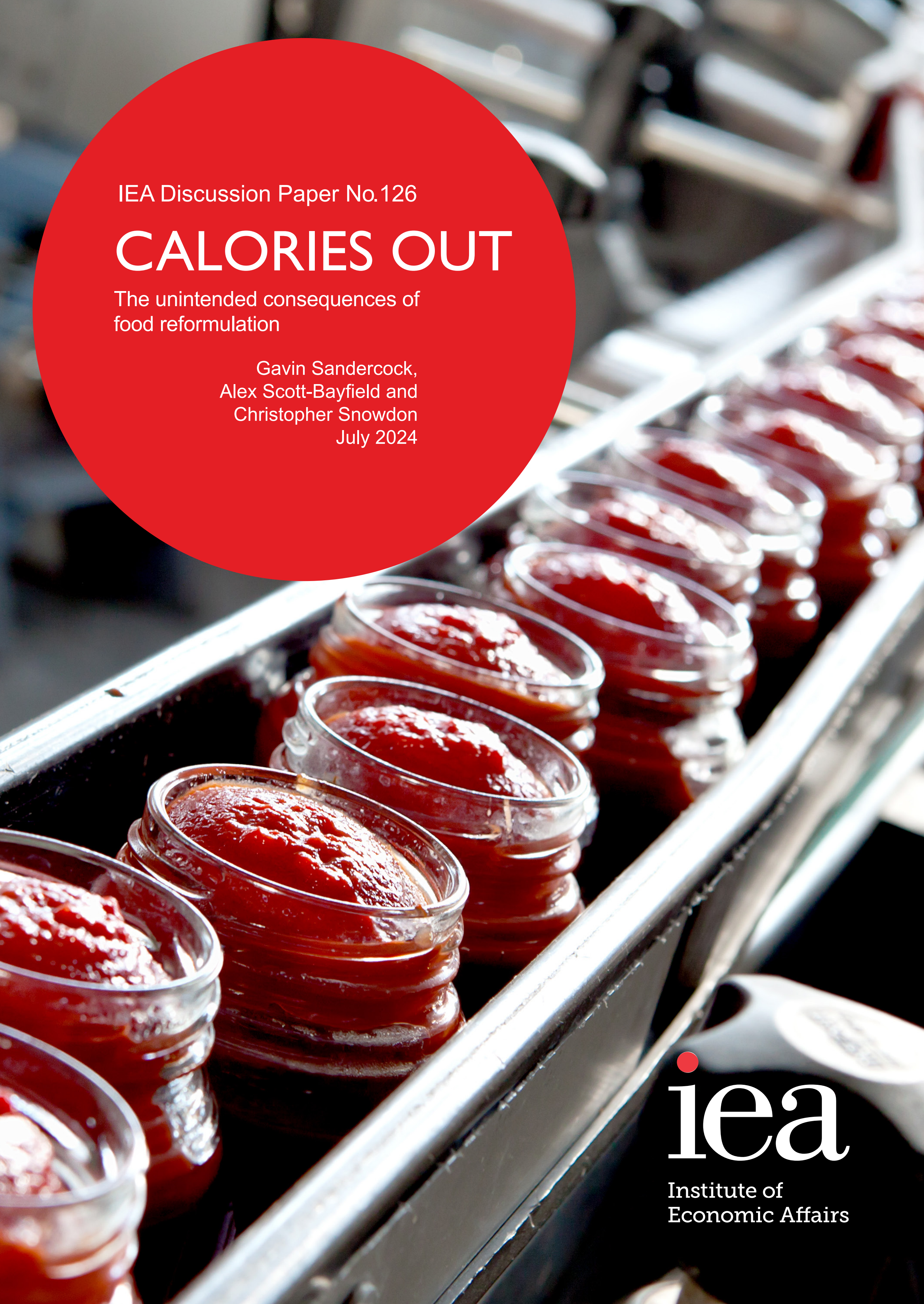

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CALORIES OUT

The unintended consequences of food reformulation

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Summary

- Since 2015, the UK government has worked with the food industry to reformulate a wide range of food products to reduce sugar, fat and calorie content. The industry has been given the target of lowering the number of calories in certain products by 20% by 2025. The reformulation scheme was overseen by Public Health England (PHE) until 2021, and is now overseen by the Office for Health Improvement and Disparities. The scheme is voluntary, but some organisations have called for it to be mandatory.
- In modelling published in 2018, PHE acknowledged that lower calorie intake could have a 'potentially negative impact' on people who are a healthy weight or underweight, but it excluded these people from its model. Since being underweight is associated with a number of serious health problems, this was a major omission which we address in this paper by modelling the impact of the calorie reduction scheme on the prevalence of underweight among children.
- Using two different estimates of baseline energy flux, our model shows that among 4–5-year-olds, the calorie reduction scheme would lead to a ~4% reduction in energy intake, and a reduction in obesity rates between 0.8 and 1.3 percentage points. However, the prevalence of underweight would increase by between 3.0 and 4.8 percentage points.
- Among 10–11-year-olds, the model shows that energy intake would decline by between 2.6% and 5.4%, leading to a reduction in obesity prevalence of between 0.2 and 1.1 percentage points, but the prevalence of underweight would rise by between 2.1 and 4.1 percentage points.

