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Public health impact of a US ban on menthol in cigarettes and cigars: a simulation study

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Received 19 February 2021
Accepted 26 July 2021
Published Online First 2 September 2021

Check for updates

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To cite: Levy DT, Meza R, Yuan Z, *et al*. *Tob Control* 2023;**32**:e37–e44.

ABSTRACT

Introduction The US Food and Drug Administration most recently announced its intention to ban menthol cigarettes and cigars nationwide in April 2021. Implementation of the ban will require evidence that it would improve public health. This paper simulates the potential public health impact of a ban on menthol in cigarettes and cigars through its impacts on smoking initiation, smoking cessation and switching to nicotine vaping products (NVPs).

Methods After calibrating an established US simulation model to reflect recent use trends in cigarette and NVP use, we extended the model to incorporate menthol and non-menthol cigarette use under a status quo scenario. Applying estimates from a recent expert elicitation on the behavioural impacts of a menthol ban, we developed a menthol ban scenario with the ban starting in 2021. We estimated the public health impact as the difference between smoking and vaping-attributable deaths and life-years lost in the status quo scenario and the menthol ban scenario from 2021 to 2060.

Results As a result of the ban, overall smoking was estimated to decline by 15% as early as 2026 due to menthol smokers quitting both NVP and combustible use or switching to NVPs. These transitions are projected to reduce cumulative smoking and vaping-attributable deaths from 2021 to 2060 by 5% (650 000 in total) and reduce life-years lost by 8.8% (11.3 million). Sensitivity analyses showed appreciable public health benefits across different parameter specifications.

Conclusions and relevance Our findings strongly support the implementation of a ban on menthol in cigarettes and cigars.

INTRODUCTION

While US cigarette smoking prevalence has declined substantially in the past decade, the prevalence of menthol smoking has remained constant.[1–5] Menthol cigarettes now represent 35% of cigarette sales[6] and are disproportionately used by youth, young adults, women and African-Americans.[3 7] Menthol cigarette use has been associated with increased smoking initiation and reduced smoking cessation.[8–11] In response, the European Union, Canada, Brazil, Ethiopia and Turkey have banned menthol in cigarettes.[12] In the USA, more than 20 localities and the state of Massachusetts have banned menthol cigarettes.[13] Recently, the Food and Drug Administration announced its intention to implement a nationwide ban on menthol in cigarettes and cigars.[14] A stronger evidence base is urgently needed about whether such a ban would improve public health.[15 16]

A small body of research has examined the potential impact of banning menthol in cigarettes. A simulation model[17] projected that a menthol ban would have major impacts on smoking prevalence and smoking-attributable deaths. However, that model simulated a ban starting in 2010 and did not consider the impact of switching to nicotine vaping products (NVPs, also known as e-cigarettes). Additionally, recent evidence finds that a menthol ban would likely increase smoking cessation, with more limited evidence of reducing smoking initiation and switching from smoking to other products.[18] To better gauge the potential impact of a menthol cigarette and cigar ban in the vaping era, we conducted an expert elicitation to explicitly consider the impact of the ban on smoking initiation and cessation and on NVP use.[19]

This paper applies the results of our expert elicitation to evaluate a US menthol ban on all combustibles, including cigarettes and cigars. We use the previously developed smoking and vaping model (SAVM)[20] to simulate the impact of the ban on cigarette and NVP use. We extend that model to distinguish menthol and non-menthol cigarette use and to estimate the public health impact of a menthol ban on combustible tobacco products.

METHODS

The SAVM is a compartmental model that simulates the public health impact of cigarette and NVP use over time for a specific set of birth cohorts in a given population.[20] The model is publicly available as a Microsoft Excel file with a user manual.[21] We extend SAVM to project menthol and non-menthol cigarette use in the absence of a ban (status quo scenario) and in the presence of a ban (menthol ban scenario). We estimate the public health impact as the difference in smoking and vaping-attributable deaths (SVADs) and life-years lost (LYLs) between scenarios. Further description of the model and model equations are found in online supplemental file 1.

Status quo scenario

The SAVM[20] first projects never, current and former smoking prevalence using age and sex-specific

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initiation and cessation rates for each cohort of males and females by individual age (0–85) beginning in 2013. The model parameters were estimated by applying an age-period-cohort statistical smoking model to National Health Interview Survey (NHIS) data through 2013,[22–25] thereby incorporating trends before NVP use became more prevalent in 2013.[26] Current smoking is defined as having smoked ≥100 cigarettes during one's lifetime and currently smoking at least some days. Current smokers become former smokers after having quit for 2 years to reflect cessation net of relapse. Future smoking prevalence is based on the estimated initiation and cessation rates.

Overlaying the smoking model, SAVM incorporates switching from smoking to regular NVP use, NVP initiation and cessation, and smoking initiation and cessation.[20] To simplify the analysis and because dual use is often unstable,[27–31] dual users of cigarettes and NVPs are included in SAVM as current smokers.[30] Those who vape de novo or who switch from smoking to vaping before age 35 are treated as exclusive vapers, reflecting the minimal smoking-related mortality risks of smokers who quit by age 35.[32 33] Those who switch from smoking to vaping after age 35 become former smokers who vape.

An earlier version of the SAVM generally validated well,[20] but underestimated the decline in smoking. Given the importance of smoking initiation to future smoking rates, we recalibrated model parameters using 2013–2018 NHIS data, as described in online supplemental file 1.

