Public Health England

Protecting and improving the nation's health

User guide: weight management economic assessment tool version 2

Economic assessment of adult weight management interventions

About Public Health England

Public Health England exists to protect and improve the nation's health and wellbeing, and reduce health inequalities. It does this through world-class science, knowledge and intelligence, advocacy, partnerships and the delivery of specialist public health services. PHE is an operationally autonomous executive agency of the Department of Health.

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Public Health England has revised its economic assessment tool for adult weight management interventions – the Weight Management Economic Assessment Tool Version 2. In this document, for reasons of brevity, it is referred to as the Weight Management e-Tool, or simply e-Tool.

This User Guide sets out the background to the tool; assumptions, limitations and differences from version 1; detailed instructions for users; and the technical details of how the tool works.

The Weight Management e-Tool version 2 is available to download from the PHE Obesity website.

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Section A: user guide

The prevalence of obesity among adults increased sharply during the 1990s and early 2000s. By 2050 obesity is predicted to affect 60% of adult men, 50% of adult women and 25% of children.[1]

Obesity is associated with a range of health conditions including type 2 diabetes, cardiovascular disease and cancer. The resulting NHS costs attributable to overweight and obesity are projected to reach £9.7 billion by 2050, with wider costs to society estimated to reach £49.9 billion per year.[1] These factors combine to make the prevention of obesity a major public health challenge.

Following the Health and Social Care Act 2012, public health interventions are commissioned across both the NHS and the local authority. Commissioners are increasingly required to consider evidence on the economic case for investment in interventions. Like many areas of local government commissioning, evidence on the economic effectiveness of interventions that aim to prevent and/or reduce the level of overweight and obesity in populations is somewhat limited. In the absence of robust evidence, it is difficult to present the case for investment in such interventions with the consequence that funding may be diverted to other priority areas where the evidence base for cost effective interventions is more robust.

Introduction to the weight management e-Tool version 2

The tool is designed to support public health professionals to understand the economic case for investing in weight management interventions. It is intended primarily to be used by commissioners who wish to compare the costs of an intervention with the potential cost savings it may produce.

The tool estimates the health impact of weight loss in any group of people who have participated in an intervention or programme. It is designed to be used to compare the costs and benefits of interventions for which there are outcome data, as well as to test theoretical or planned programmes where data are absent. In this way, the e-Tool can help to make the case for commissioning of innovative approaches to obesity prevention.

The term ‘weight management interventions’ is used here to describe any type of activity that aims to help people reduce or maintain their body weight. It is not confined to traditional weight management classes or programmes, but can include policy actions, environmental change, educational programmes or any other public health action that has led or may lead to a measured change in weight among a defined population.

One application of the e-Tool is to vary data in the different input fields and observe the impact this has on the results. This type of *sensitivity analysis* can help in programme planning by demonstrating the importance of different aspects of an intervention. For example, the tool might be used to investigate the question 'how much weight do programme participants need to lose before the benefits outweigh the costs?'

Differences from version 1

Version 1 of the e-Tool calculated costs and direct savings to the health service arising from weight management interventions. Version 2 estimates in addition the saving in local authority (LA) funded community based social care costs and the economic benefit of additional employment that may accrue as a result of weight management interventions. It considers a number of cost perspectives.

Version 2 also values the wider health benefits of weight management interventions using Quality Adjusted Life Years (QALYs). This allows a cost per QALY of any intervention to be calculated which can be readily compared with other published cost-effectiveness estimates such as those produced by NICE.

Some structural issues with version 1 have been addressed and different evidence is now used to model the association between BMI and disease incidence, and between disease status and mortality. Further details are given in the section on Data sources

What does the e-Tool do?

- provides economic assessment from a variety of cost perspectives for any intervention or programme that has resulted in participants' weight loss (measured by reduced BMI)
- compares the costs of the programme/intervention with estimated health care cost savings, community based social care cost savings and the economic value of additional employment (as a result of reduced incidence of key diseases due to weight loss)
- calculates a cost per QALY gained for the programme/intervention for each of the cost perspectives considered
- uses mean values across adult populations
- forecasts up to 25 years from the start of the intervention
- provides a breakdown of likely health care savings by disease group – five conditions are considered within this tool (type 2 diabetes, coronary heart disease, stroke, colorectal cancer and breast cancer)

- provides a basis for further work by local public health teams to model appropriate local authority data

What does the e-Tool not do?

- calculate the expected weight loss from an intervention
- provide values for individual programme participants
- provide cost saving estimates for children (aged under 18 years) – the data are not currently available to make reliable estimates of the economic impact of obesity reduction among children

Principles

The e-Tool is based on robust evidence relevant to the English population and is designed to:

- be accessible and easy to use
- produce clear and easily understandable outputs
- be transparent, with evidence-based default values clearly labelled
- allow users to enter their own local data and vary assumptions

How can the e-Tool be used?

There are three main applications for the e-Tool:

- assessing the economic case for existing weight management programmes
- assessing the economic case for any other intervention, programme or policy that has resulted in a change in BMI among a defined population
- developing scenarios and assessing the costs and benefits of potential policies, programmes and interventions

How the e-Tool works

The e-Tool considers a group of adults who have had their body mass index recorded before and after taking part in some sort of programme or intervention. It models weight loss over time (in terms of reduced BMI) and uses this to estimate reduced incidence of type 2 diabetes, coronary heart disease, stroke, colorectal cancer, and breast cancer among that population due to their lower BMI. The e-Tool then estimates the change in healthcare costs as a result of the reduced morbidity, and compares this to the costs of the intervention.

Example

A weight management programme recruited 100 men and 200 women with an average age of 46 years and an average starting BMI of 30 kg/m^2. It took a total of one year to recruit all the participants to the programme. Once recruited, participants remained on the programme for three months. The drop-out rate from the programme was 30%, that is 30% of participants did not complete the intervention. Those who completed the intervention lost on average 2 kg/m^2. This reduction in BMI was maintained on average for around six months after completion of the intervention. The programme cost a total of £18,000.

