Managing Overweight and Obesity among Adults

Report on Economic Modelling and Cost Consequence Analysis

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Contents

List of Tables

List of Figures

Glossary

Average cost per prevalence: average cost per prevalence case of disease
Cost per prevalence: cost per prevalence case of disease
Data files: a computer file which stores data to use by a computer application or system
Data pack: a pre-made database that can be fed to a software, such as software agents, Internet bots or chatterbots, to teach information and facts, which it can later look up.
Datum: data
Dominant: a health economics term. When comparing tests or treatments, an option that is both more effective and costs less is said to be dominant compared to the alternative
Non-elective spell tariff: a nationally set price of non-elective in-patient spell in hospital, from admission to discharge
Null intervention: no intervention
Object-oriented approach: a software methodology that combines data and methodology into single manageable objects
Population Attributable Fractions (PAFs): a proportional reduction in population disease or mortality that would occur if exposure to a risk factor were reduced to an alternative ideal exposure scenario
Quality Adjusted Life Years (QALYs): a measure of the state of health of a person or group in which the benefits, in terms of length of life, are adjusted to reflect the quality of life
Run time: the period during which a computer program is executing
Run: run an application
Setup: the act of making the program ready for execution
Tab-delimited text file: type of a file from Excel
Time-stamped: encoded to identify when a certain event occurred

1 Executive Summary

Introduction:

The National Institute for Health and Clinical Excellence (NICE) has been asked by the Department of Health (DH) to develop guidance on managing overweight and obesity in adults through lifestyle weight management services.

The guidance will provide recommendations for good practice, based on the best available evidence of effectiveness and cost effectiveness. It will complement NICE guidance on: obesity; behaviour change; adult nutrition; prevention of cardiovascular disease and promoting physical activity.

Objective:

The objective of the health and economic modelling component was to answer the following research questions, to the extent that evidence allows the likely cost effectiveness/cost utility of those interventions identified in the earlier effectiveness review [1] and considered by the Programme Development Group (PDG) to be of highest priority.

Question 1: To estimate the potential health and economic consequences of weight programmes/interventions management in adults.

Question 2: To calculate Quality Adjusted Life Years (QALYs) gained as a result of weight loss.

Question 3: To carry out cost-effectiveness analysis of weight management and calculate health benefits along with net cost saving for various levels of cost of the intervention.

Methods:

The PDG identified from the literature review the type of interventions that were likely to be most effective in weight management, focusing on diet, physical activity, behaviour change or any combination of these factors. Interventions may include schemes that are specifically designed for overweight or obese adults. A limitation of the modelling process is that due to the lack of long term worthwhile evidence for the effectiveness of weight loss interventions we have to make a variety of assumptions about the rate of weight regain. To attempt to overcome these uncertainties a number of % per year weight gain scenarios were modelled. Thus a 5% weight regain assumes that the individual will regain 5% of their weight loss per year, and after 20 years will have returned to the same weight trajectory that they would have been on without the intervention.

Results & Conclusion: The rate of weight regain is often the most important single factor in determining whether an intervention is cost effective, so until better evidence is available it is difficult to recommend one intervention over another. Economic modelling shows that critical elements in the likely cost effectiveness are the amount of weight lost due to the intervention but also gender, initial BMI, age, and rate of regain of BMI [% per annum]. In younger participants only a slow weight regain is cost effective but in many cases in older participants a greater rate of weight gain is still cost effective, because most of the costs accrue to the health service as a consequence of obesity occur late in life both in males and females and the intervention cost whose effects are described in the section 10 and in the following table. Generally the heavier and older the person, the more likely the intervention is to be cost effective. It should be noted that this is a population model, the results of which are based on BMI changes in a cohort, so these conclusions only apply to individuals indirectly.

Additional work

In addition we reviewed the relationship between being obese and productivity and found that generally, the association between obesity and earnings is considerably stronger for women than men. On average, obese women earn about 4%-12% less than women of a healthy weight. For men, the association was either insignificant, or the earnings “penalty” was small (about 3%). However, there is some evidence that the effect of obesity on earnings is significant for men at the bottom of the income distribution (2% wage penalty). Similarly, the effect of obesity on the probability of being employed appears stronger for women than for men (from 3% up to 10% employment probability reduction for women, and either insignificant, or a small reduction in males). In addition, unemployment spells are longer for obese compared to non-obese (with women less likely to regain employment than men).

Parameters of Interest	Intervention 1	Intervention 2	Intervention 3	Intervention 4	Intervention 5
Female					
BMI 25 kg/m² Age 20-29	5%	10%	10%	10%	15%
BMI 25 kg/m² Age 30-39	5%	10%	10%	15%	20%
BMI 25 kg/m² Age 40-49	5%	20%	25%	30%	30%
BMI 25 kg/m² Age 50-59	>30%	>40%	>40%	>40%	>40%
BMI 25 kg/m² Age 60-69	>30%	>40%	>40%	>40%	>40%
BMI 30 kg/m² Age 20-29	20%	25%	30%	40%	15%
BMI 30 kg/m² Age 30-39	20%	25%	30%	40%	20%
BMI 30 kg/m² Age 40-49	20%	30%	40%	40%	30%
BMI 30 kg/m² Age 50-59	20%	25%	30%	40%	>40%
BMI 30 kg/m² Age 60-69	25%	30%	40%	40%	>40%
BMI 40 kg/m² Age 20-29	30%	30%	40%	40%	>40%
BMI 40 kg/m² Age 30-39	30%	40%	40%	>40%	>40%
BMI 40 kg/m² Age 40-49	30%	30%	40%	40%	40%
BMI 40 kg/m² Age 50-59	30%	40%	40%	40%	40%
BMI 40 kg/m² Age 60-69	30%	40%	40%	40%	40%
Male					
BMI 25 kg/m² Age 20-29	5%	5%	10%	10%	10%
BMI 25 kg/m² Age 30-39	5%	5%	10%	15%	15%
BMI 25 kg/m² Age 40-49	5%	10%	15%	25%	30%
BMI 25 kg/m² Age 50-59	5%	>40%	>40%	>40%	40%
BMI 25 kg/m² Age 60-69	0%	>40%	>40%	>40%	>40%
BMI 30 kg/m² Age 20-29	20%	30%	30%	40%	>40%
BMI 30 kg/m² Age 30-39	20%	30%	40%	40%	40%
BMI 25 kg/m² Age 40-49	5%	30%	40%	>40%	>40%
BMI 30 kg/m Age 50-59	25%	30%	40%	>40%	>40%
BMI 30 kg/m² Age 60-69	20%	30%	40%	40%	>40%
BMI 40 kg/m² Age 20-29	40%	>40%	>40%	>40%	>40%
BMI 40 kg/m² Age 30-39	40%	40%	>40%	>40%	>40%
BMI 40 kg/m² Age 40-49	40%	>40%	>40%	>40%	>40%
BMI 40 kg/m² Age 50-59	>40%	>40%	>40%	>40%	>40%
BMI 40 kg/m² Age 60-69	40%	40%	>40%	>40%	>40%

Table 1: The rate of regain of BMI [% per annum] for which the WM program is no longer cost effective

2 Introduction

2.1 Modelling team

The modelling team consists of multiple members listed in the Table 2 and described in Appendix 1.

Member	Role
Tim Marsh (UKHF)	Project leader
Martin Brown (UKHF)	Model developer
Lise Retat (UKHF)	Bio-statistician
Marc Suhrcke (UEA)	Health Economist
Richard Fordham (UEA)	Health Economist
Richard Little (UEA)	Health Economist
David Turner (UEA)	Health Economist
Oyebanji Filani (UEA)	Health Economist

Table 2: Members of a review team and key roles

2.2 Background: The Importance of Obesity

Body Mass Index (BMI) is a measure of weight status that adjusts for height and is calculated by equation 1:

$$BMI = \frac{W}{H^2} \quad (kg/m^2)$$

eq 1

where W and H are a person's weight (kg) and height (m) respectively.

Firstly, the prevalence of obesity in England has increased by almost half in the United Kingdom over the past 20 years [2] which would suggest that, if this change is extrapolated at the same rate in future, seven of ten British people will be overweight or obese by 2020 [3]. Secondly, obesity is associated with a range of adverse increased health risk factors such as type 2 diabetes, cardio vascular disease and cancer [4]. Consequently, it is a public health priority to prevent and treat obese adults, in order to reduce morbidity and premature mortality [5].

One way to treat obesity is via behavioural weight management schemes (BWMP) which incorporate physical activity and dietary interventions.

A team at the University of Oxford carried out a review on weight management interventions among adults [1] summarising results and reported weight change for different interventions at 18 months and 36 months. Cases of moderate and strong evidence are shown below:

Strong evidence from a meta-analysis indicates that BWMPs that involve both diet and exercise can lead to greater weight loss over a 12 to 18 month period than those that involve diet only or exercise only. (Evidence statement 1.18)

There was moderate evidence to suggest that interventions that involved contact with a dietitian *were associated with greater weight loss than those which did not involve a* dietitian *contact. This variable was not significant in a single variable meta-regression, but was significant when adjusted for presence or absence of a set energy prescription. (Evidence statement 1.20)*

There is strong evidence from meta-regression that schemes which specify a daily energy intake are associated with greater weight loss than those that do not prescribe an energy intake. This association persisted and remained largely unchanged when adjusting for the involvement of a dietitian*. (Evidence statement 1.22)*

There was strong evidence that the following behavioural techniques are used in most BWMPs: goal setting and review of goals (behaviour and outcome); action planning; barrier identification and/or problem solving; graded tasks; self-monitoring of behaviour; feedback on performance; instruction on how to perform behaviour; and planning social support and/or social change. (Evidence statement 1.25)

Considering the prevalence of obesity in England and the Oxford's literature review [1] investigating the behavioural weight loss schemes, it was decided that the modelling incorporate the following approaches:

- Weight management schemes which take a lifestyle approach to helping overweight or obese adults achieve and maintain a healthy weight.
- Lifestyle approaches that focus on diet, physical activity, behaviour change or any combination of these factors.

2.3 Features of the model

- The model has estimated the potential health and economic consequences of weight management interventions
- QALYs gained associated with weight loss were estimated
- A cost-effectiveness analysis of weight management interventions and calculated health benefits along with net cost for various levels of cost of the intervention was carried out
- After discussion with the Professional Development Group (PDG), assuming that 1BMI point is around 2.6kg, the interventions modelled were the following:
    - *BWMP involving weight loss via a programme lasting between 6 and 12 months (BMI loss of 0.3 kg/m^2 corresponding to a weight loss of approximately 0.8kg)*
    - *BWMP involving weight loss via a programme length greater than 12 months (BMI loss of 0.6 kg/m^2 corresponding to a weight loss of approximately 1.6kg).*
    - *BWMP involving weight loss via group sessions (BMI loss of 1 kg/m^2 corresponding to a weight loss of approximately 2.6kg)*
    - *BWMP involving supervision (BMI loss of 2 kg/m^2 corresponding to a weight loss of approximately 5.2kg)*
    - *Largest average loss BWMP (BMI loss of 3 kg/m^2 corresponding to a weight loss of approximately 7.8kg).*

2.4 Outcomes

The UKHF undertook the development and production of an economic evaluation model capable of considering changes in BMI (adjusted for age and sex) and other lifestyle weight management outcomes and associated costs for adults.

The cost-utility analysis is calculated over several different time horizons (short, intermediate and lifetime), in accordance with the evidence and as agreed with NICE and the Programme Development Group.

The model outlines costs of interventions, expected future cost savings and the expected health and other benefits gained during the specified period. A number of weight regain scenarios were also modelled.

The approach to the model is informed by the findings of the effectiveness and cost effectiveness review and in discussion with the NICE team and the Programme Development Group. A computer model has been developed. It is capable of executing the specifications summarised under header 6 and in the Appendix 2.

3 Methodology

The model follows closely the structure and philosophy of the UKHF's health outcomes model which is described in Appendix 2.The various economic measures used in the report are described in sections 3.2 to 3.5 .

3.1 The UKHF health outcomes model

Background to UKHF health outcomes model is specified in Appendix 2.

3.2 Costs, cost-effectiveness, quality of life & cost per QALY gained

The model considers two types of cost. Firstly, the cost of providing the weight management intervention; secondly, the costs associated with diseases attributable to overweight and obesity. Two separate outcomes measures (life years and QALYs) are considered in the evaluation. When combined with an estimate of the incremental cost of the intervention compared to the null it will yield an estimate of cost per life year gained. In addition, the number of years of life spent in various health states in the model will be combined with estimates of preference based utility measures. This will result in an estimate of quality adjusted life years (QALYs) in the intervention and comparator groups and enables an estimate of incremental cost per QALY gained, carried out as a cost-utility study.

QALY values are taken from the utilities listed in Table 5 and Table 6. These are given as step functions of BMI. Because of the sensitivity of ICER values to small changes in QALY values and in order to capture small changes in QALY especially for large BMI values, the values input to the programme were first interpolated between the relevant BMI steps. There follow a few defining equations in which we denote by C_I the cost of the intervention I, $Q_I[m,y]$ the QALY value and $C^D_I[m,y]$ the incurred BMI-related disease cost for the m^{th} cohort member in the year y under intervention I. Future costs and health benefits are discounted at 3.5% per year[1].

3.3 Increments in QALYs

The total gain in QALYs provided by the intervention relative to the null intervention I_0, over the period $[y_0, y_{max}]$, is denoted Δ_{QI} and is given by the sum:

$$\Delta_{QI} = \sum_{y=y_0}^{y=y_{max}} \sum_{m=1}^{m=M\equiv|cohort|} w[m,y]\left(Q_I[m,y] - Q_{I_0}[m,y]\right)$$

eq 2

The weighting factor w[m,y] is included so as to allow for both: the possible weighting of different cohort members (see the note in section 4.1) and the discounting at 3.5% per annum.

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[1] 3.5% was the value taken from NICE, CPHE methods guide, 2009. The base-rate discount rate was changed for the most recent methods guide (2012) but the project had already begun and therefore uses the rate appropriate to the 2009 guide.

3.4 The decreases in disease costs

The total saving in BMI-related disease-costs provided by the intervention relative to the null intervention I_0, over the period $[y_0, y_{max}]$, is denoted Δ_{DI} and is given by the sum:

$$\Delta_{DI} = \sum_{y=y_0}^{y=y_{max}} \sum_{m=1}^{m=M\equiv|cohort|} w[m,y]\left(C^D_{I_0}[m,y] - C^D_I[m,y]\right)$$

eq 3

3.5 Incremental Cost Effectiveness Ratio

By estimating the cost of an intervention (cost compared to the null-Intervention, $\Delta_{CI}=C_I-C_{I0}$) and from eq 2 and eq 3 the Incremental Cost-Effectiveness Ratio (ICER) will be calculated as:

$$ICER = \frac{\Delta_{CI} - \Delta_{DI}}{\Delta_{QI}}$$

eq 4

In this model, unlike the quantities Δ_{QI} and Δ_{DI}, the function Δ_{CI} does not require a run of the programme to calculate it; Δ_{CI}, the cost relative to the null intervention, is simply an input. In consequence, once Δ_{QI} and Δ_{DI} are known the ICER can be simply computed from eq 4 for any value of Δ_{CI}.

4 Data inputs

4.1 Demographic data

National population distribution data by age and gender are used together with national mortality distribution data by age and gender. The distributions are taken from the Office for National Statistics[2] and are pre-processed to render them in a form acceptable to the model.

4.2 National BMI data

National BMI data are required both in order to predict future BMI and to support the construction of targeted interventions.

BMI predictions, by age group and gender are made using standard multivariate logistic regression techniques using data taken from the consecutive HSE surveys 2000 to 2010 [6], pre-processed to make them acceptable to the model.

The analysis of BMI for individual adults involved in weight management programmes necessarily involves an understanding of the national BMI context. Here that context is summarised by the set of graphs showing the change in national adult BMI distributions for the years 1995 and 2010. The computer modelling of individual adults experiencing weight management programmes draws heavily on data such as those shown in this sub section.

The distribution graphs shown below are derived from Health Survey for England data sets compiled for the years 1995 and 2010 [6]. In each case the lower scale gives the BMI group – the width of each group is 1 unit (or point) of BMI. Thus each column represents the probability of finding people randomly drawn from the specified population falling in that 1-point interval. The columns shown in red give the distribution in 1995; the wider columns shown in blue give the most recent distributions for which data are available, 2010.

For each distribution the sum of the probabilities over all the BMI intervals is 1. Also shown in each graph is the 85th percentile for the 2010 distribution – this indicates the position on the BMI scale below which 85% of the population are to be found. As a rough and ready rule, and as can be seen in the graphs, the BMI corresponding to the 85th percentile advances with age. Although it is not shown on the graphs, the BMI-value of the 85th percentile for the red (1995) distributions is always lower than the blue (2010) by about 3 or 4 BMI points.

All age groups and both sexes exhibit similar distributional behaviour. Almost all people fall in the BMI range 15 to 45 kg/m^2. In 1995 (the red distributions) there is an identifiable peak in the distributions at around the healthy-overweight boundary corresponding to a BMI value of 25 kg/m^2. This peak occurs at BMI=26 kg/m^2 or BMI=27 kg/m^2 for the older age groups. By 2010, the distribution has shifted to the right, and there are many more observations in the (obese) regions around BMI values of 30 to 35 kg/m^2.

[2] Office of National Statistics http://www.statistics.gov.uk/hub/population/index.html

The pictures for the intervening years (not shown here) show a regular upward progression. This upward progression in BMI at all ages began before 1995 and continues to the present, and has been called the UK obesity epidemic.

4.2.1 The 20 to 29 age group

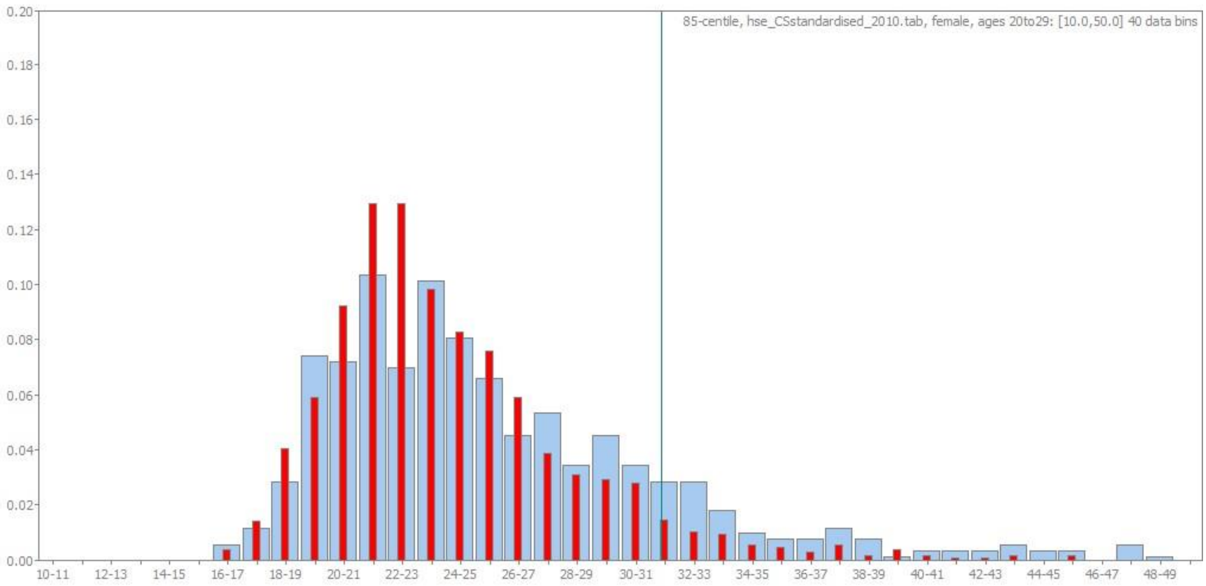

Figure 1: UK females aged 20-29, BMI distributions in 1995(red) and 2010 (blue)

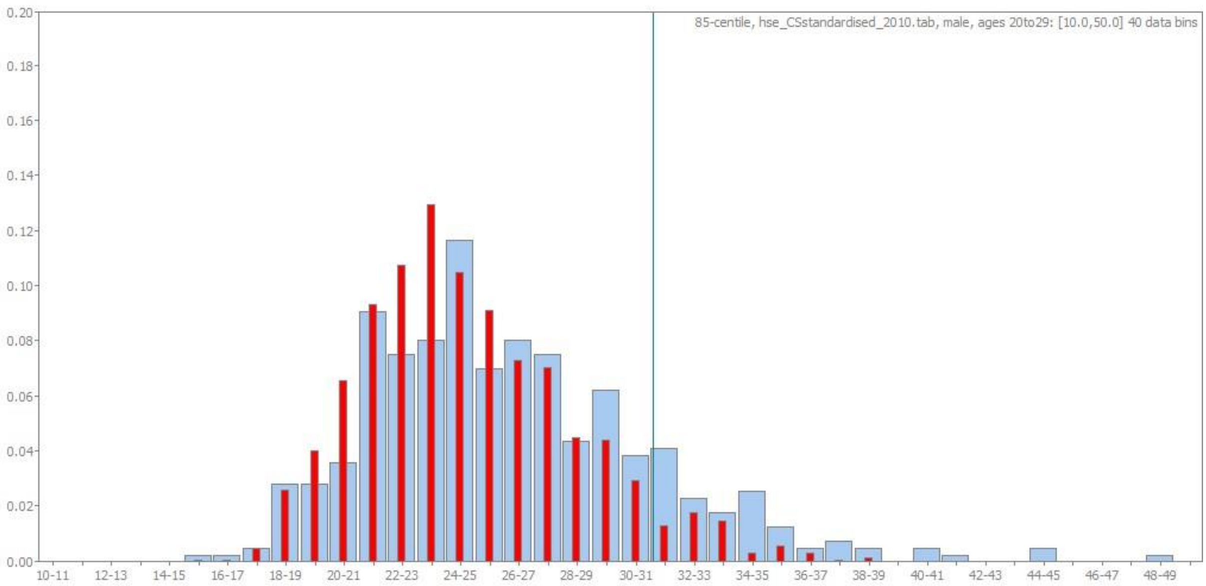

Figure 2: UK males aged 20-29, BMI distributions in 1995 (red) and 2010 (blue)

The vertical scale is 0 to 0.2. The vertical line shows the position of the 85th percentile for the 2010 cohort. The 85th percentile is the point at which the cumulative distribution takes the value 0.85 (the cumulative distribution at any point is the sum of the component probabilities up to that point). In the above graph the 85th percentile is shown corresponding to a BMI value of approximately 31 kg/m². This means that the sum of the column-heights before BMI=31kg/m² is 0.85.