To incorporate menthol use, we differentiate menthol and non-menthol smokers in the model by age and gender. Using data from the 2013/2014 to 2016/2017 Population Assessment of Tobacco and Health (PATH) study, menthol smokers are defined as those whose regular brand is flavoured to taste like menthol.[34] Transitions in the status quo scenario are illustrated in figure 1.

Smoking initiation rates for menthol and non-menthol smokers are determined assuming a constant proportion of menthol smokers among all smokers at age 30 (MP_{30}), an age when most initiation and smoking patterns have become established.[35 36] Based on our analysis of PATH data (see online supplemental file 2), less than 3% of smokers switch between menthol and non-menthol cigarettes or initiate smoking after age 30. Using PATH data for ages 25–35, MP_{30} is estimated as the average proportion of menthol smokers and is applied to smoker initiation rates at each age a in year t as:

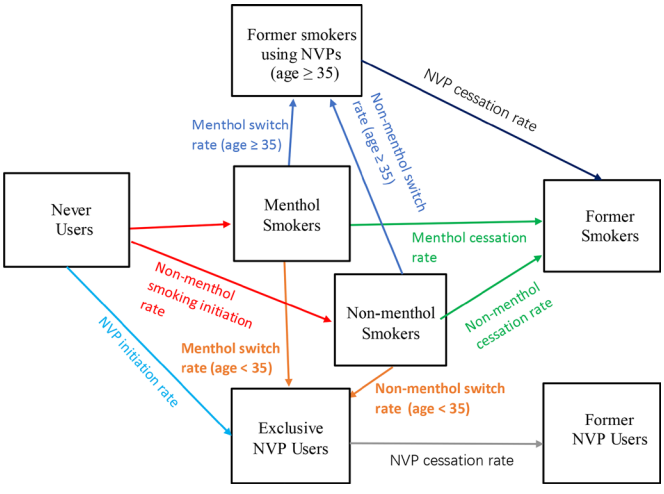

Figure 1 Transitions between smoking and nicotine vaping product (NVP) use states in the status quo scenario.

$$\text{Menthol initiation rate}_{a,t} = MP30 * \text{smoking initiation rate}_{a,t}$$

$$\text{Non}-\text{menthol initiation rate}_{a,t} = (1 - MP30) * \text{smoking initiation rate}_{a,t}$$

While this method does not explicitly model differences in the trajectories of menthol and non-menthol use prior to age 30, it implicitly allows for initiation as well as switching between menthol and non-menthol use through age 30.

Age and year-specific cessation rates of menthol and non-menthol smokers are based on transforming overall cessation using the menthol proportion at each age (MP_a) and the ratio of the menthol to non-menthol cessation rates (RMNCr), yielding:

$$\text{Non}-\text{menthol cessation rate}_{a,t} = \text{overall cessation rate}_{a,t} / (MP_a * RMNCr + 1MP_a)$$

$$\text{Menthol cessation rate}_{a,t} = \text{non}-\text{menthol cessation rate}_{a,t} * RMNCr.$$

Based on recent studies[11 37–41] and PATH data, we set RMNCr=0.8 for all ages and both genders.

To allow for different switching rates from menthol and non-menthol smoking to NVP use, we apply a similar method using the ratio of menthol to non-menthol switching (RMNSw). We assume that switching rate declines annually by 10% beginning in 2018 (to reflect that those most amenable to vaping have already switched).

$$\text{Non}-\text{menthol switching rate}_{a,t} = \text{overall switching rate}_a * (10.1)^{(t-2018)} / (MP_a\ RMNSw + (1 - MPa))$$

$$\text{Menthol switching rate}_{a,t} = \text{non}-\text{menthol switching rate}_{a,t} * RMNSw$$

Based on recent PATH data, we set RMNSw at 0.9 for all ages and both genders.

Given limited evidence of differential mortality,[42 43] we assume no difference in the mortality rates of menthol and non-menthol smokers.

Online supplemental file 1 shows projected trends. The proportion of menthol smokers among all smokers shows an upward trend, consistent with trends reported in recent studies.[1–6]

Menthol ban scenario

We model a federal menthol ban beginning in 2021. While the model focuses on cigarette use, the ban is assumed to apply to both cigarettes and cigars. We focused on the effect of a ban on both, since little cigars have been found to be a close substitute for cigarettes.[44–46] Were cigars (especially little cigars) exempted, many preban menthol cigarette smokers would likely switch to menthol cigars.

We rely on the aforementioned expert elicitation.[19] Finalised in September 2020, the elicitation was specifically developed to assess the impact of a menthol ban on smoking initiation and cessation and on NVP use.[19] The panel of experts was selected using a three-pronged approach: (1) selection of lead and senior authors of studies identified in a scoping review on the impact of menthol and flavour bans[18]; (2) a search in Scopus to identify individuals who are the most published authors on the topic of menthol tobacco and with an H-Index of ≥20; and (3) the advice of an external advisory panel. After selecting 12 of the 82 experts with the highest rated criteria 1 and 2 above and with

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no reported conflicts of interest, our final sample comprised 11 experts after one invitation was declined.

Experts were asked to estimate transitions regarding current tobacco and NVP use patterns under a menthol cigarette and cigar ban, including continued (illicit) menthol cigarette or cigar smoker[47]; switching to non-menthol cigarettes or cigars, smokeless tobacco or novel nicotine delivery products (NNDPs, including NVPs and heated tobacco products); or ceasing all nicotine product use. Because mortality risks for cigars are similar to or less than those for cigarettes,[48 49] estimated panel transitions into cigar use are modelled as non-menthol cigarette use. For convenience, the small percentage of estimated transitions to smokeless tobacco use (2% for ages 18–24 and <1% for ages 35–54) is also transferred to non-menthol cigarette use. Although the elicitation included heated tobacco products in NNDPs, we treat all such transitions as NVP use based on relatively similar risks.[50–52] The elicitation methodology and results are described further in online supplemental file 2.

