What measures are needed to achieve a tobacco endgame target? A Singapore-based simulation study

Zitong Zeng, Alex R Cook, Yvette van der Eijk

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/tc-2022-057856).

Saw Swee Hock School of Public Health, National University of Singapore, Singapore

Correspondence to
Dr Yvette van der Eijk;
yvette.eijk@nus.edu.sg

Received 15 November 2022
Accepted 25 May 2023
Published Online First
6 June 2023

ABSTRACT

Background An increasing number of countries are pursuing a tobacco 'endgame'. We sought to determine the combination of measures it would take to achieve a tobacco endgame in the city-state of Singapore.

Methods Using an open-cohort microsimulation model, we estimated the impact of existing measures (quit programmes, tobacco taxes, flavours ban) and more novel measures (very low nicotine cap, tobacco-free generation, raising the minimum legal age to 25 years), and combinations thereof, on smoking prevalence in Singapore over a 50-year horizon. We used Markov Chain Monte Carlo to estimate transition probabilities between the states of never smoker, current smoker and former smoker, updating each individual's state across each year with prior distributions derived from national survey data.

Results Without new measures, smoking prevalence is expected to rebound from 12.2% (2020) to 14.8% (2070). The only scenarios to achieve a tobacco endgame target within a decade are those combining a very low nicotine cap with a flavours ban. A nicotine cap or tobacco-free generation alone also achieve endgame targets, but after 20 and 39 years, respectively. Taxes, quit programmes, a flavours ban and minimum legal age increase do augment the impact of other measures, but even when combined are insufficient to achieve a tobacco endgame target within 50 years.

Conclusion In Singapore, achieving a tobacco endgame within a decade requires a very low nicotine cap coupled with a tobacco flavours ban, although this target can also be achieved in the long term (within 50 years) with a tobacco-free generation.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Prior studies have estimated the impact of tobacco endgame measures, notably a tobacco-free generation and very low nicotine cap, in Western countries.

⇒ Fewer studies have compared the potential impact of tobacco endgame measures in combination with upscale of existing measures or against less restrictive proposed alternatives in pursuit of a smoking prevalence target of 5% or less.

WHAT THIS STUDY ADDS

⇒ This is the first study to consider a broad combination of existing tobacco policies alongside more novel tobacco endgame measures, including quit programmes, tax increases, increasing the minimum legal age to 25 years, a tobacco flavours ban, tobacco-free generation and very low nicotine cap, to achieve a 5% smoking prevalence target in the short term (by 2035) and long term (by 2070).

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study shows that achieving a tobacco endgame target will require more novel endgame measures, notably a nicotine cap and/or tobacco-free generation, even in a setting with a low smoking prevalence of 12%, and thereby provides a case for countries to adopt these measures in their tobacco endgame strategies.

INTRODUCTION

Policies consistent with the WHO Framework Convention on Tobacco Control (FCTC)—tobacco taxes, smoke-free legislation, quit services, packaging restrictions and tobacco advertising, promotions and sponsorship bans—have successfully reduced smoking prevalence globally.[1] Following this success, discussions have started focusing on a tobacco 'endgame' in which the paradigm shifts from reducing prevalence to eliminating smoking altogether.[2 3] This is generally defined as a smoking prevalence of 5% or less, a level at which smoking is effectively obsolete.[4] Several countries have set official targets to achieve a tobacco endgame by a certain year: Ireland, Sweden and New Zealand by 2025,[5–7] Finland and England by 2030,[8] Scotland by 2034[9] and Canada by 2035,[10] while the European Union has proposed a goal to be tobacco-free by 2040.[11] Some places, such as Australia, Hong Kong, Singapore and parts of the USA, have not officially committed to a tobacco endgame but are slated as places where it is likely to succeed, owing to their low smoking prevalence (<15%), strong leadership and comprehensive tobacco control policies.[12 13]

In some countries, there are initiatives to create a tobacco-free generation which would phase out tobacco sales to younger generations born after a certain year.[14–16] A tobacco-free generation was implemented in the cities of Brookline (the USA) and Balanga (the Philippines),[11 17] and will be introduced in New Zealand to cover generations born in or after 2008.[18] It is being considered in Denmark, Malaysia and the Netherlands,[11 19] and was tabled in the Parliament of Tasmania (Australia) in 2014.[20] Opponents of a tobacco-free generation at the time suggested to raise the minimum legal age of smoking (MLA) to 21 or 25 years, as a less restrictive alternative to a tobacco-free generation.[11]

While countries' proposed endgame strategies vary, they generally include a combination of FCTC

To cite: Zeng Z, Cook AR, van der Eijk Y. *Tob Control* 2024;**33**:745–751.