4.2.2 The 30 to 39 age group

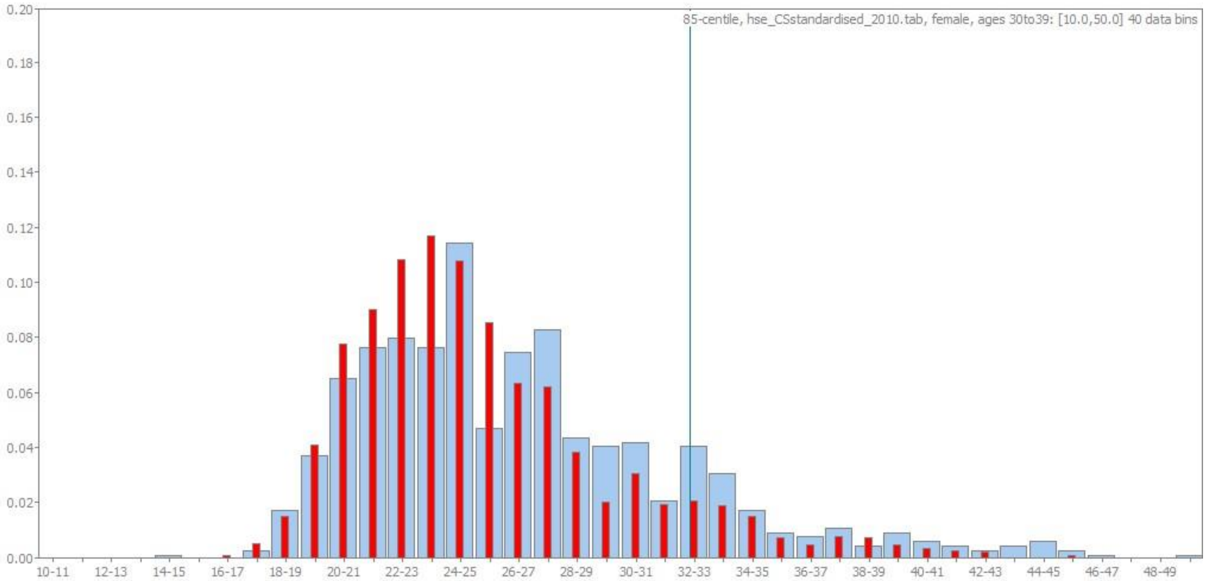

Figure 3: UK females aged 30-39, BMI distributions in 1995 (red) and 2010 (blue)

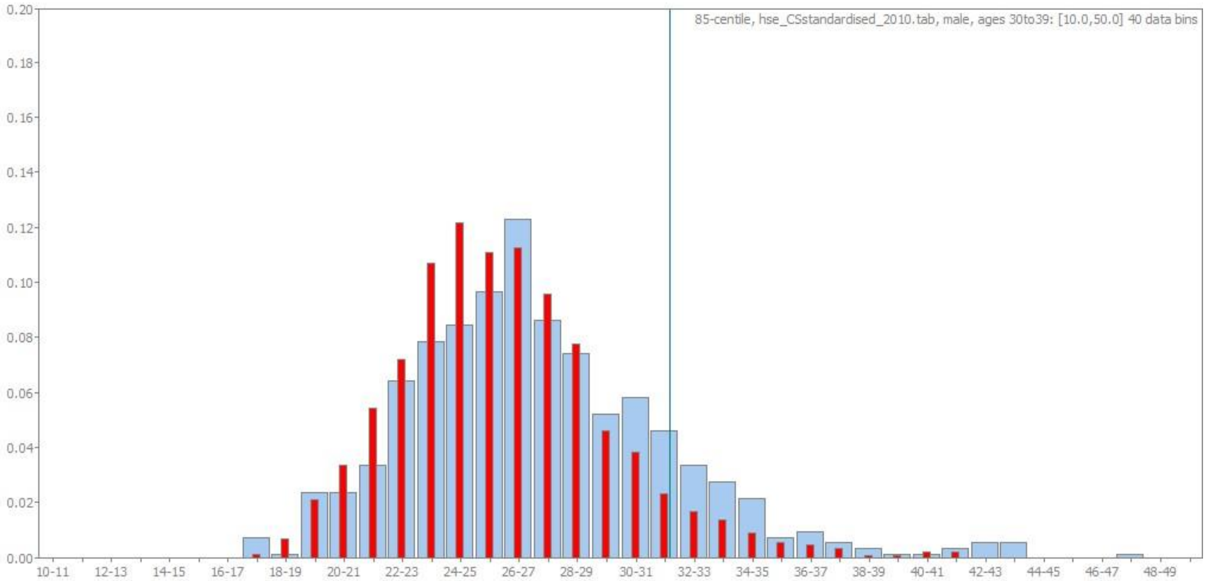

Figure 4: UK males aged 30-39, BMI distributions in 1995 (red) and 2010 (blue)

4.2.3 The 40 to 49 age group

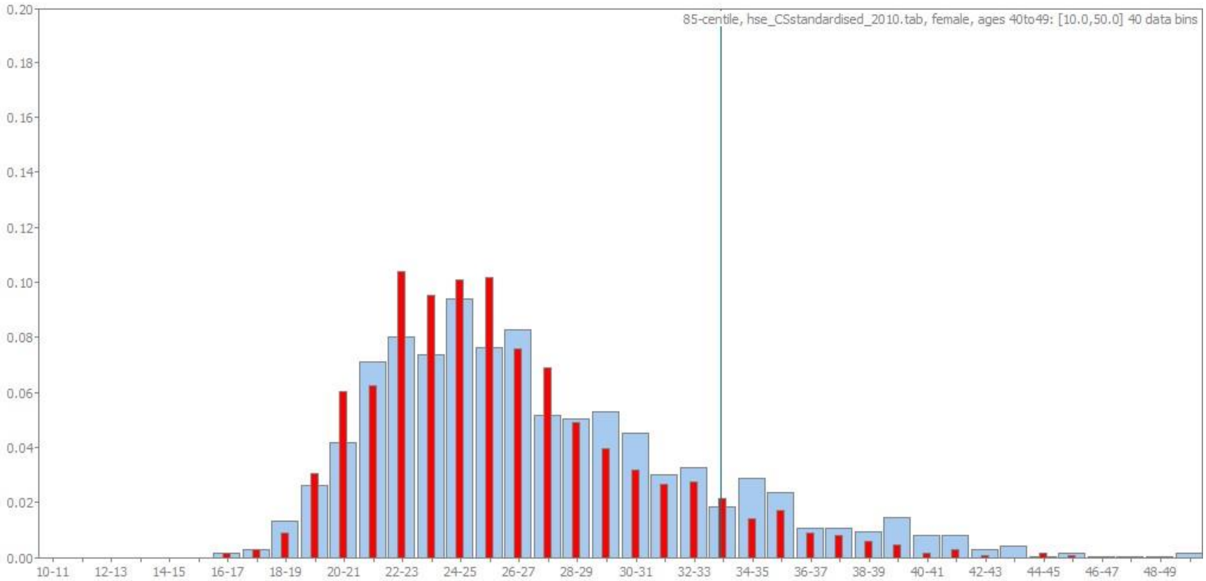

Figure 5: UK females aged 40-49, BMI distributions in 1995 (red) and 2010 (blue)

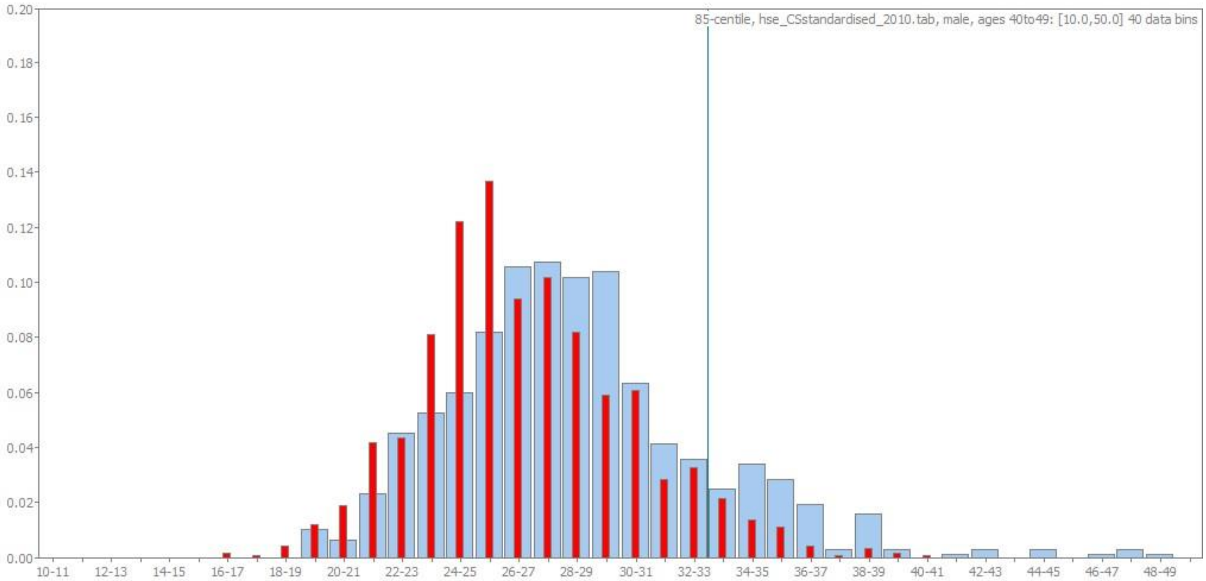

Figure 6: UK males aged 40-49, BMI distributions in 1995(red) and 2010 (blue)

4.2.4 The 50 to 59 age group

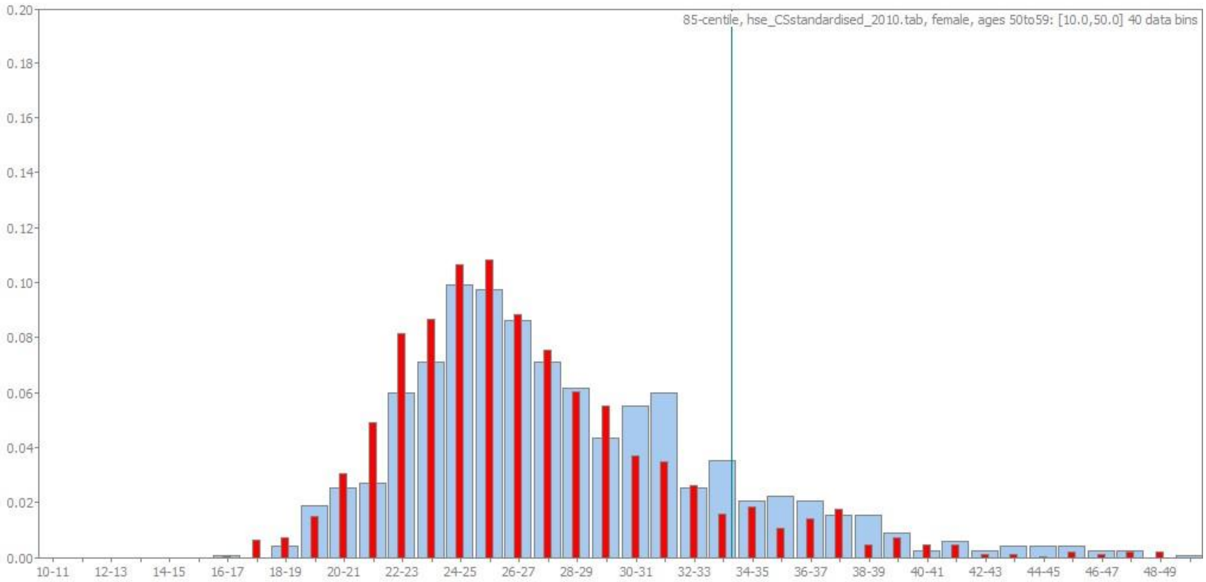

Figure 7: UK females aged 50-59, BMI distributions in 1995 (red) and 2010 (blue)

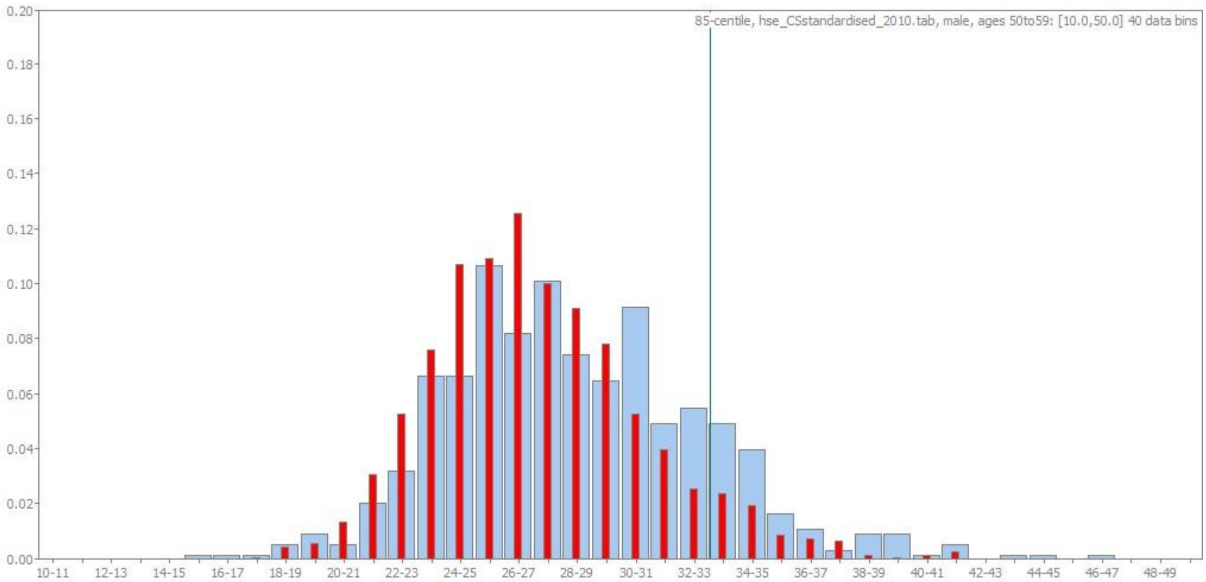

Figure 8: UK males aged 50-59, BMI distributions in 1995 (red) and 2010 (blue)

4.2.5 The 60 to 69 age group

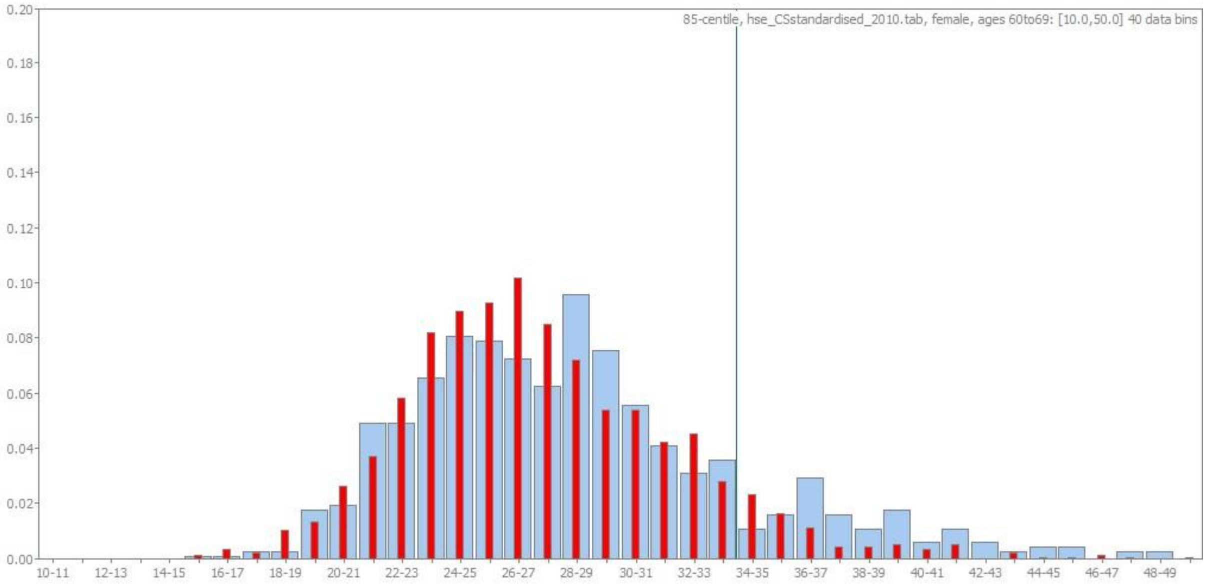

Figure 9: UK females aged 60-69, BMI distributions in 1995(red) and 2010 (blue)

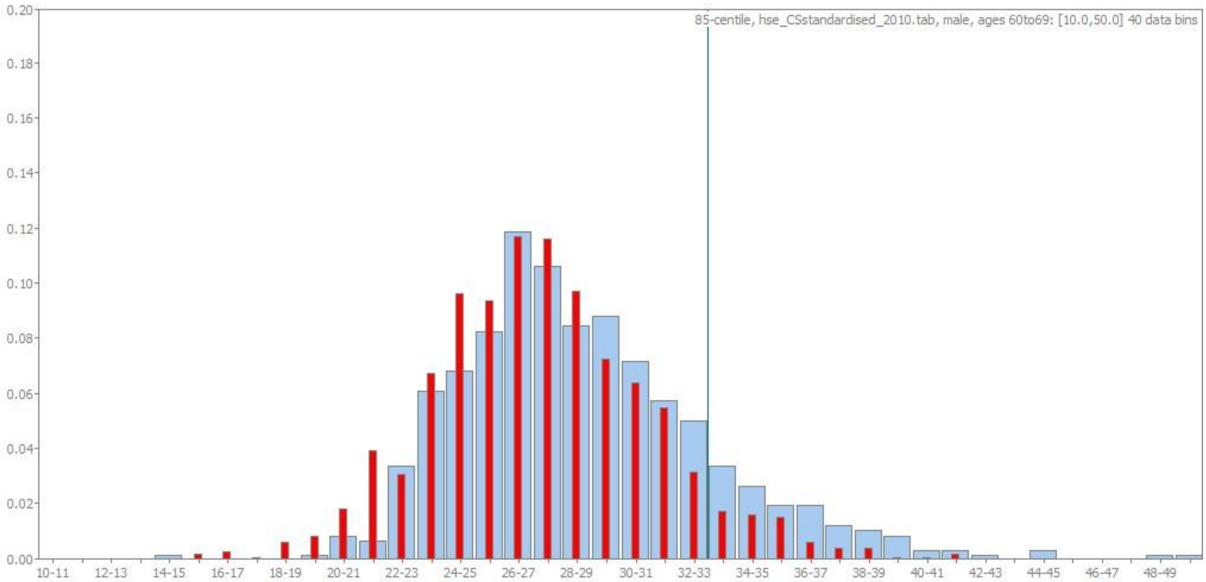

Figure 10: UK males aged 60-69, BMI distributions in 1995 (red) and 2010 (blue)

4.3 National disease data

Incidence, survival, relative risk, mortality and medical cost data are required for each of the BMI related diseases. The data consist of the most recent and discriminating that are available and are derived from a number of sources (Table in Appendix 3). Disease data are made available to the model in the form of open format, tab delimited text files.

4.4 National disease cost data

4.4.1 Introduction

Being overweight or obese predisposes an individual to a range of health conditions such as coronary heart disease (CHD), stroke, hypertension, certain cancers (breast and kidney), knee osteoarthritis and type II diabetes. This piece of work looks at the cost associated with obesity related illnesses in England.

4.4.2 Methodology

The 7 main diseases primarily associated with obesity have been included in this report: coronary heart disease (CHD), stroke, hypertension, osteoarthritis, diabetes and cancers of the breast and kidney. The co-morbidities associated with these diseases are accounted for in the model to avoid double counting of disease prevalence.

The costs of the illnesses were calculated by summing up the total cost ascribed to admissions, outpatient, A&E attendances, primary care prescribing and pharmaceutical services for each of the diseases. The following notes describe the methods actually used in calculating current expenditure by disease calculations:

4.4.3 Coronary Heart Disease - Estimating Cost of Inpatient care

The Healthcare Resource Groups (HRG) codes and inpatient data from the Hospital Episode Statistics (HES) website [6] were obtained and the estimates of total admission, calculated by using the number of admissions. The number of emergency admissions was also obtained from HES online. To estimate the number of elective admissions, we subtracted the total number of emergency admissions from the number of admissions. We then collected tariff data for these HRGs from the Department of Health: Payment by Results (PBR) web page (http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_112284).

The cost of emergency admissions was calculated by multiplying the volume of non-elective admissions by the non-elective spell tariff. The cost of elective admissions was calculated by multiplying the total number of elective admissions by the combined daycase/elective tariff. All figures used were for the 2011 and 2012 years.

4.4.4 Estimating Cost of outpatient care

Outpatient data is provided at the level of the main specialty; hence HRGs are not used here. We identified specialty of interest (e.g. cardiology) and estimated volumes from HES using first attendances and subsequent follow-ups. We then obtained costs from the PBR spread sheet[3]. The costs were multiplied by volume to obtain a total current spend. Data used were for the 2011 and 2012 years.

[3] Department of Health http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_112284

4.4.5 Estimating costs of A&E attendances

Number of A&E attendances was obtained from HES; the costs were obtained from the PBR tariff. One multiplied the costs by the volume to obtain a total current cost. There were no data available for 2011/2012/2013 A&E attendance as at the time of filing this report hence the 2010/2011 data were used.

4.4.6 Primary Care prescribing and Pharmaceutical services

One extracted underlying data from the Department of Health programme budgeting tool [7]. The data were then reformatted into a matrix with rows corresponding to PCTs and care setting (e.g. prescribing) and columns representing programme areas. The primary prescribing & pharmaceutical services were selected and one summed up the spending for the relevant programme areas [8].

4.4.7 Population Attributable Fractions (PAFs)

The methods described above provide estimates of the hospital costs of the 7 diseases. In order to establish the proportion of cost attributable to obesity in each of these diseases, we applied the percentages of PAFs of obesity to the total costs.

PAFs for stroke, hypertension, arthritis, diabetes and CHD were obtained from the National Audit Office (NAO) report (2001) [9]. The NAO report however did not have PAFs for breast and kidney cancers. Therefore PAFs obtained from World Health Organisation (WHO) EUR regional figures were used as a proxy [10].

4.4.8 Cost per disease prevalence case

Cost per prevalence case of these diseases could either be calculated as cost per person treated (intervention) or cost per person with disease (prevalence). Calculating the cost per intervention was however not feasible with the level of data we had. The reasons why are listed below: i. Individual patients may have several NHS interventions in a year - admissions, outpatient attendances and prescribing in primary care. ii. The programme budgeting data do not provide details of the number of individuals who receive interventions.

The average cost per prevalence of each obesity related illness was therefore calculated from the search for prevalence data for all the diseases. The total treatment cost was then divided by the prevalence of the disease. This process was repeated for all of the obesity related illnesses included in the model. To determine the cost of illness attributed to obesity from the total cost of these diseases, one obtained the percentage of cases attributable to obesity from the National Audit Office Report (2001) [9]. These percentages were then applied to the hospital costs.

4.4.9 Model cost inputs

The hospital costs of obesity related disease for the year 2011 and 2012 in England are shown in the tables below.

Disease area	All costs (£million)					
	Primary prescribing and pharma services	**A & E attendance**	**Outpatients**	**Admissions**	**Total**	**Cost attributable to obesity (£m)**
CHD	*16%*	*829*	*301*	*499*	*1629*	*266*
Diabetes	*47%*	*866*	*55*	*101*	*1,025*	*482*
Stroke	*6%*	*32*	*461*	*483*	*985*	*59*
Hypertension	*36%*	*899*		*10*	*909*	*327*
Osteoarthritis	*12%*	*451*	*206*	*14*	*736*	*88*
Breast cancer	*11.4%*	*134*	*434*	*57*	*634*	*72*
Kidney cancer	*11.4%*	*80*	*239*	*48*	*385*	*44*
Total					*6,334*	*1,338*

Table 3: The hospital costs of obesity related disease for the year 2011/12 (£M)

Disease area	Total cost (£m)	Attributable cost (£M)	Average total cost per person with disease (£)
CHD	*1,661*	*266*	*741*
Diabetes	*1,025*	*482*	*412*
Stroke	*985*	*59*	*998*
Hypertension	*909*	*327*	*71*
Osteoarthritis	*736*	*88*	*110*
Breast cancer	*634*	*72*	*157*
Kidney cancer	*385*	*44*	*764*

Table 4: Average costs of obesity related disease for the year 2011/12

NB - The outpatient and A&E attendance cost for hypertension were left out because the codes for A&E and Outpatient tariff and attendance are the same (Cardiology) for both CHD and hypertension.

4.4.10 Average cost per prevalence

An analysis was carried out involving:

- Calculation of the direct costs of treating obesity related illnesses,
- Estimation of the cost of the illnesses attributed to obesity
- Estimation of the average cost per prevalence of disease.

Based on that analysis, £6.33bn was spent on treating CHD, diabetes, stroke, hypertension, knee osteoarthritis, breast and kidney cancers. The costs relate only to expenditure within the hospital. NHS spending on these diseases is most likely higher as ancillary costs such as those related to community care schemes and ambulance services were not estimated.

CHD and diabetes were the main cost drivers in the present analysis, representing about 42% of the entire hospital costs. The cost of treatment for hypertension is also quite likely to be a significant driver. However, the analysis that was carried out for hypertension did not include outpatient and A&E attendance cost. The reason why was because no literature review was found which allow to separate out outpatient and A&E attendance cost for CHD and hypertension. In consequence, the analysis may have overestimated the costs of treating CHD.

The assumptions described below were used to calculate the cost of obesity related illnesses:

1. All diabetic outpatients' visits were assumed to have been treated by an endocrinologist. This assumption would result in a gross under-estimation as a number of diabetics receive treatment from their GPs. We however could not ascertain what proportion of patients who visit a GP, do so due to obesity related diabetes. We also used the outpatient tariff for endocrinologists.

2. In the Hospital Episode Statistics (HES) information centre, A & E attendance data is logged in by primary diagnosis making it challenging to rate the volume of attendance that may or may not require investigations. Therefore the tariff for the "Non-24 hour A&E Department" as the estimated cost for treating all cases of diseases seen at the A&E was used. In reality, this would be sub-optimal as each individual case would vary in complexity and hence attract different charges.