- Under every scenario, for each child who moves from the obese category to the healthy weight category, at least two children become underweight. If the reformulation scheme works as intended by reducing calorie intake across the whole population, it will increase the number of underweight 10–11-year-olds by at least 30% and possibly by as much as 60%. This will lead to a net increase in the number of children who are an unhealthy weight.
- However, neither our model nor PHE's model should be taken seriously as a prediction of what would happen if the targets were met. It is much more likely that consumers would compensate by buying more food (or buying different types of food) to obtain the same number of calories. If so, it will increase the cost of feeding a typical household by around 10%. This compensatory behaviour makes it less likely that significant numbers of children would become underweight as a result of reformulation, but it also makes it less likely that the scheme would have its intended effect of reducing rates of obesity.
- The surprising results reported in this paper should be taken as an illustration of the flaws in the reformulation theory.

Introduction

In 2018, Duncan Selbie, then Chief Executive of Public Health England (PHE), announced that 'Britain needs to go on a diet. Children and adults routinely eat too many calories, and it's why so many are overweight or obese.'[1]

One of the ways in which he intended to put the nation on a diet was by encouraging food manufacturers to reduce the number of calories in their products by 20%. PHE's 2018 report *Calorie Reduction: The Scope and Ambition for Action* predicted that if the calorie content of a wide range of processed foods was reduced by a fifth, the average person would consume 68 fewer calories per day. PHE initiated a voluntary agreement with the food industry to achieve this reduction by 2024, and produced a model which predicted that it would lead to a reduction in obesity which would decrease the number of premature deaths by 35,370 over a 25-year period and reduce health and social care costs by £9 billion over the same period (PHE 2018: 31).

A similar scheme to reduce sugar in food by 20% (by 2020) had been in place since 2015. The range of food products affected was broad, including but not limited to bread, crisps, savoury snacks, pizza, cooking sauces, sausages, potato products, ready meals, dips, egg products, processed red meat, processed poultry, pies and 'food to go' (ibid.: 30).

PHE was disbanded in 2021, but reformulation efforts have continued under its successor, the Office for Health Improvement and Disparities (OHID). In 2022, the World Health Organization launched a European-

1 'Britain needs to go on a diet, says top health official', BBC News, 6 March 2018 (https://www.bbc.co.uk/news/health-43201586).

wide reformulation campaign led by the United Kingdom.[2] In England, the target date for both the sugar and calorie reduction schemes has been pushed back to 2025, and there have recently been calls from Nesta and the King's Fund to make reformulation targets mandatory, with companies fined if they fail to meet them (Leon et al. 2024).[3]

The logic of the reformulation strategy is simple: the average adult is overweight and consumes too many calories to maintain a 'healthy weight'. Therefore, reducing the calorie content of the food they eat will – if all other things remain equal – lower their calorie consumption, and reduce obesity rates. Reformulation appears to offer a way of doing this without the public having to significantly change their behaviour; hence it is sometimes referred to as 'health by stealth'.

The practical difficulties of the sugar reduction scheme have been discussed in a previous IEA paper (Appleton 2019). In this report, we look at the unintended consequences of the calorie reduction scheme *if it works as designed*.

2 'WHO/Europe to launch new sugar and calorie reduction initiative led by the United Kingdom', BBC News, 20 January 2022 (https://www.who.int/europe/news/item/20-01-2022-who-europe-to-launch-new-sugar-and-calorie-reduction-initiative-led-by-the-united-kingdom).

3 Denis Campbell, 'Tories and Labour urged to show "courage" to act on unhealthy food', The Guardian, 16 March 2024 (https://www.theguardian.com/society/2024/mar/16/tories-and-labour-urged-to-show-courage-to-act-on-unhealthy-food).

The forgotten problem of underweight

The fundamental problem with a population-wide calorie restriction policy is that although the average adult in England is overweight, not everybody is average. PHE's Alison Tedstone said in 2018 that 'adults currently consume between 200–300 excess calories each day',[4] but this is clearly not true of everybody. A large minority of adults, and a large majority of children, are neither overweight, nor obese. A non-trivial number of people of all ages are underweight. For millions of people, a reduction in daily calorie intake would not be beneficial, and for many it would be harmful.

