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Obesity Not A Risk Factor For Adverse Seasonal Influenza Outcomes Among Hospitalized Adults: Evidence From A Us Multisite Study

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Obesity not a risk factor for adverse seasonal influenza outcomes among hospitalized adults: Evidence from a US multisite study

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INTRODUCTION

In the wake of the 2009 influenza pandemic A(H1N1), several studies linked obesity and/or morbid obesity to adverse outcomes like hospitalization [1], longer length of stay in intensive care unit (ICU) [2], and death [1, 3]. Despite strong evidence of a link between morbid obesity and adverse outcomes due to 2009 H1N1 flu, it remains unclear whether there is an association between obesity and influenza-related complications for influenza strains outside of H1N1, such as seasonal influenza [4].

Kwong and colleagues were the first to suggest a link between obesity and seasonal influenza in a cohort study over 12 influenza seasons in Canada [5]. The study found that adults classified as obese class I (body mass index [BMI] 30-34.9 units) and obese class II or III (BMI ≥35 units) had increased odds of hospitalization for respiratory disease during influenza seasons, compared to adults of normal weight [5]. However, Kwong and colleagues' study has two major limitations: use of self-reported BMI and selection of respiratory illness as an outcome [5]. Self-reported BMI may include incorrectly reported values [6], and respiratory illness outcomes may include cases that were hospitalized for causes other than influenza.

Few studies since have explored the association between obesity and seasonal influenza and those that have, have done so with conflicting results. While Cocoros and colleagues [7] found evidence of increased odds of hospitalization for influenza-like illness (ILI) in adults compared to adults of normal weight, Coleman and colleagues [8] reported no association between obesity and medically attended laboratory-confirmed influenza. The inconsistent results may be explained by Cocoros and colleagues' use of hospitalization as an outcome, while Coleman and colleagues studied laboratory-confirmed influenza as an outcome [7, 8]. Cocoros and colleagues were limited by the use of ILI as an outcome, instead of laboratory-confirmed influenza [7]. Coleman and colleagues interpreted their finding of no association by noting that "the risk factors for severe complications of influenza-associated illnesses may be fundamentally different from those for less severe, non-hospitalized influenza" [8].

In this study, we address some of the shortcomings of previous research on the possible link between obesity and influenza outcomes. Our study is, to our knowledge, the first to use laboratory-confirmed flu from a large national database to explore the association between obesity and severe outcomes among patients hospitalized for seasonal influenza. We examine the odds of receiving artificial ventilation procedure, admission to intensive care unit (ICU), and X-ray confirmed pneumonia diagnosis among hospitalized obese and morbidly obese adults compared to adults of normal weight. We control for several demographic and clinical characteristics, including influenza-related comorbidities and influenza vaccination status.

METHODS

Surveillance for Influenza-Associated Hospitalizations

We used data from the Centers for Disease Control's (CDC) Influenza Hospitalization Surveillance Project database, FluSurv-NET, gathered from October 1, 2012, to April 30, 2013 [9]. FluSurv-NET is a hospital surveillance program for laboratory-confirmed, influenza-related hospitalizations collected from participating hospitals in 81 counties in 10 states: California, Colorado, Connecticut, Georgia, Maryland, Minnesota, New Mexico, New York, Oregon, and Tennessee [9]. Emerging Infections Program sites in each of the 10 states complete Case Report Forms that are completed via medical chart review of medical records from participating hospitals [9]. Case Report Forms are then sent to the Centers for Disease Control and Prevention for aggregation [9].

Case Definition

We defined a case as an individual who tested positive for laboratory-confirmed influenza. Laboratory-confirmed influenza is defined as positive test result by viral culture, direct or indirect fluorescent antibody staining, a rapid diagnostic test, serologic testing (4-fold increase in titer), or a positive specified test indicated in the medical record. Cases were admitted to a hospital within 14 days of positive influenza test.

