Title

How health inequalities accumulate and combine to affect treatment value: A distributional cost-effectiveness analysis of smoking cessation interventions

Keywords

Smoking cessation; public health; equity; health inequality; cost-effectiveness analysis; decision model

Introduction

Reducing health inequalities is a primary goal in public health [1]–[3]. Impact on health inequality should, therefore, be an important component in determining the value of investments in public health interventions. However, public health commissioners, or the agencies that inform them with recommendations and guidelines, do not routinely undertake quantitative assessment of how interventions change health inequality. For example, the National Institute for Health and Care Excellence (NICE) produces evidence-based guidance for local commissioners in England [4]. The quantitative component of the value for money assessment is the amount of population health generated by an intervention, relative to its cost. Whilst in some cases qualitative information is provided on health inequalities relevant to the decision problem, evidence on how inequality is expected to actually change is not provided.

Distributional cost-effectiveness analysis (DCEA) is an approach to economic evaluation that considers population health and health inequality impacts simultaneously. Compared with standard economic evaluations that generate information on mean outcomes only, decision

analytic models in DCEAs use additional data to reflect social variation in the model inputs. This allows them to estimate the cumulative inequality impact of an intervention across the different stages of the course of disease and treatment, such as incidence, treatment uptake and adherence – the so-called 'staircase effect' [5]. The inequalities present at each staircase level can potentially compound or offset one another and can have vastly different effects on the overall inequality impact.

The objective of this paper is to address two key questions relating to the feasibility and practicality of conducting DCEAs: (i) how existing decision analytic models can be retrospectively adapted using existing published evidence and (ii) how incorporating social variation at specific points in the course of disease and treatment can affect the cumulative inequality impact. These issues are explored through a pilot study to formally incorporate inequality in an appraisal of behavioural and pharmacological interventions for smoking cessation for the National Institute for Health and Care Excellence's (NICE) public health guideline programme.

Methods

Overview

Our analysis is divided into three stages. Using the case study decision model (described below), we first identify evidence that describes how the model inputs vary by socioeconomic status. This produces a decision model that is able to estimate the incremental costs and health benefits for a recipient of each intervention from each socioeconomic

subgroup. Next, the results per individual are scaled up to population level using estimates of the recipient population size and utilisation levels in each socioeconomic subgroup. The net population-level effects account for the health effects of alternative uses of resources (health opportunity costs), and how these forgone benefits are expected to be distributed between subgroups.

In stage three the net health effects for each subgroup are then added to a corresponding estimate of baseline health. Population health and health inequality impacts are summarised graphically on the health equity impact plane [6]. If a dominant intervention is identified that provides the greatest increase in health and that reduces health inequality by the greatest amount, no further analysis is required. Formal analysis of the trade-off between these two objectives is required when this is not the case.

A range of scenario analyses explore how accounting for social variation in different sets of parameters affects our results. We do this estimating the distribution of health benefits when accounting for only (i) smoking prevalence or (ii) prevalence and service utilisation. Both scenarios assume that per recipient health benefits and cost impact of each intervention is uniform over subgroups.

Smoking cessation case study

Smoking remains a significant cause of ill health and death worldwide, despite public health efforts and cigarette taxes [7]. In England, approximately 4 per cent of hospital admissions and 17 per cent of deaths are related to smoking [8]. Smoking and smoking-related disease increases with measures of social disadvantage: those with low incomes, less qualifications

and living in poor neighbourhoods are more likely to smoke. In Great Britain, 20 per cent of adults who earn less than £10,000 per year smoke compared to 10 percent of those who earn £40,000 and above [9]. Smoking therefore remains a key determinant of both health inequality and population health.

NICE produced guidance for public health commissioners on the use of behavioural and pharmacological interventions to stimulate smoking cessation in 2018 [10]. The economic analysis indicated that these interventions increased health on average, and either saved costs or increased cost by less than £4,000 per quality-adjusted life year (QALY) gained. However, their impact on health inequality was not formally assessed. While the health burden of smoking is highest among socioeconomically disadvantaged groups, individuals in the most advantaged groups are more likely to utilise smoking cessation services [11], [12]. This countervailing socioeconomic variation makes the net impact of providing smoking cessation services on health inequality hard to judge. Local authorities faced with the choice between smoking cessation interventions or something else, may desire information on which works best for disadvantaged groups.