While the issue of obesity is rarely out of the news, the problems associated with being underweight attract less attention. The Office for National Statistics (ONS) does not publish figures showing the number of underweight children, and PHE never produced a report about the issue of underweight, despite it being associated with increased risk of stroke, asthma, heart attacks, osteoporosis and all-cause mortality. As James Cracknell (2016: 18) notes:

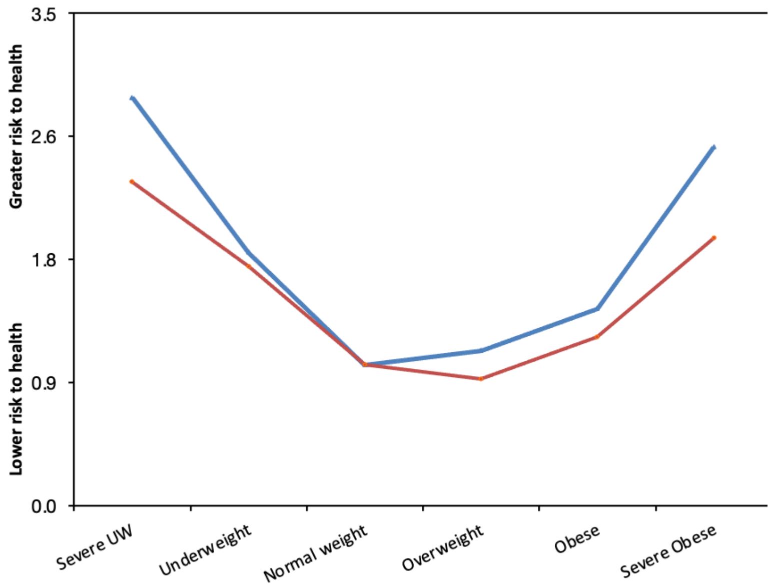
> 'There is much less awareness of the problem of the underweight, except when it tips into anorexia, yet a 2013 University of Essex study of 10,000 children found that 5.9 per cent of children aged 9 to 16 were underweight. Indeed, being a few pounds underweight is significantly more dangerous than being many pounds overweight. Researchers from St Michael's Hospital in Toronto

4 'Why we are working to reduce calorie intake', PHE, 6 March 2018 (https://publichealthmatters.blog.gov.uk/2018/03/06/why-we-are-working-to-reduce-calorie-intake/).

found that people who were clinically underweight were 1.8 times more likely to die prematurely than people of a normal weight. Obese individuals were 1.2 times more likely and the severely obese were 1.3 times more likely to die prematurely than people of a normal weight. This indicates that being underweight is more dangerous than being obese.'

Figure 1 shows the association of weight status and risk of all-cause mortality (blue line) and cardiovascular disease (red line) among adults (Prospective Studies Collaboration 2009). As can be seen, the association between weight status and health is U-shaped, with the lowest risk of cardiovascular disease found among 'normal' and overweight adults. The chances of getting ill or dying are significantly higher for those who are underweight or severely obese. It is important to note that there is an element of reverse causation here since people can become underweight by being ill, but there is also direct causation: being underweight is unhealthy.

Figure 1: Weight status, risk of all-cause mortality (blue line) and risk of cardiovascular disease (red line) among adults



Being underweight carries the greatest risk to children's health – greater than the risks of being obese (Black et al. 2008). Underweight children:

- are more susceptible to diseases such as colds and flu
- are more likely to be hospitalised if they get ill
- are more likely to suffer complications
- have longer recovery periods after surgery or treatment

Furthermore, children at risk of underweight and those who are already underweight are not evenly distributed across the population. Children are more likely to have lower body weight and to be underweight if they are from families living in poverty.

There is surprisingly little research about the health and financial costs of underweight in rich countries.[5] A rare exception is the study by Flegal et al. (2005), which attributed 33,746 excess deaths per annum in the United States to people being underweight despite only 2% of the population falling into this category. Translating these figures to the UK population, which has a similar proportion of underweight people, suggests that around 7,800 excess deaths may be caused by underweight each year.

The first systematic review to look at the costs of underweight largely focused on the Asia-Pacific region, and only found four relevant studies (Hoque et al. 2016). Of these, only one (Watson et al. 2013) had data for a western country, and this was confined to the healthcare costs of underweight pregnant women. The review found that underweight and malnutrition cost between 2.5% and 3.8% of total healthcare expenditure, but these figures are unlikely to be representative of the costs in the UK, where malnutrition is less common.

A study published in 2015 estimated that the cost of *malnutrition* in England amounted to £19.6 billion in 2011/12, equivalent to more than 15% of the nation's health and social care expenditure. It also estimated that 5% of the population was malnourished, and that 30% of adults admitted to hospital suffered from malnutrition (Elia 2015). Although malnutrition is a separate category from underweight, these figures hint at the scale of the problem.

5 In recent years, there has been an attempt to push obesity into the category of malnutrition. In this report, we use the more commonly understood definition, i.e. a deficiency of calories and/or essential nutrients.