The experts first estimated the impact of a menthol ban on smoking initiation for those aged 12–24 who, absent a ban, would have initiated menthol smoking by age 24. Based on experts' mean estimates, 38.3% of otherwise menthol smokers would instead become non-menthol smokers, 2.4% illicit menthol smokers, 17.3% NVP users and 42.0% would not use cigarettes or NVPs. These adjustments are applied to the initiation rates of otherwise menthol smokers in 2021 and as ongoing transitions in future years.

For those already menthol smokers, experts considered transitions over a 2-year period under the status quo and under a menthol ban. We model the experts' estimates of mean net transitions (the difference in 2-year transitions under the status quo and a menthol ban). Among current menthol smokers aged 18–24, 10.1% switch to illicit menthol combustibles, 48.0% switch to non-menthol combustibles, 24.2% switch to NVPs and 17.7% quit all product use. These transitions are applied to menthol smokers through age 30. Among current menthol smokers aged 35–54, 8.8% switch to illicit menthol cigarettes and cigars, 59.1% switch to non-menthol tobacco use, 17.3% switch to NVPs and 14.7% quit all product use. These transitions are applied to menthol smokers above age 30. Current non-menthol smokers were assumed to be unaffected by the ban.

Public health outcomes

Smoking-attributable deaths are estimated as the excess mortality risk at each age for current and former smokers multiplied by their respective populations. Vaping-attributable deaths are measured in the same way, except vaping excess mortality risk is initially set at 15% of excess smoking risk, higher than previously published estimates.[53 54] Total LYLs are estimated at each age by the number of SVADs multiplied by the expected years of life remaining of a never smoker.

We estimate the public health impact of a menthol ban as the differences in SVADs and LYLs in the status quo and menthol ban scenarios over a 40-year period, 2021–2060. To address uncertainties about the values of variables applied to both scenarios, we conduct sensitivity analyses of the public health impacts with excess mortality risks of NVPs at 5% and 25% that of excess smoking risks, with smoking and NVP initiation and cessation transitions and rates of switching from cigarettes to NVPs varied by −10% and +10% of their baseline levels and with the ratio of menthol to non-menthol cessation and menthol to non-menthol switching equal to 1.

RESULTS

Public health impact under the base case status quo and menthol ban scenarios

Table 1 presents the 2021–2060 menthol and non-menthol smoking and NVP prevalence, SVADs and LYLs from the model for US adults (aged >18), males and females combined (weighted by population). Results from 2026 and 2060 are presented to display illustrative short-term and long-term status. Online supplemental file 3 provides breakdowns by gender and with the time period extended from 2060 to 2080.

Under the status quo scenario, adult (age >18) menthol smoking prevalence declines from 5.4% in 2021 to 4.5% in 2026 and 2.4% in 2060, while non-menthol smoking prevalence declines from 7.1% in 2021 to 5.7% in 2026 and 2.7% in 2060. Cumulative SVADs from 2021 to 2060 of 14.2 million translate to 143.2 million LYLs.

Under the menthol ban scenario, adult menthol smoking prevalence declines to 0.3% in 2026 and 0.1% in 2060, while non-menthol smoking prevalence increases to 8.4% in 2026 but declines to 4.2% in 2060. Cumulative SVADs of 13.6 million translate to 131.9 million LYLs.

Figure 2A–C shows menthol, non-menthol and overall smoking prevalence from 2013 to 2060 under the status quo scenario and menthol ban scenario. By 2060, combined menthol and non-menthol smoking prevalence falls from 5.1% under the status quo to 4.3% with a menthol ban, a 15.1% relative reduction. Exclusive NVP prevalence increases by 25% under the menthol ban compared with status quo scenario (7.4% vs 5.8%). Cumulative SVADs by 2060 are reduced by 650 000 (4.6% relative reduction), and LYLs are reduced by 11.3 million (7.9% relative reduction).

Sensitivity to NVP relative risks and NVP transition parameters

Table 2 provides sensitivity analyses to variations in model parameters relative to the baseline levels (case 1). With NVP risk at 5% of excess smoking mortality risks and baseline levels of other parameters (case 2), both total averted SVADs and LYLs increase by 5%. With NVP risks at 25% (case 3), averted SVADs and LYLs both decline by 5%.

With a 10% change in the smoking initiation rate (case 4, case 5), averted LYLs vary by 2% in the opposite direction and vary by 6% in the same direction with a 10% change in the overall smoking cessation rate (case 6, case 7). Equating the menthol to non-menthol cessation rate (case 8) reduces the averted LYLs by 24%. With a 10% change in the overall switching rate to NVP use (case 9, case 10), averted LYLs vary by about 3% in the opposite direction. Assuming the same switching rate from menthol smokers as non-menthol smokers (case 11) reduces averted LYLs by 24%. Maintaining the switching rate at the 2018 level rather than assuming a 10% annual decline (case 12) reduces averted LYLs by 22%.

The results were relatively insensitive to NVP initiation (0.1% change) and cessation rates (0.6% change) (cases 13–16).