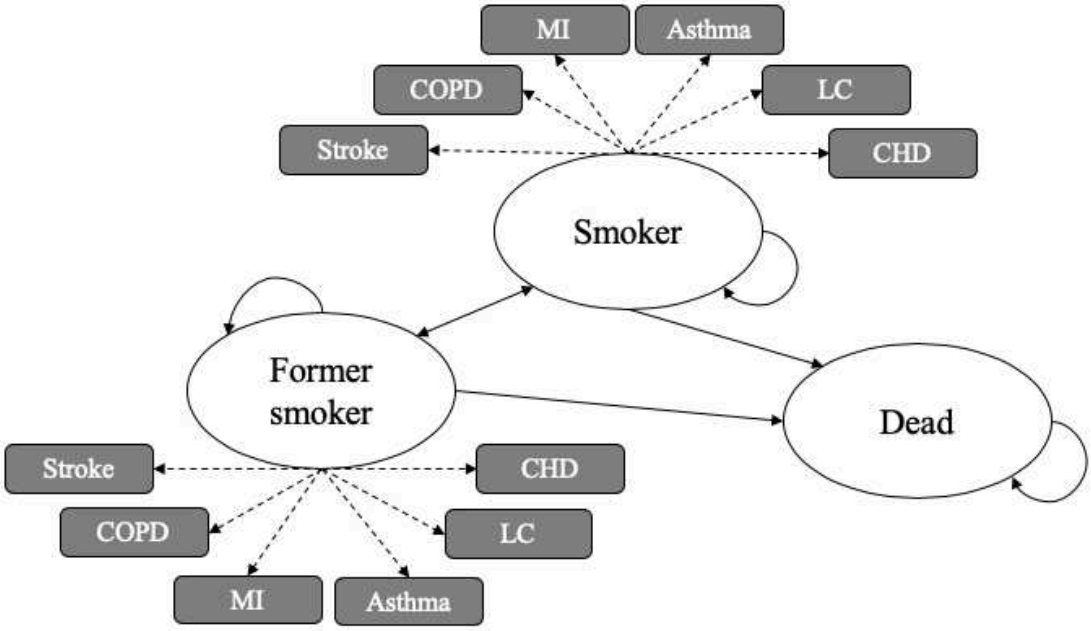
In this case study, we retrospectively adapt the decision model used in the 2018 guideline [10], [13] to conduct a DCEA of 21 behavioural and pharmacological smoking cessation interventions [14]–[24].

Decision model adaptation

The original decision model was built to reflect a health sector (NHS) perspective, and estimated costs and quality adjusted life-years over a lifetime time horizon. A cohort of

smokers enter the model (Figure 1), and transition to former smokers based on the effectiveness of interventions in supporting successful quit attempts (measured at one year). Mortality and disease risks depend on age and smoking status, with former smokers facing lower risks of developing any of the six smoking-related comorbidities and experiencing better health-related quality of life. All interventions are compared to a background annual quit rate of 2%, which represents smokers who naturally quit without intervention [25]. The model is run for cohorts of smokers of different ages, before the results are combined to calculate the weighted average costs and QALYs per smoker overall.

Figure 1 Model structure for smoking cessation interventions



Note: LC = lung cancer; CHD = coronary heart disease; MI = myocardial infarction; COPD = chronic obstructive pulmonary disease; asthma = asthma exacerbation.

We extend the model to describe inequality in quality-adjusted life expectancy associated with underlying socioeconomic factors. We show the results for subgroups defined in terms

of the Index of Multiple Deprivation (IMD), but the method extends to any characteristic associated with unfair health inequality. IMD is an area-based measure of deprivation incorporating seven dimensions: employment, income, education, crime, living environment and housing/services. Each individual in the population is associated with an IMD score based on their residence within one of 32,482 local super output areas (LSOAs) in England. We group individuals according to quintile of IMD, with IMD1 representing the most deprived fifth, and IMD5 representing the least deprived fifth.

Using pragmatic literature review for each model input, we determine whether there is appropriate evidence describing variation by IMD for the following sets of inputs: (i) health outcomes without smoking cessation interventions (baseline health); (ii) how interventions change health outcomes (effectiveness), (iii) which individuals access and use interventions (implementation). The data are summarised in Table 1.

Baseline health outcomes

The original model sourced health-related quality of life (HRQL) weights (and the associated decrements from smoking) from the literature. We characterise inequality in HRQL, measured through the EQ-5D instrument, using information from the Health Survey for England from 2012 and 2014 [26], [27]. Linear regression analysis is used to obtain average EQ-5D scores for smokers and former smokers by IMD quintile, controlling for respiratory and circulatory disease to avoid double counting the quality of life decrements of comorbidities included in the model. These results are reported in Table A1 (online appendix). Differences in mortality risk by age, sex and IMD quintile were obtained from the ONS (Figure A1) [28] and subsequently adjusted for smoking status.

Table 1 Inputs disaggregated by socioeconomic status

	IMD quintile group					
Model input	**1**	**2**	**3**	**4**	**5**	Source
Smoking population						
Number of smokers	2,457,519	1,622,583	1,448,360	927,069	773,353	[26], [27]
Proportion of male smokers	55%	56%	56%	55%	57%	[26], [27]
EQ-5D scores						
Smokers	0.794	0.848	0.837	0.866	0.884	[26], [27]
Former smokers	0.818	0.866	0.856	0.880	0.904	[26], [27]
Comorbidity risk						
Relative risk of smoking-related illness	1.03	0.99	1	0.95	0.84	[29]
Odds of quit success						
All intervention types	1	1.58	1.34	1.43	1.61	[30]
One-to-one	1	1.04	1.06	1.08	1.07	[31]
Closed group	1	1.15	1.24	1.44	1.49	[31]
Uptake of services						
Start2quit trial	2.39%	3.75%	3.59%	3.62%	3.83%	[32]
NHS SSS statistics 18/19	1.64%	3.17%	4.06%	4.37%	5.83%	[33]
Proportion of health opportunity cost						
Males	0.14	0.12	0.12	0.09	0.08	[34]
Females	0.12	0.1	0.1	0.07	0.06	[34]
Baseline quality-adjusted life expectancy						
Males	62.3	67	69.5	72.8	74.8	[35]
Females	64.1	68.2	70.4	73.4	75.2	[35]

