Public Health England

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Annexe A: Excess Weight and COVID-19

Insights from new evidence

UK and International Studies, including prevalence of adults living with severe obesity in England

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UK and international studies: excess weight and COVID-19

This annexe accompanies the report ‘Excess weight and COVID-19: Insights from new evidence’.

It contains published academic evidence of relevant research from mid-April to July and presents information from these studies that relates specifically to analyses on the association between excess weight, obesity and COVID-19.

Information has been taken from 12 UK studies and 19 international studies and is documented in Table 1 and Table 2 respectively. Only information directly linked with BMI has been extracted from the studies and summarised.

Table 3, provides prevalence and estimated population numbers of adults living in England with severe obesity.

Glossary/Abbreviations

aOR: Adjusted odds ratio

BAC: Black African or Caribbean

BMI: Body Mass Index (kg/m^2)

BME Black Minority Ethnicity

Breslow test: A test for homogeneity of odds ratio, which is used to evaluate changes in the degree of difference between 2 datasets being analysed in 2 different periods.

CI: Confidence Interval (based on 95% in all studies shown)

HbA1c: Glycated haemoglobin. The higher the HbA1c, the greater the risk of developing diabetes-related complications.

HR: Hazard Ratios

ICU: Intensive Care Unit

IMV: Invasive Mechanical Ventilation

IQR: Interquartile Range

ISARIC WHO Clinical Characterisation Protocol: International Severe Acute Respiratory and emerging Infection Consortium. A standardised protocol that enables data and biological samples to be collated rapidly

NIV: Non-invasive ventilation

OR: Odds Ratio;

p: Power

r^2: Coefficient of determination

RR: Relative Risk

RT-PCR: Real-time Polymerase Chain Reaction

SA: South Asian

SD: Standard Deviation

SES: Socio-economic status

SLI: A principal component score which comprises percentages of literacy, access to basic education, healthcare services, living conditions including drainage, dirt floor, access to water, electricity and electrical appliances for each Mexican municipality

WC: Waist circumference

WE: White European

UK Biobank: A resource that recruited 500,000 people aged between 40-69 years in 2006-2010 from across the country who have undergone measures, provided blood, urine and saliva samples for future analysis.

Table 1: UK studies on BMI and COVID-19

Source		Docherty et al. (2020)[1]	Hamer et al. (2020)[2]	Hippisley-Cox et al (2020)[3]
Title of study		**Features of 20,133 UK patients in hospital with COVID-19 using the ISARIC WHO Clinical Characterisation Protocol: prospective observational cohort study**	**Lifestyle risk factors, inflammatory mechanisms, and COVID-19 hospitalization: A community-based cohort study of 387,109 adults in UK**	**Risk of Severe COVID-19 disease with ACE inhibitors and Angiotensin Receptor Blockers including 8·3 million people**
Brief description (eg type of data/study)		Prospective observational cohort study with rapid data gathering and near real time analysis using pre-approved ISARIC-WHO Clinical Characterisation Protocol (CCP) for Severe Emerging Infection. People admitted to 166 UK hospitals with COVID-19 between 6 February and 19 April 2020	Prospective cohort study using data from UK Biobank data linked with PHE data on hospitalisation for COVID-19 for England data only[1]. Testing results were from 16 March-26 April 20	A prospective cohort study using routinely collected data from 1205 general practices in England contributing to the QResearch database, linked with COVID-19 RT-PCR positive test results held by PHE and ICNARC. The primary outcomes were (a) COVID-19 RT-PCR diagnosed disease; (b) COVID-19 disease resulting in ICU care. Data covers 1 January-27 April 2020
Characteristics of the sample (eg sample size, age, gender split)		n= 20,133 hospital inpatients with COVID-19 Median age: 73 years [IQR 58, 82] Men (60%, n=12,068) Women (40%, n=8,065)	n= 387,109 Mean age: 56.2 years (± 8.0 years) Women 55.1% 23.5% obese	n=8,275,949 participants Age (years): 20-99 years with median 47 years (IQR 33-62) Male: n= 4,115,973 (49·73%)

[1] Where it specifies for only England data being used this is determined on the information provided in each study.

Source		**Docherty et al. (2020)[1]**	**Hamer et al. (2020)[2]**	**Hippisley-Cox et al (2020)[3]**
		14.7% tested positive for COVID-19 (numbers not reported)	There was n=760 hospitalised COVID-19 cases - around 0.2% of the sample	n=19,486 patients had COVID-19 RT-PCR positive result, n=1,286 were admitted to an ICU
Key findings BMI characteristics (%) of hospitalised patients		Data on BMI characteristics not reported. The questionnaire identified patients with obesity as recognised by clinical staff. Height and weight was not measured, and BMI not reported	Baseline: Not hospitalised mean BMI 27.3±4.7. Hospitalised COVID-19 cases: mean BMI 29.0 ± 5.4 overweight = 317/165,052 obese = 277/90,895	Baseline characteristics for patients registered with QResearch: COVID-19 positive (%) BMI 25-29·99 n=5925 (30·41%) BMI 30-34·99 n=3435 (17·63%) BMI 35+ n=2409 (12·36%) COVID-19 ICU admission BMI 25-29·99 n=410 (31·88%) BMI 30-34·99 n=341 (26·52%) BMI 35+ n=294 (22·86%)
Key findings Observations, including in relation to hospitalisation and/or treatment		Survival from symptom onset in patients in hospital with COVID-19 associated with obesity: HR 1.33 (95% CI 1.19-1.49, p<0.001) Comparator not reported	After adjustment for age, sex, physical activity, smoking and heavy alcohol consumption, obesity (RR, 2.05; 95% CI 1.68, 2.49) was related to COVID-19 hospitalisation when compared to a healthy weight (BMI <25kg/m^2). After adjustment for age, sex, education, ethnicity, diabetes, hypertension, cardiovascular disease (heart attack, angina, or stroke)	The risks of COVID-19 disease and of ICU admission were higher in those with increasing BMI. The most pronounced gradient was for ICU admission, where being obese was associated with a 2·6-fold increased risk and severe obesity with a 4·4-fold increased risk compared with the healthy weight group (18.5 to <25kg/m^2).