A reduction in calorie intake would clearly have profound implications for people who are underweight or borderline underweight, but PHE never modelled the impact of food reformulation on people who do not eat enough. In *Calorie Reduction: The Scope and Ambition for Action*, PHE acknowledged that reducing calorie consumption across the general population could have a ‘potentially negative impact’, but insisted that ‘the prevalence of calorie-related under-nutrition is low in the UK’ and that ‘the calorie reduction programme is not intended to encourage significant energy restrictions that could result in adverse health outcomes in children or any other group of the population’ (PHE 2018: 28). It said that its reformulation efforts were ‘aimed at moving energy intakes of the general population more towards current UK dietary recommendations’ and that it ‘therefore anticipated that the intended approach to calorie reduction would present a low risk of significant undernutrition in the general population’ (ibid.: 28–29).

It is not clear why PHE was so confident about this. It seemed to be mistaking aspirations for outcomes. PHE may not have *intended* the scheme to lead to a reduction in calorie consumption by the undernourished, but it is a plausible unintended consequence of a broad, population-level policy designed to operate by stealth. Nevertheless, having assured itself that this would not be a problem, PHE excluded people who were of a healthy weight or underweight – as well those who were aged over 79 – from its modelling:

> ‘Outcomes were derived only for those aged 4 to 79 years who are overweight, obese or morbidly obese at the outset. It was assumed that reductions in calorie intake are likely to have minimal impact on the health of healthy weight and underweight people and these groups were therefore excluded.’ (ibid.: 82)

This strikes us as a serious omission. There are far fewer people who are underweight than overweight in England, but 1.8% of the adult population – approximately one million people – fell into that category in 2019, including 7% of 16–24-year-olds. Rates are higher among women and are twice as high among the poorest groups (NHS Digital 2020). As the reformulation scheme affects a very large proportion of the food consumed in England, people who are underweight or who maintain a healthy weight would either have to buy more food, or unnecessarily reduce their calorie intake if the 20% target were achieved.

A third possibility is that they would change their diet by purchasing more low-cost/high-calorie foods, such as biscuits, and buy fewer high-cost/high-calorie foods. However, the implicit premise of the PHE scheme is that people would continue to consume the same basket of goods after reformulation takes place. If underweight people substitute products in the way described above, there is no reason why overweight people should not do the same, thereby undermining the whole system.

Measuring childhood obesity and underweight

The focus on obesity over underweight is perhaps understandable given that 28% of adults in England are obese, while only 1.8% are underweight (NHS Digital 2020). On the face of it, there is a similar disparity between obese and underweight children, but this is largely an artefact of the way childhood obesity is measured in England.

It is often claimed that one in five children arrive at primary school obese or overweight, and one in three leave it obese or overweight. These seemingly shocking statistics come from the National Child Measurement Programme (NCMP), a mandated annual programme delivered by local authorities. Every year, in 99% of eligible state-maintained schools across England, children in Reception (aged 4–5) and Year 6 (aged 10–11) have their height and weight measured to calculate their Body Mass Index (BMI). BMI is calculated by dividing a person's weight in kilograms by their height in metres squared, i.e. kg/m2. For adults, a BMI above 25 is classed as overweight, and a BMI above 30 is classed as obese.

These thresholds do not apply to children, however. Since children have a different fat–muscle ratio and are constantly growing, varying (and lower) thresholds are used for children of different ages. To estimate the obesity prevalence among children, BMI is converted to percentiles, and then categorised based on the British 1990 growth reference table (UK1990). This table shows the weight distribution of children at different ages as they were in the 1980s. The NCMP classifies a child with a BMI falling above the 95th percentile as obese and one with a BMI above the 85th percentile as overweight.

Crucially, however, there is no evidence that all children with a BMI above the 95th percentile – i.e. 5% of the child population – were obese in the 1980s, and so, there is no reason to presume that children with a BMI that would have put them in the top 5% in that decade are obese today. On the contrary, the evidence suggests that less than 2% of children were obese when the data for the UK1990 reference table was collected (Cole et al. 1995).

The 95th percentile is an arbitrary cut-off that creates many false positives. It is not used in clinical practice, and is only used for the nationwide survey. As Henry Dimbleby (2021: 293) says in the National Food Strategy, it is 'troublesome enough to require rethinking'. Internationally and in clinical practice, the 98th percentile is used as the threshold and that is what we use in our calculations below.

Using the more realistic, internationally agreed definition of childhood obesity makes a big difference to the figures. The prevalence of obesity in Reception-year children becomes 4.2% rather than 9.9%, and the obesity prevalence in Year 6 children is 6.0% rather than 18.4%. Rates of underweight, which uses the 2nd percentile as the threshold, are actually higher than rates of childhood obesity: 5.2% in Reception and 6.9% in Year 6.

The impact of food reformulation

We now model the likely impact on children from the food reformulation programme assuming that it works as intended, which is to say that it puts Britain 'on a diet', and takes a certain number of calories out of the food supply. The PHE model is quite simplistic. It does not factor in the elasticity of demand for certain food products nor for calories overall, although these almost certainly vary from person to person. The model implicitly assumes that individuals continue buying the same basket of goods and it explicitly assumes that 'no calorie offsetting occurs', i.e. calories removed from the reformulated products are not replaced in the diet by calories from other products (PHE 2018: 82). The expected impact on different groups is shown in Table 1 below (taken from PHE 2018: 31).