Notes:

1. Quit success odds ratios are applied such that the mean quit probability across groups is equal to mean value in the original model.
2. IMD = index of multiple deprivation; SSS = Stop smoking services; *'Any service' includes services outside the four listed in Table 1.

Inequality in the burden of smoking-related comorbidity is in part due to differences in prevalence of smoking between population groups. Smoking prevalence by age, sex and IMD was estimated using the Health Survey for England data. We found evidence from Scotland of an additional independent effect of deprivation on risk of smoking-related disease [29]. We assumed that the relationship by English IMD quintile was the same as that for Scottish IMD, and that the mean prevalence of smoking-related diseases in the existing model described the prevalence in the central quintile (IMD3).

A number of other parameters are assumed constant over socioeconomic groups as we could not identify evidence detailing socioeconomic variation, such as annual healthcare cost per case of smoking related disease.

Intervention impact

We use estimates by Dobbie et al. [30] to account for socioeconomic variation in the probability of a successful quit attempt. Their analysis used NHS Stop Smoking Services data to estimate odds ratios for smoking cessation by IMD quintile. This did not differentiate between the various types of interventions and focused on the probability of quitting at four weeks. The use of these quit odds ratios assumes that the socioeconomic pattern observed in four week quit rates is reflective of the pattern in 52-week quit rates. We found one study that differentiated the relationship between quit rate and socioeconomic status for different types of behavioural intervention. Hiscock et al. [31] examined four types of behavioural intervention (one-to-one, drop-in clinic, open rolling group, closed group), using a four-category occupation-based measure of socioeconomic status (NS-SEC). We map 11 of our 21 interventions onto these intervention types (nine 'one-to-one' and two 'closed group') and

cross-tabulate NS-SEC and IMD quintile in the Health Survey for England to provide a link between these different measures. We use Dobbie et al. for the primary analysis and examine a subset of interventions using Hiscock et al. in a sensitivity analysis.

We found no studies describing socioeconomic variation in the relative risk reduction on all-cause mortality or smoking-related disease from a successful quit attempt. While we assume that these are the same in all groups, our characterisation of variable baseline levels of mortality and smoking related disease means that the absolute risk reduction is greatest in the most deprived groups.

Service utilisation

We estimate socioeconomic variation in service utilisation by IMD from a randomised controlled trial (Start2quit) of 4,300 smokers that evaluated interventions provided by NHS Stop Smoking Services (SSS) in England between 2012 and 2014 [32]. This covers the period after the funding of SSS was transferred from the NHS to local governments and Public Health England [36]. We calculate the proportion of smokers in each IMD quintile using SSS by combining the distribution of utilisation with statistics on SSS use and smoking prevalence for 2018/19 [33]. This indicates that utilisation is proportionally higher in less deprived groups but the absolute numbers of smokers utilising services is greatest in the most deprived groups (Table 1).

A more recent distribution of service utilisation by IMD for 2018/19 can be estimated from national SSS statistics. This requires assigning IMD scores to individuals based on their local authority instead of their LSOA. We use this as a scenario analysis only for two reasons. First, local authorities are a much higher level of geographical aggregation (approximately

100 times the size of LSOAs on average) and are therefore less informative about the socioeconomic conditions of individuals. Second, investment decisions on SSS are now made by individual local authorities, which increase the possibility of a postcode lottery and larger variations in service utilisation. The utilisation distribution estimated from the local authority data, provided in Table 1, shows a steeper pro-rich gradient than in the Start2quit trial.

Modelling health inequality impacts

Direct health benefits

The adapted model is run for all 21 interventions and each of the five IMD groups. This provides different incremental costs and QALYs from use of each intervention for smokers from different IMD quintiles, weighted by sex. Multiplying these 'per smoker' estimates by the number of smokers in each IMD quintile that use each intervention provides population-level costs and QALYs. We disaggregate these QALYs by sex using the ratio of male to female smokers for each IMD quintile.

Health opportunity costs

NHS resource use forms the biggest component of cost changes attributed to smoking cessation, through changes in the amount of smoking-related disease. Local authorities fund some delivery of smoking cessation services, but these implementation costs form a small proportion of the incremental cost. In NICE recommendations, an intervention is regarded as value for money if it generates at least additional one QALY per additional £20,000 of NHS resources [4]. We use one QALY per £20,000 to convert total population cost into health opportunity cost. The proportion of the health opportunity costs that fall on each sex and IMD quintile is estimated using the distribution of health benefits from marginal changes in

NHS expenditure in England [34]. By applying this to all resource use, NHS or otherwise, this assumes the same level and distribution of health opportunity cost for NHS and local authority public health resources.