measures to effectively close any remaining gaps in their implementation.[13] Among more novel tobacco endgame measures, designed to eliminate smoking altogether,[21] a tobacco-free generation is arguably the most popular, although proposals to restrict the nicotine content in tobacco products to near-zero levels (nicotine cap), generally defined as 0.4 mg/g nicotine (a 95% reduction compared with the 10–15 mg/g found in most cigarettes) are also gaining traction.[22] A nicotine cap, although not yet in force anywhere, is the most well-researched tobacco endgame measure.[23] A number of randomised clinical trials show that switching current smokers to very low-nicotine cigarettes reduces their consumption and dependence and does not result in severe withdrawal,[24–28] even in those not interested in quitting[25] and with mental health disorders or low socioeconomic status.[26 27] As a nicotine cap would strip away the addictiveness of tobacco products, it would also result in fewer smoking initiations.[29] New Zealand has announced that a nicotine cap will form part of its tobacco endgame.[7]

As an increasing number of countries move towards a tobacco endgame, either by way of FCTC measures, more novel measures, or both, uncertainties remain as to what constitutes an optimal strategy sufficient to reach a smoking prevalence target of 5% or less within the designated timeframe.[21] Prior studies have estimated the impact of a tobacco-free generation[30 31] and nicotine cap[32 33] as stand-alone measures, while others have simulated policy combinations aligned with a country's proposed endgame strategy. New Zealand studies modelled policy combinations of a nicotine cap and/or tobacco-free generation with reductions on the number of tobacco retailers, public education campaigns[34 35] and 10% annual tax increases,[36] while studies from Queensland (Australia)[37] and Ontario (Canada)[38] simulated the impact of combined FCTC measures, such as public education campaigns, plain packaging and tobacco taxes. Fewer simulation studies have compared the potential impact of more novel endgame measures against measures proposed as less restrictive alternatives (eg, MLA25) and in combination with FCTC measures in pursuit of a smoking prevalence target of 5%,[36] and none have, to our knowledge, done so in a non-Western society.

Singapore, a city-state in Southeast Asia, has a low smoking prevalence (12.2% of the population were daily or non-daily smokers in 2020),[39] strong antitobacco climate and comprehensive tobacco control measures consistent with the FCTC including a strict ban on tobacco advertising, promotions and sponsorships; comprehensive smoke-free legislation; plain packaging; MLA21; tobacco taxes and quit services.[40] Arguably, the largest remaining gaps in Singapore's tobacco control strategy pertain to tobacco taxes, tobacco flavour regulations and quit services. While tobacco taxes were increased by 15% in February 2023, Singapore has not committed to further tax increases which, historically, were infrequent and modest (with 10% tax increases in 2014 and 2018).[41] Singapore still permits the sale of menthol and other flavoured cigarettes which comprise around half of Singapore's total cigarette market,[42] and does not subsidise medicinal quit smoking aids.[40] Singapore has also not committed to a tobacco endgame goal.

Hence, we used a microsimulation model to determine the combination of measures required to achieve a 5% smoking prevalence target in Singapore, a country that has long been considered a strong tobacco endgame contender.[14 40] In our simulations, we included policies designed to emulate a more or less 'gap-free' tobacco control policy consistent with the FCTC, alongside more novel endgame measures: a nicotine cap, tobacco-free generation and MLA25 as a less restrictive alternative to TFG. Although a blanket tobacco sales ban has been passed in some US jurisdictions,[23] this approach has, with the exception of Bhutan, not been considered politically feasible at a national level.[13] While retail reduction strategies are being introduced in the Netherlands and New Zealand,[23] simulating this approach using international data is likely to yield misleading results given Singapore's small geographical size. Thus, we did not include these approaches in our simulations.

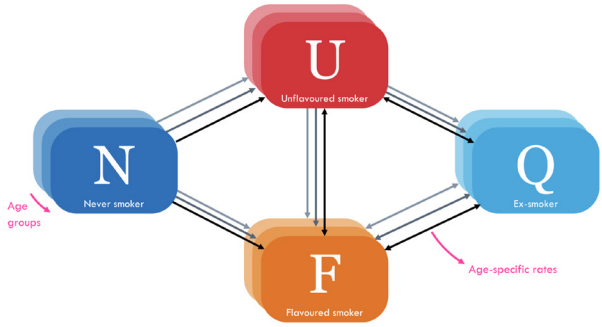

Figure 1 Transition model structure. Blocks represent the four states and arrows represent the direction of transitions from one state to another.

METHODS

Simulation and transition probabilities

We extended a previous simulation study of tobacco flavour bans in Singapore[43]; a brief summary of the model follows (for fuller details, see online supplemental file 1).

We modelled smoking rates in the Singapore population using a Markov model with four states: never smoker (N), current (regular) smoker (R), current (flavoured) smoker (F) and former smoker (Q). We defined 'smoker' as a user of cigarettes, and did not include use of non-cigarette tobacco products (eg, snus, shisha, cigars) or alternative nicotine products (eg, e-cigarettes, heated tobacco products) as use of these products is illegal or rare in Singapore. The model allows those who currently primarily smoke unflavoured cigarettes to switch to primarily smoking flavoured and vice versa.

Annual transition probabilities between the four states were age-specific, from age 11 to 80 years, allowing a total of eight between-state transition probabilities for each year of age (figure 1). We used Markov Chain Monte Carlo to estimate the posterior distribution of average transition probabilities from 2004 to 2018, based on national age-specific smoking prevalence data.[44–46] The model fits the data from these cross-sectional studies well (online supplemental figure S1-2), which is not surprising as the same data were used in parameterisation.