Source		**Docherty et al. (2020)**[1]	**Hamer et al. (2020)**[2]	**Hippisley-Cox et al (2020)**[3]
			overweight (RR 1.32 (1.09, 1.60)) and obesity (RR 1.97 (1.61, 2.42)) were both associated with an increased risk of hospitalisation when compared to a healthy weight	This was after adjustment for age, deprivation, ethnicity, geography, smoking, concurrent morbidity and long term medication
Author's Conclusions		The study identifies sectors of the population that are at greatest risk of a poor outcome, and reports the use of healthcare resources. Most patients with COVID-19 experience mild disease. However, in the cohort, of those who were admitted to hospital two weeks before data extraction, less than half had been discharged alive and a quarter had died. The remainder continued to receive care at the date of reporting. Seventeen percent of patients admitted to hospital required critical care. Factors associated with mortality in hospital were increasing age, male sex, obesity, and major comorbidities	These data suggest that adopting simple lifestyle changes could lower the risk of severe COVID-19 infection	There was no evidence of an increased or decreased risk associated with either drug for ICU admission. There are marked variations in risk of COVID-19 disease and ICU admission by ethnic group, with highest rates among BME groups. The strength of this association is greater with the more severe outcome and is not explained by age, sex, deprivation, geographical region, or several comorbidities and intercurrent medications included in the analysis

Source		**Ho et al. (2020)**[4]	**Holman et al. (2020)**[5]	**Khawaja et al. (2020)**[6]
Title of study		**Modifiable and non-modifiable risk factors for COVID-19: results from UK Biobank**	**Risk factors for COVID-19 related mortality in people with Type 1 and Type 2 diabetes in England: a population cohort study**	**Associations with COVID-19 hospitalisation amongst 406,793 adults: the UK Biobank prospective cohort study**
Brief description (eg type of data/study)		Cohort study using data from UK Biobank linked with PHE data on COVID-19 status in addition to primary care data on incident influenza and pneumonia. Study covers England only. Hospital admission data were available for the period 16 March to 14 April 2020	Investigated the relationship between risk factors and COVID-19 related deaths in a cohort alive on 16 February 2020 and followed to 11 May 2020	Prospective cohort study linking UK Biobank data with English COVID-19 test results. Conducted between 16 March and 16 April 2020, during a restricted testing policy for hospitalised individuals with severe disease
Characteristics of the sample (eg sample size, age, gender split)		n=428,225 Those testing positive in hospital: n=340 Mean age (SD) 57.66 (8.49) Male, n=194 (57.06%) Those not testing positive in hospital: Mean age 56.15 (8.12) Male, n=131,395 (46.03%)	The cohort analysis included n=264,390 people with Type 1 diabetes and n=2,874,020 people with Type 2 diabetes. The mean age of those with Type 1 diabetes was 46.6 (SD 19.6) years. For Type 2 diabetes the mean age was 67·5 (SD 13.4) years old. Type 1: Male n=149,680 (56·6%). Type 2: Male n=1,606,430 (55·9%)	n=406,793 participants. n=605 cases (tested positive for COVID-19) and n=406,188 controls (not tested). Mean age on 1 Jan 2020 was 68 years (SD 8; range 48 to 85 years). Female, n=223,644 (55%) Female cases, n= 261 (43%)

Source		Ho et al. (2020)[4]	Holman et al. (2020)[5]	Khawaja et al. (2020)[6]
Key findings BMI characteristics (%) of hospitalised patients		Mean BMI of those with admitted to hospital with a COVID-19 diagnosis: 29.02 (5.25), and without COVID-19: BMI 27.27 (4.60)	Type 1 diabetes total cohort vs deaths by BMI category: BMI 25-29.9: 82,005 (31.0%) 107 (23.1%) BMI 30-34.9 42,095(15.9%) 98 (21.1%) BMI 35-39.9 15,455 (5.8%) 44 (9.5%) BMI 40+ 8,160 (3.1%) 29 (6.3%) Type 2 diabetes total cohort vs deaths by BMI category: BMI 25-29.9 905,290 (31.5%) 2,962 (28.1%) BMI 30-34.9 743,100 (25.9%) 2,097 (19.9%) BMI 35-39.9 367,230 (12.8%) 975 (9.3%) BMI 40+ 241,570 (8.4%) 676 (6.4%)	Control mean (SD) BMI 27.2 (4.4) Cases mean (SD) BMI 28.8 (4.8)
Key findings Observations, including in relation to hospitalisation and/or treatment		Key univariable potentially modifiable risk factors for confirmed COVID-19 included higher BMI and body fat (RR 2.29 (p<0.0001) for obesity RR 1.62 (p=0.0008) for overweight. Comparator healthy weight (BMI cut offs not reported).	Adjusted HRs (95% CI and p value) for COVID-19 related death in people with Type 1 and Type 2 diabetes. Comparator BMI 25-29.9kg/m^2 BMI 30-34.9 Type 1: 1·47 (1·12 - 1·94p=0.0059) Type 2: 1·04 (0·98 - 1·1 p=0.2316) BMI 35-39.9 Type 1: 1·72 (1·21 - 2·46 p=0.0028) Type 2: 1·17 (1·08 - 1·26 p=<0.0001)	Strongest associations with severe COVID-19 included higher BMI. When compared to BMI <25kg/m^2: BMI ≥25-<30 OR 1.26, (95% CI 1.01 to 1.56, p=0.037) BMI ≥30-<35 OR 1.37 (95% CI 1.06 to 1.76. p=0.016) BMI >35 OR 2.04 (95% CI 1.50 to 2.77, p= <0.001)