Table 1: Number of daily calories reduced for each age–sex group under PHE's reformulation scheme

Age	Male	Female
4–10 years	60 calories	59 calories
11–18 years	87 calories	77 calories
19–64 years	83 calories	52 calories

Based on the principle of energy flux presented by Swinburn et al. (2006), we modelled the 'what if' scenario for population-level changes in body weight for 4–5-year-olds (Reception year) and 10–11-year-olds (Year 6). The energy flux model allows us to estimate the effects of the proposed reductions in energy intake on the mean weight of a hypothetical population with the same age, height and sex mix.

The original model was developed and cross-validated for a population consuming 10% less energy (10% fewer kcal/day). Over an average duration of 3.4 years, a 10% lower energy flux would produce a 4.61% reduction in body weight. When estimates produced by the model were validated against real-world data in ~1,000 children from three studies, it was found to produce accurate predictions (ibid.).

For each prediction, we modelled what would happen if the PHE/OHID calorie reduction targets were achieved, using two different estimates of baseline energy flux. Table 2 shows the estimates for potential weight reduction among 4–5-year-old children (%). The final estimates are lower when initial energy flux is based on energy expenditure (top portion of table) than when it is based on reported energy intakes (EI) (bottom half of table).[6]

Table 2: Weight loss after reformulation (Reception year)

	Boys	**Girls**
Energy flux (kcal) [a]	1602	1443
EI reduction (kcal) [c]	60	59
EI reduction (%)	3.9	4.1
Weight loss (%)	1.7	1.9
	Boys	**Girls**
Energy flux (kcal) [b]	1234	1105
EI reduction (kcal) [c]	60	59
EI reduction (%)	4.9	5.4
Weight loss (%)	2.5	2.5

a Based on mean energy expenditure for 4–6-year-olds measured using doubly labelled water technique assessed as part of the National Diet and Nutrition Survey.

b Based on mean energy intake for 4–6-year-olds estimated from dietary intake diary data from the National Diet and Nutrition Survey.

c Estimated reduction in energy intake for 4–10-year-olds estimated by PHE.

6 While data on energy intake are plentiful, the accuracy of these assessments, based on self- or proxy-reported dietary intake, is questionable. Estimates of energy flux based on measures of energy expenditure are more accurate as they are based on objective measurements using the doubly labelled water method. Due to cost, however, such data are scarcer for English children.

A conservative estimate of weight reduction came from using estimated reduction in energy intake (4–10-year-olds at 60/59 kcal/day for boys and girls respectively) in combination with a model of energy flux based on energy expenditure values. The ~4% reduction in energy intake would be expected to result in 1.7% and 1.9% lower body weights in Reception-year boys and girls respectively. When energy flux was based on estimates of energy intake, the reduction in energy intake was higher (4.9% in boys and 5.4% in girls), and the predicted weight loss was greater: 2.5% for both sexes.

Because Year 6 children straddle the divide between 4–10-year-olds and 11–18-year-olds, we used a conservative, lower-limit estimate of PHE-predicted reductions in energy intake for 4–10-year-old boys (60 kcal/day) and girls (59 kcal/day), as well as an upper-limit estimate based on PHE-predicted reduction in energy intake for 11–18-year-old boys (87 kcal/day) and girls (77 kcal/day).

Table 3 shows the four estimates for potential weight reduction. As before, the final estimates are lower when initial energy flux is based on energy expenditure (top portion of table) than when based on reported energy intakes (bottom half of table). The figures on the left use PHE's figures for 4-10 year olds while the figures on the right use PHE's figures for 11-18 year olds.

Table 3: Weight loss after reformulation (Year 6)

	Boys	Girls		Boys	Girls
Energy flux (kcal) [a]	2352	2119	**Energy flux (kcal) [a]**	2352	2119
EI reduction (kcal) [c]	60	59	**EI reduction (kcal) [d]**	87	77
EI reduction (%)	2.6	2.8	**EI reduction (%)**	3.7	3.6
Weight loss (%)	1.2	1.3	**Weight loss (%)**	1.7	1.7
	Boys	**Girls**		**Boys**	**Girls**
Energy flux (kcal) [b]	1602	1525	**Energy flux (kcal) [b]**	1602	1525
EI reduction (kcal) [c]	60	59	**EI reduction (kcal) [d]**	87	77
EI reduction (%)	3.8	3.9	**EI reduction (%)**	5.4	5.0
Weight loss (%)	1.8	1.8	**Weight loss (%)**	2.5	2.3

a Based on mean energy expenditure for 10–11-year-olds measured using doubly labelled water technique assessed as part of the National Diet and Nutrition Survey.

b Based on mean energy intake for 10–11-year-olds estimated from dietary intake diary data from the National Diet and Nutrition Survey.

c Estimated reduction in energy intake for 4–10-year-olds estimated by PHE.

d Estimated reduction in energy intake for 11–18-year-olds estimated by PHE.