We estimated the proportion of flavoured tobacco users from a 2020 survey of flavoured cigarette use in Singapore[42] using a polynomial regression on age: the resulting model fits the empirical data well (online supplemental tables S1 and S2). The Markov model structure used is inherently memoryless, which reduces the realism of the model but makes it more computationally tractable and seemed a necessary choice given the paucity of longitudinal individual-level smoking data in Singapore.

We projected smoking rates over a 50-year horizon, starting in 2020, in an open-cohort microsimulation which allows the entry of new birth cohorts at each single time step. Data on population age structure were included from the Department of Statistics of Singapore.[47] We obtained data of new birth cohorts used in the microsimulation from R package wpp2017. The same mortality

Table 1 Description of tobacco measures and assumptions for each measure as included in our scenarios

Code	Scenario	Assumptions
SQ	Status quo	No additional policies or upscale of ongoing programmes.
CES	Upscale of national smoking cessation programme	Upscale will reach an additional 20 000 people per year at a quit rate of 10% (2000 additional cessations per year), spread equally across age groups of current smokers (R+F).
TAX10	10% tax increase applied every 4 years	For each tax increase, price elasticity of demand is −0.38 (age 15–20 years), −0.29 (age 21–24 years), −0.19 (age 25–34 years) and −0.10 (age 35+ years), with 50% of the effect due to a reduction in smoking prevalence and 50% of the effect due to current smokers reducing consumption.[48]
TAX15	15% tax increase applied every 2 years	
FLAV	Ban on added characterising tobacco flavours including menthol and clove	5% of flavoured tobacco users continue to use flavoured tobacco illegally; of the remaining 95%, 75% switch to regular tobacco and 25% quit. Of those who would have initiated with flavoured tobacco, 50% now initiate with regular tobacco, 5% initiate with flavoured tobacco obtained illegally and the remaining 45% no longer initiate.[43]
MLA25	Raise minimum legal of smoking by 1 year each year, until 25 years is reached	The minimal legal age of smoking is raised by 1 year annually until age 25 years, by converting initiation rates to mean of the current transition probabilities of illegal smoking among underaged youths or the current transition probabilities, whichever is smaller.[30]
TFG	Raise minumum legal of smoking by 1 year each year	Similar to MLA25, whereby the minimal legal age of smoking is raised by 1 year annually with no upper limit.
NIC	Restrict nicotine content in tobacco to near-zero level	14.7% of current smokers quit in the first and each subsequent year, and smoking initiation rates decrease by 50% in the first and each subsequent year.[32]

F, flavoured; R, regular.

rates were assumed for users of flavoured and unflavoured tobacco, and relative risks were allowed to differ by age between current smokers and former smokers on the one hand and never smokers on the other (online supplemental tables S1 and S2). For further details of the model and data incorporated within it, see online supplemental file 1.

Policy scenarios

We considered a variety of FCTC and novel endgame measures (table 1): upscale of smoking cessation programmes, a conservative tobacco tax (10% increase applied every 4 years; TAX10) and more aggressive tobacco tax (15% increase applied every 2 years; TAX15), a tobacco flavours ban, MLA25, tobacco-free generation, nicotine cap and combinations thereof.

Stand-alone policies were simulated to start in 2023, while combination scenarios were systematically layered to represent the real-world context by first applying more conservative measures (already implemented elsewhere), in 2023 (smoking cessation programmes, then tax increases, then a flavours ban) and more novel measures (not yet in force on a national level anywhere) in 2024 (MLA25 or a tobacco-free generation, then a nicotine cap). As we considered MLA25 and the 10% tax as more conservative alternatives to a tobacco-free generation and 15% tax respectively, we did not combine MLA25 with a tobacco-free generation, or 10% tax with a 15% tax, in combination scenarios. Upscale of the smoking cessation programme was considered part and parcel of a comprehensive tobacco control strategy and was therefore included in all combination scenarios. In combination scenarios, we calculated the effect as the product of rates of multiple single scenarios in corresponding years, to avoid overlapping the effect of single scenarios. For details of scenario-specific parameters and calculations, see online supplemental file 1.

In the status quo scenario we assumed that, in 2020–2070, there would be no additional tobacco control policies or upscale of ongoing programmes. We simulated this by applying annual transition probabilities based on 2004–2018 national smoking prevalence surveys using Markov Chain Monte Carlo. The status quo scenario took into consideration recent policies implemented in Singapore including the 2020 plain packaging mandate, 2021 MLA increase to 21 years and ongoing smoking prevention and quit programmes.