The e-Tool calculates that this intervention would save healthcare costs of £223 in the first year, and by the end of year four would save over £19,000 in healthcare and social care costs combined. Therefore at the end of year four the project is deemed to be cost-effective from a healthcare and social care cost perspective, with a benefit:cost ratio before discounting of 1.27:1. This means that for every £1 spent on the project, it saves £1.27 in healthcare and social care costs by the end of year four.

What data are required to use the e-Tool?

The e-Tool is designed to be used by practitioners with the following minimum data on any specific weight management intervention:

- number of men and women who enrol in the intervention
- average age of participants at the start
- average starting BMI (kg/m^2)
- the uptake period of the intervention (time between the first and last person enrolling, in years)
- the percentage of participants that drop out of the intervention before completion
- the average reduction in BMI (kg/m^2)
- time taken to achieve the reduction in BMI (days, months or years)
- duration of the weight loss (days, months or years)
- the costs of the intervention (£ per project and/or per participant)

Where any of these data items are not known users are recommended to run the tool a number of times using estimated values to get an indication of the likely range of possible outcomes.

Using the e-Tool: a step by step guide

1. Download the e -Tool from the PHE Obesity website (www.noo.org.uk/visualisation). Please note this is an Excel (.xlsx) file so you will need to have Microsoft Excel installed on your computer. The e-Tool is designed to work on both PCs and Macs. The tool does not require Macros (Excel automation) to function.

2. Open the tab ‘User data’.

3. Enter the number of participants. This is the number of participants who enrol on the intervention. Ignore the number of people who do not complete the intervention: this will be dealt with separately within the tool. If unsure about the sex ratio of your participants, please enter your data assuming a 50:50 split. Example: 100 men, 200 women.

4. Enter the mean age of all participants undertaking the intervention. Example: mean age 46 years. Please note that the parameters underlying the tool are designed to work with an adult population (aged 18 to 65 years) and may not provide accurate results for children or adults aged over 65 years. Particularly the tool should not be applied to children.

5. Enter the mean starting BMI across all participants at the start of the intervention. Example: 30 kg/m^2. Please note that the tool does not model any health impacts for BMI values below 22 kg/m^2. The tool is also less likely to provide robust estimates for very obese populations (mean BMI > 45 kg/m^2).

6. Enter the uptake period. This is the time taken to recruit all participants onto the intervention in years, that is the time period between the first and last participant being recruited. Example: one year taken to recruit all partcipants. The tool assumes a linear increase in the number of participants engaged in the intervention over the time period entered.

7. Enter the percentage of participants who drop out. This is the proportion of the total number of participants starting the intervention that do not complete it. Example: 30% of men and 30% of women drop out. If you do not know the sex ratio of participants who drop out, please assume a 50:50 split. The tool assumes that participants who do not complete the intervention accrue no health or other benefits. This is likely to be an underestimate of the true impact on these individuals, but is in line with the conservative approach of the tool.

8. Enter reduction in BMI: this is the predicted or known average BMI reduction (in kg/m^2) among participants after completing the intervention. Example: mean reduction in BMI was 2 kg/m^2.

9. Enter the average time taken to achieve this reduction in BMI, that is the time between participants enrolling on the intervention and reaching the maximum weight loss achieved. Example: on average it took three months to achieve this weight loss.

10. Duration of weight loss. Please enter the average amount of time this level of weight loss is maintained. Example: the weight reduction was maintained for six months on average. After this time BMI is assumed to gradually return back to the same value as if the intervention had not occurred.

11. Enter the cost of the intervention/programme to be implemented to either NHS, local authority or both. Costs can be entered as a single cost or as a cost per participant, or both. If both are entered, the tool will sum these two figures to show a total cost of the intervention. Costs per participant will be multiplied by the total number of participants enrolled (including those who drop out). Example: Cost of £60 per participant, paid by local authority. No cost to the NHS. The tool makes the assumption that participants who drop out incur the same cost as those who complete the programme, although they incur none of the benefits. The tool further assumes that all fixed costs are borne upfront and are not spread over the time period covered by the intervention. No discounting is therefore applied to fixed costs. Costs per participant are incurred at the time of participant enrolment and appropriate discounting is applied.

12. Enter the discount rates you wish to apply to costs and health benefits that occur in the future. The default values are 1.5%, as recommended by NICE.[a,2]

The User data for this example are shown below.

[a] For an explanation of discount rates, see glossary

Figure 1. Worked example showing data inputs

User inputs			
Please enter your data into the cells shaded in green			
About the participants			
Number	100	men	A weight management programme recruited 100 men and 200 women…
	200	women	
Mean age	46	years	…of mean age 46…
Mean starting BMI	30	kg/m^2	…with a mean starting BMI of 30 kg/m^2.
About your intervention			
Uptake period		days	The programme took a total of one year to recruit all the participants.
		months	
	1	years	
Drop outs (percent)	30%	men	30% of participants did not complete the intervention.
	30%	women	
Reduction in BMI	2	kg/m^2	Those who completed the intervention lost 2 kg/m^2.
Time taken to achieve reduction		days	Once participants were recruited, they remained on the programme for three months.
	3	months	
		years	
Duration of maximum weight loss		days	The maximum weight reduction was maintained for six months after the intervention.
	6	months	
	0	years	
Costs of Intervention			
Cost to Local Authority (£s)	£0	project costs	The programme was paid for by local authority and cost a total of £18,000.
	£60	costs per participant	
	£18,000	total	
Costs to NHS (£s)	£0	project costs	The NHS did not contribute to the programme cost.
	£0	costs per participant	
	£0	total	
Discount rate for costs	1.5%	percentage	
Discount rate for health outcomes	1.5%	percentage	

Interpreting the results

The e-Tool presents results in three forms:

- a simplified summary table
- a detailed set of tables showing the results from the calculations within the tool
- a set of charts that illustrate the principal results from the tool

All results are based purely on the intervention and group of participants specified in the user inputs. The model assumes that no further weight management intervention takes place after the original intervention.

