Supplements

Contents

Yang SL, *et al. Tob Control* 2022;0:1–7. doi: 10.1136/tc-2022-057262

This document describes the data used in the simulation method, supplement method and supplement result. In the supplement method section, we show in detail the method to obtain cessation rates for status quo model and the equations involved in converting the effect size of MPOWER measures into cessation rates used in individual and combined intervention scenario models.

1. Summary of data used in this study

1.1. Preparation of mortality and population data

Table S1. Database and parameters used to prepare mortality and population data.

Data	Details	Reference
Mortality data	Sex- and age-specific all-cause mortality data (1980-2016) from Japanese Vital Statistics.	[1]
Population data	Sex- and age-specific population data (1958-2018) from Japanese Vital Statistics.	[2]
Smoking prevalence data	National Health and Nutrition Survey (NHNS) (1995-2018) recorded the prevalence of current, former and never smokers in ten-year age groups (e.g., 20-29, 30-39, …, 60-69, 70+ years old)	[3]
Total fertility rate	1.44	[4]
Infant sex ratio	Male:Female=1:1.04	[4]
All-cause mortality relative risk (RR)	RR for current male smokers: 1.6 RR for former male smokers: 1.24 RR for current female smokers: 1.48 RR for former female smokers: 1.24	[5]

2. Supplementary on method

2.1. Mortality rate projection

A Poisson regression model was used to estimate the time trend in the all-cause mortality rate for the total population (μ_t). The regression model was built using data from 1980 to 2016 and the estimates of this all-cause mortality rate were used in population projection up to 2050. The group-specific mortality rate projection was obtained by apportioning the 2018 total mortality rates using the mortality relative risk of current and former smokers, and then projected forward using the regression coefficients of year variable of total mortality model.

2.2. Group-specific mortality rate projection

Mortality relative risks were used to partition the 2018 age-specific total mortality rate (μ_t) into three groups, i.e., current (μ_c), former (μ_f) and never smokers (μ_n) mortality rates. The total number of deaths can be calculated as

$$\mu_t N_t = \mu_c N_c + \mu_f N_f + \mu_n N_n \quad (1)$$

Relative risk of mortality in each of the risk groups is known and defined as

$$r_c = \frac{\mu_c}{\mu_n} \quad \Rightarrow \quad \mu_c = r_c \mu_n \quad (2)$$
$$r_f = \frac{\mu_f}{\mu_n} \quad \Rightarrow \quad \mu_f = r_f \mu_n \quad (3)$$

Dividing equation (1) by total population (N_t) and inserting equations (2) and (3) we can obtain

$$\mu_n = \frac{\mu_t}{r_c P_c + r_f P_f + P_n}$$

Where
t designates total population
c designates current smoker
f designates former smoker
n designates never smoker
μ = mortality rate
N = population count
r = relative risk of all-cause mortality in relative to never smoker
p = prevalence

Once the mortality rate of never smokers (μ_n) was obtained, the mortality rate of current and former smokers was deduced from equations (2) and (3). The all-cause mortality relative risk for current and former smokers used in this study were 1.6 and 1.24 for men, and 1.48 and 1.24 for women.[5]
The age-specific mortality rate in each group was then projected forward using the regression coefficient of year variable from a Poisson regression model of total mortality. The age-specific formula for total mortality can be decomposed into contributions from each of the smoking groups as follows:

$$(\mu_t N_t)_i = \gamma(\mu_t N_t) = \gamma r_c \mu_n P_c N_t + \gamma r_f \mu_n P_f N_t + \gamma \mu_n P_n N_t \quad (4)$$

where

$(\mu_t N_t)_i$ = the mortality at time *i*

γ = the multiplicative time factor at time *i*, which can be derived from the regression coefficient (β) of year from a Poisson regression model of mortality trend, where $\gamma = \exp(\beta)$.

The age-specific time factor (γ) is applied to the 2018 age-specific mortality rate in each group over time to obtain future group-specific mortality rates in all three groups.

