Counting the Lifetime Cost of Obesity: Analysis based on National England Data

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Key words: Obesity, Costs, Mortality, HRCU, Life Years, Life Years Lost, Index of Multiple Deprivation, ICB, QALY

Word Count: 5415

Figures: 3

Tables: 5 and 1 supplementary Table

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# Abstract

### Introduction

Obesity has a significant impact on all-cause mortality rate and overall healthcare resource use (HCRU). These outcomes are also strongly linked to age, sex and local deprivation of the population.

We aimed to establish the lifetime costs of obesity by demographic group/geographic area using published mortality rates and HCRU use for Integrated Care Boards (ICB) in England in the context of costs of therapeutic intervention.

### Methods

Population and expected mortality rates by age, sex and deprivation were obtained from national data. Obesity class prevalence was taken from the health of the nation study. The published impact of obesity by age, group, sex and deprivation on mortality and Health Care Resource Use (HCRU) were applied to estimate life years lost and Lifetime HCRU (by sex, age band and BMI class for each Integrated Care Board (ICB). The year 2019 was chosen as the study basis data to avoid influences of COVID-19 pandemic on obesity rates with application of 2022/23 HCRU values. Outcomes including prevalence, deaths, life years lost, HCRU and Lifetime HCRU were compared by age and sex groups across 4 BMI classes Normal/Underweight (BMI <25kg/m2), Overweight (25-29.9), Obese Class I&II (30-39.9), Obese Class III (>=40), with benchmarking being set against all population being BMI<25 overall and by each of the 42 ICBs. We also associated future life with deaths to provide an estimate of ‘future life years lost’ occurring each year.

**Results**

Total population of aged>16 years was 45.4million (51% female).

**Prevalence:**

Prevalence: 13.7 million (28% of the total adult population) had a BMI ≥30mg/m2 and BMI ≥40kg/m2 were 1.50 million (12%) of these 1.0 million (68%) were Female and of these 0.6 million 40% were aged women 16-49yrs. Also 35% of those with a BMI≥40kg/m2 were in the top deprivation quintile (i.e. overall 20%).

**Mortality:** Based on expected deaths of 518k/year, modelling suggested that if a BMI<25 was achieved in all individuals, the death rate would fall by 63K to 455k/year for the English population (12% reduction). For those with a BMI≥40 the predicted reduction was 12k deaths (54% lower); while in those aged 16-49yrs with a BMI≥40 72% of deaths were linked to obesity.

**Future life years lost:** Weestimated 2.5 years were lost in people with BMI 30-39.9 6.7 years when BMI≥40. However, for those aged 16-49yrs with a BMI≥40, 8.3 years were lost.

**HCRU:** For weight reduction, the annual HCRU decrease in going from BMI≥40 kg/m2 to BMI 30-39.9 kg/m2 was £342 per person and going from BMI 30-39.9 to BMI 25-29.9 the reduction was £316/person. However, lifetime costs were similar because of reduced life expectancy for obese individuals.

**Quality Adjusted Life Years (QALY):** Overall, 791,689 future life years lost (13.1% of all) in people with BMI ≥25 were related to excess weight.

When the NICE £30,000 per QALY value was applied to the estimated total 791,689 Future life years lost then the potential QALY value reduction lost was equivalent to £24 billion/year or £522/person in the obese population. For morbidly obese men and women the potential QALY value lost was £2864/person/year.

**Geography:** Across the 42 ICBs we observed significant variation in the prevalence of BMI >=40 (1.8% - 4.3%), excess mortality (11.6% - 15.4%), and HCRU linked to higher BMI (7.2% - 8.8%). The areas with the greatest impact on HCRU were in the north-west, north-east and midlands of England, while the south shows less impact.

### Conclusion

The expected increases in annual HCRU due to obesity when considered over a lifetime are being mitigated by reduced the increased mortality of obese individuals. Our data suggest that simple short term HCRU reduction brought about through BMI reduction will be insufficient to fund additional specialist weight reduction interventions.