3. All stroke outpatients were assumed to visit a neurologist; the same assumption was made for the cost analysis. No tariff for follow up attendance for stroke was observed. Therefore the tariff for 1st attendance was applied [11]. While this could lead to an overestimate of follow up costs, we believe our assumption was fair in the scenario.

4. All PAFs used were not specific to the United Kingdom.

5. Prevalence data used were for 2006 for all the diseases except diabetes and hypertension which were 2010 prevalence data [12].

4.5 National utility data

Two types of utility data were used in the model in order to generate estimates of quality adjusted life years (QALYs). Firstly, we estimated the effect of BMI on utility for a cross sectional sample of individuals over 16. Utility scores varied by age, gender, and BMI category. Secondly, utility values for certain obesity related diseases (CHD, stroke, arthritis, and diabetes) were estimated. The utility score for a particular age/sex/BMI group and for each disease was combined with the length of time spent in that state to provide estimates of QALYs.

4.5.1 Utility values by age, gender, and BMI category

Values for utility by age, gender and BMI group were taken from Maheswaran et al [13]. The study used data from the 2008 Health Survey for England and used utility values obtained using the EQ-5D instrument. Maheswaran and colleagues used data from 14,117 individuals who were 16 or older at the time of the survey and who had complete data for EQ-5D. They present data showing estimated utility scores by age group. They also present the results of a regression analysis showing the effects of a range of patient characteristics; include gender and BMI, on EQ-5D score. The authors found that the Ordinary least-squares (OLS) [4] model performed as well as other types of regression model so results from the OLS model were published and are used in the analysis presented here.

The model required utility scores for males and females, separated into age and BMI groups. However, the above study did not present data in this form in this form and hence could not be used directly in the model. For this reason we used the data presented by Maheswaran and colleagues to estimate utility scores for each group. In order to do this a number of simplifying assumptions were necessary. As a starting point we used the utility scores by age category presented by the authors. These values were adjusted using coefficients from OLS regression for the effect of BMI groups on utility values. The effect of BMI was assumed to be the same for each age group using a weighted average approach allowing for the different numbers of individuals in each BMI group. Adjustment to each age/BMI group according to the coefficient for gender from the OLS model was carried out. Again, a weighted average approach was used to allow for the proportion of each age group that were male/female. However, as no data from the HSE were available on the proportion of each age group who were male, population estimates from the ONS were used. The estimates of utility values by age groups for the different groups are presented in Table 5 and Table 6 below.

Age	BMI (kg/m²)				
	<18.5	**18.5 to <25**	**25 to <30**	**30 to <40**	**40+**
16-24 (CI)	0.949 (0.919 , 0.979)	0.949 (0.943 , 0.955)	0.944 (0.93 , 0.957)	0.917 (0.902 , 0.935)	0.842 (0.806 , 0.883)
25-34 (CI)	0.929 (0.898 , 0.96)	0.929 (0.922 , 0.936)	0.924 (0.909 , 0.938)	0.897 (0.881 , 0.916)	0.822 (0.785 , 0.864)
35-44 (CI)	0.908 (0.877 , 0.939)	0.908 (0.901 , 0.915)	0.903 (0.888 , 0.917)	0.876 (0.86 , 0.895)	0.801 (0.764 , 0.843)
45-54 (CI)	0.867 (0.833 , 0.9)	0.867 (0.857 , 0.876)	0.862 (0.844 , 0.878)	0.835 (0.816 , 0.856)	0.76 (0.72 , 0.804)

[4] Hutcheson, G. D. (2011). Ordinary Least-Squares Regression. In L. Moutinho and G. D. Hutcheson, The SAGE Dictionary of Quantitative Management Research. Pages 224-228. http://www.research-training.net/addedfiles/READING/OLSchapter.pdf

55-64 (CI)	0.829 (0.795 , 0.864)	0.829 (0.819 , 0.84)	0.824 (0.806 , 0.842)	0.798 (0.778 , 0.82)	0.722 (0.682 , 0.768)
65-74 (CI)	0.79 (0.753 , 0.828)	0.79 (0.777 , 0.804)	0.785 (0.764 , 0.806)	0.759 (0.736 , 0.784)	0.683 (0.64 , 0.732)
75+ (CI)	0.727 (0.688 , 0.766)	0.727 (0.712 , 0.742)	0.722 (0.699 , 0.744)	0.696 (0.671 , 0.722)	0.62 (0.575 , 0.67)

Table 5: Estimated utility values by age and BMI category for women with confidence intervals (CI)

Age	**BMI (kg/m²)**				
	<18.5	**18.5 to <25**	**25 to <30**	**30 to <40**	**40+**
16-24 (CI)	0.963 (0.933 , 0.993)	0.963 (0.957 , 0.969)	0.958 (0.944 , 0.971)	0.931 (0.916 , 0.949)	0.856 (0.82 , 0.897)
25-34 (CI)	0.943 (0.912 , 0.974)	0.943 (0.936 , 0.95)	0.938 (0.923 , 0.952)	0.911 (0.895 , 0.93)	0.836 (0.799 , 0.878)
35-44 (CI)	0.922 (0.891 , 0.953)	0.922 (0.915 , 0.929)	0.917 (0.902 , 0.931)	0.89 (0.874 , 0.909)	0.815 (0.778 , 0.857)
45-54 (CI)	0.881 (0.847 , 0.914)	0.881 (0.871 , 0.89)	0.876 (0.858 , 0.892)	0.849 (0.83 , 0.87)	0.774 (0.734 , 0.818)
55-64 (CI)	0.843 (0.809 , 0.878)	0.843 (0.833 , 0.854)	0.838 (0.82 , 0.856)	0.812 (0.792 , 0.834)	0.736 (0.696 , 0.782)
65-74 (CI)	0.804 (0.767 , 0.842)	0.804 (0.791 , 0.818)	0.799 (0.778 , 0.82)	0.773 (0.75 , 0.798)	0.697 (0.654 , 0.746)
75+ (CI)	0.741 (0.702 , 0.78)	0.741 (0.726 , 0.756)	0.736 (0.713 , 0.758)	0.71 (0.685 , 0.736)	0.634 (0.589 , 0.684)

Table 6: Estimated utility values by age and BMI category for men with confidence intervals (CI)

4.5.2 Utility by disease states

Utility can vary because of a number of factors, including: age, sex, health and co-morbidities, and method of elicitation. In order to be as consistent as possible with methods used for the estimation of utilities for the effect of obesity the decision was made to derive utility, where feasible, from the EQ-5D instrument. Searches were made using Medline using terms related to utility measures as well as diseases specific terms. Where a range of possible utility values were available from a variety of sources a decision was made as to which value to use (Appendix 4).

4.5.2.1 Diabetes

A review looked at utility based measures in Type 2 diabetes [14], limited to EQ-5D only. This review found 54 publications which reported EQ-5D questionnaire responses. This review used pooling techniques to estimate EQ-5D derived utilities for a number of groups. These included a general diabetes population (utility=0.67). However, it was not clear what the mean age was of the people in these pooled samples. This value of 0.67 was used in the model for all ages.

4.5.2.2 Osteoarthritis

A study looked at 576 patients with musculoskeletal conditions [15]. Of these, 193 had symptomatic peripheral osteoarthritis (knee, hand, and hip). Utility was assessed using the EQ-5D. Mean EQ-5D-derived utility was 0.61. Mean age for the 576 patients in the study was 61.5 years and 62% were female. However, age and sex were not given for the osteoarthritis sub-group. The value of 0.61 was used in the model for all ages.

4.5.2.3 Stroke

A number of studies have examined HRQoL after stroke. Post and colleagues carried out a systematic review covering 23 studies examining the utility associated with stroke [16]. Studies were divided on the basis of the modified Rankin score (mRS) with minor stroke categorised as mRS 2 to 3 and major stroke as mRS 4 to 5. However, this review included only study that used the EQ-5D, this was by Dorman and colleagues [17]. This obtained EQ-5D responses from 152 stroke survivors; their utility values were estimated to be 0.32 and 0.71 for major and minor stroke respectively. The European stroke study estimated that 30.9% of survivors of a first stroke would be disabled. If this is taken to be major stroke then we can estimate that stroke would have a utility of (0.32*0.309) + (0.71*0.691) = 0.59. This value of 0.59 was used in the model for all ages.

4.5.2.4 CHD

As CHD comprises a number of different diseases we used a composite approach to estimate utility. Estimates of prevalence were taken from a published model of UK CHD ([18] web Appendix 4). These were derived from the GPRD database and the ECHOES study (Davis et al). These were combined with UK population estimates to estimate the numbers of individuals with different conditions and hence the proportion with each of 3 underlying CHD conditions (angina, myocardial infarction, and heart failure). These were combined with estimates of utility, again using the EQ-5D instrument. Utility for heart failure was taken from a UK study looking at 200 individuals with New York Heart Failure class II or III [19]. Participants had a mean age of 72 and 65% were male. Baseline EQ-5D-derived utility was 0.65. The utility for angina was from a US study [20]. However, rather than the EQ-5D this study derived utility values directly from study participants using the time-trade-off method. The utility value for angina derived from this study was 0.703, derived from 58 individuals with angina. Values for myocardial infarction were taken from a UK study of 229 individuals discharged from hospital following an MI [21]. Mean age was 62 and the sample was 75% male. EQ-5D derived utility at one year after discharge was estimated to be 0.735 for men and 0.66 for women.

These scores were combined with prevalence estimates to give an estimated utility for people with CHD (combined angina, MI, and HF) of 0.697.

Value used in the model 0.69**.**

4.6 Cost of Intervention

The Oxford literature review WMA1.5 and Loveman et al. 2012 [22] carried out a systematic review to determine the cost of weight management schemes (Table 7).

Study ID	**Cost per participant (or other data if cost per participant not available)**	
	Intervention	**Control (categories 1-4)**
DPP 2002	(10 year costs**) USD 4601 or USD 3023** if completed as groups and no individual sessions	(10 year costs) USD 769
Hersey 2012 (RCT 2)	RCT 2 (interactive website): **USD 160**	USD 145
Hersey 2012 (RCT 3)	RCT 3 (interactive website plus phone/e-mail): **USD 390**	USD 145
Heshka 2003	Not stated, but authors report that during the study the retail value of one voucher (for	Not stated

	a Weight Watchers session) was 9 USD. This would result in a maximum of 936 USD per participant (max session number 104).	
Jebb 2011	Cost per participant not provided. Cost per kilogram of weight loss: UK: **USD 90** Germany: USD 180 Australia: USD 122	Cost per participant not provided. Cost per kilogram of weight loss: UK: USD 151 Germany: USD 133 Australia: USD 138
Jolly 2011 (general practice)	Provider cost: 55 GBP Total cost[5]: **76.87 GBP**	Not stated
Jolly 2011 (NHS Size Down)	Provider cost: 70 GBP Total cost: **91.87 GBP**	Not stated
Jolly 2011 (pharmacy)	Provider cost: 90.43 GBP Total cost: **112.30 GBP**	Not stated
Jolly 2011 (Rosemary Conley)	Provider cost: 55 GBP Total cost: **76.87 GBP**	Not stated
Jolly 2011 (Slimming World)	Provider cost: 49.50 GBP Total cost: **71.37 GBP**	Not stated

Table 7: Results of cost studies used in the model

A first cost approximation of £100, corresponding to UK based studies was assumed. Intervention costs of £500, £1000 and £1500 were also used in the model.

5 Implementation - Computer model overview

The set of interventions and cohorts described below bracket the review findings and are designed to provide a basis for understanding what might be cost effective interventions in adults.

5.1 BMI, Interventions and cohorts

The interventions (5 in number) will cause a net loss of {0.3, 0.6, 1.0, 2.0, 3.0} BMI points respectively which will initially be sustained[6] over the life course of the recipient. This set of interventions will be augmented with the null intervention will allow the individuals BMI to grow unchecked.

The costs of the interventions are set at an arbitrary value of £100 per head. The results of the computer runs can be used to compute ICER values for different costs. The cost of the null intervention is assumed to be £0.

The age groups (5 in number) receiving this intervention are {20-29, 30-39, 40-49, 50-59, 60-69}.

The initial BMI values (4 in number) are {25, 30, 35, 40}.

There are two gender groups {male, female} and the modelling is thereby differentiated by gender.

For modelling purposes the target groups of people are gathered into cohorts. There are 40 distinct cohorts for these classifications corresponding to {gender: male, female}, {initial bmi|25, 30, 35, 40}, {age group|20-29, 30-39, 40-49, 50-59, 60-69}. The data for each cohort are gathered into separate cohort text files. An example of such a cohort file is provided by Table 8:

[5] For each arm, cost per participant recruited includes: £10 for call centre; £3.54 for practices to run a search of their lists and for GPs to screen the lists for ineligible participants; £8.33 for invitation letters sent by practices (£1 per letter, with 12% response rate).

[6] Future BMI growth will be governed by the rule that individuals stay on the same percentile as BMI distributions change over their life course due to ageing and due to population obesity growth. Maintaining a loss in BMI is modelled as the individual staying on his intervention-lowered percentile.

Age	Sex	Year	BMI
41	1	2013	40
43	1	2013	40
45	1	2013	40
47	1	2013	40
49	1	2013	40

Table 8: a typical cohort file female, BMI 40, age group 40 to 49

5.2 BMI Loss sustained for life

The UKHF computer model was used to compute the ICER values for the 5 different interventions as applied to the 40 different cohorts.

5.3 BMI loss regained at 5, 10, 20, 25, 30, 40 % per annum (PA)

The UKHF computer model was used to compute ICER values for the identical set of cohorts but now with interventions in which the initial BMI lost is recovered, because of the limited availability of evidence of rates of weight regain, rates of regain of 5, 10, 20, 25, 30 and 40 % per annum were modelled. At 5% rate of regain, an individual would return to their without-an-intervention weight trajectory in 20 years; at 10% regain, they would take 10 years to return to their without-an-intervention weight trajectory; at 20% regain, 5 years; at 25% regain, 4 years; at 30% regain, 3 years and 4 months; at 40% regain, 2 years and 6 months. It will become apparent from the Figures below that it is estimated not to be cost effective to intervene for any cohort whose return to a without-an-intervention weight trajectory is lower than about 3 years.

6 Results for cost effectiveness modelling

BMI trajectories defined in this way correspond fairly closely to an intuitive picture of weight loss and subsequent regain. The trajectories are separated by an amount depending on the scale of the intervention at the point of the intervention and subsequently stay fairly close together. However there are less intuitive features that arise from the nature of the time changing distributions.

The most important of these is that a fixed separation of percentiles does not mean that there is a fixed separation in BMI. In particular, if distribution$_B$ has a greater percentage of obese BMIs (BMI>30 kg/m^2) than distribution$_A$ then a fixed separation of percentiles (for obese BMIs) is likely to correspond to a smaller BMI-gap in distribution$_B$ than the BMI-gap in distribution$_A$. This effect is referred to as BMI-compression and is demonstrated with a pair of distributions Appendix 5. If it is the other way around and distribution$_B$ has a lower percentage for BMI>30kg/m^2 than distribution$_A$ then a fixed separation of percentiles (for BMI>30kg/m^2) will result in a widening of the gap in the associated BMI-trajectories – BMI expansion. The amount of BMI compression or expansion will depend on the particular distributions and the particular percentiles but it will not be the same for all percentiles.

In understanding the results that follow it should be remembered that the model assumes that obesity levels are rising. Thus for an ageing individual there are two separate reasons why his or her BMI is likely to increase: the ageing process and the observed national rise in obesity levels.

6.1 Intervention 1: 0.3 BMI loss (about 0.8kg Loss) costing £100 per head

- The ICERs are below with the NICE threshold (below £20,000 per QALY) except males >50 years and of starting BMI of 25.
- For figures 11 to 17, the important point it is to see whether the ICERs are above or below £20,000 for different rates of regain at different ages. The summary of the figures are shown in table 11 and shows the following points:
    - The rate of regain matters most for the cost effectiveness of younger cohorts. The rate of regain matters most for the cost effectiveness of cohorts that are at the lower end of being overweight or obese.
    - Some differences in the cost effectiveness of interventions between male and female cohorts exist, but the effects are not systematic for the various cohort ages and weight categories.

Age Female	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
20-29	2108	1,250	3,568
30-39	8,593	654	177
40-49	7,901	565	676
50-59	1,904	807	-
60-69	3,427	1,966	219

Table 9: Female ICER by age group and BMI (kg/m²) for a reduction of 0.8kg for life. A negative number implies that the intervention of interest is dominant.

Age Male	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
20-29	3,125	465	372
30-39	12,504	1,477	11
40-49	11,181	951	-60
50-59	25,845	-2,268	-207
60-69	22,908	-77	687

Table 10: Male ICER by age group and BMI (kg/m²) for a reduction of 0.8kg for life. A negative number implies that the intervention of interest is dominant.

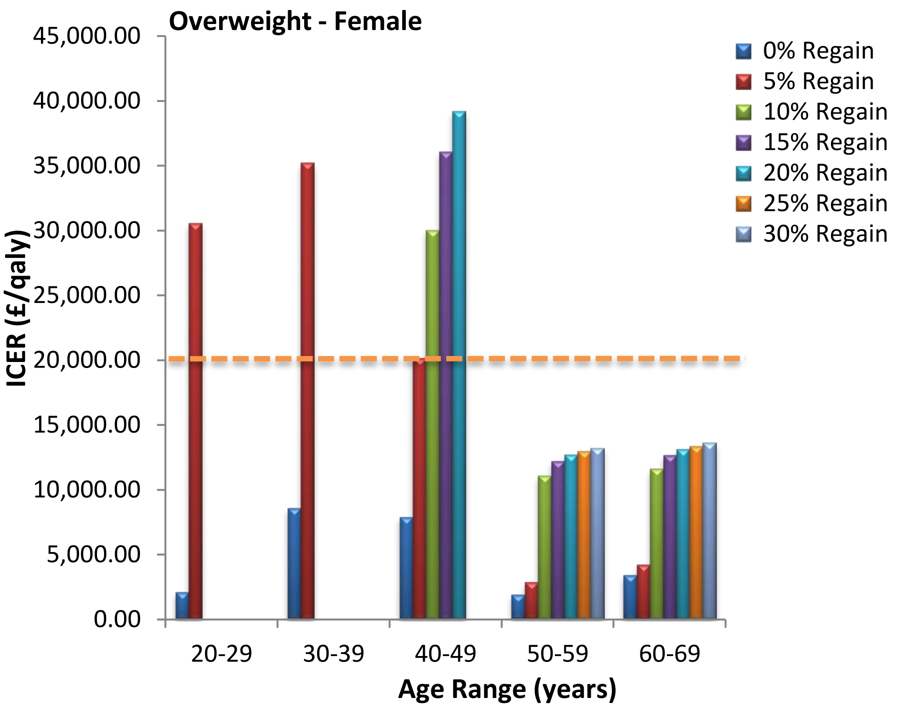

Figure 11: ICER (£/QALY) by age range, BMI % regain per annum for overweight female (The ICER were not shown if greater than £45,000).

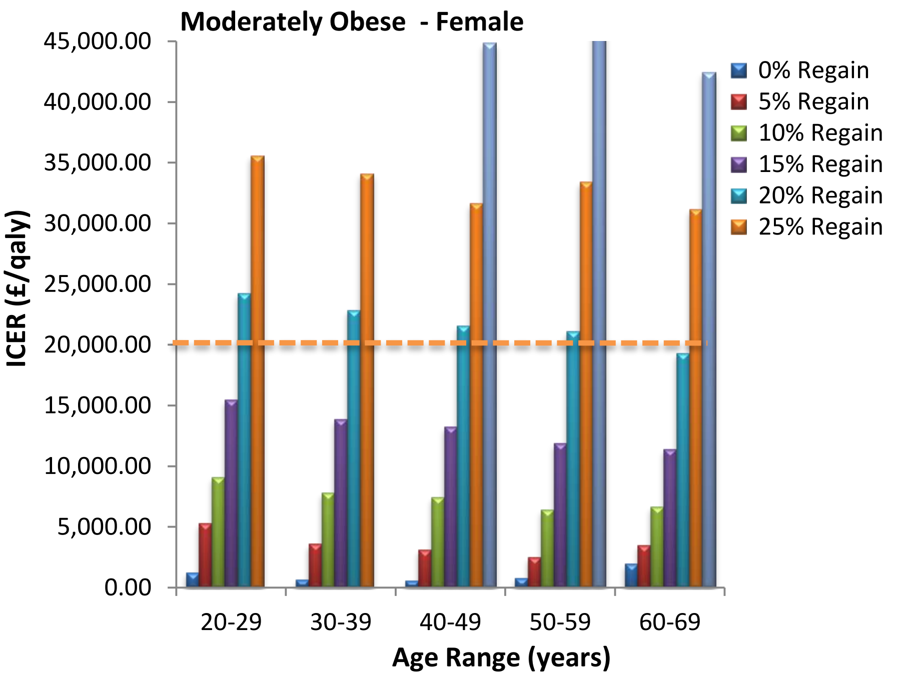

Figure 12: ICER (£/QALY) by age range, BMI % regain per annum for moderately obese female (The ICER were not shown if greater than £45,000).

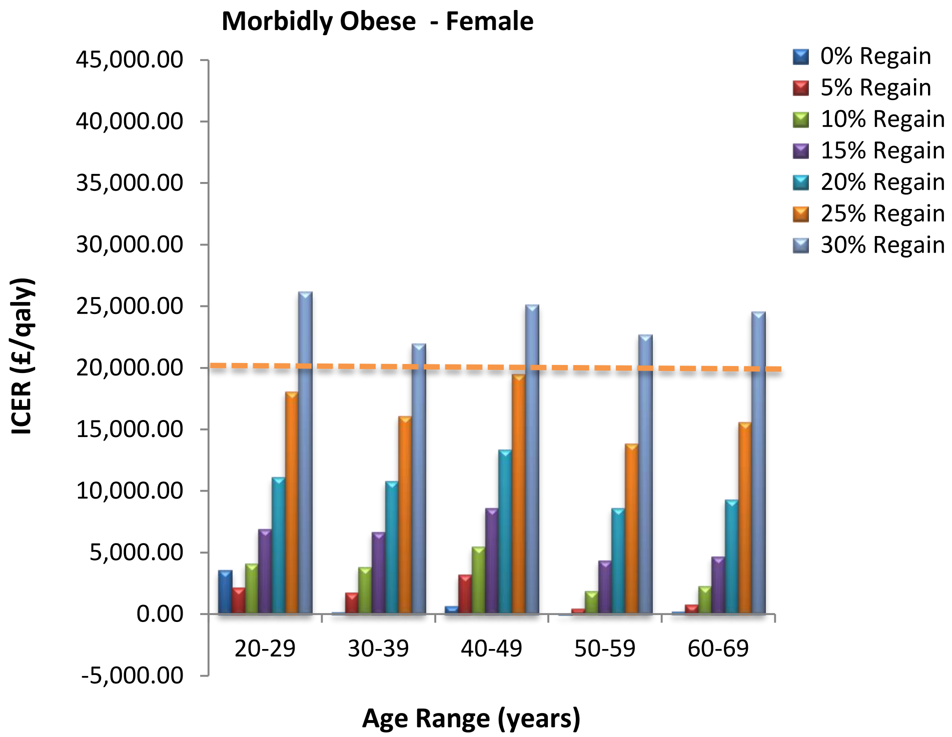

Figure 13: ICER (£/QALY) by age range, BMI % regain per annum for morbidly obese female (The ICER were not shown if greater than £45,000).