Summary results table

The simplified summary table shows the key outputs for years one, three, five, ten and 25 of the intervention.

An example of the sort of outputs provided is shown in Figure 2 for years one and three, using the example input data from Figure 1.

Figure 2. Summary of outputs from the e-Tool

Key summary indicators	Year 1	Year 3
Mean difference in BMI across whole year *(averaged across whole year, 1st year intake only)*	-2.00	-1.82
Cumulative QALYs gained *(no discounting)*	1.2	5.7
Cumulative number of premature deaths prevented	0.0	0.0
Cost effectiveness summary	*All values are discounted*	
Project costs to date	£ 18,000	£ 18,000
Cumulative savings in healthcare costs	£ 223	£ 1,863
Cumulative savings in social care costs	£ 3,048	£ 13,763
Cumulative economic benefit of additional employment	£ 5,680	£ 26,325
Benefit:cost ratio - healthcare perspective (NHS)	exceeds 1	exceeds 1
Benefit:cost ratio - social care perspective (Local Authority)	0.169	0.765
Benefit:cost ratio - additional employment perspective (Local Authority)	0.316	1.463
Benefit:cost ratio - healthcare + social care perspective	0.182	0.868
Benefit:cost ratio - healthcare + social care + additional employment perspective	0.497	2.331
Benefit:cost ratio - social care + additional employment perspective	0.485	2.227
Cost per QALY gained - healthcare perspective (NHS)	Cost saving	Cost saving
Cost per QALY gained - social care perspective (Local Authority)	£ 12,716	£ 777
Cost per QALY gained - additional employment perspective (Local Authority)	£ 10,478	Cost saving
Cost per QALY gained - healthcare + social care perspective	£ 12,527	£ 435
Cost per QALY gained - healthcare + social care + additional employment perspective	£ 7,696	Cost saving
Cost per QALY gained - social care + additional employment perspective	£ 7,885	Cost saving

The first three rows show the impact of the intervention on the BMI of the participants, the cumulative QALYs gained and the cumulative number of deaths prevented.

The main focus of the summary table is to estimate the economic benefit of the intervention from six cost perspectives. The perspectives are:

- healthcare
- social care
- additional employment
- healthcare and social care
- healthcare, social care and additional employment
- social care and additional employment

The healthcare perspective considers only costs borne by the NHS and healthcare costs saved by the NHS as a result of lower BMI in the intervention group when assessing cost-effectiveness.

The social care perspective considers only costs borne by local authority, and community-based social care costs saved by local authority as a result of lower BMI in the intervention group.

The additional employment perspective considers only costs borne by local authority, and the economic benefit of additional employment as a result of lower BMI in the intervention group.

The healthcare and social care perspective considers total costs borne by both NHS and local authority, and healthcare and social care savings combined.

The healthcare, social care and additional employment perspective reflects costs borne by both NHS and local authority, the savings in NHS and social care costs and the economic benefit of additional employment arising from lower BMI in the intervention group.

The social care and additional employment perspective does not reflect NHS cost savings or costs, only costs borne by local authority and the savings in social care costs and the economic benefit of additional employment resulting from the intervention.

Details of methods used in the calculation of costs for each of these perspectives are given in Data sources

The data on savings vs costs are based on a comparison of the savings with the costs of the programme. The benefit:cost ratio is calculated by dividing the total savings generated in each cost perspective by the project costs of that perspective. A benefit:cost ratio of greater than 1 represents a cost-saving project, and such figures are shown in green within the summary table. If the project is not cost saving within the specified year, the benefit:cost ratio figures are shown in red.

NICE generally uses a cost per QALY gained to assess cost-effectiveness, where interventions with a cost per QALY gained of less than around £20,000 per QALY are considered cost-effective.[3] If an intervention is cost saving, that is it results in a greater number of QALYs at a lower overall cost, then the cost per QALY becomes negative and is not readily amenable to interpretation. Such cases are shown in Figure 2 as ‘cost saving’.

Full results tables

Users who require more detailed results can view the ‘full output tables’. These tables can also be accessed by clicking on the hyperlinks within the tool.

The full output tables show a breakdown for each individual year over the 25 years for which the model is run, rather than just the results for selected years. In addition, these tables provide much more information on the impact of the intervention on participants and the economic benefits that result. They also provide a summary of the impact of the intervention broken down by disease group.

A full list of the fields provided in the full output tables is given in Figure 3.

Figure 3: Field list for the 'full output tables'

Indicator type	Indicator
General Summary indicators	Mean number of participants enrolled across whole year
	Mean BMI without intervention
	Mean BMI with intervention
	Difference in BMI as a result of intervention
	Enrolled participants alive without intervention at end of year
	QALYs without intervention
	Total number of deaths without intervention
	Enrolled participants alive with intervention at end of year
	QALYs with intervention
	Total number of deaths with intervention
Disease summary	Total number of cases of disease x without intervention
(provided for each of the five diseases within the model)	Total number of cases of disease x with intervention
	Number of participants with disease x alive without intervention
	Number of participants with disease x alive with intervention
	Number of 'case years' of disease x prevented
	Cumulative number of 'case years' of disease x prevented
	In-year savings in healthcare costs for participants with disease x
	Cumulative savings in healthcare costs for participants with disease x
Savings in healthcare costs	Total in year savings in healthcare costs
(with and without discounting)	Cumulative savings in healthcare costs
Savings in LA funded community-based social care costs	Total in year savings in LA funded social care costs
(with and without discounting)	Cumulative savings in LA funded social care costs
Economic benefit of additional employment	Total in year economic benefit
(with and without discounting)	Cumulative economic benefit
QALY benefit	Total in year QALY benefit
(with and without discounting)	Cumulative QALY benefit
Costs of intervention	Fixed costs
(with and without discounting)	Variable costs
	Cumulative costs
Cost effectiveness metrics	Healthcare benefit:cost ratio
(with and without discounting)	Social care benefit:cost ratio
	Additional employment benefit:cost ratio
	Healthcare+Social care benefit:cost ratio
	Healthcare+Social care+Employment benefit:cost ratio
	Social Care+Employment benefit:cost ratio
	Healthcare £/QALY gained
	Social care £/QALY gained
	Additional employment £/QALY gained
	Healthcare+Social care £/QALY gained
	Healthcare+Social care+Employment £/QALY gained
	Social Care+Employment £/QALY gained