DISCUSSION

In the absence of a ban on menthol in cigarettes and cigars, the proportion of smokers who smoke menthol cigarettes is likely to continue to increase over time even as overall smoking prevalence declines. With a ban implemented in 2021, we estimated that combined menthol and non-menthol cigarette smoking would decline by 14.7% by 2026 and by 15.1% by 2060 relative to combined smoking in the absence of a ban. With these

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Table 1 Smoking and NVP prevalence, smoking and vaping-attributable deaths, life-years lost and public health impact for both genders combined, age 18 and above, 2021–2060

Status quo scenario					
Category	**Category/year**	**2021**	**2026**	**2060**	**Cumulative impact***
Prevalence	Menthol smoker	5.4%	4.5%	2.4%	–55.7%
	Non-menthol smoker	7.1%	5.7%	2.7%	–62.6%
	Total smokers†	12.6%	10.2%	5.1%	–59.6%
	Former smoker	19.4%	18.4%	9.2%	–52.7%
	Exclusive NVP user‡	3.5%	4.7%	5.8%	64.4%
	Former NVP user	0.2%	0.6%	4.6%	1972.5%
Smoking and vaping-attributable deaths§	Menthol smoker	77 455	74 136	39 418	2 402 279
	Non-menthol smoker	122 242	106 124	37 923	2 909 245
	Former smoker	175 798	189 490	192 368	8 500 851
	Exclusive NVP user‡	5031	7296	11 032	392 107
	Former NVP user	0	0	1717	12 811
	Total	380 525	377 046	282 457	14 217 294
Life-years lost	Menthol smoker	1 335 250	1 242 012	556 131	37 846 630
	Non-menthol smoker	1 949 502	1 655 744	581 810	45 122 020
	Former smoker	1 323 247	1 404 460	1 050 414	53 496 563
	Exclusive NVP user	86 635	122 874	181 241	6 494 346
	Former smoker-NVP user	85 815	117 704	50 734	4 246 249
	Former NVP user	0	2	32 110	278 716
	Total	4 694 635	4 425 092	2 401 706	143 238 275
Menthol ban scenario					
Category	**Category/year**	**2021**	**2026**	**2060**	**Cumulative impact***
Prevalence	Menthol smoker	5.4%	0.3%	0.1%	–98.5%
	Non-menthol smoker	7.1%	8.4%	4.2%	–40.9%
	Total smokers†	12.6%	8.7%	4.3%	–65.7%
	Former smoker	19.4%	19.1%	9.2%	–52.4%
	Exclusive NVP user‡	3.5%	5.7%	7.4%	108.0%
	Former NVP user	0.2%	0.6%	5.6%	2418.0%
Smoking and vaping-attributable deaths§	Menthol smoker	77 455	6792	2557	271 469
	Non-menthol smoker	122 242	151 299	55 379	4 157 520
	Former smoker	175 798	191 098	195 744	8 620 599
	Exclusive NVP user	5031	10 768	12 859	499 475
	Former smoker-NVP user	5011	10 640	6815	413 819
	Former NVP users	0	0	1895	14 010
	Total	380 525	359 958	268 435	13 563 073
Life-years lost	Menthol smoker	1 335 250	111 678	30 555	4 174 157
	Non-menthol smoker	1 949 502	2 403 756	841 520	64 926 659
	Former smoker	1 323 247	1 424 993	1 065 194	54 531 402
	Exclusive NVP user‡	86 635	122 874	181 241	6 494 346
	Former smoker-NVP user	85 815	168 033	56 050	5 418 265
	Former NVP user	0	2	35 817	306 840
	Total	4 694 635	4 113 651	2 182 890	131 927 198
Difference between menthol status quo and menthol ban scenario¶					
Relative reduction in prevalence	Menthol smoker	–	–92.5%	–96.5%	–
	Non-menthol smoker	–	47.4%	58.0%	–
	Total smokers†	–	–14.7%	–15.1%	–
	Total NVP users‡	–	22.6%	26.5%	–
Gain	Averted deaths	–	17 088	14 022	654 221
	Averted life-years lost	–	311 441	218 817	11 311 077

*The cumulative impact is measured in terms of the relative change from 2021 to 2060 for prevalence rates (ie, (2060–2021)/2021) and the sum of the smoking and vaping-attributable deaths or life-years lost over the years 2021 through 2060.
†Total smokers include menthol and non-menthol smokers.
‡Exclusive NVP users include de novo exclusive NVP users and former smokers now using NVPs.
§The number of smoking and vaping-attributable deaths and life-years lost is rounded to the nearest integer.
¶The difference between the Status quo and Menthol ban scenarios includes the comparisons for prevalence in relative terms and for health gains in absolute terms. Relative reduction in prevalence is measured as the relative difference between the status quo scenario and the menthol ban scenario (ie, (postban–preban)/preban) in years 2026 and 2060; the health gain is measured as the change in averted deaths and life-years lost from the Status quo scenario and the Menthol ban scenario.
NVP, nicotine vaping product.

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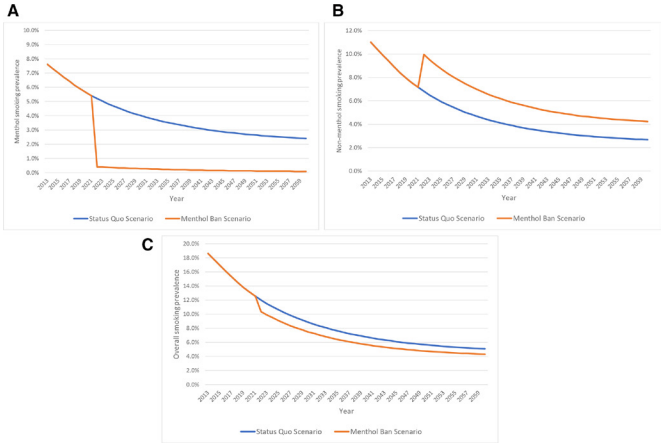