Source		Ho et al. (2020)[4]	Holman et al. (2020)[5]	Khawaja et al. (2020)[6]
		Once BMI or body fat was adjusted for, inflammatory markers were no longer associated with incident COVID-19. This suggests proinflammatory markers, arising from increased adipose deposition, are probably acting as a marker for body fat which seems to be an adverse risk factor for severe COVID-19. After multivariable adjustment for sociodemographic factors, modifiable risk factors for confirmed COVID-19 included higher BMI (RR 1.33 per SD increase (95% CI 1.21-1.46) and other measures of body fat. After adding BMI, blood pressure, FEV1 and walking pace as covariates, modifiable risk factors for COVID-19 admission continued to include higher BMI (RR 1.24 (95% CI 1.12-1.38)) alongside other modifiable risk factors	BMI 40+ Type 1: 2·33 (1·53 - 3·56 p=0.0001) Type 2: 1·6 (1·47 - 1·75 p=<0.0001). Data adjusted for all variables	
Author's Conclusions		In conclusion, these early data from UK Biobank suggest risk factors for confirmed COVID-19 infection differ in some important ways from risk factors for pneumonia, being more common in males	While several risk factors identified for COVID-19 related mortality in people with diabetes cannot readily be modified, HbA1c can be influenced by healthcare interventions. Although the association	Understanding why these factors confer increased risk of severe COVID-19 in the population may help elucidate the underlying mechanisms as well as inform strategy and policy to

Source		Ho et al. (2020)[4]	Holman et al. (2020)[5]	Khawaja et al. (2020)[6]
		than females, in lower SES, and with stronger associations with ethnicity, cardiovascular risk markers, prior smoking and adiposity	with obesity was more complex, particularly in the type 2 diabetes population, weight can also be influenced by healthcare interventions and is a goal of routine care. Improved achievement of standard diabetes care recommendations that target prevention of cardio-renal, lower limb and ocular complications would also serve to modify some of the risk factors that we have found to be associated with COVID-19 related mortality.	prevent this disease and its consequences

Source		Perez-Guzman et al. (2020)[7]	Prats-Uribe. et al (2020)[8]	Razieh et al. (2020)[9]
Title of study		**Clinical characteristics and predictors of outcomes of hospitalised patients with COVID-19 in a London NHS Trust: a retrospective cohort study**	**Ethnicity, comorbidity, socioeconomic status, and their associations with COVID-19 infection in England: a cohort analysis of UK Biobank data**	**Body mass index and risk of COVID-19 across ethnic groups: analysis of UK Biobank study**
Brief description (eg type of data/study)		A retrospective cohort study on all patients hospitalised with laboratory-confirmed SARS-CoV-2 infection at Imperial College Healthcare NHS Trust between 25 February and 5 April 2020	UK Biobank data. Prospective cohort study. Linked to Hospital Episode Statistics and COVID-19 tests from 16 March until 14 April 2020	Cohort study using UK Biobank data linked with COVID-19 laboratory test data through PHE. Study covers data from 16 March 2020 to 14 June 2020

Source		**Perez-Guzman et al. (2020)**[7]	**Prats-Uribe. et al (2020)**[8]	**Razieh et al. (2020)**[9]
Characteristics of the sample (eg sample size, age, gender split)		n=520 patients median age 67 years, (IQR 26) Male, n=322 (62%)	n=415,582 participants with n=1,416 tested and n=651 positive for COVID -19. Female 55.0%	n=5,623 unique test results available (WE: n=5,352; BME: n=271), of which n=1,087 (19·3%) were positive (WE: n=1,000 [18·7%]; BME: n=87 [32·1%]). Women (WE): n=2650 (49.5%) Women (BME): n=136 (50.2%)
Key findings BMI characteristics (%) of hospitalised patients		50% of admissions had BMI data missing. Authors commented that this might relate to the severity of disease on admission. BMI all cohort 28.92 (7.37) BMI died 29.7 (8.43) BMI discharged alive 28.81 (7.1) Authors do not state whether median	Mean (SD) BMI was higher among tested (28.7 (5.7) and COVID-19 infected (29.2 (5.5) participants than non-tested participants (27.4 (4.8)	WE individuals with test data had a median (IQR) age of 71.3 (62·3, 76·1) years, BMI of 27·6 (24·8, 30·9). Comparatively, BME individuals were 64·8 (57·9, 73·2) years and had a BMI of 28·2 (25·2, 33·1)
Key findings Observations, including in relation to hospitalisation and/or treatment		No association was found between increasing BMI and mortality. Authors suggest that this may be due to missing BMI data. Unadjusted regression BMI 25-29·9, OR (CI) 0·95 (0·46, 1·97, p=0·89) BMI 30-34·9, OR (CI) 1·01 (0·47, 2·14, p=0·98) BMI 35 - 39·9 OR (CI) 1·49 (0·50, 4·33, p=0·46	Multivariable analysis showed that high body weight was independently associated with COVID-19 infection risk, with an adjusted RR of 1.04 (1.02-1.05) per kg/m^2 increase in BMI. Note: the authors document these results differently in a box plot: RR of 1.04 (1.03-1.05). Adjusted for age, sex, alcohol, drinking and smoking.	BMI was associated with the risk of a positive test for COVID-19 in both BME and WE individuals. However, the dose response association differed by ethnic group (p for interaction=0.05). In WE individuals, there was no additional higher risk of COVID-19 beyond a BMI of 25, whereas in BME individuals, the risk was greater for higher BMI values. Greater risk of COVID-19 in BME individuals relative to WEs was only

Source		Perez-Guzman et al. (2020)[7]	Prats-Uribe. et al (2020)[8]	Razieh et al. (2020)[9]
		BMI ≥ 40 OR (CI) 1·86 (0·61, 5·74, p=0·27) Comparator BMI 18-24.9kg/m^2		apparent at higher BMI values. For example, at a BMI value of 25, there was no difference in risk (OR = 0.96; CI: 0.61, 1.52), whereas at a BMI of 30 or 35, the odds of COVID-19 were 1.75 (1.24, 2.48) and 2.56 (1.63, 4.03) higher in BME individuals relative to WEs, respectively. Reference OR BMI 25kg/m^2 Analysis adjusted for age at test, sex, social deprivation (Townsend score), smoking status, cancer illnesses (number) and non-cancer illnesses (number), systolic blood pressure, HDL cholesterol, total cholesterol and HbA1c
Author's Conclusions		The data showed that older age, male sex and admission hypoxia, thrombocytopenia, renal failure, hypoalbuminaemia and raised bilirubin are associated with increased odds of death	COVID-19 rates in the UK are higher in BAME communities, those living in deprived areas, obese patients, and patients with previous comorbidity	The data suggest that the association between BMI and the risk of COVID-19 may vary by ethnicity and act as an effect modifier for the increased risk of COVID-19 in BME populations. The results suggest that the combination of obesity and BME status may place individuals at particularly high-risk of contracting COVID-19, consistent with findings for associations of BMI and ethnicity with cardiometabolic dysfunction