2.3. Population projection

Using the 2010 population as base, the population was projected up to 2050 using parameters such as all-cause total mortality rate estimates, total fertility rate, and infant sex ratio. The base population and all-cause total mortality rate estimates were organized in 5-year age groups (0-4, 5-9, …, 75-79, 80+) for more accurate estimates. We started by projecting the female population because that would provide the number of newborns each year. In a yearly cycle, first, the mortality cases were removed by multiplying the population by that year's mortality rate. Second, we multiplied fertility rates by the number of women at reproductive age (15-49 years old) to provide the number of newborns that would enter the 0-4 years old cohort in the following year. The number of newborns was apportioned by sex according to the infant sex ratio. Third, we shifted the age group by 1 year as the population matured into subsequent years and repeated the cycle. The projection of the male population was conducted similarly by adding the number of male newborns into the 0-4 years old male cohort. We assumed a constant total fertility rate (TFR) of 1.44 and male-to-female infant ratio of 1:1.04 throughout the model. TFR of 1.44 is the medium fertility variant in the population projection conducted by National Institute of Population and Social Security Research, throughout this model [4].

2.4. Cessation rates for status quo model

To obtain the cessation rate for the status quo model, the 2010 to 2018 current smoker prevalence data from the National Health and Nutrition Survey (NHNS) was used to run a linear regression model on the log of prevalence. The basic linear regression model equation is:

$$\ln{(p_i)} = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i1} x_{i2} + \epsilon_i$$

Define the prevalence for observation *I* (in year i) as p_i. Define year variable for the i-th year as x_{i1}, where x_{11} is 0 in 1995, and age group variable as x_{i2}. This ensures the intercept of all models is the value of prevalence in 1995. In practice, the age group variable x_{i2} is decomposed as a set of dummy variables (one for each age group with the reference category omitted). However, for simplicity, it is represented as a single variable in the above equation. The estimated coefficient of the year variable $(\beta_1 + \beta_3)$ is the estimated age-specific cessation rate.
The predicted prevalence using the estimated coefficients fits well with the original data (Figure S1). In male 60-69, female 60-69 and female 70+ age groups, the estimated coefficients were positive, indicating growth in the number of current smokers, but the values were small (0.005, 0.039 and 0.020) and so we set them to zero in our model, indicating no cessation or growth in number of smokers. The status quo cessation rate was applied throughout all years in the status quo model (2018-2050) and for two years in the intervention model (2018-2019).

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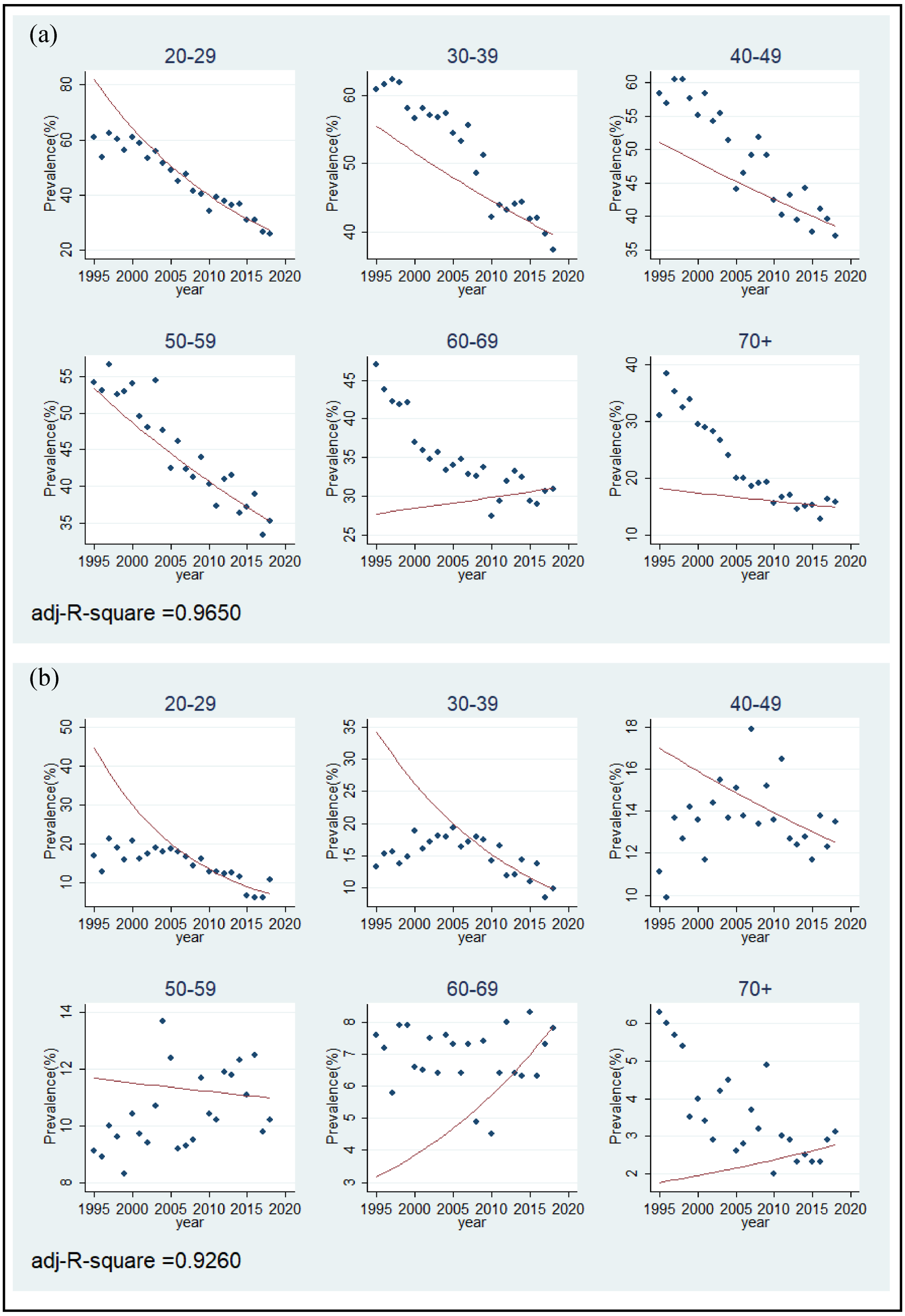