Body Mass Index

We determined BMI values for cases in the FluSurv-NET dataset by calculating BMI = weight (in kg) / height (in m)^2 using weight and height from a case's medical record. Because the CDC indicates that BMI categorization for individuals less than 20 years of age is different than BMI categorization for individuals greater than or equal to 20 years of age [10], we excluded 49 cases <20 years of age from our dataset. Pregnant women were also excluded from our analysis.

We calculated BMI for 9014 cases using weight and height abstracted from medical records. For cases where BMI could not be calculated because of missing height and/or weight values in our dataset, BMI abstracted from the medical record was used if available; 37 cases had missing calculated BMI replaced by BMI abstracted from medical record. For 14 cases with extreme values of calculated BMI, i.e. BMI ≥ 100 or BMI ≤ 10, BMI abstracted from medical record was used, if available; in all but 3 cases, extreme BMI values were replaced with BMI abstracted from medical record. In total, there were 778 cases with missing BMI value due to one of the following two conditions: 1) the case had extreme value of BMI (see definition of extreme value above) and no BMI from medical record available, or 2) height and/or weight was missing and BMI from the medical record was missing. Cases with missing BMI values were excluded from the analysis, resulting in a sample size of 9048.

We classified BMI into one of five categories: underweight (BMI <18.5), normal (BMI 18.5 to <25), overweight (BMI 25 to <30), obese (BMI 30 to <35), and morbidly obese (BMI ≥35).

Main Outcome Measures

We explored the relationship between obesity and three severe flu outcomes: artificial ventilation, ICU admission, and X-ray confirmed pneumonia. We defined artificial ventilation as a case that received either mechanical ventilation procedure or extracorporeal membrane oxygenation (ECMO). ICU admission includes but is not limited to: medical ICU, surgical ICU, and cardiac care unit. ICU admission excludes admission to a step-down unit or transitional care unit. X-ray confirmed pneumonia was determined using chest X-ray results. If chest X-ray results concluded one of the following, the subject was determined to have confirmed pneumonia: bronchopneumonia/pneumonia, air space density/opacity, pleural effusion, or multiple lobar infiltrate (unilateral or bilateral).

Covariates

Covariates were selected from one of four broad categories: demographic characteristics, comorbidities, lifestyle factors, and patient care factors that may be associated with severe influenza outcomes and/or BMI category. Our criteria for selection of covariates were comorbidities recognized by the Advisory Committee on Immunization Practices as risk factors for influenza [11], lifestyle factors associated with BMI and/or influenza outcome, demographic characteristics (age, sex, race), and patient care factors. Data for these variables were abstracted by trained medical chart reviewers at Emerging Infections Program centers across the US. Medical chart reviewers abstracted data directly from clinician's notes in patient's medical record using a well-defined procedure outlined in *Case Report Form Instructions*, Version 8, an instruction manual produced by the CDC [12].

Demographic Characteristics

The selected demographic characteristics we controlled for were age, sex, and race. Age was classified into 5 categories: 20 to <50, 50 to <65, 65 to <75, 75 to <85, and 85+. Race was abstracted from medical records in seven categories: white, black, American Indian or Alaska Native, Asian/Pacific Islander, multiracial, Latino, and unknown. We reclassified these categories into 4 new categories: white, black, Latino, and other/unknown to ensure a sufficient number of subjects in each race category to perform statistical analyses. Our other/unknown category combined cases classified on medical record as American Indian or Alaska Native, Asian/Pacific Islander, and unknown.

