



# Impact of the 2003 to 2018 Population Salt Intake Reduction Program in England

## A Modeling Study

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**ABSTRACT:** The United Kingdom was among the first countries to introduce a salt reduction program in 2003 to reduce cardiovascular disease (CVD) incidence risk. Despite its initial success, the program has stalled recently and is yet to achieve national and international targets. We used age- and sex-stratified salt intake of 19 to 64 years old participants in the National Diet and Nutrition Surveys 2000 to 2018 and a multistate life table model to assess the effects of the voluntary dietary salt reduction program on premature CVD, quality-adjusted survival, and health care and social care costs in England. The program reduced population-level salt intake from 9.38 grams/day per adult (SE, 0.16) in 2000 to 8.38 grams/day per adult (SE, 0.17) in 2018. Compared with a scenario of persistent 2000 levels, assuming that the population-level salt intake is maintained at 2018 values, by 2050, the program is projected to avoid 83 140 (95% CI, 73 710–84 520) premature ischemic heart disease (IHD) cases and 110 730 (95% CI, 98 390–112 260) premature strokes, generating 542 850 (95% CI, 529 020–556 850) extra quality-adjusted life-years and £1640 million (95% CI, £1570–£1660) health care cost savings for the adult population of England. We also projected the gains of achieving the World Health Organization target of 5 grams/day per adult by 2030, which by 2050 would avert further 87 870 (95% CI, 82 050–88 470) premature IHD cases, 126 010 (95% CI, 118 600–126 460) premature strokes and achieve £1260 million (95% CI, £1180–£1260) extra health care savings compared with maintaining 2018 levels. Strengthening the salt reduction program to achieve further reductions in population salt intake and CVD burdens should be a high priority. (*Hypertension*.2021;77:1086–1094. DOI:10.1161/HYPERTENSIONAHA.120.16649.) • [Data Supplement](#)

**Key Words:** cardiovascular disease ■ diet ■ health care cost ■ incidence ■ ischemic heart disease ■ salt reduction ■ stroke ■ United Kingdom

Excess salt intake is strongly linked with raised blood pressure (BP) and thereby increased risks of cardiovascular disease (CVD), as well as with kidney disease, gastric cancer, and osteoporosis,<sup>1–5</sup> and is recognized as a global health challenge.<sup>6</sup> Raised BP (>115/75 mm Hg) is responsible for half of the burden of ischemic heart disease (IHD) and >60% of stroke burden.<sup>7</sup> Consequently, the World Health Organization (WHO) and national governments have issued recommendations to reduce population-level salt intake.<sup>6,8</sup> Different strategies have been implemented to achieve such reductions, most

of them involving industry engagement toward voluntary salt reformulation in processed food.<sup>9</sup> Partial success of such strategies has been observed in high-income countries, where about 80% of consumed salt comes from processed foods,<sup>10</sup> including the United Kingdom where it represents up to 86% of all salt intake.<sup>11</sup> Nevertheless, no country has yet achieved salt intake reductions to recommended levels.

Since 1996, the nongovernmental organization, Consensus Action on Salt and Health, have continuously raised awareness about the health benefits of

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## Novelty and Significance

### What Is New?

- Between 2000 and 2018, the daily salt intake of adults in England declined by 1 gram/day, from 9.38 to 8.38 grams/day.

### What Is Relevant?

- We used 2000 to 2018 representative population surveys' salt intake data and a multistate life table model to project the impact of the 2000 to 2018 salt reduction program on cardiovascular disease, quality of life, health care and social costs and value of further salt reduction efforts in England.

### Summary

We project that, if 2018 salt intake levels are maintained, by 2050, the 2000 to 2018 salt reductions would have led to 193 870 fewer adults developing premature cardiovascular disease; 542 850 more quality-adjusted life years; and large savings from reduced health care and social care utilization. If the 5 grams/day, World Health Organization recommended salt intake is achieved by 2030 in England, these benefits could double.

