Public Health England

Protecting and improving the nation's health

Excess Weight and COVID-19

Insights from new evidence

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Published July 2020
PHE publications
gateway number: GW-1405

PHE supports the UN
Sustainable Development Goals

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Acknowledgements

Public Health England (PHE) would like to thank the following peer reviewers and colleagues for their expertise and insight that has shaped the development of this resource: Naveed Sattar, Professor Metabolic Medicine, Institute of Cardiovascular and Medical Sciences, University of Glasgow; Susan Jebb, Professor of Diet and Population Health, University of Oxford; and John Wilding, Professor of Medicine and Honorary Consultant Physician, Aintree University Hospital.

Glossary of terms

Body mass index (BMI) definition: BMI is an estimate of body mass and is calculated by dividing a person's weight by the square of their height.

Table 1: BMI classification

BMI Range	BMI Category
Less than 18.5kg/m^2	Underweight
18.5 to <25kg/m^2	Healthy weight
25 to <30kg/m^2	Overweight
30 to <40kg/m^2	Obesity
40kg/m^2 or more	Severe obesity

Excess weight: Classified by the National Institute for Health and Care Excellence (NICE)[1] as an adult living with overweight, obesity or severe obesity with a BMI ≥25kg/m^2. BMI cut-off for treatment services are lower for Black, Asian and Minority Ethnic (BAME) groups than White groups[2]; 23kg/m^2 indicate increased risk and 27.5kg/m^2 indicate high risk, respectively.

Weight management support: Weight management services in England are offered at different 'tiers' or level of intervention: Tier 1 includes universal prevention services, such as health promotion; tier 2 includes multicomponent behaviour change and often takes the form of group-based support run by commercial providers; tier 3 is specialist multi-disciplinary weight management; and tier 4 includes bariatric surgery.

Executive summary

This report provides evidence-based insights on the relationship between excess weight and COVID-19. Evidence has been brought together from UK and international studies published during the pandemic. These have been identified using a pragmatic methodology; the report is not a systematic review. Findings have been contextualised with information on the prevalence, causes, and risks of excess weight. Information on food and drink purchases and physical activity during lockdown is also included.

The prevalence and disease burden resulting from excess weight is a major international public health concern. Almost two-thirds of adults in England are living with excess weight for their height (BMI $\geq 25kg/m^2$), with similar figures in Scotland, Wales and Northern Ireland.

Excess weight affects all population groups but is higher for those people aged between 55-74 years, people living in deprived areas and in some Black, Asian and Minority Ethnic (BAME) groups compared with the general population. It is established that the health risk of excess weight for some BAME groups occur at a lower BMI than for White populations.

Living with excess weight is a risk factor for a range of chronic diseases, including type 2 diabetes, cardiovascular disease, many cancers, liver and respiratory disease. Obesity is also associated with reduced life expectancy, and lower quality of life.

Evidence on the links between weight status and COVID-19 outcomes are drawn primarily from three sources: retrospective cohort studies, clinical audits of patients with COVID-19 in hospital and routine primary care records with data linkage to outcomes. This evidence suggests excess weight is associated with an increased risk of the following for COVID-19: a positive test, hospitalisation, advanced levels of treatment (including mechanical ventilation or admission to intensive or critical care) and death. The risks seem to increase progressively with increasing BMI above the healthy weight range, even after adjustment for potential confounding factors, including demographic and socio-economic factors. There is also some evidence to suggest that disparities in excess weight may explain some of the observed differences in outcomes linked to COVID-19 for older adults and some BAME groups.

These observations are supported by plausible mechanisms which might explain the association between obesity and COVID-19 outcomes. These include the effects of excess adipose tissue on respiratory function, metabolic dysfunction, the cardiovascular system, enhanced inflammatory response and impaired response to infection. There may also be an interaction with weight-related comorbidities, including type 2 diabetes, cardiovascular and respiratory diseases, which are also associated with more severe COVID-19. In addition, socio-economic and demographic factors associated with excess weight, are also associated with COVID-19 severity. Stigma experienced by people living with obesity, may delay interaction with health care and may also contribute to increased risk of severe complications arising from COVID-19.

Rapid emergence of research relating to excess weight and COVID-19 has been vital in supporting policy and decision makers. However, there remain limitations with the evidence to date, including unrepresentative sampling, small sample sizes in many studies or limited numbers of COVID-19 infections. In addition, BMI has been estimated and not measured in some studies or measured many years prior to exposure to COVID-19 infection. There is much more to understand when it comes to obesity and the pathogenesis of COVID-19, including why some population groups appear to have greater risk.

Nonetheless, despite its limitations, the evidence consistently suggests that people with COVID-19 who are living with overweight or obesity, compared with those of a healthy weight, are at an increased risk of serious COVID-19 complications and death. Some of the studies suggest that the association is attenuated by, but independent of, other important factors including age, sex and ethnicity. It is also independent of social economic status in studies which considered this. At this time, however, conclusions on excess weight and COVID-19 severity are tentative and more research is needed to build the evidence base.

It is currently unclear to what extent the relatively high prevalence of excess weight seen in the UK, compared with other countries, may have contributed to the severity of COVID-19 in the UK. In addition, it is uncertain to what extent differences in the prevalence of excess weight for different population groups (including for different ethnic groups and those living in deprived areas), have contributed to inequalities in outcomes. However, these inequalities, related to obesity, appear to be key factors in the risk of COVID-19.

For groups living with obesity, weight loss has been shown to bring long-term health benefits. There is currently no high-quality research on the effects of weight loss on COVID-19 risks, however, based on the potential mechanisms underpinning the associations, the role of excess weight as a risk factor for serious COVID-19 complications warrants further consideration.

Factors, such as age and ethnicity cannot be changed and factors such as deprivation, are complex to address. Supporting people who are overweight or living with obesity to lose weight, together with interventions to prevent or slow weight gain across the population will plausibly reduce future population risks of COVID-19. Moreover, there is robust evidence these interventions will bring wider health benefits to individuals and reduce pressures on the NHS due to overweight and obesity.

There is no single solution to tackling obesity. Actions will be required to both prevent excess weight gain and support people who are living with overweight or obesity to move towards a healthier weight. Drivers of excess calorie intakes and low levels of physical activity, within the environment people live, will need to change at a national and local level to support population-level weight change. Improving and increasing access to weight management options for the large numbers of people who could benefit, and which are tailored to individual needs and preferences would also help address levels of obesity.

The COVID-19 pandemic has brought the health crisis caused by overweight and obesity to the fore. The case for action at scale and over the long term to prevent excess weight and support people living with obesity is strong. Doing more for those groups most affected can help improve health overall and help address some of the inequalities in health.

Key insights

What we knew about excess weight pre-pandemic:

- most adults in England are living with overweight or obesity (63% are >25kg/m^2); some groups have higher levels than others including those aged between 55-74 years, those living in deprivation and some BAME groups
- as BMI increases above the healthy range (18.5 to <25kg/m^2)[i] it is a risk factor for a wide range of chronic diseases, including type 2 diabetes, cardiovascular disease, many cancers, liver and respiratory disease, and premature mortality increases
- it is hard to study the effect of weight loss on diseases that take many years to develop, such as cancer, however evidence shows that reducing weight towards a healthier BMI range improves biological markers associated with better health (such as blood pressure) and reduces the risk of type 2 diabetes, and improves quality of life scores, depression and mobility

New evidence on COVID-19 and health:

- there are a number of limitations in the evidence to date, including sampling and testing strategies, unequal exposure to COVID-19, sample sizes and limited number of COVID-19 infections. More research is needed

Laboratory confirmed COVID-19:

- as BMI increases above the healthy range (20 to <25kg/m^2)[1] there is an association with testing positive with COVID-19 (may be subject to possible selection bias)
- BMI is more strongly related to testing positive with COVID-19 in BAME groups compared with White ethnic groups
- Findings in this section may be particularly affected by selection bias primarily due to the testing strategy in place at the time the studies were carried out

Hospitalisation:

- patients with COVID-19 living with overweight (BMI ≥25kg/m^2) or obesity (BMI ≥30kg/m^2), compared with patients with a healthy weight (BMI 20 to <25kg/m^2) are more likely to be hospitalised if infected with COVID-19

[i] Healthy range of BMI is 18.5 to 24.9kg/m^2. Some of the studies cited in this report refer to a healthy range of 20 to <25kg/m^2.

- patients living above a healthy weight (BMI ≥25kg/m^2), are at a progressively increased risk of being hospitalised compared with patients with a BMI <25kg/m^2

Admission to intensive/critical care and treatment:

- patients living with overweight or obesity (BMI ≥25kg/m^2), compared with patients with a BMI<25 kg/m^2 are more likely to be admitted to intensive/critical care and to require advanced treatment for severe COVID-19 symptoms

Risk of mortality:

- there is potentially a higher risk of COVID-19 related death with increasing BMI
- where studies have adjusted for confounding factors such as age, sex, measures of socio-economic status (SES), ethnicity and co-morbidities, the relationship between excess weight and COVID-19 risk has persisted

1. Introduction

It is established that excess body weight is one of the leading causes of poor health in Britain[3]. This is because most of the population carry excess body weight, which is known to increase the risk of a range of chronic diseases including type 2 diabetes, many cancers, liver disease and cardiovascular diseases[4, 5, 6].

New evidence from studies, in the UK and around the world provide evidence about excess weight and its association with COVID-19. This report collates insights from this evidence, on:

- the prevalence, causes, and other health risks of overweight and obesity
- food purchases and physical activity during lockdown
- drivers of excess weight, what is and could be done to tackle the problem and where more action is needed

Much of the information provided is drawn together from existing technical reports, policy and strategy documents, public health and clinical guidance and published academic evidence.

The publication is intended to provide insights to inform policy and practice when it comes to supporting people living with obesity. It is aimed at policy makers in national and local government, local public health teams, health professionals who have an interest in obesity and treating COVID-19, charities and organisations supporting people living with obesity, academics and other colleagues working in the health and social care sector. It is also intended to support health marketing campaigns.

COVID-19 is an infectious disease, which is caused by a novel coronavirus. Many people infected with COVID-19 can suffer a range of mild to moderate respiratory disease and symptoms, such as high temperature, a persistent cough and sore throat. Many can also be symptomless. However, for some people COVID-19 will cause more severe symptoms, and it can adversely affect the lungs and many other body systems and it can cause death[7].

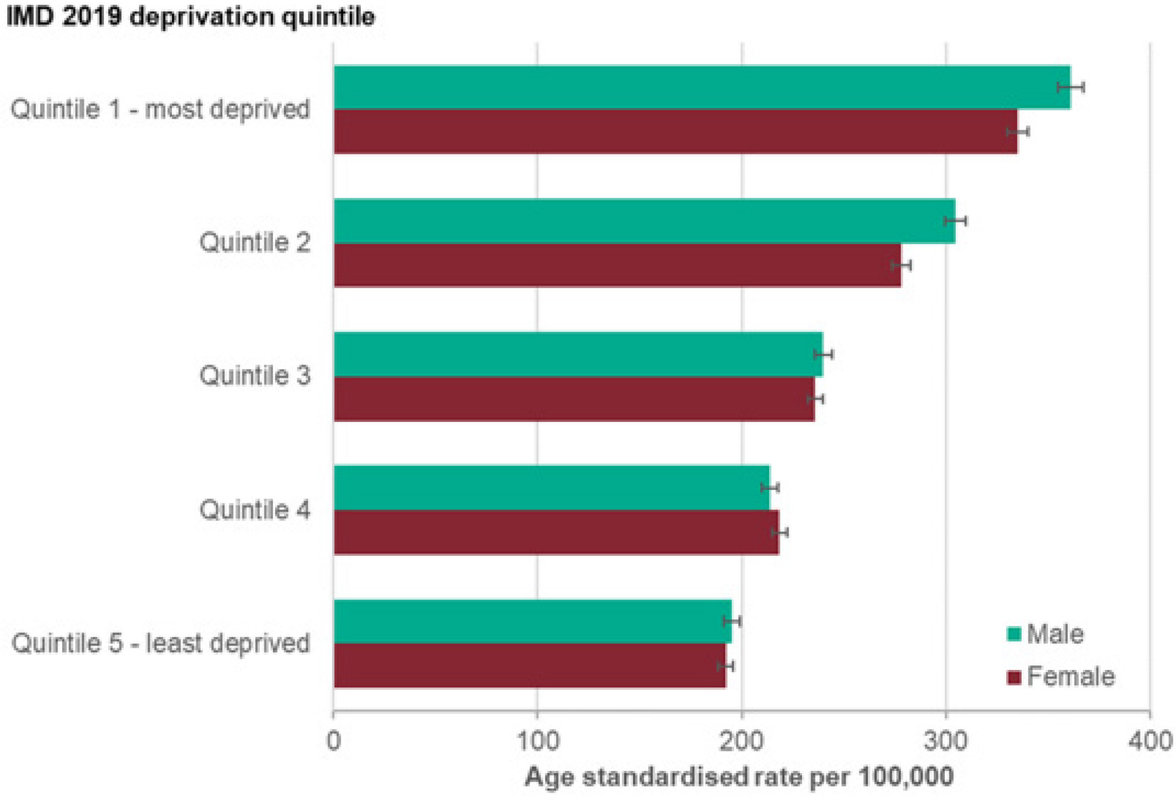
On the 12 March, the World Health Organization characterised COVID-19 as a pandemic[7]. Up until the 24 July 2020, there were 297,146 confirmed cases in the UK, with over 45,550 people dying because of COVID-19[8].

