Managing overweight and obesity among children

Report on Economic Modelling and Cost Consequence Analysis

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1 Glossary

average cost per prevalence: average cost per prevalence case of disease
BMI z score: indicates by how many standard deviations an observation or datum is above or below the mean rather than just focusing on weight loss per se
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 less effective and costs more is said to be 'dominated' by 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): the integral over time of the time-dependent utility of an individual.
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
utility: a time-dependent measure of the benefits to an individual of his state of health.

Acknowledgement

The modelling team gratefully acknowledges the kind assistance of the review team at the Support Unit for Research Evidence (SURE) Cardiff University, for provision of the search strategies from their reviews of effectiveness and cost effectiveness [33], and for data appropriate for use in the cost effectiveness model developed in this report.

2 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 children and young people 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; maternal and child nutrition; prevention of cardiovascular disease and promoting physical activity.

Objective: The objective of the health and economic modeling 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 Program Development Group (PDG) to be of highest priority.

Question 1: To estimate the potential health and economic consequences of running weight management programs in children.
Question 2: To calculate Quality Adjusted Life Years (QALYs) gained associated with 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

The evidence review of effects of obesity on bullying and self-esteem has been carried out and cost consequence analysis is presented in section 10.

Methods: The PDG identified from the literature review the type of interventions that was likely to be most effective in weight management focusing on diet, physical activity, behavior change or any combination of these factors. They may include programs, courses or clubs (including online services) that are specifically designed for overweight or obese children and young people and their families. In consultation the PDG, NICE and the modelling group concluded that the existing published evidence submitted to the PDG in the literature review would, if modelled, prove to not be cost effective. This is because of the limitations of the evidence which reported small effects, lack of follow up or small sample sizes and that no raw data from providers of interventions were made available during the study period.

Rather than model the presented evidence the PDG economic group (drawn from individual members of the PDG and NICE advisors) took the decision to model hypothetical outcomes from interventions to see at what level they would have to be effective to prove cost effective.

The interventions chosen were:
1. Child and Parent / Family Interventions
2. Child Exercise Interventions
3. Parent Only Interventions
4. Child Residential Weight Management Interventions.

Results:

Results of weight loss interventions: Most of the health benefits of weight loss as a child will be realised only as an adult. Estimates for cost effectiveness are predicated on two important assumptions: (1) that as cohort members age they stay on the same BMI-percentile relative to their peers and (2) interventions which in childhood succeed in lowering a person's BMI-percentile are maintaining the effects throughout life. A 5% reduction in BMI – the largest intervention considered – if sustained, is normally cost effective to the overweight (BMI 25-30 kg/m²) and obese (BMI 30-40 kg/m²) cohorts. For the morbidly obese (BMI >40 kg/m²), the interventions that maintain a fixed percentile difference appear to do relatively little to alleviate their condition. However, the model has only a limited capability accurately to compute the effects of small percentile changes in the tails of BMI distributions; more reliable calculations in which morbidly obese children maintain a fixed BMI loss relative to their initial BMI percentile are seen to yield cost effective outcomes very similar to their less obese peers. These numbers are quoted in the summary table. A summary table of costs employed in the model, changes in BMI and incremental cost effectiveness ratio (ICER) by age group and gender is presented in Table 1.

Results of cost consequence analysis: Bullying during childhood has significant negative impacts on social and psychological well-being, with socially stigmatising physical features such as obesity being a characteristic that could increase the likelihood of teasing.

Conclusion:

This model has focussed on single, modestly sized (0.5-5%), time-localised (confined to a single year) interventions. If the impacts of intervention are sustained through time, they can be seen to have an appreciable effect on those who are marginally obese (BMI close to 30 kg/m²). One lesson that can be drawn from this study is that it is well worth correcting children's tendencies to become obese, provided that the effect of interventions, which reduce weight levels below what they would have otherwise been, persist unchanged throughout life.

Besides, there was evidence of strong associations between BMI and victimisation and between bullying and affective disorders. It may be possible that there is an inverse relationship, such that adolescents and children with poor mental health may be more susceptible to teasing compared with their peers who are emotionally healthy.

ΔBMI	Males									Females								
	Morbidly obese			**Obese**			**Overweight**			**Morbidly obese**			**Obese**			**Overweight**		
	Age																	
	2-5	**6-11**	**12-17**	**2-5**	**6-11**	**12-17**	**2-5**	**6-11**	**12-17**	**2-5**	**6-11**	**12-17**	**2-5**	**6-11**	**12-17**	**2-5**	**6-11**	**12-17**
Referred by GP - cost £353																		
-0.50%	15,800	12,300	7,600	8,100	9,000	13,900	9,500	5,600	3,300	15,100	11,200	7,000	5,400	8,600	11,500	13,400	9,800	5,300
-1%	7,800	6,000	3,700	3,800	4,400	7,000	8,100	4,100	2,400	7,500	5,500	3,400	2,800	4,300	5,700	13,300	8,600	3,900
-1.50%	5,100	3,900	2,400	1,300	2,300	4,600	5,900	3,000	1,900	4,900	3,600	2,200	800	2,500	3,700	11,500	6,900	3,000
-2%	3,800	2,900	1,700	1,100	1,400	3,300	3,500	2,200	1,500	3,600	2,600	1,600	700	1,000	2,700	7,700	5,200	2,400
-3%	2,400	1,900	1,100	800	800	700	1,700	1,300	1,100	2,300	1,700	1,000	500	600	500	3,100	3,000	1,700
-5%	1,400	1,000	600	500	500	600	700	600	700	1,300	900	500	200	400	300	300	900	800
Parent only - cost £389																		
-0.50%	17,400	13,500	8,400	8,900	10,000	15,300	11,000	6,600	4,000	16,700	12,400	7,800	6,000	9,500	12,700	15,300	11,300	6,200
-1%	8,600	6,700	4,100	4,200	4,900	7,800	9,300	4,800	2,900	8,300	6,100	3,800	3,000	4,800	6,200	15,200	10,000	4,600
-1.50%	5,600	4,400	2,700	1,500	2,600	5,100	6,900	3,500	2,300	5,400	4,000	2,400	1,000	2,800	4,100	13,200	8,000	3,600
-2%	4,200	3,200	1,900	1,300	1,600	3,700	4,100	2,600	1,900	4,000	2,900	1,800	900	1,200	3,000	8,900	6,100	2,900
-3%	2,700	2,100	1,200	900	900	900	2,000	1,600	1,400	2,600	1,900	1,100	700	800	700	3,600	3,500	2,000
-5%	1,500	1,200	600	600	600	700	800	800	900	1,500	1,000	600	300	500	400	500	1,200	1,000
Family intervention - cost £437																		
-0.50%	19,600	15,200	9,500	10,000	11,200	17,300	12,900	7,900	4,900	18,800	13,900	8,800	6,800	10,700	14,200	17,900	13,400	7,600
-1%	9,600	7,500	4,600	4,700	5,500	8,800	11,000	5,800	3,600	9,300	6,800	4,300	3,400	5,400	7,000	17,800	11,800	5,700
-1.50%	6,400	4,900	3,000	1,800	2,900	5,700	8,100	4,300	2,800	6,100	4,500	2,800	1,300	3,200	4,600	15,500	9,500	4,400
-2%	4,700	3,600	2,200	1,500	1,900	4,200	4,900	3,200	2,300	4,500	3,300	2,000	1,100	1,500	3,300	10,400	7,200	3,500
-3%	3,100	2,400	1,400	1,100	1,100	1,200	2,400	1,900	1,700	2,900	2,100	1,300	800	1,000	900	4,300	4,200	2,500
-5%	1,800	1,300	800	700	700	1,000	1,100	1,100	1,100	1,700	1,200	700	400	600	600	700	1,500	1,300
Family intervention - cost £651																		
-0.50%	29,200	22,800	14,200	14,900	16,700	26,000	21,700	13,800	9,000	28,100	20,800	13,200	10,100	16,100	21,300	29,500	22,700	13,500
-1%	14,500	11,300	7,000	7,100	8,200	13,200	18,500	10,300	6,700	14,000	10,300	6,500	5,200	8,200	10,500	29,300	20,100	10,200
-1.50%	9,600	7,500	4,600	3,000	4,500	8,700	13,600	7,600	5,200	9,200	6,800	4,200	2,400	5,100	6,800	25,500	16,200	7,900
-2%	7,100	5,500	3,400	2,500	3,100	6,400	8,500	5,700	4,300	6,900	5,000	3,100	2,100	2,700	5,000	17,500	12,400	6,400

-3%	4,700	3,600	2,200	1,900	2,000	2,300	4,100	3,500	3,200	4,500	3,300	2,000	1,600	1,900	1,800	7,300	7,400	4,500
-5%	2,700	2,100	1,200	1,300	1,500	1,900	2,200	2,200	2,300	2,600	1,900	1,100	1,000	1,300	1,200	1,600	2,800	2,400
Residential intervention - cost £1980																		
-0.50%	89,400	69,700	43,800	45,200	50,900	80,000	75,900	50,200	34,600	85,900	63,900	40,500	30,900	49,500	65,000	101,300	80,200	50,200
-1%	44,500	34,800	21,800	21,500	25,100	40,600	64,800	37,700	25,600	42,900	31,800	20,100	16,000	25,600	32,000	100,800	71,200	38,200
-1.50%	29,600	23,100	14,400	10,600	14,600	27,100	48,100	28,200	20,100	28,500	21,100	13,300	9,400	16,500	20,800	87,900	57,700	29,900
-2%	22,100	17,300	10,800	8,900	10,500	20,200	31,000	21,400	16,500	21,300	15,800	10,000	8,300	10,500	15,200	61,200	44,700	24,100
-3%	14,700	11,500	7,100	6,700	7,600	9,600	15,000	13,200	12,600	14,100	10,400	6,600	6,300	7,900	7,600	26,000	26,800	17,000
-5%	8,800	6,800	4,200	5,000	5,900	8,100	9,000	8,900	9,500	8,400	6,200	3,800	4,200	5,400	5,100	7,500	11,200	9,500

Table 1: Incremental cost effectiveness ratio (ICER) values by Intervention cost for different interventions and cohorts. ICER values are rounded to the nearest 100 £/QALY; values in excess of 20,000 £/QALY are shown in red

3 Introduction

3.1 Modelling team

The modelling team consists of multiple members listed Table 2.

Member	Role
Tim Marsh (NHF)	Project lead
Martin Brown (NHF)	Model developer
Ketevan Rtveladze (NHF)	Researcher
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

3.2 Background

3.2.1 Definition of child obesity

Body Mass Index (BMI) is a measure of weight status that adjusts for height. BMI is a person's weight in kilograms divided by the square of their height in metres. In this briefing the British 1990 growth reference (UK90) is used to determine weight status according to a child's age and sex. For population monitoring, children whose BMI is between the 85th and less than the 95th percentile for UK90 are classified as overweight,those at or above the 95th percentile are classified as obese and those at the 99.5th percentile morbidly obese. We are not using the corresponding clinical definitions of the 91st and 98th percentiles for overweight and obese respectively..

Obesity in children and adolescents is associated with a range of adverse increased health risk factors [2, 3]. These include type 2 diabetes, cardio vascular disease and cancer [2, 3]. Obese children are more likely to be obese as adults and also have an increased risk of coronary heart disease (CHD) in adulthood [5]. It is a public health priority to prevent and treat obesity in children and adults, in order to reduce morbidity and premature mortality [6].

The prevalence of child obesity in England increased sharply in the 1990s and early 2000s [7]. The prevalence of obesity in children aged between 2-15 years in England for 2011 was estimated to be 17% (using the 95th percentile of the UK 1990 growth reference to define obesity); the number of children aged 2-15 who were considered overweight was 30% [8] (the 53rd percentile of the 2011 distribution). Data from the Health Survey for England (HSE) show the prevalence of child overweight and obesity increased mostly between 1995 and 2004, since by 2004 there is evidence of a levelling off in child obesity prevalence for 2-15 year-olds [9]. Data from the National Child Measurement survey in 2011/12 show that amongst children aged 4-5, 13.1% were overweight and 9.5 % were obese rising to 14.7% overweight and 19.2% obese in Year 6 (aged 10-11) [10]. Of particular concern are the increasing numbers of severely obese: 4.1% of year 6 boys and 2.9% of year 6 girls had a BMI that exceeded the 99.5th percentile of the UK90 growth reference.

The percentage of National Health Service (NHS) costs attributable to a weight that exceeded the 85th percentile on the 1990 reference measure was 6% in 2007, and is predicted to rise to 11.9% in 2025 and 13.9% in 2050 in the whole population [11]. Small reductions in child obesity, if maintained, can lead to significant cost savings over the life course of a child [12, 13].

The Foresight report [9] referred to obesity as a "complex web of societal and biological factors that have, in recent decades, exposed our inherent human vulnerability to weight gain". The British Government has introduced a number of measures to prevent higher levels of obesity and overweight [14]. As a significant number of children are already overweight and obese, interventions are also needed to address these children's existing weight problems.

Because children are still growing it is not possible to recommend a suitable effect size (i.e. how much weight change can be expected from an effective intervention). The success of inventions targeting children needs to be assessed in the context of the target population. Some interventions may aim to support children and young people to 'grow into their weight' (which may of course involve maintaining their weight over time as they grow taller) rather than lose weight. It is therefore important to examine changes in measures such as BMI percentile or BMI-z score (which indicates by how many standard deviations an observation or datum is above or below the mean rather than just focusing on weight loss per se). The measure of success of an intervention is the extent by which a child's BMI-z score is reduced. Failures occur when the BMI-z score remains the same or increases. It is also important to look at any changes in the context of quality of life and behaviour change indicators.

The modelling incorporates the following approaches:

- Weight management programs which take a lifestyle approach to helping overweight or obese children and young people achieve and maintain a healthy weight.
- Lifestyle approaches that focus on diet, physical activity, behaviour change or any combination of these factors. These include programs, courses or clubs (including online services) that are:
    - specifically designed for overweight or obese children and young people
    - designed for the parents, carers or families of obese or overweight children and young people
    - designed primarily for adults but which accept, or may be used by, children and young people
    - provided by the public, private or voluntary sector, in the community or in (or via) primary care organisations.

3.3 Features of the model

- The modelling has estimated the potential health and economic consequences of weight management interventions in children
- We have estimated QALYs gained associated with weight loss (where the loss in weight is in comparison with the weight the child would have been without the intervention).
- We have carried out cost-effectiveness analysis of weight management interventions and calculated health benefits along with net cost for various levels of cost of the intervention
- Interventions modelled: Referred by GP, parent only, family intervention 1 and family intervention 2, Residential Intervention.

3.4 Outcomes

The NHF 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 cohorts of overweight and obese children and young people. 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 Program Development Group.

The model outlines costs of interventions, expected future cost savings and the expected health and other benefits gained during the specified period. Consideration has also being given to indicators, such as bullying that impinge upon non-health benefits for cost-consequences analysis.

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 Program Development Group.   A computer model has been developed. It is capable of executing the specifications summarized under header 6 and in the Appendix 3.

4 Methodology

The model follows closely the structure and philosophy of the NHF's health outcomes model which is described in Appendix 3 .The various economic measures used in the report are described in sections 4.2 to 4.5 .

4.1 The NHF health outcomes model

Background to NHF health outcomes model is specified in Appendix 3.

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

The model considers two types of cost. Firstly, there is the cost of providing the weight management intervention that is being evaluated. Secondly, there are costs associated with diseases attributable to overweight and obesity. Two separate outcomes measures (life years and QALYs) are considered in the evaluation. The 'life-year' outcome, when combined with an estimate of the incremental cost of the intervention compared to the null, will yield an estimate of cost per life year gained. This comprises a cost-effectiveness study. In addition, numbers of years of life spent in various health states in the model will be combined with estimates of preference based utility measures. This will give an estimate of quality adjusted life years (QALYs) in the intervention and comparator groups and this enables an estimate of incremental cost per QALY gained, carried out as a cost-utility study.

Utilities (the quality-of-life measures used in the analysis) are 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 (see eq 3) and in order to capture small changes in QALY especially for large BMI values, the values input to the program 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].

4.3 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 1

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 5.1) and the discounting at 3.5% per annum.

4.4 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:

[1] 3.5% was the value taken from NICE, CPHE methods guide

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

eq 2

4.5 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 1 and eq 2 the Incremental Cost-Effectiveness Ratio (ICER) will be calculated as:

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

eq 3

4.5.1 ICER as a function of Δ_{CI}

In this model, unlike the quantities Δ_{QI} and Δ_{DI}, the function Δ_{CI} does not require a run of the program 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 3 for any value of Δ_{CI}.

5 Data inputs

5.1 Demographic data

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

Note: The particular cohorts selected by the PDG for this study did not require the use of the population distributions by age and gender. The mortality distributions are used in computing death probabilities for diseases and causes of death not explicitly modelled.

5.2 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 [15], pre-processed to make them acceptable to the model.

BMI distributional data, necessary in determining the structure of age-sex-BMI-specific cohorts, is taken from the latest available HSE (2010) data. For the purposes of illustration these data are drawn as graphs below. Note the significantly different structure of the distributions (all are drawn with the same vertical and horizontal scale and show the BMI distributions of the relevant age-sex group as measured in 2010; 95% confidence intervals are shown for each, one BMI unit wide, column of the histogram). Y axis denotes probability and X axis BMI group (Figure 1-6).

Apart from their intrinsic interest these graphs serve to illustrate the difficulties in standardising childhood obesity: they are very different for different age groups and are obviously not normally distributed. This variability in their structure is answered by performing Box Cox transformations to normal distributions and relating obesity levels to z-scores for those distributions. These topics are further discussed in section 8.