Source		**Sattar et al (2020)[10]**	**Williamson et al. (2020)[11]**	**Yates et al (2020)[12]**
Title of study		**BMI and future risk for COVID-19 infection and death across sex, age and ethnicity: Preliminary findings from UK biobank**	**OpenSAFELY: factors associated with COVID-19 death in 17 million patients**	**Obesity and risk of COVID-19: analysis of UK Biobank**
Brief description (eg type of data/study)		Cohort study using data from UK Biobank and PHE data on SARS-CoV-2 tests. All data was from England only. Tests conducted in hospital settings between 16 March to 31 May 2020 were used	Cohort study using national primary care electronic health data in England linked to in-hospital COVID-19 death rate and Office for National Statistics death data. To determine factors associated with risk of death from COVID-19 in England. Study covers 1 February 2020 to 25 April 2020	Investigation between obesity and laboratory confirmed COVID-19 using UK Biobank data linked to national SARS-CoV-2 laboratory test data through PHE. COVID-19 data available 16 March 2020 to 3 May 2020
Characteristics of the sample (eg sample size, age, gender split)		n=374,503 n=4855 participants tested for SARS-CoV-2 in hospital, n=839 tested positive and n=189 of these individuals died from COVID-19	n=17,278,392 adults. n=10,926 COVID-19 deaths Of the deaths Male, n=6,162 (0.07% within stratum) and Female 4,764 (0.06% within stratum)	n=2,494 unique test results available, of which n=882 (35.4%) were positive; n=1,408 (56.5%) tests were conducted on inpatients
Key findings BMI characteristics (%) of hospitalised patients		BMI at baseline or for patients in hospital not reported.		Those with test data had a median (IQR) age of 71 (61, 76) years, BMI of 27·6 (24.7, 31.1), WC of 93 (83, 103)cm

Source		**Sattar et al (2020)[10]**	**Williamson et al. (2020)[11]**	**Yates et al (2020)[12]**
Key findings Observations, including in relation to hospitalisation and/or treatment		BMI was associated strongly with positive test, and risk of death related to COVID-19. The gradient of risk in relation to BMI was steeper in those aged <70, compared with those aged ≥70 years for COVID-19 related death ($P_{interaction}$ = 0.03). BMI was more strongly related to test positivity $P_{interaction}$ = 0.010) and COVID-19 related death ($P_{interaction}$ = 0.002) in non-White ethnic groups (predominantly SA's and Afro-Caribbeans), compared with White ethic groups. Models were adjusted for age, socioeconomic status (Townsend Index), ethnicity, smoking (current, former, never), alcohol intake (unit/week), and baseline cardiovascular disease and diabetes	The study showed increasing risk of death with degree of obesity when compared to non-obese individuals (BMI <30): Adjusted for age, sex, BMI, smoking, index of multiple deprivation quintile, and comorbidities: BMI 30-34.9 HR: 1.05 (95% CI 1.00-1.11). BMI 35-39.9 HR: 1.40 (95% CI 1.30-1.52) BMI ≥40 HR: 1.92 (95% CI 1.72-2.13)	A dose-response relationship with BMI and WC were associated with testing positive for COVID-19. Adjustment for confounders did not change the results. The adjusted OR for overweight, obese and severely obese subjects was 1·31 (95% CI: 1·05, 1·62), 1·55 (1·19, 2·02), and 1·57 (1·14, 2·17), respectively, compared to healthy weight (BMI 20-24.9kg/m^2). It is not clear from the paper which of 2 adjustment models used these results related to.
Author's conclusions		These data add support for adiposity being more strongly linked to COVID-19-related deaths in younger people and non-white ethnicities. If future studies confirm causality, lifestyle interventions to improve adiposity status may be important to reduce the risk of COVID-19 in all, but perhaps particularly, non-white communities	The authors generated early insights into risk factors for COVID-19 related death using an unprecedented scale of 17 million patients' detailed primary care records, maintaining privacy, in the context of a global health emergency	Although limited by possible selection bias, these results provide early evidence for a dose-repose association between BMI, WC and COVID-19. Further analysis on the association between obesity and COVID-19 complications, severity and mortality will be possible as UK Biobank data continues to be updated

Table 2: International Studies: Obesity and COVID-19

Source		Argenziano et al[13]	Bello-Chavolla et al (1)[14]	Bello-Chavolla et al (2)[15]
Title of study		**Characterization and clinical course of 1000 patients with coronavirus disease 2019 in New York: retrospective case series**	**Unequal impact of structural health determinants and comorbidity on COVID-19 severity and lethality in older Mexican adults: Considerations beyond chronological aging**	**Predicting Mortality Due to SARS-CoV-2: A Mechanistic Score Relating Obesity and Diabetes to COVID-19 Outcomes in Mexico**
Country/region		USA/New York City	Mexico/National data	Mexico/National data
Brief description (eg type of data/study)		Retrospective manual medical record review of COVID-19-positive patients presented to the emergency department, or admitted to hospital between 1 March-5 April 2020	Analysis of confirmed COVID-19 cases in older adults using data from the General Directorate of Epidemiology of Mexican Ministry of Health collected up to 3 June 2020	Analysis of data (collected up to 8 May 2020) of confirmed and negative COVID-19 cases and their demographic and health characteristics from the General Directorate of Epidemiology of the Mexican Ministry of Health to identify risk factors and propose a clinical score to predict COVID-19 lethality
Characteristics of the sample (eg sample size, age, gender split)		n=1000 Age (years): median 63.0 (IQR 50.0-75.0). Male: n=596	n=20,804 confirmed COVID-19-positive SARS-CoV-2 cases in adults aged ≥60 years, of whom 4136 (19.9%) were obese Male: n=12,257 (58.9%)	n=177,133, of whom 51,633 subjects had SARS-CoV-2 Age (years) 46.65 ± 15.83 Male: n=29 803 (57.7%)