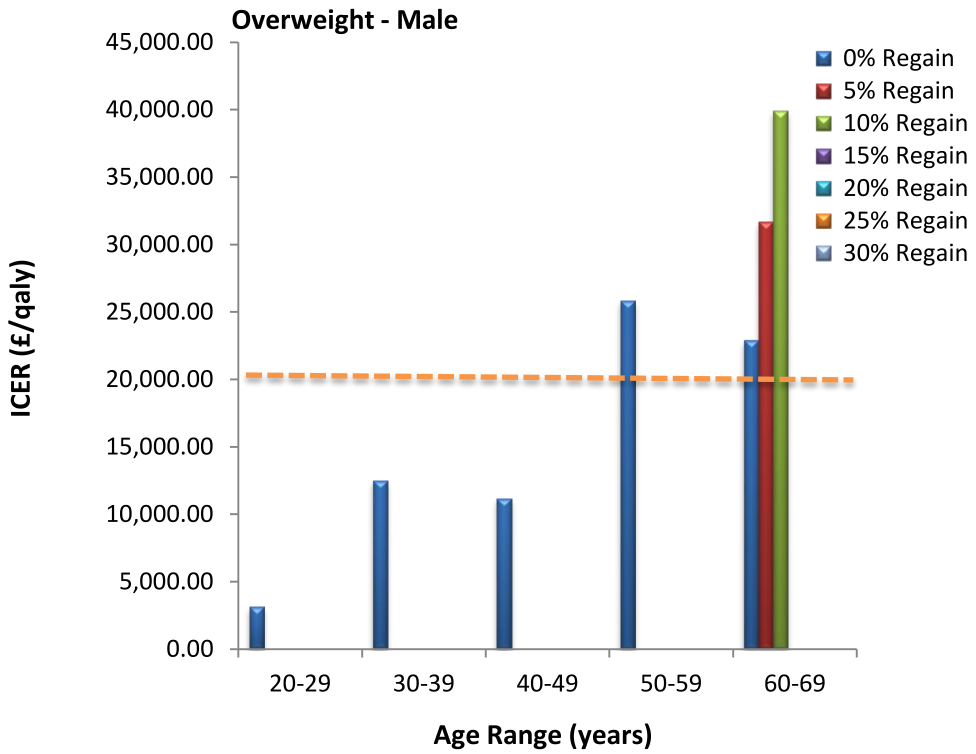

Figure 14: ICER (£/QALY) by age range, BMI % regain per annum for overweight male (The ICER were not shown if greater than £45,000).

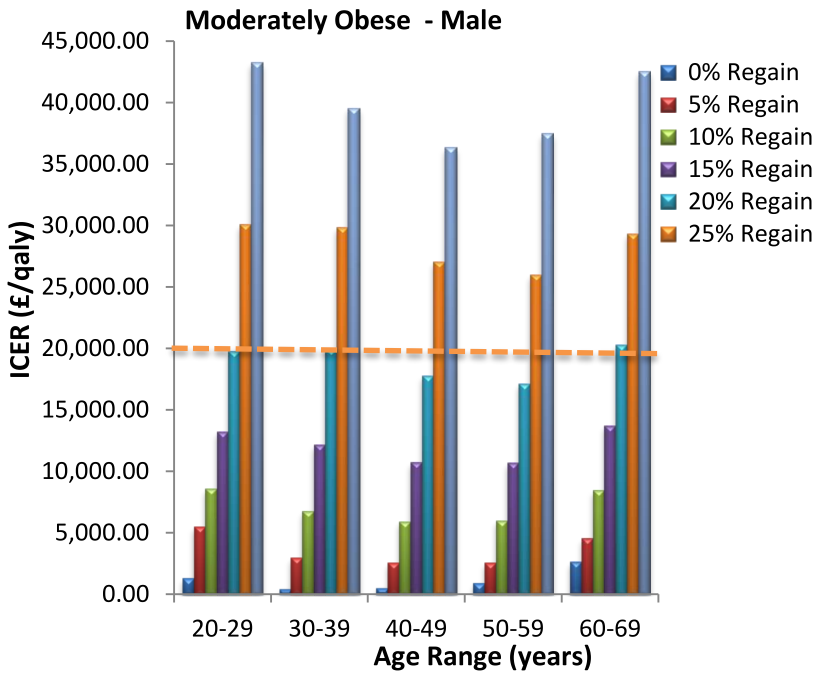

Figure 15: ICER (£/QALY) by age range, BMI % regain per annum for moderately obese male (The ICER were not shown if greater than £45,000).

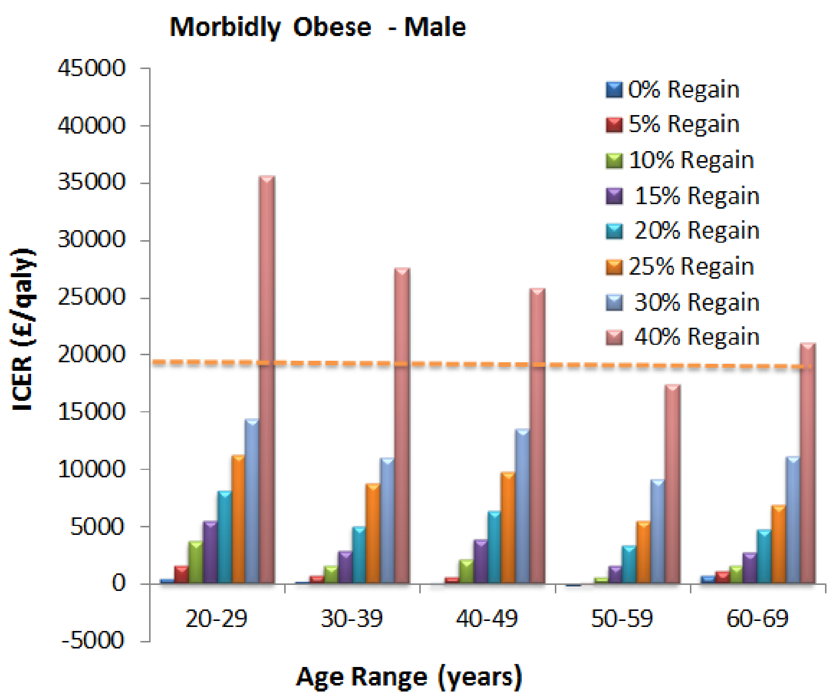

Figure 16: ICER (£/QALY) by age range, BMI % regain per annum for morbidly obese male (The ICER were not shown if greater than £45,000).

From these comments, the important message is shown in the following table 11 which summarises the rate of regain of BMI [% per annum] for which the WM program is no longer cost effective.

At 25 kg/m^2, the regains of BMI [% per annum] (averaged over the different age groups) for which the WM program is no longer cost effective are approximately 15% and 4% for female and male respectively.

At 30 kg/m^2, the averaged regains of BMI [% per annum] for which the WM program is no longer cost effective are approximately 21% and 18% for female and male respectively.

At 40 kg/m^2, the averaged regains of BMI [% per annum] for which the WM program is no longer cost effective are approximately 30% and 40% for female and male respectively.

Age	Initial BMI (kg/m^2)		
	25 kg/m^2	30 kg/m^2	40 kg/m^2
		FEMALE	
20-29	5%	20%	30%
30-39	5%	20%	30%
40-49	5%	20%	30%
50-59	>30%	20%	30%
60-69	>30%	25%	30%
		MALE	
20-29	5%	20%	40%
30-39	5%	20%	40%
40-49	5%	5%	40%
50-59	5%	25%	>40%
60-69	0%	20%	40%

Table 11: The rate of regain of BMI [% per annum] for which the WM program is no longer cost effective

6.2 Intervention 2: 0.6 BMI loss (about 1.6kg Loss) costing £100 per head

The PDG recommendations to assess the WM programs should take into considerations the four following parameters:

- Loss of an average 0.6 BMI for life is estimated to be either cost effective or cost saving for both men and women's cohorts, for all age cohorts and for the three categories of overweight and obese considered.
- For figures 17 to 22, it is important to see whether the ICERs are above or below £20,000 for different rates of regain at different ages. The summary of the figures are shown in table 14 and shows similar tendencies as for intervention 1 (initial loss of 0.3 BMI – this set of figures is for double that loss).
    -

Age Female	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
20-29	941	-52	
30-39	3,373	4	-95
40-49	2,724	-55	63
50-59	-1,619	7	-277
60-69	664	659	-75

Table 12: Female ICER by age group and BMI (kg/m²) for a reduction of 1.6 kg for life. A negative number implies that the intervention of interest is dominant.

Age Male	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
20-29	1,433	-204	107
30-39	5,452	-298	-174
40-49	4,660	-81	-260
50-59	4,554	86	-336
60-69	3,061	1,139	271

Table 13: Male ICER by age group and BMI (kg/m²) for a reduction of 0.8kg for life. A negative number implies that the intervention of interest is dominant.

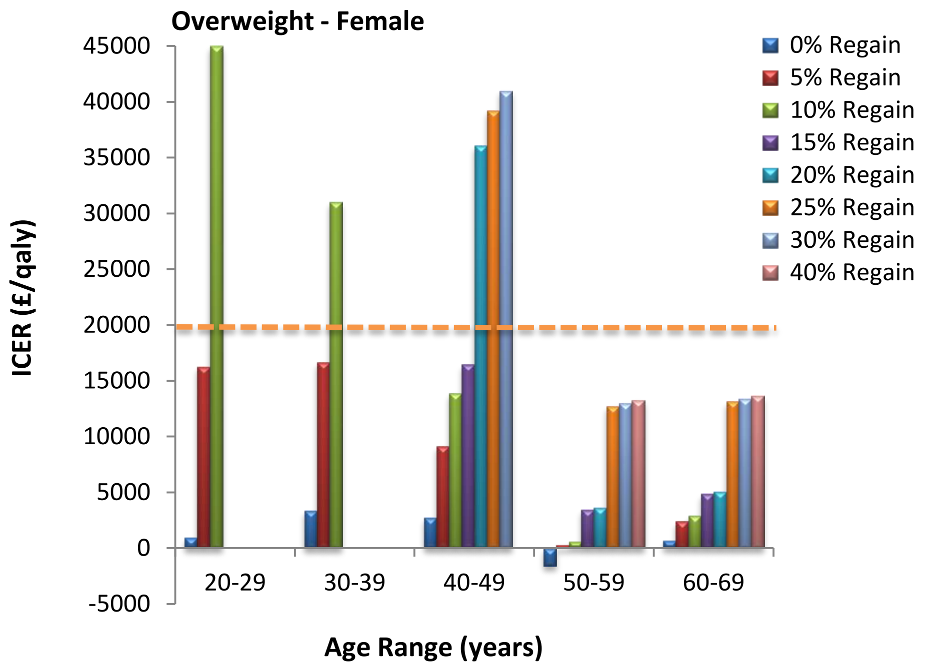

Figure 17: ICER (£/QALY) by age range, BMI % regain per annum for overweight (The ICER were not shown if greater than £45,000).

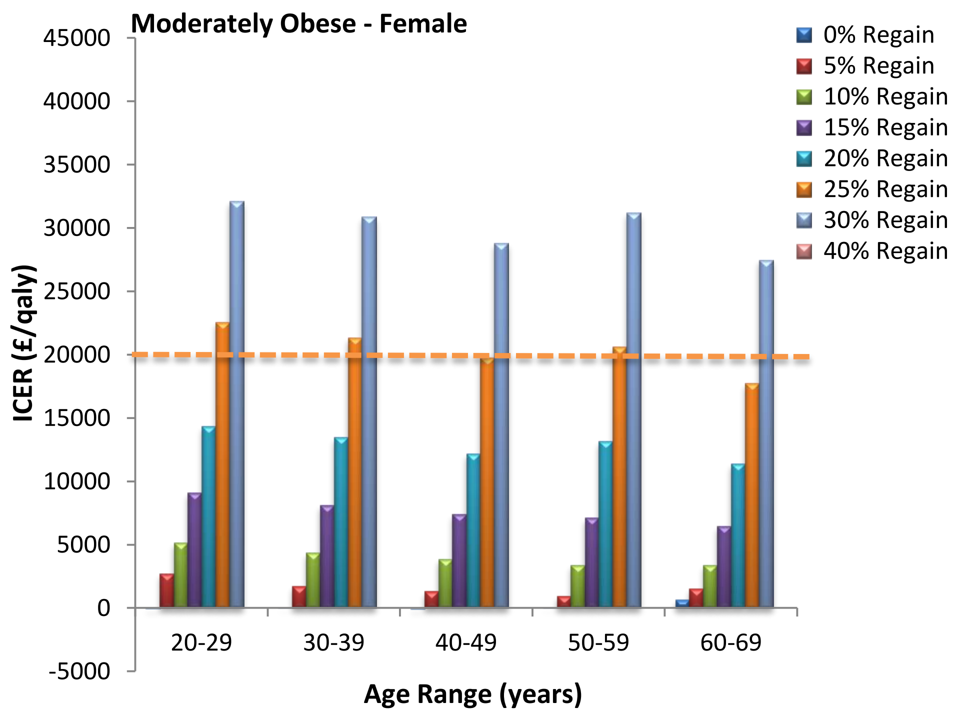

Figure 18: ICER (£/QALY) by age range, BMI % regain per annum for moderately obese (The ICERs were not shown if greater than £45,000).

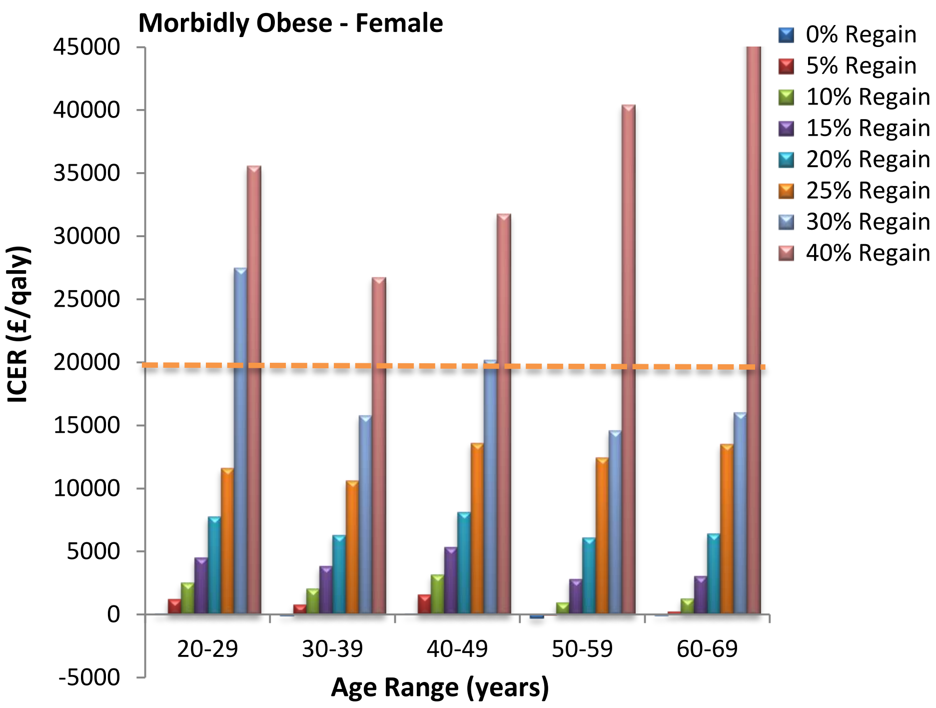

Figure 19: ICER (£/QALY) by age range, BMI % regain per annum for morbidly obese (The ICERs were not shown if greater than £45,000).

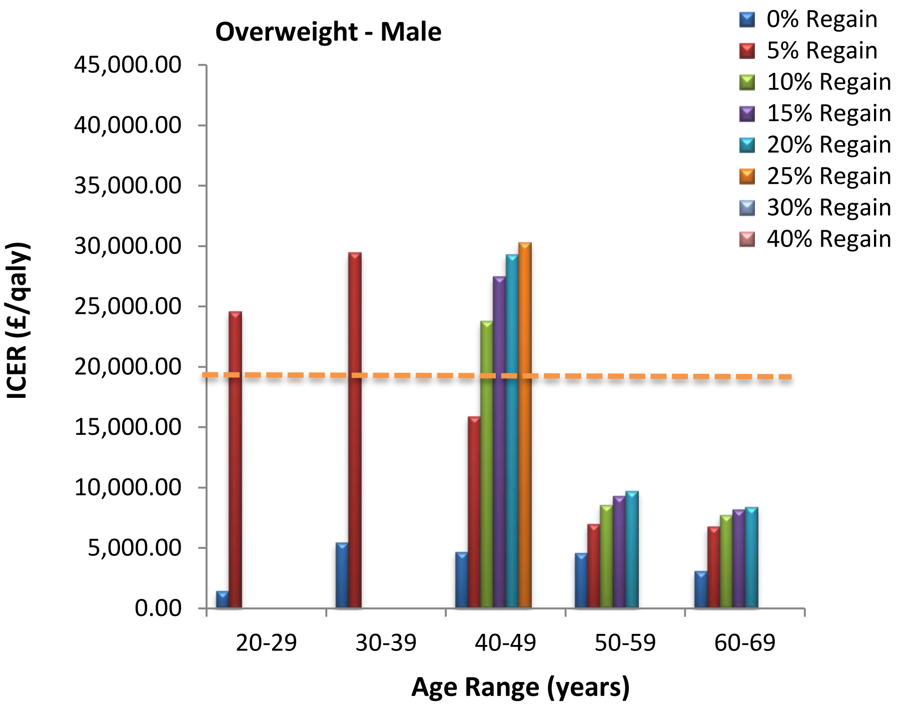

Figure 20: ICER (£/QALY) by age range, BMI % regain per annum for overweight male (The ICERs were not shown if greater than £45,000).

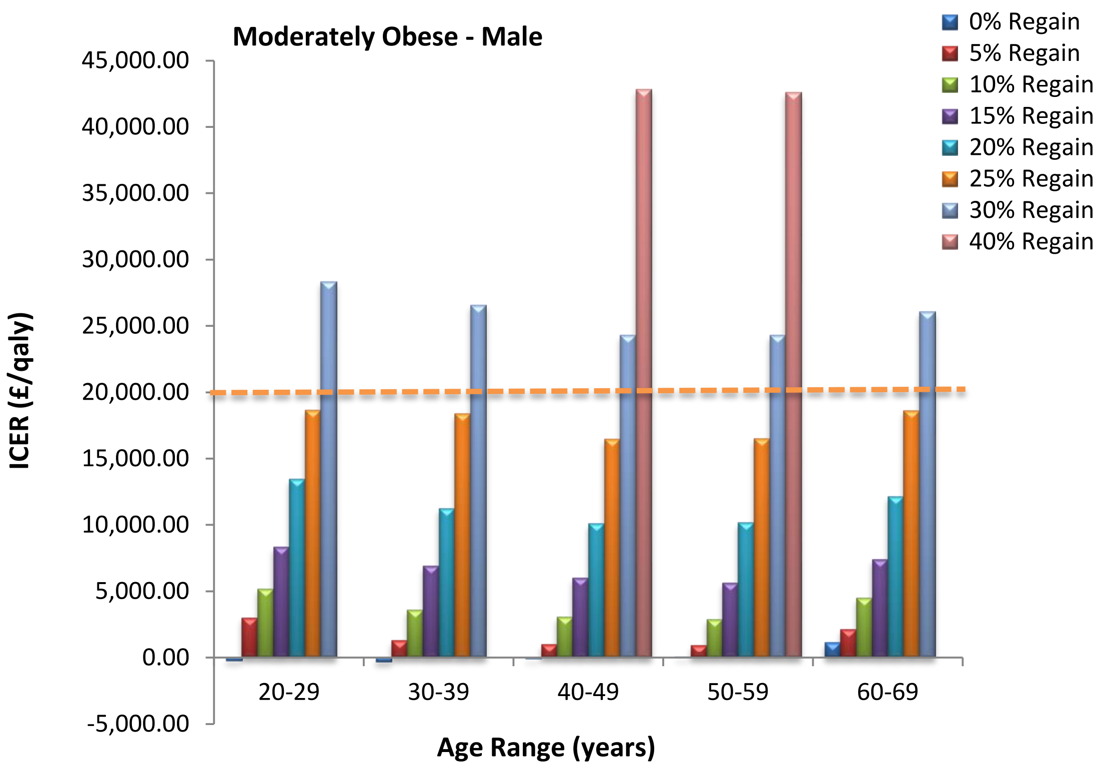

Figure 21: ICER (£/QALY) by age range, BMI % regain per annum for moderately obese male (The ICERs were not shown if greater than £45,000).

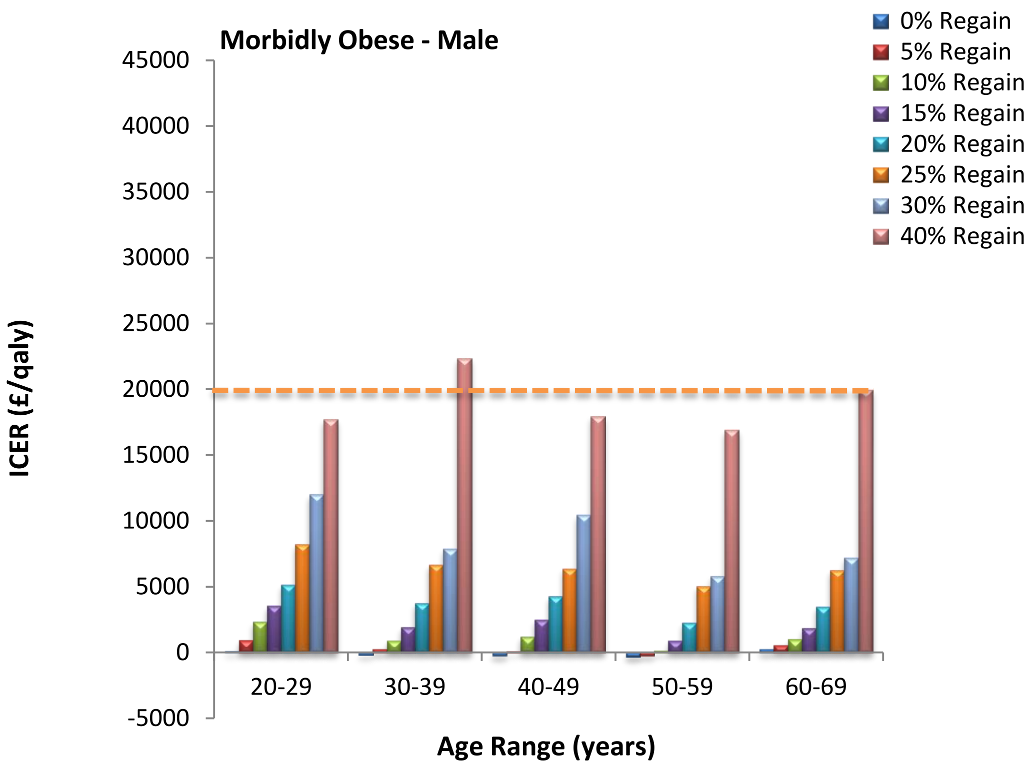

Figure 22: ICER (£/QALY) by age range, BMI % weight regain per annum for morbidly obese male (The ICER were not shown if greater than £45,000).

Age	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
		FEMALE	
20-29	10%	25%	30%
30-39	10%	25%	40%
40-49	20%	30%	30%
50-59	>40%	25%	40%
60-69	>40%	30%	40%
		MALE	
20-29	5%	30%	>40%
30-39	5%	30%	40%
40-49	10%	30%	>40%
50-59	>40%	30%	>40%
60-69	>40%	30%	40%

Table 14: The rate of regain of BMI [% per annum] for which the WM program is no longer cost effective

6.3 Intervention 3: 1 BMI loss (about 2.6 kg loss) costing £100 per head

When the weight is lost for the whole of life, an intervention costing £100 will be even more cost effective when 1 BMI point is lost than for intervention 2, where 0.6 BMI points were lost for the same cost.

What is more interesting is the number of years the weight has to be kept off before the intervention moves from being not-cost-effective to cost effective. For interventions where the weight loss averages as much as 1 BMI point, some distinctions that have so far appeared become more pronounced.

- For both the male and female cohorts called 'overweight' at the time of the intervention, there are very distinct differences between the two younger cohorts (20-29 and 30-39), the middle cohort (40 to 49) and the two older cohorts (50-59 and 60-69). To be cost effective:
    - For the two younger cohorts, it would appear that the weight should not be regained for more than 20 years
    - For the middle cohort, the weight loss should not be regained within 5 years
    - For the older 2 cohorts, it should not be regained within 2 to 3 years

Part of the reason for this is that the group called 'overweight' has an initial BMI of 25. As time passes, this cohort for both men and women will gain weight so as to maintain their relative weight ranking, and the average BMI will rise to the high 20s and perhaps beyond. For this cohort, it will take a number of years for younger men and women to contract diabetes and other conditions, so the weight must be kept off for a number of years for the intervention to be cost effective, whereas at ages above about 50, having lost weight yields potential gains almost immediately, so the weight loss does not have to be maintained for long in order for the intervention to become cost effective.

- For the cohorts called 'moderately obese' and 'morbidly obese', results do not differ in any appreciable way by age cohort. The difference between the sexes is also small, and the intervention would appear to be slightly more cost effective in the morbidly obese (but the differences probably would not translate to differences in recommendations for policy). The intervention is estimated to be cost effective if the weight trajectory returns to the pre-intervention trajectory after some 3 to 4 years.