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

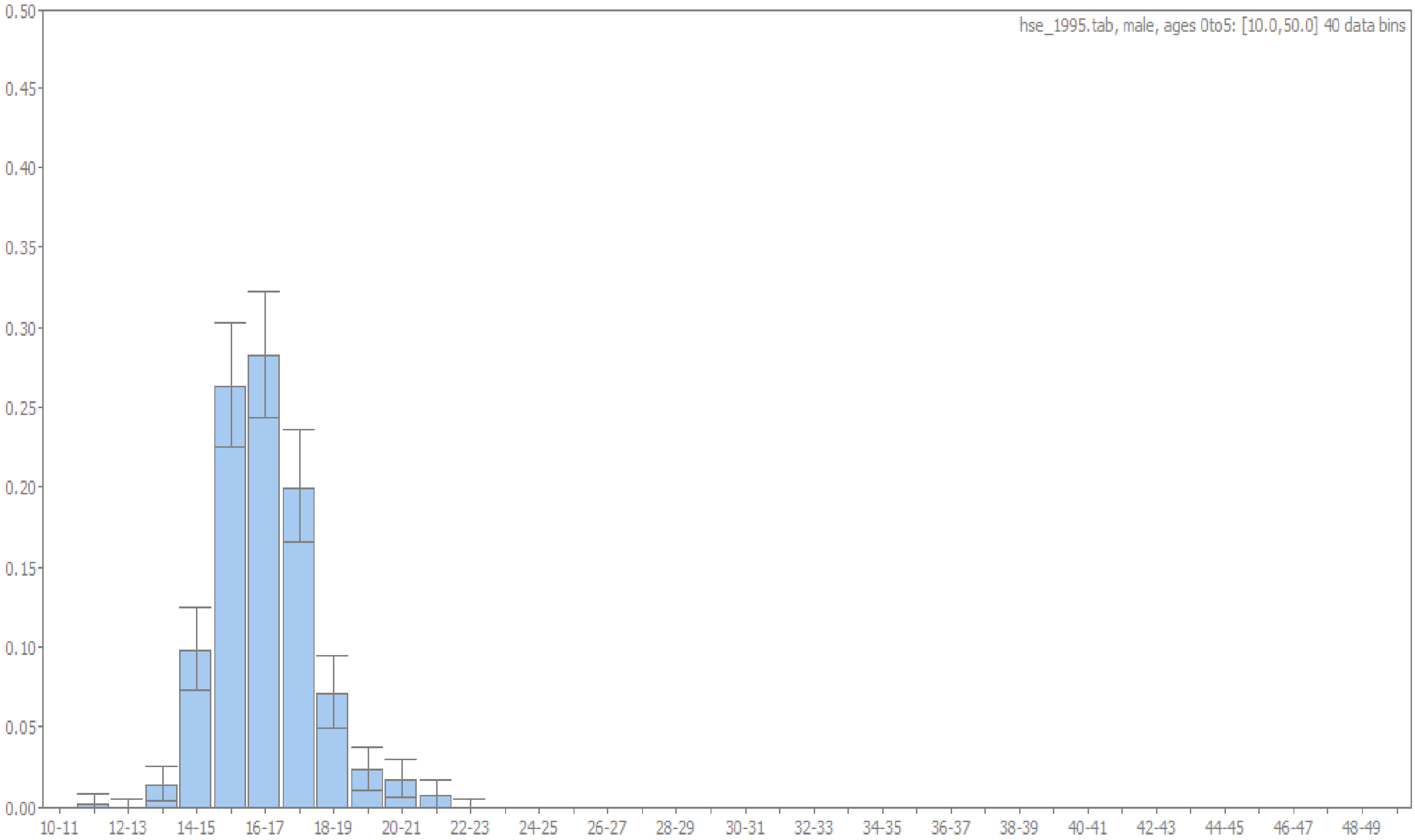

Figure 1: BMI distribution, 0-5 boys

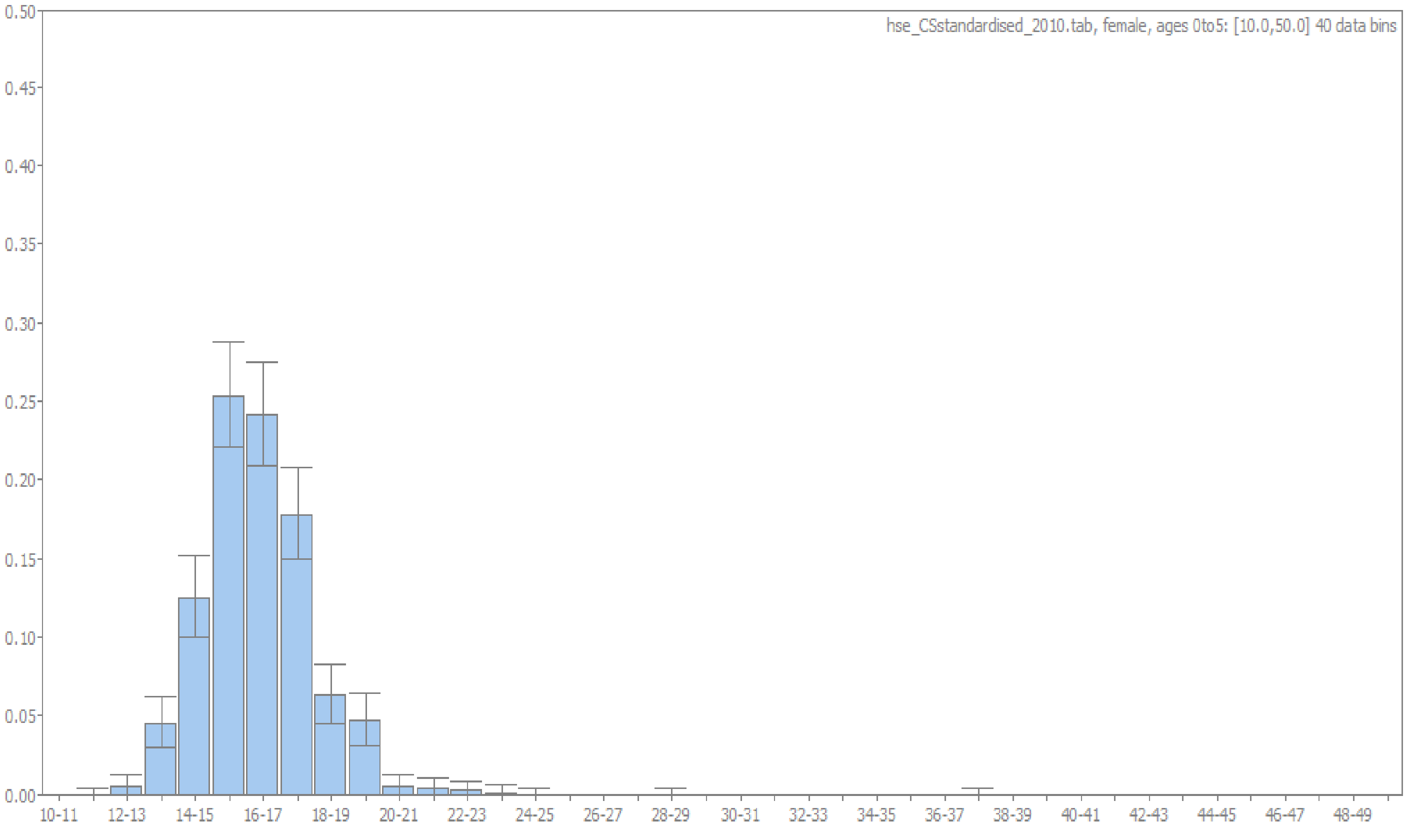

Figure 2: BMI distribution, 0-5 girls

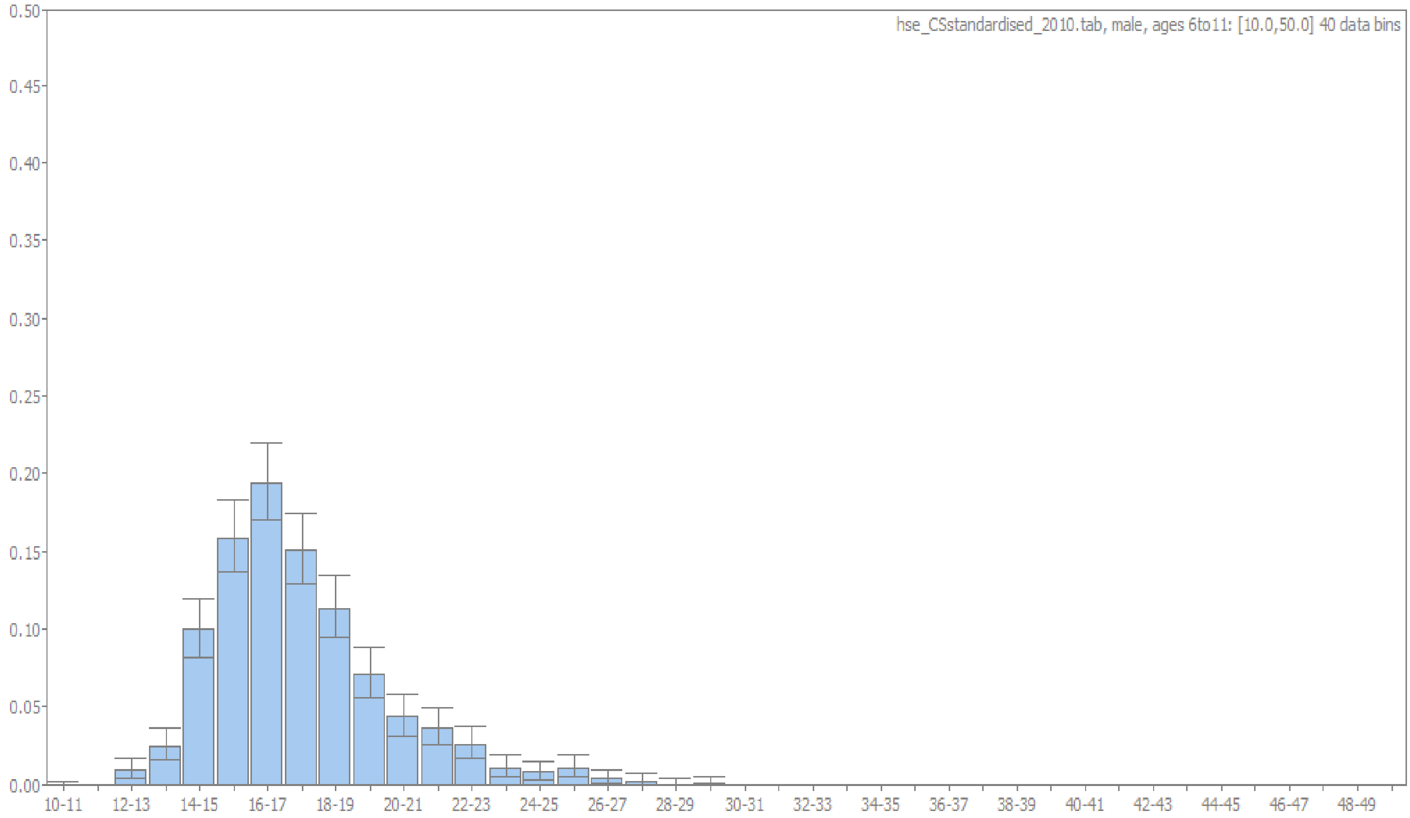

Figure 3: BMI distribution, 6-11 boys

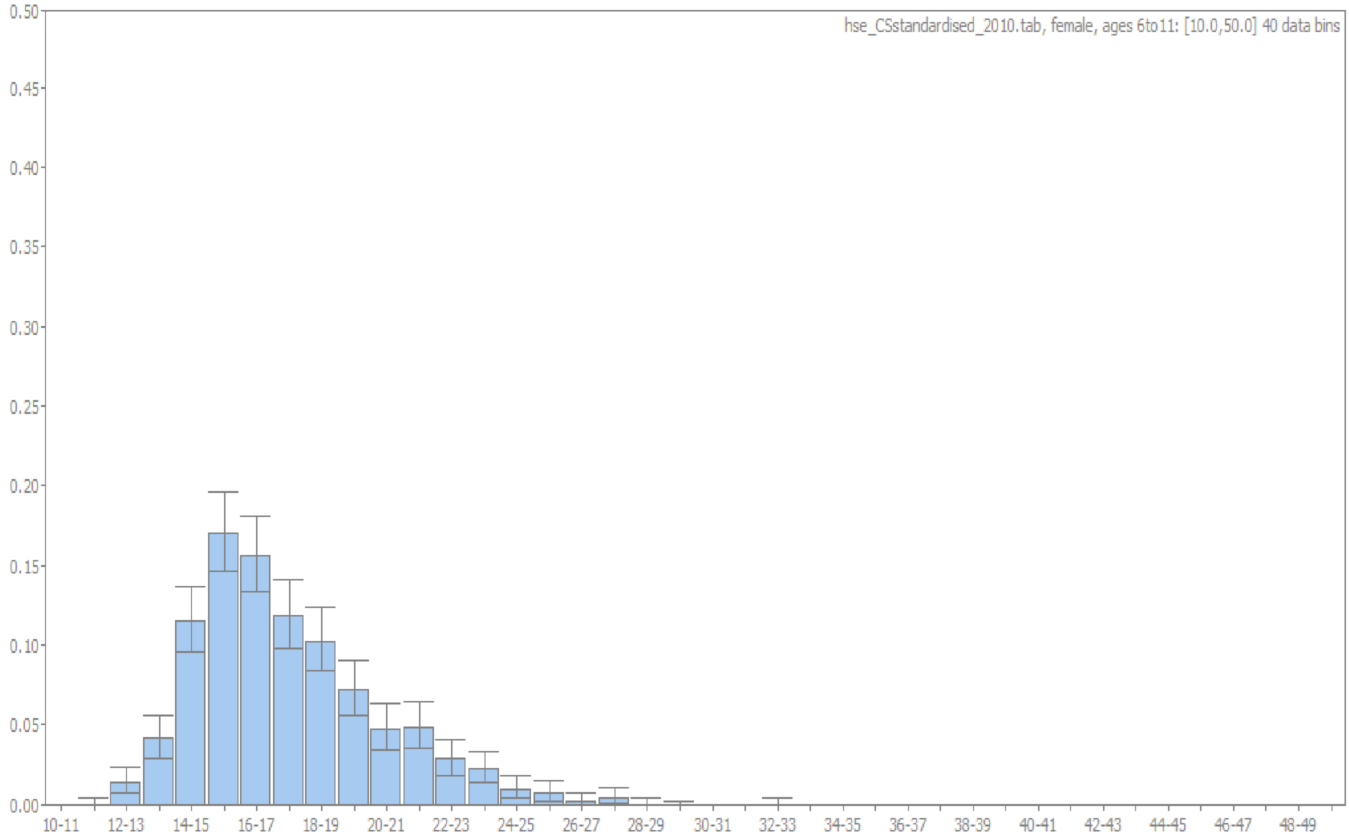

Figure 4: BMI distribution, 6-11 girls

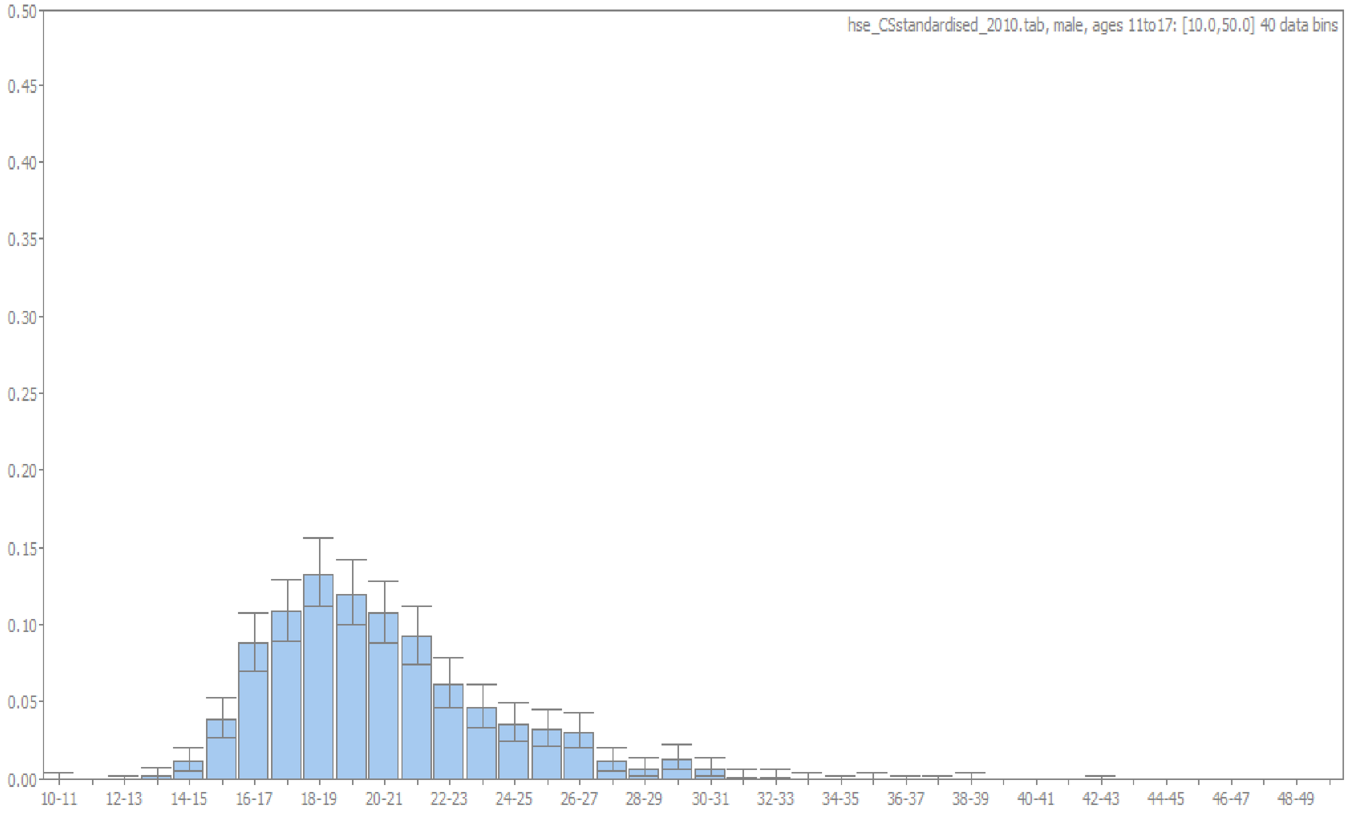

Figure 5: BMI distribution, 11-17 boys

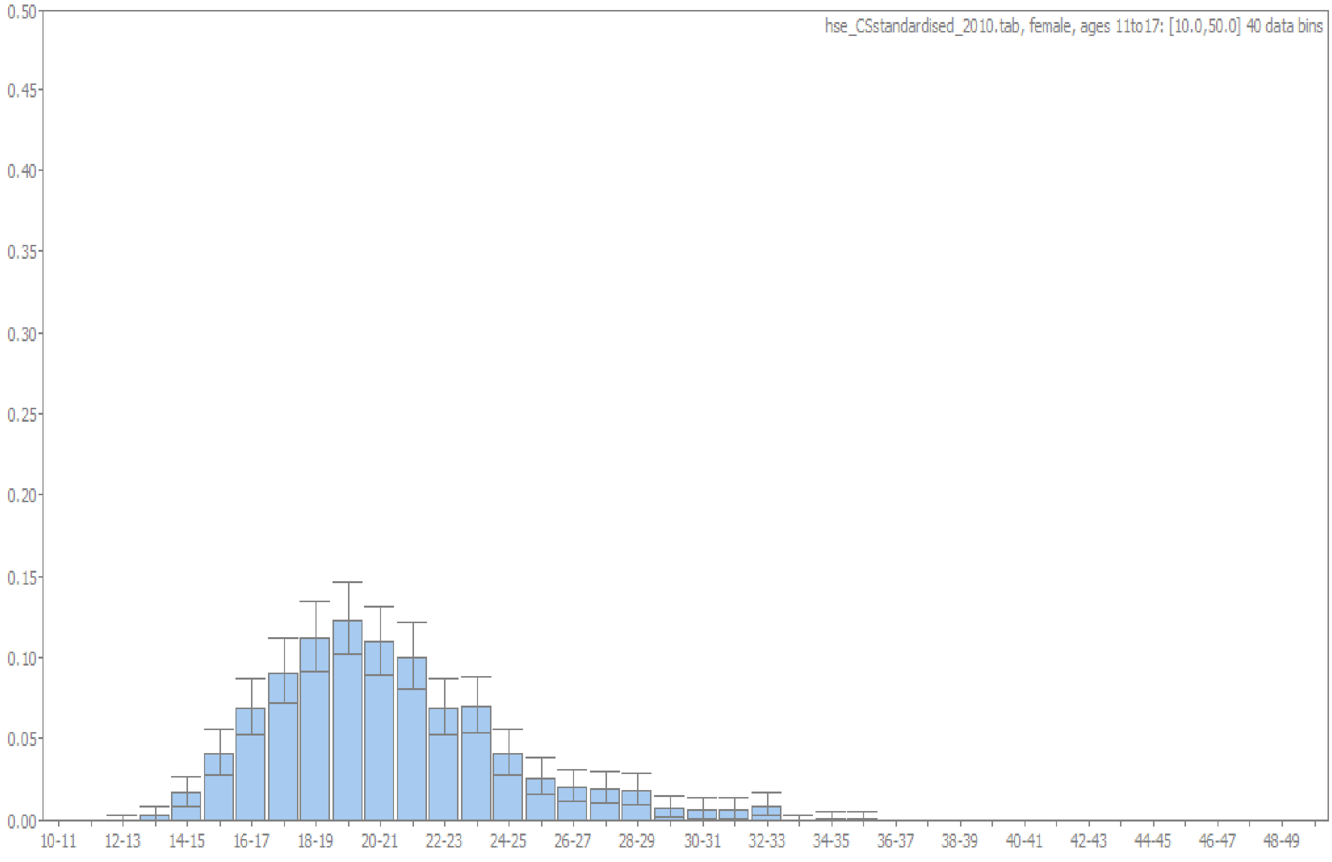

Figure 6: BMI distribution, 11-17 girls

5.3 National disease data

Incidence, survival, relative risk, mortality and medical cost data are required for each of the BMI related diseases. These data consist of the most recent and discriminating that are available and are derived from a number of sources (Table in Appendix 2, section 13.1) . Disease data are made available to the model in the form of open format, tab delimited text files. These files are included in the Data Pack that accompanies this report.

5.4 National disease cost data

5.4.1 Introduction

Being overweight or obese predisposes an individual to a range of health condition 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.

5.4.2 Methodology

We set out to estimate the cost of major illnesses related to obesity. The 7 major diseases primarily associated with obesity were 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.

We calculated the cost of the illnesses 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:

5.4.3 Coronary Heart Disease - Estimating Cost of Inpatient

We obtained Healthcare Resource Groups (HRG) codes and inpatient data from the Hospital Episode Statistics (HES) website [16]. Estimates of total admission were 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 2011/12 year.

5.4.4 Estimating Cost of outpatient

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 spreadsheet[3]. The costs were multiplied by volume to obtain a total current spend. Data used were for the 2011/2012 year.

5.4.5 Estimating costs of A&E attendances

Number of A&E attendances was obtained from HES; the costs were obtained from the PBR tariff. We multiplied the costs by the volume to obtain a total current cost. There were no data available for 2011/12 A&E attendance as at the time of filing this report hence the 2010/2011 data were used.

5.4.6 Primary Care prescribing and Pharmaceutical services

We extracted underlying data from the Department of Health program budgeting tool [17]. We then reformatted the data into a matrix with rows corresponding to PCTs and care setting (e.g. prescribing) and columns representing program areas. The primary prescribing & pharmaceutical services were selected and we summed up the spending for the relevant program areas [18].

5.4.7 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) [19]. The NAO report however did not have PAFs for breast and kidney cancers. We therefore used PAFs obtained from World Health Organisation (WHO) EUR regional figures as a proxy [20].

5.4.8 Cost per disease prevalence case

Cost per 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. This was because:

1. Individual patients may have several NHS interventions in a year - admissions, outpatient attendances and prescribing in primary care.
2. The program budgeting data do not provide details of the number of individuals who receive interventions.

We therefore decided to calculate the average cost per prevalence of each obesity related illnesses. We did this by searching for prevalence data for all the diseases. We then divided the total treatment costs by the prevalence of the diseases. 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, we obtained the percentage of cases attributable to obesity from the National Audit Office Report (2001) [19]. These percentages were then applied to the hospital costs.

5.4.9 Model cost inputs

The hospital costs of obesity related disease for the year 2011/12 in England are shown in the tables below.

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

Disease area	All costs (£million)					Costs attributable to obesity (£m)	
	Primary prescribing and pharma services	A & E attendance	Outpatients	Admissions	Total	Cost	% of total cost
CHD	16%	829	301	499	1,661	266	16
Diabetes	47%	866	55	101	1,025	482	47
Stroke	6%	32	461	483	985	59	6
Hypertension	36%	899		10	909	327	36
Osteoarthritis	12%	451	206	14	736	88	12
Breast cancer	11.40%	134	434	57	634	72	11.4
Kidney cancer	11.40%	80	239	48	385	44	11.4
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.

5.4.10 Average cost per prevalence

We have calculated the direct costs of treating obesity related illnesses, estimated the cost of these illnesses attributed to obesity and analysed the average cost per prevalence of disease. Based on our analysis, £6.33bn was spent on treating CHD, diabetes, stroke, hypertension, knee osteoarthritis, breast and kidney cancers. These costs relate only to expenditure within the hospital. NHS spending on these diseases is most likely higher as we have not estimated ancillary costs such as those related to community care programs and ambulance services.

CHD and diabetes were the main cost drivers in our 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 our analysis of hypertension did not include outpatient and A&E attendance cost. This was because it wasn't possible to separate out outpatient and A&E attendance cost for CHD and hypertension. In consequence, our analysis may have overestimated the costs of treating CHD.

We believe that by using the assumptions described below, the results reported represent the use of the best available evidence in calculating the cost of obesity related illnesses:

1. All diabetic outpatients' visits were assumed to have been treated by an endocrinologist. We are aware that this 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 center, 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. We have therefore used 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 In reality, this would be sub-optimal as each individual case would vary in complexity and hence attract different charges.
3. We have assumed that all outpatient stroke visits were attended to by the neurologist; the same assumption was made for costs. We observed during our analysis that there was no tariff for follow up attendance for stroke. We therefore decided to apply the tariff for 1st attendance [21]. 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 [22].

Note: National disease cost-per-case-per-year statistics are required. These data are pre-processed and attached to the disease data files. Each cohort member modelled by the model maintains a personal cost trajectory[4]: each year their total disease cost[5] is recorded.

5.5 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 used estimates of the utility of individuals without obesity related disease. These varied by age, gender, and BMI category. Secondly, we estimated utility values for

[4] An individual's cost trajectory is a list of costs incurred by the individual, one cost for each year from the start of the trajectory until its end.

[5] Disease costs are taken from the *Technical Report upon the Cost of Obesity related Illnesses*, UEA, 21st Jan 2013

certain obesity related diseases (CHD, stroke, arthritis, and diabetes). The average utility 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.

5.5.1 Utility by age, gender, and BMI category

The children age and become adults, so it is necessary to see the effect on the quality of life of reductions in BMI of these children once they reach adulthood.

Values for utility by age, gender and BMI group were taken from Maheswaran et al (2012) [23]. This study used data from the 2008 Health Survey for England. Utility values were obtained by means of the EQ-5D instrument. Their analysis was based on 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 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-based utility. The authors found that the Ordinary least-squares (OLS)[6] 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 utilities for males and females, separated into age and BMI groups. However, the information was not presented in this form by Maheswaran et al [23] and hence could not be used directly in the form presented in their paper. For this reason we estimated average utilities for groups using some simplifying assumption. As a starting point we used the utility by age category presented by the authors. These values were adjusted using coefficients from OLSregression for the effect of BMI groups on utility. We assumed that the effect of BMI was the same for each age group using a weighted average approach allowing for the different numbers of individuals in each BMI group. We then adjusted each age/BMI group according to the coefficient for gender from the OLS model. Again, a weighted average approach was used to allow for the proportion of each age group that were male/female. However, as we did not have data from the HSE on the proportion of each age group who were male we used population estimates from the ONS. The estimates of utility by age groups for the different groups are presented in Table 5 and Table 6 below.

Age	BMI in kg/m², with 95% confidence intervals in parentheses				
	<18.5	**18.5 to <25**	**25 to <30**	**30 to <40**	**40+**
16-24	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	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	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	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)
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	0.79	0.79	0.785	0.759	0.683

[6] 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

(CI)	(0.753 , 0.828)	(0.777 , 0.804)	(0.764 , 0.806)	(0.736 , 0.784)	(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 95% confidence intervals

Age	**BMI in kg/m², with 95% confidence intervals in parentheses**				
	<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)

5.5.2 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 possible, 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 5, section 16.1).

5.5.2.1 Diabetes

A review looked at utility based measures in Type 2 diabetes [24], 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 [24].

5.5.2.2 Osteoarthritis

An Italian study looked at 576 patients with musculoskeletal conditions [25]. 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.

Value used in the model was 0.61.

5.5.3 Stroke