Summary intervention impact measures

We add the net health benefit (the difference between the QALY gains and the health opportunity cost) by sex and IMD quintile to the baseline quality adjusted life expectancy for each group [35]. This yields the post-intervention distribution of quality adjusted life expectancy across all groups in the population. This can be compared with the baseline distribution to evaluate how interventions change total health and health inequality. Change in total population health is described as population net health benefit in QALYs. Absolute and relative inequality are measured using the slope index of inequality (SII) and the relative index of inequality (RII), respectively [37]. A change of -0.1 in the SII indicates that the difference in between the least and most healthy groups in the population has decreased by 0.1 QALYs. The same change in RII indicates that the difference between the least and most healthy quintile has decreased by 10 percentage points.

We compute health-related social welfare indices that integrate concern for changes in both total population health and health inequality. These functions contain an inequality aversion parameter that quantifies the strength of preference for health gains at the bottom of the distribution and yield a single summary measure for each distribution: equally distributed equivalent (EDE) health. EDE health increases with total population health and decreases with enlargement of health inequality. The functional forms we use to calculate this summary measure are the Kolm index [38] for absolute inequality and Atkinson index [37] for relative inequality. A change in EDE can be compared against the corresponding change

in population net health benefit to express the value of inequality impacts in terms of QALYs. When the change in EDE health is lower than change in net health benefit, the loss of welfare due to inequality has increased by more than the welfare gain from health improvement. In the absence of evidence on the level of aversion to health inequality between areas defined on the basis of IMD, we use rich versus poor health inequality aversion parameters of α=0.15 (Kolm) and ε=10.95 (Atkinson) [40]. These values are based on a UK general population study, in which respondents were asked how much total population health they would forgo for reductions in health inequality between rich and poor groups. This implies that gains to the poorest fifth are weighted 6-7 times greater than those to the richest.

Scenario and sensitivity analysis

Our analysis constitutes a full distributional cost effectiveness analysis, in which the cumulative inequalities throughout disease and treatment course are captured (prevalence, access, short- and long-term health effects). We conduct sensitivity analysis to show how excluding information on inequalities in some of these stages of the intervention affects the estimated inequality impacts of the interventions. Two scenarios are explored, where (i) only differences in smoking prevalence are included (with mean utilisation and net health benefit) and (ii) differences in prevalence and utilisation are included. These scenarios correspond to inequality impacts that can be captured using aggregate distributional cost effectiveness analysis, a simplified form of analysis that can be applied without model adaptation [41], [42]. The difference between our base case and scenario (ii) therefore demonstrates the effect of conducting full DCEA compared with the aggregate approach.

Four further sensitivity analyses are conducted. First, we provide separate results for the subset of behavioural interventions for which we can specify socioeconomic variation in effectiveness specific to the type of intervention. Second, we use the socioeconomic distribution of local authority-level service utilisation from national SSS statistics. Third, we vary the rate at which total costs are converted into health opportunity cost to show how the results change with different estimates for the marginal productivity of NHS and local authority public health resources. Fourth, we test the degree of inequality aversion on results by varying the Atkinson parameter for the most and least cost-effective interventions.

Results

Descriptive statistics

The characteristics of the 21 interventions are reported in Table A2 (online appendix).[1] The quit success rate at 12-months ranges from 7% for counselling to 40% for a sequence of varenicline, bupropion and selective serotonin reuptake inhibitors (SSRI). Intervention costs (excluding over-the-counter therapies) range from £19 for brief advice to £764 for a course of nicotine patches and nasal spray.

The change in population costs and health for each intervention are presented by IMD quintile in Table 2. Summed to population-level, all interventions produce health gains and all but one are cost saving (Patch + Nasal Spray). All interventions provide greater direct health benefits to recipients in less deprived groups. However, greater smoking prevalence in

[1] The different forms of counselling combined with placebo (three alternatives) and varenicline (two alternatives) are differentiated by number.

the most deprived groups mean that the interventions reduce the absolute gap in quality-adjusted life expectancy between the most and least deprived.

Impact on the distribution of health

The summary measures of the intervention impacts on population health and health inequality are shown in Table 3. All interventions reduce absolute health inequality according to the SII and RII.

All interventions increase EDE health when accounting for both absolute (Kolm index) and relative (Atkinson index) inequality. Inequality reductions from the interventions create health-related social welfare gains, measured by the difference between the change in net health benefit and change in EDE health. For the Atkinson index, the range of these gains were equivalent to 848 QALYs for counselling to 11,237 QALYs for patch and nasal spray.

The health equity impact plane (Figure 2) shows that all the interventions lie in the northeast quadrant, increasing population health and reducing absolute health inequality compared to no smoking cessation service. The interventions would be ranked in the same order based on net health benefit or EDE health.