Source		Argenziano et al[13]	Bello-Chavolla et al (1)[14]	Bello-Chavolla et al (2)[15]
Key findings (risk of hospitalisation, symptoms and outcomes)		Patients in hospital, particularly those treated in ICU's, often had baseline comorbidities including obesity. Multivariate modelling on this population might be limited by residual confounding and bias	Mortality was significantly higher in adults aged $\geq$60 years compared with those aged $\leq$60 years (29.49% vs 6.95%) After adjustment for age, structural factors (that is, SLI, private care) and comorbidities, obesity remained a significant predictor of mortality even in individuals without other comorbidities (HR 1.17; 95% CI 1.01 – 1.34) and was also a predictor of increased risk of pneumonia (OR 1.76; 95% CI 1.51 – 2.06), hospitalisation (OR 1.45; 95% CI 1.23 – 1.71), ICU admission (OR 1.53; 95% CI 1.14 – 2.05) and requirement of invasive ventilation (OR 1.50; 95% CI 1.13 -2.05), over chronological age	Risk factors for lethality in COVID-19 include early-onset diabetes and obesity; obesity mediates 49.5% of the effect of diabetes on COVID-19 lethality. Compared with non-obese patients, COVID-19-positive patients with obesity had higher rates of mortality (13.5% vs 9.4%), ICU admission (5.0% vs 3.3%) and intubation (5.2% vs 3.3%). Overall, COVID-19 increased the risk of mortality in obesity nearly 5-fold (HR 4.989; 95% CI 4.44 - 5.60). The addition of obesity to any number of comorbidities significantly increased the risk of COVID-19 lethality (Breslow test p<0.001)
Author's conclusions		Patients admitted to hospital with COVID-19 at this medical centre faced major morbidity and mortality, with high rates of acute kidney injury and inpatient dialysis, prolonged intubations, and a bimodal distribution of time to intubation from symptom onset	Structural factors and comorbidity explain excess risk for COVID-19 severity and mortality over chronological age in older Mexican adults. Clinical decision-making related to COVID-19 should focus away from chronological aging onto more a comprehensive geriatric care approach	Proposal a mechanistic approach to evaluate the risk for complications and lethality attributable to COVID-19, considering the effect of obesity and diabetes in Mexico. *"Our score offers a clinical tool for quick determination of high-risk susceptibility patients in a first-contact scenario"*

Source		Bhasin et al[16]	Busetto et al[17]	Caussy et al[18]
Title of study		**Is BMI higher in younger patients with COVID-19? Association between BMI and COVID-19 hospitalization by age**	**Obesity and COVID-19: an Italian snapshot**	**Prevalence of obesity among adult inpatients with COVID-19 in France**
Country/region		USA/Chicago	Italy, Padova	France/Lyon
Brief description (eg type of data/study)		Cross-sectional analysis of patients hospitalised with moderate to severe COVID-19 from 19 March - 4 April 2020	Analysis of clinical data of all patients hospitalised in the COVID-19 ward from 23 March– 11 April 2020	Assessment of the prevalence of obesity among patients requiring hospitalisation for severe COVID-19, including those with critical COVID-19, admitted to Lyon University Hospital ICU on 27 March 2020 compared with a retrospective non-COVID-19 ICU comparison group of patients with BMI values admitted to ICU units on 27 March each year between 2008 and 2019
Characteristics of the sample (eg sample size, age, gender split)		n=227 patients hospitalised with COVID-19 Age (years) 58.1 (56.0–60.2) Male: n=121 (53%)	n=92 patients Age (years): 70.5±13.3 Male: (61.9%)	n= 340 patients with confirmed, severe COVID-19 and data available on BMI, of whom 85 (25%) were obese n=1210 non-COVID-19 ICU comparison group, of whom 314 (26%) were obese
Key findings (risk of hospitalisation, symptoms and outcomes)		In the subset of patients <50 years of age hospitalised with COVID-19 without diabetes or hypertension, mean BMI was greater than those >50 years of age, with BMI 43.1 (95% CI 34.5–51.7) vs	After adjusting for sex, age and comorbidities, patients with overweight and obesity had a higher need for assisted ventilation (IMV or NIV) compared with only oxygen support (OR 3.62; CI 95% 1.09-11.97, p<0.05) and a	After adjustment for age and sex, the prevalence of obesity was higher in patients with critical COVID-19 than in those with non-critical COVID-19 (aOR 1·96; 95% CI 1·13–3·42, p=0·018).

Source		Bhasin et al[16]	Busetto et al[17]	Caussy et al[18]
		30.1 (95% CI 27.7–32.5) (p=0.02). BMI appears to inversely correlate with increasing age amongst patients hospitalised with COVID-19. Adjusted by comparing patients 'type 2 diabetes-unknown' separately	higher admission to ICU or semi-ICUs s medical ward (OR 12.46; CI 95% 3.48-44.54, p<0.001) than healthy weight patients	The prevalence of obesity was numerically higher in patients with critical COVID-19 than in ICU patients without COVID-19 (p=0.066). After adjustment for age and sex, odds of obesity were significantly higher in patients with critical COVID-19 compared with non-COVID-19 patients (aOR 1·69; 95% CI 1·10–2·56, p=0·017)
Author's conclusions		Younger patients (age <50 years) with COVID-19 had higher mean BMI than older patients with COVID-19, with and without diabetes and hypertension. This trend did not exist in patients without COVID-19 hospitalised during the same time-period	Patients with overweight and obesity admitted in a medical ward for SARS-CoV-2 related pneumonia, despite their younger age, required more frequently assisted ventilation and access to intensive or semi-ITU's than healthy weight patients	This study reports a significant association between the prevalence of obesity and severe COVID-19, including critical COVID-19, and suggests that obesity might be a risk factor of pejorative evolution of COVID-19, increasing the risk of ICU admission