Figure S1. Fitted graph of observed current smoker prevalence from the National Health and Nutrition Survey data and predicted prevalence from regression model.

Red lines were fitted to the observed prevalence of current smokers from 2010 to 2018 for (a) men and (b) women.

2.5. Adaptation of effect size

We used the 40-years horizon effect size reported in Levy et al's table 1 [6] as the basis of our adaptation. The table provides the effect sizes with upper and lower bound values that are to be adjusted according to national policy implementation. We use the central or "best" value as the basis of our adjustment to reflect the current policy status of Japan. For example, Japan's 2018 grading for the P component of MPOWER is 1, minimal policy with weak enforcement. To improve from 1 (minimal policy) to 4 (comprehensive smoke-free regulations), we calculated the effect size to be 12.5%, using the "best" case scenario. For improvement between intermediate stages and comprehensive policy, we divided the full effect into steps to allow for movements between measures. For example, Japan's 2018 grading for W(MM) component of MPOWER is 2, weak policy. To improve from 2 (weak policy) to 4 (comprehensive policy) is a 75% improvement. The central value effect size reported by Levy et al for W(MM) component is 12% and therefore our adjusted effect size is 9%, that is 0.75*12%.

2.6. Cessation rates for intervention scenarios

The cessation effect of the intervention model was calculated based on the effect size in Table 1 of the main text, added on to the cessation rate for status quo, and then applied to the intervention model from 2020 onwards. The formula to derive cessation rate of each intervention is described below.

Consider the original text in Levy *et al.* 2018 [6] about effect size, "*we convert their estimates to relative terms, that is, the absolute change relative to the initial smoking prevalence*." From this, the effect size is defined as,

$$ES = \frac{p_0 - p_1}{p_0}$$

$$ES = \frac{p_0 - p_1}{p_0} = 1 - \frac{p_1}{p_0} = 1 - r \qquad (5)$$

Assume $p_1 < p_0$ because the prevalence is on a declining trend. Define the relative prevalence as $r = \frac{p_1}{p_0}$. Rewrite r as a multiplier,

$$p_1 = r p_0$$

Decompose this into a series of t time steps, so that

$$p_1 = (1 - \alpha)^t p_0$$

So,

$$\alpha = 1 - r^{1/t} \qquad (6)$$

Where α is the annual percentage change, also known as the cessation rate. In the case of the status quo model, the cessation rate has been estimated from a regression model (section 2.4). So now, with a declining status quo trend and an intervention, let us define the annual intervention effect as α_I and the annual status quo trend term as α. Then, a single year's change in smoking prevalence, from year j to year j+1, can be calculated as

$$p_{j+1} = (1 - \alpha_I)(1 - \alpha) p_j$$

An intervention applied to a starting prevalence over *t* years would be,

$$p_t = (1 - \alpha_I)^t (1 - \alpha)^t p_0$$

Rewrite the equation,

$$p_t = [(1 - \alpha_I)(1 - \alpha)]^t p_0$$

Expand the terms in the square brackets,

$$(1 - \alpha_I)(1 - \alpha) = 1 - \alpha_I - \alpha + \alpha_I \alpha \approx 1 - (\alpha_I + \alpha)$$