A number of studies have examined HRQoL after stroke. Post and colleagues [year] carried out a systematic review covering 23 studies examining the utility associated with stroke [26]. 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, only one study used the EQ-5D [27]. Dorman et al [27] carried out EQ-5D on 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.

Value used: 0.59.

5.5.4 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 ([28] web appendix). 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 [29]. Participants had a mean age of 72 and were 65% male. Baseline EQ-5D-derived utility was 0.65. The utility for angina was from a US study [30]. 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 [31]. 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**.**

6 Implementation - Computer model overview

The computer model ("the model" calculates the potential health and economic consequences of using weight management interventions on specified cohorts of children and or young people; the model is capable of processing adult data and will be used to do that in the companion study of weight management in adults. It is intended that the underlying model structure for adults and children should be essentially the same – the differences will be manifest in the type of intervention and in the assessment of the effectiveness of those interventions.

The model provides cost-effectiveness and health benefit analyses, calculated both for adults and children over several different time horizons (short, intermediate and lifetime) and, if required, by age. The model relates the costs of interventions, to the expected cost savings, gains in Quality Adjusted Life Years (QALYs) and the expected health and other benefits gained during the specified period. The model runs from the start-year to the stop-year and is divided into one year intervals.

Details of the model's processing chain and its components can be found in Appendix 3.

7 Cost of Interventions

7.1 Methodology

We extracted data from the systematic review of the effectiveness and cost effectiveness of lifestyle weight management services for children and young people by Morgan et al (2012). We noted that the review highlighted 10 papers which provided varying degrees of cost data. An analysis of the systematic review was undertaken. We used seven papers on the subject of children only weight management interventions, details of which are given in Table 8.

Prices were inflated to 2010 prices using the tool created by Campbell and Cochrane Economics Method Group (CCEMG) and the Evidence for Policy and Practice Information and Coordinating centre (EPPI-Centre) [32], and then to 2012 prices in accordance with NICE guidelines.

We used papers from the US and Australia and the UK [34-40] found by Morgan et al 2012 [33] that incorporated an economic analysis in their studies. Articles that reported details of the resources used in the costing analysis were selected from the systematic review. Where resources utilised were similar to those in the UK, we took the cost per child and converted it to GBP (pound sterling).

The conversion was done using a tool developed by CCEMG and the EPPI-Centre, converting the price-year adjusted cost estimate from the original currency to GBP, using conversion rates based on Purchasing Power Parities (PPP) for GDP.

7.2 Results of cost studies used in the model

Paper	Janicke et al. [34]		Moodie et al.[35]	Hughes et al.[36]	Goldfield et al.[37]	Wake et al.[38]	Wake et al.[39]	Gately et al. [40]
Year	2009		2008	2008	2001	2008	2009	2005
Country	US		Australia	UK	USA	Australia	Australia	UK
Setting	Rural Community		Community	Hospital	Community	Community	Community	Residential weight loss
Age	8-14 years			5-11 years	8 – 12 year olds	5-9 years	5 -10 years	9-18 years
Intervention	Two intervention arms: parent only and family based. Both interventions focused on behavioural change (diet and physical activity) plus either family-based intervention including diet and physical activity sessions for children or parent-only sessions.		Intervention modelled on the LEAP (live eat and play) trial. Primary care behaviour modification (diet and physical activity)	behavioural program delivered by paediatric dieticians.	Behavioural change diet and physical activity	Behavioural change diet and physical activity over 12 weeks vs no intervention	Behavioural change diet and physical activity vs no intervention	Residential weight loss Camp. Mixture of physical activity and diet modification
Population type	Parent only	Family Based	Family based	Family Based	Child and parent based program	Family Based	Child and parent	Child based
Cost	Parent £10169	Family £6582	£6.3 million	Not Stated	£14538	£23438	£73857	
Cost per child	£389	£651	£783	£108	£1212	£426	£640	£478
Cost Methodology	Included personnel costs; 2 Trainers, 2 group leaders materials; pedometers, participant manuals, incentives and food and cost per travel	Included personnel costs;4 Trainers, 2 group leaders, materials; pedometers, participant manuals, incentives and food and cost per travel	Included GP recruitment training, delivery of intervention and costs associated with resultant changes	Not Stated	Orientation / screening costs, Treatment costs(i.e. materials incl. treatment manuals, handouts and habit book), travel costs and salary costs were included	Included visit GP costs, sports and physical activity costs, weekly adult time costs	Included BMI surveillance, GP recruitment and training	Not stated

Table 7: Results of cost studies used in the model

Resource use reported in the Janicke et al [34] is reasonably similar to what pertains in the UK. The model uses the cost per child of both the family based and parent-only interventions provided in the article. These costs were £651 and £389 per child respectively.

7.3 Discussion & Conclusion about costs

Since Gately et al 2005 [40] is a UK paper, the model uses the cost per child for children's residential weight loss programs. This cost was £478 (1980/478 = 4.14 weeks = 29 days) per child per week and lasted for 4 weeks.

The systematic review also indicated that physical activity-only interventions for children could be used as treatment for obese and overweight children. However no cost data were available in the papers that were examined. The lack of adequate cost data for children-only interventions meant that only the residential weight loss management program could be analysed. Therefore, we did not provide a cost estimate for physical activity interventions for children only.

The lack of adequate detail on the structure of the interventions evaluated in the UK papers reduced the applicability of the papers to this economic analysis [36, 40]. We observed that the YHEC (2010)[7] article referenced a paper which provided a full technical report on the methodology, assumptions and results of the economic evaluation of the MEND 7-13 program. The author was sent an e-mail requesting for a copy of the article however no response was obtained.

[7] http://www.yhec.co.uk/

8 Results for cost effectiveness modelling

The model simulations are listed by cohort. In all 18 different cohorts are considered, 9 male and 9 female. For each gender the 9 cohorts consist of three age groups (2 to 5 years, 6 to 11 years, and 12 to 17 years). For each age group there are three BMI groups: overweight, obese and morbidly obese. The overweight group have BMI values that lie on the 85^{th} percentile – the boundary between healthy weight and overweight; obese: the 95^{th} percentile – the boundary between overweight and obese and morbidly obese: the 99.5^{th} percentile the boundary between obese and morbidly obese.

Each run of the program consists of a specified interaction affecting a specified cohort. The runs are batched so that for a given cohort the effect of a number of interventions can be compared. The main set of batched runs consisted of 6 Interventions for each of the 18 cohorts. The interventions were the same for each cohort and consisted of the following BMI reductions:

Intervention	Effect
0	The null (do nothing) intervention
1	An immediate 0.5 % reduction in absolute BMI
2	An immediate 1.0 % reduction in absolute BMI
3	An immediate 1.5 % reduction in absolute BMI
4	An immediate 2.0 % reduction in absolute BMI
5	An immediate 3.0 % reduction in absolute BMI
6	An immediate 5.0 % reduction in absolute BMI

Table 8: The basic set of 6 interventions

These batched runs of the program were chosen so as to cover the areas of interest identified by the PDG. Section 8.1 provides a record of that interaction and cross references the PDG's requirement with the set of runs of the program.

8.1 Classification of PDG preferred Interventions and Inputs

The eventual set of runs grew out of discussions with the PDG. The following classification is intended to organise the run inputs:

$Input_0$: The intervention start year and stop year – {two years}

$Input_1$: To whom the intervention is applied – {the cohort, a collection of people identified by age, sex, BMI or z-score, year}

$Input_2$: The cost of the intervention- {cost per person}

$Input_3$: The net BMI reduction caused by the intervention- {effective BMI change by year}.

$Input_4$: BMI-related disease statistics and costs

The model operates by computing the expected disease costs of $Input_1$ (the beginning year and end-year) and comparing them with the intervention costs specified in $Input_2$ (the particular intervention group) to produce cost effectiveness measures for the intervention.

In order to obtain an output for a given set of inputs it is necessary to run the program. However, a single run of the program is sufficient to produce a graph of cost effectiveness/intervention cost. Thus it is relatively straightforward to determine the intervention cost at which a particular intervention would become cost-effective.

The relationship between percentiles, age, BMI and gender is given in Table 11 and Table 12. The L,M, S values[8] are the Box, Cox[9] parameters that map the observed BMI onto the reference normal distribution. The set of BMI reference distributions are those for UK children in 1990.

The correspondence between z-scores and key percentiles is given in Table 10.

percentile	85^{th}	95^{th}	99.5^{th}
z-score	1.036	1.6449	2.652

Table 9: Percentiles and their z-scores

The classification of overweight, obese and severely obese corresponds respectively to the ranges (1.036<z<1.6449), (1.6449<z<2.652) and z>2.652.