Source		**Chen et al[19]**	**Denova-Gutiérrez et al[20]**	**Gao et al[21]**
Title of study		**Clinical characteristics of 145 patients with corona virus disease (COVID-19) in Taizhou, Zhejiang, China**	**The association between obesity, type 2 diabetes, and hypertension with severe COVID-19 on admission among Mexicans**	**Obesity is a risk factor for greater COVID-19 severity**
Country/region		China/Taizhou/Zhejiang	Mexico/National data	China/Wenzhou
Brief description (eg type of data/study)		Single centre retrospective observational study performed between 1 January-11 March 2020.	Analysis of data from COVID-19-positve patients collected from National Epidemiological Surveillance System from February 27 (when the first case of COVID-19 in Mexico was confirmed) until 10 April 2020	Adult patients with COVID-19 from three hospitals in China enrolled between 17 January-11 February 2020 into a case: control study. Obesity was defined as BMI ≥25
Characteristics of the sample (eg sample size, age, gender split)		n=145 hospitalised patients with COVID-19 Non-severely ill patients (n=102) Severely ill patients (n=43) Age (years): 47.5 (SD, 14.6) Male: n=79 (54.5%)	n=3,844 Age (years): Mean, 45.4 (± 15.8) Male: 58%	n=150, 75 obese patients (cases) were randomly matched to a non-obese control by sex (1:1) and age (± 5 years). Age (years): mean 48 Male: (62.7%) Mean BMI for non-obese and obese patients was 21.8 ± 2.3 and 27.7 ± 2.7, respectively
Key findings (risk of hospitalisation, symptoms and outcomes)		Compared with non-severely ill patients, severely ill patients were older (mean 52.8 years vs 45.3 years, p<0.01), had a higher proportion of diabetes mellitus (16.3% vs	Patients who tested positive for COVID-19 had a higher proportion of obesity (17.4%), compared with those without a confirmed diagnosis.	After adjustment for age, sex, smoking status, hypertension, diabetes, and dyslipidaemia, there remained a significant association between obesity (or increasing BMI values) and greater

Source		Chen et al[19]	Denova-Gutiérrez et al[20]	Gao et al[21]
		6.9%, p=0.08) and had a higher BMI (mean 24.78 vs 23.20, p=0.02). To note that the analyses have not been adjusted for multiple comparisons and, given the potential for type I error (false negative), the findings should be interpreted as exploratory and descriptive	After adjusting for age, sex, smoking status, history of chronic diseases (including hypertension and diabetes) and drug treatment, patients with obesity showed a 1.43-fold higher odds of developing severe COVID-19 on admission compared with patients without obesity	COVID-19 severity (aOR 3.00; 95% CI 1.22–7.38 for obesity, and aOR 1.13; 95% CI 1.01–1.28 for BMI, respectively)
Author's conclusions		Older patients or patients with comorbidities such as obesity or diabetes mellitus were more likely to have severe condition	Obesity, diabetes, and hypertension were significantly associated with severe COVID-19 on admission and the association of obesity was stronger in patients <50 years	Health care professionals caring for COVID-19 patients should be cognizant of the increased likelihood of severe COVID-19 in obese patients. In particular, the presence of obesity increases the risk of severe illness approximately threefold with a consequent longer hospital stay

Source		**Kalligeros et al[22]**	**Kass et al[23]**	**Klang et al[24]**
Title of study		**Association of Obesity with Disease Severity Among Patients with COVID-19**	**Obesity could shift severe COVID-19 disease to younger ages**	**Morbid obesity as an independent risk factor for COVID-19 mortality in hospitalized patients younger than 50**
Country/region		USA/Rhode Island	USA/multiple locations	USA/New York City
Brief description (eg type of data/study)		A retrospective electronic chart review study of patients with laboratory confirmed SARS-Cov-2 infection admitted to one of three hospitals between 17 February-5 April 2020	Examination of the correlation between BMI and age in patients with COVID-19 admitted to ICU at university hospitals at Johns Hopkins, University of Cincinnati, New York University, University of Washington, Florida Health, and University of Pennsylvania	Retrospective analysis of data from COVID-19 patients hospitalised between 1 March-17 May 2020 Obesity defined as BMI≥30 with subgroup analysis for patients with BMI 30-40 and BMI≥40 and aged ≤50 and ≥50 years
Characteristics of the sample (eg sample size, age, gender split)		n=103, of which 49 (47.5%) were obese Age (years): 60 (52-70) Male: n=63 (61.17%)	n=265 patients Median BMI = 29.3 (only 25% individuals had a BMI<26 and 25% had a BMI >34.7) Male: 58%	n=3,406 patients, of which n=572 were ≤ 50 years and 2,834 were ≥50 years Age ≤50 years - Male survivors: n=352 (68.8%); non-survivors: n=45 (75.0%). p=0.376 Age ≥50 years - Male survivors: n=949 (54.0%); non-survivors: n=615 (57.2%). p=0.102

Source		Kalligeros et al[22]	Kass et al[23]	Klang et al[24]
Key findings (risk of hospitalisation, symptoms and outcomes)		In a multivariate analysis, after adjusting for age, sex, gender and co-morbidities, severe obesity (BMI ≥35) was associated with ICU admission (aOR: 5.39; 95% CI 1.13-25.64). Patients who required IMV were more likely to be obese (BMI=30-35.9. aOR 6.85; 95% CI 1.05-44.82), severely obese (BMI≥35 aOR 9.99; 95% CI 1.39-71.69) to have had heart disease (aOR 3.41; 95% CI 1.05-11.06)	Significant inverse correlation (r^2=0.051; p=0.0002) between age and BMI, in which younger individuals admitted to hospital were more likely to be obese. Unadjusted analysis	After adjustment for demographics, comorbidities and smoking (past or present), morbid obesity (BMI ≥40) was strongly and independently associated with COVID-19 mortality in hospitalised patients aged ≤50 years (aOR 5.1; 95% CI 2.3-11.1, p<0.001) and was also independently associated with mortality in those aged ≥50 years (aOR 1.6; 95% CI 1.2-2.3, p=0.004)
Author's conclusions		Severe obesity (BMI ≥35) was associated with ICU admission, while history of heart disease and obesity (BMI ≥30) were independently associated with the use of IMV	In populations with a high prevalence of obesity, COVID-19 will affect younger populations more than previously reported	This study demonstrates that hospitalised patients younger than 50 with morbid obesity are more likely to die from COVID-19