Provided that the annual percentage changes (α *and* α_I) are small, so $\alpha_I \alpha$ would be very small and negligible. Therefore, the cessation rate of the intervention model is the summation of cessation rate for the status quo (α) and the annual intervention effect (α_I). α_I can be deduced by inserting equation (5) into equation (6),

$$\alpha_I = 1 - r^{1/t}$$
$$\alpha_I = 1 - (1 - ES)^{1/t}$$

For example, given that the effect size of P is 12.5% (from Levy *et al.* 2018), the annual P intervention effect over a 40-year horizon is

$$\alpha_I = 1 - (1 - 0.125)^{1/40}$$
$$\alpha_I = 0.0033$$

Then, given that the cessation rate of male 20-29 age group from status quo model is 0.0483 (from the regression model outlined in section 2.4), the cessation rate of male 20-29 age group under full P intervention is $(\alpha_I + \alpha)$= 0.0033 + 0.0483 = 0.0516. (Table S2.)

2.7. Cessation rate for combined MPOWER intervention model

For the combined MPOWER model, the cessation rate is obtained by multiplying the separate terms together. So, the cessation rate for the combined MPOWER model is

$$(1 - \alpha) \prod_{I=1}^{6} (1 - \alpha_I)$$

Again, under the condition that all annual percentage terms are very small and $\alpha_I \alpha$ would be very small and negligible. The above equation can also be expressed approximately by

$$1 - \sum_{k=0}^{6} \alpha_k$$

where k=0 corresponds to the status quo cessation rate (α) and k=1,2, …, 6 corresponds to each full intervention.

Table S2. The cessation rates used in the status quo model, and individual and combined intervention model.

			P	**O**	**W(L)**	**W(MM)**	**E**	**R**	**Combined MPOWER**
			Effect size						
			12.50%	5.00%	8.33%	9.00%	6.00%	20-29: 15%, 30-39: 10%, >40: 5%	-
			Annual intervention effect (α_i)						
	Age group	**Status quo cessation rate (α)**	0.0033	0.0013	0.0022	0.0024	0.0015	20-29: 0.0041, 30-39: 0.0026, >40: 0.0013	-
			Cessation rate of full intervention model ($\alpha+\alpha_i$)						**($\alpha+\alpha_{i1}+\alpha_{i2}+\alpha_{i3}+\alpha_{i4}+\alpha_{i5}+\alpha_{i6}$)**
Male	20-29	0.0483	0.0516	0.0496	0.0505	0.0507	0.0498	0.0524	0.0630
	30-39	0.0147	0.0180	0.0160	0.0169	0.0171	0.0162	0.0173	0.0280
	40-49	0.0123	0.0156	0.0136	0.0145	0.0147	0.0138	0.0136	0.0243
	50-59	0.018	0.0213	0.0193	0.0202	0.0204	0.0195	0.0193	0.0300
	60-69	0	0.0033	0.0013	0.0022	0.0024	0.0015	0.0013	0.0120
	70+	0.0088	0.0121	0.0101	0.0110	0.0112	0.0103	0.0101	0.0208
Female	20-29	0.0797	0.0830	0.0810	0.0819	0.0821	0.0812	0.0838	0.0944
	30-39	0.0542	0.0575	0.0555	0.0564	0.0566	0.0557	0.0568	0.0675
	40-49	0.0133	0.0166	0.0146	0.0155	0.0157	0.0148	0.0146	0.0253
	50-59	0.0027	0.0060	0.0040	0.0049	0.0051	0.0042	0.0040	0.0147
	60-69	0	0.0033	0.0013	0.0022	0.0024	0.0015	0.0013	0.0120
	70+	0	0.0033	0.0013	0.0022	0.0024	0.0015	0.0013	0.0120