Comorbidities

The selected comorbidities we controlled for were cardiovascular disease (CVD), chronic metabolic disease (CMD), neuromuscular disorder, neurologic disorder, immunocompromised condition, renal disease, and asthma. We defined CVD by indication of one or more of the following conditions on the patient's medical record: aortic aneurysm, aortic stenosis, atherosclerotic cardiovascular disease, atrial fibrillation, cardiomyopathy, cerebral vascular incident/stroke, congenital cardiac anomaly, congenital heart disease, coronary artery disease, heart failure/CHF, ischemic cardiomyopathy, or non-ischemic cardiomyopathy. We defined CMD as presence of diabetes and/or thyroid disease on patient's medical record. We defined neuromuscular disorder by indication of at least one of the following conditions on patient's medical record: Duchenne muscular dystrophy, muscular dystrophy, multiple sclerosis, mitochondrial disorder, myasthenia gravis, or other specified conditions such as Parkinson's disease and myasthenia gravis. We defined neurologic disorder by indication of one of the following conditions on patient's medical record: cerebral palsy, cognitive dysfunction, dementia, development delay, Down syndrome, plegias/paralysis, seizure/seizure disorder, or other related conditions that include schizophrenia and spinal cord injuries. We defined immunocompromised condition by indication at least of one of the following conditions on patient's medical record: AIDS or CD4 count <200, cancer diagnosis in last 12 months, complement deficiency, HIV infection, immunoglobulin deficiency, immunosuppressive therapy (e.g. chemotherapy), organ transplant, stem cell transplant, steroid therapy, or other specified conditions such as lupus. We defined renal disease by indication of one of the following conditions on patient's medical record: chronic kidney disease/chronic renal insufficiency, end stage renal disease/dialysis, glomerulonephritis, or nephrotic syndrome. We defined asthma by indication of asthma or Reactive Airway Disease (RAD) on patient's medical record.

Lifestyle Factors

The selected lifestyle factors we controlled for were alcohol abuse, smoking status, and influenza vaccination status. We defined three categories of alcohol abuse: "current" if the patient quit abusing alcohol in the past 12 months or if no time frame is given, "former" if the patient quit abusing alcohol more than 12 months ago, and "non-abuser" if there was no indication of alcohol abuse, dependency, or alcoholism on the patient's medical record. We defined three categories of tobacco "smoker": "current" if the patient quit smoking tobacco in the past 12 months or if no time frame is given, "former" if the patient quit smoking tobacco more than 12 months ago, and "non-smoker" if there was no indication of smoking tobacco on the patient's medical record.

Patient Care Factors

Antiviral administration in the hospital was classified into 3 categories: "prompt" for patients who received antivirals the same day that they were admitted to the hospital, "late" for patients who received antivirals between day 2 and up to and including day 5 in the hospital, "none" for patients who received antivirals after day 5 in hospital or no antivirals at all. We classified vaccination into two categories: patients who were vaccinated during the fall or winter of the 2012-2013 influenza season and patients who were not vaccinated during this period. Vaccinated subjects typically receive protection against influenza from antibodies that develop during the body's response to the influenza vaccine [8].

Statistical Analyses

We performed a bivariate analysis using the chi-square test of homogeneity to determine whether, for a given covariate, the frequency of cases was distributed identically across our five BMI categories. To evaluate whether there is an association between obesity and/or morbid obesity and severe flu outcomes, we used logistic regression models with logit link function to calculate the odds of having a severe flu outcome for each of our five BMI categories. For each of three selected flu outcomes – artificial ventilation, ICU admission, and X-ray confirmed pneumonia – we ran unadjusted, sex- and age-adjusted, and fully-adjusted (for all covariates of interest) models. We selected the normal weight BMI category (BMI greater than 10 but less than 25) as the reference group for all models. We produced odds ratio point estimates, 95% Wald confidence limits, and associated p-values for each of the five BMI categories for our three outcome variables. SAS Version 9.3 was used for all statistical analyses [13].

RESULTS

This study included 9048 cases with laboratory-confirmed influenza. Table 1 shows characteristics of the study population. The mean and standard deviation of the age of cases was 68.3 ± 18.3 years. The majority of subjects were aged 50 or above, with only 16.5% of cases under 50 years old. 413 (4.6%) cases were underweight, 2847 (31.5%) were normal weight, 2701 (29.9%) were overweight, 1526 (16.9%) were obese, and 1561 (17.3%) were morbidly obese. Overall, the frequency of cases in each age group was evenly distributed. However, when stratifying age by BMI category, the majority of cases in the underweight category (31.0%) and normal weight category (31.8%) were 85+, while the majority of cases in the obese (26.3%) and morbidly obese (33.1%) categories were 50-64. Slightly more than half (53.8%) of our study population was female, and the distribution of males versus females for normal, overweight, and obese BMI groups was relatively even. However, there was a larger percentage of females than males in the underweight (65.6% female) and morbidly obese (63.4%) BMI categories.