Charts provided within the e-Tool

Thirteen charts are provided within the tool. These charts illustrate both the principal fields which drive the tool, for example change in BMI and number of

participants; and the principal outputs, for example cases of disease and economic outputs. The full list of charts is:

1. Cumulative savings in costs by type, with discounting.
2. Cumulative net savings in cost by cost perspective, with discounting.
3. Cumulative costs per qaly with discounting, by cost perspective.
4. Total qalys by intervention.
5. Employment rate by intervention.
6. Cumulative savings in healthcare costs by condition, no discounting.
7. Mean bmi with and without intervention.
8. Enrolled and active participants by year of intervention.
9. Number of cases of diabetes and number of participants alive with diabetes.
10. Number of cases of chd and number of participants alive with chd.
11. Number of cases of stroke and number of participants alive after stroke.
12. Number of cases of colorectal cancer and number of participants alive with colorectal cancer.
13. Number of cases of breast cancer and number of participants alive with breast cancer.

Sensitivity analyses

If the e-Tool is being used for programme planning (rather than assessing the economic benefits of a completed intervention) it can be helpful to re-run some of the calculations with different input values. This may help to answer the following questions about a programme:

- what age group should the programme target?
- what BMI ranges should the programme target?
- how much weight do participants have to lose for the cost savings to outweigh the investment?
- how long do participants have to be at their lower weight in order for the cost savings to outweigh the investment?
- what is the maximum drop-out rate that would still allow the programme's costs to be lower than the savings over the desired time period?
- what number of participants needs to be recruited and retained (not drop out) in order to make an intervention cost effective?

This type of sensitivity analysis can also be performed on a programme or intervention where some effectiveness data are available, but where not all the data required to run the e-Tool are known. So for example a programme/intervention might not have evidence on the likely duration of weight loss. In such cases, by running the tool with a variety of input values for this field,

the duration of weight loss required to make a programme cost effective can be established.

Section B: technical background

Principles

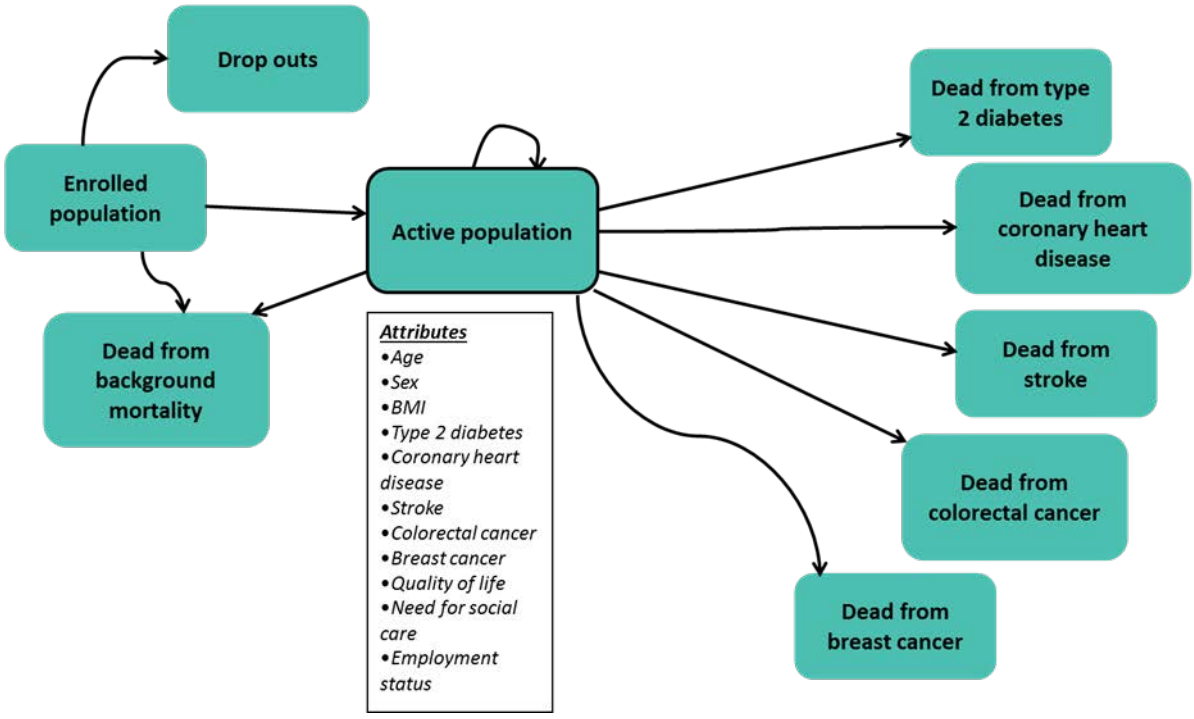
- the weight management e-Tool works on the principle of modelling the mortality and morbidity of a cohort of individuals who participate in an intervention to reduce their BMI
- this process is undertaken twice – both with and without the impact of the intervention; the inputs into these two sets of calculations differ only in terms of the assumptions made about the BMI of the participants
- the calculations without the intervention assume the BMI of the participants increases slightly over time, in line with the best available evidence for UK adults
- the calculations which take account of the intervention assume the BMI of participants initially decreases according to the values entered by the user – the user enters the mean decrease in BMI achieved, as well as how long it takes to achieve this reduction and for how long it is sustained; at the end of this time period the model assumes the BMI of participants increases gradually to the estimated BMI value had the intervention not taken place
- BMI has an impact on both mortality and the incidence of obesity-related health conditions; therefore the two sets of calculations produce different results in terms of the number of participants alive and the number living with disease, depending on whether or not they have taken part in the intervention
- the final outputs of the tool are expressed in terms of expected savings to: NHS healthcare costs; local authority community based social care costs; additional employment economic benefit; and combinations of these – these are calculated by estimating the difference between the two sets of calculations in the number of individuals living with obesity-related health conditions in each year for those with and without the intervention; this difference is then used to calculate the difference in the various types of cost per year. – these figures are summed within the model to calculate the cumulative savings as a result of the intervention