- First of all, ICERs are small compared with the NICE threshold (below £20,000 per QALY)
- Secondly, gender, BMI, age, and %BMI regain per annum have a direct impact on the WM programmes' s ICER:

Age	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
20-29	465	-578	-72
30-39	1,477	-260	-217
40-49	951	-339	-349
50-59	-2,268	-319	-421

60-69	-77	82	-258

Table 15: Female ICER by age group and BMI (kg/m²) for a reduction of 2.6 kg for life . A negative number implies that the intervention of interest is dominant.

Age	Initial BMI (kg/m²)		
	25 kg/m²	**30 kg/m²**	**40 kg/m²**
20-29	659	-780	-39
30-39	2,897	-453	-269
40-49	2,560	-328	-367
50-59	132	-243	-452
60-69	513	51	-123

Table 16: Male ICER by age group and BMI (kg/m²) for a reduction of 2.6 kg for life A negative number implies that the intervention of interest is dominant.

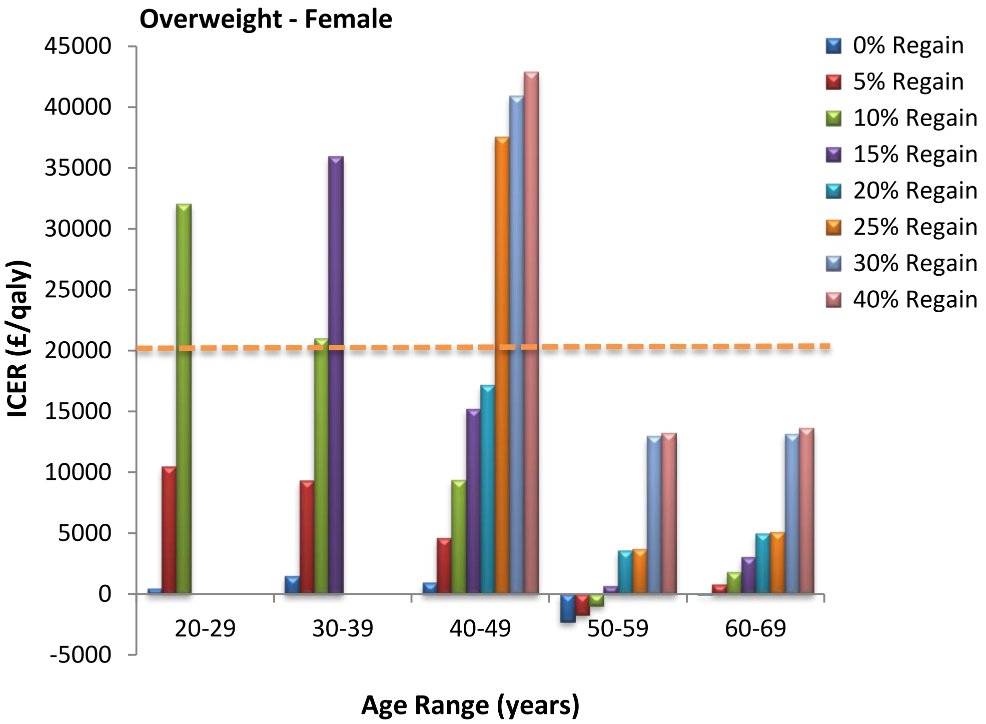

Figure 23: 23: ICER (£/QALY) by age range, BMI % weight regain per annum for overweight female (The ICER were not shown if greater than £45,000).

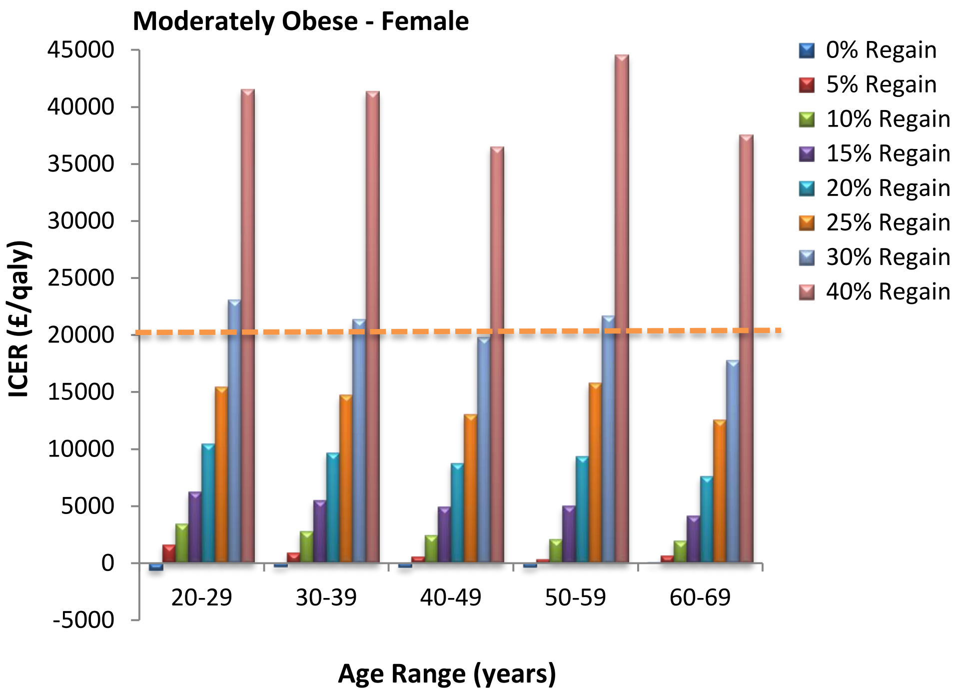

Figure 24: ICER (£/QALY) by age range, BMI % weight regain per annum for moderately obese female (The ICER were not shown if greater than £45,000).

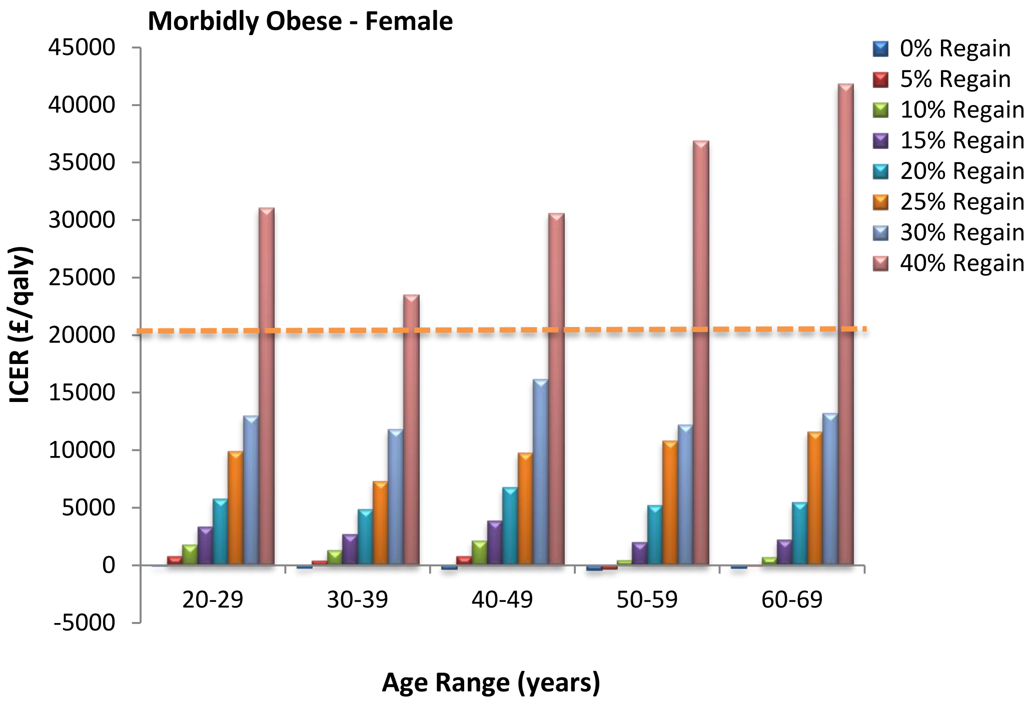

Figure 25: ICER (£/QALY) by age range, BMI % weight regain per annum for morbidly obese female (The ICER were not shown if greater than 45kg/m^2

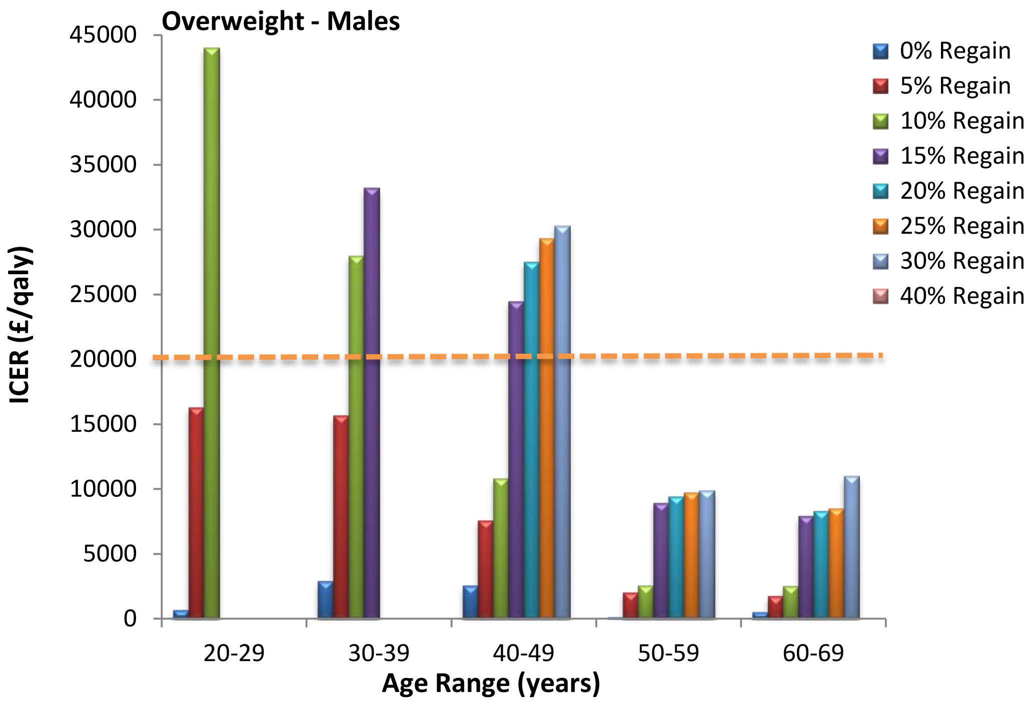

Figure 26: ICER (£/QALY) by age range, BMI % weight regain per annum for overweight male (The ICER were not shown if greater than £45,000).

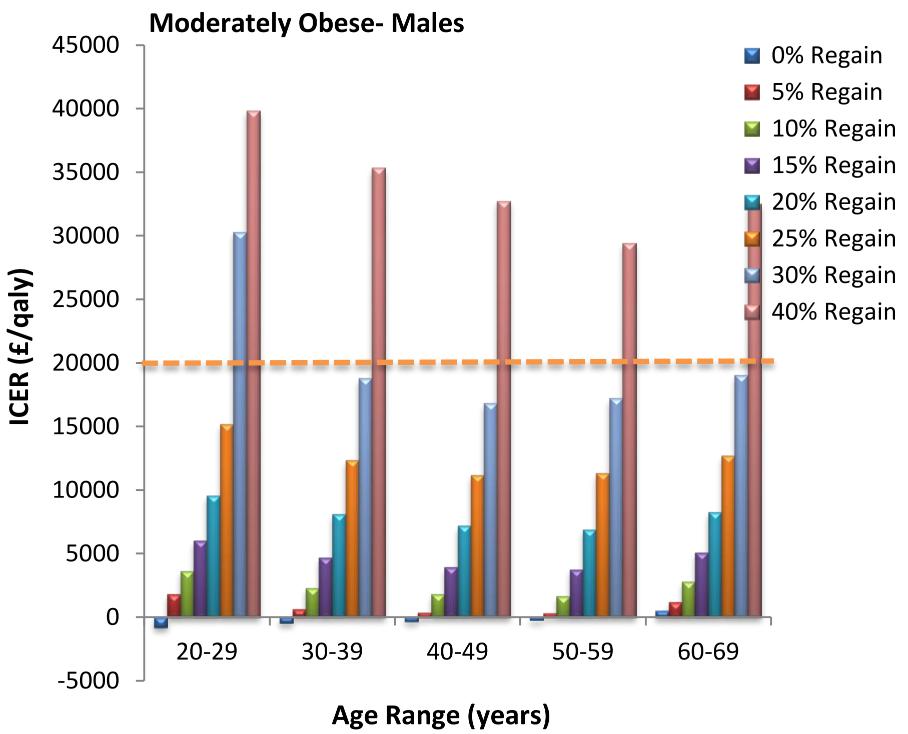

Figure 27: ICER (£/QALY) by age range, BMI % weight regain per annum for moderately obese male (The ICER were not shown if greater than £45,000).

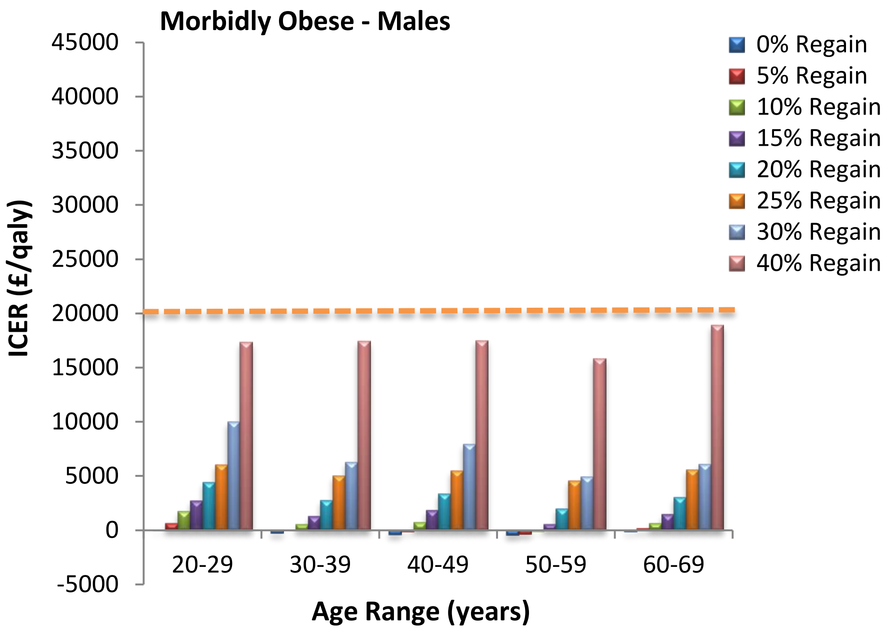

Figure 28: ICER (£/QALY) by age range, BMI % weight regain per annum for morbidly obese male (The ICER were not shown if greater than £45,000).

From these comments, the important message is shown in the following table which summarises the rate of regain of BMI [% per annum] for which the WM program is no longer cost effective:

Age		Initial BMI (kg/m²)	
	25 kg/m²	30 kg/m²	40 kg/m²
		FEMALE	
20-29	10%	30%	40%
30-39	10%	30%	40%
40-49	25%	40%	40%
50-59	>40%	30%	40%
60-69	>40%	40%	40%
		MALE	
20-29	10%	30%	>40%
30-39	10%	40%	>40%
40-49	15%	40%	>40%
50-59	>40%	40%	>40%
60-69	>40%	40%	>40%

Table 17: The rate of weight regain of BMI [% per annum] for which the WM program is no longer cost effective

6.4 Intervention 4: 2 BMI loss (about 5.2 kg loss) costing £100 per head

Few interventions would appear to reach this level of effect. Tables 18 and 19 show that if they do, they will be cost saving in the long run for all age, weight-category and sex cohorts, with the exception of the 30-39 and 40-49 'overweight' male cohorts.

Age	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
20-29	-111	-720	-212
30-39	-18	-474	-408
40-49	-252	-584	-987
50-59	-2,244	-623	-724
60-69	-710	-396	-609

Table 18: Female ICER by age group and BMI (kg/m²) for a reduction of 5.2kg for life. A negative number implies that the intervention of interest is dominant.

Age	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
20-29	-35	-1,091	-210
30-39	832	-585	-368
40-49	586	-585	-587
50-59	-1,321	-489	-708
60-69	-454	-86	-718

Table 18: Male ICER by age group and BMI (kg/m²) for a reduction of 5.2kg for life A negative number implies that the intervention of interest is dominant.

As for intervention 3 (loss of 1 BMI point) there is a distinction to be made by age for men and women in the 'overweight' category. To be cost effective, for those on cohorts up to the age of 40, weight regain must not take place for 10 to 20 years or more; for those aged 40-49, it must not take place for at least 4 years, and for those over 50, it should not take place for about 3 years.

For both men and women of all age cohorts in the 'moderately' and 'morbidly' obese weight categories, cost effectiveness is estimated to occur if weight is not regained within about 3 years.

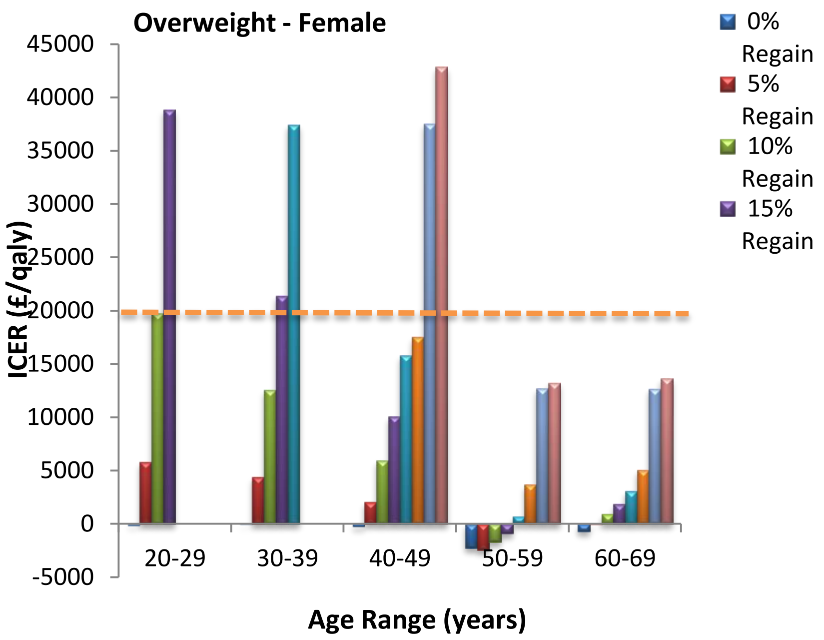

Figure 29: ICER (£/QALY) by age range, BMI % Weight regain per annum for overweight female (The ICER were not shown if greater than £45,000).

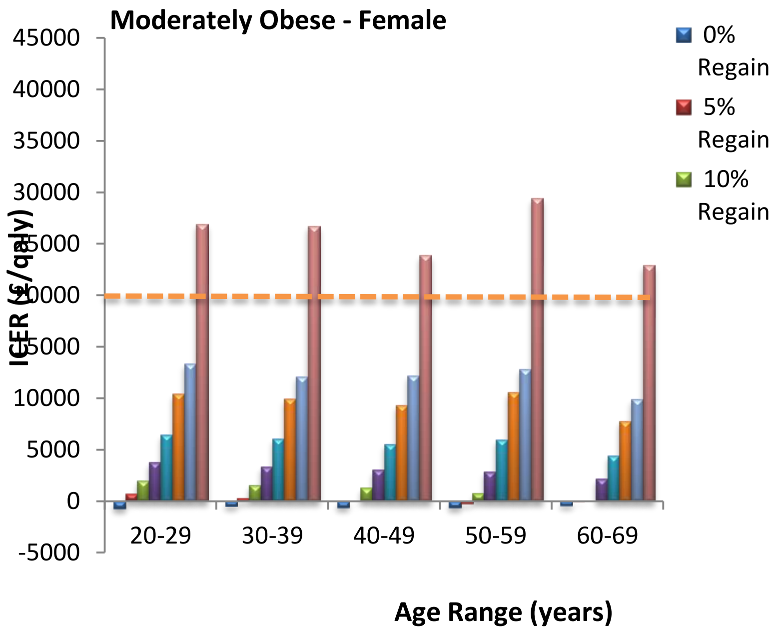

Figure 30: ICER (£/QALY) by age range, BMI % Weight regain per annum for moderately obese female (The ICER were not shown if greater than £45,000).

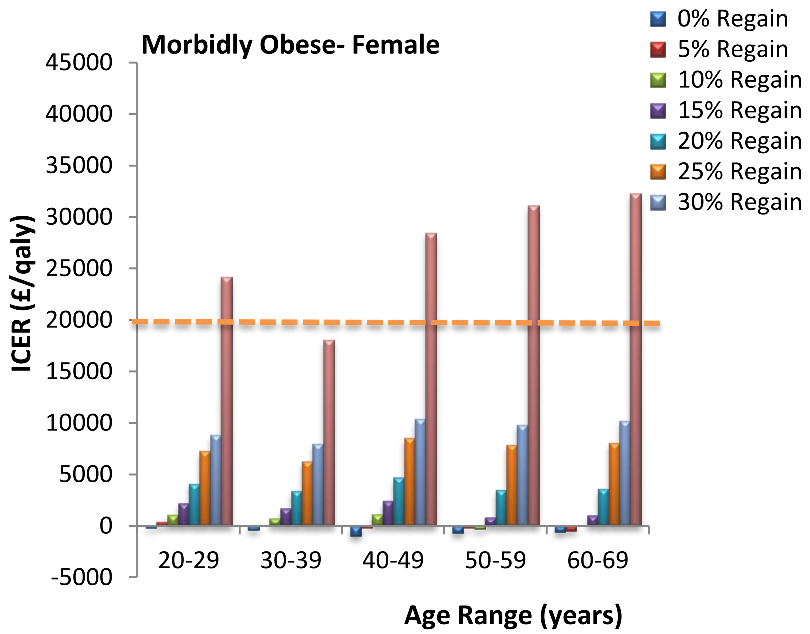

Figure 31: ICER (£/QALY) by age range, BMI % Weight regain per annum for morbidly obese female (The ICER were not shown if greater than £45,000).

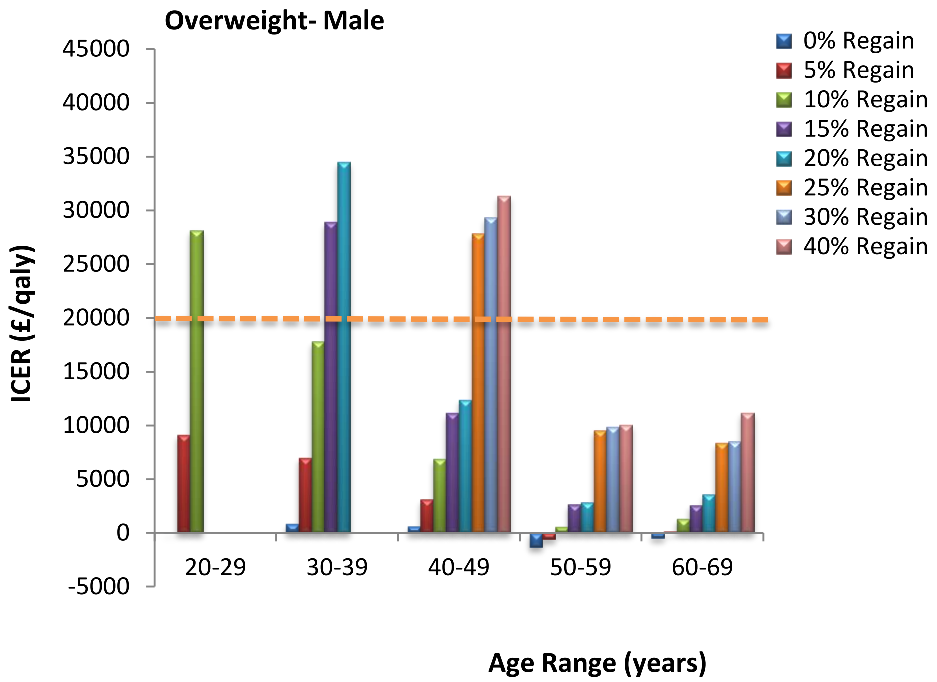

Figure 32: ICER (£/QALY) by age range, BMI % Weight regain per annum for overweight male (The ICER were not shown if greater than £45,000).