To obtain the z-score (z) from a BMI measurement bmi, one uses the following equation:

$$z = \frac{1}{LS}\left(\left(\frac{bmi}{M}\right)^{L} - 1\right)$$

eq 4

where L, M and S are the values from the appropriate table (L is a measure of skewness, M is the mean and S the standard deviation of the BMI distribution for a given age). The percentile corresponding to a given z-score is 100 times the value of cumulative Normal Distribution at the value z.

Age in years	L	M	S	overweight (85^{th} – 95^{th} centile in 1990)	moderately obese (95^{th} – 99.5^{th} percentile in 1990)	severely obese (99.5^{th} to 100^{th} percentile in 1990)
0	-0.23	13.28	0.09	14.63	15.51	17.10
1	-0.72	17.64	0.08	19.16	20.16	22.03
2	-0.81	16.66	0.08	18.12	19.10	20.94
3	-1.06	16.13	0.08	17.55	18.51	20.36
4	-1.29	15.75	0.08	17.13	18.08	19.95
5	-1.48	15.55	0.08	16.96	17.94	19.95
6	-1.63	15.50	0.08	17.01	18.10	20.39
7	-1.75	15.56	0.09	17.24	18.48	21.22
8	-1.82	15.75	0.10	17.61	19.04	22.33
9	-1.85	16.04	0.10	18.08	19.70	23.58
10	-1.86	16.42	0.11	18.64	20.42	24.84
11	-1.84	16.89	0.11	19.26	21.18	26.03
12	-1.80	17.43	0.11	19.93	21.96	27.11
13	-1.75	18.04	0.12	20.65	22.77	28.10
14	-1.70	18.68	0.12	21.39	23.58	29.02

[8] The values LMS (originally lambda, mu, sigma) are obtained as the maximum likelihood estimates that transform a set of measurements onto a Normal distribution.
[9] Box, George E. P.; Cox, D. R. (1964). "An analysis of transformations". Journal of the Royal Statistical Society, Series B 26 (2): 211–252. JSTOR 2984418. MR 192611.

15	-1.64	19.32	0.12	22.12	24.36	29.85
16	-1.59	19.94	0.12	22.82	25.09	30.60
17	-1.54	20.52	0.12	23.46	25.77	31.25
18	-1.49	21.05	0.12	24.05	26.37	31.82

Table 10: LMS values, BMI for given percentiles by age, males

Age in years	L	M	S	overweight (85^{th} – 95^{th} percentile)	moderately obese (95tyh – 99.5^{th} percentile)	severely obese (99.5^{th} to 100^{th} percentile)
0	-0.41	13.03	0.09	14.35	15.22	16.82
1	-1.01	17.25	0.08	18.75	19.77	21.71
2	-1.04	16.34	0.08	17.83	18.84	20.79
3	-1.08	15.88	0.08	17.39	18.42	20.44
4	-1.15	15.66	0.09	17.23	18.32	20.49
5	-1.22	15.48	0.09	17.16	18.35	20.78
6	-1.28	15.49	0.10	17.32	18.65	21.47
7	-1.32	15.68	0.11	17.71	19.22	22.52
8	-1.34	15.99	0.12	18.23	19.93	23.76
9	-1.35	16.40	0.12	18.82	20.70	25.02
10	-1.34	16.90	0.13	19.49	21.51	26.25
11	-1.32	17.48	0.13	20.22	22.36	27.41
12	-1.30	18.12	0.13	20.98	23.22	28.49
13	-1.28	18.77	0.13	21.74	24.06	29.47
14	-1.26	19.40	0.13	22.45	24.82	30.33
15	-1.24	19.96	0.13	23.07	25.48	31.04
16	-1.23	20.44	0.13	23.61	26.05	31.64
17	-1.21	20.85	0.13	24.06	26.52	32.11
18	-1.19	21.19	0.13	24.43	26.91	32.50

Table 11: LMS values, BMI for given percentiles by age, females

8.1.1 Intervention Groups:

Four groups of interventions were modelled, based on the corresponding effectiveness report (ref)

Child and Parent / Family Based Interventions

There was strong evidence [1] that both the child and parent/carer and family based interventions were effective.

Child Based Exercise Interventions

The systematic review[10] did not appear to provide any strong evidence that child only based exercise interventions were likely to be effective

Parent Only Based Interventions

There was inconsistent evidence that parent only interventions were effective.

Child Based Residential Interventions

[10] Systematic review reference:

There was some evidence that child based residential weight management camps were effective.

For each Intervention-group, in addition to the possibility of not intervening, 6 BMI-reductions were considered; these are listed in Table 9.

For each Intervention-group and BMI-reduction separate simulations were conducted for cohorts divided by:

- Age: Three age ranges (2-5 years. 6 -11 years and 12-17 years)
- Gender: Males and females
- Initial BMI: Three BMI categories (overweight, obese and morbidly obese)

The set of cohorts was the same for all Intervention-groups.

The complete set of modelled Interventions thus total 432 consisting of 4 Intervention-groups by 6 BMI reductions by 18 cohorts (3 by 2 by 3).

8.2 Results for the 18 child cohorts under 6 BMI interventions

The sensitivity of the results to variations in the input data is discussed in section 9.3.

Results are all shown relative to the null intervention. The measures are as defined in sections 4.3, 4.4, and 4.5 with the addition of Δ_{LI} the Intervention induced discounted gain in life expectancy.

Δ_{LI}=cohort mean, discounted gain in life expectancy
Δ_{QI}=cohort mean, discounted gain in QALYs, (This figure includes the QALY gain due to increased life expectancy) .
Δ_{DI}=cohort mean, discounted gain in lifetime BMI-related disease costs

Units are pounds sterling (£) and years. The discount rate was 3.5% and the intervention was applied in 2013.

The shorthand, for example overweight/obese, is used to signify that the cohort has BMI values that lie on the overweight to obese boundary.

The interventions modelled and reported below all had an intervention cost of a nominal £100. It will be observed that when the discounted gain in disease costs is greater than £100 the resulting ICER will be negative (one gets back more than one puts in); such negative ICER values are recorded as *dominates*. As already explained, the results for different and more realistic costs are easily calculated from the data here recorded. Indeed this is done comprehensively in the Table provided in Section 9, where there are no negative ICERs. All figures represent 'what-if' comparisons compared with doing nothing, all for a cost of £100.

Positive ICER values are rounded to the nearest 100 £/QALY.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**

-0.5%	0.02	0.02	120.36	dominates
-1.0%	0.02	0.03	121.48	dominates
-1.5%	0.03	0.04	124.33	dominates
-2.0%	0.03	0.06	145.16	dominates
-3.0%	0.04	0.12	149.84	dominates
-5.0%	0.05	0.20	223.95	dominates

Table 12: Cohort of overweight males aged 2-5 for an intervention costing £100 and where future costs are discounted at 3.5% per year. ICER is in comparison with no intervention.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.04	0.15	2300
-1.0%	0.00	0.09	0.15	1100
-1.5%	0.06	0.17	124.17	dominates
-2.0%	0.06	0.21	125.28	dominates
-3.0%	0.06	0.28	130.39	dominates
-5.0%	0.06	0.36	180.71	dominates

Table 13: Cohort of obese males aged 2-5 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.02	0.00	6500
-1.0%	0.00	0.03	0.15	3100
-1.5%	0.00	0.05	0.15	2000
-2.0%	0.00	0.07	0.32	1400
-3.0%	0.00	0.12	0.46	900
-5.0%	0.00	0.25	0.64	400

Table 14: Cohort of morbidly obese males aged 2-5 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.03	0.04	146.86	dominates
-1.0%	0.03	0.05	153.89	dominates
-1.5%	0.03	0.06	162.56	dominates
-2.0%	0.03	0.09	169.81	dominates
-3.0%	0.04	0.14	175.26	dominates
-5.0%	0.05	0.20	227.40	dominates

Table 15: Cohort of overweight males aged 6-11 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.04	1.83	2500
-1.0%	0.00	0.08	3.43	1200
-1.5%	0.02	0.13	51.84	400
-2.0%	0.04	0.18	104.71	dominates
-3.0%	0.07	0.24	170.18	dominates
-5.0%	0.07	0.30	214.32	dominates

Table 16: Cohort of obese males aged 6-11 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.01	0.00	8700
-1.0%	0.00	0.02	0.03	4200
-1.5%	0.00	0.04	0.08	2700
-2.0%	0.00	0.05	0.18	2000
-3.0%	0.00	0.08	0.28	1200
-5.0%	0.00	0.16	0.55	600

Table 17: Cohort of morbidly obese males aged 6-11 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.04	0.05	182.75	dominates
-1.0%	0.04	0.07	184.65	dominates
-1.5%	0.04	0.09	185.84	dominates
-2.0%	0.04	0.11	186.46	dominates
-3.0%	0.04	0.14	192.38	dominates
-5.0%	0.05	0.18	225.83	dominates

Table 18: Cohort of overweight males aged 12-17 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.02	11.96	3600
-1.0%	0.00	0.05	11.96	1800
-1.5%	0.00	0.07	22.73	1100
-2.0%	0.00	0.10	31.48	700

-3.0%	0.08	0.18	223.94	dominates
-5.0%	0.08	0.22	230.23	dominates

Table 19: Cohort of obese males aged 12-17 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.01	0.00	9000
-1.0%	0.00	0.02	0.00	4400
-1.5%	0.00	0.04	0.00	2800
-2.0%	0.00	0.05	0.00	2100
-3.0%	0.00	0.08	0.14	1300
-5.0%	0.00	0.14	0.31	700

Table 20: Cohort of morbidly obese males aged 12-17 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.02	0.02	105.60	dominates
-1.0%	0.02	0.02	105.77	dominates
-1.5%	0.02	0.02	107.87	dominates
-2.0%	0.02	0.03	119.97	dominates
-3.0%	0.03	0.07	130.04	dominates
-5.0%	0.08	0.23	277.56	dominates

Table 21: Cohort of overweight females aged 2-5 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.06	5.17	1500
-1.0%	0.00	0.12	15.25	700
-1.5%	0.05	0.19	193.78	dominates
-2.0%	0.05	0.21	193.78	dominates
-3.0%	0.06	0.28	203.32	dominates
-5.0%	0.07	0.41	258.38	dominates

Table 22: Cohort of obese females aged 2-5 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.01	0.02	8900
-1.0%	0.00	0.02	0.03	4300
-1.5%	0.00	0.04	0.03	2700
-2.0%	0.00	0.05	0.04	1900
-3.0%	0.00	0.08	0.26	1200
-5.0%	0.00	0.17	0.79	600

Table 23: Cohort of morbidly obese females aged 2-5 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.02	0.02	127.34	dominates
-1.0%	0.02	0.03	129.68	dominates
-1.5%	0.02	0.03	133.75	dominates
-2.0%	0.02	0.04	139.15	dominates
-3.0%	0.02	0.07	147.43	dominates
-5.0%	0.05	0.16	204.93	dominates

Table 24: Cohort of overweight females aged 6-11 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.04	11.17	2200
-1.0%	0.00	0.08	22.62	1000
-1.5%	0.01	0.12	60.60	300
-2.0%	0.05	0.17	184.19	dominates
-3.0%	0.06	0.23	219.69	dominates
-5.0%	0.08	0.33	232.07	dominates

Table 25: Cohort of obese females aged 6-11 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.01	0.01	1200
-1.0%	0.00	0.02	0.02	5800
-1.5%	0.00	0.03	0.02	3800
-2.0%	0.00	0.04	0.02	2700
-3.0%	0.00	0.06	0.04	1700

-5.0%	0.00	0.11	0.28	900

Table 26: Cohort of morbidly obese females aged 6-11 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.03	0.04	162.81	dominates
-1.0%	0.03	0.05	168.65	dominates
-1.5%	0.03	0.06	172.44	dominates
-2.0%	0.03	0.07	173.97	dominates
-3.0%	0.03	0.11	173.97	dominates
-5.0%	0.04	0.19	196.51	dominates

Table 27: Cohort of overweight females aged 12-17 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.03	3.82	3200
-1.0%	0.00	0.06	3.82	1600
-1.5%	0.00	0.10	3.82	1000
-2.0%	0.00	0.13	3.83	700
-3.0%	0.07	0.22	233.99	dominates
-5.0%	0.09	0.34	248.06	dominates

Table 28: Cohort of obese females aged 12-17 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

	Discounted gains in:			
Change in BMI	Life expectancy	QALYs	Future cost savings	**ICER**
-0.5%	0.00	0.01	0.00	11000
-1.0%	0.00	0.02	0.00	5500
-1.5%	0.00	0.03	0.01	3600
-2.0%	0.00	0.04	0.01	2600
-3.0%	0.00	0.06	0.01	1700
-5.0%	0.00	0.11	0.02	900

Table 29: Cohort of morbidly obese females aged 12-17 for an intervention costing £100 and where future costs are discounted at 3.5% per year.

8.3 Comments on the results

8.4 Cohorts differentiated by BMI

Whether male or female, the model suggests that there are relatively small gains to be made in reducing BMI for the morbidly obese category by the levels included here. Much greater reductions would be required.

The overweight and obese cohorts are the more dynamic as a function of Δ_{BMI} yielding good gains in Δ_{QI} and Δ_{DI} for medium BMI reductions.

The healthy weight to overweight cohorts yield the most cost effective results. This is not surprising: The obesity model that is used predicts a moderate rise in obesity over the next 30 years (The obesity distributions for different age groups and gender are held fixed after that period).Thus children who are already obese will tend, on average, to become more so as they become adults and move into old age. A small reduction in BMI will help these children but the BMI reduction will prevent borderline overweight children from becoming obese.

Obese and severely obese children are affected less by small changes in BMI than their lower BMI peers because, for the obese and the severely obese, a small change in BMI in childhood equates to a very small BMI change in later life. This is a consequence of modelling BMI growth by the requirement that children stay on the same percentile. This point is discussed with diagrams in section 0.

8.5 Cohorts differentiated by age group

Different age groups exhibit similar behaviour across the range of BMI categories. However it is misleading perhaps to compare different age groups directly – it is not comparing like with like. Whereas it is true that each age- cohort has the same BMI percentiles the same is not true of the interventions. The interventions reduce BMI by various percentages; but in terms of percentiles a percentage reduction of 5% aged 5 is different from a 5% reduction aged 17. Nevertheless the results across the age groups for similar BMI cohorts are comparable.

8.6 Cohorts differentiated by gender

The two tables of results for the cohorts of overweight females aged 12-17 and overweight males aged 12-17 are both included in the table below. It is clear that the sexes differ considerably – the males benefitting more than the females for the same intervention (I).

	female			**male**		
	Discounted gains in:			Discounted gains in:		
Change in BMI	QALYs	Future cost savings	**ICER**	QALYs	Future cost savings	**ICER**
-0.5%	0.03	3.82	3200	0.02	11.96	3600
-1.0%	0.06	3.82	1600	0.05	11.96	1800
-1.5%	0.10	3.82	1000	0.07	22.73	1100
-2.0%	0.13	3.83	700	0.10	31.48	700

-3.0%	0.23	233.99	dominates	0.18	223.94	dominates
-5.0%	0.34	248.06	dominates	0.22	230.23	dominates

Table 30: comparison cohorts of overweight females and overweight males (aged 12-17)

8.7 The general structure of the results

The results show a spectrum of results in which children who are initially more obese achieve smaller gains in QALYs and savings in lifetime disease costs than their less obese peers. This has the result that the same intervention will be more cost effective for the child with the lower initial obesity level.

This is a result of the way in which the children's BMI growth is modelled over their lifetime. As has already been stated, children are assumed to remain on the same BMI percentile throughout their lives. If, in childhood, they experience an intervention which lowers their BMI then they will move to a lower percentile on which, if they do not regain weight, they will subsequently remain. The principal reason for lower BMI children doing better has to do with the way the percentiles relate to BMI in later life. This is explained below.

Saying that people remain on the same BMI percentile means that societal BMI is ordered; over the years the fattest people stay the fattest and the thinnest stay the thinnest and all points in between. It is simply an ordering – it says how people shift from one distribution to another, it says nothing about how percentiles relate to BMI. When, as is assumed in the model, national obesity trends continue to increase there will be many more obese people in 2030 than there are now or there were at the turn of the century. This has the consequence that children who are merely overweight now will be obese by 2030; most who are obese now will become morbidly obese by 2030. As an example Figure 9 shows the predicted rise in obesity levels for males aged 40 to 49. At 2030 the percentage obese for this age group is just over 50%. In other words – for this age group the 50th percentile determines the level above which people are classified as obese (BMI>30). People aged 20 in 2010 who were merely overweight and had a BMI value corresponding to the then 85th percentile by 2030 still sit on the 85th percentile but that percentile now equates to a BMI>40. The important point is that when obesity levels in the population rise the relationship between percentiles and BMI becomes compressed for high values of BMI. In other words: in 2010 the percentile range 85 to 100 corresponds to a BMI range 25 to 45; by 2030 the same range in percentiles corresponds to the BMI range 40 to 45. Moreover this percentile packing is more pronounced for higher BMI values.

For each Intervention, the model compares a person's life on two different BMI percentiles. At the start of the simulation when the person is a child the percentiles will differ by a few points depending on the severity of the intervention. As this person ages his two possible BMI paths are still described by the same percentile difference but in terms of BMI, because of the percentile compression on the BMI scale, his two possible BMI values have converged. Moreover the compression is more severe the higher the person's initial BMI. What affects the person's health and quality of life is his BMI; his percentile simply says what his peers are doing. And it is particularly his BMI in later life that matters. The idea behind the childhood interventions is to lower his BMI in later life. The problem is that, when national BMI is predicted to rise, in order to achieve a significant BMI reduction in later life one has to arrange a very substantial BMI reduction as a child.

What is seen happening in the simulation results is just this effect: the more obese children simply do not experience a big enough effect from the intervention to shift their BMI in later life. The result is that they achieve smaller gains and are deemed to be less cost effective targets. A less financially oriented conclusion might be that they need more money being spent on them than their thinner peers, to the extent that the money is estimated to be better spent elsewhere within the NHS. Percentiles and BMI compression are further discussed in Appendix 4, Section 15.1.

8.7.1 Comparison with other methods of calculation

At the risk of being repetitive, this short section is included to avoid possible misconceptions as to the workings of the model used in this report.

The method of calculation employed in deriving the above results is similar in form to, but not the same as, much standard *life table* analysis where, each year, probabilities of dying are used to determine the likelihood that a given person is alive or dead. In a conventional calculation of simple life expectancy the death statistics are taken to be the most recent available and are held fixed at those values when calculating the probability of being dead in future years. The point to stress is that in such a calculation no attempt is made to model the future – the death statistics are as given in the initial year when the stats were valid and stay fixed at those values. The probability of dying in a given year may depend on the person's age but it is a probability that was relevant in the initial year.