For the two tax scenarios, due to the absence of local data, we applied price elasticity of demand estimates from a New Zealand study,[48] which used combined price elasticity data from other high-income countries, to the year of each tax increase. Assumptions for the flavours ban were consistent with a prior study, in which we simulated the impact of a tobacco flavours ban in

Table 2 Smoking prevalence estimates in 2035 and 2070 for all stand-alone policy and combination scenarios

Scenario	Overall smoking prevalence	
	2035	2070
Status quo (SQ)	13.3%	14.8%
Stand-alone policy scenarios		
Upscale of cessation programme (CES)	13.2%	14.7%
10% tax every 4 years (TAX10)	12.9%	12.7%
15% tax every 2 years (TAX15)	12.2%	9.8%
Flavours ban (FLAV)	10.7%	10.0%
Minimum legal age 25 years (MLA25)	12.5%	12.0%
Tobacco-free generation (TFG)	10.8%	3.4%
Nicotine content restriction (NIC)	6.3%	1.6%
Combination scenarios		
CES+TAX10+FLAV	9.8%	7.8%
CES+TAX10+FLAV+MLA25	9.4%	6.5%
CES+TAX15+FLAV	9.3%	5.9%
CES+TAX15+FLAV+MLA25	8.9%	5.1%
CES+TAX10+TFG	10.0%	2.6%
CES+TAX15+TFG	9.6%	2.4%
CES+TAX10+FLAV+TFG	8.5%	2.3%
CES+TAX15+FLAV+TFG	8.1%	2.1%
CES+TAX10+TFG+NIC	6.3%	1.6%
CES+TAX15+TFG+NIC	6.1%	1.6%
CES+FLAV+NIC	4.5%	1.0%
CES+TAX10+FLAV+NIC	4.4%	1.0%
CES+TAX15+FLAV+NIC	4.2%	1.0%
CES+TAX10+FLAV+MLA25+NIC	4.3%	0.9%
CES+TAX15+FLAV+MLA25+NIC	4.1%	0.9%
CES+TAX10+FLAV+TFG+NIC	4.2%	0.9%
CES+TAX15+FLAV+TFG+NIC	4.1%	0.9%

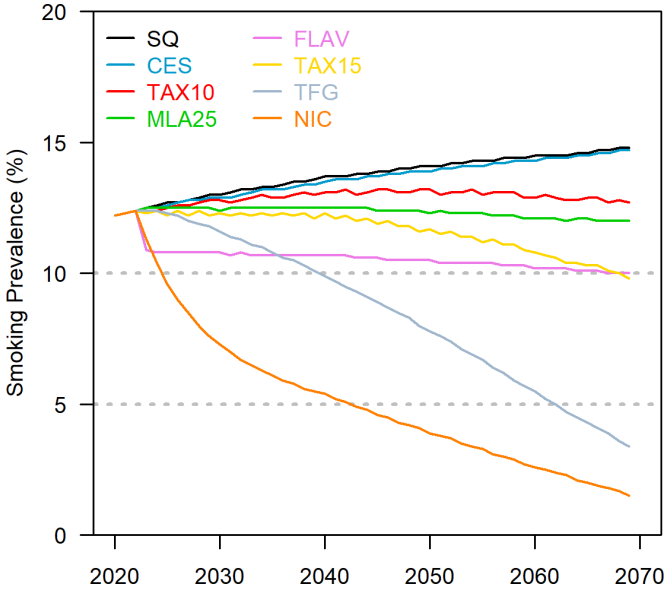

Figure 2 Overall smoking prevalence projected over a 50-year horizon for stand-alone policy scenarios: status quo (SQ), upscale of smoking cessation programme (CES), 10% tax increase every 4 years (TAX10), 15% tax increase every 2 years (TAX15), tobacco flavours ban (FLAV), minimum legal age of 25 years (MLA25), tobacco-free generation (TFG) and nicotine restriction (NIC).

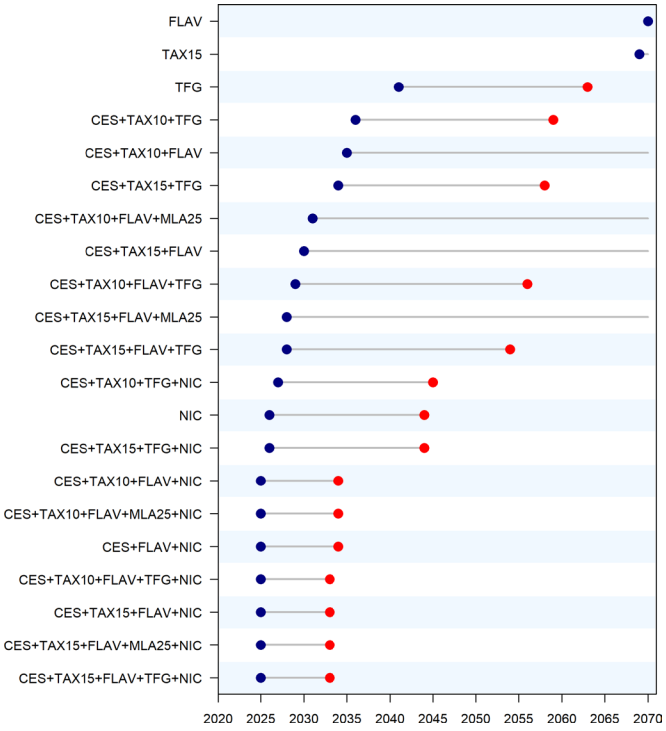

Figure 3 The years in which scenarios reach a 10% (blue) and 5% (red) smoking prevalence: status quo (SQ), upscale of smoking cessation programme (CES), 10% tax increase every 4 years (TAX10), 15% tax increase every 2 years (TAX15), tobacco flavours ban (FLAV), minimum legal age of 25 (MLA25), tobacco-free generation (TFG), nicotine restriction (NIC).