Source		Lighter et al[25]	Moriconi et al[26]	Petrilli et al[27]
Title of study		**Obesity in patients younger than 60 years is a risk factor for COVID-19 hospital admission**	**Obesity prolongs the hospital stay in patients affected by COVID-19, and may impact on SARS-COV-2 shedding. Enrolment between 16 March-15 April, 2020**	**Factors associated with hospitalization and critical illness among 4,103 patients with COVID-19 disease in New York City**
Country/region		USA/New York City	Italy, Pisa	USA/New York City
Brief description (eg type of data/study)		Retrospective analysis of BMI stratified by age in COVID-19-positive symptomatic patients between 3 March–4 April 2020	Single-centre, retrospective, observational cohort study of COVID-19-positive patients admitted to the hospital COVID-19 unit between 16 March-15 April 2020	Cross-sectional analysis of all patients with laboratory-confirmed COVID-19 treated between 1 March-2 April, with follow up through 7 April 2020. Primary outcomes were hospitalisation and critical illness (intensive care, mechanical ventilation, hospice and/or death)
Characteristics of the sample (eg sample size, age, gender split)		n=3,615 of which 775 (21%) had BMI 30-34 and 595 (16% of the total cohort) had a BMI ≥35	n=100, of whom 29 were obese (age 70±15 years) and 71 were non-obese (age 69±17 years) Obese (OB) and non-obese N-OB patients were similar in gender and comorbidities, with the exception of hypertension which was more frequent in the obese group	n=4,103, of which 1,999 (48.7%) were hospitalised Age (years): median 52 (IQR 36,65) Male: n=2071 (50.5%)

Source		Lighter et al[25]	Moriconi et al[26]	Petrilli et al[27]
Key findings (risk of hospitalisation, symptoms and outcomes)		In patients aged <60 years, those with BMI 30-34 were 2.0 (95% CI 1.6-2.6. p<0.0001) and 1.8 (95% CI 1.2-2.7, p=0.006) while those with BMI ≥ 35 were 2.2 (95% CI 1.7– 2.9; p<0.0001) and 3.6 (95% CI 2.5–5.3; P<0.0001) times more likely to be admitted to acute and critical care, respectively compared with patients in the same age category with BMI <30. Moreover, younger group patients with obesity grade I and II had an increased likelihood to receive critical care 1.8 (1.2-2.7; p<0.006) and 3.6 (2.5-5.3; p<0.0001) times respectively, compared with healthy weight and overweight groups	BMI was related to longer length of hospital stay and time for negative swab but in this relatively small study, obesity did not predict higher mortality	**Risks of hospitalisation:** Age ≥75 years (OR 66.8; 95% CI 44.7-102.6) Age 65-74 years (OR 10.9; 95% CI 8.35-14.34) **BMI>40** (OR 6.2; 95% CI 4.2-9.3). Heart failure (OR 4.3; 95% CI 1.9-11.2) In the decision tree for admission, the most important features were age >65 and obesity
Author's conclusions		Obesity in people <60 years is a newly identified epidemiologic risk factor for hospital admission and need for critical care for COVID-19 that may contribute to increased morbidity rates experienced in the United States	Subjects with obesity affected by COVID-19 require longer hospitalisation, more intensive and longer oxygen treatment, and they may have longer SARS-COV-2 shedding	Age and comorbidities are powerful predictors of hospitalisation; however, admission oxygen impairment and markers of inflammation are most strongly associated with critical illness

Source		Pettit et al[28]	Simonnet et al[29]	Suleyman et al[30]
Title of study		**Obesity is associated with increased risk for mortality among hospitalized patients with COVID-19**	**High prevalence of obesity in severe acute respiratory syndrome Coronavirus-2 (SARS-CoV-2) requiring Invasive Mechanical Ventilation IMV**	**Clinical characteristics and morbidity associated with coronavirus disease 2019 in a series of patients in metropolitan Detroit**
Country/region		USA/Chicago	France/Lille	USA, Detroit
Brief description (eg type of data/study)		Retrospective analysis including patients with COVID-19 between 1 March-18 April 2020 to determine if obesity is a predictor of mortality	Retrospective analysis of the relationship between clinical characteristics, including BMI, and the requirement for IMV in patients admitted in IC between 27 February-5 April 2020	A case series study of COVID-19-postive patients from 9 March-27 March 2020 and comparative analysis of hospitalised and ambulatory patient populations
Characteristics of the sample (eg sample size, age, gender split)		n=238, of whom 218 (91.6%) were African American Age (years): mean 58.5 Male: n=113 (47.5%) 146 (61.3%) patients were obese (BMI>30), with 63 (2.5%), 29 (12.2%) and 54 (22.7%) with class 1, 2 and 3 obesity, respectively	n=124 admitted to IC for SARS-CoV-2 Age (years): median 60 (IQR, 51,70) Male: n=90 (73%) 47.6% patients had BMI >30 and 28.2% BMI >35 Overall, 85 patients (68.6%) required IMV	n=463, of whom 334 (72.1%) were African American Age (years): mean [SD], 57.5 [16.8] Female: n=259 (55.9%)
Key findings (risk of hospitalisation,		After adjustment for age, gender and other comordbities, obesity was identified as a predictor for mortality (aOR 1.7; 95% CI 1.1-2.8, p=0.016)	Proportion of patients requiring IMV increased with body mass categories (p<0.01). It was greatest in patients with BMI >35 (85.7%).	Adjusting for significant factors and race, male sex, severe obesity BMI≥40 (OR 2.0; 95% CI 1.4-3.6, p=0.02) was