Some people are more at risk of developing serious illness if infected by COVID-19, including older people, and people with underlying medical conditions, including, amongst others, cardiovascular disease, diabetes, chronic respiratory disease, and current or recent cancer. People living with severe obesity (BMI ≥40kg/m^2) are also deemed to be clinically more vulnerable[9].

Understanding how COVID-19 affects different groups in the population is important to help protect people from the disease. PHE analysed COVID-19 diagnosis data and published a report, which demonstrated that COVID-19 has a disproportionate impact on certain population groups, including people living in more deprived areas (Figure 1) and BAME groups (Figure 2)[10]. Some of these population groups are also disproportionally affected by obesity (see Section 4).

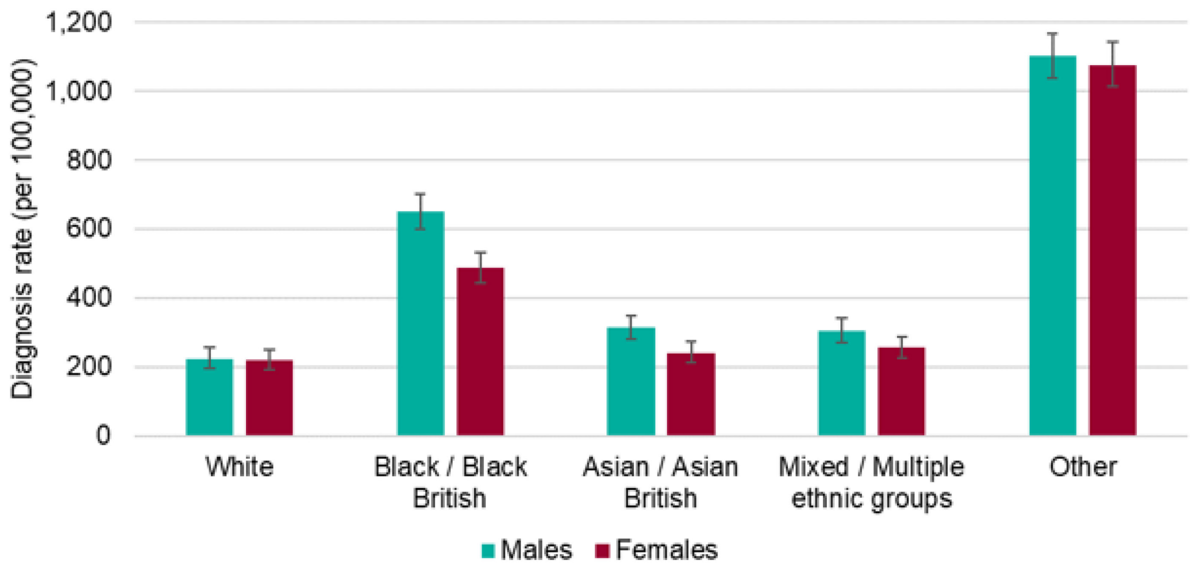
At the time of publication, treatment includes steroids and dexamethasone for severely ill people. There are many trials ongoing to develop and test vaccines and research into treatments for COVID-19, and there is also research underway to understand the factors that are associated with risk of severe symptoms associated with COVID-19. This includes investigating who may be affected more by the disease and how conditions, such as living with overweight or obesity might impact on how the body responds to being infected with COVID-19.

Figure 1. Age standardised diagnosis of COVID-19 rates by deprivation quintile and sex, as of 13 May 2020, England



Source: PHE Second Generation Surveillance System

Figure 2. Age standardised diagnosis rates of COVID-19, by ethnicity and sex, as of 13 May 2020, England



Source: PHE Second Generation Surveillance System

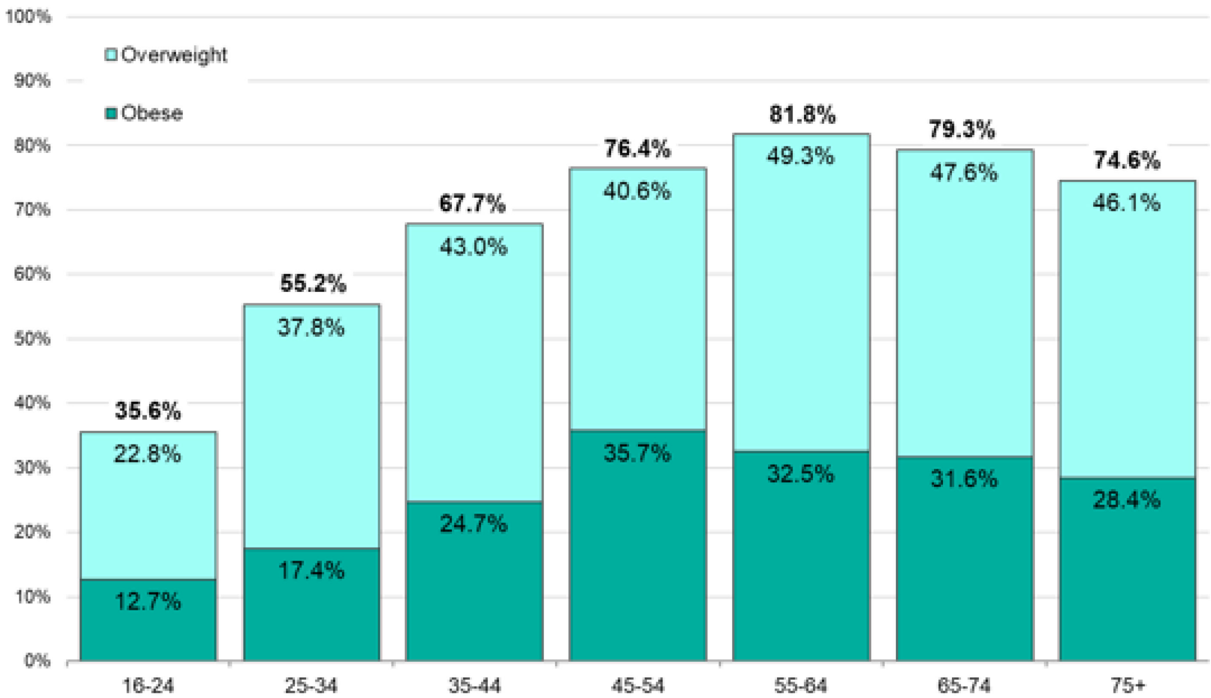
2. Scale of obesity prevalence and risk to health

63% of adults in England are above a healthy weight, with 36% and 28% of adults living with overweight or obesity respectively. Two-thirds of men are living with overweight or obesity (67%) and 6 out of 10 women are living with overweight or obesity (60%).

One out of 4 men is living with obesity (26%) and 29% of women are living with obesity[11]. Annexe A, Table 3, to this publication provides data on levels of adults living with severe obesity.

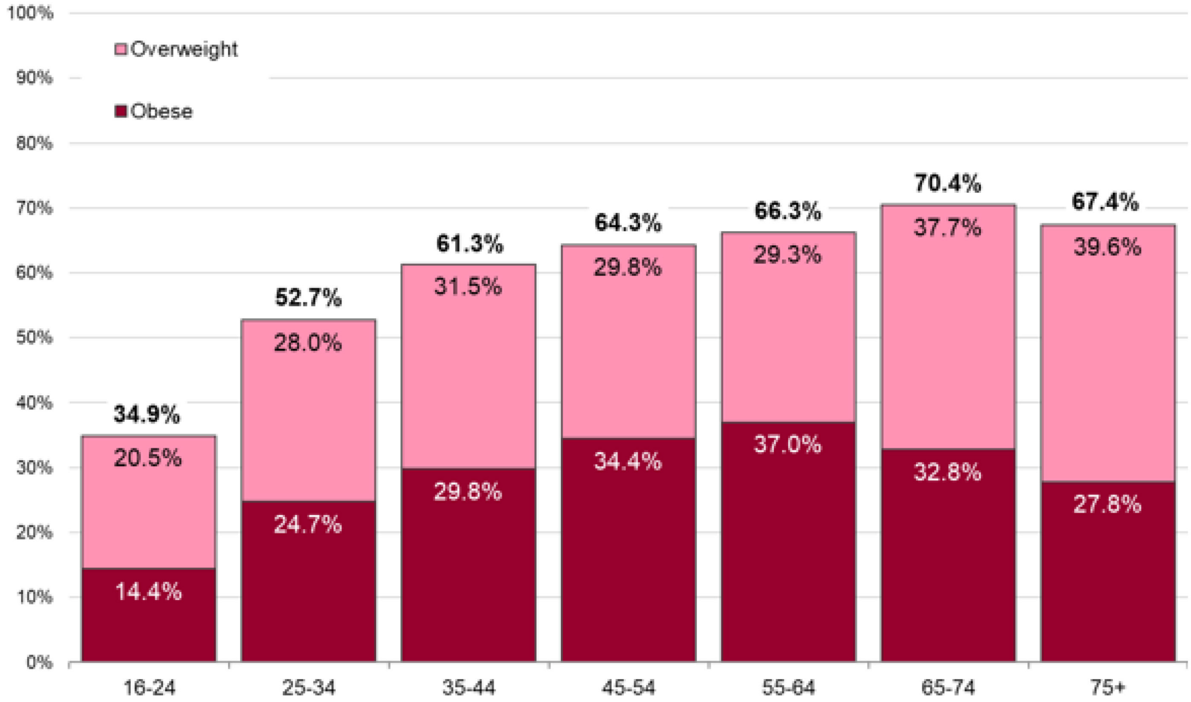
Overweight and obesity tend to increase with increasing age, with the lowest prevalence in 16-24-year olds. This peak occurs for men at the 55-64-year age group (82%) and in the 65-74-year age group in women (70%), followed by a decline in the oldest age group for men and women. Figure's 3 and 4, present prevalence rates, by age, for men and women respectively.

Figure 3: Prevalence of men living with overweight and obesity by age (Health Survey for England (HSE), 2018)



Adult (aged 16+) BMI thresholds: Overweight: 25 to <30kg/m^2; Obese: ≥30kg/m^2

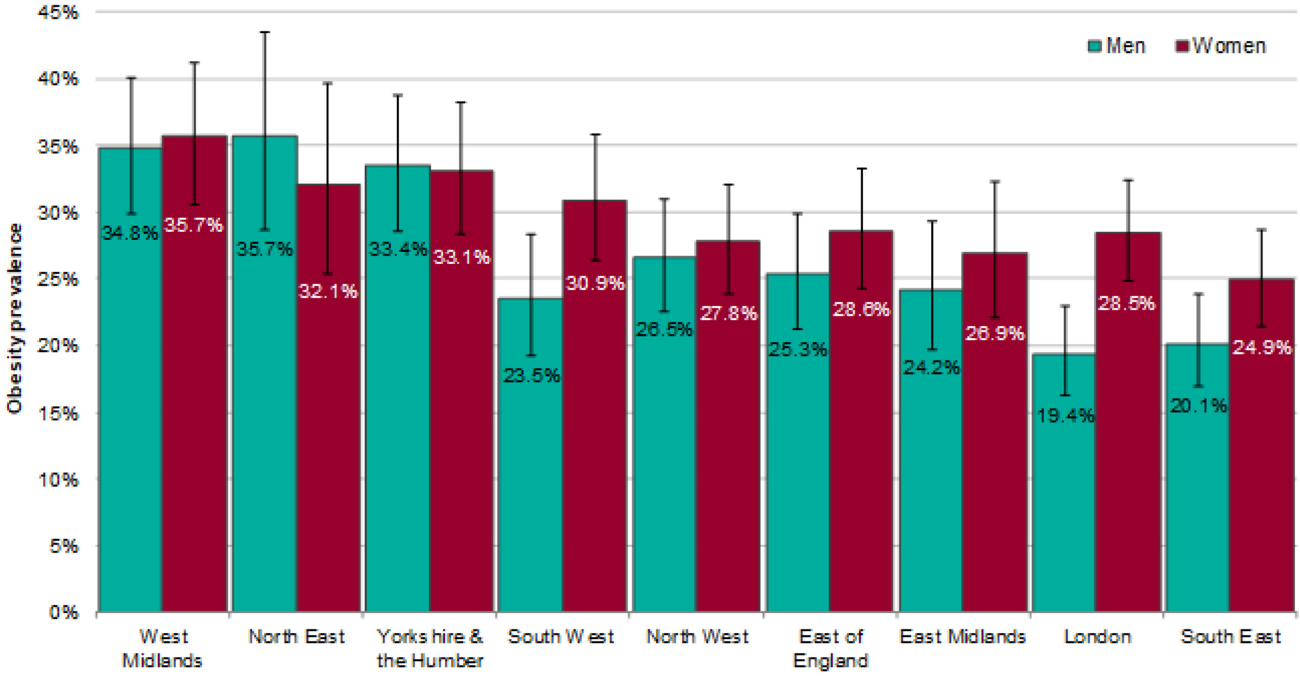
Figure 4: Prevalence of women living with overweight and obesity by age (HSE, 2018)



Adult (aged 16+) BMI thresholds: Overweight: 25 to <30kg/m^2; Obese: ≥30kg/m^2

Figure 5, presents the prevalence of obesity among adults and shows that this varies by region in England, with the highest prevalence in the West Midlands and the lowest prevalence in London and the South East.