## Nonstandard Abbreviations and Acronyms

<b>CVD</b>	cardiovascular disease
<b>IHD</b>	ischemic heart disease
<b>BP</b>	blood pressure
<b>WHO</b>	World Health Organization
<b>QALY</b>	quality-adjusted life-year

reducing salt intake in the United Kingdom through providing scientific evidence and advocating political action.<sup>12</sup> Such efforts contributed to a voluntary agreement between the United Kingdom government and the food industry. In 2003 to 2010, the Food Standards Agency, in collaboration with the food industry, established salt reduction targets in several food categories under a voluntary scheme,<sup>13</sup> which also involved product labeling, public awareness campaigns, and monitoring of targets' achievement. Reductions in the added salt in processed food were implemented gradually following a stepwise process.<sup>14</sup> Consequently, the average population-level salt intake was reduced by 15% in the period 2000 to 2011,<sup>15–17</sup> with the decline attributed to food companies reformulating processed products rather than consumers switching to a lower salt diet.<sup>13</sup> The program's success was based on the fact that gradual marginal reductions are undetected by human taste receptors,<sup>18</sup> thus, not affecting consumers' preferences or industry sales.

After several years of sustained salt intake reductions aimed at limiting the burden of excess salt by encouraging companies to reformulate recipes, in 2013, the National Institute for Health and Clinical Excellence recommended a maximum salt intake of 6 grams/day per adult by 2015 and 3 grams/day per adult by 2025.<sup>19</sup> From 2011 to 2017, the salt reduction program continued under the Department of Health as part of the Public

Health Responsibility Deal. It first aimed to meet the 2012 targets for reducing salt added into 85 food categories, such as bread, cheese, cereals, or soups; but it lacked the political commitment to achieve further reductions necessary to progress toward the recommended levels.<sup>15</sup> Few of the proposed actions were implemented under the Responsibility Deal and, thus, the program failed to achieve the salt intake targeted: in 2014, the average population-level salt intake among adults remained at about 8 grams/day.<sup>20</sup> By 2018, however, an increase in salt intake was reported in adult women while no progress was reported in adult men.<sup>21</sup>

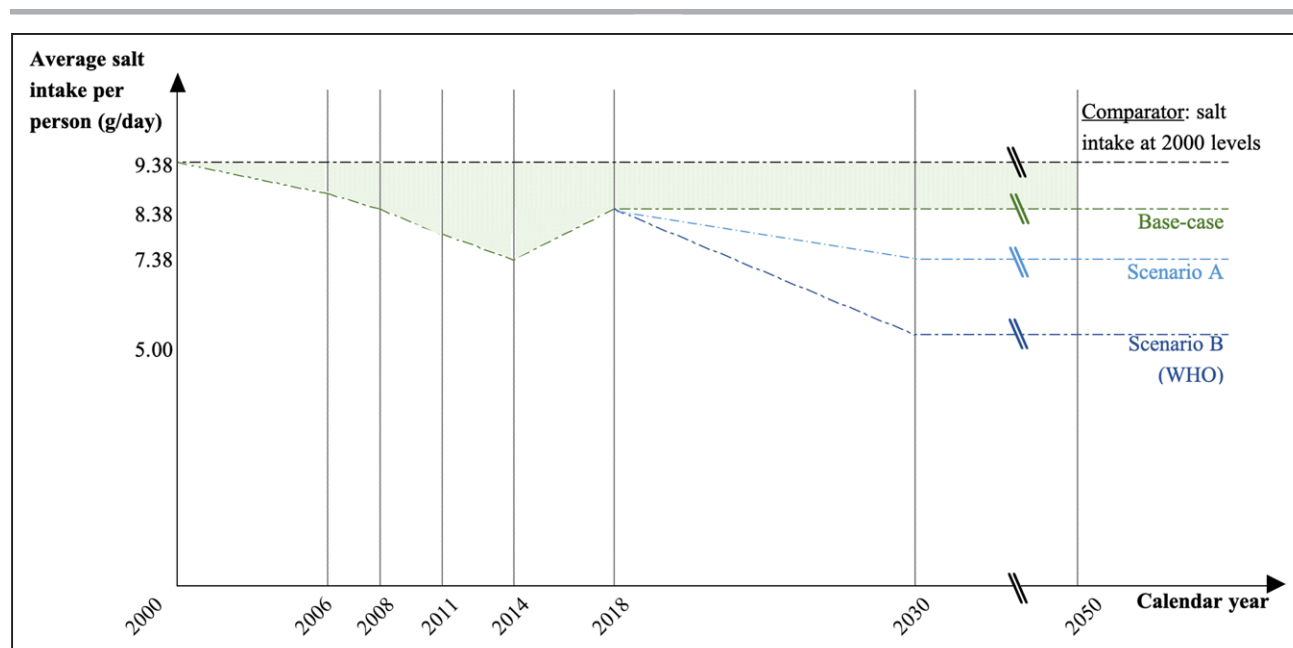
The present study evaluates the long-term effects of the 2003 to 2018 salt intake reduction program in England using a model to project its effects on premature CVD, individuals' healthy survival, and health care and social care costs. Moreover, it estimates the potential effects of further salt intake reductions by 2030.