Model structure

A schematic diagram of the model structure is given in Figure 4. The model has a time step of one year and a time horizon of 25 years. In their first year after enrolment participants may either drop out, die from background mortality, or continue to complete the intervention and form the active population, that is the population remaining after deaths and drop outs. After its first year the active population may either die from background mortality, develop one of the comorbidities, or, from the second year onwards, die from one of the comorbidities. The model assumes that there are no comorbidities in the cohort at the start of the modelling period.

The attributes of the active population given in Figure 4 are tracked throughout the model period. Thus for any given year within the time horizon it is possible to calculate the proportion of the active population with, for example type 2 diabetes, or the proportion which is employed.

Figure 4. Schematic diagram of e-Tool model structure



Calculations

- the e-Tool applies average values across the population that participate in the intervention – this approach allows the model to be used by those who do not have detailed individual level information about the participants
- mortality rates, disease incidence rates, health-related quality of life, social care need and employment status vary by sex so men and women are treated separately within the model; users will need to enter the number of participants and proportion dropping out separately by sex, or assume a 50:50 split if these data are not available, however to simplify the input data required for the tool all other input variables use the same average values for both men and women and the final results are presented with the sexes combined – the same calculations are conducted for both men and women, although the underlying variables used are different
- the tool models participants' mortality and morbidity for a follow-up period of 25 years after the start of the intervention; results are calculated per year so a minimum of 25 sets of calculations are carried out when the model is run and these are repeated four times: for men and women separately both with and without the impact of the intervention
- a form of matrix model is used to allow the calculations to take account of different 'build up' periods (whether participants all start in the first year or whether they join over a period of time) – participants are treated as 'cohorts' depending upon the year of entry to the intervention – the same calculations are repeated for each cohort, but offset by one or more years – results for all cohorts are then summed for each year of the intervention in order to obtain the final results

In each set of calculations there are a number of stages. At each stage, each variable is calculated according to the age and sex of the participants. The calculation worksheets are hidden from view in the model as provided, however they are not password protected and may be viewed in more detail by the user by 'un-hiding' them and turning off protection if applicable.

The calculations are described below in the order in which they are carried out. In all cases these are only estimates, based on the input data and the parameters within the tool. The Data sources section within section B gives details of the assumptions and data underlying the calculations.

1. Number of enrolled participants by year
   Calculates the number of individuals who are enrolled on the intervention per year, taking into account the uptake period. The effect of dropouts and deaths among participants is not factored in at this stage.

2. Active participants
   The number of participants remaining on the intervention after dropouts and deaths from any cause including comorbidities have been accounted for.

3. Mean age
   Starts at the initial value entered by the user and increases by one per year.

4. Mean BMI at year end
   Starts at the value entered by the user. In the 'no intervention' calculations BMI then increases by the typical annual increase, based on age and sex. In the 'intervention' calculations mean BMI is reduced according to the impact of the intervention as described by the user. After the time period over which the intervention has an impact, BMI returns to the same value as in the 'no intervention' calculations at a rate of approximately 0.56 kg per year.[4] In BMI units this equates to approximately 0.2 kg/m^2 per year for English adults of average height.[5]

5. Baseline mortality rate
   All cause mortality probability based on the mean age and sex of participants.

6. Number of deaths from baseline mortality
   Active participants in the previous year multiplied by the baseline mortality probability.

7. Incidence rate of diabetes
   Incident rate of diabetes based upon the mean age, sex and BMI of participants.

8. Incident cases of diabetes
   Incident cases of diabetes in the portion of the active population which is not already diabetic, based upon the prevailing incidence rate from step 7.

9. Prevalent cases of diabetes
   Number of cases of diabetes in the active population after incidence and deaths from any cause including comorbidities have been accounted for.

10. Excess deaths among enrolled diabetics
    Number of deaths due to diabetes in prevalent cases of diabetes. Based upon age and sex as well as diabetes status.

11. All cause deaths among enrolled diabetics
    Number of deaths due to all cause mortality in prevalent cases of diabetes. Based upon age and sex and baseline mortality rate from step 5.

12. Excess deaths attributed to other comorbidities occurring in those with diabetes
    Number of deaths in prevalent cases of diabetes due to comorbidity of stroke, coronary heart disease, colorectal cancer and breast cancer. These excess deaths occur in proportion to the prevalence of the four other comorbidities in the active population.

13. QALYs
    The QALYs accrued by active participants based upon their age, sex, BMI and disease status.

14. Probability of need for social care
    The probability that active participants will have a need for local authority community based social care based upon their age, sex, and BMI.

15. Probability of being in employment
    The probability that active participants will be in employment based upon their age, sex, and BMI.