Singapore.[43] Our assumptions for MLA25 and a tobacco-free generation were consistent with a prior simulation of a tobacco-free generation in the Singapore context.[30] We converted initiation rates to mean of current transition probabilities of illegal smoking among underaged youths or the current transition probabilities, whichever was smaller.

Assumptions for the nicotine cap were based on a prior US simulation, which used an expert elicitation process to predict the effects of this policy.[32] We obtained the 25th quantile, median as well as 75th quantile estimations of the ratios from the study for male and female smokers, respectively. As our simulation does not have gender attribute, we calculated the weighted average of the rates based on gender ratios of smokers in Singapore.

We undertook sensitivity analyses on some of the key parameters of the model, assessing impact on smoking prevalence by 2035 and 2070. Online supplemental file 2 contains details of the sensitivity analyses conducted.

RESULTS

We estimated overall smoking prevalence in all stand-alone policy and combination scenarios in the short term (by 2035) and long term (by 2070—see table 2 and figure 2), as well as the year by which each scenario reaches a smoking prevalence of 10% and 5% (figure 3).

Stand-alone policy scenarios

With no new policies or upscale of ongoing programmes (status quo scenario), smoking prevalence gradually rises from 12.2% (2020) to 14.8% (2070). Upscale of the smoking cessation programme generates a trend that closely follows the status quo scenario. With a conservative tax increase of 10% every 4 years, smoking prevalence rises to 12.7% by 2070, while with more aggressive tax increases of 15% every 2 years it drops to 9.8%; a 22.8% reduction in prevalence compared with the conservative tax. MLA25, implemented alone, is sufficient to maintain smoking prevalence at 2020 levels but not to reduce them further, thereby following a very different trajectory to a tobacco-free generation (figure 2).

Policies with dramatic short-term impacts include the flavours ban and nicotine cap, which reduce smoking prevalence to 10.7% and 6.3% by 2035, respectively. The large immediate drop with the flavours ban is due to Singapore's large proportion of flavoured tobacco users (around 50%), of whom an estimated 25% will quit following the flavours ban. As fewer initiate, the flavours ban continues to gradually reduce prevalence into the long term, to 10.0% by 2070. The nicotine cap drives down smoking rates faster than a flavours ban, reaching a prevalence of 1.6% by 2070. As with the nicotine cap, a tobacco-free generation on its own is sufficient to achieve a 5% tobacco endgame target, although it achieves this in 2062; almost two decades after the nicotine cap which reaches a 5% prevalence in 2043.

Combination scenarios

All combination scenarios with a tobacco-free generation and/or nicotine cap reach the 5% tobacco endgame targets by 2070, although the only scenarios to achieve this target by 2035 are those that combine a nicotine cap and flavours ban (table 2 and figure 2). A flavours ban and nicotine cap combination reduces prevalence to 4.5% by 2035; a 1.8 percentage point decrease compared with a nicotine cap alone (6.3%). Layering further measures (aggressive taxes and tobacco-free generation) onto a flavours ban and nicotine cap combination does reduces prevalence further but only modestly, from 4.5% to 4.1% (by 2035). In the absence of a flavours ban and nicotine cap combination, the most effective combination policies are those with a nicotine cap, tobacco-free generation and aggressive taxes, although

this achieves similar prevalence levels as a nicotine cap alone. For instance, with a combination of a nicotine cap, tobacco-free generation and 15% tax, prevalence is 6.1% by 2035, similar to 6.3% with only the nicotine cap.

Without a nicotine cap, the most effective combination policies in the short term are those that include a flavours ban, while the most effective in the long term include a tobacco-free generation. Aggressive taxes have a modest long-term impact when combined with a tobacco-free generation (reaching a 2.4% prevalence in 2070, compared with 3.4% with a tobacco-free generation alone), but do augment the impact of a flavours ban (reaching a 5.9% prevalence in 2070, compared with 10.0% with a flavours ban alone). While combining an aggressive tax, flavours ban and tobacco-free generation results in a similar 2070 prevalence (2.1%) as a tobacco-free generation alone (3.4%), it does accelerate the downwards trajectory, with a lower 2035 prevalence in this combined scenario: 8.1% in the combined scenario, compared with 12.2% with aggressive taxes, 10.7% with a flavours ban and 10.8% with a tobacco-free generation.

Without any novel endgame measures, a combination of more stringent FCTC measures (aggressive tax and flavours ban) is insufficient to achieve an endgame target, reaching 5.9% in 2070. Adding on MLA25 as a modest alternative to a tobacco-free generation results in a 2070 prevalence of 5.1%; just shy of a tobacco endgame target. Thus, a tobacco-free generation, compared with MLA25, is far more effective in achieving a tobacco endgame target, reaching a 3.4% prevalence by 2070 even when implemented on its own.