## METHODS

We evaluated the health and economic impact of reductions in population-level salt intake in England during the period 2003 to 2018 by comparing population health outcomes and costs under the observed salt intake over the period 2003 to 2018 and assuming it remained at 2018 levels in 2019 to 2050 (base-case analysis) with population-level salt intake maintained at 2000 to 2001 values across the 2003 to 2050 period (comparator; Figure 1). All data used in this study are publicly available.

## Salt and Sodium

The terms salt and sodium are often used interchangeably. However, on a weight basis, salt comprises 40% sodium and 60% chloride. Salt is the major source of sodium in the diet ( $\approx 90\%$ ). One gram of sodium=2.5 g of salt. Sodium is the term used in most scientific journals and in nutritional labels in the United States and Canada, and salt is used in Europe and other countries. We used the term salt throughout the article as it reports analysis for England.<sup>4</sup>



**Figure 1. Population salt intake (grams/day) scenarios.**

In the base-case analysis, we assessed the long-term health and economic impact of the achieved salt intake reduction during the period 2003 to 2018, with 2018 levels maintained until 2050 (base-case scenario) compared with the population-level salt intake in 2000 maintained until 2050 (area in green). In 2 further scenarios, the additional long-term impacts were assessed with further annual salt intake reductions in 2019 to 2030 of (scenario A) 1.37% (the annual reduction rate in 2000–2014); and (Scenario B) 3.36% (achieving the World Health Organization [WHO] recommendation of 5 grams/d per adult in 2030). In both scenarios, we assumed that 2030 salt-intake levels were maintained until 2050.

## Population-Level Salt Intake Data

We used publicly available data on salt intake from the National Diet and Nutrition Surveys in adults 19 to 64 year of age in England<sup>21</sup> that assessed salt intake by 24-hour urinary sodium excretion for a representative population sample in years 2000/2001, 2006, 2008, 2011, 2014, and 2018. The data from complete urinary sodium samples (ie, para-amino benzoic acid  $\geq 70\%$ ), stratified by sex and age (19–34, 35–49,  $\geq 50$ ) and adjusted using age- and sex-specific survey weights were used to estimate dietary salt intake (grams/day).

## Salt Reduction Program Costs

The costs of the salt reduction program were based on estimates by Collins et al,<sup>22</sup> which were obtained from the Food Standards Agency Impact Assessment of 2009. Program activities under the Responsibility Deal were similar to those under the Food Standards Agency scheme, and, with the exception of the 2009 to 2012 media campaign, costs included: (1) food industry costs of reducing salt in specific food categories and (2) UK government costs of administering and monitoring the program. No extra food industry costs were considered as costs of labeling and reformulating specific product lines to reduce salt content were assumed to be fully absorbed during the natural product development life cycle<sup>22</sup> and progressive salt reformulations were assumed not to impact on industry sales as consumers progressively adjust to lower-salt diets.<sup>17</sup>

UK government costs included the cost of a media campaign conducted between 2009 and 2012 (£41.62 million), as well as the cost of monitoring salt intake in the general population and monitoring food industry activities to guarantee