The HRCUs associated with BMI are not in most cases related to short term health conditions. They are a cumulative result over a number of years, so for age 16-49 years reducing BMI from ≥40 to 30-39.9kg/m2 might show an annual decrease HCRU/person by £325/year for women and £80/year for men but this might not be immediately occurred within that year. For those aged >70 years reducing BMI from ≥40 to 30-39.kg/m2 might show an annual decrease HCRU/person by £777/year for women and £796/year for men but also not be manifest within that year.

However, for morbidly obese men and women the potential QALY value lost was £2864/person/year with the potential for these funds to be applied to intensive weight management programmes including pharmacotherapy.**Key Summary Points**

Obesity has a significant impact on risk for all-cause mortality and overall healthcare resource use (HCRU). These outcomes are also strongly linked to age, sex and local deprivation of the population with significant regional variation.

Weestimated 2.5 years were lost in people with BMI 30-39.9 6.7 years when BMI≥40. However, for those aged 16-49yrs with a BMI≥40, 8.3 years were lost.

We estimate the lifetime costs associated with obesity by demographic group/geographic area. Expected lifetime cost was £4,357 billion; if their BMI was <25 this is £4,333 billion - thus the total cost remains similar, because of the on-average shorter lives of people with obesity.

When the NICE £30,000 per QALY value was applied to the estimated total 791,689 Future Life Yeas Lost, then the potential QALY value lost was equivalent to £24 billion/year or £522/person in the obese population. For morbidly obese men and women the potential QALY value lost was £2864/person/year with the potential for these funds to be applied to intensive weight management programmes.

# Introduction

The increasing rate of obesity is one of the greatest challenges facing health care systems across the world (1). Obesity has a causal role in many commonly associated chronic conditions including cardiometabolic, digestive, respiratory, neurological, musculoskeletal, and infectious diseases (2). The health economic cost of obesity has been estimated at £1.3 trillion, or 2.8% of global annual economic activity (3).

Data from the United States of America (USA) have suggested that adults with obesity have double the annual medical care costs than those with healthy body mass index (BMI <25 kg/m2). Furthermore, costs were greater the higher the class of obesity - from 68.4% greater costs for BMI 30.0 - 34.9 kg/m2 to 234% for BMI $\geq $40 kg/m2 (4,5). In the UK, analysis of health records of 2.4 million adults in north-west London (6) showed that individuals with a BMI <25 kg/m2 cost the NHS an average of £638 annually, compared with £1,375 for those with a BMI of $\geq $40 kg/m2 (Class 3 Obesity).

In England, the proportion of people living with obesity increased from 15% in 1993 to 28% in 2019 (pre-pandemic data) and the proportion with BMI ≥ 40 kg/m2 has increased to 3% of the total population. The prevalence of obesity in adults varies significantly by region in England – being highest in the Northeast (34%) and Northwest (30%) of adults) and lowest in the Southeast (24%) and London (23%) (7,8). Socioeconomic inequalities are seen in the prevalence of obesity, and this is particularly so in women; 39.5% of women in the most deprived areas of England were living with obesity compared with 21.9% in the least deprived areas. In a recent analysis, modelling people from age 40 years onwards in the UK, it was estimated that reducing BMI from 35 to 25 kg/m2 would result in a QALY gain of 3.48 years, and a cost saving of £8838 (9). However, the effect of socioeconomic inequality was not part of the model, neither were cost predictions for those aged <40 years included in model development.

Our objectives were threefold: firstly, to assess the long-term economic cost of obesity in England, in age and sex strata; secondly, to evaluate the potential health economic benefit of reducing BMI; thirdly, to create a representation of the distribution of health burdens linked to BMI across different UK regions.

# Methods

Most data for obesity and its complications are published at national (England) level. However, NHS funding is regionally allocated to 42 Integrated Care Boards (ICBs). We applied the published prevalence and risk ratio for main BMI classes to published models for mortality rates and health care resource utilization (HCRU) in the given populations by age sex and deprivation of the 42 Integrated Care Boards (ICBs) in England. We examined data from 2019 to avoid influences of the Sars-Cov-2 (COVID-19) pandemic on obesity prevalence, mortality rates and HCRUs.