16. Cost of social care
    The probability of need for social care calculated in step 14 multiplied by the proportion of need which which is met, the likely annual cost of a home care worker and the current active population.

17. Economic benefit of additional employment associated with intervention
    The difference in number between the employed active participants in the intervention and no intervention arms, multiplied by the likely annual marginal benefit of employment to an individual.

Calculations (7) to (12) are repeated for each comorbidity considered by the model, that is stroke, coronary heart disease, colorectal cancer and breast cancer, as well as type 2 diabetes.

Data sources

The data underlying the tool are drawn from a number of sources.

All-cause mortality

All-cause mortality data are taken from Office for National Statistics (ONS) National Life Tables for England for 2011 to 2013.[6] These data update the ONS Death Registration Summary Tables 2011 which were used in e-Tool version 1.

All-cause mortality probability was adjusted by BMI in version 1 of the e-Tool. This adjustment has been removed from version 2 where excess deaths associated with high BMI are assumed to come entirely from increased incidence of disease.

Disease incidence

In e-Tool version 1 all disease incidence estimates came from a modelling study by van Baal et al of the Netherlands population.[7] These estimates have been updated by primary evidence of incidence obtained in an English or UK population, as given in Table 1.

Table 1. Sources of baseline disease incidence estimates used in e-Tool

Baseline incidence parameter	Source
Heart attack	Smolina et al 2012.[8] Table 2
Stroke	Rothwell et al 2004.[9] Table 1
Diabetes	Holden et al 2013.10 Figure 2
Colorectal cancer	Cancer Research UK[11]
Breast cancer	Cancer Research UK[12]

Excess mortality from disease

The relative risk of mortality from each of the diseases by age and sex has been calculated from the sources given in Table 2.

Table 2. Sources of disease excess mortality estimates used in e-Tool

Excess mortality parameter	Source
Heart attack	Simpson et al 2011[13]
Stroke	Hankey et al 2000[14]& Bronnum-Hansen et al 2001[15]
Diabetes	National Diabetes Audit 2011 to 2012 Report 2: Complications and Mortality.[16] Figure 9. (Rate ratios converted to one year probability of death using ONS death rates for 2011.[17])
Colorectal cancer	Cancer Research UK[18]
Breast cancer	Cancer Research UK[19]

Association between BMI and increased risk of disease incidence

The modelled association between BMI and the risk of having heart disease, stoke, colorectal cancer or breast cancer is based on data published by the World Obesity Federation.[20] These give constant relative risk estimates of incidence of these diseases by unit BMI above 22 kg/m^2, that is, relative risk increases as a linear function of BMI. The relative risk may also vary by age in these estimates

The relative risk of type 2 diabetes with BMI is non-linear and this risk is estimated in the e-Tool using the modelled association between doctor-diagnosed diabetes prevalence and BMI calculated from Health Survey for England (HSE) data for 2011 to 2013.[21,22,23] This model was developed to apply to ages 18 years and above, and to BMIs above 22. It is therefore consistent with the baseline BMI used elsewhere in the e-Tool. HSE does not distinguish between type 1 and type 2 diabetes, however type 2 accounts for at least 90% of all cases.[24]

Although this model is of increase in prevalence of type 2 diabetes, rather than incidence, this is felt to be a reasonable approximation given that diabetes is not an acute condition, and conservative given the increase in mortality associated with diabetes.

Change in BMI with age

The expected change in BMI as adults get older has been taken from the model produced by Ara et al.[25] Based on their analysis of the UK General Practise Research database Ara et al found that BMI among non-diabetic adults increased by around 0.175 kg/m2 per year for women and 0.145 kg/m2 per year for men.

In the e-Tool these values have been used for ages 18 to 65 years. Beyond age 65 years a lower rate of increase has been assumed, with a linear change down to age 85 years at which no annual increase is assumed.

NHS costs

We used national programme budgeting data to estimate the annual NHS cost per case associated with heart disease, stroke, breast cancer and colorectal cancer. The total NHS secondary and primary care spending in England on each of these four diseases was divided by the estimated prevalence of each disease, derived from the NHS Clinical and Health Outcomes Knowledge Base compendium indicators or cancer registry data, to estimate the cost per patient per year of disease in the model. This method is described in Hollingworth et al.[26]

The total cost of direct patient care for diabetes and its complications has been estimated to be around £2,500 per patient per year.[27] The e-Tool uses a conservative value of £2,155 in order to be consistent with other modelling work undertaken in PHE.

Social care costs

The association between BMI and self-reported need for help with at least one of the usual activities of daily living (ADL) is used as the basis for the estimation of community-based social care costs by BMI and age and sex. This association was calculated using HSE data from 2011 to 2013 in a population of adults aged 65 years and over and is extended to adults aged under 65 years in the e-Tool using an assumption of linear decline of need with decreasing age.

The probability of need for care is combined with a typical cost of a homecare worker per hour,[28] the proportion of social care need which is met and the typical hours of help received by an individual from local authority sources on an annual basis in order to calculate an annual cost. It is important to note that this is a cost for community-based social care and does not extend to social care costs in the care home population.

Further details of the method are given in Copley et al.[29]

Economic value of additional employment

An estimate of increased production resulting from lower BMI and reduced premature mortality is made by combining an estimate of employment status (employed or not employed) with the fiscal and economic benefit of additional employment and the number of active participants.

The probability of being employed and how this varies as a function of age, sex and BMI is calculated from a logistic regression model built using HSE data for 2011 to 2013.[21,22,23]

The fiscal and economic benefit of additional employment is then calculated in the e-Tool as the difference in number between the employed active participants in the intervention and no intervention arms, multiplied by the likely annual economic benefit of employment per individual.