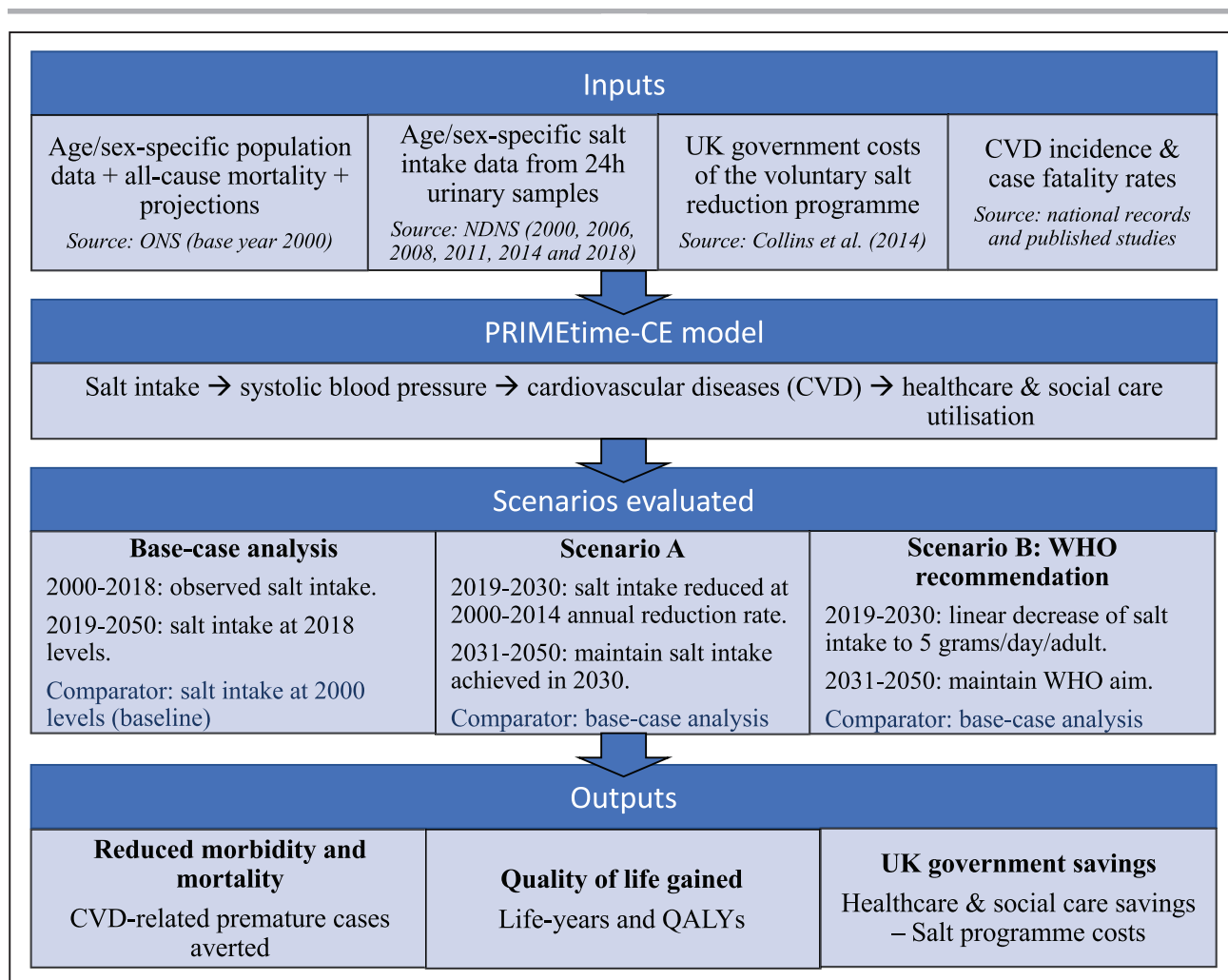
manufacturers are labeling and effectively reducing the salt content of food products (£2.15 million per year each).<sup>22</sup> Annual monitoring costs were assumed over the lifespan of the program, but future media campaigns were discontinued because of their limited effectiveness: public awareness of the salt-related harmful effects temporarily increased during the campaigns but diminished quickly again after the first campaign year.<sup>14</sup> We present program costs for the total population of England.

## The PRIMetime-CE Model: Impact on Health and Health Care Utilization

PRIMetime-CE is a multistate life table model, which links sociodemographic and behavioral risk factors to noncommunicable diseases' morbidity and mortality and health and social care costs.<sup>23–29</sup> Figure 2 summarizes the conceptual framework in our study.

We used official statistics on age and sex stratified population distribution and all-cause mortality in England in the year 2000.<sup>30,31</sup> In mid-2000, the population of England was 49.2 million, 51% of which were female, and 62% were aged above 30 years (Figure S1 in the [Data Supplement](#)). All-cause mortality rates were calculated using deaths registered by age and sex divided by corresponding population estimates (Figure S2). Population was annually adjusted in subsequent years using the age- and sex-specific rates of population increase during 2000 to 2015. We used an open cohort design to account for all adults over time.