## Baseline Data

The following latest available data sets were applied to establish baseline population numbers, HCRU and mortality for each age, sex and deprivation quintile in each ICB.

* Local Population Numbers by age and sex. NHS England publishes the population by each age and sex for every ICB (10).
* Population Numbers by Social Deprivation. NHS England publishes the numbers for every ICB in each index of multiple deprivation (IMD) decile. The IMD is a measure of relative deprivation of small geographical areas of the UK. We assumed this percentage is evenly distributed across ages and sex, and so could be uniformly applied (11).
* Mortality Rate by Age and Sex National life tables England. Each national life table is based on population estimates, births and deaths for a period of three consecutive years. Tables are published annually (12).
* Mortality Rate by socioeconomic status. Numbers of deaths, and age standardised mortality rates, by socioeconomic decile, month and sex: 1 January 2019 to 31st December 2019 (to exclude effects of COVID-19 pandemic) (13).
* Total HCRU available in each ICB was taken for the years 2022/23 published by NHS England for each ICB were taken and applied as a baseline for ongoing costs / population. These include primary care, medication, elective and emergency secondary care costs (14).
* HCRU by socioeconomic level, by age & sex. NHS Digital produces a report of hospital activity by sex, age group, and socioeconomic group. This covered over 50% of total ICB costs and as no further split was available it was assumed the same allocation would apply the remaining costs. We therefore applied to the population to derive cost per person and used these to allocate the total ICB budget to each age, sex and deprivation quintile (15).

## Obesity Impact

The following analysis of national data sets were applied to establish the allocation of the total population in 2019, mortality and HCRUs into:

* Prevalence of obesity by age, sex and socioeconomic group. The Health Survey for England (HSE) (16) monitors trends in the nation’s health and care. It provides information of adults living in private households in England. We used 2019 survey results to show prevalence by age group, sex and socioeconomic quintile of the four obesity classes: Underweight or normal (BMI<25 kg/m2), Overweight (BMI 25-29.9 kg/m2), Obese Class I&II (BMI 30-39.9 kg/m2), Obese Class III (BMI ≥ 40 kg/m2). It was not possible to split obese classes I (BMI 30-34.9 kg/m2) and II (BMI 35-39.9 kg/m2) as prevalence data was only given for the sum of these two cohorts. Additional data was provided by the papers of Kent et al and Le Roux et al (17,18).
* Data from a 2019 cohort study of 3·6 million adults (19) from Clinical Practice Research Datalink (CPRD) linked to national death registration data for individuals with BMI data in the UK to estimate the impact of obesity on mortality, through Cox regression models fitted for all-cause mortality, where expected age of death by BMI category was estimated using a simplified Poisson model including BMI category, age, sex, and interactions between these variables. Allocation of HCRU per person (by BMI, age, and sex) was taken from Ward et al (20) who used de-identified data from the Medical Expenditure Panel Survey (MEPS) 2011–2016, for 139,143 adults to show relative BMI-related health care expenditures in the USA they used a generalized additive models to estimate the relationship between log BMI and the log of the standardized expenditures and published their results to a BMI, age, and sex granularity). As overall personal health costs are not collated in the NHS HCRU data / person by age sex and BMI classes is not available for the UK. The relative cost/person given for each BMI, sex and age class in the USA was then taken as a ratio to the overall total average cost/person. This ratio was applied to an average cost/person by sex and age group in England to give the costs/person in each sex, age and BMI class in England. This allocation was assumed as appropriate given the broad similarity in population mix of BMI, age and healthcare levels.

## Integrated Data Model

The Integrated Data Model that we utilised applied the published papers and models (outlined above) on the impact of obesity class to the estimated numbers of population. Data were classified by ICB, age, sex, socioeconomic quintile, and BMI class.

## Outcomes

**Population:** The population for each ICB, by sex and single year age, was split by relative prevalence in each deprivation quintiles in each ICB and the relative prevalence of each BMI class by age, sex and deprivation. This gave a population number in each class ICB (n=42), Age (n=90), Sex (n=2), Deprivation (n=5), and BMI (n=4), giving a total of 152,880 cohorts of distinct populations.