In this report, the calculation of life expectancy and likely disease prevalence *do* attempt to predict the future. This is essential if one is to investigate the effects of changing BMI, BMI like age is an intrinsically dynamic quantity. On average a child starts life with a low BMI and finishes life with a significantly higher BMI. In any year his probability of getting BMI-related diseases, or his probability of dying from them changes because of his BMI. Each year the model calculates afresh these probabilities from the child's BMI, age and gender and tables of relative risks. The probabilities that the child is in any of an exhaustive number of possible states are calculated, updated and the calculation moves on. In this calculation the child's BMI-trajectory in life plays a key part– it enables the relevant probabilities to be calculated at each year. The model makes the assumption that the child's BMI-trajectory is determined by the rule that he stays on the same BMI-percentile as he ages. If the child experiences an intervention to reduce his BMI, his future BMI is modelled by requiring that he stays on his new BMI-percentile. *This does not mean* that he maintains a constant BMI difference between his pre-intervention BMI-trajectory and his post-intervention BMI-trajectory. As the child ages the gap between his pre-intervention percentile and his post-intervention percentile stays the same but the gap between his pre-intervention BMI-trajectory and his post-intervention BMI trajectory does not remain the same. In fact, over the years, it tends to close up and the more obese the child the greater the closure of the gap. This narrowing of the BMI gap is called BMI compression and it has important consequences for BMI interventions on children:

- An intervention achieving a BMI reduction on a child does not achieve the same BMI reduction for that child in later life – the reduction in BMI becomes smaller as the child ages;
- Interventions on obese children are less effective than the same intervention on overweight children.

As already stated these effects are discussed in Appendix 4, Section 15.1.

BMI compression is most severe for morbidly obese children. Their initial loss of BMI amounts to only a very small change from their 99.5th percentile – they drop to approximately the 99th percentile. This is to be contrasted to obese and overweight children who drop 5 or more percentiles. In later life the small percentile gap translates into a much reduced BMI reduction.

The ability of the model accurately to compute the BMI change corresponding to very small percentile changes in the tail of the distribution is limited. The model assumes a simple histogram structure for its BMI distributions and cannot reliably capture the extreme changes in shape at around the 99th percentile seen in children's Normal distributions. The results quoted for morbidly obese children thus overestimate the BMI compression and under estimate the cost effectiveness of the Interventions.

It is beyond the scope of the current model accurately to compute these effects which require high resolution in the tails fo BMI distributions. However there does exist a reliable alternative which requires a small change to the nature of the intervention. This is provided in the next sub-section where the impact of Interventions are computed for which there are no BMI compression effects – the recipient of an Intervention maintains a post-intervention BMI trajectory that is a constant BMI difference with respect to their pre-intervention BMI trajectory; the initial BMI reduction is maintained throughout their modelled lifetime; it is no longer subject to distribution induced compression effects. These modelled trajectories will not suffer from the difficulties of computing effects of small percentile changes in the tails of distributions and provide a reliable guide to the effects of Interactions on the morbidly obese group.

8.8 BMI trajectories separated by a constant BMI difference

One would expect that the fixed BMI difference between the no-intervention and the post-intervention trajectory would reap far greater health and QALY benefits than the results already reported and this is indeed obvious from the results shown in the table below.

Change in BMI	ICER (fixed percentiles)	ICER (fixed Δ_{BMI})
-0.5%	8,600	3,300
-1.0%	4,200	1,600
-1.5%	2,700	1,000
-2.0%	2,000	700
-3.0%	1,200	400
-5.0%	600	100

Table 31: ICER values for a cohort of morbidly obese males aged 6-11 for an intervention costing £100 where future costs are discounted at 3.5% per year – with and without BMI compression.

The effect of maintaining a fixed reduction in BMI more than halves the ICER values previously obtained.

The complete set of results for the morbidly obese cohorts are provided below in Table 32.

	Discounted gains in:		
Change in BMI	QALYs	Future cost savings	ICER
-0.5%	0.02	5.11	4100
-1.0%	0.05	10.23	2000
-1.5%	0.07	15.36	1200
-2.0%	0.09	20.51	900
-3.0%	0.14	30.87	500
-5.0%	0.23	51.83	200

morbidly obese females, aged 2-5, Intervention cost £100

	Discounted gains in:		
Change in BMI	QALYs	Future cost savings	ICER
-0.5%	0.03	6.88	3000

-1.0%	0.06	13.77	1400
-1.5%	0.09	20.70	900
-2.0%	0.12	27.65	600
-3.0%	0.19	41.64	300
-5.0%	0.31	69.99	100

morbidly obese females, aged 6-11, Intervention cost £100

	Discounted gains in:		
Change in BMI	QALYs	Future cost savings	ICER
-0.5%	0.05	10.84	1800
-1.0%	0.10	21.75	800
-1.5%	0.15	32.71	500
-2.0%	0.19	43.73	300
-3.0%	0.29	65.94	100
-5.0%	0.49	111.10	0

morbidly obese females, aged 6-11, Intervention cost £100

	Discounted gains in:		
Change in BMI	QALYs	Future cost savings	ICER
-0.5%	0.02	4.80	4300
-1.0%	0.04	9.62	2000
-1.5%	0.07	14.47	1300
-2.0%	0.09	19.34	900
-3.0%	0.13	29.14	500
-5.0%	0.22	49.01	200

morbidly obese males, aged 2-5, Intervention cost £100

	Discounted gains in:		
Change in BMI	QALYs	Future cost savings	ICER
-0.5%	0.03	6.14	3300
-1.0%	0.06	12.31	1600
-1.5%	0.08	18.51	1000
-2.0%	0.11	24.75	700
-3.0%	0.17	37.30	400
-5.0%	0.28	62.78	100

morbidly obese males, aged 6-11, Intervention cost £100

	Discounted gains in:		
Change in BMI	QALYs	Future cost savings	ICER
-0.5%	0.05	9.82	2000
-1.0%	0.09	19.70	900
-1.5%	0.14	29.65	500
-2.0%	0.18	39.65	300
-3.0%	0.27	59.84	100
-5.0%	0.45	100.99	0

morbidly obese males, aged 12-17, Intervention cost £100

Table 32: ICER values for morbidly obese females and males for an intervention costing £100 where future costs are discounted at 3.5% per year – with and without BMI compression.

These results would suggest that the morbidly obese cohorts do benefit in a way that is similar to their less obese peers.

9 Results differentiated by intervention type, cohort and intervention cost

The results presented in section 8 are all for a hypothesised intervention cost of £100. The results presented here use the relevant values for Δ_{QI} and Δ_{DI} to compute more realistic ICER values for the estimated Intervention costs corresponding to the different types of intervention. The results here quoted for the morbidly obese refer to those obtained for the zero-BMI compression interventions and are shown in bold face to distinguish the fact that a slightly different intervention structure is being employed.

ICER values by Intervention cost for different interventions and cohorts – males									
ΔBMI	Morbidly obese			Obese			Overweight		
	Age								
	2 to 5	6 to 11	12 to17	2 to 5	6 to 11	12 to17	2 to5	6 to 11	12 to 17
Referred by GP - cost £353									
-0.5%	**15,800**	**12,300**	**7,600**	8,100	9,000	13,900	9,500	5,600	3,300
-1.0%	**7,800**	**6,000**	**3,700**	3,800	4,400	7,000	8,100	4,100	2,400
-1.5%	**5,100**	**3,900**	**2,400**	1,300	2,300	4,600	5,900	3,000	1,900
-2.0%	**3,800**	**2,900**	**1,700**	1,100	1,400	3,300	3,500	2,200	1,500
-3.0%	**2,400**	**1,900**	**1,100**	800	800	700	1,700	1,300	1,100
-5.0%	**1,400**	**1,000**	**600**	500	500	600	700	700	700
Parent only - cost £389									
-0.5%	**17,400**	**13,500**	**8,400**	8,900	9,900	15,000	11,000	7,000	4,000
-1.0%	**8,600**	**6,700**	**4,100**	4,200	4,900	7,800	9,300	4,800	2,900
-1.5%	**5,600**	**4,400**	**2,700**	1,500	2,600	5,100	6,900	3,500	2,300
-2.0%	**4,200**	**3,200**	**1,900**	1,300	1,600	3,700	4,100	2,600	1,900
-3.0%	**2,700**	**2,100**	**1,200**	900	900	900	2,000	1,600	1,400
-5.0%	**1,500**	**1,200**	**600**	600	600	700	800	800	900
Family intervention - cost £437									
-0.5%	**19,600**	**15,200**	**9,500**	10,000	11,200	17,300	12,900	7,900	4,900

-1.0%	**9,600**	**7,500**	**4,600**	4,700	5,500	8,800	11,000	5,900	3,600
-1.5%	**6,400**	**4,900**	**3,000**	1,800	2,900	5,700	8,100	4,300	2,800
-2.0%	**4,700**	**3,600**	**2,200**	1,500	1,900	4,200	4,900	3,200	2,300
-3.0%	**3,100**	**2,400**	**1,400**	1,100	1,100	1,2000	2,400	1,900	1,700
-5.0%	**1,800**	**1,300**	**800**	700	700	1,000	1,100	1,100	1,100
Family intervention - cost £651									
-0.5%	**29,200**	**22,800**	**14,200**	14,900	16,700	26,000	21,700	13,800	9,000
-1.0%	**14,500**	**11,300**	**7,000**	7,100	8,200	13,200	18,400	10,200	6,700
-1.5%	**9,600**	**7,500**	**4,600**	3,000	4,500	8,700	13,600	7,600	5,200
-2.0%	**7,100**	**5,500**	**3,400**	2,500	3,100	6,400	8,500	5,700	4,30
-3.0%	**4,700**	**3,600**	**2,200**	1,900	2,000	2,300	4,100	3,500	3,200
-5.0%	**2,700**	**2,100**	**1,200**	1,300	1,500	2,000	2,200	2,200	2,300
Residential intervention - cost £1980									
-0.5%	**89,400**	**69,700**	**43,800**	45,200	50,900	80,000	75,900	50,200	34,600
-1.0%	**44,500**	**34,800**	**21,800**	21,500	25,100	40,600	64,800	37,700	25,600
-1.5%	**29,600**	**23,100**	**14,400**	10,600	14,600	27,100	48,100	28,200	20,100
-2.0%	**22,100**	**17,300**	**10,800**	8,900	10,500	20,200	31,000	21,400	16,500
-3.0%	**14,700**	**11,500**	**7,100**	6,700	7,600	9,600	15,000	13,200	12,600
-5.0%	**8,800**	**6,800**	**4,200**	5,000	5,900	8,100	9,000	8,900	9,500

Table 33: ICER values by Intervention cost for different interventions and cohorts - males

ICER values by Intervention cost for different interventions and cohorts – females									
∆BMI	**Morbidly obese**			**Obese**			**Overweight**		
	Age								
	2 to 5	6 to 11	12 to17	2 to 5	6 to 11	12 to17	2 to5	6 to 11	12 to 17
Referred via GP - cost £353									
-0.5%	**15,100**	**11,200**	**7,000**	5,400	8,600	11,500	13,400	9,800	5,300
-1.0%	**7,500**	**5,500**	**3,400**	2,800	4,300	5,600	13,300	8,600	3,900
-1.5%	**4,900**	**3,600**	**2,200**	800	2,500	3,700	11,500	6,900	3,000

-2.0%	**3,600**	**2,600**	**1,600**	700	1,000	2,700	7,700	5,200	2,400
-3.0%	**2,300**	**1,700**	**1,000**	500	600	500	3,100	3,000	1,700
-5.0%	**1,300**	**900**	**500**	200	400	300	300	900	800
Parent only - cost £389									
-0.5%	**16,700**	**12,400**	**7,800**	6,000	9,500	12,700	15,300	11,300	6,200
-1.0%	**8,300**	**6,100**	**3,800**	3,000	4,800	6,200	15,200	10,000	4,600
-1.5%	**5,400**	**4,000**	**2,400**	1,000	2,800	4,000	13,200	8,000	3,600
-2.0%	**4,000**	**2,900**	**1,800**	900	1,200	3,000	9,000	7,000	2,900
-3.0%	**2,600**	**1,900**	**1,100**	700	800	700	3,600	3,500	2,000
-5.0%	**1,500**	**1,000**	**600**	300	500	400	500	1,200	1,000
Family intervention - cost £437									
-0.5%	**19,600**	**15,200**	**9,500**	6,800	10,700	14,200	17,900	13,400	7,600
-1.0%	**9,600**	**7,500**	**4,600**	3,400	5,400	7,000	17,800	11,800	5,700
-1.5%	**6,400**	**4,900**	**3,000**	1,300	3,200	4,600	15,500	9,500	4,400
-2.0%	**4,700**	**3,600**	**2,200**	1,100	1,500	3,300	10,400	7,200	3,500
-3.0%	**3,100**	**2,400**	**1,400**	800	1,000	900	4,300	4,200	2,500
-5.0%	**1,800**	**1,300**	**800**	400	600	600	700	1,500	1,300
Family intervention - cost £651									
-0.5%	**29,200**	**22,800**	**14,200**	10,100	16,100	21,300	29,500	22,700	13,500
-1.0%	**14,500**	**11,300**	**7,000**	5,200	8,200	10,500	29,300	20,100	10,200
-1.5%	**9,600**	**7,500**	**4,600**	2,400	5,100	6,800	25,500	16,200	7,900
-2.0%	**7,100**	**5,500**	**3,400**	2,100	2,700	5,000	17,500	12,400	6,400
-3.0%	**4,700**	**3,600**	**2,200**	1,600	1,900	1,800	7,300	7,400	4,500
-5.0%	**2,700**	**2,100**	**1,200**	1,000	1,300	1,200	1,600	2,800	2,400
Residential intervention - cost £1980									
-0.5%	**89,400**	**69,700**	**43,800**	30,900	49,500	65,000	101,300	80,200	50,200
-1.0%	**44,500**	**34,800**	**21,800**	16,000	25,600	32,000	101,000	71,200	38,200
-1.5%	**29,600**	**23,100**	**14,400**	9,400	16,500	20,800	87,900	57,700	29,900

-2.0%	**22,100**	**17,300**	**10,800**	8,300	10,500	15,200	61,200	44,700	24,100
-3.0%	**14,700**	**11,500**	**7,100**	6,300	7,900	7,600	26,000	26,800	17,000
-5.0%	**8,800**	**6,800**	**4,200**	4,200	5,400	5,100	7,500	11,200	9,500

Table 34: ICER values by Intervention cost for different interventions and cohorts – females

9.1 Sample graphs

As described earlier: for a given cohort, one run of the program allows ICER values to be shown as a linear function of the Intervention cost.

Figure 7 plots ICER [Intervention cost] for the 6 Interventions affecting the male overweight cohort ages 6 to 11. Figure 8 plots ICER [Intervention cost] for the 6 Interventions affecting the female overweight cohort ages 6 to11.

Individual points are marked for the costs {353, 389, 437, 651, 1980} listed in Table 33 and Table 34.

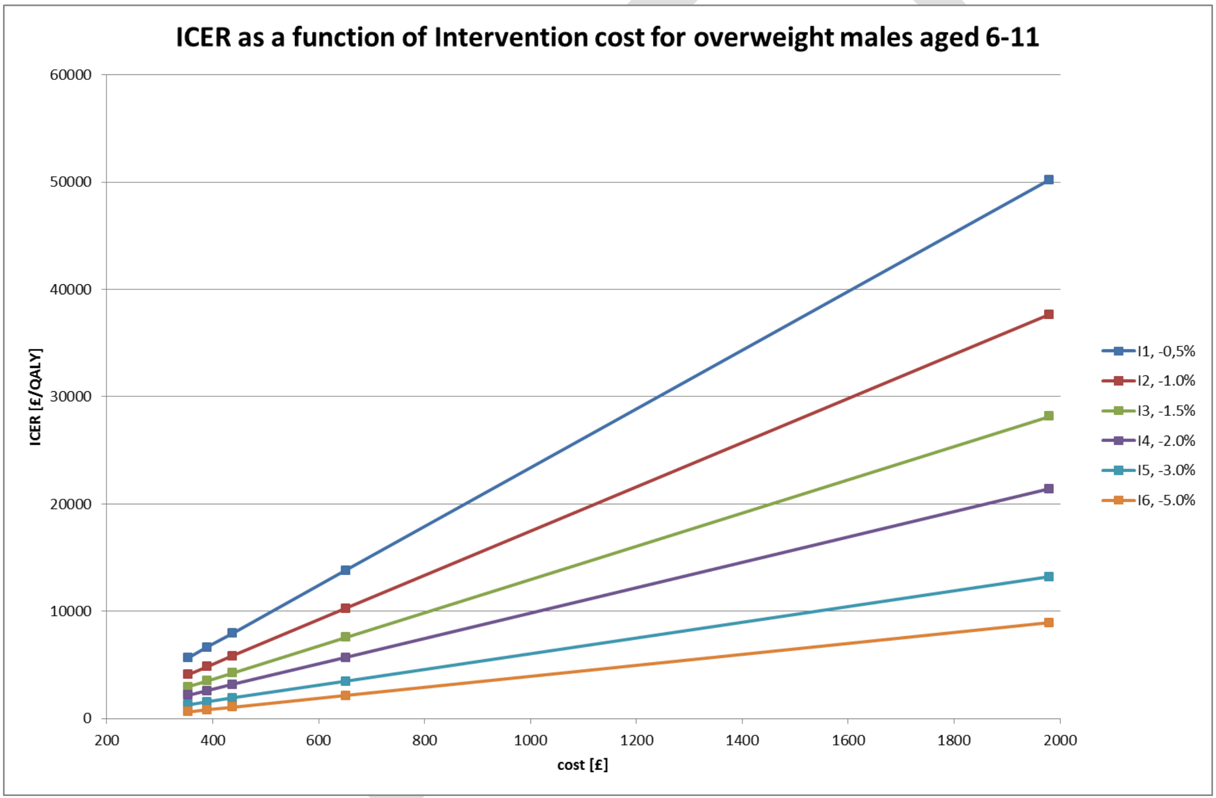

Figure 7: overweight males aged 6-11; ICER (cost) for different interventions

Assuming a threshold of £20000 per head per QALY gained, this graph indicates that all levels of weight loss are cost effective up to a cost of about £850 per head, and that weight losses of over 3% are cost effective even up to £2000 per head, provided the weight loss is permanent.