Online supplemental file 2 contains results from the sensitivity analyses. The mean difference in overall smoking prevalence in 2035 across all the scenarios we looked at between the primary analysis and the lower and upper bounds of the sensitivity analysis was 1.2 percentage points, with relatively more uncertainty of the impact of policies containing nicotine content restrictions.

DISCUSSION

With no new measures, smoking rates are expected to gradually increase, primarily due to changes in population structure and a rebound in smoking rates as observed previously in Singapore when no new measures were introduced.[49] Thus to achieve a tobacco endgame target, measures must stem increases in smoking prevalence, and reduce them to a level of 5% or less.

Most countries with tobacco endgame goals strive to reach a smoking prevalence target of 5% or less by 2035 and, with the exception of New Zealand, plan to do so using a combination of FCTC measures.[5–10] Yet policies based on FCTC measures alone appear to be insufficient to achieve a tobacco endgame target within 50 years, reaching levels of around 9% by 2035. Of all the policy scenarios we simulated, the only ones to reach a 5% tobacco endgame target by 2035 were those combining a nicotine cap and flavours ban. This is owing to their immediate impact on current smokers: we conservatively assumed that a nicotine cap would drive quitting in 15% of smokers annually and a flavours ban in 25% of flavoured tobacco users who, in Singapore, comprise roughly half of all smokers.[42] Both measures would continue to drive down prevalence in the long term as fewer youth initiate.[43] Thus, a combination of the flavours ban and nicotine cap measures would be the most effective, and arguably the only combination successful in achieving a tobacco endgame target by 2035; especially in countries with large flavoured tobacco markets such as the USA, Malaysia, the Philippines, Hong Kong and Singapore.[43]

A tobacco-free generation, as with a nicotine cap, was sufficient to achieve a tobacco endgame on its own. A tobacco-free generation was also far more effective than MLA25, following a very different smoking prevalence trajectory; hence, consistent with prior discussions, it is not appropriate to compare MLA25 with a tobacco-free generation as an 'alternative'.[11] While a tobacco-free generation was highly effective in the long term, it does not affect current smokers and would therefore take 38 years to reach a smoking prevalence target of 5% or less. Unless the tobacco endgame target is set four decades into the future, a tobacco-free generation needs to be complemented with measures that drive smoking cessation. Of these, the nicotine cap was the most effective, although a combination of a tobacco-free generation with aggressive taxes (15% tax increase applied every 2 years) and a flavours ban would achieve an endgame target by 2053; almost a decade sooner than a tobacco-free generation alone. Thus, countries such as New Zealand, Denmark, Malaysia and the Netherlands, when considering a tobacco-free generation, should plan to complement this policy with effective short-term measures that also target current smokers.

Between conservative taxes (10% tax increase applied every 4 years), aggressive taxes (15% tax increase applied every 2 years) and MLA25, an aggressive tax policy was the most effective by far, again due to its combined impact on quitting and initiation rates. The aggressive tax policy, compared with the conservative tax policy, reaped substantial benefits in the long term, once again highlighting the importance of significant *and* frequent tobacco tax increases as opposed to tax increases that are infrequent or sporadic, or insufficient to reduce tobacco affordability over time.[50] Aggressive taxes were also effective in augmenting the impact of a flavours ban, but not nicotine cap; likely due to the more substantial effect of a nicotine cap on current smokers compared with a flavours ban. Thus, a strong tax policy should be considered an integral part of a tobacco endgame, especially if the endgame does not include a nicotine cap.

While upscale of the smoking cessation programme was found to have a limited impact on smoking prevalence, smoking cessation services are essential health services that, by right, should be available to smokers.[51] Furthermore, we may have underestimated the impact of this scenario when combined with measures that drive cessation, especially as we assumed the number of additional people quitting per year would remain fixed at 2000. A strategical upscale of smoking cessation programmes when policies such as aggressive taxes, a flavours ban or nicotine cap are implemented might enhance engagement and quit rates beyond what was simulated in our study.

Limitations

As in all simulation studies, our projected impacts were based on multiple assumptions. A limitation was the lack of reliable data for the estimation of transition probabilities, especially for more novel measures such as MLA25, a tobacco-free generation and nicotine cap that are, as at May 2023, not yet in effect at a national level anywhere. As the use of non-cigarette alternative products (eg, e-cigarettes, heated tobacco products, snus, cigars, cigarillos) is rare or illegal in Singapore, our model did not factor in the impact of switching to such products. Our results should be read within these limitations, especially when interpreting in the context of countries that permit the use of e-cigarettes and

heated tobacco products. As our model calculated combination scenarios as a product of individual policies, it does not account for the synergistic impact of some policy combinations, such as policies that drive smoking cessation coupled with upscale of smoking cessation programmes. As our model looks at overall smoking prevalence, it does not account for how the different measures may affect inequalities in smoking rates. A further limitation of the model is its memorylessness, a feature common to Markov models. This restricts its ability to characterise subgroups of the population—such as persuadable and recalcitrant users—with differences in response to policies. Future work should explore this area, to improve the overall effectiveness of policies to end tobacco use.