The most conservative estimate of weight reduction came from using the lower estimated reduction in energy intake (60/59 kcal/day for 4–10-year-old boys and girls respectively) in a model in which energy flux was based on energy expenditure. At energy fluxes of 2352 and 2119 kcal/day, 60 and 59 fewer kcal/day represents a 2.6% (boys) and 2.8% (girls) reduction in energy intake. Over 3.4 years, this would result in 1.2% and 1.3% weight loss for boys and girls respectively. Based on the same energy flux model, the greater proportional reductions in energy intake (87/77 kcal/day in boys and girls respectively) would result in a 1.7% weight loss in both sexes.

Because energy flux estimates are lower when based on values for energy intake, the same two sets of values posited for reduced energy intake are proportionally higher. The lower estimates (59/60 kcal) represent a 3.8% and 3.9% lower energy intake which, over 3.4 years, would produce 1.8% weight loss in both sexes. The highest estimate for weight loss was generated using the larger reduction in energy intake (87/77 kcal/day). These values represent a 5.4% and 5.0% reduction in energy flux in boys and girls respectively. Over 3.4 years, these reductions would result in 2.5% weight loss in boys and 2.3% weight loss in girls (mean average 2.4%).

Energy flux estimates based on expenditure are higher and, undoubtedly, more accurate, yet they are only available for a very small number of children. Energy flux estimates based on energy intake from dietary analysis are more readily available in nationally representative samples, yet these are known to be underestimates. Approximations for energy flux for this age group, based on energy intake values published by PHE, sit within the mid-range of our upper and lower estimates at just over 2000 kcal for boys and girls.

Based on these estimated values, we would expect a weight reduction of around 1.8%, and commensurate figures for the reduction in obesity. Applying the same methods, the reduction in the number of obese children and the increases in those deemed underweight would, however, remain proportionate to one another – albeit at values around the middle of the estimates presented here.

When weight loss had been calculated, we assessed the effects of the lowest and highest estimates by applying the predicted values to bodyweight measurements for Year 6 children from the NCMP data. Bodyweight values were recalculated based on predicted weight loss and used to recalculate BMI (using the extant values height). Using individuals' sex and decimal age, we calculated z-scores, percentiles and predicted BMI values.

Figure 2 shows our estimates for Reception-year children. Assuming a 1.8% weight loss, the percentage of Reception-year children who are obese drops from 4.2% to 3.4% (a decrease of 0.8 percentage points). The larger estimate of 2.5% weight loss results in an obesity prevalence of 2.9% (a decrease of 1.3 percentage points).

However, the lower estimate for potential weight loss would mean the number of Reception-year children who are underweight would increase from 5.2% to 8.2% (a rise of 3.0 percentage points). The upper estimate of 2.5% weight loss would increase the prevalence of underweight from 5.2% to 10.0% (a rise of 4.8 percentage points).

Figure 2: Impact of weight loss on underweight and obese children: Reception year

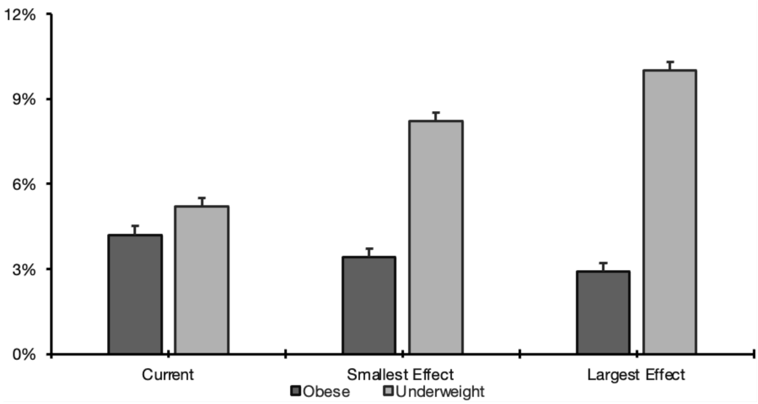


Figure 3 shows our estimates for Year 6 children. Assuming 1.3% weight loss, the percentage of Year 6 children who are obese drops from 6.0% to 5.8% (a decrease of 0.2 percentage points). The larger estimate of a 2.4% weight loss would result in obesity rates falling from 6.0% to 4.9% (a decrease of 1.1 percentage points). However, the increase in the number of underweight children is greater than the reduction in the number of obese children. On the lower estimate for potential weight loss, the number of Year 6 children who are underweight rises from 6.9% to 9.0% (an increase of 2.1 percentage points). The upper estimate of 2.4% weight loss increases the prevalence of underweight from 6.9% to 11.0% (an increase of 4.1 percentage points).

In other words, under every scenario, for every child who moves from the obese category to the healthy weight category, at least two children become underweight.