The value of the economic benefit of additional employment per individual is based upon figures published by New Economy Manchester which are in turn based upon unpublished modelling by the Department for Work and Pensions.[30] The benefit relates to the fiscal and economic benefit which results when an Employment and Support Allowance (ESA) claimant moves into employment for one additional year and is £13,236 per individual per year (2012/13 figures). (This amount does not include the value of the ESA benefit to the Department for Work and Pensions as this is a transfer payment.)

Health related quality of life

Health related quality of life is measured in the e-Tool using mean EQ-5D values drawn from HSE from 2011 to 2013. A tobit regression model was constructed using HSE data to describe the association between mean EQ-5D score and: age; sex; BMI; and disease status for the five diseases considered in the e-Tool. Mean EQ-5D score predicted from this model is combined in the e-Tool with the number of active participants in each model year and the number with each of the diseases, to calculate the total QALYs by year.

The EQ-5D is the NICE-preferred instrument for valuing health related quality of life in adults.[31]

Validating the e-Tool

The e-Tool was validated by checking the model structure, calculations and data inputs for correctness.

The structure was primarily assessed by the advisory group for version 1. The group agreed that the tool is based on a valid mathematical model.

Internal consistency was examined by varying input values and verification that any change to the input values produced changes in the model outputs of the expected direction and magnitude. To establish its external consistency the model results were compared with published outcomes of survival in the English general

population and with diabetes prevalence by age and weight category. Results were also compared with existing cost-effectiveness evidence on weight management interventions published by NICE.[32] Details are given below.

The predicted prevalence of type 2 diabetes calculated by the e-Tool for various starting values of BMI was compared with prevalence of doctor-diagnosed diabetes estimated using HSE data from 2009 to 2013. The comparisons are given in Table 3. The model estimates of prevalence were calculated using a 25 year time horizon with a starting age of 35 years. As noted previously HSE does not distinguish between type 1 and type 2 diabetes, however type 2 accounts for at least 90% of all cases.[24]

Table 3. Comparison of diabetes prevalence percentage estimates by BMI at age 60 predicted by e-Tool with estimates obtained from HSE 2009 to 2013 for age group 55 to 64

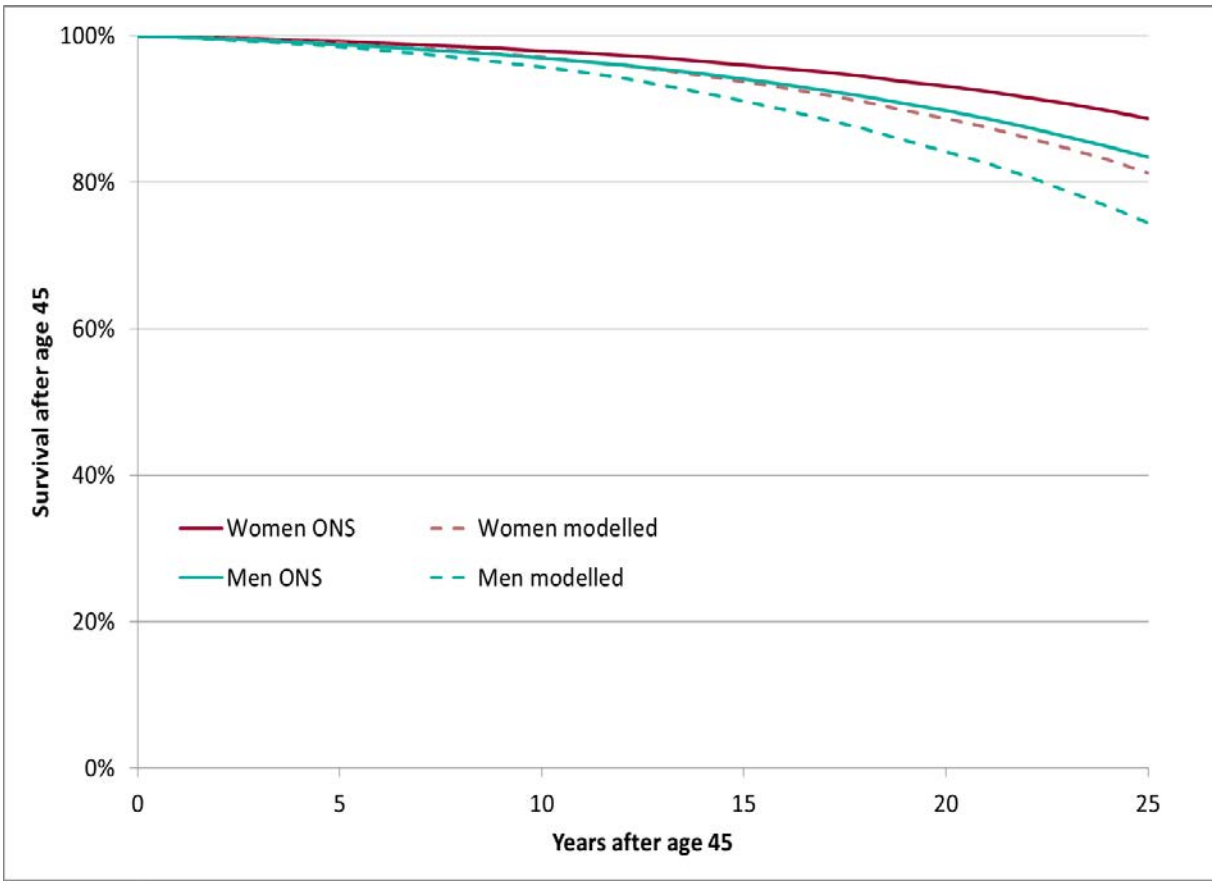
	E-tool BMI (kg/m^2)					
	26	**29**	**31**	**34**	**39**	**44**
Male	7.2	10.6	13.5	18.5	28.0	37.7
Female	5.1	7.6	9.7	13.4	20.8	28.8
	HSE BMI category (kg/m^2)					
	25 to 30		**30 to 40**		**40+**	
Male	7.0		17.5		37.1	
Female	4.8		13.0		29.0	

Table 3 shows that in all cases the model predictions of diabetes prevalence increase with increasing BMI, indicating that the model is working correctly in this respect. The prevalence estimates produced by the e-Tool compare favourably with those obtained using HSE data. The e-Tool slightly overpredicts prevalence at a BMI of 26 compared to the HSE BMI category 25 to 30, and naturally this overprediction is somewhat greater at a BMI of 29, although not excessive. The model predictions at a BMI of 34 are very similar to the estimates of prevalence in the HSE weight category 30 to 40, and again similar at an e-Tool BMI of 44 compared to the HSE severely obese 40+ BMI category. The e-Tool thus appears to predict diabetes prevalence satisfactorily.