CONCLUSION

Even in Singapore, which has long been considered a strong tobacco endgame contender, more novel tobacco endgame measures are needed to achieve a smoking prevalence target of 5% or less. A tobacco-free generation and reducing nicotine content to near-zero levels are, on their own, sufficient to achieve this target but reaching it within a decade will require a nicotine content restriction coupled with a tobacco flavours ban.

Contributors ZZ: data analysis, writing. ARC: conceptualisation, data analysis. YvdE: conceptualisation, data analysis, writing. All authors reviewed and approved the final draft before submission. YvdE is responsible for the overall content as the guarantor, accepts full responsibility for the work and/or conduct of the study, had access to the data, and controlled the decision to publish.

Funding This work was supported by funding from the Singapore Health Promotion Board, and Singapore Ministry of Health through the Population Health Metrics and Analytics Programme.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. Data may be obtained from a third party and are not publicly available. No data are available. A mixture of data sources was used to build the microsimulation model. Some of these are publicly available (eg, national smoking prevalence statistics); others are not publicly available but may be available on request from a third party (eg, Ministry of Health); others are not available due to ethics reasons (eg, survey of flavoured cigarette use).

ORCID iD

Yvette van der Eijk http://orcid.org/0000-0002-8095-1214

REFERENCES

1 Flor LS, Reitsma MB, Gupta V, *et al*. The effects of tobacco control policies on global smoking prevalence. *Nat Med* 2021;27:239–43.
2 Smith EA. Questions for a tobacco-free future. *Tob Control* 2013;22 Suppl 1:i1–2.
3 Warner KE. An endgame for tobacco. *Tob Control* 2013;22 Suppl 1:i3–5.
4 Houghton F, Houghton S, O'Doherty D, *et al*. The tobacco endgame: the importance of targets and geography. *Can J Public Health* 2018;109:900–1.
5 Irish Department of Health. *Tobacco free Ireland*. Ireland, 2013.
6 Sohlberg T. In favour of tobacco control? Former Smokers' support for tobacco policies. *Nordisk Alkohol Nark* 2019;36:496–510.
7 New Zealand Ministry of Health. *Smokefree Aotearoa 2025 action plan*. New Zealand, 2021.
8 Tobacco-Free Finland 2030 Network. Tobacco-free Finland 2030. 2022. Available: https://savutonsuomi.fi/en/
9 Scottish Government. *Raising Scotland's tobacco-free generation*. Scotland, 2018.
10 Government of Canada. Canada's tobacco strategy. 2022. Available: https://www.canada.ca/en/health-canada/services/publications/healthy-living/canada-tobacco-strategy.html
11 Berrick J. Drawing on adolescent psychology to achieve tobacco-free generations. *Public Health Rev* 2022;43:1604321.
12 Thomson G, Edwards R, Wilson N, *et al*. What are the elements of the tobacco endgame. *Tob Control* 2012;21:293–5.
13 van der Eijk Y. Development of an integrated tobacco endgame strategy. *Tob Control* 2015;24:336–40.
14 Khoo D, Chiam Y, Ng P, *et al*. Phasing-out tobacco: proposal to deny access to tobacco for those born from 2000. *Tob Control* 2010;19:355–60.
15 Berrick AJ. The tobacco-free generation proposal. *Tob Control* 2013;22 Suppl 1:i22–6.
16 van der Eijk Y, Porter G. Human rights and ethical considerations for a tobacco-free generation. *Tob Control* 2015;24:238–42.
17 Amul GGH, Ong SE, Mohd Khalib A, *et al*. Time for tobacco-free generations in the Western Pacific? *Lancet Reg Health West Pac* 2022;24:100530.
18 Dyer O. New Zealand plans to outlaw tobacco sales to citizens born after 2008. *BMJ* 2021;375:n3057.
19 Heijndijk S. Towards a Smokefree generation in the Netherlands: from campaign to social movement to an ambition embraced by the government. *Tob Prev Cessation* 2018;4.
20 Barnsley K. Smokefree Tasmania. 2018. Available: https://www.smokefreetasmania.com/new-law/
21 McDaniel PA, Smith EA, Malone RE. The tobacco endgame: a qualitative review and synthesis. *Tob Control* 2016;25:594–604.
22 van der Eijk Y. Standardised cigarettes: the next step for tobacco policy? *Tob Control* 2024;33:258–62.
23 Puljević C, Morphett K, Hefler M, *et al*. Closing the gaps in tobacco endgame evidence: a scoping review. *Tob Control* 2022;31:365–75.
24 Walker N, Howe C, Bullen C, *et al*. The combined effect of very low nicotine content cigarettes, used as an adjunct to usual quitline care (nicotine replacement therapy and behavioural support), on smoking cessation: a randomized controlled trial. *Addiction* 2012;107:1857–67.
25 Donny EC, Denlinger RL, Tidey JW, *et al*. Randomized trial of reduced-nicotine standards for cigarettes. *N Engl J Med* 2015;373:1340–9.
26 Higgins ST, Tidey JW, Sigmon SC, *et al*. Changes in cigarette consumption with reduced nicotine content cigarettes among smokers with psychiatric conditions or socioeconomic disadvantage: 3 randomized clinical trials. *JAMA Netw Open* 2020;3:e2019311.
27 Krebs NM, Zhu J, Wasserman E, *et al*. Switching to progressively reduced nicotine content cigarettes in Smokers with low socioeconomic status: a double-blind randomized clinical trial. *Nicotine & Tobacco Research* 2021;23:992–1001.
28 Hatsukami DK, Luo X, Jensen JA, *et al*. Effect of immediate vs gradual reduction in nicotine content of cigarettes on biomarkers of smoke exposure: a randomized clinical trial. *JAMA* 2018;320:880–91.
29 Benowitz NL, Henningfield JE. Reducing the nicotine content to make cigarettes less addictive. *Tob Control* 2013;22 Suppl 1:i14–7.
30 Doan TTT, Tan KW, Dickens BSL, *et al*. Evaluating smoking control policies in the E-cigarette era: a modelling study. *Tob Control* 2020;29:522–30.
31 Kypridemos C, Reeve J, Buchan I, *et al*. PL02 Tobacco control in england: using microsimulation modelling to quantify the potential impact of a tobacco-free generation or a total ban. Society for Social Medicine, 61st Annual Scientific Meeting, University of Manchester, 5–8 September 2017; September 2017
32 Apelberg BJ, Feirman SP, Salazar E, *et al*. Potential public health effects of reducing nicotine levels in cigarettes in the United States. *N Engl J Med* 2018;378:1725–33.
33 Wilson N, Hoek J, Nghiem N, *et al*. Modelling the impacts of tobacco denicotinisation on achieving the Smokefree 2025 goal in Aotearoa New Zealand. *N Z Med J* 2022;135:65–76.
34 Ait Ouakrim D, Wilson T, Waa A, *et al*. Simulation modelling of tobacco endgame interventions and their impact on Māori: non-Māori health inequity in Aotearoa-New Zealand. *SSRN Journal* 2022. 10.2139/ssrn.4118872 Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4118872
35 Ouakrim DA, Wilson T, Waa A, *et al*. Tobacco endgame intervention impacts on health gains and māori:non-māori health inequity: a simulation study of the aotearoa-new zealand tobacco action plan. *Public and Global Health* [Preprint] 2022.
36 van der Deen FS, Wilson N, Cleghorn CL, *et al*. Impact of five tobacco endgame strategies on future smoking prevalence, population health and health system costs: two modelling studies to inform the tobacco endgame. *Tob Control* 2018;27:278–86.
37 Skinner A, Walker P, Atkinson J-A, *et al*. Policy options for endgame planning in tobacco control: a simulation modelling study. *Tob Control* 2021;30:77–83.