Figure 2 (A) Current menthol smoking prevalence (age 18 and above), menthol SAVM, status quo and menthol ban scenarios, 2013–2060. (B) Current non-menthol smoking prevalence (age 18 and above), menthol SAVM, status quo and menthol ban scenarios, 2013–2060. (C) Current overall smoking prevalence (age 18 and above), menthol SAVM, status quo and menthol ban scenarios, 2013–2060. SAVM, smoking and vaping model.

reductions, SVADs were estimated to fall by about 5% and LYLs by 8.8%, translating to 650 000 deaths averted (16 250 per year) and 11.3 million life-years gained (almost 300 000 per year) over a 40-year period. These impacts are large relative to other tobacco control policies,[55] and the public health gains are observed over a wide range of parameter values in the model. Further, while we focus on health gains over a 40-year period, much of the impact is on initiation and related health effects that occur after 40 years. When the analysis is extended to consider a 60-year period, life-years gained increase from 11.3 to 14.7 million (see online supplemental file 3).

Our analysis expands on previous research by incorporating NVP use. A relatively large percentage of menthol smokers, particularly young menthol smokers, switch to NVP use. While increased NVP use presents its own risks, sensitivity analyses indicated that assuming NVP excess mortality risks are 25% those of smokers still yields 620 000 deaths averted and 10.7 million life-years gained under a ban. Increasing the NVP initiation rate and reducing the NVP cessation rate also had minimal effects, despite our assumption that cessation from NVPs is no more likely than from cigarettes. Nevertheless, these risks and the potential for NVPs to be a gateway to smoking, while uncertain, could influence the public health impact of a menthol ban in combustibles. If these prove to be a significant problem, stronger policies may be needed to reduce NVP use among youth. However, while the public health implications were relatively insensitive to changes in the rate of NVP initiation and cessation, they were sensitive to rates of switching from cigarette to NVP use, suggesting that policies to reduce NVP use among youth could also reduce their use by adults, thereby reducing adult smoking cessation.

Our results are conservative in some respects. First, we considered impacts through 2060. Beyond 2060, deaths averted would increase both in absolute and relative terms as the effects on younger generations of reduced smoking are fully realised. We also limited the direct effects of a menthol ban on current menthol smokers to 2 years. Further increases might be expected over time (eg, via additional cessation from illicit menthol or from non-menthol smoking by previous menthol smokers). Our analysis does not consider the effects of a menthol ban on non-menthol smokers. Peer effects of reduced menthol smoking by family, friends, parents or coworkers may motivate more non-menthol smokers to quit.[18] While the expert elicitation expected relatively small impacts on non-menthol smokers,[19] a 5% reduction in non-menthol use (as suggested by one expert) spread equally between NVPs and no tobacco use would further avert 69 000 deaths (a 9% increase compared with our baseline findings) and 1.1 million LYLs (10% increase) by 2060. Finally, we do not explicitly include current cigar use in this application of the model. Public health benefits are also likely to accrue for

Table 2 Sensitivity analysis of averted smoking and vaping-attributable deaths and life-years lost to NVP relative risks and individual transition parameters, both genders combined, all ages, 2021–2060

Case	Description	Smoking and vaping-attributable deaths averted	% change*	Smoking and vaping-attributable life-years lost averted	% change*
1	Base case with NVP at 15% of cigarette excess mortality risk	654 221	–	11 311 077	–
2	NVP risk at 5% of cigarette-attributable excess mortality risk	687 209	5.0	11 924 114	5.4
3	NVP risk at 25% of cigarette-attributable excess mortality risk	622 425	−4.9	10 707 764	−5.3
4	Reduce overall smoking initiation rates by 10%	647 128	−1.1	11 083 049	−2.0
5	Increase overall smoking initiation rates by 10%	661 201	1.1	11 535 131	2.0
6	Reduce overall smoking cessation rates by 10%	702 353	7.4	11 979 548	5.9
7	Increase overall smoking cessation rates by 10%	609 459	−6.8	10 679 917	−5.6
8	Menthol cessation rate the same as non-menthol rate	461 006	−29.5	8 577 213	−24.2
9	Reduce overall switching rate by 10%	670 082	2.4	11 612 042	2.7
10	Increase overall switching rate by 10%	638 805	−2.4	11 019 404	−2.6
11	Menthol cessation rate the same as non-menthol rate	461 006	−29.5	8 577 213	−24.2
12	Reduce the annual decline in switching rate from 10% to 0%	520 179	−20.5	8 830 696	−21.9
13	Reduce NVP initiation rates by 10%	654 443	0.03	11 318 431	0.1
14	Increase NVP initiation rates by 10%	654 001	−0.03	11 303 795	−0.1
15	Reduce NVP cessation rates by 10%	650 266	−0.6	11 253 710	−0.5
16	Increase NVP cessation rates by 10%	657 768	0.5	11 363 818	0.5

*% change is in terms of the relative difference from the base case (eg, (687 209–654 221)/654 221 for case 2 relative to case 1).
NVP, nicotine vaping product.

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current cigar smokers, who may quit all use or switch to NVPs in reaction to a ban.