Figure 5: Prevalence of men and women living with obesity by England region (HSE, 2018)

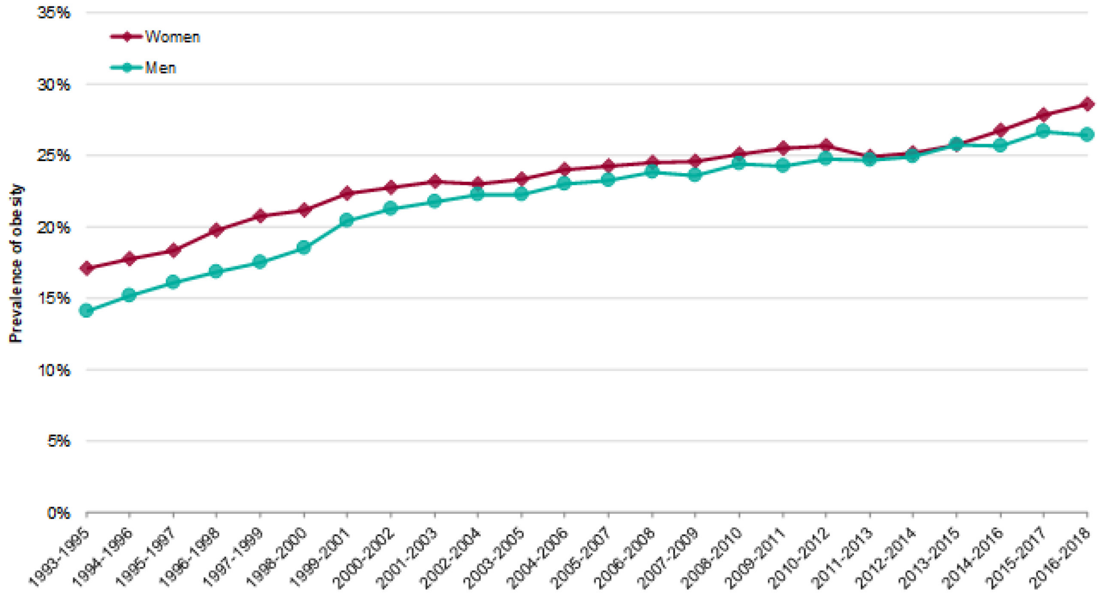


Obesity prevalence is age standardised. 95% confidence intervals are shown: Adult (aged 16+) obesity: BMI ≥30kg/m^2

Trends, projections and international comparators

Figure 6, presents data demonstrating that obesity prevalence increased steeply between 1993 and around 2000 with a slower rate of increase after.

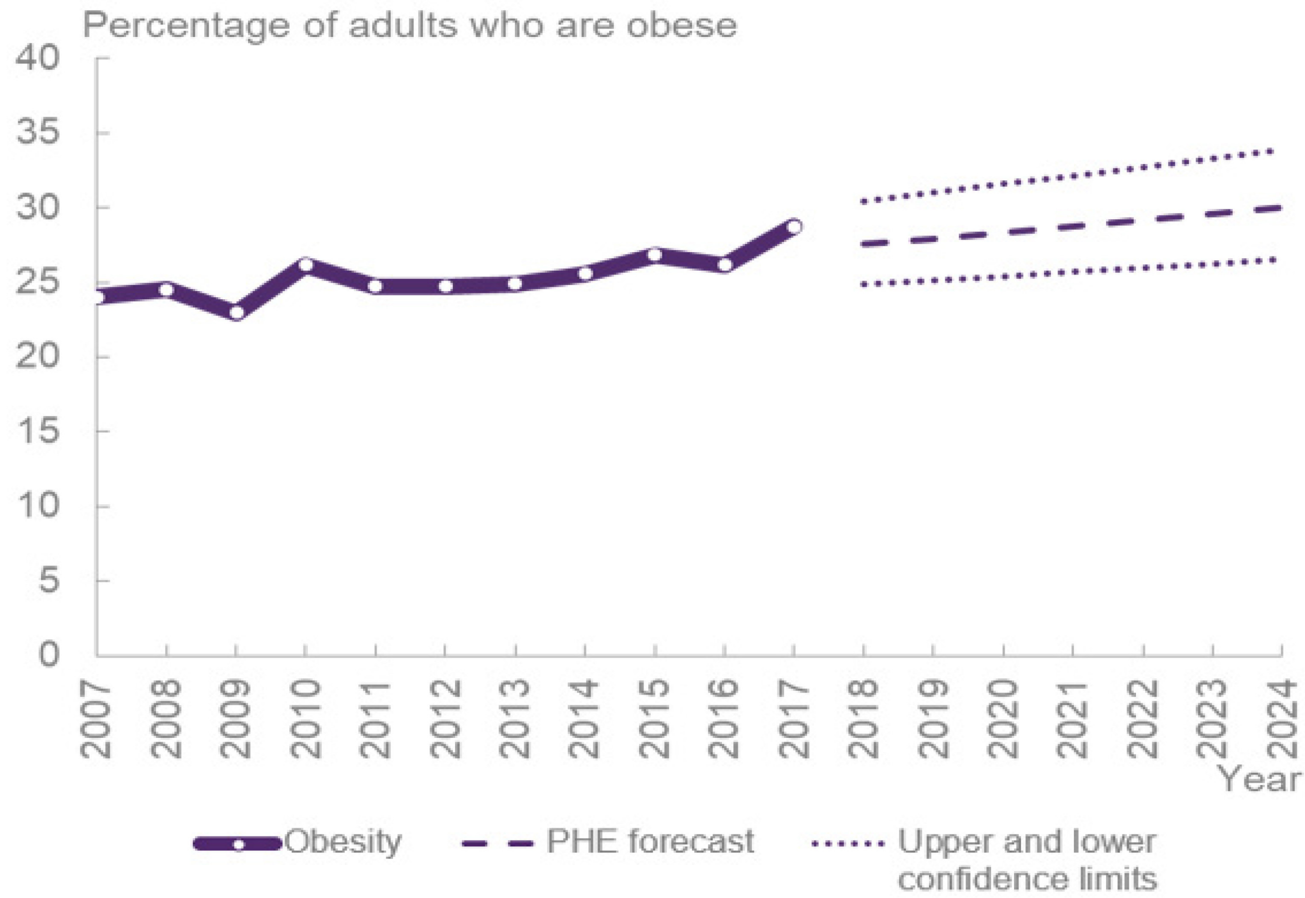
Figure 6: Trend in obesity prevalence data for adults aged 16+ 1993 to 2018 (HSE, 2018)



Adult (aged 16+) obesity: BMI ≥30kg/m^2

Figure 7, presents an analysis of obesity prevalence trends carried out for the Health Profile for England 2019[12]. This includes forecast data up to 2024, which suggests that without intervention, obesity rates will continue to rise among the adult population. However, it is not known what effect the pandemic might have on future trends of obesity.

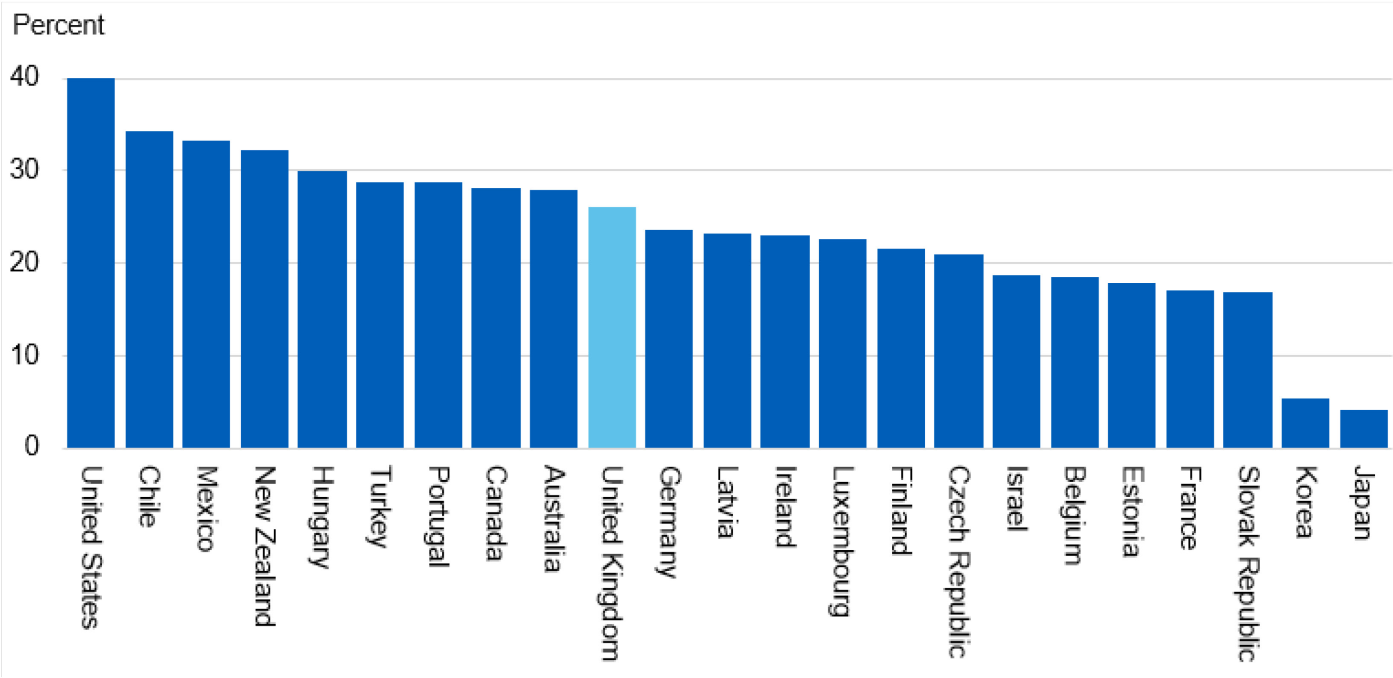
Figure 7: Trend in prevalence of adults living with obesity, aged 16+ 2007 to 2018, PHE forecasts 2018 to 2024[12]



Obesity prevalence in the UK compared with other Organisation for Economic Co-operation and Development (OECD) countries

Figure 8, provides comparisons for OECD countries based on data for 2017 adults aged 15 and over, or closest available. Data is for 2017 or nearest available year. Only countries with measured data are included here. The UK reports an adult obesity level of 26%. This is 14 percentage points lower than the US which reports the highest adult obesity level. Japan and Korea report obesity levels of less than 10%[13].

Figure 8. Prevalence of adults living with obesity in OECD countries, (OECD, 2017)



Measured data only (excludes countries with only self-reported data)

3. Obesity and risks to health

Population levels of obesity have resulted in significant disease burden[14].

Compared with individuals of a healthy weight (BMI 18·5–24·9kg/m²), life expectancy from age 40 years was 4·2 years shorter in men living with obesity (BMI ≥30kg/m²) and 3·5 years shorter in women living with obesity, furthermore for a BMI >40kgm^2 life expectancy was reduced by 9.1 years for men and 7.7 years for women[15].

Living with obesity seriously affects people's quality of life and their health. It increases the risk of hypertension, heart attacks, stroke, heart failure, type 2 diabetes, non-alcoholic fatty liver disease and some cancers in adults [4, 5, 6]. Obesity is the second biggest preventable cause of cancer in the UK with more than 1 in 20 cancer cases caused by excess weight[16]. These diseases for which obesity is a risk factor are over represented in patients diagnosed with COVID-19 in hospital or with more severe COVID-19[17].

Each year, 20% of people in the UK see a doctor about a musculoskeletal problem (such as, osteoarthritis). Seven in 10 people who report living with a long-term musculoskeletal problem are either living with overweight or obesity[18]. There are multiple risk factors that can heighten people's susceptibility to musculoskeletal problems in addition to excess weight, physical inactivity, vitamin D status or calcium, smoking, older age and genetic predisposition to some musculoskeletal conditions.

Table 2, shows the extent to which obesity increases the risk of diseases relative to not living with obesity. For example, a woman living with obesity is 12.7 times more likely to develop type 2 diabetes, than a woman who is not living with obesity.

Table 2: Relative risk factors for men and women living with obesity, compared to men and women not living with obesity of developing selected diseases

	Men	Women
Type 2 diabetes	5.2	12.7
Hypertension	2.6	4.2
Myocardial infarction	1.5	3.2

Cancer of the colon	3.0	2.7
Angina	1.8	1.8
Gall bladder diseases	1.8	1.8
Ovarian cancer		1.7
Osteoarthritis	1.9	1.4
Stroke	1.3	1.3

Source: National Audit Office, 2006 as referenced in Statistics on Obesity, Physical Activity and Diet: England, 2006[19]

Compared with people with a healthy weight, those people living with obesity are more likely to experience respiratory issues including obstructive sleep apnoea/hypopnoea. Obesity is also associated with asthma[20]. Mental health problems are also associated with obesity[21].