Table 2 Population costs and quality-adjusted life year impacts by intervention and index of multiple deprivation (IMD) quintile

	IMD1 (most deprived)		IMD2		IMD3		IMD4		IMD5 (least deprived)	
Intervention[†]	**ΔQALY**	**ΔCost**	**ΔQALY**	**ΔCost**	**ΔQALY**	**ΔCost**	**ΔQALY**	**ΔCost**	**ΔQALY**	**ΔCost**
NRT OTC	3,052	*-£6,917,329*	4,916	*-£12,536,763*	3,534	*-£10,866,434*	2,397	*-£7,580,235*	2,501	*-£7,108,358*
Placebo + counselling	1,781	*-£2,339,445*	2,904	*-£5,642,704*	2,077	*-£4,880,282*	1,411	*-£3,494,127*	1,478	*-£3,344,725*
Varenicline	6,847	*-£2,609,309*	10,653	*-£13,766,638*	7,764	*-£12,424,147*	5,238	*-£9,193,651*	5,411	*-£8,868,230*
Placebo + counselling	6,503	***£5,410,739***	10,149	*-£4,967,773*	7,388	*-£4,844,534*	4,986	*-£4,261,915*	5,156	*-£4,492,789*
Varenicline + counselling	12,515	***£1,394,028***	18,526	*-£16,358,331*	13,768	*-£15,938,888*	9,219	*-£12,160,750*	9,389	*-£11,676,392*
Placebo + counselling	7,183	*-£5,173,847*	11,142	*-£16,884,573*	8,131	*-£15,149,871*	5,483	*-£10,996,687*	5,659	*-£10,480,942*
Varenicline + counselling	13,868	*-£10,715,488*	20,294	*-£30,249,635*	15,148	*-£28,205,614*	10,126	*-£20,194,289*	10,279	*-£18,766,157*
Brief advice	2,101	*-£3,641,208*	3,415	*-£7,545,233*	2,446	*-£6,526,479*	1,661	*-£4,613,773*	1,738	*-£4,374,674*
Varenicline + brief advice	11,024	*-£13,617,599*	16,530	*-£30,351,061*	12,223	*-£27,503,658*	8,201	*-£19,443,962*	8,382	*-£18,087,399*
Self-determination intervention	3,733	***£3,205,651***	5,825	*-£3,129,570*	4,306	*-£2,892,154*	2,918	*-£2,563,280*	3,039	*-£2,755,371*
Sequence (var, bup, SSRI)	19,158	*-£27,633,058*	26,834	*-£52,036,923*	20,363	*-£48,612,249*	13,525	*-£33,757,995*	13,566	*-£30,588,817*
Minimal intervention (MI)	13,399	*-£27,827,429*	19,686	*-£47,556,967*	14,672	*-£42,863,154*	9,814	*-£29,585,882*	9,973	*-£27,057,935*
CBT + MI	13,086	*-£13,914,755*	19,278	*-£32,816,012*	14,353	*-£30,169,970*	9,604	*-£21,382,006*	9,767	*-£19,817,171*
Bupropion + CBT + MI	8,959	***£343,214***	13,678	*-£13,450,354*	10,043	*-£12,568,624*	6,756	*-£9,575,333*	6,942	*-£9,316,603*
NRT + CBT + MI	13,399	*-£23,583,103*	19,686	*-£43,152,845*	14,672	*-£39,098,215*	9,814	*-£27,161,666*	9,973	*-£24,918,233*
Patch and nasal spray	12,050	***£17,500,254***	17,910	***£833,633***	13,289	*-£1,114,011*	8,904	*-£2,565,173*	9,078	*-£3,204,614*
Patch	4,156	*-£2,399,150*	6,626	*-£9,611,101*	4,782	*-£8,478,754*	3,238	*-£6,232,902*	3,370	*-£6,036,621*

Bupropion and lozenge	11,331	*-£21,059,033*	16,946	*-£38,410,670*	12,544	*-£34,472,153*	8,412	*-£23,965,120*	8,592	*-£22,083,546*
Lozenge	5,769	*-£8,514,139*	9,063	*-£18,376,614*	6,580	*-£16,188,630*	4,446	*-£11,456,361*	4,606	*-£10,789,322*
7.2mg e-cigarette	5,105	*-£9,078,790*	8,069	*-£17,988,710*	5,844	*-£15,760,721*	3,952	*-£11,076,204*	4,102	*-£10,399,664*
7.2mg then 5.4mg e-cig	3,215	*-£4,794,989*	5,171	*-£10,600,069*	3,719	*-£9,226,940*	2,522	*-£6,552,379*	2,631	*-£6,220,374*

Note: NRT = nicotine replacement therapy; OTC = over the counter; Var = varenicline; Bup = bupropion; SSRI = selective serotonin reuptake inhibitors; SDI = self-determination intervention; MI = minimal intervention; CBT = cognitive behavioural therapy; QALY = quality adjusted life year

† Three different forms of placebo + counselling and two different forms of varenicline + counselling were compared as mutually exclusive alternatives. They are numbered to distinguish them.