We did not perform analyses of subpopulations within the USA. Our expert elicitation[19] suggested larger impacts on African-Americans. Under a menthol ban, experts estimated 48% of African-Americans who would otherwise initiate menthol smoking would not initiate smoking or vaping compared with 39% for the overall population, and African-American menthol smokers aged 35–54 would be more likely to quit all tobacco use (27% vs 22%). With African-Americans having disproportionately high rates of menthol smoking,[3 7 56] a menthol ban would reduce downstream health disparities in smoking-related morbidity and mortality.[57 58]

Limitations

The results depend on parameters and assumptions underlying the model. While the model was calibrated to incorporate the increase in NVP use through 2018, youth NVP rates increased further in 2019[59 60] and then fell substantially in 2020,[59] indicating that NVP use is difficult to predict. Although some evidence suggests that NVP use may increase smoking initiation,[61 62] recent increases in youth vaping coincide with rapid declines in smoking by youth and young adults.[63 64] If these reductions in youth and young adult smoking are not maintained, the increased smoking rates among youth and young adults would lead to a larger impact from a menthol ban.

Another limitation is that SAVM does not distinguish dual use of NVPs and cigarettes from exclusive cigarette use. While some studies indicate stable levels of dual use,[65 66] other studies indicate dual use is an unstable use state, with high rates of transition to exclusive NVP use or cigarette smoking.[27–31] Moreover, some studies suggest similar health risks for dual users as for exclusive smokers,[67–69] although others have suggested higher levels.[70–72] Further study is warranted on health impacts and patterns of dual use. The model also does not distinguish the health impact experienced by exclusive menthol cigarette smokers who switch to cigar use as a result of a menthol ban. While a recent study found similar levels of biomarker-based risk exposure of exclusive cigar and exclusive cigarette users[48 73] and smoking patterns of little cigar users have been found to be similar to those of cigarette users,[74] further exploration is warranted on the health impacts of cigar use, especially different types of cigars, for example, little cigars, cigarillos or large cigars. Those switching to smokeless tobacco were also not distinguished. While our expert panel indicated minimal switching to smokeless tobacco, current marketing of oral products, such as ON!,[75] may increase the likelihood of switching to these products.

The results are also subject to uncertainties regarding the impact of a menthol ban. The menthol ban transitions were based on results of an expert elicitation.[19] While we adopted a well-defined selection process that screened for menthol-related research expertise, the results are dependent on the selected reviewers.[19] In addition, because expert elicitations rely on opinions, they are subject to heuristics and biases that are difficult to correct.[76–79] The opinions of individual experts differed considerably, especially regarding the extent of switching to exclusive NVP and no use. However, the use of median rather than mean estimates of net transitions (not shown) had little effect on the results. The elicitation results are also consistent with our recent review of menthol ban studies,[18] while the magnitude of our findings is broadly consistent with those of a previous menthol ban model[17] and a recent study of menthol bans.[80]

We modelled a ban on menthol applied to both cigarettes and cigars to restrict substitution from cigarettes to little cigars.[81–84] We did, however, ask the experts about the impact of a menthol ban on just cigarettes, which the experts indicated would have substantially less impact. We also asked experts about the impact of a menthol ban that is extended to all nicotine delivery products, including NVPs, and they indicated that menthol smokers were less likely to switch out of menthol cigarette use (ie, into NVPs or no regular use) in that scenario compared with a ban limited to cigarettes and cigars. This outcome is consistent with expectations that menthol smokers would be especially likely to switch to menthol NVPs.[85] The effects of a menthol ban will also depend on other tobacco control policies. In particular, higher cigarette taxes would reduce smoking initiation and increase cessation,[86–90] and increased enforcement of age 21 purchase laws would likely reduce smoking initiation.[91 92] While these policies would reinforce the effects of a ban, they may reduce its relative impact, as suggested by our sensitivity analyses regarding reduced smoking initiation and increased smoking cessation.

Finally, the results depend on the modelling approach. Further research might consider expanded categories of nicotine delivery product types (eg, inclusion of smokeless tobacco, distinguishing NVP device type) and multiproduct use, feedback loops via system dynamics models (eg, due to reactions by government or industry to policy changes) and heterogeneity of the population via microsimulation (eg, differential effects by race or socioeconomic status).[24 25]

CONCLUSION

Our findings strongly support the implementation of a ban on menthol in cigarettes and cigars on public health grounds. These gains reflect reduced smoking initiation and increased smoking cessation. Support for a menthol ban is strengthened by sensitivity analyses showing that large public health benefits accrue under a broad range of model parameters. Additional public health benefits may be expected through reductions in menthol cigar use.

What this paper adds

⇒ The US Food and Drug Administration (FDA) recently announced its intention to ban menthol in combustible products. Previous research has focused on the relationship between menthol cigarette use and initiation and cessation and on the impact of menthol use on overall smoking, but has not considered the potential impact on future cigarette and nicotine vaping product use if a ban of menthol in cigarettes and cigars were to be implemented. Additional evidence is needed by the FDA on its public health impact.

⇒ Our model estimates that such a menthol ban on cigarettes and cigars could prevent 650 000 premature tobacco-related deaths and reduce life-years lost by 11 million over a 40-year period. These gains accrue under a broad range of assumptions.

⇒ Our findings strongly support implementation of a ban on menthol in cigarettes and cigars on public health grounds.

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Acknowledgements We would like to thank Stephanie Land for her helpful comments.

Contributors DTL and RM supervised the project and were the principal writers of the original manuscript and the revised manuscript. ZY conducted the original data analysis and wrote the original methods and results sections. YL conducted the

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original data analysis and helped write the original methods and results sections. CC led the original expert elicitation and helped write the methods section and revisions. LMS-R and NT helped lead the original expert elicitation and helped write the methods section and revisions. MK conducted the data analysis on the expert elicitation and helped write the methods section and revisions. RMi, JLH, NFL, SS, AFB, ACL and CD helped write the original paper and revisions. JJ helped conduct the analysis, and write the original paper and revisions. KEW was a major contributor to the original paper and revisions.