**Mortality:** The ONS published mortality rate, by age and sex was then adjusted by the odds ratio taken from ONS publication linking mortality to social deprivation decile (13) and the odds ratio for impact of BMI class on mortality taken from a UK based study (19). All together his gave the mortality rate for each of the cohorts. The value was then applied to the population to give the number of expected deaths.

**Expected Future Life Years:** In each cohort, the current mortality rate for each life year can then be used over the future age years to calculate the life expectancy for each given age year, ‘Future Life Years’.

**Healthcare Resource Use (HCRU):** The total HCRU in each ICB (2022/2023 financial year prices) was divided by the ICB population and then the average HCRU / population was adjusted by the relative (expected) ratio for the age, sex and BMI class.

**Lifetime HCRU** It was assumed that people remain within an obesity class over their lifetime (21,22). A Lifetime HCRU was estimated by taking the sum of the annual HCRU over each of the age years between current age and age of death for each cohort. The model had a maximum age of 90 years and so all future expected life years above 90 years were costed at the 90-year HCRU value.

## Comparison Basis

To establish the impact of obesity, a counterfactual scenario was evaluated where the values calculated for BMI <25 kg/m2 were applied to both Class I/II obesity and Class III obesity.

In lifetime HCRU the impact of increased annual HCRU is offset by increased mortality leading to decreased expected future life years. A further counterfactual was applied to Lifetime HCRU scenario where costs by age were taken as expected for that BMI class cohort, but the Future Expected Life Years was taken as for BMI < 25 kg/m2 class i.e., obese cohort costs with the life expectancy of BMI<25 class. This allowed the effect of the increased costs, to be separated from the increased mortality.

## Geographical Variation

The indicators and outcomes described above were calculated for each ICB by applying the national prevalences and risk ratios for impact of obesity to their population demographics and deprivation. The outcomes calculated for each ICB included percentage with obesity class I & II, percentage with obesity class III, BMI additional deaths, BMI deaths as percentage expected, Future Life Years lost as a percentage of expected life years lost, additional HCRU/pop compared to BMI<25, % HCRU linked to BMI, Additional HCRU compared to BMI<25 /Obese population and colour-scaled, to highlight local relative challenges.

## Statistics

The data analysis consisted of consolidation of the datasets and odds ratios at local Integrated Care Board levels to derive a simple model showing the population prevalence and impacts on mortality and HCRU for populations at each age year, sex, deprivation and BMI class. The division by population numbers and comparison between BMI classes provided the scenarios considered and then upscaled to total population effects. This arithmetical analysis was carried out within power pivot in Microsoft Excel.

# Results

## Prevalence of obesity

The total English population aged over 16 years was 45.5 million (m) (males 22.3m (49%) and females 23.2m) (Table 1). Class III obesity (BMI ≥ 40 kg/m2) were 1.50m (3.3%) (males 0.49m; females 1.01m). The younger (16-49 years) were 0.86m (males 0.26m; females 0.60m); older (50-69 years) were 0.47m (males 0.15m; females 0.32m); age ≥70 years were 0.17million (males 0.07m; females 0.10m). Class I & II Obesity (BMI 30.0-39.9 kg/m2) were 11.23m (males 5.50m; females 5.73m). Overweight (BMI 25.0-29.9 kg/m2) were 16.54m (males 9.22m; females 7.32m).

A total of 35.1% with Class III obesity were in the highest quintile of social disadvantage, compared to 20% expected (a ratio of 1.75). 39.8% of women aged 16-50 were living with class III obesity, compared to 26.7% of the total population (a ratio of 1.49).

Women are more highly represented in obesity class III. This was particularly evident in those less than 50 years old, who constitute 27% of the total population but 39.8% of obesity class III.

## Mortality

The total expected deaths, per year, for England was estimated at 518k (males 262k; females 256k). Hypothetically, if the population were all BMI <25 kg/m2, then deaths per year would be expected to be 455k (males 224k; females 231k) (Table 2). The 63k difference (12.2% of the 518K expected deaths) splits into Class III 12k (53.9% of expected deaths in that group), Class I and II 41k (25.4% expected excess deaths) and overweight 10k (4.7% expected excess deaths). The 14.7% excess deaths seen in males, were in relative terms 50% higher than that seen in females (9.7% excess deaths).