The effects of a reduction in population-level salt intake are propagated in the model through the reduction in BP.<sup>32</sup> The effect of salt intake on BP is based on a meta-analysis by He et



**Figure 2. Conceptual framework.**

PRIMEtime-CE is a multistate life table model for estimating the health and economic impact of health interventions.<sup>23–29</sup> CVD indicates cardiovascular disease; NDNS, National diet and nutrition survey; ONS, office for national statistics; QALY, quality-adjusted life-year; and WHO, World Health Organization.

al,<sup>32</sup> which estimated that a reduction in salt intake of 6 grams/day was associated with a decrease of 5.8 mmHg (95% CI, 2.50–9.20) in systolic BP. Salt intake changes in the model are implemented by sex and age and account for the positive association between higher dietary salt intake and BP: for a given reduction in salt intake, the fall in systolic BP is larger in older compared with younger individuals.<sup>33</sup> Reductions in systolic BP are associated with reductions in risk of CVD, including IHD and stroke.<sup>34</sup> During each year in the model, IHD and stroke prevalence and incidence were computed using population impact fractions, which accounted for the proportion by which disease incidence and mortality in the population were reduced given changes in BP because of the salt reduction program. Table S1 summarizes the parameters, probability distributions, and respective data sources used in the model; as well as the data sources informing the epidemiological estimates used in PRIMEtime-CE.

Quality-adjusted life-years (QALYs) were obtained by combining life years and EQ-5D utilities, associated with included diseases,<sup>35</sup> stratified by age and sex. During each year, the extra years and QALYs, and health care and social care cost

savings due to reductions in IHD and strokes associated with the salt reductions achieved, were estimated (Methods in the [Data Supplement](#)).

### Base-Case Analysis

We estimated the effects of the salt reduction program for the adult population in England, aggregated in 5-year bands, over the periods 2000 to 2018 and 2019 to 2050. For both study periods, age- and sex-specific CVD morbidity and mortality were simulated annually according to the risk associated with salt intake. Starting at 2000 levels, population salt intake was assumed to change according to the population-level salt intake observed in England from 2000 to 2018 and to remain at 2018 values for the remaining time horizon. Due to lack of data, individuals older than 64 years of age were assumed to have daily salt intake corresponding to the 50- to 64-year-old age and sex category. We estimated the total premature CVD morbidity and mortality cases, life-years, and QALYs, and health care and social care costs associated with 2000 to 2018 salt intake values, and compared them with those obtained

should the salt intake levels remained at 2000 levels (baseline; Figure 1). Health gains associated with the salt reduction program were expressed as: premature (ie, before 75 years of age) IHD and stroke cases avoided, and life years and QALYs gained. We considered IHD and stroke cases occurring to individuals dependent on BP reductions and adjusted for decreasing trends in prevalence of CVD according to age and sex.<sup>36</sup> We present nondiscounted CVD cases, life years and QALYs, as well as discounted at 1.5% per annum QALYs gained with the salt reduction program.<sup>37</sup>

Health care and social care costs were presented in 2014 UK£ values and discounted at an annual rate of 1.5%.<sup>37</sup> Health care savings were calculated for the period 2000 to 2050 as the difference between the cumulative health care costs associated with the salt intake levels before the salt reduction program (year 2000) minus the cumulative health care costs under decreasing population salt intake in 2000 to 2018. For the base-case analysis, we further calculated the incremental costs to the UK government as the government costs associated with monitoring and administering the salt reduction program minus the cost savings due to reducing health care and/or social care utilization.

### Scenarios of Further Salt Reductions

We used PRIMETIME-CE to evaluate 2 additional scenarios with further population-level salt intake reductions after 2018. Between 2019 and 2030, we assumed a linear reduction in the average population-level salt intake (1) equivalent to the annual reduction rate of 1.37% observed over the period 2000 to 2014 (scenario A) or (2) of 3.36% to achieve WHO recommendation of 5 grams/day per adult (scenario B; Figure 1). We assumed that thereafter, salt intake was maintained at 2030 levels until 2050. For each scenario, we estimated the health outcomes and health care and social care costs associated with reduced salt intake and expressed the outcomes as the additional premature morbidity and mortality cases averted, life-years gained, QALYs gained, as well as the additional health care and social care savings compared with the base-case analysis (maintained salt intake at 2018 levels).

### Sensitivity Analyses

We undertook a probabilistic sensitivity analysis to account for the uncertainty in model parameters using 1000 random draws from their probability distributions (Table S1) to estimate the SEs and 95% CIs.

