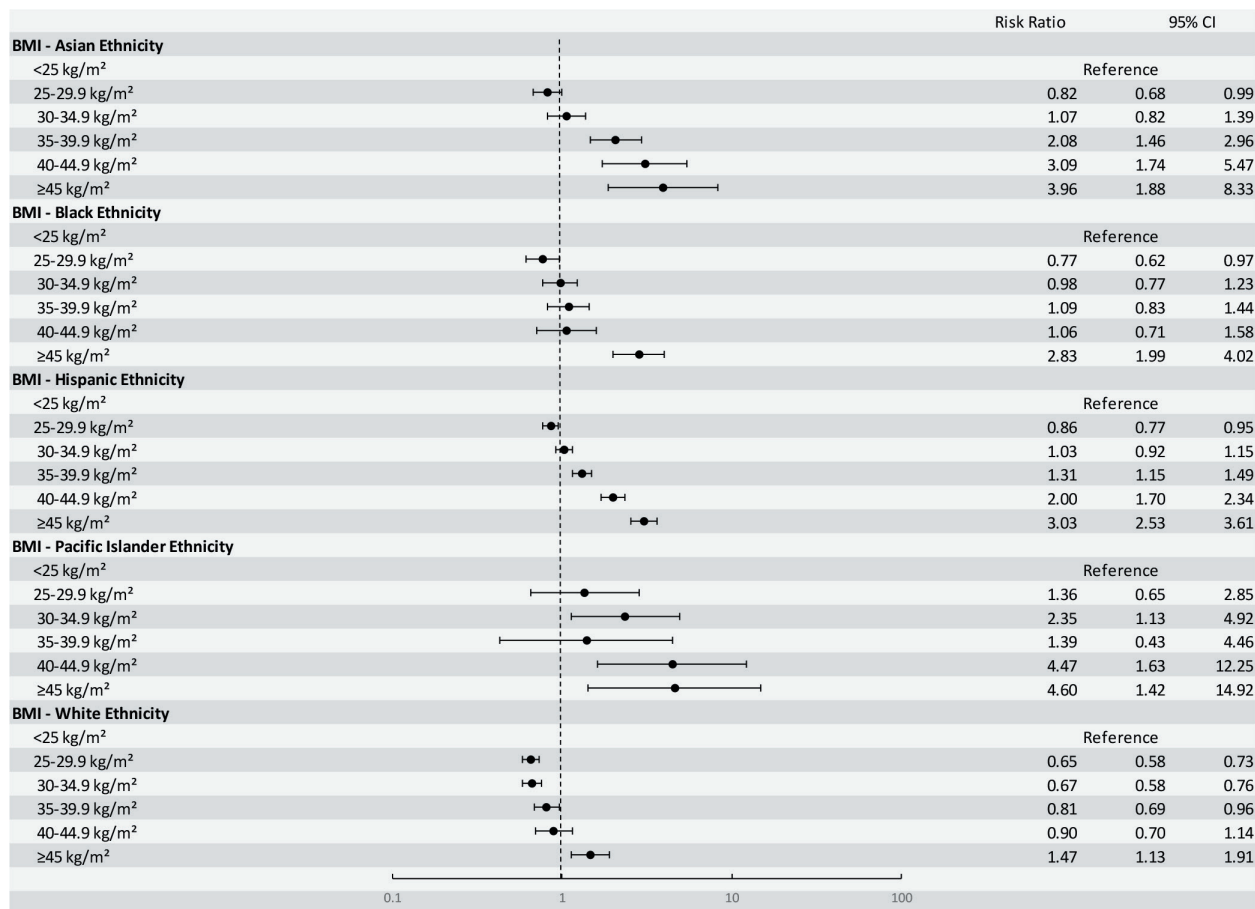
Figure 3 Forest plots of adjusted risk ratios of body mass index for mortality stratified by ethnicity (n=5670). Models were adjusted for ethnicity, age, gender, income, smoking history, pregnancy, hypertension, heart failure, diabetes, coronary artery disease, atherosclerosis, sleep apnoea, chronic obstructive pulmonary disease, chronic kidney disease, end-stage renal disease, HIV, cerebrovascular disease, chronic liver disease, fatty liver, immunosuppressive treatment and malignancy. BMI, body mass index.