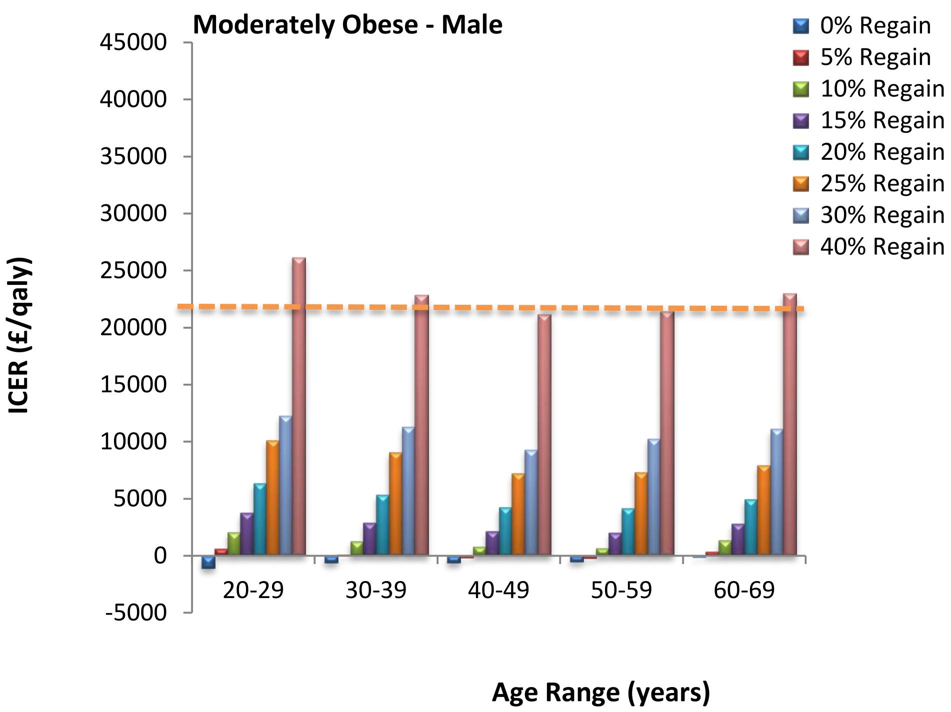

Figure 33: ICER (£/QALY) by age range, BMI % Weight regain per annum for moderately obese male (The ICER were not shown if greater than £45,000).

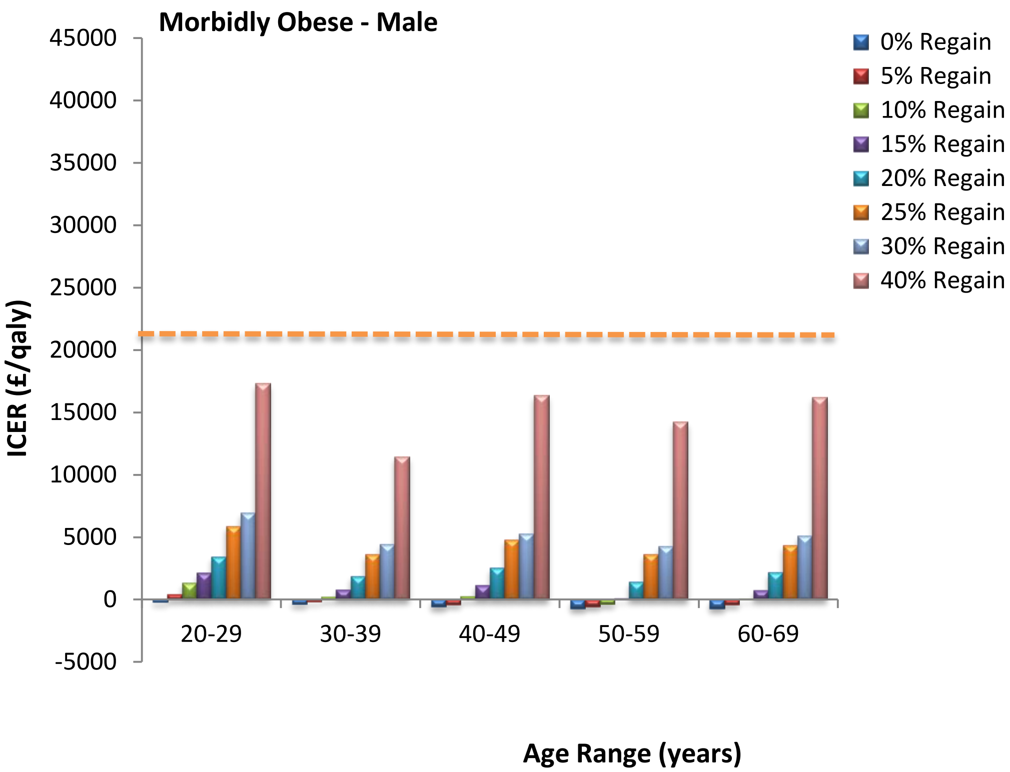

Figure 34: ICER (£/QALY) by age range, BMI % Weight regain per annum for morbidly obese male (The ICER were not shown if greater than £45,000).

Age	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
FEMALE			
20-29	10%	40%	40%
30-39	15%	40%	>40%
40-49	30%	40%	40%
50-59	>40%	40%	40%
60-69	>40%	40%	40%
MALE			
20-29	10%	40%	>40%
30-39	15%	40%	>40%
40-49	25%	>40%	>40%
50-59	>40%	>40%	>40%
60-69	>40%	40%	>40%

Table 19: The rate of Weight regain of BMI [% per annum] for which the WM program is no longer cost effective

6.5 Intervention 5: 3 BMI loss (about 7.8 kg loss) costing £100 per head

Few interventions will reach this level in terms of population average weight loss. Those that do are estimated to be cost saving in the long run for almost all cohorts.

Age	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
20-29	-391	-675	-675
30-39	-653	-568	-568
40-49	-1,618	-686	-686
50-59	-1,904	-780	-780
60-69	-975	-598	-598

Table 20: Female ICER by age group and BMI (kg/m²) for a reduction of 7.8 kg for life. A negative number implies that the intervention of interest is dominant.

Age	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
20-29	-267	-293	-293

30-39	-574	200	200
40-49	-1,441	-1	-1
50-59	-991	-1,633	-1,633
60-69	-882	-669	-669

Table 21: Male ICER by age group and BMI (kg/m²) for a reduction of 7.8 kg for life. A negative number implies that the intervention of interest is dominant.

Once again, the results are similar to those already seen in interventions where lower amounts of weight are lost. For overweight cohorts under the age of 40, weight should not be fully regained within 10 years for the intervention to be cost effective. For overweight cohorts above this age, and for the two obese categories of all age cohorts for both men and women, full weight-regain should not occur within 3 or 4 years for the intervention to be cost effective.

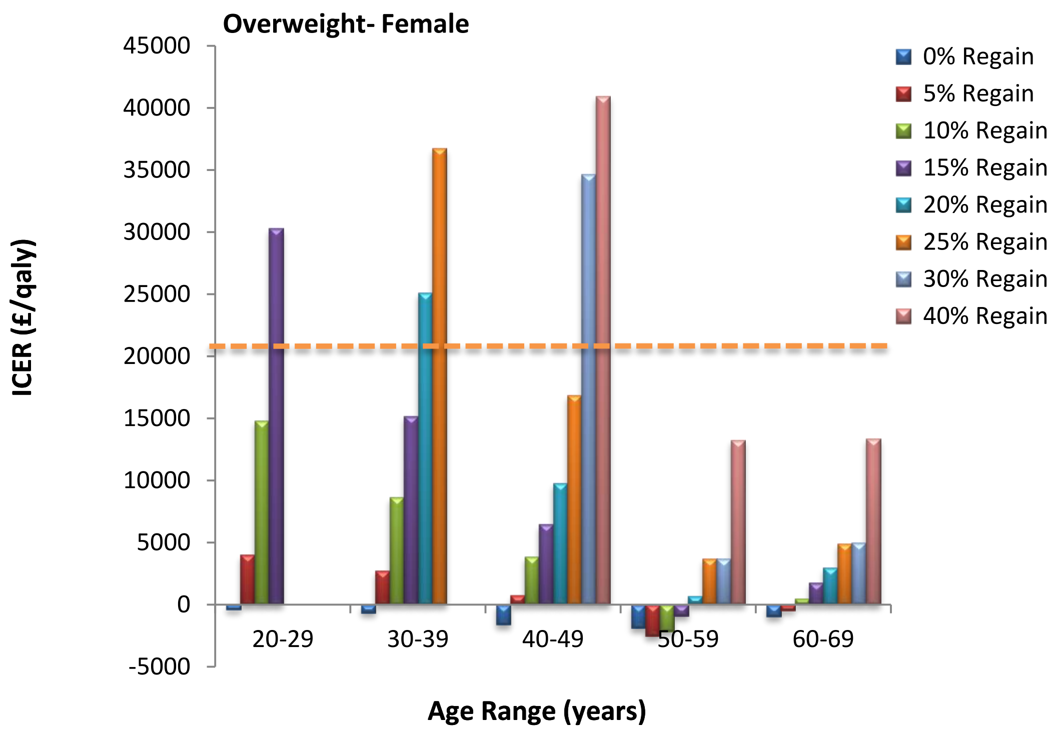

Figure 35: ICER (£/QALY) by age range, BMI % Weight regain per annum for overweight female (The ICER were not shown if greater than £45,000).

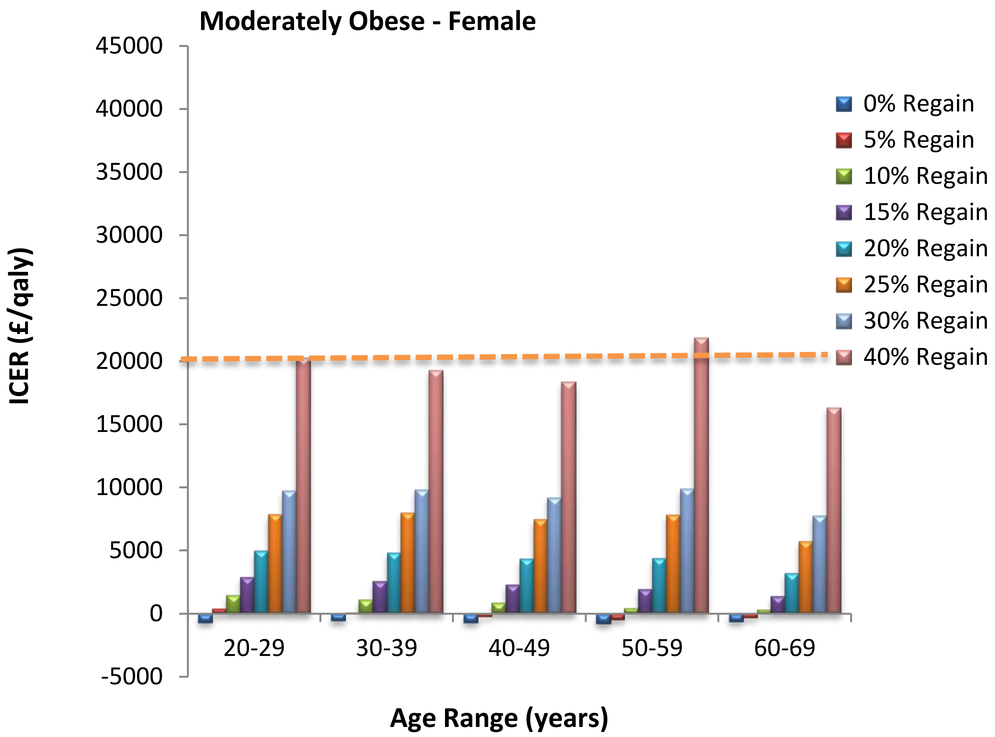

Figure 36: ICER (£/QALY) by age range, BMI % Weight regain per annum for moderately obese female (The ICER were not shown if greater than £45,000).

Figure 37: ICER (£/QALY) by age range, BMI % Weight regain per annum for morbidly obese female (The ICER were not shown if greater than £45,000).

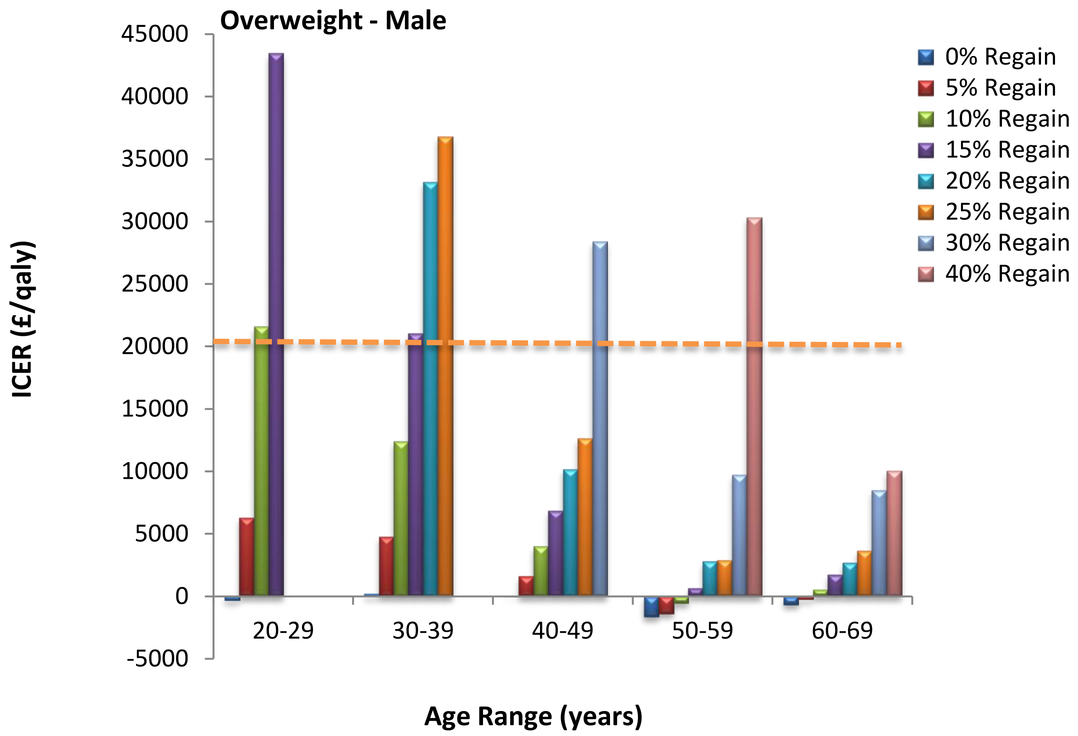

Figure 38: ICER (£/QALY) by age range, BMI % Weight regain per annum for overweight male (The ICER were not shown if greater than £45,000).

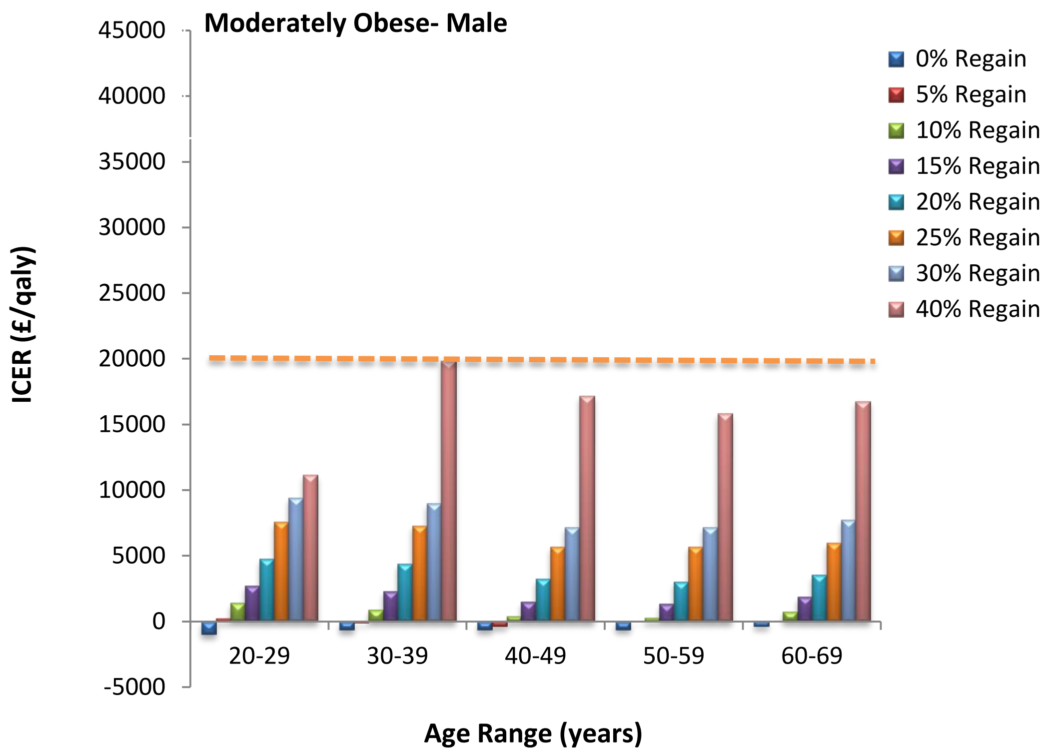

Figure 39: ICER (£/QALY) by age range, BMI % Weight regain per annum for moderately obese male (The ICER were not shown if greater than £45,000).

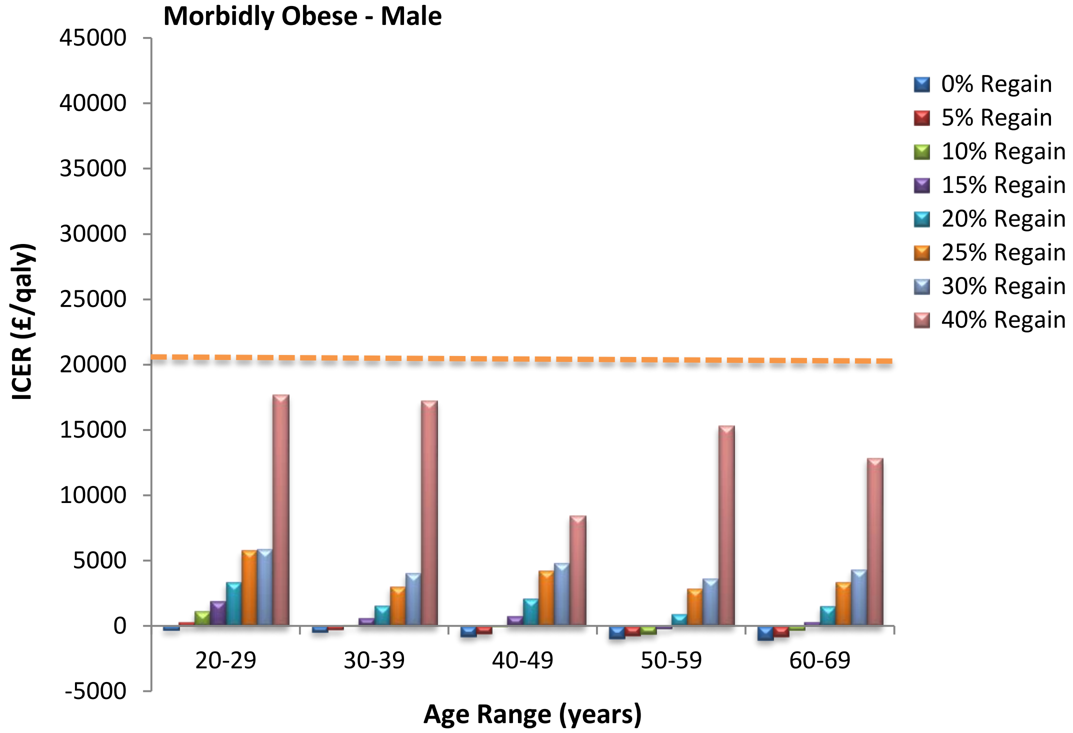

Figure 40: ICER (£/QALY) by age range, BMI % Weight regain per annum for morbidly obese male (The ICER were not shown if greater than £45,000).

Age	Initial BMI (kg/m²)		
	25 kg/m²	30 kg/m²	40 kg/m²
FEMALE			
20-29	15%	40%	>40%
30-39	20%	>40%	>40%
40-49	30%	>40%	40%
50-59	>40%	40%	40%
60-69	>40%	>40%	40%
MALE			
20-29	10%	>40%	>40%
30-39	15%	40%	>40%
40-49	30%	>40%	>40%
50-59	40%	>40%	>40%
60-69	>40%	>40%	>40%

Table 22: The rate of Weight regain of BMI [% per annum] for which the WM program is no longer cost effective

6.6 Cohorts differentiated by price (Intervention cost £100/ £500/ £1000/£1500)

The results presented in the previous sections are for a hypothesised intervention cost of £100. The results presented in this section compute ICER values for the estimated intervention costs of £100/ £500/ £1000 / £1500 (Figure 41). As expected, the greater the intervention cost, the higher the ICER – all that has changed is the initial cost.

For a given BMI loss and associated change in QALYs, the variation of ICER with Intervention Cost is a linear relationship (see eq 5), the slope being given by the inverse of the change in QALYs effected by the change in BMI. In Figure 41 it is possible to see the linear relationship among the columns of the same colour. The (linear) effect the intervention cost is shown with reference to the particular 50-59 year old, Overweight, Female Cohort who lose 0.3,0.6,1.0, 2.0 and 3.0 BMI points and do not regain the weight lost. The same data are redrawn in Figure 42, making the linear relationship clearer.

As a general rule: the smaller the BMI loss, the smaller the change in the quality of Life, the more rapid growth of the ICER and the greater the effect of the Intervention Cost.