The distribution of race was also similar across BMI categories. The distribution of current, former, and non-smokers was similar across BMI categories. The percentage of cases with chronic metabolic disease (CMD) increased as BMI category increased, while the percentages of cases with neurologic disorder, neuromuscular disorder, and immunosuppressive condition decreased as BMI category increased. The timing of antiviral administration was similarly distributed across BMI categories, with the majority of cases receiving prompt antiviral administration within one day of admission. A larger percentage of cases in the normal weight category (57.5%) received influenza vaccine compared to the morbidly obese category (46.5%).

Artificial Ventilation

There were 562 cases (6.2%) who received artificial ventilation. Unadjusted odds ratios (shown in Table 2) for artificial ventilation of obese and morbidly obese cases compared to normal weight cases were not significantly different from 1 (OR = 1.03, 95% CI = 0.80, 1.33, p=0.9789; OR=1.14, 95% CI = 0.89, 1.46, p=0.3030). Adjusting for all clinical and demographic characteristics did not reveal a significant association between obesity status and artificial ventilation. For overweight cases compared to normal weight cases, odds ratios for the unadjusted, age- and sex-adjusted, and fully-adjusted models were all protective, but non-significant (OR = 0.91, 95% CI = 0.72, 1.13, p=0.3828; OR = 0.86, 95% CI = 0.69, 1.08, p=0.1486; OR = 0.87, 95% CI = 0.68, 1.12, p=0.2796).

Intensive Care Unit

There were 1396 cases (15.5%) who were admitted to the ICU. Unadjusted odds ratios (shown in Table 4) for ICU admission among obese and morbidly obese cases compared to normal weight cases were not significant (OR=0.906, 95% CI 0.763 to 1.077, p=0.7374; OR=0.913, 95% CI 0.768 to 1.085, p=0.8780). Adjusting for sex and age did not reveal a

significant association between obesity or morbid obesity and ICU admission. The odds ratios for the fully-adjusted model revealed a non-significant protective effect of obesity and morbid obesity on ICU admission (OR = 0.89, 95% CI = 0.74, 1.07, p=0.2282; OR = 0.86, 95% CI = 0.71, 1.04, p=0.1109). There was a significant protective effect of overweight on ICU admission compared to normal weight group, after adjusting for all covariates in Table 1 (OR = 0.79, 95% CI = 0.67, 0.92, p=0.0036).

X-Ray Confirmed Pneumonia

There were 2854 cases (32.6%) with X-ray confirmed pneumonia. Unadjusted odds ratios (shown in Table 3) for X-ray confirmed pneumonia among obese and morbidly obese cases compared to normal weight cases were significantly less than 1 (OR = 0.73, 95% CI = 0.64, 0.84, p=0.0002; OR = 0.72, 95% CI = 0.63, 0.83, p<.0001). Adjusting for sex and age revealed a similar association of obesity and morbid obesity with X-ray confirmed pneumonia. After adjusting for all clinical and demographic characteristics, there was a significantly protective effect for odds of X-ray confirmed pneumonia for overweight compared to normal weight and obese compared to normal weight (OR = 0.87, 95% CI = 0.77, 0.98, p=0.0217; OR = 0.80, 95% CI = 0.69, 0.92, p=0.0023). The odds of X-ray confirmed pneumonia among morbidly obese compared to normal weight was protective, but non-significant (OR = 0.89, 95% CI = 0.76, 1.04, p=0.1353).