Non-Hispanic Black patients have less visceral adipose tissue (VAT) compared with non-Hispanic White patients and Hispanic patients.[34]

Those with higher levels of VAT have been independently linked to worse outcomes related to COVID-19.[33 35] VAT is found at higher levels in Asian and Pacific Islander patients and has been more strongly associated with cardiometabolic risk, systemic inflammation and insulin resistance.[32–34 36 37] Hypertrophied adipocytes in excess VAT can be infiltrated by macrophages leading to reduced levels of anti-inflammatory adiponectin and increased production of inflammatory cytokines such as tumour necrosis factor alpha and interleukin 6.[38] ACE-2, the receptor SARS-CoV-2 uses to achieve intracellular entry, is present at especially high levels in VAT which is located around the organs.[33] ACE-2 has been found to be expressed at higher levels in adipose tissue in general, the lungs and in Asian patients compared with Black and White patients.[19 39]

Because of this difference in fat distribution, it has been suggested that Asian individuals at lower BMIs compared with other ethnicities may carry a greater cardiometabolic risk.[40] When we adjusted BMI for Asian patients,

we did not find a striking difference in trends compared with results with standard cut-off points except for a few instances when examining the risk of invasive ventilation and death. While Asian patients with a BMI of 40–44.9 kg/m² had a 4.5 times higher risk of invasive ventilation compared with Asian patients with a normal BMI, this risk was 6.6 times higher in Asian patients with a BMI between 37.5 and 42.4 kg/m² compared with Asian patients with a BMI under 23 kg/m² (online supplemental eTable 2). The risk of mortality was 4.0 times greater for Asian patients with a BMI above 45 kg/m² and 3.0 times greater when the BMI was adjusted to above 42.5 kg/m² (online supplemental eTable 2).

Other important explanations for poor outcomes associated with COVID-19 among different ethnicities have been identified. Previous reports indicate diabetes and advanced age were associated with increased risk factors of infection with COVID-19 particularly in Hispanic patients.[41] We observed an increased risk of unfavourable outcomes in patients with diabetes, but this risk was overshadowed in patients with severe obesity (online supplemental eFigures 2–4). Our report found a significantly increased risk of severe disease and death in patients over

the age of 81 compared with patients between the ages of 51 and 60 (online supplemental eFigure 4). Poverty, which has been identified as an independent risk factor for COVID-19, has been shown to result in an increased risk of infection among White, Black and Hispanic patients.[41] Our results indicate wealthier patients who earned over $100 000 experienced a lower risk of hospitalisation and death due to COVID-19 (online supplemental eFigures 2 and 4).

Additional reports suggest Asian and Hispanic patients may experience barriers to quality and timely care due to various factors including limitations in English proficiency.[7 10] The COVID-19 pandemic led to a surge in patients seeking care by telemedicine. Disparities in telehealth use have been identified indicating utilisation was lower in Hispanic and Asian patients and higher in Black patients.[42–44] Reports have also found telehealth use was higher in Black patients with obesity during the pandemic.[45]

It has been reported in the UK that obesity is linked to a higher risk of hospitalisation and mortality in South Asian, Black and other ethnic minority patients compared with White patients.[20] Our study showed obesity carried a greater risk of poor outcomes in Asian, Pacific Islander and Hispanic patients—Black patients often had a similar risk to White patients. Few reports have highlighted Asian, Pacific Islander and Hispanic ethnic groups in such detail and as a result their outcomes with COVID-19 have been understudied.

This study has many important strengths. We included a large cohort from an integrated healthcare system where access to care is expected to be more uniform. With the use of a robust electronic medical record system, we accurately obtained information from virtual, outpatient and inpatient platforms. This report also has limitations. Patients who tested positive outside of KPSC, were undiagnosed or encountered barriers to care were not included. Further, we did not include patients who lacked a BMI on file or had an ethnicity listed as other. We also noted the representation of Pacific Islander patients was small compared with other ethnicities in our cohort.

CONCLUSIONS

We report new information showing obesity is disproportionately associated with a higher risk of hospitalisation, invasive ventilation and death in people of colour, particularly Asian, Hispanic and Pacific Islander patients. Based on a large and diverse cohort from an integrated medical system in Southern California, findings from this study illuminate the disproportionate risk of poor COVID-19 outcomes faced by ethnic minorities with severe obesity. While we did not directly measure SAT and VAT in this study, future research connecting higher levels of VAT with poor outcomes to COVID-19 could lead to a greater understanding of who may be most vulnerable.

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