## Future Life Years

The projected average age (as modelled) was 48.0 years and future life years was 36.6 years (Table 3). For Class III obesity, age was 46.6 years and future life years 32.0 years (for matched individuals if BMI <25 kg/m2, future life years was 38.7 years) giving a 6.7-year reduction in future life years. The future life years increased with decreasing BMI category (Table 3 and Figure 3).

Attaching the future life years to the deaths gives us an estimate of ‘future life years lost’ occurring each year, through early deaths. Overall, 13.1% of all 791,689 deaths in people with BMI ≥25 kg/m2 were related to excess weight.

If the NICE £30,000 per QALY value was applied to the estimated total 791,689 future life years lost (assuming for simplicity at this stage that each Life year lost has a quality life year utility factor = 1), then the potential QALY value lost is equivalent to £24 billion/year or £522 per person population. For morbidly obese men and women the potential QALY value lost is £2864 per person, per year.

## Health Care Resource Utilization

Table 4 shows the difference between the modelled HCRU per person, by age group, sex and BMI class. We also show the value of a similar population, but with BMI <25 kg/m2.

Across all ICBs the current total HCRU/year in adults is £84.0 billion (£1,848/person). If the whole population had a BMI <25 kg/m2 then the total HCRU/year would equal £77.6 billion (£1,708/person).

The annual HCRU cost for women aged 16-49 years and with class III obesity is £1,930, a value double that of comparable males (£874).The annual difference in HCRU for the 1.5 million population with BMI ≥40 is £721 per person (add 31% to this if they achieved a full life expectancy of someone with BMI < 25 kg/m2); for the 11.2 million people with BMI 30-39.9 is £379/person (add 17% to this if they achieved a full life expectancy of someone with BMI < 25 kg/m2) and for the 16.6 million people with BMI 25-29.9 the cost is £63/person (add 3% to this if they achieved a full life expectancy of someone with BMI < 25 kg/m2).

Thus, for weight reduction, the annual HCRU decrease in going from BMI ≥ 40 kg/m2 to BMI 30-39.9 kg/m2 is £342 per person and going from BMI 30-39.9 kg/m2 to BMI 25-29.9 kg/m2 the reduction is £316 per person.

## Lifetime health resource utilization cost

Calculated using current life expectancies at current age and current HCRUs, the total lifetime HCRU for the current set of adults (supplementary figure) is £4,357 billion (£95,831k per person; Supplementary Table). If all adults had BMI <25 kg/m2, then the total lifetime-HCRU per year would be £4,333 billion (£95,307k per person). The difference of £524 per person contains both the increases in HCRU per year and increased mortality and so reduced future expected life years.

If future expected life years taken from for BMI <25 kg/m2 were applied for all the BMI classes this gives a total lifetime-HCRU excluding the effect of increased mortality of £4,642 billion (£102,125k per person). This difference of £286 billion for the effect of increased HCRU with future life years for BMI<25 by BMI category is BMI ≥40 kg/m2 £67 billion or +£45k per person (+31% over BMI <25 kg/m2 value); BMI 30-39.9 kg/m2 £176billion +£16k/person (+14% over BMI < 25); BMI 25-29.9 kg/m2 £43billion +£3k per person (+3% over BMI <25).

## Geographical Variation

Table 6 gives the outcomes as applied to populations at ICB level, ranked by the proportion of the population with Class III obesity. Colour coding for each column highlight the highest and lowest figures, indicates the spread across ICBs for differences in population size, numbers by age, sex, deprivation and annual HCRU spending, for each outcome including deaths, life years lost and HCRU impact.

Deprivation varied considerably with 0.6% to 51.4% of individuals being in the top (most deprived) IMD quintile, leading to a variation in the expected proportions with BMI Class III (across the 42 ICB) from 1.8 - 4.3% of population. Accounting for the numbers living with obesity in any ICB, the excess HCRU, adjusted for obesity, varied from £412 to £597 per head of population with obesity. This suggests that, in terms of resources and outcomes, the ICBs in the North of England and parts of the Midlands of England face the largest challenges in this area, while the southeast is less impacted.