DISCUSSION

We found no association between obesity (BMI from 30-34.99) or morbid obesity (BMI ≥ 35) and severe seasonal flu outcomes among adults hospitalized during the 2012-2013 influenza season, after controlling for comorbidities, demographic characteristics, lifestyle factors, and patient care factors. We did find significantly reduced adjusted odds of X-ray confirmed pneumonia for both obese and morbidly obese compared to normal weight. These apparent protective effects were remained significant for obese cases, even after adjusting for all covariates. We found a significantly protective effect of overweight compared to normal weight for ICU admission outcome and X-ray confirmed pneumonia, for unadjusted, sex- and age-adjusted, and fully-adjusted models. Our results add to a growing body of research exploring the association between obesity and severe outcomes during influenza seasons where non-pandemic flu strains are dominant.

Our findings that obesity and morbid obesity are not associated with odds of artificial ventilation or ICU admission suggest that once an adult is admitted to the hospital, obesity does not affect the level of severity of patients. Age, sex, and other pre-existing comorbidities may explain the majority of variation in adverse outcomes, while BMI may play an insignificant role in explaining variation in adverse outcomes among patients. Another possible explanation of our findings that obesity and morbid obesity are not associated with increased odds of artificial ventilation or ICU admission is that obese patients may be “more likely to be admitted to hospital, even with milder disease” [15]. This could lead to a larger proportion of obese subjects with less severe outcomes compared to normal weight subjects, resulting in a finding of no or a protective effect of obesity on severe seasonal flu outcomes.

We suggest two possible explanations for our finding of significant protective effect of overweight and obesity for X-ray confirmed pneumonia. The first is that overweight and obesity may offer a protective effect for pneumonia. This result would provide evidence in favor of the obesity paradox, a phenomenon that has been observed among patients with chronic disease, where overweight and obese patients may have better health outcomes than lean patients [14]. Singanayagam and Chalmers have found that obesity (BMI ≥ 30) was independently associated with reduced 30-day mortality in patients hospitalized with community-acquired pneumonia [15]. An alternative explanation is that increased body thickness of obese individuals leads to limited diagnostic quality image, poor X-ray penetration, and poor visualization [16]. These technical difficulties associated with X-ray imaging of obese individuals may lead to lower rates of X-ray diagnosed pneumonia among obese and morbidly obese.

This study had several limitations. The administration of a laboratory influenza test depends on clinician's judgment of patient's symptoms [12]. This suggests that initiation of laboratory influenza testing may vary by clinician. Some clinicians may be more likely to initiate laboratory testing, or may differentially administer tests to patients based on patients' clinical and demographic characteristics. Adults who were hospitalized for influenza but were not tested for influenza by a clinician were not included in our FluSurv-NET database[12].

A second limitation of our study was that clinical diagnoses not listed in medical record were not included in FluSurv-NET database[12]. This may lead to underreporting of comorbidities associated with our outcomes of interest. Another possible limitation was that despite the inclusion of more than 9,000 cases of laboratory-confirmed influenza in our study, there were too few deaths (n=237) to study the association between BMI and death. Future studies may examine the association between death and obesity among patients hospitalized for seasonal influenza.

Nevertheless, our study had a number of strengths. First, all cases in our dataset had laboratory-confirmed influenza diagnosis, which allowed us to examine the association between BMI and adverse outcomes, for only patients who had confirmed seasonal influenza. Additionally, our database includes comprehensive data regarding patient comorbidities, vaccination status, antiviral administration, and severe in-hospital outcomes. With more than 1,500 cases in each of obese and morbidly obese categories, we had sufficiently large numbers of observations of severe outcomes in both obese and morbidly obese categories to create methodologically sound statistical models.

Our results suggest that severe obesity is not associated with increased risk of severe in-hospital outcomes among patients hospitalized for influenza during the 2012-2013 influenza season. These findings are in contrast to Cocoros et al.'s recent finding of a positive association between obesity and hospitalized influenza-like illness (ILI) among adults [7]. Our findings are more aligned with Coleman et al.'s finding that obesity was not associated with medically attended influenza among adults with acute respiratory illness [8]. Because dominant influenza strains tend to vary by flu season, further exploration of this association during different influenza seasons or among non-hospitalized adults may help elucidate the association between obesity and severe seasonal influenza outcomes.