4. Inequalities relating to obesity

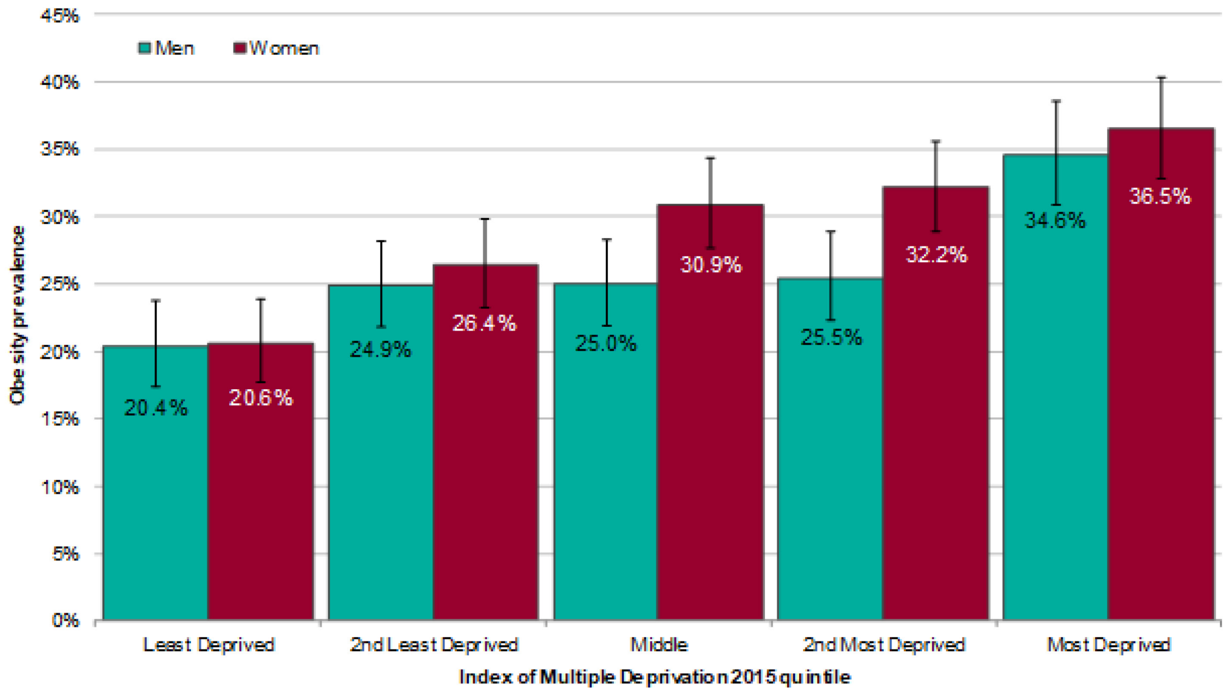
Socio-economics

Deprived areas have higher levels of overweight and obesity compared with more affluent areas in England[22, 23]. A higher prevalence of excess weight is also seen in some BAME groups and the health risks of obesity arise at a lower BMI.

Like the PHE Disparities report, some studies looking at ethnicity, social differences and disparities associated with COVID-19 indicated that age and gender, ethnicity, geography and deprivation are associated with poorer COVID-19 outcomes[24, 25, 26].

Obesity prevalence is highest among the most deprived groups (>34%) compared with just over 20% in the least deprived groups. Figure 9, shows that around 20-21% of men and women in the least deprived quintile compared with 35% men and 37% women in the most deprived quintile were living with obesity. Analyses of HSE 2018 data (Annexe A, Table 3) indicates that the prevalence of men and women living with severe obesity increases with level of deprivation.

Figure 9: Prevalence of adults living with obesity by deprivation, HSE, 2018



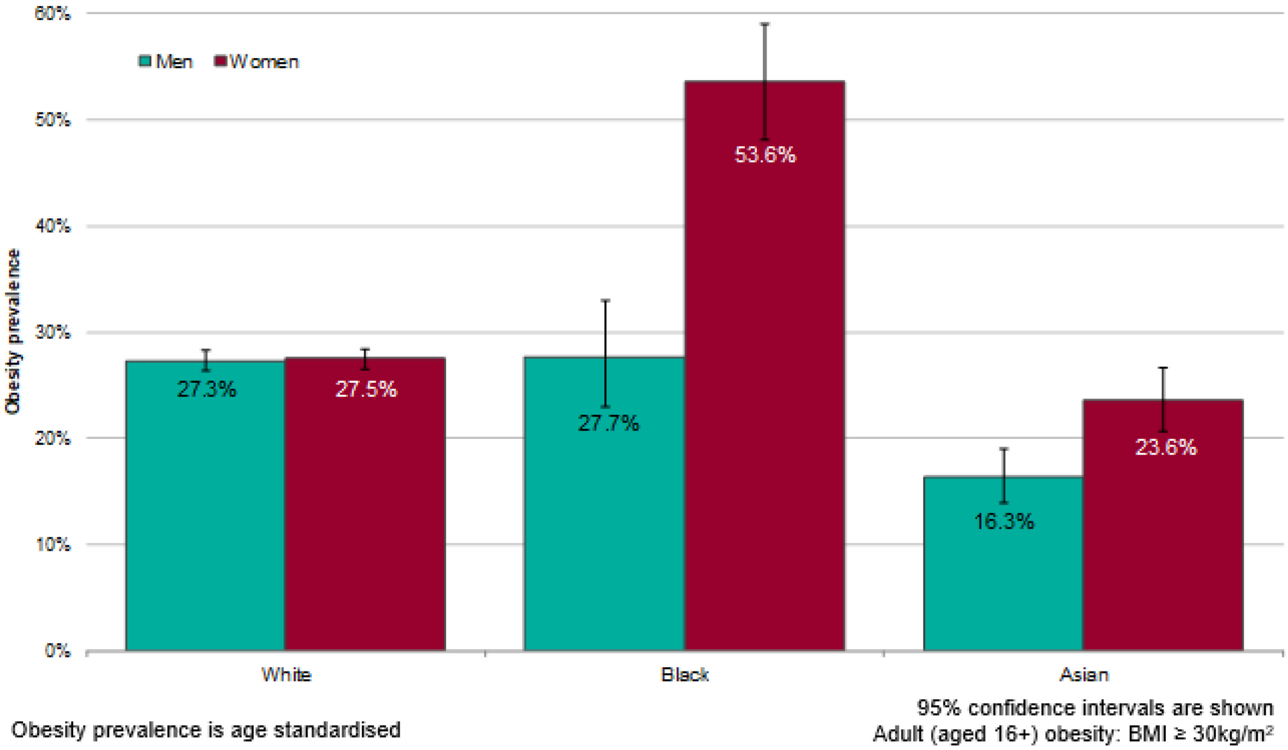
Obesity prevalence is age standardised. 95% confidence intervals are shown: Adult (aged 16+) obesity: BMI ≥30kg/m^2.

Ethnicity

As illustrated in Figure 10, differences are also seen in the prevalence of obesity between different ethnic groups. Obesity among Black women is 53.6%, White women 27.5% and Asian women 23.6%. Obesity among men was similar for Black men (27.7%) and White men (27.3%) and lowest among Asian men (16.3%)[27].

An important consideration to the information presented here is that cardiometabolic health risks of excess weight occur at a lower BMI for BAME groups compared to White groups. Accordingly, the BMI thresholds for intervention are set at a lower level (BMI 23kg/m^2 to indicate increased risk and 27.5kg/m^2 to indicate high risk) than for White groups[1].

Figure 10: Prevalence of adults living with obesity by ethnic group, HSE 2017



The disproportionate burden of COVID-19 on certain groups such as people living in more deprived areas and some BAME groups, overlaps with variations in the prevalence of obesity. Evidence in the PHE Disparities report and commentary from Lassale et al in an analysis of the ethnic disparities on hospitalisation with COVID-19, reflect that ethnic minority groups are often living in more deprived areas. It is not uncommon for some BAME families to live as part of intergenerational and or larger households. Some BAME groups may be more likely to be exposed to infection due to their employment, for example in public and community facing jobs, exposing them more to infection[10, 24, 28].

Other groups are also disproportionally affected by obesity compared with the general population including people living with severe mental illness or learning disabilities. The prevalence of obesity is almost double in adult patients, aged 15-74 years, with severe mental illness compared with all patients[29]. Published data in 2016, for people with learning disabilities reports that more men and women were living with obesity (BMI≥ 30kg/m^2) 31% and 45% compared with 24% of men and 27% of women without a learning disability[30].

5. Excess weight and COVID-19

Between mid-April and July PHE has monitored the evidence relating to COVID-19 and obesity, particularly in relation to diagnosis and risk of illness including hospital and ICU admission, the need for advanced treatment and mortality. Evidence was identified through routine obesity literature scans and contact with experts. Information was extracted from studies into a standard template on an ongoing basis and reviewed and checked by at least two other people. PHE has not undertaken a systematic or complete review of the literature, however checks have been undertaken with experts in the field to ensure key studies have been identified and for accuracy of interpretation.

Data extraction tables have been replicated in this publication for the UK studies (Annexe A, Table 1) and adapted to provide summaries of studies from other countries (Annexe A, Table 2).

Several issues, that may limit the interpretation and should be considered when reviewing the studies that are summarised in this section, include that:

- the studies published to date have mostly analysed data on hospitalised patients with COVID-19 of which some comprise of very small samples. This makes findings from individual studies non-generalisable due to bias towards people with severe illness

- all people in studies admitted to, or in hospital, have proven COVID-19 infection. There may be differences in characteristics of people who do not seek help, or in their timing of admission to hospital in relation to disease progression, or unknown variations in viral load

- there is uncertainty on which people in the population were infected (in prospective cohort studies), with potential differences in patterns of infection by BMI, ethnicity or deprivation

- many adjustment factors have varied in different studies, with some potentially over adjusting, either for parameters related to disease severity, or for parameters potentially mediating the link between obesity and COVID-19, and other studies not adjusting for relevant factors such as deprivation

- in the UK, most of the current studies have used the UK Biobank dataset. This is a large set of data following half a million people who volunteered to participate, and researchers have linked data to confirmed COVID-19 tests. It is important to note that BMI measurements would be relatively outdated and some authors stated measurement was 12 years old. However, adult BMI levels generally track over time. The data on prevalence rates is not representative of the general population. However, whilst prevalence rates may not be generalisable, they are deemed to provide valid assessments of disease exposure and relationships[31]

- some of the evidence reviewed has been rapidly published and, in some cases, gone through rapid review so could be subject to unchecked errors

- there is likely variation in how and when, in relation to subsequent COVID-19 outcomes, height and weight and/or BMI is assessed in these data sources; whether through anthropometric measurements (height and weight); existing patient records; self-reported; or assessed in some other way. Therefore, some people's BMI and hence categorisation is likely to have been assessed incorrectly. Also, not all studies have used the same BMI thresholds or have combined them to classify levels of overweight and obesity

Evidence from systematic reviews on the association between excess weight and COVID-19 severity

Two of the most recent systematic reviews are described in this section. Not all studies captured in this report were included in the reviews.

Yang et al[32] (2020) conducted a systematic review with meta-analysis to assess the relationship between BMI and obesity, and severity of COVID-19, based on literature searches up until 21 April 2020. The review included 9 case-control and retrospective cohort studies, 8 of which were included in the meta-analyses. Seven of the 9 studies were conducted in China, while 2 studies were conducted in France and the US. At least 2 studies conducted in China used a BMI cut-off for obesity of >24kg/m^2, while the studies conducted in France and the US used the WHO diagnostic criteria of ≥30kg/m^2. The review authors did not define disease severity.

In this systematic review, based on the findings of 6 studies including 667 patients, patients with severe COVID-19 had a higher BMI compared with patients with mild COVID-19 (WMD[ii]) 2.67 BMI units; 95% confidence interval (CI) 1.52 to 3.82). In addition, patients with obesity had more severe COVID-19 outcomes compared to patients without obesity (Odds Ratio (OR) 2.31; 95%CI 1.30 to 4.12) based on the findings of 4 studies that included 2,644 patients.

The pooled estimates of the association between obesity and COVID-19 severity should be interpreted with caution as it is unclear whether these were based on individual effect estimates that had been adjusted for key confounding factors

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[ii] Weighted mean deviation

including age, sex, ethnicity and the existence of co-morbidities such as hypertension and type 2 diabetes, although such conditions may also in part mediate the link between obesity and more severe outcomes. Only 2 of the 9 included studies explicitly identified co-morbidities, 1 of which also stratified its sample by age. Given the potential for residual confounding, the pooled results may have overestimated the association between obesity and COVID-19 severity.

Hussain et al[33] (2020) conducted a meta-analysis to investigate whether patients living with overweight or obesity were more likely to die from COVID-19 compared to patients with a healthy weight. Fourteen studies including 403,535 patients with COVID-19 from various countries (including at least 5 conducted in Chinese patients), the latest study included was published 9 July 2020. Although the review contained some retrospective analyses, the design of some of the studies, including those coming from the unpublished literature, was unclear.

Compared with patients living with a healthy weight, patients living with overweight or obesity (defined as having a BMI >25kg/m^2) were more likely to die (OR 3.68; 95% CI 1.54 to 8.83), need advanced respiratory support (OR 6.98; 95% CI 5.37 to 9.07) and be critically ill from COVID-19 (OR 2.03; 95% CI 1.75 to 2.36). The review did not specifically analyse the risk of COVID-19 outcomes in patients living with obesity BMI ≥30kg/m^2.

The results from this meta-analysis should be interpreted with caution. The pooled estimates had high heterogeneity (I^2>80%) which was inadequately investigated by the review authors. The pooled results may also overestimate the association between higher BMI and COVID-19 outcomes. Only 5 of the 14 included studies controlled for confounding factors. In addition, it is unclear whether existing comorbidities such as hypertension and type 2 diabetes, which whilst may mediate the association between obesity and risk of severe COVID-19 outcomes, were accounted for.

Evidence from individual studies on the association between weight status and COVID-19 diagnosis and severity

Twelve UK studies reported analysis relating to obesity (see Annexe A, Table 1). Seven used UK Biobank data linked to testing positive for COVID-19 [34, 35, 36, 37, 38, 39, 40]; 3 explored hospital data [41, 42, 43]; and 3[iii] linked primary care data to testing positive for COVID-19, Hospital Episode Statistics (HES) and Office for National Statistics (ONS) deaths [44, 45, 46]. Intensive care data is also presented, collated by the Intensive Care National Audit and Research Centre (ICNARC) [47].