The overall survival predicted by the model for male and female participants at starting ages of 25, 45 and 65 years and starting BMIs of 22 and 27 has been compared with corresponding survival curves generated using English life tables[6] over a 25 year time horizon. Values of 22 and 27 were examined for BMI as the population average BMI in England is currently 27 while the model uses a BMI of 22 as its baseline value. In all cases the e-Tool slightly underestimates overall survival by between 1% and 9%. The underestimation is smallest at a starting age

of 25 years and a starting BMI of 22. This degree of underestimation is felt to be acceptable and arises from the model design, where comorbidity mortality is applied in addition to all cause mortality. Figure 5 compares e-Tool estimated survival with life table survival for a population aged 45 years with a BMI of 27.

Figure 5. Comparison of survival after age 45 years predicted by e-Tool for population of BMI 27 with survival calculated from ONS life tables for English general population[6]



Economic considerations published as part of NICE guidance for maintaining a healthy weight note that weight loss that is regained quickly will not usually be cost effective from a healthcare perspective.[32] The NICE threshold for cost-effectiveness of public health interventions is around £20,000 per QALY gained.[3] The e-Tool produces outputs which agree with this general finding, that is interventions tend to cost more than £20,000 per QALY gained after 25 years when the duration of weight loss is short. (Overall duration of weight loss is calculated in the e-Tool using both the duration of maximum weight loss entered on the 'User data' tab and the rate of BMI regain specified on the 'Set parameters' tab.) Cost effectiveness of a short duration weight loss is also dependent upon the characteristics of the study population and the cost perspective adopted.

NICE guidance further notes that at least a 1kg per head weight loss among overweight or obese adults, if maintained for life, is likely to be cost effective, provided that the cost per person of intervening is less than £100.[32] A 1kg per head weight loss equates to a BMI reduction of approximately 0.35kg/m^2 for English adults of average height.[5] Plugging this in to the e-Tool with a starting age of 45 years does give a cost-effective result at a threshold of £20,000 per QALY after 25 years. If the intervention cost is increased to £250 per participant then the same intervention in the same population is not cost effective at a threshold of £20,000 per QALY. The e-Tool outputs thus appear to broadly agree with outputs from economic models of weight loss interventions in adults which have been used to develop NICE guidance.

As the e-Tool is developed further, one area of attention will be further work on calibrating and a review of the underlying parameters used to see if any improvements can be made.

In addition to the work undertaken to check the accuracy and applicability of the e-Tool's outputs, draft versions of the tool have been released in pilot form to a number of commissioners of weight management interventions in public health across the UK. They have used the e-Tool in real-life situations and provided feedback, especially on the usability of the draft tool and the results it provided. On the whole this feedback has been positive and many of the changes suggested by this user group have been implemented in the current version. This user testing suggests that the model is fit for purpose and has also confirmed that the results appear to have face validity in a real world environment.

Discussion

Assumptions and limitations of the e-Tool

The e-Tool model currently covers only a relatively limited number of diseases and does not take account of ethnic origin or socio-economic status of participants, which might affect the outcomes, however, if the tool is used among ethnic or socio-economic groups that have a higher mortality rate than the general population, then the tool will provide conservative estimates.

Despite these limitations, the e-Tool provides public health practitioners with a practical basis on which to assess the economic evidence for weight management interventions.

Future developments of the e-Tool

The Obesity Risk Factors Intelligence team would be very grateful for feedback from users. Please send all comments and suggestions to the PHE Obesity mailbox.

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Glossary

Body mass index (BMI). A person's weight in kilograms divided by the square of their height in metres.

Cost benefit analysis. A systematic process for calculating and comparing the benefits and costs of a project, decision or policy.

Cost effectiveness analysis. A form of economic analysis that compares the relative costs and outcomes (effects) of two or more courses of action. While cost-benefit analysis typically assigns a monetary value to the measure of effect, cost effectiveness analysis results in a ratio where the denominator is a gain in health from a measure (such as years of healthy life) and the numerator is the cost associated with the health gain.

Discount rate. The theoretical or observed rate commonly used by economists to discount future payoffs. Since benefits occurring in the future are generally considered less valuable than those occurring in the present, a discount rate is applied to future benefits. For example, if you invested £100 today it might be worth £120 in the future as it would gain interest. As the tool is assessing the value of future savings, the value has to be discounted back to the present day. In this example, the £120 future saving can be expressed as £100 current value (ie after discounting).

Weight management interventions. Any type of activity that aims to help people reduce or maintain their body weight. In this guide, the term is not confined to traditional weight management classes or programmes. It can include policy actions, environmental change, educational programmes or any other public health action that has led to a measured change in BMI among a defined population.

Mortality rate. A measure of the number of deaths (in general, or due to a specific cause) in a population, scaled to the size of that population, per unit of time.

Quality Adjusted Life Year (QALY). A measure of disease burden, including both the quality and the quantity of life lived. It is used in assessing the value for money of many public health interventions.

Sensitivity analysis. The study of how the uncertainty in the output of a model or system can be apportioned to different sources of uncertainty in its inputs.

Reader information

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