Source		Pettit et al[28]	Simonnet et al[29]	Suleyman et al[30]
symptoms and outcomes)		and was also a risk factor for hypoxemia (aOR 1.7; 95% CI 1.3-2.1, p<0.0005)	In multivariate logistic regression, need for IMV was associated with male sex (p<0.05) and BMI category (p<0.05), independent of age, diabetes and hypertension. The odds ratio for patients with BMI >35 compared with patients with BMI was 7.36 <25 (95% CI 1.63-33.14; p=0.02)	independently associated with ICU admission
Author's conclusions		Obesity was found to be a significant predictor for mortality among inpatients with COVID-19 after adjusting for age, gender, and other comorbidities. Patients with obesity were also more likely to present with hypoxemia. Risks of hospitalisation: Age ≥75 years (OR 66.8; 95% CI 44.7-102.6) Age 65-74 years (OR 10.9; 95% CI 8.35-14.34) BMI>40 (OR 6.2; 95% CI 4.2-9.3). Heart failure (OR 4.3; 95% CI 1.9-11.2) Age and comorbidities are powerful predictors of hospitalisation; however, admission oxygen impairment and	This study showed a high frequency of obesity among patients admitted in IC for SARS-CoV-2. Disease severity increased with BMI. Obesity is a risk factor for SARS-CoV-2 severity, requiring increased attention to preventive measures in susceptible individuals	In this review of urban metropolitan patients with COVID-19, most were African American with a high prevalence of comorbid conditions and high rates of hospitalization, ITU admission, complications, and mortality due to COVID-19

Source		Pettit et al[28]	Simonnet et al[29]	Suleyman et al[30]
		markers of inflammation are most strongly associated with critical illness		

Source		Qingxian et al[31]
Title of study		**Obesity and COVID-19 severity in a designated hospital in Shenzhen, China**
Country/region		China/Shenzhen
Brief description (eg type of data/study)		Analysis between BMI and clinical outcome of all patients admitted to hospital with a diagnosis of COVID-19 between 11 January-16 February 2020
Characteristics of the sample (eg sample size, age, gender split)		n=383 Overweight (BMI 24.0-27.9), 32%: Age (years): median 50 (37-61) Male: n=73 (59·4%) Obese (≥28.0), 10.7%: Age: median 48 (39-54) Male: n=32 (78·1%) BMI –cut off values for overweight (24·0-27·9) and obesity (≥28.0)
Key findings (risk of hospitalisation, symptoms and outcomes)		After adjusting for potential confounders (including age and sex) compared with healthy weight patients: overweight patients had 86% higher risk of developing severe pneumonia (aOR 1.96; 95% CI 0.78-4.98 in men; aOR 1.51; 95% CI 0.57-4.01 in women)

Source		Qingxian et al[31]
		Patients with obesity showed 2·42-fold higher odds of developing severe pneumonia (aOR 5.70; 95% CI 1.83-17.76 in men; aOR 0.71; 95% CI 0.07-7.3 in women)
Author's conclusions		Obesity, especially in men, significantly increases the risk of developing severe pneumonia in COVID-19 patients

Table 3. Prevalence of severe obesity and estimated number of adults (aged 16+) in the population with severe obesity (Adults aged 16 and over with valid height and weight measurements)

Table 3a. Adults living with severe obesity (BMI ≥40) prevalence, by age and sex

% Severely obese	16-24	25-34	35-44	45-54	55-64	65-74	75+	Total
Men	1.3	1.4	1.1	3.2	3.2	1.2	0.7	1.8
Women	2.6	4.1	5.3	5.5	4.5	5.3	2.7	4.4
All adults	1.9	2.8	3.2	4.3	3.8	3.3	1.7	3.2

Table 3b: Estimated number of adults (age 16+ years) living with severe obesity in England by age and sex (rounded to nearest 1000)

Sex	Age group							
	16-24	25-34	35-44	45-54	55-64	65-74	75+	Total

Men	40,000	54,000	39,000	120,000	103,000	33,000	14,000	408,000
Women	75,000	155,000	189,000	215,000	150,000	152,000	70,000	1,024,000
All adults	115,000	210,000	230,000	334,000	254,000	184,000	80,000	1,428,000

Notes:

1. Numbers may not sum to totals due to rounding and due to the Health Survey for England gender and age distributions not quite matching the population distribution
2. Severe obesity: BMI of 40kg/m^2 or above
3. 2018 mid-year population estimates
4. Source: https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/2018/health-survey-for-england-2018-data-tables https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland

Table 3c: IMD quintile – Adults living with severe obesity, 2017 Health Survey for England

	IMD 2015 Quintile				
	1 Least deprived	**2**	**3**	**4**	**5 most deprived**
Males					
% Severely Obese	1.0	1.8	2.3	2.9	4.6
Number Severely Obese	41,000	79,000	103,000	131,000	195,000
Females					
% Severely Obese	2.8	4.6	4.2	4.1	7.7

Number Severely Obese	127,000	214,000	198,000	190,000	341,000

Table 3d: Adults living with severe obesity by Ethnic group – 2015 to 2017 (pooled data) Health Survey for England

	Ethnic group				
	White	**Black**	**Asian**	**Mixed**	**Other**
Males					
% Severely Obese	2.4	2.3	0.9	1.5	2.9
Number Severely Obese	443,000	16,000	15,000	6,000	8,000
Females					
% Severely Obese	4.0	8.3	2.3	3.2	4.0
Number Severely Obese	798,000	65,000	40,000	13,000	8,000

Notes:

1. Severe obesity: BMI of 40kg/m^2 or above
2. Asian ethnic group includes Chinese
3. **Source:**

Health Survey for England PHE datasets
NatCen Social Research, University College London. Department of Epidemiology and Public Health. (2018). Health Survey for England, 2015, 2016, 2017. UK Data Service.
ONS Population denominators by ethnic group, regions and countries: England and Wales, 2011 to 2018
https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/adhocs/008780populationdenominatorsbyethnicgroupregionsandcountriesenglandandwales2011to2017
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