# Discussion

Our aim here was firstly, to assess the long-term economic cost of obesity in England, relative to age and sex; secondly, to evaluate the potential economic benefit from the treatment of obesity to normal BMI values, through a hypothetical health intervention; and thirdly, to create a visual representation of the distribution of health burdens across BMI groups in different regions of the UK.

Our data supports the premise that high healthcare economic costs are associated with obesity. We have shown that if the whole population had a BMI <25 kg/m2 then the total HCRU/year could be as low as £77.6 billion (£1,708/person) compared to the £1,848/person that is spent, on average, at the current time. The financial burden of living with obesity has been reported before (9,23,24) but our analysis has also highlighted the high prevalence of obesity in younger women – with this demographic comprising 43% of all individuals with class III obesity. The annual HCRU cost for women aged 16-49 years and with class III obesity is £1,930, a value double that of comparable males (£874). Furthermore, we found that the future life years for the whole population is decreased by 1 year in association with obesity – but for those with Class III obesity, the future life years was 6.7 years lower. For men aged 16-49 future life years was 10 years lower while in women aged 16-49 future life years was 7 years lower. Taken together, these data show that the costs associated with obesity in younger women are considerable, and yet it is the males who have a greater mortality risk associated with living with the same degree of obesity. The cost differential will include management of menstrual cycle disorders and infertility associated with obesity (25), as well as maternal costs - as women with obesity have pregnancy related costs that are a third higher than healthy weight peers (26).

We show that the mortality disadvantage of living with obesity is considerable, with just over 63,000 deaths per annum being related to overweight or obesity. Normalising BMI with a hypothetical treatment could have a profound impact on future life years saved. Lowering elevated BMI levels could potentially result in decreased expenses associated with obesity-related illnesses. However, we must be mindful that these savings may be offset, at least in part, by increased healthcare expenditures for other conditions over the extended lifespan. Medical treatments that can normalise BMI are becoming a reality (27,28, 29). The STEP-5 trial of semaglutide, a weekly GLP-1 agonist reported 15% weight loss over 2 years (29,30), the SURMOUNT-4 trial of tirzepatide (GLP-1/GIP co-agonist) reported mean 21% weight loss up to 88 weeks (31) and phase 2 trials of a once-weekly triple receptor (GIP/GLP-1/glucagon) agonist retatrutide (LY3437943), at the 12mg dose, reported 24% weight loss by 48-weeks (32).

The prevalence of Obesity by age, sex and deprivation was taken from Health Survey for England (HSE) (16) is a series of annual surveys, of which the 2019 survey is the twenty ninth. The surveys provide regular information that cannot be obtained from other sources about the public’s health and associated factors. Each survey in the series includes core questions, and measurements such as age, sex, blood pressure, height and weight measurements and analysis of blood and saliva samples. The sample for HSE 2019 was designed to be representative of the population living in private households in England, it adopted a multi-stage stratified probability sampling design with sampling frame taken from the small user Postcode Address File (PAF). The sample consisted of 9,612 addresses selected at random in 534 postcode sectors. The HSE is a cross-sectional survey of the population. It examines associations between health states, personal characteristics and behaviour.

The study linking mortality rate to obesity for age and sex, data was taken from the Clinical Practice Research Datalink (CPRD) (18) dataset which contains primary care records from general practitioners (GPs) covering around 9% of the UK population; with linkage to death registration data, including the date and causes of death, was available for 80% of GP clinics in England. CPRD data, including the linked subset, have been shown to be broadly representative of the general population in terms of age, sex, ethnicity, and BMI.

We accept that we have not accounted for changes in BMI that may occur over time. There is limited date in this area. It was reported that for simple obesity (body mass index = 30.0–34.9 kg/m2) (21), the annual probability of attaining normal weight was 1 in 210 for men and 1 in 124 for women, increasing to 1 in 1290 for men and 1 in 677 for women with morbid obesity (body mass index = 40.0–44.9 kg/m2. Nevertheless, account must also be taken of those who increase weight. In our next analyses we will take account of these factors.