Table 3 Summary measures of intervention impact on distribution of health

Intervention	Population NHB (QALYs)	Inequality reduction		Combined total health and inequality impact	
		ΔSII	ΔRII	$\Delta EDE_{K,\alpha}$	$\Delta EDE_{A,\varepsilon}$
NRT OTC	18,650	0.00020	0.00000	19,807	20,220
Placebo + counselling	10,636	0.00011	0.00000	11,255	11,484
Varenicline	38,256	0.00043	0.00000	40,702	41,554
Placebo + counselling	34,839	0.00039	0.00000	36,957	37,715
Varenicline + counselling	66,154	0.00078	0.00000	70,893	72,431
Placebo + counselling	40,532	0.00046	0.00000	43,173	44,082
Varenicline + counselling	75,123	0.00090	0.00000	80,777	82,564
Brief advice	12,696	0.00014	0.00000	13,452	13,729
Varenicline + brief advice	61,810	0.00072	0.00000	66,251	67,695
Self-determination intervention	20,378	0.00022	0.00000	21,526	21,958
Sequence (var, bup, SSRI)	103,077	0.00129	0.00001	111,741	114,314
Minimal intervention	76,289	0.00091	0.00000	82,141	83,976
CBT + MI	71,994	0.00086	0.00000	77,365	79,071
Bupropion + CBT + MI	48,607	0.00056	0.00000	51,830	52,927
NRT + CBT + MI	75,440	0.00090	0.00000	81,189	82,997
Patch and nasal spray	60,658	0.00071	0.00000	64,797	66,174
Patch	23,809	0.00026	0.00000	25,243	25,762
Bupropion and lozenge	64,825	0.00076	0.00000	69,581	71,111
Lozenge	33,730	0.00038	0.00000	35,906	36,662
7.2mg e-cigarette	30,286	0.00034	0.00000	32,227	32,905
7.2mg then 5.4mg e-cig	19,128	0.00021	0.00000	20,289	20,708

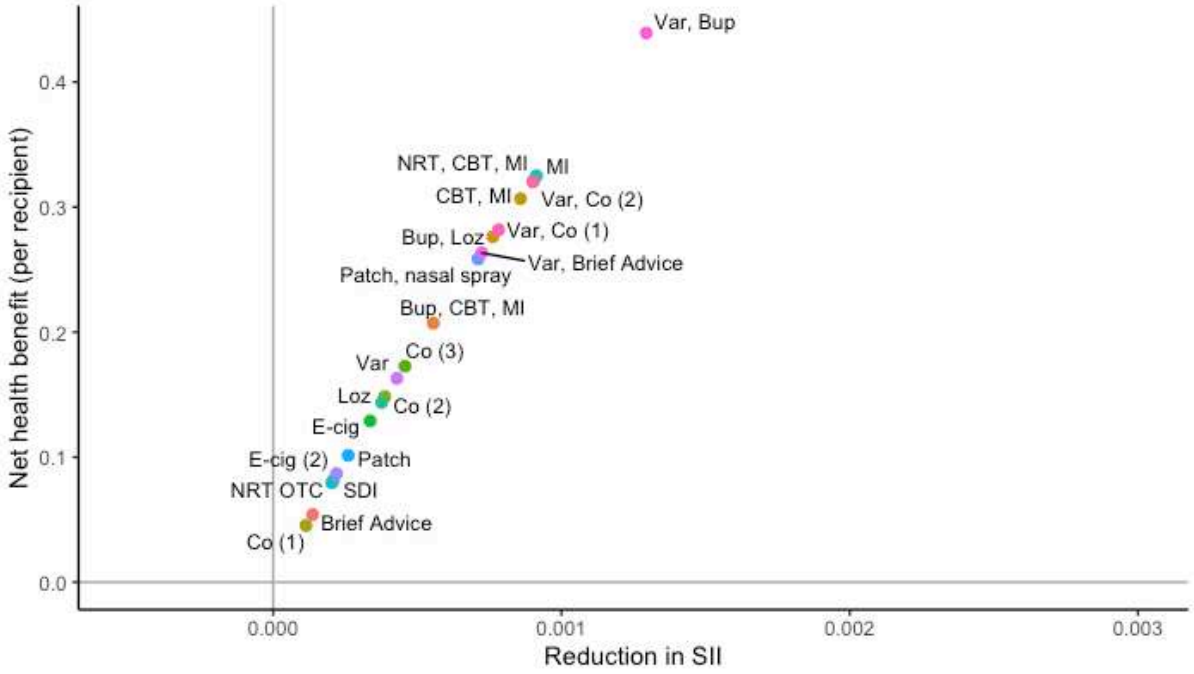
Notes:

1. ΔSII = reduction in slope index of inequality; NHB = population net health benefit; QALYs = quality adjusted life years; ΔRII = reduction in relative index of inequality; $\Delta EDE_{K,\alpha}$ = change in equally

distributed equivalent QALYs derived from Kolm Index; $\Delta EDE_{A,\varepsilon}$ = change EDE QALYs derived from Atkinson Index