[iii] Williamson et al pre-publication and final peer reviewed publication are included (references 44 and 45 respectively)

Summary information on the study design of the 12 studies, including reported limitations is included in Appendix 1. Information on relevant confidence intervals are included in Annexe A, Table 1.

Nineteen studies from other countries (China, France, Italy, Mexico and the USA) are included, see Annexe A, Table 2. These studies were retrospective or cross-sectional data analyses of a relatively small number of cases of hospitalised patients [48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63] and of larger numbers of patients[64, 65, 66]. Information on adjustments made during data analysis are noted. The details of the results are described in Annexe A, including where there is significance.

Laboratory confirmed COVID-19

One UK study, Yates et al, used UK Biobank of over half a million participants linked to COVID-19 test data, in which 882 patients tested positive for COVID-19. Adjusted for a range of possible confounding factors, the authors reported a dose response association between BMI or waist circumference and a positive test for COVID-19 in people with overweight, obesity and severe obesity of 1·31, 1.55 and 1·57 respectively, compared with healthy weight range[34]. The authors acknowledge that their findings are limited by possible selection bias.

Hospitalisation

In the UK, there have been several studies using UK Biobank data linked to diagnosis for COVID-19, which have reported that individuals living with overweight or obesity were more likely to be tested positive in a hospital setting than individuals with a healthy weight[36, 37]. For instance, Hamer et al reported that, compared with patients with BMI <25kg/m^2, those living with overweight or obesity had an increased risk of hospitalisation, RR 1.32 and 1.97 respectively (after adjusting for age, sex, education, ethnicity, diabetes, hypertension, cardiovascular disease)[35].

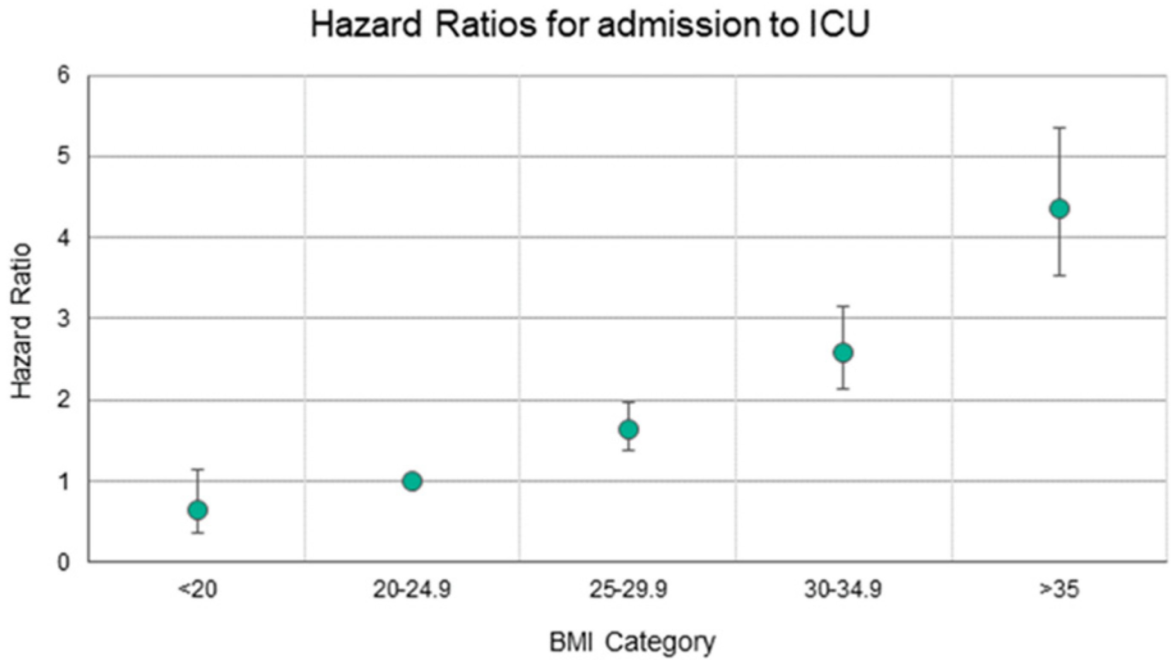
In New York, Petrilli et al reported that people living with obesity (BMI 30-39.9kg/m^2) or severe obesity (BMI ≥40kg/m^2) and diagnosed with COVID-19 (median age of 52 years), were 4 and 6 times, respectively, more likely to be hospitalised compared with patients with COVID-19 and a BMI<30kg/m^2 [61]. In another US study, Bhasin et al, analysed a subset of patients less than 50 years of age hospitalised with COVID-19 without diabetes or hypertension. Mean BMI was greater than those >50 years of age. The authors reported an inverse relationship between BMI and age amongst patients hospitalised with COVID-19. Bhasin et al during the same period observed that this BMI to risk association was not present in non-COVID-19 patients[54], whilst Sattar et al showed that risk of death from COVID-19 was more strongly associated with increasing BMI in younger adults (<70 years) when compared with those aged >70 years[40].

Admission to intensive/critical care

In England, Wales and Northern Ireland data from the ICNARC reported that 31.3% and 7.9% of patients critically ill in intensive care units (ICU) with confirmed COVID-19 had a BMI ≥30kg/m^2 or a BMI ≥40kg/m^2 compared with 28.9% and 2.9% of the general population respectively (after adjusting for age and sex). This disparity was also seen when looking at severe levels of obesity in White and non-White patients[47].

Hippisley-Cox et al analysed general practice data for over 8 million people, of which 19,486 had tested positive for COVID-19 and 1286 were admitted to ICU. The authors reported that patients living with overweight (BMI ≥25-29.9kg/m^2), obesity (BMI ≥30-34.9kg/m^2) or severe obesity (BMI ≥35kg/m^2), compared with patients with a BMI ≥20-24.9kg/m^2, had increased odds of ICU admission of 1.64, 2.59 and 4.35 (adjusted for age, sex, ethnicity, deprivation co-morbidity, treatment and other factors). Figure 11, reproduced, a figure depicting the hazard ratios (HR) for ICU admission according to BMI category[43].

Figure 11, reproduced, a figure depicting the HR for ICU admission according to BMI category. Hippisley-Cox et al, QResearch database University of Oxford[43]



The findings from UK based studies are supported by analyses conducted in a range of studies from different countries (US, France, Mexico and China). See Annexe A, Table 2.

Risk of mortality

Williamson et al looked at primary care data on 17 million adults, of which there were 10,926 COVID-19 deaths[44, 45]. This data showed an increasing risk of death with increasing BMI (fully adjusted for age, sex, ethnicity, deprivation and co-morbidities) with HR 1.05, 1.40 and 1.92 for people with a BMI between 30-34.9kg/m^2, ≥35-39.9kg/m^2 and ≥40kg/m^2 respectively, relative to BMI <30kg/m^2.

Docherty et al[41] reported that of patients hospitalised, in 208 UK hospitals, there was a 33% increased risk of mortality (after adjusting for age, sex, and major comorbidities) for those recognised by clinical staff as living with obesity[iv].

Perez-Guzman et al analysed data on a small number of COVID-19 hospitalised patients in a London trust and reported a lack of association between BMI and mortality (unadjusted analyses). However, the authors reported that BMI data was missing for half of the patients, which may explain this finding[42].

The association between obesity, a high BMI and COVID-19 related death has also been reported using National Diabetes Audit data, which explored the

[iv] The classification of obesity was made by a clinician and it is not clear how this was assessed.

impact in people with diabetes (type 1 and 2 diabetes). The authors reported that the risk of mortality, compared with individuals with a BMI 25-29·9kg/m^2 was particularly marked at higher levels of BMI (≥40kg/m^2) for individuals with both type 1 and type 2 diabetes (HR 2.33 and 1.60, respectively). Of interest, elevated BMI was less strongly linked to deaths not linked to COVID-19 in people with diabetes during the same period[46].

Bello-Chavolla et al analysed 51,633 subjects with COVID-19 and reported that the presence of obesity explained almost half of the total risk association of diabetes on COVID-19 mortality. COVID-19 was also reported to increase the risk of mortality in patients living with obesity, compared to those not living with obesity, by five-fold. The authors also reported that addition of obesity, in their analyses, to other comorbidities was associated with a significantly increased risk of mortality from COVID-19[66].

In the US, Klang et al and Suleyman et al both reported that BMI ≥40kg/m^2 was independently associated with mortality after adjustment for demographics and co-morbidities [58, 63].

A small US hospital study, of which >90% of the patients were African American, reported that obesity (BMI >30kg/m^2) was a predictor for mortality (OR 1.7) After adjusting for age, gender, and other comorbidities, compared to BMI <30 kg/m^2 [59].

Specific analysis relating to COVID-19, obesity and Black, Asian and Minority Ethnic Groups

The level of BMI recommended to refer into weight management services in relation to certain chronic diseases for BAME groups is lower than for White Europeans (WE's)[1], as health risk increases at a lower level of excess weight.

Razieh et al used Biobank data linked to PHE laboratory COVID-19 test data. The authors stated that their analysis is limited by non-random testing for COVID-19 within the UK, but reported that a higher BMI was associated with increased odds of COVID-19 diagnosis for WE and BAME groups. However, when comparing the two groups, the authors reported a greater risk for BAME individuals, relative to WE, at higher levels of BMI. For example, at a BMI of 35kg/m^2 the odds of COVID-19 were 2.56 times higher for BAME individuals compared with WE's. At a BMI of 25kg/m^2 there was no such difference[38].

Sattar et al also used linked Biobank data to COVID-19 related deaths. Out of 839 COVID-19 diagnoses 189 died from COVID-19. The authors reported that increasing BMI was strongly associated with positive diagnosis of COVID-19 and risk of death. With regards to ethnicity, an increased BMI was more strongly associated with positive diagnosis ($P_{interaction}$ = 0.010) and death ($P_{interaction}$ = 0.002) for non-White ethnic groups (mainly South Asians and Afro-Caribbeans) compared with White ethnic groups[40].

COVID-19 and non-COVID 19 patient comparisons

Some studies have also investigated differences between different patient groups in hospital settings.

In the UK, ICNARC data indicates that a higher proportion of patients living with obesity and severe obesity were admitted to ICU with COVID-19 (31.3% and 7.9%), compared with a cohort of patients admitted to ICU (before the pandemic), with non-COVID-19 viral pneumonia (23.5% and 7%)[46].

Ho et al used UK Biobank data linked to COVID-19 diagnoses, to compare the risks associated with COVID-19 compared with that of viral pneumonia. In an adjusted model, a higher BMI, compared to a healthy weight, was associated with a 1.24 relative risk of COVID-19 whereas the relative risk for patients and non-COVID-19 viral pneumonia was 1.13 for the same BMI comparisons (adjusted models)[37].

Similarly, Simonnet et al reported significant differences in the proportion of patients living with obesity or severe obesity[v] in a COVID-19 cohort compared with a cohort diagnosed with a non-COVID-19 acute respiratory disease (47.6% vs 25.2% and 28.2% vs 10.8%, respectively)[48]. Caussy et al, also reported that the proportions of patients living with obesity and with critical COVID-19 were significantly higher in ICU compared with a cohort of non-COVID-19 patients living with obesity and admitted to ICU (OR 1·69) after adjusting for age and sex[57].

Summary

The set of studies referred to in this section, summarised in Annexe A, provide valuable insights into the association between excess weight and COVID-19. Consideration of this information and future high-quality research is required to inform policy and practice to help prevent weight gain and provide treatment for people living with overweight or obesity.

The findings, so far from several different study types (prospective cohort, clinical audits of patients with COVID-19 in hospital and routine primary care

[v] Simonnet et al reported that the sex distribution and age in the COVID-19 sample were not significantly different from participants in the non COVID-19 cohort.

records with data linkage to outcomes, early systematic reviews and meta-analyses) carried out in the UK and other countries, are in broad agreement on the relationship between weight status and COVID-19 outcomes.

Living with excess weight is being consistently reported to be associated with an increased COVID-19 risk: testing positive (noting that much of early testing in the UK was undertaken in hospitals), hospitalisation, advanced levels of treatment (including mechanical ventilation or admission to intensive or critical care) and death. The risks seem to increase progressively with increasing BMI above the healthy weight range, even after adjustment for potential confounding factors, including demographic and socio-economic factors. There is also some evidence to suggest that disparities in excess weight may explain some of the observed differences in outcomes linked to COVID-19 for older adults and some BAME groups.

However, there are limitations in the current evidence base linking weight status to COVID-19 (outlined earlier in this section) which means that only tentative conclusions can be drawn. A key limitation in terms of the analyses conducted included those who have had tests in hospitals. At this time, it is not possible to be sure if it is excess weight that is directly causing the reported increased risk of COVID-19, for patients who are living with overweight or obesity compared with those of a healthier weight, another factor not taken into account or identified, in the currently published studies. There are a number of other limitations in the evidence to date, including sampling and testing strategies, unequal exposure to COVID-19, sample sizes and limited number of COVID-19 infections. Further research is needed, including more systematic reviews and meta-analyses.

6. Obesity and COVID-19: Potential plausible mechanisms

Along with emerging evidence on the association between obesity and COVID-19, there has been a breadth of published articles describing the potential mechanisms associated with obesity which might interact with the pathology of COVID-19.