3. Supplementary results

3.1. Smoking prevalence under the status quo scenario

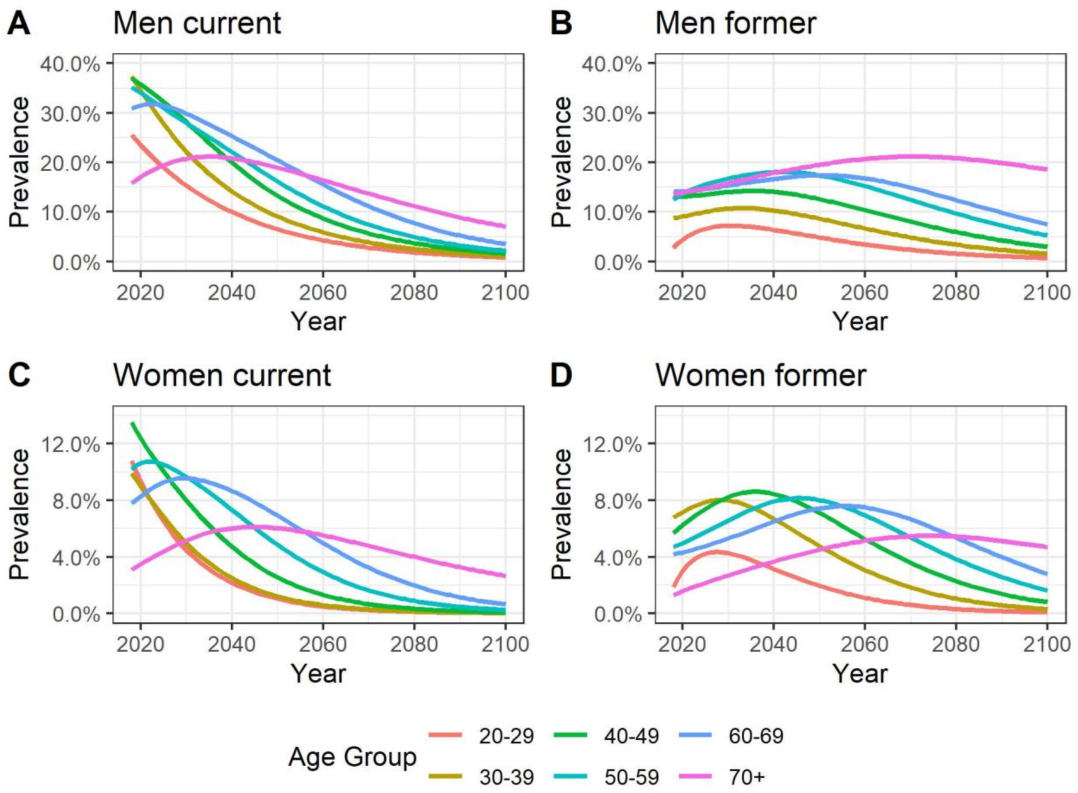

Figure S2. Sex- and age-specific prevalence of current and former smokers under the status quo scenario.

A. Current smoking in men, B. Former smoking in men, C. Current smoking in women, D. Former smoking in women.

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4. Sensitivity analysis

In the main method, the cessation rates for the status quo and intervention scenarios are applied as constant from 2018 through 2050. In sensitivity analysis 1 we assume that the intervention policies effects start to wane after 10 years, the cessation rates from 2018 to 2030 were applied as constant, and from 2030 onwards, the cessation rates were set to reduce by 3% annually.

$$\alpha_{n+1} = \alpha_n \times 0.97$$

Where n = 2030, 2031, 2032, …, 2049

In sensitivity analysis 2, we assume that the long-term effects are realized in 10 or 20 years instead of 40 years.