Figure 3: Impact of weight loss on underweight and obese children: Year 6

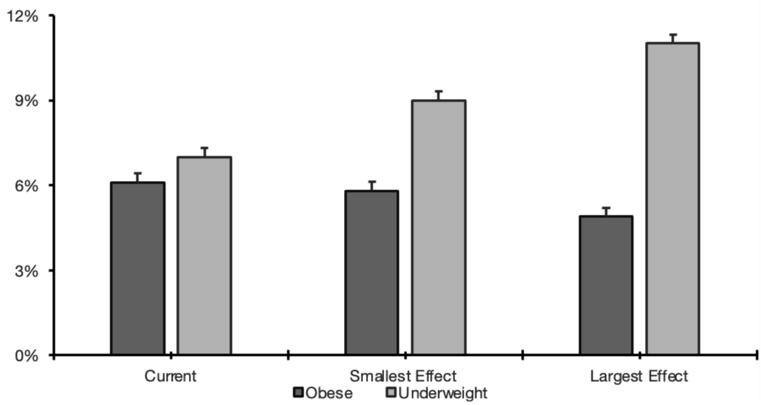
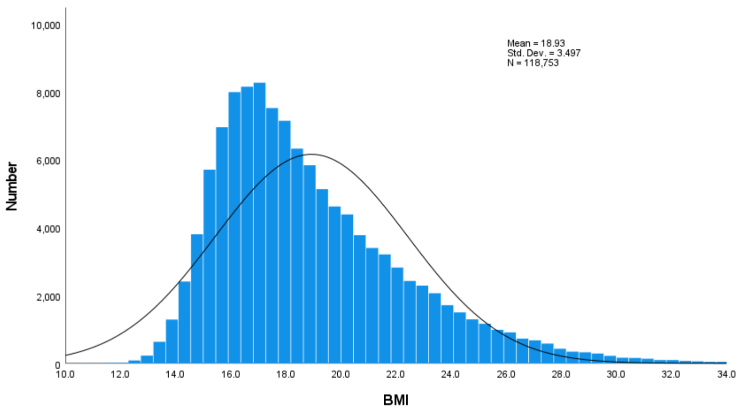


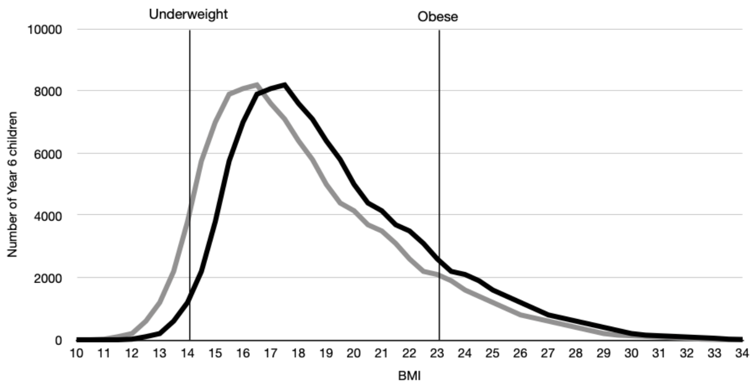
Figure 4 below helps explain why universal weight loss would increase the number of underweight children more than it would reduce the number of obese children. In this graph, children on the right tail are obese, and children on the left tail are underweight. Notice the way the graph leans to the left. There are some very high BMI values to the right, showing some potentially very large children, but most values (shown by taller bars) are on the left hand side of the graph.

Figure 4: BMI distribution among Year 6 children



Note that it is a skewed distribution (a normal distribution is illustrated by the thin black line). If the entire curve shifts to the left, as would be expected from a population-wide measure designed to change everyone's consumption equally (Rose 2008), a larger number of children move into the underweight category than move out of the obese category. This is illustrated in Figure 5 below, with the black line representing the weight distribution before the calorie reduction and the grey line showing the distribution after the intervention. There is a disproportionate increase in the number of underweight children, who at this age have a BMI of 14 or less, compared with the modest decreases in the number of obese children (who have a BMI of around 23 or more) moving from the far right to the centre of the graph.

Figure 5: BMI distribution among Year 6 children before and after food reformulation



This is what our model shows, with the prevalence of underweight among Reception-age children rising from 5.2% to between 8.2% and 10.0%, and prevalence of underweight among Year 6 children rising from 6.9% to between 9% and 11%. Despite rates of obesity falling among both age groups, the total number of children who are an unhealthy weight (i.e. obese or underweight) actually increases after reformulation, from 9.4% to between 11.6% and 12.9% in Reception, and from 12.9% to between 14.8% and 15.9% in Year 6.

Policy implications

At this point, the reader might be thinking that the reformulation scheme is unlikely to produce a measurable increase in the number of underweight children because families will change their shopping behaviour. If they cannot acquire enough calories through their normal basket of goods, they will find high-calorie/low-cost products to use as substitutes, or spend more money on food. If food companies reduce the size of their products (a common way of meeting PHE's targets), people will simply buy more of them.