This section provides key insights into some of the known effects of obesity and excess adipose tissue and which provide for plausible mechanisms that may be linked to COVID-19 outcomes.

Insights from the body of evidence detailing mechanisms about obesity and influenza may prove relevant to obesity and COVID-19, though the authors of two papers that describe these mechanisms caution that they may not be transferable nor plausible mechanisms or pathways for other viruses, which includes COVID-19[67, 68].

When it comes to COVID-19 and excess weight, there has not been any mechanistic studies to date. However, commentators and authors of studies have hypothesised about several mechanisms by which obesity and particularly severe obesity might affect COVID-19 outcomes. This includes the distribution in the body and metabolic effects of excess (and ectopic) adipose tissue and how this adversely impacts respiratory function, inflammatory response, haematological and immune function, and how the body responds to infection with COVID-19.

Excess adipose tissue and deposition

The physiological implications of obesity, including fat deposition around the upper airway and a heavier thorax can directly impact on and reduce lung function, which along with the effects of the virus may affect circulating levels of oxygen[20, 69].

Sanchis-Gomar et al[69] explored the role of obesity and its interactions with COVID-19 and detailed how adipose tissue, due to containing high levels of the angiotensin-converting enzyme 2 (ACE-2; the enzyme that the virus latches onto to gain access to cells) and that this may make adipose tissue more susceptible to infection. Hormonal changes linked to adipose deposition have also been speculated to also play a part[70].

Honce and Schultz-Cherry[67] described that people living with obesity may experience a higher viral load when infected with influenza virus; prolonged and increased viral shedding; and that recovery from infection may be affected.

Inflammatory and immune response

Obesity is known to induce a pro-inflammatory response, which has been suggested to affect the performance of anti-viral treatment of influenza[67].

Sattar et al[71] and Lockhart and O'Rahilly[70], commented on the plausibility of various mechanisms where obesity is implicated with COVID-19, including an increased inflammatory response in individuals living with obesity and links to cytokine production. Simonnet et al[48], Petrilli et al[61], Chiapetta et al[72] and Kim and Nam[73] also draw parallels between the pro-inflammatory response associated with obesity and the inflammatory response observed in obesity related chronic diseases and in severe COVID-19 cases.

Potential mechanisms that have been postulated in relation to obesity and influenza (not COVID-19) describe how hyperinsulinemia or hyperleptinemia may impair the function of T-cells and hence how the immune system responds and adapts to viral infections[68]. Notably, the authors also observe that vaccinated adults living with obesity have a two-fold risk of influenza compared with vaccinated adults not living with obesity. It is not known if this is relevant to COVID-19.

Thrombosis

Sattar et al reflected on known links between obesity and thrombotic risks, important as the hyperimmune response in COVID-19 may cause harm via widespread microvascular thrombosis, and a higher risk of venous thromboembolism. Links between excess fat and impaired metabolic responses are also relevant, given obesity is a major risk factor for diabetes, and diabetes appears to be more common in people with severe COVID-19[71]. Sanchis-Gomar et al[69] also commented on how obesity is associated with hypercoagulability and that this may also be an important factor in the observed elevated risk of thrombosis in patients with COVID-19.

In the above, obesity may increase the risks of infection leading an exaggerated hyperimmune response. At the same time, obesity may lessen the body's ability to cope with the multiple effects of the virus-induced immune response (for example, metabolic, cardiovascular, respiratory, thrombotic).

Lockhart and O'Rahilly[70] provided a detailed account of the potential mechanisms and postulated a few hypotheses, which if tested in experiments and proven could help make the case for preventative and curative approaches, including preventative energy deficit behavioural programmes.

Psycho-social factors

In-addition to the biological mechanisms summarised there are psycho-social factors, which may impact on people living with obesity. It is evident that people living with obesity suffer stigma and discrimination[74].

Such stigma could mean that people living with obesity are reluctant to access healthcare[75], or may delay seeking care until their disease is more advanced. Clinicians, academics and patient groups with shared interests in obesity have reflected on relevant factors including weight bias and stigma and variations in care and treatment for people living with obesity[76]. These are important issues, particularly when trying to prevent chronic and infectious disease.

7. Potential benefits of healthier weight

It is hard to study the effects of weight loss on conditions that take many years to develop, however, multiple shorter-term studies show that there are some health benefits for a range of conditions. Given the mechanisms being suggested that link adipose tissue, excess weight and COVID-19, it is conceivable that the benefits of weight loss could mitigate COVID-19 severity.

Intentional weight loss of between 5kg–10kg in women living with obesity-related illness is associated with lowered risk of death, cardiovascular death, cancer and diabetes-related death. In men, those who lost weight intentionally appeared to have a reduced risk of diabetes-related death[77]. The NICE guidance on behavioural weight management recognises that even modest amounts of weight loss of 5% can benefit health[78].

Health benefits of weight loss relate to improved cardiovascular risk, and reduced osteoarthritis-related disability[79]. In individuals with pre-diabetes, for every kilogram of weight lost there was a 16% reduction in risk for progression to diabetes[80].

In a metabolic study a 5% weight loss improved multi-organ insulin sensitivity and β cell function, and in the same study additional weight loss of 11%–16% further increased insulin sensitivity in muscle[81]. The DiRECT trial assessed remission of type 2 diabetes via a primary care-led weight management programme and found that diabetes remission (among a third of patients) was sustained at 24 months, which was linked to the extent of sustained weight loss[82]. The DROPLET study trialling very low-calorie diets showed at 12 months substantial weight loss and greater improvements in cardiometabolic disease[83].

For cardiovascular disease risk factors there are potentially profound benefits. In a retrospective cohort study of 13,722 patients (including 2,287 patients who underwent bariatric surgery and 11,435 matched controls), metabolic surgery was significantly associated with a lower risk of major adverse cardiovascular events (HR, 0.61)[84].

Diastolic blood pressure and HDL cholesterol are improved with around ≥5 to <10% weight loss[85]. Systolic blood pressure is also reduced by around 1mmHg per kg weight loss[86]. In a post-hoc analysis of the Look AHEAD trial, there were fewer major adverse cardiac events by 21% for >10% of body weight lost[87]. Research has also shown benefits such as quality of life scores, depression and mobility:

- Quality of Life assessments at 1 year, show improvement with weight loss[88]
- depression scores reduce with weight loss[89]
- mobility improves with weight loss[90]
- improvements in self-esteem have also been shown with weight loss[88]

Other genetic and observational evidence strongly support important causal effects of obesity and potential benefits of weight loss on risks for heart attacks, heart failure and chronic kidney disease[91,92].

8. Drivers of obesity

Helping people living with overweight or obesity to achieve or maintain a healthier weight is complex. There is no single solution and the situation has been decades in the making and is driven by environmental, behavioural, biological, societal and cultural factors and importantly, the interaction of these drivers.

At its simplest level, obesity is caused by consuming more calories than the body uses which over time results in excess weight being gained. It is estimated that on average adults in England are consuming 200-300 excess calories per day[93].

People's diets are influenced by a range of factors, including preferences and habits formed early on in life, educational opportunities, employment and psychosocial factors that influence behaviours such as family food preferences and meal patterns. The environment where people live is a key driver of the unhealthy behaviours causing obesity; where the easiest food and drink options are less than healthy and very often the easiest way to get around is by car[94].

At a population level there remains low consumption (relative, compared with at least 5 portions a day) of fruit and vegetables[95]. Food and drinks, high in sugar, fat, salt and calories are abundant and for most people are easily accessible. The many choices people make are driven by multiple factors including price, availability, advertising and promotions. There are also more food outlets than ever before, and takeaways and food deliveries have been made very easy with the growth of digital apps[96]. The burden of poor diet and obesity is not equal and falls disproportionately on people in underserved communities, often living in more deprived areas[22, 23, 97]. Areas with more fast-food outlets[98] more advertising and less access to green space than those that are more affluent[99]**.**

Life is much more sedentary than ever before and physical activity, which uses up energy, plays a role in maintaining a healthier weight, including the prevention of weight gain and reduction in body fat. It also plays a role in the prevention of weight regain after weight loss[78]. Increasing physical activity also independently offers benefits to health and most people, including those living with obesity, can reduce their risk of cardiovascular disease and improve their health by being physically active. In combination with calorie deficit diets, physical activity can support maintenance of weight loss.

Food purchasing and physical activity during lockdown

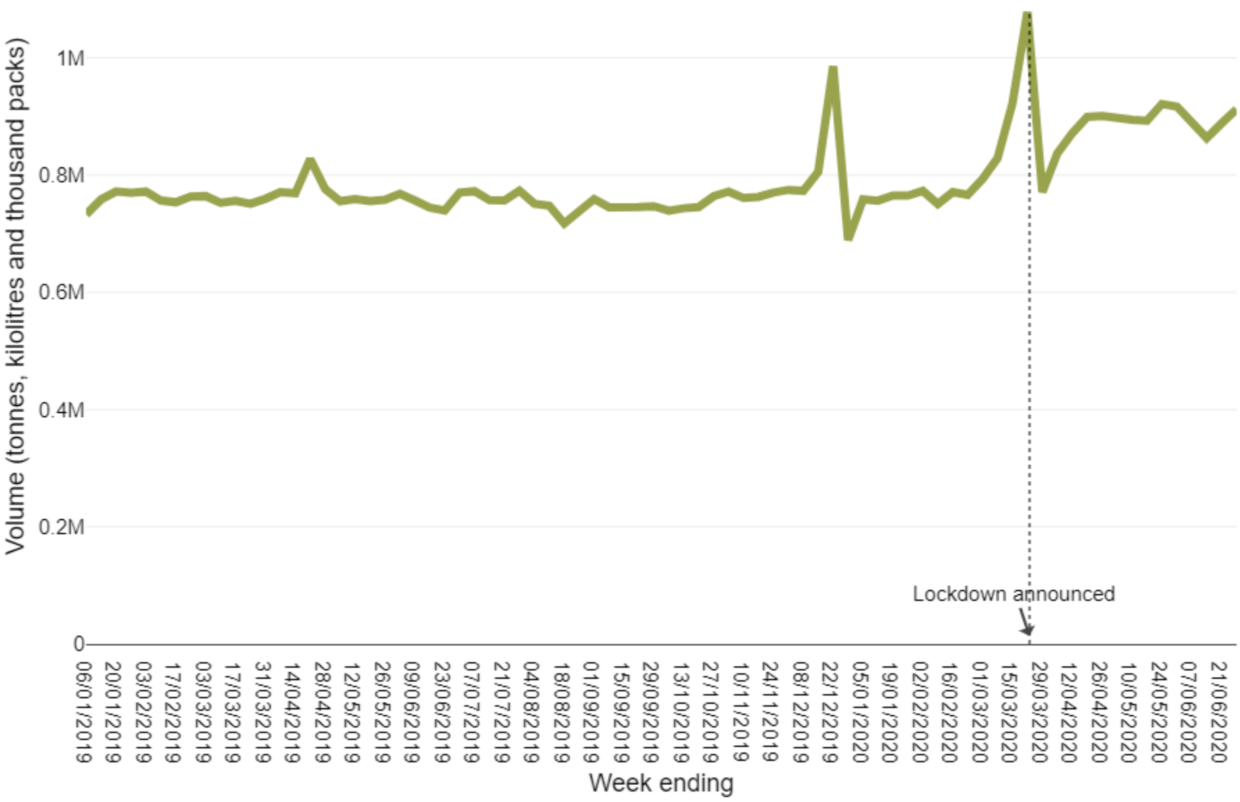
Insights provided here explore changes to dietary and physical activity behaviour during lockdown, which are relevant to obesity.

Most of the regular surveys to monitor what people are doing have been suspended during lockdown, so it is not possible to get a full picture of diets, physical activity or any body weight changes. Currently available evidence is limited. However, there have been large shifts in where food is purchased and the types of food being bought.

In pre-lockdown around three quarters of energy intake came from foods consumed at home, mainly from supermarkets and other retailers. Around a quarter of energy intake came from eating out, mainly from outlets such as cafes, restaurants and canteens, or as complete ready to eat meals from takeaways or deliveries[95]. Volume sales of food for consumption in the home has increased by 11.5% for the current calendar year up to 21 June 2020, when compared to the same period last year[100]. This is likely to reflect in part closure of some food outlets. It is not however clear the net effect this had had on energy consumed or diet composition.

Figure 12, shows an increase in volume sales of food and drink purchased for consumption at home leading up to a peak in the week ending 22 March which was the day before lockdown was announced on 23 March. Volume sales for the week ending 22 March were the highest recorded even surpassing the peak at Christmas. Volume sales fell heavily in the following week ending 29 March which may reflect the amount of stock piling (which took place in the previous few weeks), the difficulty in purchasing certain grocery products, due to a lack of supply and the introduction of lockdown measures restricting movement outside of the home. However, sales in that week were still above the same week in 2019 and have remained above 2019 levels since[100].