In conclusion, using data from a large and comprehensive, multisite surveillance program, we found no evidence of increased odds of adverse influenza-related outcomes among obese and morbidly obese adults hospitalized for seasonal influenza. In addition, we found that overweight patients had decreased odds of adverse outcomes compared to normal weight patients. Although it has been widely demonstrated that obese and morbidly obese adults hospitalized during the 2009 H1N1 pandemic were at greater risk for adverse health outcomes, obese and morbidly obese patients who are hospitalized during seasonal influenza epidemics do not appear to fare any worse than their normal weight counterparts.

Table 1. Patient characteristics by BMI category

		BMI Categories					
	Overall N = 9048*	**1) Underweight (BMI <18.5)**	**2) Normal (BMI 18.5 to <25)**	**3) Overweight (BMI 25 to <30)**	**4) Obese (BMI 30 to <35)**	**5) Morbidly (Obese BMI ≥35)**	**p-value**
Demographic Characteristics							
Age Group							
20-49	1496 (16.53)	62(15.01)	431 (15.14)	396 (14.66)	230 (15.07)	377 (24.15)	**<.0001**
50-64	1966 (21.73)	74 (17.92)	465 (16.33)	510 (18.88)	401 (26.28)	516 (33.06)	
65-74	1587 (17.54)	57 (13.80)	425 (14.93)	460 (17.03)	325 (21.30)	320 (20.50)	
75-84	2007 (22.18)	92 (22.28)	620 (21.78)	716 (26.51)	329 (21.56)	250 (16.02)	
85+	1992 (22.02)	128 (30.99)	906 (31.82)	619 (22.92)	241 (15.79)	98 (6.28)	
Sex							
Male	4177 (46.16)	142 (34.38)	1337 (46.96)	1417 (52.46)	709 (46.46)	572 (36.64)	**<.0001**
Female	4871 (53.84)	271 (65.62)	1510 (53.04)	1284 (47.54)	817 (53.54)	989 (63.36)	
Race							
White	5989 (66.19)	275 (66.59)	1948 (68.42)	1844 (68.27)	971 (63.63)	951 (60.92)	**<.0001**
Black	1523 (16.83)	65 (15.74)	378 (13.28)	411 (15.22)	296 (19.40)	373 (23.89)	
Hispanic	605 (6.69)	17 (4.12)	155 (5.44)	185 (6.85)	125 (8.19)	123 (7.88)	
Other/ Unknown	931 (10.29)	56 (13.56)	366 (12.86)	261 (9.66)	134 (8.78)	114 (7.30)	
Comorbidities							
CVD	4354 (48.12)	163 (39.47)	1341 (47.10)	1317 (48.76)	786 (51.51)	747 (47.85)	**0.0003**
CMD	3769 (41.66)	126 (30.51)	962 (33.79)	1113 (41.21)	724 (47.44)	844 (54.07)	**<.0001**
Neuro-Muscular Disorder	406 (4.49)	21 (5.08)	148 (5.20)	129 (4.78)	64 (4.19)	44 (2.82)	**0.0054**
Neurologic Disorder	1833 (20.26)	124 (30.02)	723 (25.40)	551 (20.40)	239 (15.66)	196 (12.56)	**<.0001**
Immuno-compromised Condition	1516 (16.76)	99 (23.97)	512 (17.98)	425 (15.73)	244 (15.99)	236 (15.12)	**<.0001**
Renal Disease	1718 (18.99)	62 (15.01)	527 (18.51)	526 (19.47)	331 (21.69)	272 (17.42)	**0.0051**
Asthma	1664 (18.39)	47 (11.38)	386 (13.56)	439 (16.25)	317 (20.77)	475 (30.43)	**<.0001**
Lifestyle Factors							
Alcohol Abuse							
Current	321 (3.55)	21 (5.08)	124 (4.36)	92 (3.41)	49 (3.21)	35 (2.24)	**0.0039**
Former	298 (3.29)	10 (2.42)	88 (3.09)	81 (3.00)	64 (4.19)	55 (3.52)	
Smoking Status	1755 (19.40)	106 (25.67)	555 (19.49)	468 (17.33)	287 (18.81)	339 (21.72)	**0.0011**
Current	2551 (28.19)	102 (24.70)	783 (27.50)	781 (28.92)	452 (29.62)	433 (27.74)	
Former							
Patient Care Factors							
Antiviral Administra-tion							
Prompt	4117 (46.10)	182 (44.72)	1254 (44.63)	1252 (47.00)	707 (46.73)	722 (47.01)	0.1328
Late	3225 (36.11)	143 (35.14)	1049 (37.33)	975 (36.60)	513 (33.91)	545 (35.48)	
Influenza Vaccine	4495 (53.63)	194 (50.79)	1506 (57.52)	1381 (55.35)	737 (51.54)	677 (46.50)	**<.0001**