Regarding the geographical variations seen in HCRU, we speculate that these are underpinned by the combination of 1) factors that are not accounted for in the current modelling of socioeconomic disadvantage and 2) differences across England in policy regarding prevention of obesity and lifestyle interventions for obesity between different Clinical Commissiong Groups (CCGs) and local authorities, the latter having significant influence over matters from the provision of swimming pools and leisure centres to the planning regular concerning density of take-away outlets in a particular area

We have not here undertaken modelling around the precise consequences for reduction in the numbers of obese and morbidly obese individuals on associated comorbidities. However, there is good evidence that such reductions are associated with reduced rates of T2D (36) and cardiovascular disease (37). Furthermore, stratification of interventions in relation towards at risk groups such as people with severe enduring mental illness (SMI) will have significant benefits in these groups in terms of improved life expectancy (38) with the potential to improve quality of life.

The current model does not incorporate the changes in quality-of-life utility factor associated with aging or BMI, while this is planned as future work. Therefore, applying the NICE valuation for QALYs years directly to the Life Years Lost contains some degree of over valuation, which is not quantifiable at this stage.

Our data may help to inform policy makers regarding cost-modelling for the use of medicines (and/or dietary programmes or surgery) for obesity. In particular, our baseline HCRU model could provide helpful date relating to the commissioning of specialist obesity services regionally, across ICBs (33,34). Weight loss services could be more HCRU cost-effective for selected patient groups including younger women (age 16-44 years) with Class III BMI. This HCRU reduction may offset service provision costs. However, there are limited data for the longer-term cost outcomes of treatment under specialist weight management services in relation to bariatric surgery, medical management and psychological intervention.

There are major implications for healthcare policy and resource allocation in relation to our findings. In particular a balance has to be struck between healthcare expenditure and the potential benefits to individuals. The implications of our findings are that investment now and in the coming years in the new and emerging pharmacotherapies could improve life expectancy and the burden of comorbidity for many. However, it is important to consider not just years of life gained but also take into account quality adjusted life expectancy as recently described as the ‘QALE’ (35). This beyond the scope of this paper, the purpose of which is to set the scene for further discussion.

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When the NICE £30,000 per QALY value was applied to the estimated total 791,689 Future Life Yeas Lost, then the potential QALY value lost was equivalent to £24 billion/year or £522/person in the obese population. For morbidly obese men and women the potential QALY value lost was £2864/person/year with the potential for these funds to be applied to intensive weight management programmes. This we believe is an important consideration going forward.

A decrease in the incidence and prevalence of T2D and cardiovascular disease may reduce the attendant costs to any health care system. In order to have a significant impact, the interventions to reduce obesity rates would need to be at scale with the caveat that weight reducing strategies need to be tailored to the social and cultural context of the individual while taking account of specific vulnerabilities such as learning disability or severe mental illness.

Such interventions must by their nature be multidisciplinary and be flexible enough to take account of the complex interplay between obesity and comorbidities.

While the impact of obesity in life expectancy and on HCRU is the focus of this article, consideration must be given to the impact of obesity on quality of life. A recent study Harrison et al (34) estimated that a single unit increase in BMI decreased QALYs by 0.65% of a QALY (95% confidence interval [CI]: 0.49% to 0.81%) per year and increased annual total healthcare costs by £42.23 (95% CI: £32.95 to £51.51) per person. Thus any reduction in BMI that is achieved with a therapeutic intervention has the potential to improve quality of life.

# Limitations

All modelling is subject to inherent bias and cannot account for all confounding factors. In this case we depend on the accuracy of the models we have obtained and applied for prevalence, mortality, HCRU in linking to BMI and age and sex. HCRU data taken from Ward et al (20) where BMI-related health care expenditures in the USA was estimated using data from the Medical Expenditure Panel Survey (MEPS). This is such detailed stratified HCRU data is not available in the UK (34).