38 Chaiton M, Dubray J, Guindon GE, *et al*. Tobacco endgame simulation modelling: assessing the impact of policy changes on smoking prevalence in 2035. *Forecasting* 2021;3:267–75.
39 Ministry of Health Singapore. *National population health survey 2020*. Singapore, 2020.
40 Amul GGH, Pangestu Pang T. Progress in tobacco control in Singapore: lessons and challenges in the implementation of the framework convention on tobacco control. *Asia & the Pacific Policy Studies* 2018;5:102–21.
41 Southeast Asia Tobacco Control Alliance. SEATCA tobacco tax program: Singapore. 2021. Available: https://tobaccotax.seatca.org/country/singapore/
42 van der Eijk Y, Ng XY, Lee JK. Lee cross-sectional survey of flavored cigarette use among adult smokers in Singapore. *Tob Induc Dis* 2021;19:42.
43 Zeng Z, Cook AR, Chen JI-P, *et al*. Evaluating the public health impact of partial and full tobacco flavour bans: a simulation study. *Lancet Reg Health West Pac* 2022;21:100414.
44 Ministry of Health Singapore. *National health survey 2004*. Singapore, 2005.
45 Ministry of Health Singapore. *National health survey 2010*. Singapore, 2011.
46 Ministry of Health Singapore. *National population health survey 2018/2019*. Singapore, 2019.
47 Department of Statistics Singapore. Population and population structure - latest data. 2022. Available: http://www.singstat.gov.sg/find-data/search-by-theme/population/population-and-population-structure/latest-data
48 Cobiac LJ, Ikeda T, Nghiem N, *et al*. Modelling the implications of regular increases in tobacco taxation in the tobacco endgame. *Tob Control* 2015;24:e154–60.
49 van der Eijk Y, Lee JK, M Ling P. How Menthol is key to the tobacco industry's strategy of recruiting and retaining young smokers in Singapore. *J Adolesc Health* 2019;64:347–54.
50 Chaloupka FJ, Yurekli A, Fong GT. Tobacco taxes as a tobacco control strategy. *Tob Control* 2012;21:172–80.
51 Pipe AL, Evans W, Papadakis S. Smoking cessation: health system challenges and opportunities. *Tob Control* 2022;31:340–7.