Sensitivity analyses evaluated the impact of model parameters on key results. First, we projected the long-term benefits if the program had not stalled in 2014 to 2018 by assuming continued decrease in salt intake from 2014 to 2030 at the 2000 to 2014 annual rate with achieved reduction by 2030 maintained until 2050. Second, we evaluated the effect of assuming the government salt reduction program was responsible for only half of the observed 2000 to 2018 salt intake decrease. Third, we assessed the impact of using a higher effect of a decrease in salt intake on BP, as estimated from observational data under a more prolonged period of lower salt intake (compared with randomized trials), in which a decrease in salt intake of 1.4 grams/day, as measured by 24-hour urine sodium excretion in a random population sample, was associated with a fall

in systolic BP of 2.7 mmHg.<sup>1</sup> Finally, we used a higher suggested estimate for 2014 population-level salt intake.<sup>38</sup>

## RESULTS

### Reduction in Population-Level Salt Intake and Its Short and Long-Term Effects

In 2000 to 2001, the average population-level salt intake was 9.38 grams/day (SE, 0.16), 10.72 grams/day (SE, 0.25) in men, and 8.08 grams/day (SE, 0.18) in women. By 2014, the average population-level salt intake fell to 7.58 grams/day (SE, 0.18), 8.68 grams/day (SE, 0.27) in men, and 6.43 grams/day (SE, 0.22) in women. The 19.20% reduction in salt intake in the period 2000 to 2001 to 2014 (Table S2) was somewhat larger in younger adults with >25% reduction in individuals 35 years of age or younger. However, the salt intake trend then stalled and by 2018, men had increased their intake to 9.19 grams/day (0.29) and women to 7.58 grams/day (0.23).

Table 1 reports the estimated impact of the achieved reduction in population-level salt intake on CVD burden and health care and social care cost. The model estimated that 27 630 (95% CI, 26 580–27 650) premature IHD and 39 250 (95% CI, 38 500–40 050) premature stroke cases were avoided during the period 2000 to 2018. These health gains translated into 33 660 (95% CI, 31 840–33 750) QALYs gained for the adult population in England. In that period, the overall costs of the salt reduction program reached £103 million (95% CI, £103–£104), whereas the reduced CVD morbidity resulted in health care savings of £310 million (95% CI, £295–£311). Overall, the salt reduction program was cost-saving, estimated to save £860 million (95% CI, £830–£870) in health care and social care costs.

The model estimated that by 2050, even in the absence of further salt intake reductions (Table 1), 83 140 (95% CI, 73 710–84 520) premature IHD and 110 730 (95% CI, 98 390–112 260) premature stroke cases would be averted by achieved reductions to date, if maintained, compared with 2000 levels. Adopting a 50-year time horizon, the estimated UK government costs for the salt intake reduction program rose to 190 million (95% CI, £189–£191), whereas the estimated cost savings due to reducing health care and social care utilization increased to £7110 million (95% CI, £6940–£7230), and quality of life in England increased by 542 850 (95% CI, 529 020–556 850) QALYs, or 334 660 (95% CI, 319 650–343 680) discounted QALYs (Table 1).

### Further Salt Intake Reductions

The extra benefits with further salt intake reductions in the population of England on CVD morbidity and the health care and social care savings are shown in Table 2.

**Table 1. Projected Health Benefits and Costs of the 2003 to 2018 Salt Reduction Program Among Adults in England**

Study outcome	2000–2018	2019–2050	Whole 2000–2050 period
Health benefits (95% CI)			
Premature IHD cases averted*	27 630 (26 580–27 650)	55 850 (54 080–57 610)	83 140 (73 710–84 520)
Premature stroke cases averted*	39 250 (38 500–40 050)	72 110 (69 350–73 670)	110 730 (98 390–112 260)
Years of life gained	37 130 (34 250–38 240)	702 960 (694 250–720 660)	740 090 (728 490–760 900)
QALYs gained	33 660 (31 840–33 750)	516 190 (497 180–523 100)	542 850 (529 020–556 850)
QALYs gained (discounted)†	27 490 (26 450–27 840)	307 170 (293 200–315 840)	334 660 (319 650–343 680)
Costs‡ (£ mln) (95% CI)			
Total care cost savings	960 (930–970)	6340 (6200–6450)	7300 (7130–7430)
Health care cost savings	410 (400–420)	1220 (1170–1240)	1640 (1570–1660)
Social care cost savings	550 (530–560)	5120 (5030–5210)	5670 (5560–5770)
Government cost for salt reduction program	103 (103–104)	87 (86–87)	190 (189–191)
UK government cost savings‡ (£ mln) (95% CI)			
Total cost savings	860 (830–870)	6250 (6110–6370)	7110 (6940–7230)
Cost savings excluding social care costs	310 (295–311)	1130 (1080–1160)	1450 (1380–1470)

Health effects and costs were estimated using the population-level salt intake reduction achieved during 2000 to 2018 and assuming the 2018 levels were maintained until 2050 compared with a scenario with the 2000 salt intake levels were maintained until 2050. Costs expressed in 2014 UK£. CVD indicates cardiovascular disease; IHD, ischemic heart disease; mln, million; and QALY, quality-adjusted life-year.