Funding This project was funded through the National Cancer Institute (NCI) and the Food and Drug Administration (FDA) grant U54CA229974.

Disclaimer The opinions expressed in this article are the authors' own and do not reflect the views of the National Institutes of Health, the Department of Health and Human Services, or the US government.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The model and data will be provided upon request. The model and data will be provide upon request.

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Supplement 1. The Menthol SAVM Model

Calibration of the NVP Model

A previous version of SAVM had been shown to validate well overall,[25] but underestimated the decline in smoking rates at younger ages. Due to the importance of these age groups to future smoking rates, we recalibrated model parameters against 2013-2018 NHIS data. Because NHIS and SAVM begin in 2013 with different prevalence levels, we employ the relative change in smoking prevalence [(2018 prevalence -2013 prevalence)/2013 prevalence] to re-calibrate the models. We also compare model predictions to confidence intervals (CIs) from the 2018 NHIS.

Based on comparison of relative changes and confidence intervals, we adjusted the parameters of model until the model predictions were within 10% of the survey estimates for 2018. In our final calibration, we reduced the initiation rate of those below age 24 by 40% and the switching rate at ages 18-24 was doubled for those below ages 18 in order to calibrate smoking at younger ages. We also reduced the cessation rate by 20% except females ages 25-54 (reduced 10%) to better predict smoking at older ages. To account for the potential reduction in the percent of smokers who switch to NVP (e.g., as those most attracted to NVPs have already switched and technological advance slows), switching rates were reduced by 10% annually starting in 2018 at all ages.

The predictions from the re-calibrated SAVM are compared to the NHIS in Table 1. From 2013 to 2018, adult smoking prevalence for males falls from 21.4% to 16.6%, compared reductions of 20.3% to 15.8% (15.0%-16.6%) from NHIS, and for females from 15.9% in 2013 to 12.5% in 2018 compared with 15.4% to 12% from NHIS. While SAVM prevalence is above

NHIS for both males and females, the prevalence in relative terms declines by 22.4% for males compared to 22.2% from NHIS, and by 21.4% for females compared to 22.1% from NHIS. While discrepancies in relative reductions were greater for some age groups (i.e., males ages 18-24, females ages 45-64 and males and females above age 65), the 2018 predictions were within NHIS CIs except for males and females ages 25-44.

In the calibrated model, male smoking prevalence declines from 16.6% in 2018 to 7.5% in 2040 and 5.7% in 2060, while female prevalence declines from 12.5% in 2018 to 6.0% in 2040 and 4.5% in 2060. Much of the reduction results from the reduced initiation rates.

The age 18 and above NVP prevalence increases from 3.1% in 2018 to 7.1% in 2060 for males, and from 1.9% in 2018 to 4.6% in 2060 for females. The NVP rates increase from ages 18-24 to 25-44 and then decline with age.

Menthol Model

Background

According to a recent study, approximately 40% of US smokers prefer menthol over non-menthol cigarettes.[2] According to 2004-2010 data from the National Surveys on Drug Use and Health (NSDUH),[3] the proportion of menthol smokers is higher among youth (ages 12-17 years) and young adult (ages 18-25 years) smokers (56.7% and 45.0% respectively, vs. 30.5%-34.7% among older age groups); among women (39.6% vs. 31.4% among men); and among African Americans (88.5% vs. 25.7% among Caucasians). Similar results were reported by Villanti et al.[2] extending to later years and by Mattingly et al.[4] using the NHIS. In the latter study, proportion of menthol smokers in 2015 was 28% for males and 37% for females, and by age group: 18-24 (35-44%), 25-34 (40%), 35-54 (29%) and 55+ (27%).

For the percent menthol and non-menthol smokers among smokers in the base year (2013), we also examine data from the Population Assessment of Tobacco and Health (PATH) in wave 3 (2015/16) and 4 (2016/17) and the Tobacco Use Supplement to the Current Population Survey (TUS-CPS) in 2018/19. Both PATH and TUS-CPS measured current smokers by those who smoked ≥100 cigarettes in their lifetime and now smoke cigarettes every day or some days. Among those current smokers, menthol and non-menthol smokers were defined by those who regularly smoked each type. Those current smokers missing menthol use information were classified as unknown current smokers, accounting for 3%-7% by age group and gender, and are excluded in estimating the proportion of menthol and non-menthol smokers, as shown in Table S1.1.

In PATH wave 4, menthol smokers accounted for 38.9% of all smokers age 18+ (36.1% among males and 42.2% among females). Distinguishing by age, menthol smokers accounted for 65.1% among those age 15-17, 46.2% among those age 18-24, 48.7% among those age 25-34, 35.3% among those age 35-54, and 32.5% among those age 55+. The menthol smoking prevalence was higher among females than males and increased with age from 18-24 to 25-34 and then declined with age. The percentage change in proportion of menthol smokers between Wave 3 and Wave 4 is less than 1% (38.3% vs. 38.9%) overall as well as by gender and age. We also considered PATH Waves 1 and 2 (2013/14 and 2014/15) by age and did not find major differences.