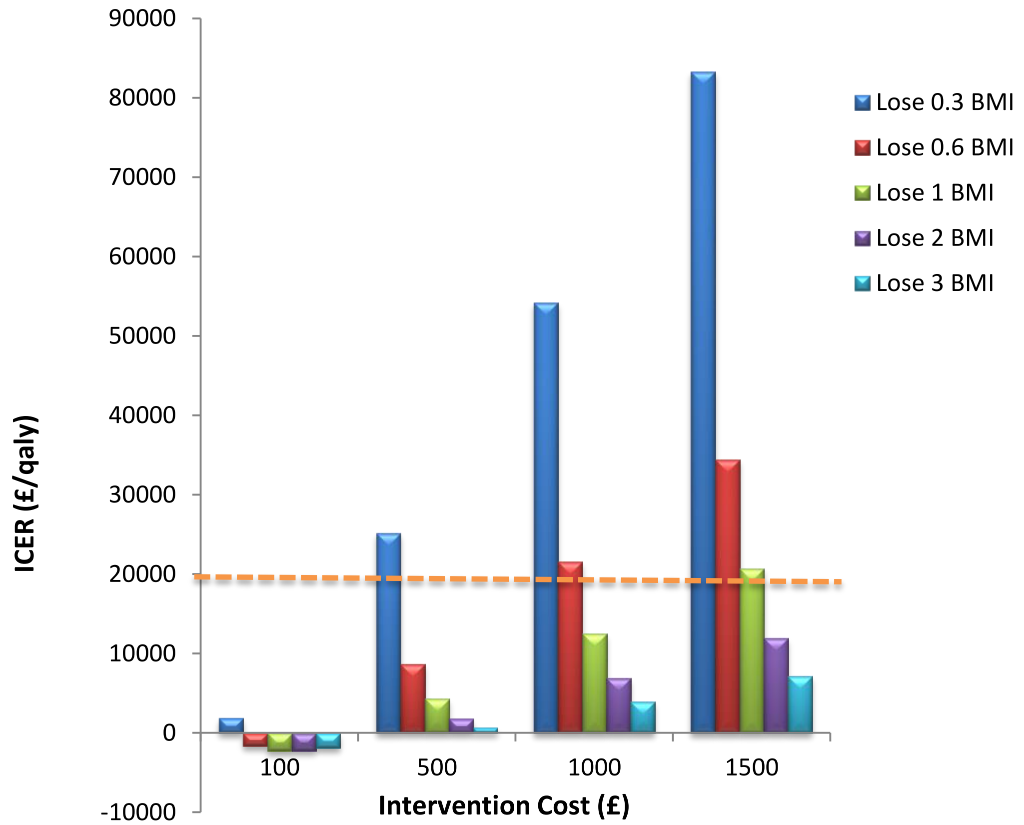

Figure 41. Effect of intervention cost on ICER

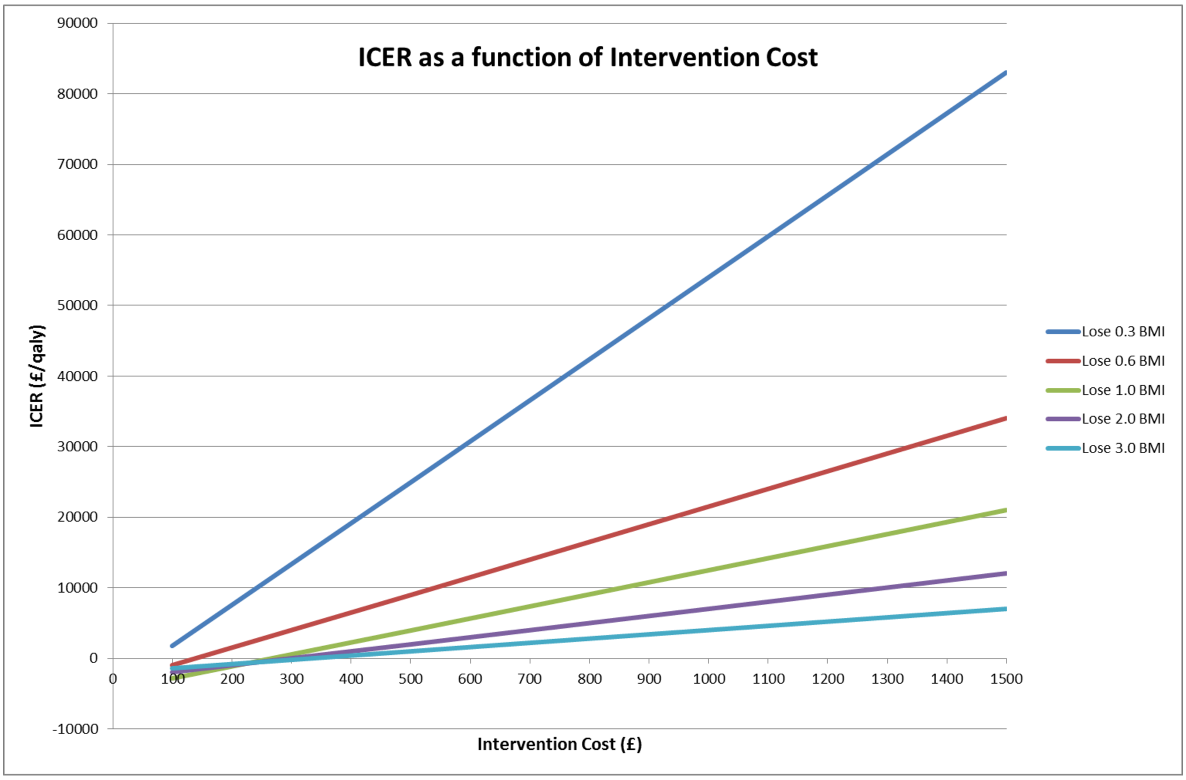

Figure 42: Effect of intervention cost on ICER showing the linear relationship between ICER and Intervention Cost

6.7 Summary

BMI tends to increase naturally with age and increases most after middle age. The UK's proportion of people with BMI greater than 25 continues to rise annually. BMI is a significant risk factor for a number of BMI-related diseases. These diseases mostly afflict people from middle to old age. The chances of contracting these diseases increase once an adult's BMI is greater than 25 and can increase by factors of 10 as they become seriously obese. A person's quality of life, as measured by utility, decreases with increasing BMI.

An Intervention directed at lowering the BMI of a group of people will make cost savings by lowering the incidence of BMI-related diseases. The same intervention will cause an improvement in the quality of life of individuals from their reduced BMI.

All of these effects are captured by the model used in this study.

6.7.1 The larger picture – weight loss and weight maintenance

At present, the statistical understanding of life-time weight control is limited.

It is known that over a lifetime it is normal for an adult's BMI to increase significantly: for example, in the UK in 2011, 20 year old males differed by about 5 BMI points from 70 year old males and the weight of females similarly increased. With nationally increasing obesity levels this tendency can be expected to increase.

The interventions described in this section vary in their initial BMI loss and in the number of years taken to recover the weight. Here, recovering the weight is understood to mean 'returning to the original percentile' – the weight is recovered gradually over the specified number of years. For any individual in an intervention what matters it is the length of time and the amount by which their BMI score is reduced from its value at the same year in the undisturbed BMI-trajectory. The results presented above vary with the age and gender and BMI of the cohorts. *Interventions on cohorts that can achieve a sustained, significant reduction in BMI for the BMI-related disease years will produce lower ICER values.*

It is important not to conflate a cost effective intervention with the intervention that may be necessary to restore a cohort or an individual to a good state of health – removing 1 BMI point from a severely obese individual may be cost effective and it will improve their health but they will still be left with an enhanced and serious risk of developing BMI related diseases. So it should not necessarily be considered to be a fully effective intervention just because it is cost effective.

The second is that one should not confuse the most cost effective intervention with the most desirable – there are many possible ways of reducing BMI. This report does not say which are good or bad, it merely provides the numbers by which they can be scored. With that caveat, the message that interventions which achieve lifelong weight reduction are much more cost effective than relatively shorter term measures is an important one. Here it is loosely assumed that they can be delivered for similar costs; in practice this may not be true. It is true that the majority of the population need to reduce their BMI for their life time and it is necessary to find cost effective ways of doing that. At the time of writing this report it is simply not known which those long term interventions are.

7 Effect of data uncertainties

7.1 Uncertainty in ICER

The expression for the ICER value can be regarded as a random variable, itself composed of a number of dependent random variables C_I, Δ_{DI}, Δ_{QI}. These random variables are related by the equation

$$ICER = \frac{C_I - \Delta_{DI}}{\Delta_{QI}}$$

eq 4

The standard method for obtaining the combined error from a number of component errors in its constituents is to expand the random variable in a Taylor series[7] about its mean value. Here this is achieved as follows. Denoting mean values by <> brackets, we write

[7] This method is known as *delta method; Oehlert GW, 1992; A Note on the Delta Method; The American Statistician, Vol.46, No.1, 27-29*

$$C_I = \langle C_I \rangle + \delta C_I$$
$$\Delta_{DI} = \langle \Delta_{DI} \rangle + \delta \Delta_{DI}$$
$$\Delta_{QI} = \langle \Delta_{QI} \rangle + delta \Delta_{QI}$$

eq 5

Equation 5 can then be expanded

$$\mathrm{ICER} = \langle \mathrm{ICER} \rangle + \frac{1}{\langle \Delta_{QI} \rangle}\left(\delta C_I - \delta\Delta_{DI} - \langle \mathrm{ICER} \rangle \delta\Delta_{QI}\right) + \ldots$$
$$\Rightarrow$$
$$\left\langle \left(\mathrm{ICER} - \langle \mathrm{ICER} \rangle\right)^2 \right\rangle = \frac{1}{\left(\langle \Delta_{QI} \rangle\right)^2}\left(\langle \delta C_I \delta C_I \rangle + \langle \delta\Delta_{DI}\delta\Delta_{DI} \rangle + \left(\langle \mathrm{ICER} \rangle\right)^2 \langle \delta\Delta_{QI}\delta\Delta_{QI} \rangle\right) + \ldots$$

eq 7

Equation 7 makes the assumption that the errors in the individual components are uncorrelated, $\langle \delta\Delta_{DI}\delta\Delta_{QI} \rangle = 0$, etc. and that the expectation values of the higher moments of the distribution are small compared with the mean. With the exception of the dependence of both Δ_{DI}, Δ_{QI} on possible errors in BMI these are reasonable assumptions. The variation of the ICER values with changes in BMI is discussed separately in the next section; here we shall take the BMI values as given.

The standard error in the cost estimates ($\sqrt{<\delta C_I \delta C_I>}$) is not listed in this report but a reasonable estimate might be that it is of the order of 5% of the cost C_I. (The 95% confidence limit is approximately $\pm$ twice the standard error.)

The standard error in the disease cost is again not listed in the report. However, experience would suggest that these are possibly less well known than the intervention costs. Here we again assume that the error in Δ_{DI} is approximately 2.5% of its vale.

The errors in the QALY values are tabulated and are approximately 1% of the QALY value.

Summarising these estimates we have

$$\sqrt{\langle \delta C_I \delta C_I \rangle} \approx 0.025 \times C_I$$
$$\sqrt{\langle \delta\Delta_{DI}\delta\Delta_{DI} \rangle} \approx 0.025 \times \Delta_{DI}$$
$$\sqrt{\langle \delta\Delta_{QI}\delta\Delta_{QI} \rangle} \approx 0.01 \times \Delta_{QI}$$

eq 8

The consequent 95% confidence limits for the errors in ICER values are obtained by substitution into eq 8.

7.2 Uncertainties in BMI

There are several sources of error in the BMI data supporting this study.

The original BMI distributions inferred from survey data (HSE, 2010) are subject to errors arising from sample size. Each survey is of approximately 20,000 people equating to approximately 1000 in each ten-year age-gender group.

The graphs drawn in Figure 9 and Figure 10 show the data points and predicted trends for the age group 40 to 49 for males and females respectively. The shaded red areas are the 95% confidence regions for the predicted proportion of obese people; the blue region corresponds to overweight and the green to normal weight. The solid coloured lines show the maximum likelihood prediction. The short vertical coloured lines show the 95% confidence intervals for the data points. Other (less likely) sets of trend lines could be drawn: 95% of them would fall in the coloured regions; they would tend to focus in the middle of the data points (around 2002) and would also have the property that in any year the sum of the red, green and blue values would be 1.

The graphs are generated automatically from a purpose built computer program and use labels fro a wide range of different BMI classifications. For the graphs shown here the International Obesity Task Force (OTF) classification is used, which for adults may be defined as bmi<25 = OTFok, 25<bmi<30 = OTFow, bmi>30 = OTFob} .

The properties of the set of all possible trend lines are contained in the regression coefficients (a_1,b_1; a_2,b_2) and their 4x4 joint, posterior, probability distribution function. The trend lines have equations

$$p_{ok}(t) = \frac{1}{1 + e^{a_1 + b_1 t} + e^{a_2 + b_2 t}}$$
$$p_{ow}(t) = \frac{e^{a_1 + b_1 t}}{1 + e^{a_1 + b_1 t} + e^{a_2 + b_2 t}}$$
$$p_{ob}(t) = \frac{e^{a_2 + b_2 t}}{1 + e^{a_1 + b_1 t} + e^{a_2 + b_2 t}}$$

eq 6

p_{ok}, p_{ow}, p_{ob} refer to the normal – green, overweight-blue and red-obese lines respectively.

A complete error analysis of the variation in ICER values consequent on this type of variation in BMI predictions would involve a Monte Carlo analysis of the ICER computation and is beyond the scope of this report.

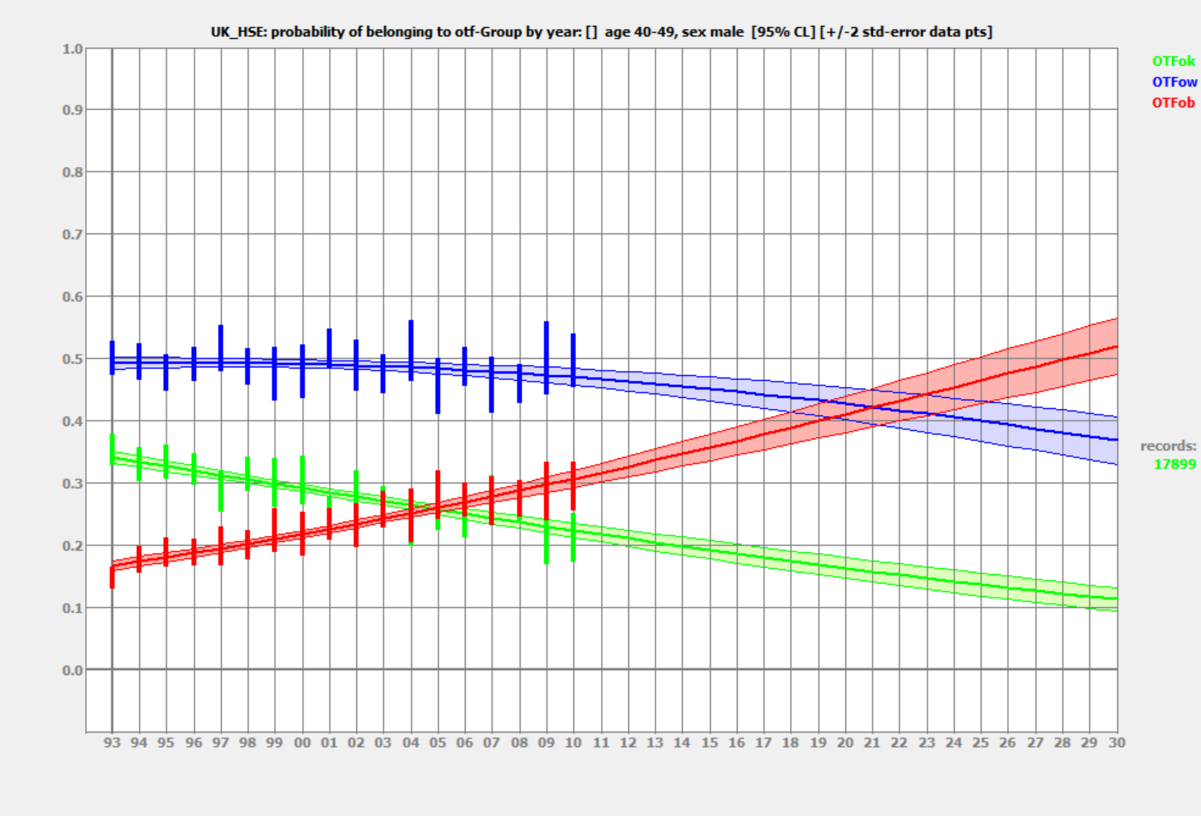

Figure 43: Predicted male (ages 40 to 49) BMI distributions {bmi<25 = OTFok, 25<bmi<30 = OTFow, bmi>30 = OTFob} from 1993 to 2030 for the HSE data sets {1993 to 2010} showing 95% confidence intervals

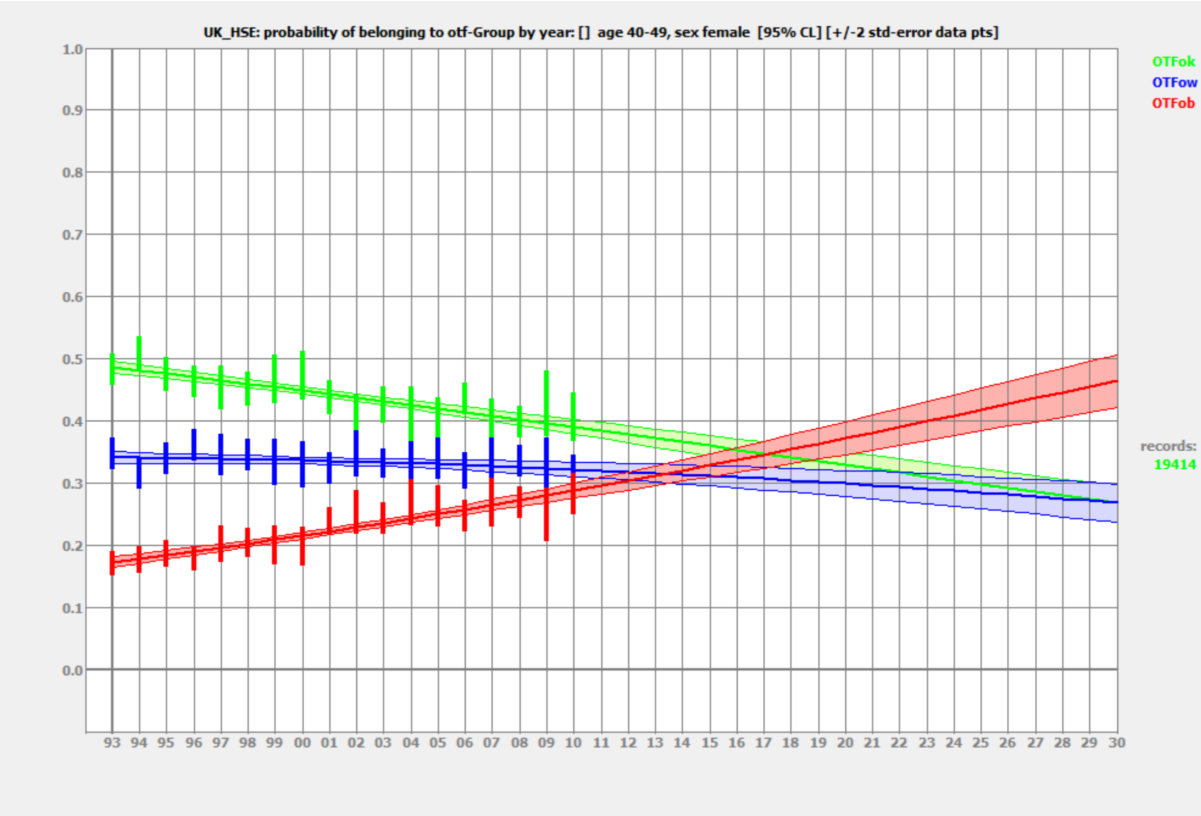

Figure 44: Predicted female (ages 40 to 49) BMI distributions {bmi<25 = OTFok, 25<bmi<30 = OTFow, bmi>30 = OTFob} from 1993 to 2030 for the HSE data sets {1993 to 2010} showing 95% confidence intervals

In order to give some appreciation of the magnitude of the effect on the ICER calculation arising from the variation in these uncertainties in the BMI trends the following results (Table 24 and Table 25) were derived by the model using a BMI file in which the slope of the p_{ob} trend was increased by 1 standard deviation in all of its component distributions. In each case the column headed ICER(ML+σ) gives the new result, the results reported earlier for the maximum likelihood trajectory are repeated for comparison purposes in the column headed ICER(ML).

Male		
BMI Loss	ICER(ML +σ)	ICER(ML)
-0.5%	18,394	4,889
-1.0%	9,226	3,600
-1.5%	6,178	2,809
-2.0%	4,726	2,305
-3.0%	3,240	1,724
-5.0%	1,898	1,148

Table 23: ICER as a function of I-sigma variation in BMI trend

Female		
BMI Loss	ICER(ML+σ)	ICER(ML)
-0.5%	12,822	7,574
-1.0%	7,260	5,661
-1.5%	5,308	4,373
-2.0%	4,170	3,512
-3.0%	2,707	2,481
-5.0%	1,542	1,284

Table 24: ICER as a function of 1-sigma variation in BMI trend

The results are similar for males and females and tend to make the same intervention less cost effective – it makes the population more obese and harder to remove the weight in a cost-effective manner.

Of course, the future BMI distributions may not correspond to the predicted trend lines at all. In matching a trend to a set of data a judgement has to be made as to the appropriate functional dependence. Here that choice is manifest in the logistic functions used in eq 6. They are chosen to represent a set of probabilities that must sum to unity and otherwise to have a linear-like, slowly varying dependence on time. They have proved to be very successful in capturing a wide class of different obesity growths, there is no reason to suppose that one would wish to choose a different functional form but that is not to say that what has been chosen is necessarily correct.

8 Sensitivity Analysis

The relative impact of each parameter (cost, BMI, QALY) on the ICER was evaluated. The incremental ICER change was obtained for each parameter by increasing the parameter value by 5%. Ranking identified the parameters which most influenced the ICER. The parameters of interest were QALY, Costs, individual BMI. The current study shows the impact that relative importance of the parameters of importance on the ICER and consequently the effect it has on the cost effectiveness of the intervention.

For a 20 year-old female of BMI of 29kg/m2 and 26kg/m2 in 2010 and 2011 respectively, the change of 5% in BMI, cost and QALY introduced a change of 27%, 13% and 9% respectively in the ICER value (Figure 45).

Let the ICER be £18,000. The change of QALY values by 5% does not change the status of the intervention i.e. cost effective. However, if the cost is changed from £100 to £105, then the intervention is no longer cost effective.

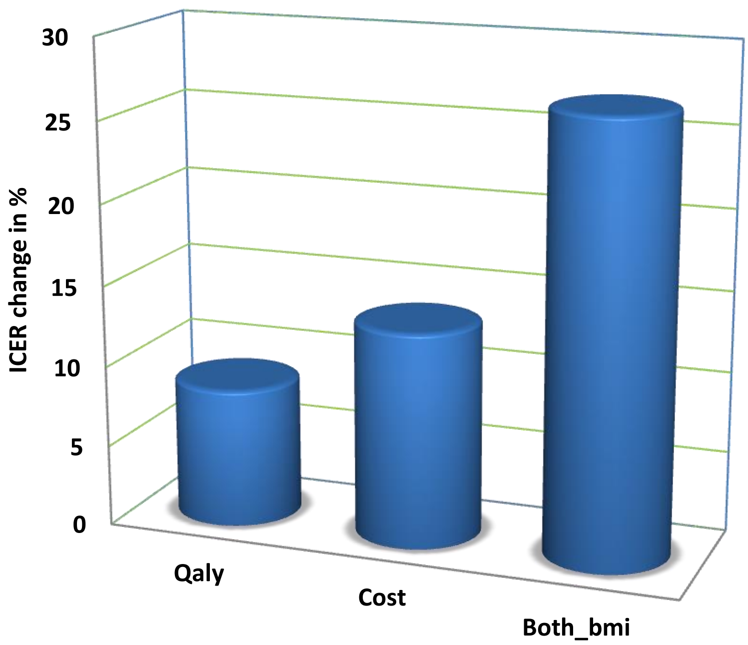

Figure 45. Effect of 5% change in Qaly, Cost and BMI on ICER

9 Summary of the results

Our economic modelling shows that critical elements in the likely cost effectiveness are the gender, initial BMI, age, rate of regain of BMI [% per annum] and the intervention cost whose effects are described in sections 7, 8 and 9. The general comments that one can make for most of the data shown in the present report are the following:

1. ICERs for the cohorts of people considered are small compared with the NICE threshold (below £20,000 per QALY) for most of the interventions studied in the present report whose costs were set at £100, provided that weight regain does not return the cohort to its per-intervention trajectory.

2. The parameters which have the most impacts on the ICER and consequently on the cost effectiveness of the interventions are the BMI, gender, cost of the interventions, the number of kilograms lost during the intervention and the regain of BMI% per annum.

3. For the moderately obese and the morbidly obese groups of both men and women of all age cohorts from 20 to 70 years, even very small losses of weight, such as 0.3 BMI points (or about 1 kg, depending on height) need to be lost for the intervention to be estimated to be cost effective, as long as weight does not return to its pre-intervention trajectory for about 5 years.

4. In order to select the best intervention from the following table, assuming the fact that weight is always regained either at short or long term:

Sections, 6.1 to 6.5, provide ICER values for: 2 gender groups {male, female}, 3 BMI groups {overweight, obese, morbidly obese} , 5 weight-loss interventions {0.8 kg, 1.6 kg, 2.6 kg, 5.2 kg, 7.2 kg} with the weight being recovered at {0, 5, 10, 20, 25, 30, 40} per cent per annum. For each intervention and cohort there will be a rate of weight regain above which the intervention ceases to be cost effective. These results are recorded here and are the same as those shown in Table 1 of the Executive Summary.