\*Premature cases are cases among adults up to 75 y of age.

†Discounted at 1.5% per annum.

‡Government cost savings calculated as the difference between the total health care and social care savings because of averted CVD minus the government costs of monitoring and administering the salt reduction program.

Reducing the population-level salt intake during 2018 to 2030 at the same annual rate observed in 2000 to 2014 was estimated to achieve average salt intake levels of 6.77 grams/day per adult by 2030. Such a reduction was estimated to result in 37 870 (95% CI, 36 310–38 550) further premature IHD cases and 56 310 (95% CI, 54 480–57 890) further premature stroke cases avoided by 2050, representing a 45% and 50% increase respectively of base-case results. Such health gains had additional health care and social care savings of £2560 million (95% CI, £2510–£2620). Achieving larger population salt intake reductions, as recommended by WHO, by 2030 implied an average salt intake reduction of 3.38 grams/day per adult, which led to 87 870 (95% CI, 82 050–88 470) fewer premature IHD cases and 126 010 (95% CI, 118 600–126 460) fewer premature stroke cases by 2050 compared with the health gains in the base-case analysis. This reduction in disease burden led to 343 260 (95% CI, 334 810–352 430) further QALYs gained and additional cost savings of £5330 million (95% CI, £5120–£5380). The program remained a cost-saving policy strategy.

### Sensitivity Analyses

We investigated the impact of specific model assumptions on results. First, we estimated the impact if the salt intake reduction trend from 2000 to 2014 had continued until 2030 (Table S3). Under this scenario, the estimated

premature CVD cases avoided doubled by 2050, with an additional 91 000 premature IHD cases and 143 700 premature stroke cases avoided, while the population quality of life in England increased by further 463 300 QALYs, compared with the base-case analysis. While health gains and governmental savings decreased when we attributed only 50% of salt intake reductions to the salt reduction program (Table S4), even under this assumption, the program averted 29 300 premature IHD cases and 38 400 premature stroke cases over 2000 to 2050, with £2500 million government cost savings. Conversely, assuming a higher effect of salt intake reduction on BP doubled the premature CVD cases averted (Table S5) with 154 100 premature IHD cases and 205 500 premature stroke cases averted in the period 2000 to 2050 (base-case); and further 312 400 premature IHD cases and 431 200 premature stroke cases potentially averted if the WHO salt intake recommendation was achieved. Finally, adopting the adjusted 2014 salt intake estimates resulted in about 10% less health gains compared with the base-case with the program remaining cost-saving (Table S6).

### DISCUSSION

The 2003 to 2018 population salt reduction program put in place in England has been remarkably successful in reducing population-level salt intake. We report that, according to our model, this reduction projects 193 870 fewer premature CVD cases and 542 850 extra QALYs

**Table 2. Projected Benefits for Adults in England With Further Population Salt Intake Reductions Post-2018**

Study outcome	Scenario A: 1.37% annual reduction in salt intake 2019–2030 (reaching 6.77 grams/d in 2030) and maintaining 2030 level to 2050	Scenario B: 3.36% annual reduction 2019–2030 (reaching 5 grams/d in 2030) and maintaining 2030 level to 2050
Additional health benefits (95% CI)		
Additional premature IHD cases averted*	37 870 (36 310–38 550)	87 870 (82 050–88 470)
Additional premature stroke cases averted*	56 310 (54 480–57 890)	126 010 (118 600–126 460)
Additional years of life gained	220 530 (188 370–226 130)	451 930 (435 300–494 900)
Additional QALYs gained	171 520 (167 340–220 530)	343 260 (334 810–352 430)
Additional QALYs gained (discounted)†	95 120 (92 870–98 210)	189 540 (189 160–191 530)
Additional costs† (£ mln) (95% CI)		
Additional total care cost savings	2560 (2510–2620)	5330 (5120–5380)
Additional health care savings	570 (540–580)	1260 (1180–1260)
Additional social care savings	1980 (1970–2050)	4080 (3940–4120)

Effects of scenarios A and B were compared with maintaining 2018 levels until 2050. No additional government costs were included as costs of reformulating specific products were assumed to be absorbed by the food industry. Costs expressed in 2014 UK£. IHD indicates ischemic heart disease; mln, million; and QALY, quality-adjusted life-year.