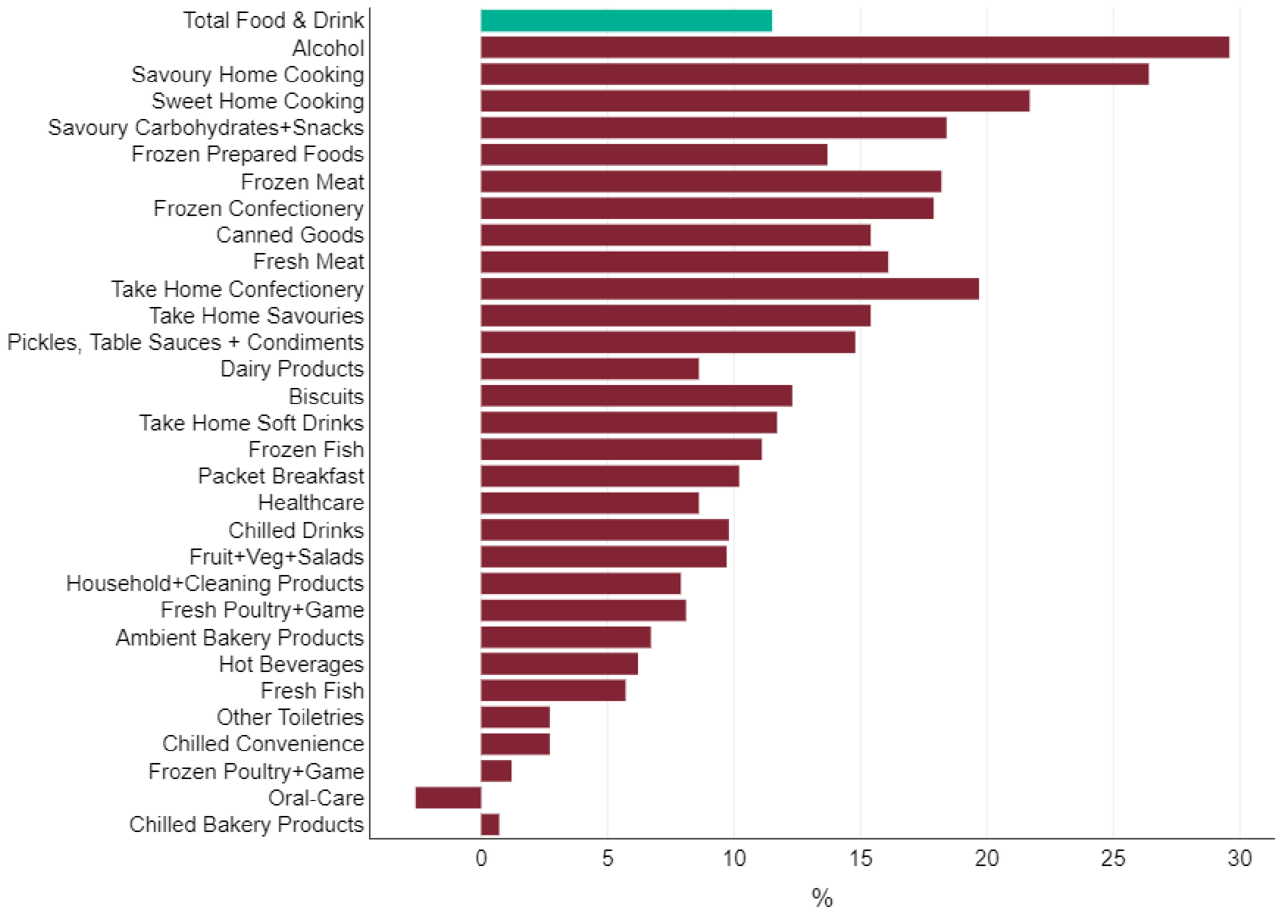
Figure 12: Trend in food & drink volume sales - Great Britain



Source: PHE analysis of take home purchasing data from Kantar Worldpanel

Figure 13, shows the change in volume sales of categories of household items including food and beverages, for 2020 year to date with the equivalent period for 2019[100]. Overall, volume sales are up 11.5% for the same period last year but there are some differences by category. Alcohol (up 29.6%) has shown the largest increase followed by Savoury Home Cooking (up 26.4%), Sweet Home Cooking (up 21.7%) and Take Home Confectionery (up 19.7%). As explained previously however, some or all these increases may be due to food which was previously being consumed outside of the home in 2019 such as work and school lunches and snacks, food and drink in restaurants, cafes and pubs, now being purchased for consumption at home since the lockdown restrictions were put in place.

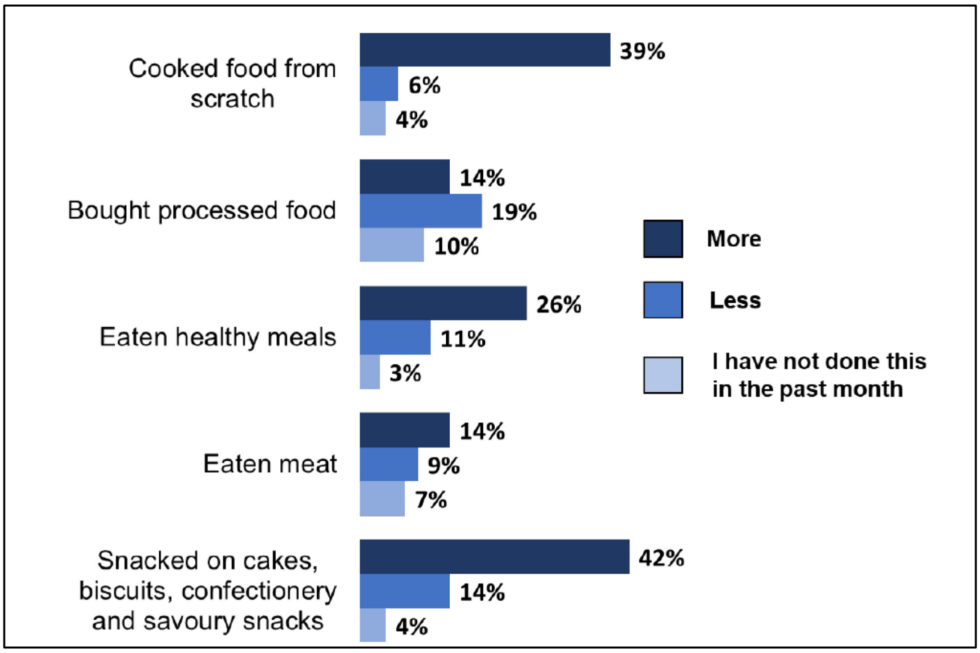
Figure 13: Comparison of 2020 volume sales up to 28/06/2020 with the same period 2019



Source: PHE analysis of take home purchasing data from Kantar Worldpanel

At a population level a recent survey (of >2,000 adults aged 16-75 years) reported changes in types of food people were eating. When respondents were asked *'In the last month have you done any of the following more or less often?'* they reported that they were cooking food from scratch, eating healthy foods and snacking on cakes, biscuits, confectionery and savoury snacks more often (Figure 14)[101].

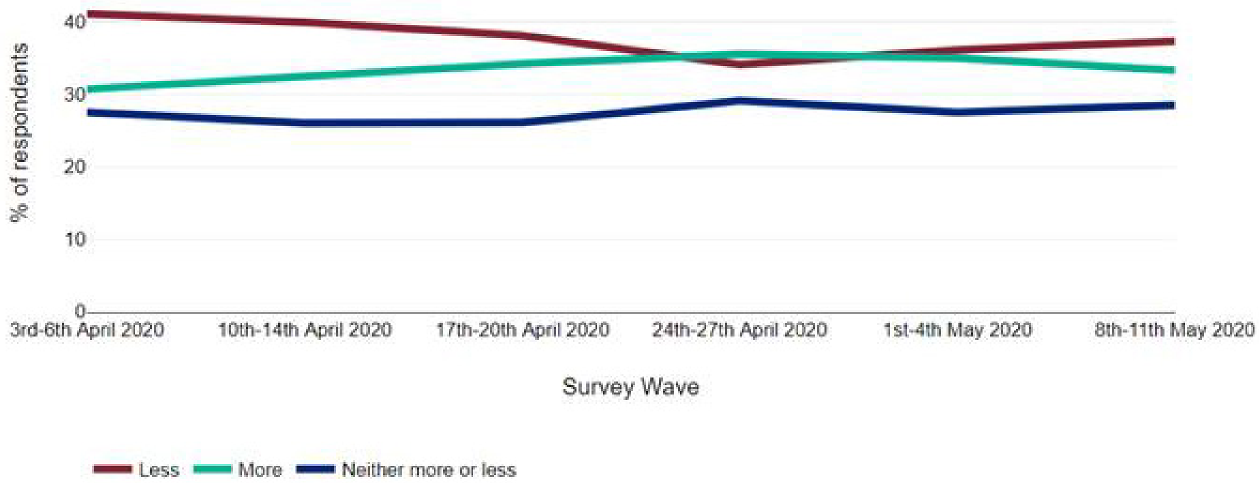
Figure 14: Changes in nutrition behaviour over the last month



Source: Food Standards Agency and IPSOS Mori: COVID-19 Consumer Tracker Waves 1 and 2. Base: 2,040 Online, England, Wales and NI, adults 16-75, 8-12 May 2020

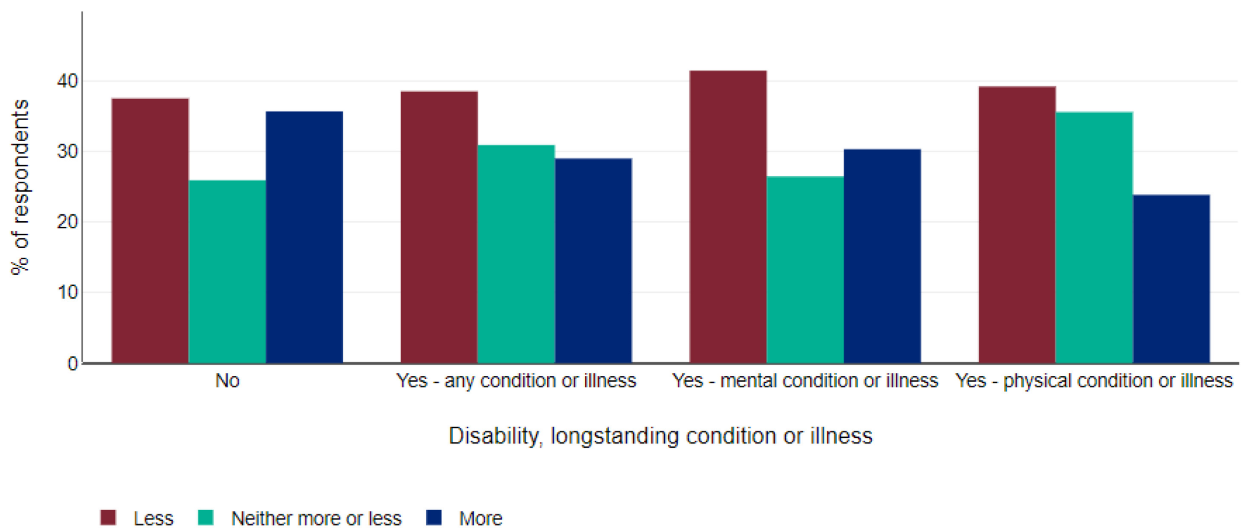
The COVID-19 pandemic has had a contrasting effect on physical activity. Interest in activity has never been higher[102] and over 2 in 3 people saying it is important to exercise regularly[100, 103]. However, actual activity levels appear to have gone down, with a weekly survey of over 2,000 people during April and May suggesting more people have been doing less physical activity than normal compared with those doing more (Figure 15)[100,104]. It also appears that the pandemic has exacerbated inequalities, including for adults with a disability, long standing conditions or illness who were already more likely to be amongst the least active (Figure 16)[100,104].

Figure 15: Trend in percentage of adults doing more or less physical activity than usual. Survey Wave period: 03/04/2020–11/05/2020



Source: Survey into adult physical activity attitudes and behaviour. Sport England by Savanta ComRes

Figure 16: Percentage of adults doing more or less physical activity than usual by disability, longstanding condition or illness; pooled survey wave from 03/04/2020-11/05/2020



Source: Survey into adult physical activity attitudes and behaviour. Sport England by Savanta ComRes

Current action and how future action might look

Addressing obesity requires multiple action, at national and local level, including prevention and treatment. Some of the policies and programmes, such as the sugary drinks industry levy, product reformulation and school food standards, which are needed to contribute towards addressing obesity are set out in the government's Childhood Obesity Plan(s)[105, 106].

Advancing our Health: prevention in the 2020s, outlined additional opportunities on clearer food labelling, improving the nutrient content of everyday food and drinks, and the use of digital approaches to support for individuals to achieve and maintain a healthier weight and promote positive mental health[107].

During lockdown, local authority and NHS commissioned behavioural weight management services, which provide support to people wanting to change behaviour and achieve a healthier weight, were either paused and/or have adapted. Ongoing research looking into how local approaches have adapted suggests that many services have continued to deliver using virtual and remote approaches. Some early feedback from service users has reported that although some people miss the groups interactions, for some the virtual approach is convenient and saves having to find childcare or transport to attend a meeting.

Supporting people who are living with excess weight to lose weight in a sustainable manner, together with interventions to prevent weight gain across the population will plausibly reduce future population risks of COVID-19. Consideration as how to support modified services and to restart weight management services and provide such approaches, including more intensive approaches, at scale to support people living with obesity is required. Further research is needed to understand the mechanisms involved regarding obesity and COVID-19 and the effect of weight loss on the severity of the infection.

Commitments in the NHS Long Term Plan include support for behavioural weight management services and this affords opportunity to better identify and offer support to people in communities that are facing a higher burden[108].

Positive changes to the environment, as a response to COVID-19, include infrastructure to support more walking and cycling. Whilst, many local authorities are already working to support access to healthier food options, there are opportunities to scale this up[109].