4.1. Results of sensitivity analysis: smoking prevalence and time to achieve target

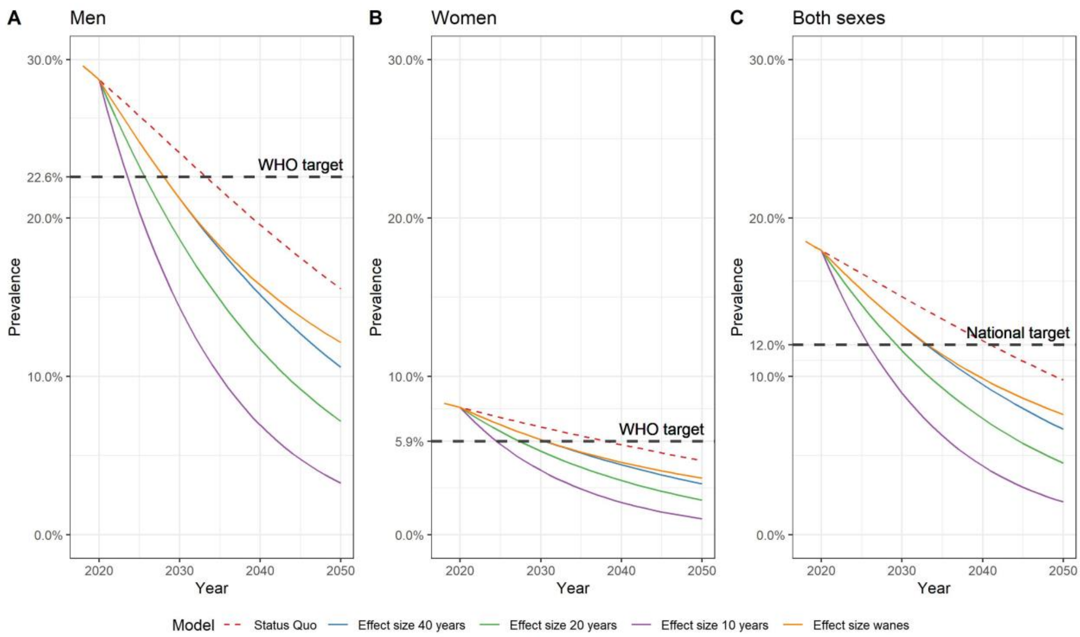

Figure S3. Projected prevalence of current smokers from 2018 to 2050 under the status quo, main model and the sensitivity scenarios.

A. Current smokers in men, B. Current smokers in women, C. Current smokers in men and women combined.

Table S3. Time to achieve the national and international targets.

Effect size over x years	Time to achieve WHO target		Time to achieve Japan's target
	Men	Women	Overall
Status quo	2034	2038	2041
40 years	2028	2031	2033
20 years	2026	2028	2030
10 years	2024	2025	2026

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4.2. Results of sensitivity analysis: number of averted deaths

Table S4. The number of sex-specific averted deaths from main model and sensitivity analysis scenarios.

	Scenarios	2018-2030			2018-2050		
		Men	Women	Total	Men	Women	Total
Main model (for comparison)	P	8,443	1,378	9,821	59,001	12,331	71,332
	O	3,268	533	3,801	23,143	4,840	27,982
	WL	5,523	902	6,424	38,886	8,130	47,016
	WMM	5,984	977	6,961	42,088	8,799	50,886
	E	3,938	643	4,581	27,842	5,822	33,664
	R	3,363	544	3,907	24,607	5,017	29,624
	MPOWER	29,597	4,826	34,423	196,455	40,844	237,299
Sensitivity analysis 1: (effect size wanes after 10 years)	P	8,443	1,378	9,821	55,148	11,289	66,437
	O	3,268	533	3,801	21,580	4,420	26,000
	W-L	5,523	902	6,424	36,298	7,433	43,731
	W-MM	5,984	977	6,961	39,295	8,046	47,341
	E	3,938	643	4,581	25,970	5,318	31,288
	R	3,363	544	3,907	23,064	4,599	27,664
	MPOWER	29,597	4,826	34,423	185,471	37,794	223,265
Sensitivity analysis 2: (effect size 10 years)	P	32,570	5,316	37,886	213,836	44,552	258,389
	O	12,888	2,104	14,992	89,037	18,598	107,635
	W-L	21,573	3,521	25,094	145,723	30,405	176,127
	W-MM	23,330	3,808	27,138	156,880	32,725	189,605
	E	15,487	2,528	18,015	106,277	22,191	128,468
	R	13,254	2,144	15,398	94,259	19,231	113,490
	MPOWER	105,692	17,220	122,912	575,988	118,597	694,585
Sensitivity analysis 2: (effect size 20 years)	P	16,682	2,723	19,405	114,120	23,826	137,945
	O	6,504	1,062	7,566	45,685	9,550	55,235
	W-L	10,958	1,789	12,746	76,081	15,895	91,977
	W-MM	11,866	1,937	13,803	82,195	17,171	99,365
	E	7,831	1,278	9,110	54,815	11,457	66,272
	R	6,693	1,083	7,775	48,503	9,891	58,394
	MPOWER	56,965	9,286	66,251	352,120	72,967	425,087

Abbreviations. P: Protect people from tobacco smoke, O: Offer help to quit tobacco use, W-L: Warn about the dangers of tobacco (Labelling), W-MM: Warn about the dangers of tobacco (Mass Media), E: Enforce bans on tobacco advertising, promotion and sponsorship, R: Raise taxes on tobacco, MPOWER: Simultaneous implementation of all MPOWER tobacco control measures at the highest recommended level.

5. Reference

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