\*Premature cases are cases occurring up to 75 y of age.

†Discounted at 1.5% per annum.

among the adult population in England by 2050. More importantly, further strengthening and scaling up of the salt reduction program, to achieve the WHO recommendation of 5 grams/day per adult by 2030, could bring further large reductions in CVD burden with 213 880 further premature CVD cases avoided by 2050. These health gains could bring substantial accumulated savings to the UK government of £5330 million by 2050 due to reductions in population need for health care and social care.

Our results underscore the value of investing in public health interventions to reduce the burden of noncommunicable diseases, with substantial savings to the UK government.<sup>39</sup> The food industry in the UK is still producing high-salt products in spite of strong evidence that it is technologically feasible and commercially viable to produce lower-salt products, and there is ample room for incremental reductions in their salt content to achieve further population salt reductions in the United Kingdom.<sup>15</sup>

The salt reduction program in England was highly successful until 2011 because of the government pressure on industry to reduce salt content, resulting in a decline in the average population-level salt intake of 14% (Table S2; 8.3% reduction 2006–2011). A recent study reported 5.1% reduction in the salt content of the UK grocery basket of a nationally representative sample of households from 2005 to 2011.<sup>13</sup> These estimated reductions are consistent with the reduction reported by He et al, in high-salt products in supermarkets (from 3.3 to 1.8 g of salt per serving of product), which identified bread as the single largest contribution to salt to the UK diet: 18% of total salt intake.<sup>14</sup> The salt reductions were also driven mainly by product reformulation, as opposed to net product introduction and changes in consumer preferences.<sup>14</sup> The observed decline in program effectiveness after

2011<sup>21</sup> was attributed to reduction in the government pressure on industry.<sup>15</sup> To get back on track, the program will benefit from (1) a strict enforcement of salt reduction targets, for example, through legislation or financial penalties for food companies failing to comply; (2) setting more stringent salt targets; and (3) extending salt targets to the out-of-home sector, which remain lenient and lack the proper monitoring mechanisms.

Several studies have previously indicated that salt reduction strategies have been effective and cost-effective in the United Kingdom,<sup>22,40–42</sup> and worldwide.<sup>43–53</sup> Our study adds further important evidence to the literature as it also includes the latest 2018 data on sodium excretion obtained from 24-hour urinary samples, that is, the most accurate way to assess salt intake, to estimate the health gains associated with reducing salt intake. Furthermore, we also project the reduction in CVD burden with further strengthening of salt reduction strategies to achieve the WHO recommendations on salt intake.

Despite the high-quality data on population-level salt intake and disease burden used, our study has some limitations. First, the sample size for 24-hour urine collections was small, particularly after stratifying by age and sex. Second, our model does not capture the effect of salt intake on the burden of gastric cancer, renal disease, and osteoporosis,<sup>2,5,12</sup> and, therefore, likely underestimates the health benefits of the program. Moreover, the effect of salt reduction policies in children<sup>54</sup> were also not included because of lack of salt intake data in children. Finally, the long study period may present a further limitation due to the uncertainty in model parameters, assumptions on continuity of the salt reduction program, and evolution of CVD and salt intake trends. In particular, salt intake trajectories from 2019 onward are a main source of uncertainty, especially given the salt intake increase

observed after 2014. However, the main objective of the current study was to highlight the long-term population health benefits should the government strengthen and enhance the UK salt reduction program.

## PERSPECTIVES

The 2003 to 2018 salt reduction program in England achieved an overall salt intake reduction of 1 gram/day in the adult population from 9.38 grams/day per adult in 2000 to 8.38 grams/day per adult in 2018. We modeled the long-term effects of this reduction and demonstrated that the program led to reduced cardiovascular burden and improved quality-adjusted life expectancy of the adult population, as well as yielding large savings in health care and social care. However, reductions in salt intake achieved by 2014 are already being lost. Reversing this and achieving the WHO recommended salt intake of 5 grams/day per adult requires continuous efforts in strengthening the implementation and monitoring of the program. Such efforts are shown likely to be well compensated by further reductions in cardiovascular disease burden.

## ARTICLE INFORMATION

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