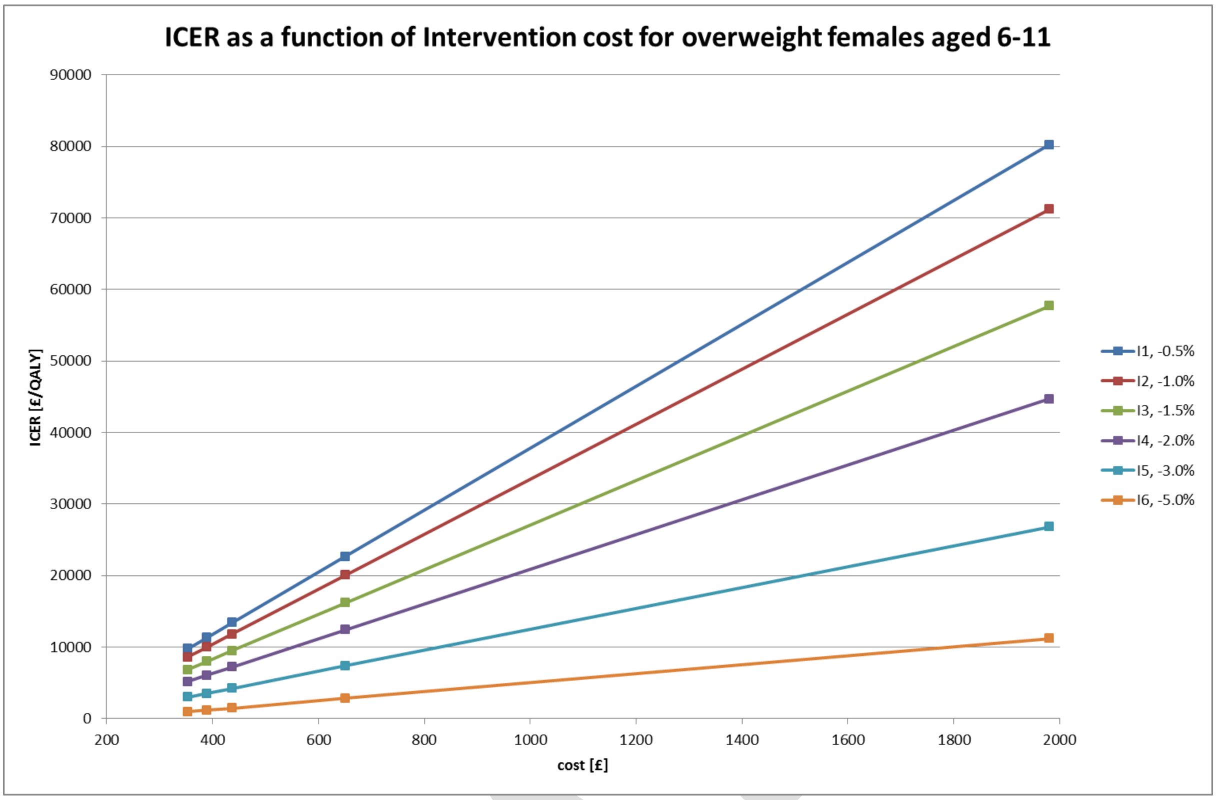

Figure 8: overweight females aged 6-11; ICER (cost) for different interventions

Figure 8 indicates that all levels of weight loss (from 0.5% to 5%) are estimated to be cost effective for Intervention costs up to £600 per head; only weight losses of more than 4% are still estimated to be cost effective at £2000 per head.

9.2 The persistence of interventions

The interventions modelled and reported above assume an initial weight loss immediately following the intervention which is sustained for the lifetime of the individual children affected. In terms of the way in which this process is modelled: the weight loss dictated by the intervention causes a child to move from their initial percentile, p say, to a lower percentile, $p \rightarrow p_l$, and they go through life having a BMI appropriate to the percentile p_l. In the real world, it is widely observed that weight, once lost, is frequently recovered (either in the short or long term) although there are few, if any, reported statistics supporting this assertion over the whole of life. The modelled interventions allow for weight recovery via the field *bmi_recovery_pa* (see 6.2.2 where it is shown as part of an Intervention file). This parameter sets a percentage rate at which *percentile*s are recovered per annum following the intervention. For example, a 2% per annum decay rate indicates that it will take 50 years to recover the initial weight loss in the sense that the individual will, in that time, fully return to their original percentile – each year they will shift their percentile upwards by an amount that is 2% of the initial difference (p-pl). This will correspond to a slightly different amount of BMI each year depending on the appropriate national BMI-distribution at the time. This sort of weight recovery is implemented in such a way that once a person's original percentile is reached they do not subsequently exceed it.

In this section representative results are provided showing the effect on computed ICERs for rates of weight recovery of 2%, 4%, 6%, 8% and 10% per year. First there are some general observations concerning what might be expected from this process.

ICER values are formed from two key statistics – the discounted relative gain in QALYs and the discounted relative future cost saving. In the course of a modelled person's life, weight loss relative to no intervention will cause gains in QALYs to be accrued from the age of 16 onwards and cost savings to be accrued from the time at which the BMI-dependent diseases become prevalent; roughly speaking this is from the age 30 onwards. The *Intervention-lifetime* is the number of years for which a person's post Intervention percentile differs from their original percentile. Clearly a very short Intervention-lifetime (a few years) will have almost no effect and will give rise to very high ICERs ; a long Intervention-lifetime (0% weight recovery) will maximise the effect of the intervention (corresponding to the lowest ICER value); intermediate Intervention-lifetimes will produce intermediate ICER values. If the Intervention-lifetime is shorter than the time to the onset of BMI-related diseases then the ICER values will depend solely on gains in the quality of life -in this case there will be no future cost savings.

Males overweight aged 12 to 17					
		Discounted gains in:			
Initial BMI loss	% BMI recovery pa	Life expectancy	QALYs	Future cost savings	ICER
-5%	0	0.05	0.18	225.83	1100
-5%	2	0.04	0.16	204.85	1500
-5%	4	0.00	0.10	17.66	4000
-5%	6	0.00	0.07	4.53	6400
-5%	8	0.00	0.04	2.98	11300
-5%	10	0.00	0.02	1.78	20600

Table 35: The effect on ICER values for different BMI recovery rates for the male overweight 12 to 17 cohort initially having a 5% BMI reduction in an intervention costing £437 per person

Females overweight aged 12 to 17					
		Discounted gains in:			
Initial BMI loss	% BMI recovery pa	Life expectancy	QALYs	Future cost savings	ICER
-5%	0	0.04	0.19	196.51	1300
-5%	2	0.03	0.14	176.11	1800
-5%	4	0.00	0.08	16.92	5000
-5%	6	0.00	0.05	11.53	7600
-5%	8	0.00	0.03	2.58	12700
-5%	10	0.00	0.02	0.00	22600

Table 36: The effect on ICER values for different BMI recovery rates for the female overweight 12 to 17 cohort initially having a 5% BMI reduction in an intervention costing £437 per person

Table 33 and Table 34 exhibit the expected behaviour: The first row (0 weight regained) of each table is the value already recorded; the intervention steadily becomes less cost effective as the weight is regained. The substantial drop in future cost savings arises when the weight has effectively been regained before middle age.

The predictable message is that the targeted children must keep the BMI off for a significant period of their life for the intervention to be cost effective. How rapid a weight gain can be tolerated for the intervention still to be cost effective will depend on the cohort and intervention. The example given above might be said to be robustly cost effective for the sorts of rates considered; no intervention will be cost effective for any cohort with a rapid reacquisition of weight.

9.3 Effect of data uncertainties

It is a reasonable assumption to suppose that the many contributing errors cause the eventual expression for the ICER value to be an approximately normally distributed function of its contributing approximately normally distributed random variables C_I, Δ_{DI}, Δ_{QI}. These random variables are related by the equation

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

eq 5

A 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[11] about its mean value. Here this is achieved as follows. Denoting mean values by <> brackets, we write

$$\begin{aligned} C_I &= \langle C_I \rangle + \delta C_I \\ \Delta_{DI} &= \langle \Delta_{DI} \rangle + \delta\Delta_{DI} \\ \Delta_{QI} &= \langle \Delta_{QI} \rangle + \Delta_{QI} \end{aligned}$$

eq 6

eq 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

eq 7 makes the assumption that the errors in the individual components are uncorrelated, $\langle \delta\Delta_{DI}\delta\Delta_{QI} \rangle = 0$, etc. With the exception of the dependence of both Δ_{DI}, Δ_{QI} on possible errors in BMI this is a simplifying assumption. 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 10% of the cost C_I. (The 95% confidence limit is approximately ± 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 10% of its value.

The errors in the QALY values are tabulated and are approximately 1% of the QALY value. Here we assume a lower accuracy of 10% of the QALY value.

[11] 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*

Summarising these estimates we have

$$\sqrt{\langle \delta C_I \delta C_I \rangle} \approx 0.1 \times C_I$$
$$\sqrt{\langle \delta \Delta_{DI} \delta \Delta_{DI} \rangle} \approx 0.1 \times \Delta_{DI}$$
$$\sqrt{\langle \delta \Delta_{QI} \delta \Delta_{QI} \rangle} \approx 0.1 \times \Delta_{QI}$$

eq 8

The consequent 95% confidence limits for the errors in ICER values are obtained by substitution into eq 7; these are tabulated below in the column headed CI +/-.

In this table ICER values and Confidence Interval values are rounded to the nearest £100 per QALY. In order to avoid having negative ICER values the cost of the intervention is set at a nominal £400 per person.

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.02	120.36	14,000	4900
-1.5%	0.03	121.48	9,300	3300
-2.0%	0.04	124.33	6,900	2500
-2.5%	0.06	145.16	4,200	1600
-3.0%	0.12	149.84	2,100	800
-5.0%	0.2	223.95	900	500
Male, overweight, 2-5, costing £400 per person				
	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.04	0.15	10,000	2800
-1.5%	0.09	0.15	4,400	1200
-2.0%	0.17	124.17	1,600	600
-2.5%	0.21	125.28	1,300	500
-3.0%	0.28	130.39	1,000	300
-5.0%	0.36	180.71	600	300
Male, obese, 2-5, costing £400 per person				
	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.02	0	20,000	5500
-1.5%	0.03	0.15	13,300	3700
-2.0%	0.05	0.15	8,000	2200
-2.5%	0.07	0.32	5,700	1600
-3.0%	0.12	0.46	3,300	900
-5.0%	0.23	0.64	1,700	500
Male, morbidly obese, 2-5, costing £400 per person				
	Discounted gains in:			

Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.04	146.86	6,300	2400
-1.5%	0.05	153.89	4,900	1900
-2.0%	0.06	162.56	4,000	1600
-2.5%	0.08	169.81	2,900	1200
-3.0%	0.14	175.26	1,600	700
-5.0%	0.2	227.4	900	500

Male, overweight, 6-11, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.04	1.83	10,000	2800
-1.5%	0.08	3.43	5,000	1400
-2.0%	0.13	51.84	2,700	800
-2.5%	0.18	104.71	1,600	600
-3.0%	0.24	170.18	1,000	400
-5.0%	0.3	214.31	600	300

Male, obese, 6-11, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.01	0	40,000	11100
-1.5%	0.03	0.03	13,300	3700
-2.0%	0.04	0.08	10,000	2800
-2.5%	0.05	0.18	8,000	2200
-3.0%	0.08	0.28	5,000	1400
-5.0%	0.16	0.55	2,500	700

Male, morbidly obese, 6-11, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.05	182.75	4,300	1900
-1.5%	0.07	184.65	3,100	1400
-2.0%	0.09	185.87	2,400	1100
-2.5%	0.11	186.46	1,900	900
-3.0%	0.14	192.38	1,500	700
-5.0%	0.18	225.83	1,000	500

Male, overweight, 12-17, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.02	11.96	19,400	5500
-1.5%	0.05	11.96	7,800	2200
-2.0%	0.07	22.73	5,400	1500
-2.5%	0.1	31.48	3,700	1100

-3.0%	0.18	223.94	1,000	500
-5.0%	0.22	230.23	800	400

Male, obese, 12-17, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.01	0	40,000	11100
-1.5%	0.02	0	20,000	5500
-2.0%	0.04	0	10,000	2800
-2.5%	0.04	0	10,000	2800
-3.0%	0.08	0.14	5,000	1400
-5.0%	0.14	0.31	2,900	800

Male, morbidly obese, 12-17, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.02	105.6	14,700	5000
-1.5%	0.02	105.76	14,700	5000
-2.0%	0.02	107.87	14,600	5000
-2.5%	0.03	119.97	9,300	3300
-3.0%	0.07	130.04	3,900	1400
-5.0%	0.23	277.56	500	400

Female, overweight, 2-5, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.06	5.17	6,600	1800
-1.5%	0.12	15.25	3,200	900
-2.0%	0.19	193.78	1,100	500
-2.5%	0.22	193.78	900	400
-3.0%	0.28	203.32	700	300
-5.0%	0.41	258.38	300	200

Female, obese, 2-5, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.01	0.02	40,000	11100
-1.5%	0.02	0.03	20,000	5500
-2.0%	0.04	0.03	10,000	2800
-2.5%	0.05	0.04	8,000	2200
-3.0%	0.08	0.26	5,000	1400
-5.0%	0.17	0.79	2,300	700

Female, morbidly obese, 2-5, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.02	127.34	13,600	4900
-1.5%	0.03	129.67	9,000	3300
-2.0%	0.032	133.75	8,300	3100
-2.5%	0.04	139.15	6,500	2400
-3.0%	0.07	147.43	3,600	1400
-5.0%	0.16	204.93	1,200	600

Female, overweight, 6-11, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.04	11.17	9,700	2700
-1.5%	0.08	22.62	4,700	1300
-2.0%	0.12	60.6	2,800	900
-2.5%	0.17	184.19	1,300	600
-3.0%	0.22	219.69	800	400
-5.0%	0.33	232.07	500	300

Female, obese, 6-11, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.01	0.01	40,000	11100
-1.5%	0.02	0.02	20,000	5500
-2.0%	0.03	0.02	13,300	3700
-2.5%	0.04	0.02	10,000	2800
-3.0%	0.06	0.04	6,700	1800
-5.0%	0.11	0.28	3,600	1000

Female, morbidly obese, 6-11, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.04	162.81	5,900	2400
-1.5%	0.04	168.65	5,800	2400
-2.0%	0.06	172.44	3,800	1600
-2.5%	0.07	173.97	3,200	1400
-3.0%	0.11	173.97	2,100	900
-5.0%	0.19	196.51	1,100	500

Female, overweight,12-17, costing £400 per person

	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.03	3.82	13,200	3700
-1.5%	0.06	3.82	6,600	1800
-2.0%	0.1	3.82	4,000	1100

-2.5%	0.13	3.83	3,000	800
-3.0%	0.23	233.99	700	400
-5.0%	0.34	248.06	400	300
Female, obese, 12-17, costing £400 per person				
	Discounted gains in:			
Change in BMI	QALYs	Future cost savings	ICER	CI (+/-)
-1.0%	0.01	0	40,000	11100
-1.5%	0.02	0	20,000	5500
-2.0%	0.03	0.01	13,300	3700
-2.5%	0.04	0.01	10,000	2800
-3.0%	0.06	0.01	6,700	1800
-5.0%	0.11	0.02	3,600	1000
Female, morbidly obese, 12-17, costing £400 per person				

Table 37: ICER values and their Confidence intervals for an Intervention costing £400 per person

The 95% confidence intervals shown in Table 37 vary considerably depending on the size of the ICER but are approximately 50% that of the ICER.

9.3.1 Uncertainties in BMI

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

The original BMI distributions inferred from survey data 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.

In addition to their being coloured the graphs are labelled OTFok, OTFow, OTFob corresponding to normal weight, overweight and obese.

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[12]

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[12] This is standard, non-linear, Bayesian, multivariate, logistic, regression analysis. A recent reference is Hilbe, Joseph M. (2009). *Logistic Regression Models*. Chapman & Hall/CRC Press. ISBN 978-1-4200-7575-5.

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

eq 9

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.

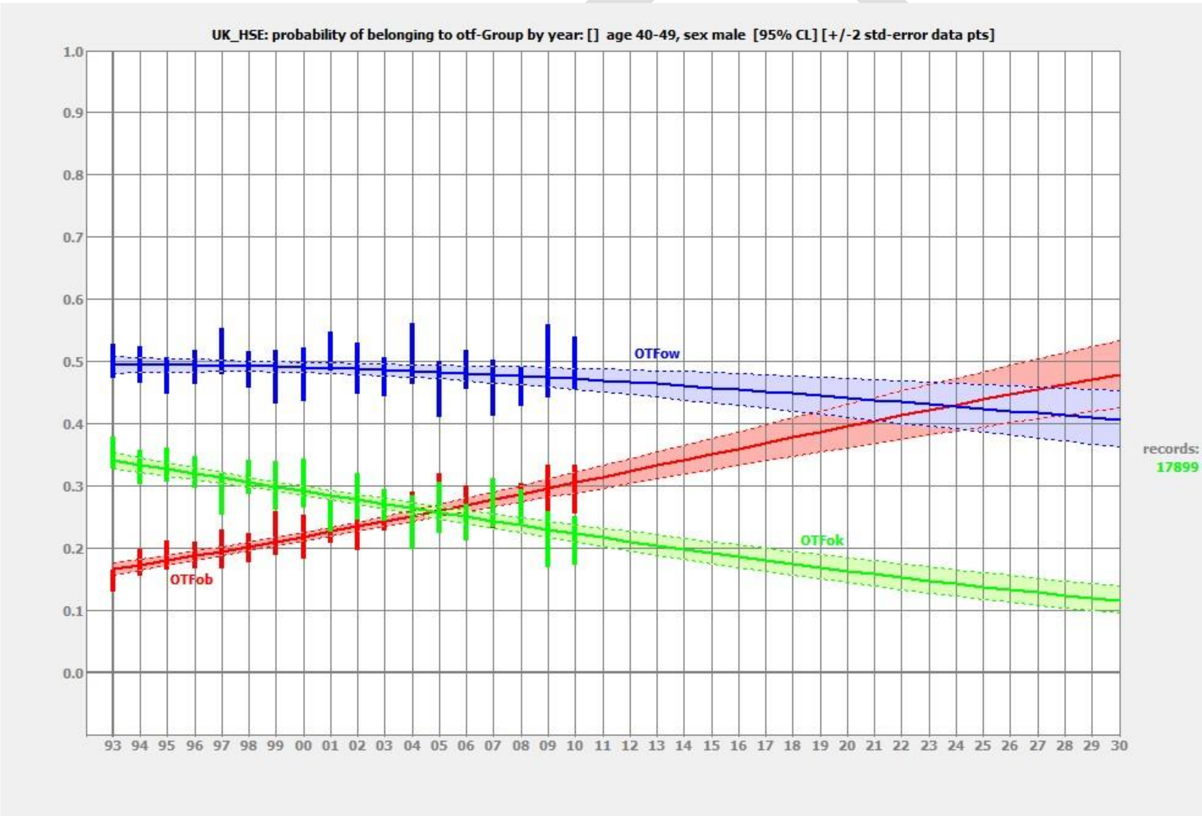


Figure 9: Predicted male (ages 40 to 49) BMI distributions {bmi<25 is labelled OTFok, 25<bmi<30 is labelled OTFow, bmi>30 is labelled OTFob} from 1993 to 2030 for the HSE data sets {1993 to 2010} showing 95% confidence intervals