Parameters	0.8 kg loss	1.6 kg loss	2.6 kg loss	5.2 kg loss	7.8 kg loss
Female					
BMI 25 kg/m² Age 20-29	5%	10%	10%	10%	15%
BMI 25 kg/m² Age 30-39	5%	10%	10%	15%	20%
BMI 25 kg/m² Age 40-49	5%	20%	25%	30%	30%
BMI 25 kg/m² Age 50-59	>30%	>40%	>40%	>40%	>40%
BMI 25 kg/m² Age 60-69	>30%	>40%	>40%	>40%	>40%
BMI 30 kg/m² Age 20-29	20%	25%	30%	40%	15%
BMI 30 kg/m² Age 30-39	20%	25%	30%	40%	20%
BMI 30 kg/m² Age 40-49	20%	30%	40%	40%	30%
BMI 30 kg/m² Age 50-59	20%	25%	30%	40%	>40%
BMI 30 kg/m² Age 60-69	25%	30%	40%	40%	>40%
BMI 40 kg/m² Age 20-29	30%	30%	40%	40%	>40%
BMI 40 kg/m² Age 30-39	30%	40%	40%	>40%	>40%
BMI 40 kg/m² Age 40-49	30%	30%	40%	40%	40%
BMI 40 kg/m² Age 50-59	30%	40%	40%	40%	40%
BMI 40 kg/m² Age 60-69	30%	40%	40%	40%	40%
Male					
BMI 25 kg/m² Age 20-29	5%	5%	10%	10%	10%
BMI 25 kg/m² Age 30-39	5%	5%	10%	15%	15%

BMI 25 kg/m^2 Age 40-49	5%	10%	15%	25%	30%
BMI 25 kg/m^{2}Age 50-59	5%	>40%	>40%	>40%	40%
BMI 25 kg/m^2 Age 60-69	0%	>40%	>40%	>40%	>40%
BMI 30 kg/m^{2}Age 20-29	20%	30%	30%	40%	>40%
BMI 30 kg/m^2 Age 30-39	20%	30%	40%	40%	40%
BMI 25 kg/m^2 Age 40-49	5%	30%	40%	>40%	>40%
BMI 30 kg/m Age 50-59	25%	30%	40%	>40%	>40%
BMI 30 kg/m^2 Age 60-69	20%	30%	40%	40%	>40%
BMI 40 kg/m^{2}Age 20-29	40%	>40%	>40%	>40%	>40%
BMI 40 kg/m^2 Age 30-39	40%	40%	>40%	>40%	>40%
BMI 40 kg/m^2 Age 40-49	40%	>40%	>40%	>40%	>40%
BMI 40 kg/m^{2}Age 50-59	>40%	>40%	>40%	>40%	>40%
BMI 40 kg/m^2 Age 60-69	40%	40%	>40%	>40%	>40%

(Table 1) Rate of weight regain per annum at which the intervention ceases to be cost effective

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A.1 Appendix 1

10.1 National Heart Forum (UKHF)

The UK Health Forum (UKHF) modelling team have extensive experience in modelling the impact of obesity on health and economy. For a list of previous modelling work undertaken by the UKHF team, please see: http://www.mhsimulations.co.uk/

10.2 University of East Anglia Health Economics Group (UEA HEG)

The UEA Health Economics Group (HEG) was established in 1997. Health Economics Consulting (HEC) is a University of East Anglia Enterprise, a fully-owned subsidiary of the university. For a list of previous modelling work undertaken by the HEC team, please see: http://www.healtheconomicsconsulting.co.uk/

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10.4 Acknowledgements

NICE Team
NICE PDG Economics group members

Appendix 2

10.5 Modelling concept

The model allows the user, at run-time, to partially specify the setup for each run. In addition the model relies on many supporting data files and these must be provided in suitable formats for access by the model during the run. The complete set of data inputs, user inputs and supporting data, are logged and appended to the set of output files generated by the run.

The following subsections briefly describe the nature and number of the data used.
Each run of the model is specified by its complete set of data inputs. These inputs consist of either supporting data in the form of named, tab-delimited text files or user-selected options made at run-time. The specifications are usefully divided into the categories listed as sub-sections below.
At the start of each run, the model reads in the input data files and creates the necessary data structures. Note that the model uses the data that are provided in this way; it does not have any pre-conceived notion of what these data are. [This feature is important in maintaining the currency of the model: all that has to be done is to update the relevant text files. It also allows better data to be used as and when they are available – for example, if better, more exhaustive, QALY data were to become available, one would merely supply the new, correctly formatted file.]

10.6 Run specification

At the start of every run of the model the user must specify the start-year, the stop-year, the target cohort (text file), the intervention (text file) and the BMI growth model to be applied in the absence of any intervention.

10.7 Cohort specification

The model's target cohort is specified by the number of members of the cohort and for each cohort member their age (years) and BMI (Kg/m^2) is valid in the start-year and their gender. For children, it is assumed they do not have diseases at the start of the simulation. The model accepts equivalent data inputs that use distributional z-scores in place of BMI values.

10.8 Intervention specification

The number of possible interventions addressed by this project is large but those acceptable to the model must consist simply of a specified series of time-stamped, costed, BMI-changes[8] to targeted sub-groups (or the totality) of the cohort's members. Interventions which, for example, make life-style changes to eating and/or exercise regimes must be pre-processed so as to be presented to the model in an acceptable format.

The model is capable of processing, suitably presented, individual level data.
Interventions are described by open format, tab-delimited text files[9]. This allows new types of interventions to be included with minimal change to the software – for example, when the software is expanded so that adults can be included.

The null-intervention consists in doing nothing other than to allow the cohorts' BMI to grow in accordance with the selected BMI growth model. It is of importance for comparative purposes.
For all members of the cohort, an Intervention must specify changes to BMI in such a way so as to fully describe the departures of the individual's BMI trajectory[10] (the BMI for every year of the simulation) from their BMI trajectory derived from the null-Intervention's BMI growth model.
At the end of the Intervention and after allowance has been made for possible regaining of weight, each cohort member's BMI growth reverts to being described by the user-selected BMI growth model from the age and BMI by then attained.

The interventions included have been informed by those shown significant by the review[11] undertaken for the PDG and subsequent meetings of the PDG.

10.9 Pre-processing

The model requires a complete set of pre-processed data files. The precise set of files depends on the user-specification of the run. Failure to have any of the necessary data files produces an error message indicating the omission.

[8] Child z-scores
[9] An open format, tab delimited text file consists of a number of headers (recognisable to the model) followed by rows of tab delimited text items <text>|<text>|…|<text>; different headers may be separated by different numbers of rows of text.
[10] An individual's BMI trajectory is a list of the individual's BMI values, one for each year from the start of the trajectory until its end.
[11] NICE Guidance title: Managing overweight and obesity among children and young people: lifestyle weight management services Review 1: Effectiveness and cost effectiveness of lifestyle weight management services for children and young people

Some form of pre-processing was necessary given the potentially huge number of possible interventions. As part of the modelling, an agreed set of interventions is both pre-processed and processed by the model. The necessary data format for additional interventions is provided.

Pre-processing usually took a form of collating, cleaning and formatting relevant intervention data using, for example, Excel. [Although the model itself will be configured as an Excel hosted Visual Basic model it is useful to maintain a functional separation of the two schemes.]

10.10 Outputs

In the first instance, as with the inputs, the model writes outputs to Excel spread sheets. These are variously written to tab delimited text files.
User-specified outputs are produced by the model and made available both on the model's output screen and as tab delimited text files. In addition the complete set of cohort state vector trajectories are filed as tab-delimited text files. The complete set of user-defined inputs, user-defined outputs, input data files and output files are recorded in time-stamped run-configuration files.

A.3 Appendix 3

10.11 Sources of data inputs

Disease		Source
Incidence	Hypertension	British Heart Foundation Statistics http://www.bhf.org.uk/research/heart-statistics.aspx
	CHD	European cardiovascular statistics 2008 http://www.herzstiftung.ch/uploads/media/European_cardiovascular_disease_statistics_2008.pdf
	Diabetes	British Heart Foundation Statistics http://www.bhf.org.uk/research/heart-statistics.aspx
	Stroke	British Heart Foundation Statistics http://www.bhf.org.uk/research/heart-statistics.aspx
	Cancer	Cancer Research UK statistics http://www.cancerresearchuk.org/cancer-info/cancerstats/
Mortality	CHD	European cardiovascular statistics 2008 http://www.herzstiftung.ch/uploads/media/European_cardiovascular_disease_statistics_2008.pdf
	Cancer	Cancer Research UK statistics http://www.cancerresearchuk.org/cancer-info/cancerstats/
Survival	CHD	Euroheart 2008 http://www.ehnheart.org/projects/euroheart/about.html
	Cancer	Recent cancer survival in Europe: a 2000-02 period analysis of EUROCARE-4 data. http://www.ncbi.nlm.nih.gov/pubmed/17714993

RR	All diseases	International Association for the Study of Obesity http://www.iaso.org/policy/healthimpactobesity/dynamohiaproject/datasourcesestimatesrelative-risk/

Table 25: Sources of data inputs

A.4 Appendix 4: Prototype of search done in Medline

	Searches	Results	
1	Quality of Lif$.m_titl.	2379	Group 1 – Outcomes
2	(quality of lif$ adj2 (EQ-5D or HRQL or QALY or outcome$ or wellness factor$)).ti,ab.	516	
3	1 or 2	2720	
4	obes$.ti,ab.	9866	Group 2- Weight
5	(obese adj2 body image$).mp.	2	

Table 26: Literature search prototype in Medline

A.5 Appendix 5: BMI, distributions and percentiles

The model pivotally uses BMI percentiles to describe BMI growth of individuals and populations. The idea is that individuals maintain a fixed BMI percentile throughout life as the BMI distributions change. The BMI distributions will change because of the ageing process and, independently, because nation obesity levels are rising.

When an individual experiences a BMI-intervention he will be shifted to a different percentile. Thus there will be two fixed percentiles of interest in his life - the pre intervention percentile and the post-intervention percentile. The gap between these percentiles is fixed by hypothesis but the associated gap in BMI will vary with the change in distributions. It is the gap in BMI that affects the individual's health.

Figure 46 shows a picture of all these things.

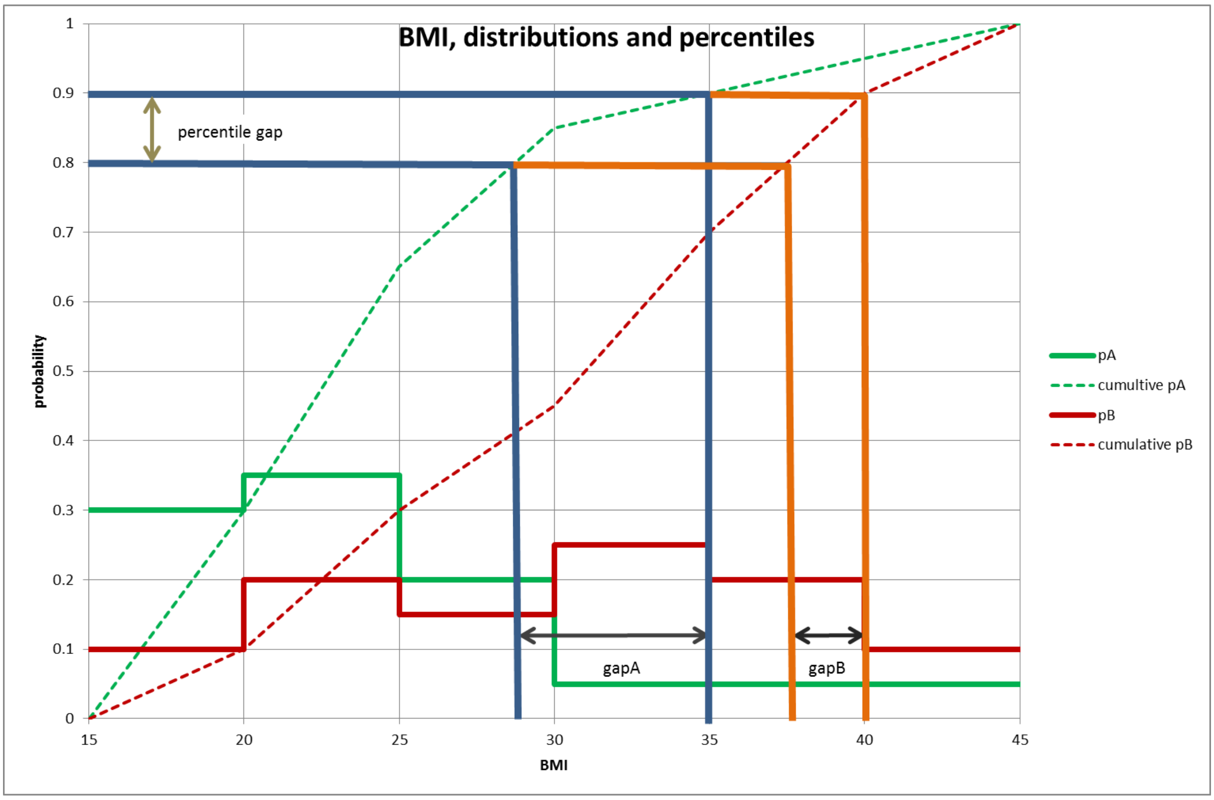

Figure 46: BMI distributions, percentiles, cumulative distributions and BMI compression

The Figure shows two BMI distributions (p_A in green and p_B in red) which have constant probability within the BMI intervals 15-20, 20-25, 25-30, 30-35, 35-40, 40-45, but which change these probabilities from one BMI-group to the next. People are assumed uniformly distributed in BMI within any BMI group.

The distributions differ in that the red distribution has a higher percentage of obese people (55%) than the green (15%). They are not intended to be particularly realistic but distributions very like those shown do arise in practice. The green might refer to a person's early life and the red to some fifty years later.

The cumulative distribution for these distributions, p_A(BMI) and p_B(BMI), are drawn in matching colours as dashed lines, starting at zero at BMI=15 and finishing at 1 for BMI=45.

The thick blue and orange lines show the 80th and 90th percentiles for the green and red distributions respectively. For these two illustrative percentiles the associated BMI gaps are denoted as gap_A for the green distribution and gap_B for the red distribution.

An intervention which lowered a person's BMI percentile from 90 to 80 would thus correspond to a reduction in BMI of gap_A (about 6.25 BMI points) when their BMI is described by the green distribution and of gap_B (about 2.5) when their BMI distribution when their BMI distribution is described by the red distribution.

For an individual experiencing an intervention lowering his BMI ranking (from 90 to 80) in his 20's say when he is part of the green distribution, his reduction in BMI will be 6.25 points. In later life, in his 60's say, when he is part of the red distribution, this same intervention amounts to only 2.5 BMI points. It has been compressed. In his 20's he gets the benefit of the full 6.25 BMI points (albeit the benefits are very few at that age); in his 60's he gets the benefit of only a reduction of 2.5 BMI points. The benefits from 2.5 points are still worth having but they are very many fewer than those that would have arisen from 6.25 BMI points at that age.

Appendix 6: The productivity cost of obesity

This annex section was prepared by Yevgeniy Goryakin, Siobhan Bourke and Marc Suhrcke at UEA

The cost-effectiveness analysis undertaken in this report adopts the perspective of the NHS, in line with NICE recommendations. Hence, only those costs (or cost-savings) are taken into account that are incurred by the NHS. Costs (or cost-savings) incurred by society at large, or by the individual participating in the intervention are not taken into account. Societal costs would for instance include the costs that occur to individuals having, for instance, to take time off work in order to attend weight management courses or activities. Excluding such societal costs makes sense if it is the NHS that is ultimately paying for the intervention in question, and/or if the costs associated with a given interventions are *mainly* located within the health sector.

During the discussions of the PDG, there was an interest in considering *one* specific aspect of societal cost savings, in the form of "productivity" benefits that might be had from a reduction in obesity. The idea behind was that if it is the case that obesity has a causal impact on productivity - here defined as earnings, wage rate, hours worked, employment probability - then a reduction in BMI that would result from the intervention might lead to increased individual productivity, first of all at the level of the individual, but at least conceivably also at the societal level. And if these productivity effects are likely to be "large", then including those effects in the form of cost reductions into the cost-effectiveness estimates in some way might well priority-setting recommendations to be derived.

In order to explore the idea further we started by conducting a rapid review of reviews).[12] We have identified a number of relevant and fairly recent reviews on the subject and have extracted a set of primary studies from those reviews. In the selection of the primary studies we focused our attention on those studies that had undertaken an econometric analysis using individual level data, for instance from nationally representative household surveys. This was done because regression analysis - in particular more advanced such analysis - arguably has the greatest chance of overcoming the challenges involved in assessing the causal impact of obesity, conditional on all other relevant factors, on productivity. We have then complemented the review of reviews by a rapid review of primary studies that were published from 2010 onwards. Taken together we have identified 14 primary studies Table 28

Upon assessing each of these studies, we have come to the following preliminary conclusions:

(1) Generally, the association between obesity and earnings is considerably stronger for women than men. On average, obese women earn about 4%-12% less than normal weight women. For men, the association was either insignificant, or the "penalty" was small (about 3%).
(2) However, there is some evidence that the effect of obesity on earnings is significant for men at the bottom of the income distribution (2% wage penalty).
(3) Similarly, the effect of obesity on the probability of being employed appears stronger for women than for men (from 3% up to 10% employment probability reduction for women, and either insignificant, or small reduction in males). In addition, unemployment spells are longer for obese compared to non-obese (with women less likely to regain employment than men).
(4) The fact that studies that used BMI as the independent variable have tended not to find a significant effect on the measures of "productivity", while using obesity status did often find such effects, suggests that the relationship between weight and productivity is non-linear.
(5) A range of fairly advanced methods are used in the studies. At the very least, studies used multiple regression OLS/Probit models, controlling for a range of confounders. In addition, several studies applied other methods, such as IV regression, quintile regression, matching, fixed effects. Attempts to account for problems of reverse causality etc. were – perhaps unexpectedly – the rule rather than exception.

[12] While we have - in light of very tight time and resource constraints - adopted an explicit search strategy (see below) for both, we have limited the search to the literature database Medline.

(6) In some studies, applying methods that controlled for problems such as reverse causality changed the results from significant to insignificant effects (e.g. Lindeboom (2010), while in others the significance of the effects were maintained (Morris 2007).
(7) Significant association was also found between obesity and short and long term illness-related spells out of work.
(8) For some alternative indicators of obesity, significant effects were found (e.g., waist circumference, body fat, BMI)
(9) Inter-study comparisons are sometimes complicated because reference groups differ (e.g., obese are sometimes compared to normal, and sometimes to non-obese. However, in the majority of cases, obese are compared to normal).

What does this mean for the idea of including some of these effects in the cost-effectiveness estimates?

First, we believe that because of the apparent non-linearity in the relationship between BMI and productivity (see point (4) above), a small weight loss of the kind considered in most of the modelling in this report is unlikely to make a big difference to productivity.

Second, and perhaps more fundamentally, some may object to the idea of adopting a societal perspective by including productivity effects, without then also taking into account societal cost items such as time costs or travel costs for participants in the weight management interventions.

Hence, while productivity effects do seem to exist, in particular for women, we would refrain from including them in the cost-effectiveness estimate, and instead stick to the standard NICE reference case of adopting a health care system perspective.

Table 27 Search strategy for review of reviews on productivity effects on obesity

Search strategy for review of reviews on productivity effects of obesity

1	obesity.mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	272747 hits
2	(wage or employment or unemployment).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	83012 hits
3	(absenteeism or presenteeism or "sick leave").mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	16639 hits
4	discrimination.mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	123091 hits
5	1&2	1187 hits
6	1&3	16639 hits
7	1&4	123091 hits
8	5 OR 6 OR 7	2135 hits
9	limit 8 to (English and "review" and last 20 years)	226 hits

Table 28. Tabulation of results of shortlisted primary studies on the productivity effects of obesity (n=14)

Author, Title, year	Country	Sample size	Outcome	Main independent variable	Main control variables	Main empirical strategy	Study type
Are Employers Discriminating with Respect to Weight? Vincenzo Atella, Noemi Pace and Daniela Tor Vergata Research Paper Series, 2008	Denmark, Belgium, Ireland, Italy, Greece, Spain, Portugal, Austria and Finland (the European Com-munity Household Panel (ECHP)	About 77,000 Age restricted to 25-64 years.	log hourly wage for the respondent's current job (converted into real wage, adjusted for PPP)	Obese (bmi>=30). Other categories: underweight, normal, overweight	age, education, training, health status, number of days absent from work, smoking, private or public sector of activity, occupation and sector of activity, insurance, time and country dummies	1) Poole OLS with country fixed effects 2) Quantile Regression to characterize the heterogeneous impact of obesity at different points of the wage distribution. 3) Instrumental Variable, and IV quintile regression (IVQR). IV used-averaged out BMI for all other family members.	Repeated cross-section
Bozoyan, Christiane Wolbring, Tobias. Fat, muscles, and wages. Economics and Human Biology, 2011	Germany (German Socioeconomic Panel)	About 11,000	Log-transformed hourly net wage	BMI, body fat (BF) and FFM (i.e. weight-BF).	Education, work experience training, subjective health, number of visits to a doctor age, marital status, number of children area of Germany dummies	-OLS -distributed lags model - IV regressions with parents' variables as well as fixed-effects models.	Panel, 4 waves
Marco Caliendo, Wang-Sheng Lee. Fat Chance! Obesity and the Transition from Unemployment to Employment. IZA Discussion Paper No. 5795 June 2011	Germany, IZA-Evaluation Dataset	784 men and 673 women Aged 16-54	Employment status and realised wage	Obese (bmi>=30).	Education, demographics, personality, health	-pooled linear decomposition approach to estimate the gap in labour market outcomes between obese and healthy weight persons -kernel matching	Panel

Author, Title, year	Country	Sample size	Outcome	Main independent variable	Main control variables	Main empirical strategy	Study type
Impact of high waist circumference on productivity in us and German overweight/ obese subjects (Caterson et al, poster abstract)	Germany	Subjects recruited by internet- 5,406. Restricted to overweight and obese (>25 BMI)	Presenteeism (using validated questionnaire WPAI); Absenteeism (self-reported number of days missed from work in last 3 months) Indirect cost: adding monetised value of presenteeism and absenteeism.	Waist circumference (proxy for abdominal obesity). High WC group defined using gender-specific value of WC	None mentioned	Simple means comparison (t-test?)	Cross-section
BMI, Obesity, and Sickness Absence in the Whitehall II Study. Ferrie et al, 2006, obesity.	UK	2564 women and 5853 men, who were British civil Servants	Short and long absences from work	Obese (BMI>=30)	employment grade, health-related behaviours, and health status	Poisson regression adjusted for over dispersion	Panel
Obesity and labour market outcomes in Denmark Jane Greve, 2008. Economics and Human Biology	Denmark, Danish Work Environment Cohort Study	8,000	Probability of being employed	Obese (BMI>=30)	age, foreign nationality, marital status, children 6 years or below, children above 6 years, education, work experience in years, work experience squared, and region dummies.	Probit regression	Panel
Obesity and labour market success in Finland: The difference between	Finland, Health 2000 population survey	2,300	Log wages Being employed	Obese, BMI, waist circumference.	Good health, age, education	Probit regression	Cross section

Author, Title, year	**Country**	**Sample size**	**Outcome**	**Main independent variable**	**Main control variables**	**Main empirical strategy**	**Study type**
having a high BMI and being fat. Johansson et al. Economics and Human Biology, 2009.							
Assessing the impact of obesity on labour market outcomes. Maarten Lindeboom, Economics and Human Biology, 2010.	UK, British National Child Development Study (NCDS).	About 8,000	Employment status (i.e. having a full or part time job, or being self-employed)	Obese (BMI>=30)	demographic, socioeconomic, environmental and behavioural variables.	OLS; IV regression (using obesity status of parents). First difference model (comparing people at age 33 and 42).	Panel
Martín AR, Nieto JMM, Ruiz JPN, Jiménez LE. Overweight and obesity: The role of education, employment and income in Spanish adults. 2008	Spain	2640	Education, employment and income	Obesity: BMI ≥30	age, physical activity, marital status,	logistic regressions	Cross section
Morris S. Body mass index and occupational attainment. 2006	England	12,137	employment	BMI	Education, family, health, impact of local area characteristics on individual employment	OLS and IV regression	Cross section
Morris S. The impact of obesity on employment. 2007	England	16,967	employment	Obesity	Education, family, health, impact of local area characteristics on individual employment	Matching; IV Regression	Cross section

Author, Title, year	Country	Sample size	Outcome	Main independent variable	Main control variables	Main empirical strategy	Study type
Mosca I. Body Mass Index, Waist Circumference and Employment: Evidence from Older Irish Adults. 2013	Ireland	3,203	employment	Obesity: BMI ≥30 and waist circumference	Demographic and socioeconomic characteristics, socioeconomic characteristics in childhood, measures of health	Regression: Probit model	Cross section
Paraponaris A, Saliba B, Ventelou B. Obesity, weight status and employability: Empirical evidence from a French national survey. 2005	France	1620	employment	Obesity: BMI ≥30	Number of unemployment periods, age, age squared, nationality, school level, occupation, family composition, housing and place of residence	Probit/OLS model/ cox regression analysis	longitudinal
Sydsjö A, Claesson IM, Ekholm Selling K, Josefsson A, Brynhildsen J, Sydsjö G. Influence of obesity on the use of sickness absence and social benefits among pregnant working women 2007	Sweden	693	Absenteeism	Obesity	BMI, sickness absence, parental benefit and pregnancy benefit claims and occupation	regression	Cross section