2. NRT = nicotine replacement therapy; OTC = over the counter; Var = varenicline; Bup = bupropion; SSRI = selective serotonin reuptake inhibitors; SDI = self-determination intervention; MI = minimal intervention; CBT = cognitive behavioural therapy; QALY = quality adjusted life year

Figure 2 Health equity impact plane of smoking cessation interventions



Notes:

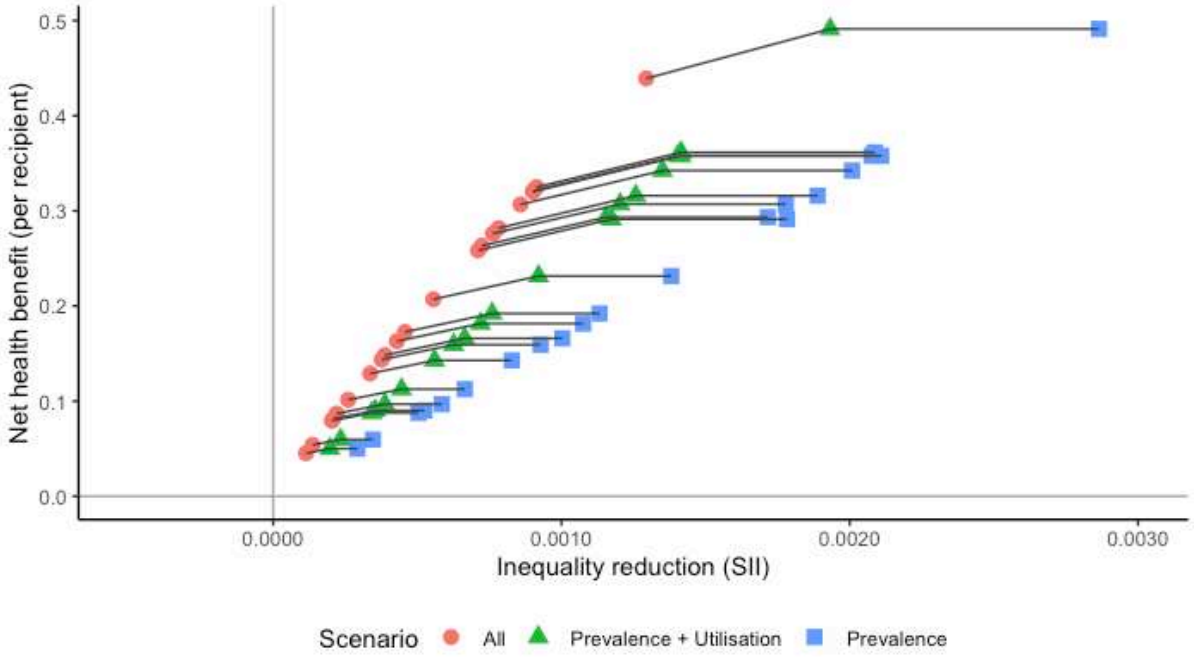
1. QALYs = quality-adjusted life years; SII = slope index of inequality
2. Intervention abbreviations are provided in Table A2 (online appendix)

Sensitivity and scenario analysis

Incorporating less socioeconomic variation in our example changes the direction of the inequality impact of nearly all interventions (Figure 3). Compared with an average base case SII reduction of 0.0005, including only variation in utilisation and prevalence yields an

average SII reduction of 0.0009. When only prevalence variation is accounted for, all interventions yield yet larger SII reductions at an average of 0.0013.

Figure 3 Comparison of equity impact plane locations of smoking cessation interventions when accounting for socioeconomic variation in all available model parameters (base case), prevalence and utilisation only and prevalence only



Note: QALY = quality-adjusted life year; SII = slope index of inequality

When alternative set of odds ratios are applied to eleven behavioural interventions from Hiscock et al., the nine mapped to one-to-one interventions showed larger reductions in inequality, whilst the two closed group interventions had smaller reductions. These are summarised in Table A3 (online appendix). For the scenario in which local authority SSS utilisation statistics are used, all interventions shift from inequality reducing to increasing (see Figure A2, online appendix). The change in the SII across interventions ranged from 0.001 to 0.00008.

As the marginal productivity of the health sector increases, greater health gains can be generated from elsewhere in the healthcare system. The third scenario analysis shows that as cost-per-forgone QALY reduces, the reduction in health inequality from cost saving interventions increases (see Figure A3, online appendix). This is because marginal increases in expenditure on existing NHS services predominately benefit the most disadvantaged. The SII reduction from the varenicline, bupropion and SSRI sequence halves from 0.0024 to 0.0012 when the cost-per-forgone QALY increases from £2,000 to £30,000, respectively. The counselling intervention follows a similar trend at a greatly reduced magnitude.