Despite having information on food purchases and physical activity changes during lockdown, information is not available on dietary patterns or comparable population physical activity levels during this period. It is also not clear what has happened to weight status, or the extent to which any changes during lockdown will be sustained.

There is no single solution to tackling obesity. It is likely that many actions will be required to address this, including ones that help prevention of excess weight gain by supporting healthier choices. It is important that actions are sustained and include ones that impact on the population not just those who are more engaged in health. PHE have already recommended a range of interventions to achieve this aim, including limiting advertising and promotion of less healthy foods[110] and promotion of active travel[111].

Improving access to weight management approaches, including digital, face to face and virtual/remote options, to the large numbers of people who could benefit, and which are tailored to individual needs would also help address this national public health problem.

9. Concluding remarks

The impact on health and life expectancy of excess weight has been known for years. Evidence published during the pandemic, despite its limitations, consistently suggests that people with COVID-19 who are living with overweight or obesity, are at notably increased risk of serious COVID-19 complications and death. There are also several plausible mechanisms why excess body fat could worsen COVID-19 outcomes. However, at this time a more definitive conclusion on excess weight and the severity of COVID-19 cannot be made.

The UK has a relatively high prevalence of obesity compared with other countries. It is currently unclear to what extent this may have contributed to the high incidence of COVID-19 seen so far in the UK, compared with many other countries.

In addition, it is uncertain to what extent differences in the prevalence of excess weight for different population groups (including for different ethnic groups and those living in deprived areas), explain the variation seen in COVID-19 risk across society.

Research on obesity and its association with COVID-19 adds to the evidence of the impacts on health vulnerability, health outcomes, inequalities and the demands on health and social care services of excess weight. It is predicted that the numbers of people living with overweight or obesity are likely to increase. Unless there is deep, meaningful and sustained intervention to reduce the drivers on excess calorie intakes and low levels of physical activity, the impact on health is likely to worsen.

For people living with obesity, weight loss has been shown to bring health benefits. There is currently no direct research of the effects of weight loss on COVID-19 risks. However, based on the putative mechanisms underpinning the associations it is reasonable to conclude that reducing excess weight could help reduce the risk of severe COVID-19 illness. Moreover, there is good evidence these interventions will bring wider health benefits to individuals and reduce pressures on the NHS due to overweight and obesity.

As the country looks to recover and live with COVID-19, the association between, excess weight and severity of COVID-19 disease strengthens the case for long-term, sustained action to address obesity. There is however, no single solution. Multiple actions will be required to both prevent weight gain and offer treatment support to people who are living with overweight or obesity. These actions need to change the environment we live in, so making the healthier options the easier option, and unhealthier ones more difficult. To achieve population level improvements and not widen health disparities, structural drivers of excess calorie intakes and low levels of physical activity will need to be tackled. More targeted actions are needed to support change in groups disproportionately affected by obesity, and its causes, including people in the country's most deprived socio-economic groups.

Excess weight may be one of the few modifiable risk factors for COVID-19 where there is extant evidence of interventions that are effective. Other factors, such as age and ethnicity cannot be changed and factors such as deprivation, are complex to address. Supporting people who are living with overweight or obesity to lose weight, together with interventions to prevent weight gain across the population will plausibly reduce future population risks of COVID-19.

Rapid development of research, relating to obesity and COVID-19, and its outputs have been vital in supporting policy and decision makers. It is, however, clear that there is much more to understand when it comes to obesity and the mechanisms that may be involved and interact with the pathogenesis of COVID-19. What puts some groups more at risk and what effect achieving a healthier weight and weight loss might have are key questions to explore.

PHE will continue to monitor evidence as it emerges on excess weight and COVID-19 and encourages more research in the area and more evidence syntheses.

Appendix 1: Summary information on study design of UK studies

	Docherty et al	Hamer et al	Ho et al	Khawaja et al.
Aim(s) of study	To characterize the clinical features of patients with severe COVID-19 in the UK	General population study on lifestyle risk factors (including obesity) on COVID-19	To investigate demographic, lifestyle, socio-economic, and clinical risk factors, comparing them to risk factors for pneumonia and influenza	To identify the sociodemographic, lifestyle, comorbidity and antihypertensive medication associations with the development of hospitalisation with COVID-19 in an English population
Study description (type & data source and key methods)	Prospective observational cohort study with rapid data gathering and near real time analysis, using a pre-approved questionnaire adopted by the WHO	UK Biobank study Prospective cohort data with national registry linkage to hospitalisation	UK Biobank study	UK Biobank study. Prospective cohort study
Assessment of BMI (measured ht/wt; records etc)	Obesity identified as recognised by clinical staff. Height and weight was not measured	BMI was calculated from measured height and weight at baseline between 2006 and 2010	BMI was calculated from measured height and weight at baseline between 2006 and 2010	BMI was calculated from measured height and weight at baseline between 2006 and 2010

	Docherty et al	Hamer et al	Ho et al	Khawaja et al.
Sample size (total) and period of data collection (2020)	n= 20,133 6 February-19 April	n= 387,109 n=760 (positive COVID-19 cases) 16 March-26 April	n=428,225 n=340 (positive result in hospital) 16 March-14 April	n=406,793 n=605 cases (positive test for COVID-19) 16 March-16 April
Factors adjusted/controlled	The association of age with in-hospital mortality was assessed, adjusting for pre-existing patient characteristics (sex and comorbidities - including obesity)	Adjustments for age, sex smoking, physical activity, excessive alcohol intake, education, ethnicity, diabetes, hypertension and cardiovascular disease	Adjustments for: Age, sex, ethnicity, SES, long-standing illness, high cystatin C (non-modifiable factors). BMI, smoking, slow walking pace, use of blood pressure medications (modifiable factors)	Examined all comorbidities together in a multivariable model Adjusted for sex, ethnicity, BMI, smoking, hypertension, and chronic obstructive pulmonary disease
Peer reviewed (as at 18 July 2020)	Certified by peer review	Certified by peer review	Not certified by peer review	Not certified by peer review
Limitations	Height and weight not measured. Data on BMI characteristics not reported. The questionnaire identified patients with obesity as recognised by clinical staff	Not representative of UK population	Not representative of UK population	Not representative of UK population

	Perez-Guzman et al	Prats-Uribe et al	Razieh et al	Holman et al
Aim(s) of study	1.Describe baseline characteristics and outcomes for patients hospitalised with laboratory confirmed SARS-CoV-2 infection in hospital since the start of the pandemic. 2. Evaluate demographic and clinical factors associated with outcomes. 3. Evaluate the proportion of patients hospitalised for COVID-19 from BAME groups and evaluate whether ethnicity is associated with different outcomes	To study the association between ethnicity and risk of COVID-19 and adjust it by deprivation and previous comorbidity	Adjusted logistic regression to: 1. quantify the association of BMI with the risk of a positive test for COVID-19, stratified by ethnic group, 2. investigate whether the odds of COVID-19 in BME (South Asian (SA) and Black African or Caribbean (BAC) individuals relative to White Europeans (WEs) varied by BMI level	To investigate the relationship between hyperglycaemia and other modifiable risk factors including obesity, and risk of COVID-19 related mortality in both community and hospital environments
Study description (type & data source and key methods)	A retrospective cohort study on all patients hospitalised with laboratory-confirmed SARS-CoV-2 infection at Imperial College Healthcare NHS Trust	UK Biobank study. Prospective cohort study. Linked to HES and COVID-19 tests	UK Biobank study linked to national COVID-19 laboratory test data through PHE	National Diabetes Audit and General Practice Extraction Service - supplemented by data submitted by specialist diabetes services.

	Perez-Guzman et al	Prats-Uribe et al	Razieh et al	Holman et al
				Cox proportional hazards analysis investigated the relationship between risk factors and COVID-19 related death in a cohort alive on 16 February 2020 and followed to 11 May 2020
Assessment of BMI (measured ht/wt; records etc)	50% of admissions had BMI data missing. Authors commented that this might relate to the severity of disease on admission	BMI was calculated from measured height and weight at baseline between March 2006 and July 2010	BMI was calculated from measured height and weight at baseline between March 2006 and July 2010	BMI was identified using the latest recorded measurement between 1 January 2017 and 31 December 2019
Sample size (total) and period of data collection (2020)	n=520 25 February-5 April	n=415,582 16 March-14 April	n=5,623 unique test results 16 March-14 June	The cohort analysis included n=264,390 people with Type 1 diabetes and n=2,874,020 people with Type 2 diabetes
Factors adjusted/controlled	Adjusted for age, sex and admission hypoxia, thrombocytopenia, renal failure, hypoalbuminaemia and ethnicity	Adjusted for age, sex, alcohol drinking and smoking.	Adjusted for age at test, sex, social deprivation (Townsend score), smoking status, cancer illnesses and non-cancer illnesses, systolic blood	Adjusted for sex, age, deprivation, region, ethnic group, HbA1c, duration of diagnosis, eGFR, BMI, smoking, co-morbidities

	Perez-Guzman et al	Prats-Uribe et al	Razieh et al	Holman et al
			pressure, HDL cholesterol, total cholesterol and HbA1c	(previous stroke, previous heart failure
Peer reviewed (as at 17 July 2020)	Unable to determine, Imperial College report	Not certified by peer review	Certified by peer review	Not certified by peer review
Limitations	50% of admissions had BMI data missing	Not representative of UK population	Not representative of UK population	The higher risk seen in people with lower BMI could be linked unmeasured confounding or residual confounding

	Williamson et al (2020)	Yates et al (2020)	Hippisley-Cox et al (2020)	Sattar et al (2020)
Aim(s) of study	To determine factors associated with risk of death from COVID-19 in England	Obesity and risk of COVID-19: analysis of UK Biobank. Hypothesis: BMI and waist circumference are independently associated with COVID-19	Whether patients prescribed angiotensin converting enzyme inhibitor (ACE inhibitor) and angiotensin receptor blocker (ARB) drugs associated with differential risks of contracting severe COVID-19 disease and receiving associated ICU admission	To examine the link between BMI and risk of a positive test for SARS-CoV-2 and risk of COVID-19-related death among UK Biobank participants

	Williamson et al (2020)	Yates et al (2020)	Hippisley-Cox et al (2020)	Sattar et al (2020)
Study description (type & data source and key methods)	OpenSAFELY: A cohort study using national primary care electronic health record data linked to in-hospital COVID-19 death data - COVID-19 Patient Notification System (CPNS) from NHSE/X, and Office for National Statistics	Investigation between obesity and laboratory confirmed COVID-19 (UK Biobank)	A large, open cohort study of all patients aged 20-99 registered with 1205 general practices in England contributing to the QResearch database linked to COVID-19 Real-time Polymerase Chain Reaction test records and with IC records	Used UK Biobank data to examine the association between BMI and test positivity for SARS-CoV-2 infection in hospital, as well as COVID-19 related deaths
Assessment of BMI (measured ht/wt; records etc)	BMI was ascertained from weight measurements within the last 10 years, restricted to those taken when the patient was over 16 years old	BMI was calculated from measured height and weight at baseline between 2006 and 2010	BMI taken from the latest information recorded in the GP record	BMI was calculated from measured height and weight at baseline between 2006 and 2010
Sample size (total) and period of data collection (2020)	n=17,278,392 adults. 1 February-25 April 2020	n= 2,494 unique test results available 16 March-3 May 2020	n=8·28 million participants. n=19,486 patients who had COVID-19 disease, n=1,286 received ICU care. 1 January-27 April 2020	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. 16 March-31 May 2020
Factors adjusted/controlled	Adjusted for age, sex, BMI, smoking, index of multiple deprivation quintile, and comorbidities	Model 1: unadjusted. Model 2 adjusted for: age, sex, ethnicity, social deprivation [Townsend	Adjusted for age, sex, deprivation, ethnicity, geographical region, smoking, concurrent	Models were adjusted for age, SES (Townsend Index), ethnicity, smoking (current, former, never), alcohol intake

	Williamson et al (2020)	Yates et al (2020)	Hippisley-Cox et al (2020)	Sattar et al (2020)
		index], cancer illnesses [number], non-cancer illnesses [number], treatments/medications undertaken [number], systolic blood pressure and household density [number per house]. Model 3 adjusted for: Model 2 plus smoking status [never, past, current], walking pace [slow, steady average, brisk], leisure time physical activity [MET.minutes/week], fruit and vegetable consumption [portions per week], red meat consumption [portions per week] and alcohol intake [units/day]	morbidity and long term medication	(unit/week), and baseline cardiovascular disease and diabetes
Peer reviewed (as at 17 July 2020)	Certified by peer review	Letter to editor	Certified by peer review	Certified by peer review
Limitations	Not representative of UK population. Some possible misclassification of COVID-19 positive cases, and some misclassification of deaths resulting from COVID-19	Not representative of UK population	Exposure to medication; class of drug; bias relating to laboratory confirmed cases; false negative tests for COVID-19; selection bias for those submitted to	Only a small proportion of overall UK Biobank participants were tested for SARS-CoV-2; total numbers of deaths were modest; those untested, as

	Williamson et al (2020)	Yates et al (2020)	Hippisley-Cox et al (2020)	Sattar et al (2020)
			hospital or ICU; ICU deaths were not included in the analysis	well as those tested negative, were grouped together in the analysis; baseline anthropometric measures were collected a median of 10.9 (IQR 9.7e12.4) years before SARS-CoV-2 testing was conducted. However, baseline BMI values reliably estimate BMI variance. Race crudely categorised as White and non-White; individuals with higher weights may have had greater exposure to the virus

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