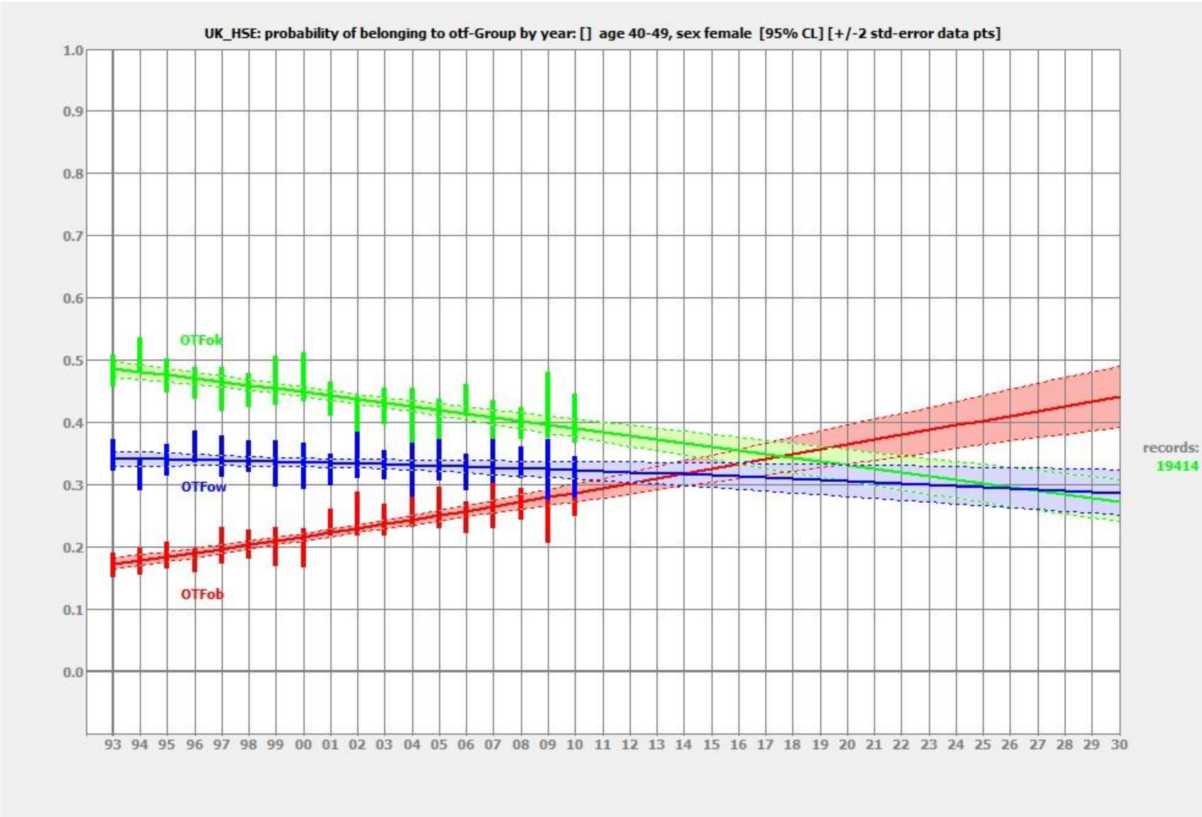


Figure 10: Predicted female (ages 40 to 49) BMI distributions {bmi<25 is labelled OTFok, 25<bmi<30 is labelled OTFow, bmi>30 is labelled OTFob} from 1993 to 2030 for the HSE data sets {1993 to 2010} showing 95% confidence intervals

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 38 and Table 39) were derived by the model using a BMI file in which the slope of the p_{ob} trend was increased by 1 standard deviation (**σ)**) 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 (ML) trajectory are repeated for comparison purposes in the column headed ICER(ML).

Male		
Intervention	**ICER(ML +σ)**	**ICER(ML)**
-0.5%	18,400	4,800
-1.0%	9,200	3,600
-1.5%	6,200	2,800
-2.0%	4,700	2,300
-3.0%	3,200	1,700
-5.0%	1,900	1,100

Table 38: ICER as a function of I-sigma variation in BMI trend for an Intervention cost per person of £437

Female		
Intervention	**ICER(ML+σ)**	**ICER(ML)**
-0.5%	12,800	7,600

-1.0%	7,300	5,700
-1.5%	5,300	4,400
-2.0%	4,200	3,500
-3.0%	2,700	2,500
-5.0%	1,500	1,300

Table 39: ICER as a function of 1-sigma variation in BMI trend for an Intervention cost of £437 per person

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, cost effectively to remove the weight.

Of course, the future BMI distributions may not correspond to the predicted trend lines at all. There is little that can be said of this possibility.

9.3.2 Quantisation errors

9.3.3 Overview of cost effectiveness results

Most of the benefits of weight loss as a child will be realised only as an adult. The estimates for cost effectiveness presented here are predicated on two important assumptions: (1) that as cohort members age, they stay on the same BMI-percentile relative to their peers and (2) that the impact of interventions which in childhood succeed in lowering a person's BMI-percentile are maintained throughout life. The hope is that although this rule is likely often to be broken it nonetheless provides a pointer to the average behaviour. It provides a useful metric by which to assess different interventions.

A 5% reduction in BMI – the largest outcomes considered in this report – if sustained for life is estimated to be usually cost effective to the overweight and obese cohorts. To the morbidly obese this level of change does little to alleviate their condition and a much more substantial weight reduction is required to achieve standard levels of cost-effectiveness.

This study has focussed on single, modestly sized, time-localised interventions. They can be seen to have an appreciable effect on those who are not too obese if the weight lost or not put on is maintained indefinitely.

10 Cost consequence analysis: obesity, bullying and self-esteem

10.1 Summary

1. The effects of obesity on bullying and self-esteem are quantified in studies on various scales;
2. 12 Studies mostly looked at self-esteem and or affective disorders (anxiety/ depression) of these studies 5 were based in the US, 3 in Canada, the remaining papers were from European studies including 2 from the UK;
3. There was evidence of strong associations between BMI and victimisation and between bullying and affective disorders. It is possible that adolescents and children with poor mental health may be more susceptible to teasing compared with their peers who are likely to be emotionally healthier.

10.2 Introduction

Bullying during childhood has significant negative impacts on social and psychological well-being, with socially stigmatising physical features such as obesity being a characteristic that could increase the likelihood of teasing. Several studies have been carried out to look into the relationship between obesity, bullying and self-esteem.

10.3 Methodology

In order to capture an extensive list of articles on obesity, self-esteem and bullying, multiple databases were explored by two researchers with the intention of retrieving studies that were relevant. The approach of the rapid review is described below.

10.3.1 Search Strategy

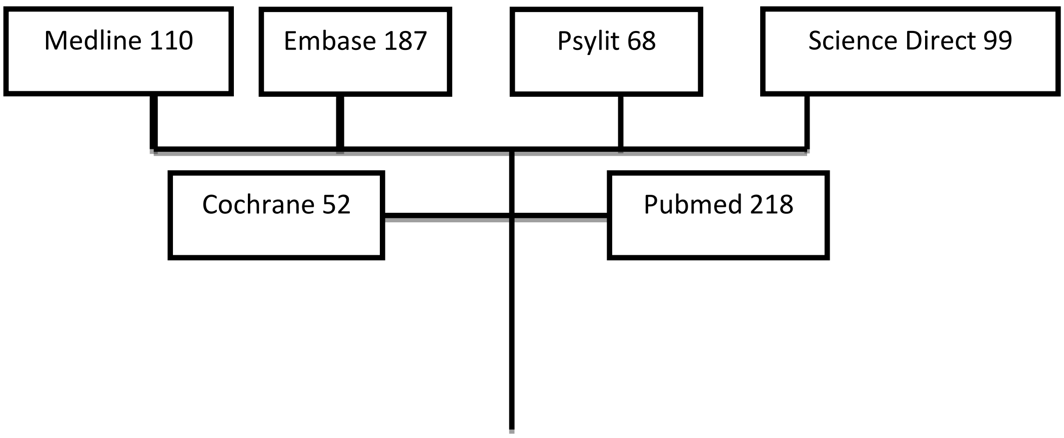
A prototype of the search strategy can be found in Appendix 5, section 16.1. Six electronic databases were searched, namely:

I. Ovid MEDLINE
II. Ovid Embase
III. Cochrane Library (NHS Economic Evaluation Database)
IV. PsychLit
V. Pubmed
VI. Science Direct

Using the same search terms, we searched for articles on Google scholar. However, no new papers were found. Searches were carried out in January 2013. Articles published between 1998 and 2013 were included. The time span chosen considered the need to evaluate articles that were topical and relevant to modern realities.

An online search of databases identified 735 potentially relevant papers (see figure 11),529 after removal of duplicates. The titles, keywords and abstracts of the 529 articles were examined in order to screen out irrelevant articles, using the research question and selection criteria of studies as a guide. This strategy limited the number of articles to 43. The six databases were each divided and searched independently by two researchers based on title and abstract using the following inclusion criteria described below in section 10.3.2.

Comparison of results was done between them. No arbitrating intervention by a third researcher was needed.
The 43 articles were electronically downloaded and assessed. After careful evaluation, 31 articles were excluded for not meeting the requirements of the quality assessment. This left a final total of 12 papers for review. Cross referencing checks performed did not generate any new articles.



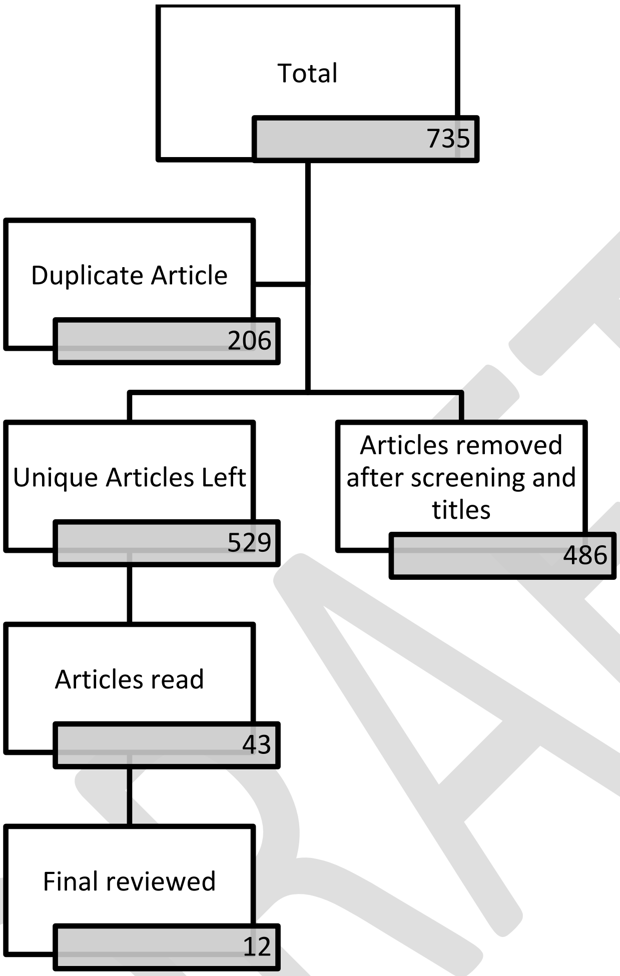


Figure 11: Literature Search Strategy

10.3.2 Inclusion/exclusion criteria

Articles included were not limited by type of study design. The participant population eligible included overweight and obese children and adolescents. No emphasis was placed on ethnicity or cultural background. Study settings included were for OECD countries only. The principal outcome of interest was the relationship between BMI and bullying/victimisation, while association between BMI and negative effects were explored secondarily.

We excluded non English language papers, articles written before 1998 and grey literature.

10.3.3 Data extraction

Data were extracted from eligible studies that met the review criteria. Information extracted included: The name of the study and their authors, study design, objectives, methodology, measures of outcome, key findings and conclusions was completed by one reviewer.

10.4 Description of studies

A total of 12 studies met the inclusion criteria and were reviewed. The age of the participants involved ranged from 5 to 18 years old. Nine of the studies collected data in an educational setting including Canada, the United States, the United Kingdom, Denmark and the Netherlands. Of the remaining 3, Griffith et al 2006 [44] included a cohort of children from the Avon health authority area UK, Storch et al 2007 [45] included participants that attended a primary care clinic in the United States while Jensen and Steele 2010 [46] collated data from children and adolescents who participated in a behavioural weight management program carried out in the US.

Study	Population	Study location	Study design	Country	Outcomes of Interest
Brixval et al. (2011) [47]	Ages 11, 13 and 15 year old school children n=4781	School	Cross Sectional Epidemiological study	Denmark	Bullying, body image, ethnic background, family type
Jensen and Steele (2010) [46]	Children and teenagers aged 7-17 n=93	Participants were enrolled in a paediatric weight management program	Longitudinal study (10 weeks weight management program +1 year follow up)	United States	Victimisation and Health Related Quality of Life.
Kukaswadia et al. (2011) [50]	Ages 14-17 n=1738	High School	Longitudinal study (1 year)	Canada	Self-reported physical and social bullying
Fox et al. (2009) [49]	Ages 11 – 14 years n=376	School	Cross Sectional Study (1 year)	United Kingdom	Verbal Physical and social bullying, global self-worth, self-esteem for physical appearance and body dissatisfaction.
Eisenberg et al. (2003) [60]	Ages 12- 17 n=4746	Middle school and High School	Cross Sectional	United States	Weight based teasing from peers or family members, body satisfaction, self-esteem, depressive symptoms suicidal ideation and suicide.
Neumark-Sztainer et al. (2002) [57]	Ages 12- 17 n=4746	Middle school and High School	Cross Sectional	United States	Prevalence of weight teasing across gender/ weight status/ethnicity, Degree to which youths reported being bothered by teasing, associations between weight related teasing and eating behaviour
Giletta et al. (2010) [58]	Age 10 -16 years n=2051	School	Cross Sectional	Netherlands	Self/peer identified bullying, depressive symptoms and self esteem

Study	Population	Study location	Study design	Country	Outcomes of Interest
Storch et al. (2007) [45]	Ages 8 to 18 n=92	University of Florida paediatric lipid clinic	Cross Sectional study	United States	Peer teasing, child reported depression, anxiety, social physique anxiety, loneliness and physical activity
Puhl et al. (2012) [54]	Ages 14 - 17 n=1555	High School	Cross Sectional study	United states	Bulling, responses and locations, coping strategies and school related consequences.
Griffiths et al. (2006) [44]	Age 7.5 to 8.5 years	Avon Longitude study of parents and childhood	Longitudinal Study	England	Prevalence of bullying, weight predicted bulling status.
Janssen et al. (2004) [48]	11 – 16 years old n=5794	School	Analysis of cross sectional survey data	Canada	Verbal, physical, relational bullying and sexual harassment
Goldfield et al. (2010) [55]	12- 17 Years n=1491	School	Cross sectional study	Canada	Bullying, Eating disorders, negative mood, interpersonal problems, negative self-esteem, depression and anhedonia.

Table 40: Description of Studies included

10.5 BMI

All the papers reported the ratio of boys to girls, age range and total number of participants. BMI measurements were taken by qualified personnel in 8 of the studies while the others [47,49,50,54] used self-reported measures. Participants were defined as overweight if BMI = 85-94.99th percentile and obese if BMI > 95th percentile using standard cut off points defined by the US Centre of Disease Control BMI for age growth charts. Reference data used in determining the percentiles was in line with the country of study in nine of the articles reviewed. The other four papers i.e. Brixval et al 2011 [47], Janssen et al 2004 [48], Fox et al 2009 [49] and Kukaswadia et al 2011 [50] used the international cut-offs developed by Cole et al 2000 [51] to classify participants into different weight categories.

10.6 Victimisation/ Bullying and Weight Based Teasing

Victimisation or bullying was consistently defined in nine of the papers to include physical and verbal bullying while three papers [47,44,54] included relational bullying (i.e. causing harm to social standing) in their definition. Of the eight studies that used bullying as an outcome measure, four utilised the Olweus Bully/victim Questionnaire 1991 [52]. Griffiths et al 2006 [44] utilised a bullying and friendship interview scale, Storch et al 2007 [45] used the Schwartz Peer Victimisation scale 2002 [53], Fox et al 2009 [49] made use of an adapted form of the Olweus tool [52] and Puhl et al 2011 [54] used a tool developed by one of its authors.

Weight based teasing was measured in three papers: Goldfield et al 2010 [55] used the McKnight Risk Factor Survey III 1999 [56] tool, Neumark-Sztainer et al 2002 [57] utilised a tool developed by Thompson et al 1995

[58] and Puhl et al 2011 [54] made use of an instrument developed by one of its authors using different forms of standardised questionnaires.

10.7 Self-esteem and affective disorders

Five of the articles reviewed had self-esteem and/or affective disorders such as depression and anxiety as measures of outcome. Three papers measured self-esteem, two of which (Giletta et al 2010 [58] and Eisenberg et al 2003[60]) used the Rosenberg Self-Esteem scale 1965 [61] as the measuring tool. Storch et al 2007 [45] and Goldfield et al 2007 [55] measured anxiety using the Multidimensional Anxiety Scale 1997 [62]. Depression as an outcome measure was quantified using varying tools of measurement, the studies namely; Storch et al 2007 [45], Goldfield et al 2010 [54], utilised the Children's Depression Inventory Short Form [63] while Eisenberg et al 2003 [59], used a depressive mood measure developed by Kandel and Davis 1982 [64] and Gilleta et al 2010 [59] applied the Dutch Version of the Centre of Epidemiological Studies Depression Scale [65].

Other measures captured in the studies include coping strategies in the Puhl et al 2011 [54], weight control behaviours in the Neumark-Sztainer et al 2002 [57], loneliness in the Storch et al 2007 [45], suicidal ideation and attempt in the Eisenberg et al 2003 [60] study and body dissatisfaction in the Fox et al 2006 [49].