We agree. Our model only produces realistic predictions if the PHE/OHID scheme works as intended – but that is highly doubtful. Like Adam Smith's 'man of system', those who propose reformulation as an anti-obesity policy seem to think that they can 'arrange the different members of a great society with as much ease as the hand arranges the different pieces upon a chess-board'. The problem is, as Smith recognised, that 'in the great chess-board of human society, every single piece has a principle of motion of its own' (Smith [1759] (2017): 274). Consumers will not blindly continue to eat the same quantities of food products that have been altered or shrunk. PHE's own analysis shows that, despite some modest progress in its sugar reduction programme, there has been no reduction in the amount of sugar consumed in food overall. Instead, people are buying less of the reformulated products, as PHE's final report on sugar reduction acknowledged in 2020:

> 'Sustained progress in sugar reduction has been seen for breakfast cereals (down 13.3%) and yogurt and fromage frais (down 12.9%). However, as described previously, these reductions are not being fully realised in the programme overall. This is due to a reduction in the proportion of total sales from these lower sugar categories and increases in sales in higher sugar categories such as chocolate

> confectionery (which is reporting hardly any change in total sugar per 100g).
>
> Overall these changes have resulted in more sugar from these products now appearing in shopping baskets than was the case in 2015' (PHE 2020: 61).

If people continue to consume the same number of calories under a system in which food has been extensively reformulated to meet a target, we would not expect to see a rise in either underweight or overweight. The main consequence would be a rise in expenditure on food. It has been estimated that 50.4% of food bought by families in the UK is 'ultra-processed' (Monteiro et al. 2017). The vast majority of these products would be subject to PHE's targets on calories and/or sugar. Leaving aside the extreme difficulty of reformulating many of these products, *if* the 20% reduction targets were met and consumers continued to purchase the same number of calories from these products, it would raise the cost of their food shopping by around 10%.

Such an increase in the cost of living would be undesirable for all households, but it would hit those on low incomes particularly hard. As mentioned above, children are more likely to be underweight if they come from families living in deprivation. People in the bottom quintile of the income distribution spend twice as much money on food and soft drinks than those in the top quintile, as a proportion of their income (ONS 2021). Any increase in the price of food will have a disproportionately negative effect on the poorest members of society. If the price rise affects products which the poorest consume more of, this effect will be amplified.

Conclusion

In its report launching the food reformulation programme, PHE (2018: 30) emphasised the importance of cost-benefit analysis: 'When implementing a new policy or programme it is important to consider the wider benefits and impacts it may have.'

Unfortunately, PHE failed to carry out the kind of full cost-benefit analysis that would be required in a normal government Impact Assessment. Not only did it fail to look at the impact of reformulation on household expenditure and consumer welfare, it did not even try to assess the direct, weight-related impacts on people who are not overweight. Although most adults and the vast majority of children are not obese, the agency simply assumed that significantly cutting the number of calories in their diet would have a 'minimal impact' on them.

This assumption is implausible. If the reformulation scheme works as intended by reducing calorie intake across the whole population, it will increase the number of underweight 10–11-year-olds by at least 30%, and possibly by as much as 60%. However, if it does *not* work as intended and consumers adapt to the new food environment by buying more food, it will increase the cost of feeding a typical household by around 10%.

We consider the second of these scenarios to be the more realistic one. Neither our model nor PHE's model should be taken seriously as a prediction of what would happen if the targets were met. It is much more likely that consumers would compensate by buying more food (or buying other types of high-calorie food), regardless of their weight. This has already been demonstrated with the sugar reduction scheme in the UK and has also been shown in a randomised controlled trial (Markey et al. 2016). Demand for food is highly inelastic, and people are generally prepared to make sacrifices in other parts of the household budget before they abandon their favourite foods. The surprising results reported in this paper should therefore be taken as an illustration of the flaws in the reformulation theory, rather than as a serious prediction.

If we are mistaken and large-scale food reformulation results in consumers continuing to buy the same brands of food in the same quantities, the modest reductions in childhood obesity prevalence modelled in this paper are likely to occur, but it logically follows that there will also be a substantial increase in the number of underweight children, and a net increase in the number of children who are an unhealthy weight. At best, the reformulation policy prioritises the overweight over the underweight, and the obese at the expense of the hungry. It attempts to change a characteristic of an entire population in order to possibly benefit the health of a minority while increasing risks to the health of a significant number of vulnerable people.

However, for the reasons given above, we do not fear a substantial increase in the number of underweight children as a result of reformulation, and we do not anticipate a reduction in obesity for the same reasons. The most plausible outcome from such a scheme, if it could be made to work, is an increase in expenditure on food. If there is any change in body weight, it is likely to be among children in the poorest households who cannot afford to pay for more food. In these households, the policy will move at least twice as many children into the underweight category as it will move out of the obese category.

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