The effects of the same two interventions are analysed with respect to Atkinson inequality aversion. As aversion to inequality increases generated by the interventions increases, the health-related social welfare benefits increase. For the counselling intervention, EDE QALYs increase from 10,636 at $\varepsilon=0$ (no aversion) to 11,396 at $\varepsilon=30$. The corresponding figures for the varenicline, bupropion and SSRI sequence are 103,077 and 118,397, respectively. These are summarised in Figure A4 in the online appendix.

Discussion

Main findings

Our case study demonstrates how published epidemiological and effectiveness evidence can be used to adapt standard decision analytic models to estimate health inequality impacts. Pragmatic searching and data analysis techniques identified socioeconomic variation in a wide range of model inputs from across the treatment pathway. We found that despite

smokers from higher socioeconomic groups having a higher probability of utilising services and quitting upon receiving them, all interventions were expected to reduce health inequalities. This was due to higher prevalence of smokers in lower socioeconomic groups. This distribution of direct health benefits is enhanced by the reduction in health inequality from cost savings, which release NHS resources that benefit the most disadvantaged more [34]. Our results support the NICE recommendations on the value for money of NRT, pharmacological and behavioural interventions [10].

Our results indicate when a full DCEA incorporating social variation in the direct health benefits is favourable compared to the aggregate approach, namely when the course of disease and treatment is likely to have countervailing inequality impacts (e.g. pro-rich quit success vs. pro-poor prevalence) and when there is a strong behavioural component determining the treatment effect (quit success in the case of smoking). Our full DCEA finds the magnitude of the inequality impacts were 1.6 times greater when only differences in prevalence and service utilisation are accounted for and 2.4 times larger when prevalence differences only are included.

The scenario results demonstrate the value of targeted provision of smoking cessation services that reduce socioeconomic variation in service uptake, which in our analysis higher in the least deprived areas compared with the most deprived (3.83% vs 2.39%) [43]. Evidence suggests that these differences have increased since SSS funding was transferred from the NHS to local authorities in England in 2013 as total utilisation as steadily as decreased [44], [45]. Improving the implementation of smoking cessation interventions therefore represents a potentially fruitful area of future research [46], [47].

Other studies have investigated the differential impact of smoking cessation policies between socioeconomic groups in settings outside the UK [48], [49]. However, these studies present results in a dashboard of effects across socioeconomic groups, and do not attempt to summarise impact on health inequality nor consider the distribution of health opportunity cost. The benefit of our approach is that it explicitly estimates the net impact on health inequality and can help decision makers navigate trade-offs between population health benefit and health inequality impacts, which health-related social welfare analysis can do quantitatively. The case study results show that the inequality reductions of the smoking cessation interventions account for up to 10% of the overall social value in terms of EDE QALYs at our base case levels of inequality aversion.

Limitations

Due to the resource constraint of this pilot study we use pragmatic reviews to identify relevant evidence. Socioeconomic variation in smoking behaviours and outcomes are well-researched, and evidence in other health and disease areas might be more limited [50], [51]. We made additional assumptions on top of those in the original economic evaluation for NICE. Where we do not find evidence describing how an input varies with IMD, we apply the average value to all groups, i.e. assuming no inequality. However, the relative risk reduction of all-cause mortality might be greater in heavier smokers, who may be more concentrated in lower socioeconomic groups [9]. The HRQL benefits of smoking cessation, whilst well established in the literature [52], do not control for all confounding factors that may be associated with socioeconomic status, such as stress level or BMI. Where these factors are more common amongst lower socioeconomic groups, this will lead to an overestimate of health inequality reductions (and vice versa). Assuming that the

socioeconomic variation in quit success at four weeks is maintained at 52 weeks may underestimate inequality if we expect more relapse in lower socioeconomic groups. We also assume that service interventions do not alter the relative odds of quit success between socioeconomic groups, as we could not find information on how the 'natural' background quit rate varied by IMD.

While we assess differences in effectiveness and uptake between socioeconomic groups, we lack sufficient evidence on how this varies by type of intervention. Likewise, data on uptake are only available for broad intervention type and are contaminated by systematic variation in the availability of services in each local authority.

Our analysis assumes the same marginal productivity for NHS and local authority public health resources. In this particular application is may be reasonable given the predominance of health sector costs in determining the overall cost impact. Conclusions about interventions providing value for money were not sensitive to alternative assumptions about the size and distribution of the health opportunity costs. However, for interventions that impose greater impacts on budgets outside the health sector (i.e. public health or social care), potential differences in the size and distribution of health opportunity costs should be reflected.

The inequality aversion parameter we used is estimated for inequalities in healthy life expectancy between "rich" and "poor" groups IMD groups. Identifying social values for health inequality reduction compared to increases in population health is a complicated process. However, the level of health inequality aversion did not alter the rank order of the smoking cessation interventions.

Conclusions

We show how that cost-effectiveness models can be extended to conduct a full DCEA within the resource constraints of a national guideline development. This adaptation can be influential in determining the direction and magnitude of the inequality compared with more simplified approaches that account for differences in utilisation or prevalence only. The analysis can also help to inform how DCEA could be incorporated into existing formal health technology assessment processes given analysts may have to be selective about which diseases they should focus on identifying evidence for.

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