10.8 Self-esteem and affective disorders

Five of the articles reviewed had self-esteem and/or affective disorders such as depression and anxiety as measures of outcome. Three papers measured self-esteem, two of which (Giletta et al 2010 [58] and Eisenberg et al 2003[60]) used the Rosenberg Self-Esteem scale 1965 [61] as the measuring tool. Storch et al 2007 [45] and Goldfield et al 2007 [55] measured anxiety using the Multidimensional Anxiety Scale 1997 [62]. Depression as an outcome measure was quantified using varying tools of measurement, the studies namely; Storch et al 2007 [45], Goldfield et al 2010 [54], utilised the Children's Depression Inventory Short Form [63] while Eisenberg et al 2003 [59], used a depressive mood measure developed by Kandel and Davis 1982 [64] and Gilleta et al 2010 [59] applied the Dutch Version of the Centre of Epidemiological Studies Depression Scale [65].

Other measures captured in the studies include coping strategies in the Puhl et al 2011 [54], weight control behaviours in the Neumark-Sztainer et al 2002 [57], loneliness in the Storch et al 2007 [45], suicidal ideation and attempt in the Eisenberg et al 2003 [60] study and body dissatisfaction in the Fox et al 2006 [49].

10.9 Key findings

All the articles reported an association between BMI and victimisation, bullying or weight based teasing. Table 41 below shows the statistical results of the papers. The general trend in the articles revealed that the higher the BMI, the more likely that a child would be bullied. Seven of the papers (Goldfield et al 2010 [55], Puhl et al 2011 [54], Griffith et al 2006 [44], Brixval et al 2011 [47], Neumark-Sztainer et al 2002 [57], Eisenberg et al 2003 [60] and Fox et al 2009 [49]) observed that bullying/weight based teasing was more prominent in girls. Kukaswadia et al 2011 [50], Jensen and Steele 2010 [46] and Giletta et al 2010 [58] claimed that boys were more affected by weight based teasing while the Jensen and Steele 2010 [46] other papers did not provided data on gender based difference observed in gender based victimisation.

Studies that measured negative effects such as depression and anxiety reported a correlation between bullying and negative effects. The studies however emphasised the point that a causal relationship could not be established because of the study design employed in carrying out the analyses (cross-sectional data).

Coping strategies such as avoidance of physical activity and binge eating were reported to have been used by children who were prone to negative effects.

Jensen and Steele 2010 [46] looked at the longitudinal association between teasing and Paediatric Health Related Quality of Life (HRQOL). The paper measured teasing using Perceptions of Teasing Scale (POTS; Thompson et al., 1995 [58]), Quality of Life using the Pediatric Quality of Life Inventory (PedsQL) 4.0 Generic Core Scales while the parent-report of HRQOL was measured using the PedsQL 4.0 Parent Proxy Report. The study found that there was an association between teasing and HRQOL across the three measurement periods spanning the 15 months study period providing evidence of stability of teasing over time. It could, however, not establish a directionality of influence to demonstrate that teasing led to a lower quality of life. A key finding by the article, however, was that functional impairments associated with poor HRQOL, (e.g., physical limitations, school problems, social impairments) predict higher subsequent levels of teasing. These results suggest that increasing social skills may discourage bullying among overweight and obese youths.

Author	**Type of analysis**	**Results**
Kukaswadia et al. (2011) [50]	Multi-level Logistic Regression model	Analysis examining BMI as a risk factor for bullying showed an Odds Ratio (OR) of 1.09 (0.56-2.10) and 2.07 (0.85- 5.02) for overweight and obese males respectively while female participants had OR of 0.24 (0.03-1.80) and 2.11 (0.95-4.70) for overweight and obesity respectively
Griffiths et al. (2006) [44]	Multiple logistic regression analysis	Weight category at age 7.5 was found to predict overt bullying status (at age 8.5) for boys (x2 (6) =22.94, P< 0.05) and girls (x2 (6)=14.38, P< 0.05). Compared to average weight boys, obese boys were 1.40 times more likely to be overt victims. Compared to average weight girls, obese girls were 1.52 times more likely to be overt victims.
Storch et al. (2007) [45]	Pearson correlations	Results indicated that victimisation was negatively associated with physical activity R2 =0.10, F (1, 90) = 10.1, P < 0.001, Depressive symptoms was positively associated with peer teasing in overweight and obese youths, R2 = 0.16, F (1, 90) = 16.1, P <0.001.
Gilleta et al. (2010) [59]	Hierarchical logistic regression	Higher BMI z scores were significantly associated with greater probability to report victimisation. Girls did not differ from boys.
Brixval et al. (2011) [47]	X^2 , bivariate and multivariate logistic regression analysis	Analyses showed that among students exposed to bullying, there was a statistically significant amount of overweight students (P < 0.000). Among boys, the OR for exposure to bullying is 1.74 (1.18–2.57) in overweight boys when compared to normal weight peers. Further, there was a high although not significant evidence of bullying [OR = 2.05 (0.83–5.08)] in obese compared with normal weight boys.

		Among girls, the OR for exposure to bullying is 1.88 (1.25–2.83) in overweight and 3.60 (1.37–9.47) in obese girls.
Goldfield et al. (2010) [55]	X^2 analyses and Pearson Correlation	The prevalence of weight-based teasing by peers was significantly higher among overweight and obese youth than among normal weight youth (45% versus 22%; $P<0.001$).
Neumark – Sztainer et al. (2002) [57]	X^2 tests and logistic regression	Weight teasing by peers (ever) was reported by significantly more girls (n=667, 30.0%) than by boys (n=546, 24.6%; $X^2=16.3$, $P<0.001$). Weight-teasing by family members (ever) was reported by significantly more girls (n=637, 28.7%) than boys (n=356, 16.1%; $X^2=101.5$, $P<0.001$). Associations between weight status and weight-teasing were found to be statistically significant among girls and boys in univariate analyses.
Eisenberg et al. (2003) [60]	Multivariate Logistic Regression	Overweight Girls – Low self-body satisfaction was calculated to be2.18 (1.81-2.61) ($P< 0.05$), Low self-esteem was estimated at 0.97 (0.76-1.24) Overweight Boys - Low self-body satisfaction was calculated at 2.06 (1.61-2.64) ($P< 0.05$), Low self-esteem was valued at .86 (0.60-1.24)
Janssen et al. (2004) [48]	X^2 tests and logistic regressions	Direct and significant relationship between BMI category in girls and boys. An Odds Ratio (OR) of 1.37 (0.93–2.00) and 1.44 (0.87–2.39) $P<0.05$ for overweight and obese males respectively was recorded while female participants had OR of 1.26 (0.83–1.88) and 1.91 (1.07–3.38) $P<0.05$ for overweight and obesity respectively.
Fox et et al. (2009) [49]	Mediation analysis	Effects of verbal and social bullying were observed with girls reporting being on the receiving end of more verbal and social bullying than boys [$F(1,192) = 3.91$, M*SE*= .69, $p < .05$; $F(1,190) = 12.09$, M*SE*= .52, $p < .001$]. In addition, there was a main effect of Overweight and Obesity status on physical bullying, with Overweight and Obesity adolescents more likely to report experiencing physical bullying than those who were not overweight [$F(1,192) = 4.46$, M*SE* .82, $p < .05$].
Jensen and Steele (2010) [46]	Structural Equation Modelling	Teasing did not significantly predict HRQOL at 3 different time periods. Teasing at Time 1 did not significantly predict HRQOL at Time 2 nor did Teasing at Time 2 predict HRQOL at Time 3 (β = .07, $p > .05$; β = .039, $p > .05$, respectively). HRQOL was however found to significantly predict teasing. HRQOL at Time 1 significantly predicted Teasing at Time 2 (β = .33, $p < .01$) and HRQOL at Time 2 predicted Teasing at Time 3 (β = .40, $p < .01$). Levels of teasing negatively

		affected quality of life
Puhl et al. (2011) [54]	Pearsons Correlation	The odds of students reporting that their grades were harmed because of being victimised about their weight increased by approximately 5% per teasing incident. The underlying proportional odds assumption was confirmed with the Brant test (v2 = 7.48, df = 6, p = 0.278; Long 1997).

Table 41: study results

10.10 Discussion and Conclusion

This review has looked at the association between obesity and bullying with a view to synthesise evidence that may be useful for the NICE obesity weight management model. All findings from the review point to a positive relationship between high BMI's and victimisation in adolescents. Negative effects and coping strategies adopted by children have also been shown to have a strong correlation with victimisation although causal inference could not be drawn due to the nature of the cross sectional studies. It may be possible that adolescents and children with poor mental health may be more susceptible to teasing compared with their peers who are likely to be emotionally healthier. In the longitudinal studies there were diverse findings. Jensen and Steele 2010 [46] suggested that it was improvements in HRQL that would lead to a decreased risk of peer victimisation in obese adolescents and not necessarily weight-loss. Kukaswadia et al 2011 [50] found that the types of bullying varied by gender with boys being more likely to be physically bullied while girls are more typically involved in relational bullying. Through a longitudinal study Griffiths et al 2006 [43] were able to determine the pathway and negative implications of weight based teasing by gender. It found that while both boys and girls can be affected by bullying some obese boys cope with bullying by becoming bullies themselves. All the information leads to the need for effective interventions to support and prevent children and adolescents with weight based teasing and ways to prevent its harmful effects in overweight teenagers and children.

Unfortunately no HRQL information in the papers was deemed suitable for inclusion in the model parameters. This does not diminish the effect that bullying has on obese children and adolescents but, as there is no suitable information on HRQL in obese children and adolescents it is difficult for this information to be added to the model. It may be the case that bullying is already included intrinsically in the model, through the general HRQL measures for overweight and obese children although this cannot be known for certain. To be included in the model without the possibility of double counting we would need to know the incremental effect of teasing on HRQL in overweight and obese children and adolescents, however no such study exists. Therefore because of this difficulty it was decided that bullying in children suffering with obesity would not be included in the model.

10.11 Limitations

A systematic review was beyond the resources of this study and could not have been completed in the timeframe given.

Although data extracted consisted of the study design, methodology and measures of outcome, this report was conducted as a rapid review hence the quality of evidence was not formally fully appraised.

11 References

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Appendix 1

National Heart Forum (NHF)

The National Heart Forum (NHF) 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 NHF team, please see: http://www.mhsimulations.co.uk/

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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Appendix 2

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	Eurohear 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 42: Sources of data inputs

Appendix 3

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.]

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.

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.

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[13] 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[14]. 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.

[13] Child z-scores

[14] 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.

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[15] (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[16] undertaken for the PDG and subsequent meetings of the PDG.

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.

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 programs.]

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.

[15] 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.
[16] 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

The processing chain

User interface

The model's opening screen will present the various run options to the user. Once set, the user can initiate the run. Runs will usually be grouped into batches, with each run of the batch corresponding to a different Intervention. It will be usual to include the null-Intervention in each batch.

Processing

Individual cohort members are sequentially processed. From the start-time to the end-time, each cohort member compiles, year by year, an individual State vector trajectory[17]. For each year the State vector is a record containing: {identifier, year, age, gender, BMI, cost in year, QALY in year, diseases in year, alive/dead}. The complete set of cohort state vector trajectories will be available[18] for post-run and post-model processing.

Inputs and data structures

Data input files are read into separate Excel spread sheets. The Visual basic program, WeMaCh_1.exe follows as far as possible an object-oriented approach and creates a new class for each such spread sheet: alldeathsClass, bmiClass, diseaseClass, interventionClass, personClass, populationClass, qalyClass, stateClass. For example, the bmiClass contains the BMI data and methods necessary for its manipulation; a new class is instantiated for Disease modelled – CHD, stroke, diabetes, etc.
The model allows editing of various run parameters and the selection of pre-processed data files; it also allows for the editing and creation of Intervention files.

Intervention files

A short user-guide to the software accompanies this report. Data formats for the various input files are appended to this report.

Cohort files

The component members of the modelling activity are contained in Cohort files.
Cohort files are versatile and can be used to input both the immediate results of interventions and follow-up studies; the files can be composed of real data samples or can be simulated data inputs. The simple example shown below shows the effects of an intervention made on three children aged 14, 15, and 16 in 2012. The first child (person number 1) in the intervention lost 0.5 BMI points in 2012 recovering 0.3 BMI points by 2014, and so on.

			Start of intervention			End of intervention			Follow-up		
Child number	**Age at start (year)**	**sex**	**year**	**BMI**	**BMI-z score**	**year**	**BMI**	**BMI-z score**	**year**	**BMI**	**BMI-z score**
1	14	1	2012	20.5		2012	20		2014	20.3	
2	15	2	2012	16.2		2012	15.3		2014	15.3	
3	16	1	2012	18.7		2012	18.4		2014	24.2	

Table 41: Sample cohort file

[17] An individual's state vector trajectory will consist of a sequential set of state vectors, one for each year of the sequence.
[18] This will be subject to computing space requirements, but they are unlikely to cause any problem.

Notes:

There can be any number of children whose details are in the file.

There can be any number of years (one could fill a cohort's entire life, for example).

If BMI z-scores (denoted z-score) are used they must be appropriate to the cohort member's age and sex in the specified year. Z-scores will be converted to BMI values using the standard formulae and LMS parameters taken from the UK90 dataset.

For the years following a BMI datum (until the year of the next entered datum or until the final year), BMI is calculated by assuming that the individual will stay on the BMI trajectory as determined by that datum.

Appendix 4

BMI, distributions, percentiles and BMI-compression

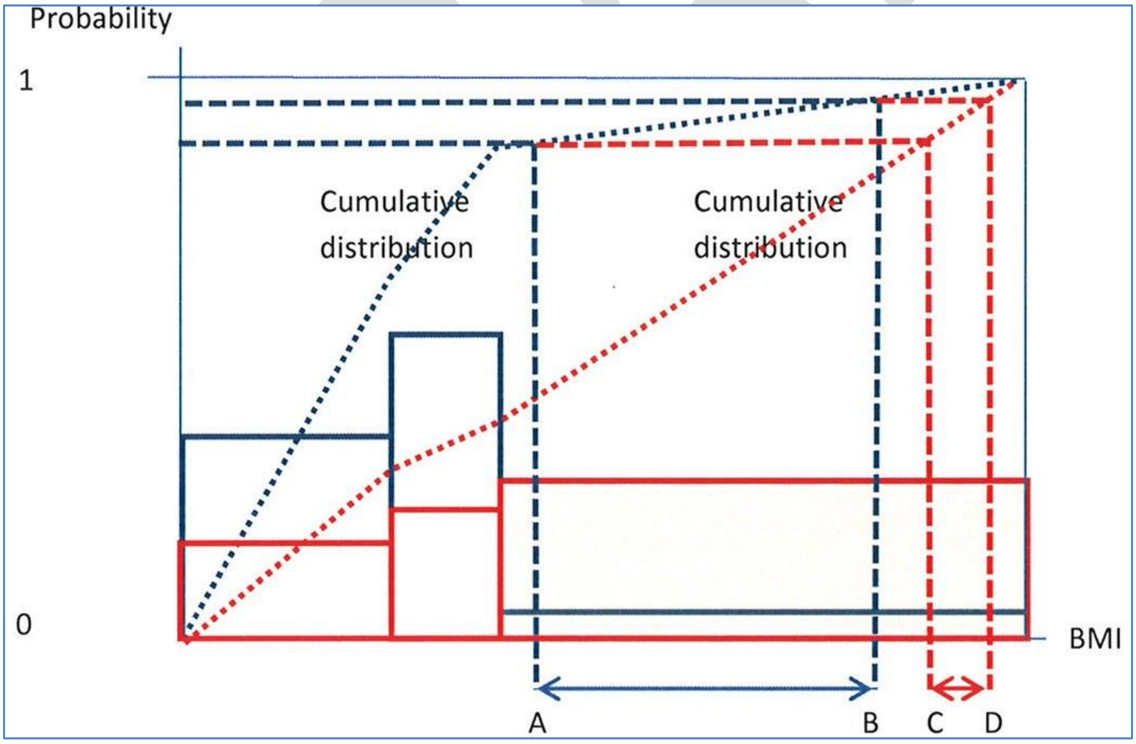

Figure 11: Percentiles and BMI-compression

The Figure 11 shows two distributions, one blue the other red. They represent the probability density in three regions corresponding to normal weight, overweight and obese, in which BMI is supposed uniformly distributed. The blue distribution has a small probability of being obese; the red distribution has a larger distribution – the red distribution's probability of being obese is the area of the right hand red solid rectangle and is lightly shaded. The blue distribution might represent the distribution of adolescents; the red might represent the distribution of 40 year olds. Equally the blue distribution might be that of some age group in 2010; the red the distribution of the same age group in 2030 when obesity levels have been rising.

Superimposed on the probability distributions are the cumulative probability distributions. The red and blue cumulative distributions are drawn as small squares – necessarily they both start at probability 0 and finish at probability 1.

The cumulative distributions provide the correspondence between percentiles and BMI: the BMI for a given percentile being given by the intersection of a horizontal line drawn from that percentile value (division by a factor of 100 turns percentiles into probabilities) with the cumulative distribution line.

The figure shows two percentiles drawn in blue dashes as far as the blue cumulative distribution and continued in red dashes as far as the red cumulative distribution. These two percentiles might represent the effect of a childhood intervention: BMI is lowered by an amount given by the double sided blue arrow, marked AB. The same difference in percentiles but now for the red distribution corresponds to a BMI separation represented by the double sided red arrow marked CD. This is an example of the BMI-compression effect brought about by rising obesity levels. It happens both as a consequence of ageing and as a consequence of obesity growth in the population. In both cases the BMI distributions change from less obese to more obese.

The BMI-compression for a given percentile gap shown in the figure is large – about a factor of ten. It is also possible to see from the figure that the compression will be less severe as the percentiles (horizontal dashed lines) are lowered. Once the percentiles are dropped so that their BMI's lie in the overweight regions the compression will be much less severe. This is a simple demonstration of why it appears to be more effective to intervene on less obese children.

Appendix 5

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$)).ti,ab.	516	
3	1 or 2	2720	
4	Bull$.ti,ab.	2775	Group 2- Bullying
5	Teas$.ti,ab.	246	
6	Victim$.ti,ab.	1556	
7	Or/4-6	4470	
8	obes$.ti,ab.	9866	Group 3- Weight
9	(obese adj2 overweight$).mp.	929	
10	(obese adj2 body image$).mp.	2	
11	(Obese$ and (overweight$ or Body Image)).ti,ab.	1268	
12	Adolescent$.ti,ab.	7688	Group 4- Age specific
13	(Teenager and Adolescent$).mp.	31	
14	child$.ti,ab.	38762	
15	(Teen$ and (Adolescent$ or child$ or Kid$)).ti,ab.	448	
16	Or/12-15	43020	
17	3 and 7	68	Results
18	9 and 16	31	
19	17 and 18	11	

Table 43: Literature search prototype in Medline