We accept a limitation is that we have not addressed is third party factors – i.e. the cost to others. One such person is the patient themselves. One BMI point above 30 kg/m2 has been associated with a 2% decrease in income (39,40). Furthermore, BMI is inferior to waist circumference or waist to hip ratio in discriminating for adverse cardiometabolic outcomes (41,42). The aggregated public health data that we accessed did not include these measures. A further point is that our model had a maximum age of 90 years and so all future expected life years above 90 years were costed at the 90-year HCRU value.

The main total HCRU use and split by age and sex was taken from NHS England data. The North American BMI data model results were used to split this English HCRU/person by age and sex across the chosen BMI classes by age and sex. Unfortunately, there is no English or United Kingdom data that provides this level of detail; the closest we found was given by le Roux et al (18) which examined the HCRU through CPRD data impact of diabetes however it did not provide the granularity of data detail that we needed for this paper.

The statements about the effects of BMI intervention based on data derived from the counterfactual analysis is potentially flawed by confounding factors such as poor mental health, high cholesterol levels and smoking that are linked to obesity and adverse health outcomes such as mortality risk but not accounted for in the analysis. I would suggest adding a comment about this in the limitations section of the discussion.

# Conclusion

We have shown a high relative prevalence in younger women (age 16-49) of Class III obesity with national lifetime relative costs of obesity equating to approximately 3.5% of the current National Health annual total expenditure. Reductions in ongoing HCRU for morbidly obese patients treated with Tier 3 weight management services might offer a significant offset to the longer-term health management costs as could the current and future developments in weight mitigating pharmacotherapy.

Lifetime-HCRU are mitigated by the increased mortality of obese individuals. Our data suggest that simple short term HCRU reduction brought about through BMI reduction will be insufficient to fund additional specialist weight reduction interventions.

However, for morbidly obese men and women the potential QALY value lost was £2864/person/year with the potential for these funds to be applied to intensive weight management programmes including pharmacotherapy.

Younger people with obesity do not cost much must more at their current age but will cost much more in the future in terms of HCRU. Effective weight reduction strategies have the potential significantly to reduce health care costs year on year while allowing people to achieve their full life years potential.

**Figure Legends**

Figure 1: Data Sources and Integration.

R = reference in figure (publication reference number) R1 = Population by Age & Sex – ONS (10) / R2 = NHS England Integrated care board (ICB) core services target allocation incl Population by Deprivation analysis (11) / R3 = ONS Life tables 2017-2019 (12) / R4 = ONS numbers of deaths and age-standardised mortality rates by deprivation decile (13) / R5 = NHS England allocation of resources 2022/2023 (14) / R6 = Acute Patient Level Activity and Costing, 2019-2020 Experimental statistics by Age Group and Sex and Deprivation, (15) / R7 = NHS Digital Health of Nation 2019 Prevalence of Obesity by age and sex and Deprivation, (16) / R8 = Impact of Obesity on Mortality Association of BMI with overall and cause-specific mortality: a population-based cohort study of 3.6 million adults in the UK Bhaskaren et al, (19) / R9 = Association of body mass index with health care expenditures in the United States by age and sex Ward et al (2021) (20).

Figure 2: Distribution of Population within Obesity Class by Age and Sex.

Figure 3: Expected Future Life Years lost / person compared to BMI <25 kg/m2 split by sex, age and BMI.

Table Legends

Table 1: Obesity Class Prevalence by age, sex and deprivation

Table 2: Impact of Obesity on Expected Deaths based ONS Life tables, split by age group, sex, and BMI Class

Table 3: Impact of Obesity on Expected Future Life Years / person and Expected Future Life Years Lost overall through early death.

Table 4: Annual Healthcare Resource Use per person of Obesity Class. Data are split by age and sex and compared to a value costed for BMI<25 kg/m2.

Table 5: Lifetime HCRU Total and / person split by sex and gender A) Model B) if both HCRU and Life years were for BMI<25 C) HCRU Model and Life years based on age & sex.

Table 6: Obese Indicators calculated at ICB level based on demographics and NHS 2022/23 HCRU allocation to ICBs.

## Acknowledgements

This work was supported by the NIHR Manchester Biomedical Research Centre

## Conflict of interest

No author has any conflict of interest.

## Funding

There was no external funding for the work reported here.

## Data availability

The data used in the analysis is available from the corresponding author on request.

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