* Numbers may not sum to totals due to missing data

Bold p-values indicate a statistically significant chi-square test of homogeneity.

Table 2. Unadjusted and adjusted associations between BMI category and artificial ventilation

Artificial Ventilation n=9014	**Model 1: Unadjusted OR (95% CI)**	**Model 2: OR (95% CI) adjusted for sex and age (as categorical)**	**Model 3: OR (95% CI) adjusted for all covariates in Table 1**
Underweight	1.105 (0.731, 1.669)	1.126 (0.744, 1.705)	1.167 (0.752, 1.810)
Normal Weight	1	1	1
Overweight	0.905 (0.724, 1.132)	0.860 (0.687, 1.078)	0.870 (0.676, 1.120)
Obese	1.029 (0.797, 1.329)	0.927 (0.716, 1.201)	1.045 (0.788, 1.386)
Morbidly Obese	1.137 (0.887, 1.455)	0.969 (0.751, 1.249)	1.033 (0.774, 1.379)

Table 3. Unadjusted and adjusted associations between BMI category and ICU admission

ICU Admission n = 9017	**Model 1: Unadjusted OR (95% CI)**	**Model 2: OR (95% CI) adjusted for sex and age (as categorical)**	**Model 3: OR (95% CI) adjusted for all covariates in Table 1**
Underweight	1.121 (0.854, 1.471)	1.135 (0.864, 1.491)	1.055 (0.785, 1.419)
Normal Weight	1	1	1
Overweight	0.838 (0.723, 0.972)	0.809 (0.697, 0.940)	0.787 (0.670, 0.924)
Obese	0.971 (0.819, 1.152)	0.906 (0.763, 1.077)	0.892 (0.741, 1.074)
Morbidly Obese	1.013 (0.857, 1.198)	0.913 (0.768, 1.085)	0.855 (0.706, 1.036)

Table 4. Unadjusted and adjusted associations between BMI category and X-ray confirmed pneumonia

X-Ray Confirmed Pneumonia n=8769	**Model 1: Unadjusted OR (95% CI)**	**Model 2: OR (95% CI) adjusted for sex and age (as categorical)**	**Model 3: OR (95% CI) adjusted for all covariates in Table 1**
Underweight	1.291 (1.044, 1.596)	1.343 (1.085, 1.663)	1.330 (1.061, 1.668)
Normal Weight	1	1	1
Overweight	0.825 (0.736, 0.924)	0.831 (0.741, 0.932)	0.867 (0.768, 0.979)
Obese	0.734 (0.640, 0.841)	0.775 (0.675, 0.890)	0.795 (0.687, 0.921)
Morbidly Obese	0.724 (0.632, 0.829)	0.834 (0.724, 0.960)	0.890 (0.764, 1.037)

*n =8769 subjects who received chest X-ray

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