In TUS-CPS 2018/19, menthol smokers accounted for 29.4% among male smokers age 18+ and 38.8% among female smokers age 18+. By age, menthol smokers accounted for 35.3% among males age 18-24 and 44.1% among females age 18-24, 36.1% among males age 25-34 and

52.8% among females age 25-34, 31.9% among males age 35-44 and 37.9% among females age 35-44, 25.4% among males age 45-64 and 34.9% among females age 45-64, and 23.6% among males age 65+ and 31.5% among females age 65+. We also considered the TUS-CPS 2014/15 and found similar patterns, but the TUS-CPS 2018/19 at each age were still below, but closer to the PATH wave 3 and wave 4 estimates. We also considered the 2012 and 2018 NSDUH. Different from the PATH and TUS-CPS (regular use), NSDUH measured menthol smokers by those current who smoked menthol cigarettes in the past 30 days. In 2018, menthol smokers accounted for 38.9% of all smokes age 18+ (35.1% for males and 43.5% for females). The 2018 NSDUH estimates were generally below, but closer to PATH waves 3 and 4 than the TUS-CPS.

We also considered studies of recent trends in menthol vs. non-menthol use. Although the prevalence of non-menthol cigarette use is decreasing, the prevalence of menthol cigarette use has either increased or remained unchanged.[2, 3, 5] Data from the NSDUH showed that the prevalence of menthol cigarette use stayed constant from 2004 to 2010 among adults aged 26+ years but increased among adults aged 18-25 from 14.0% to 16.3%.[3] Similar increases were observed in a later study.[2] Among past-30 day cigarette smokers, the proportion of menthol cigarette use increased between 2004 and 2014 for ages 12-17 (42% to 53%), ages 18-25 (32% to 51%) and age 26+ (29% to 37%).[2] Most of the increase was between 2004 and 2010, although a reduction from 55% to 53% was observed for ages 12-17 from 2010-2014.[2] Mattingly et al.[4] found that the prevalence of non-menthol cigarette use generally fell by gender and age in 2005-2010 and 2010-2015 using NHIS. However, menthol use increased between 2005 and 2010, but fell during 2010 to 2015. These latter reductions were most prominent among males and those ages 18-24 and 25-34. Our calculations using Matting et al. estimates indicated increases from 2005 to 2015 in the

proportion of smokers using menthol by males (21.5% to 28%), females (32% to 36.5%), ages 18-24 (30.5% to 35.5%), 25-34 (24% to 40%), 35-54 (27% to 29%) and 55+ (23% to 27%), with generally stable trends from 2010 to 2015 except among those 18-24 (from 44% to 35.5%).

In general, while non-menthol use has clearly fallen in the last 15 years, menthol use appears to have been relatively stable, and thus making up a larger percent of overall cigarette use. These tendencies are most pronounced among younger smokers, except possibly for those ages 18-24 from 2010-2015 in NHIS. Most apparent is the increase among those ages 25-34, ages when regular use is often established. The relative increase in menthol use is also confirmed by Delnevo et al.[6] They examined consumption data (reflecting quantity and prevalence) and found that since 2009 (at the time of the Tobacco Control Act), menthol cigarette sales increased from 25.9% in 2010 to 35.4% of the cigarette market in 2018.

We also examined recent trends in the proportion menthol use from the PATH, TUS-CPS and NSDUH surveys. Between 2013/4 and 2016/7, PATH had an increase from 35% for males and 40% for females to 36% for males and 42% for females. The TUS-CPS had larger increases from 2010/11 to 2014/5 compared to 2014/5 to 2018/9. The largest increases were for those age 25-34 (45% to 49%) and 35-54 (32% to 35%). According to NSDUH, the proportion of menthol use rose slightly from 33.5% male and 42% female in 2013 to 35% male and 43.5% female in 2018. Notably, the largest 2013-2018 increase was among those ages 25-34 (44% to 48%) and 35-49 (31% to 38%). Thus, trends show increases in the use of menthol relative to non-menthol smoking, with the largest increase among those ages 25-34. These results suggest that initiation rates have been increasing and cessation rates have been declining among menthol relative to non-menthol smokers.

A recent review by Villanti et al.[7] finds that smoking initiation often occurs with menthol use and that those initiating menthol smoking often progress to more established levels of either menthol or switching to non-menthol smoking. This latter result suggests the need to gauge initiation into regular use. They also note the increase in the proportion of menthol use over time by youth and young adults. These results are consistent with our review of levels and trends in menthol use in the relevant age groups.

A large literature also examines whether smoking cessation rates differ between menthol and non-menthol smokers. While most studies indicate some difference, the results are mixed regarding whether the differences are significant. Four earlier reviews have summarized findings across a heterogeneous literature and concluded that, despite mixed evidence, menthol cigarette use is probably associated with a lower likelihood of smoking cessation.[7-10] A recent meta-analysis[11] did not obtain a significant association between menthol use and cessation; however, menthol users were significantly less likely to quit among African American smokers (OR = 0.88). A recent study[12] using PATH (2013/4-2016/7) found that daily menthol smokers were less likely to quit compared to non-menthol smokers (OR=0.76 [0.63, 0.91]), but no differences was found for non-daily smokers nor in relapse rates. Schneller et al[13] found no significant differences after adjusting for sociodemographic characteristics in the longitudinal association menthol status and smoking cessation over two one-year intervals (PATH Waves 1 and 2). Cook et al. (2020, unpublished study) found menthol smokers generally had a lower likelihood of having quit smoking (OR =0.8). Two studies[14, 15] also found indications of higher levels of dependence among menthol compared to non-menthol smokers, as discussed also by Villanti et al.[7] We also considered PATH data Waves 1-4, and found that cessation rates were similar for

males and females, but that cessation rates among menthol smokers were about 80% that of non-menthol smokers for ages 25 and above, although were below those of menthol smokers for those ages 18-24 (11% vs. 8.6%). Table S1.2 shows cessation rates from PATH for waves 1-4, where cessation is measure as those who were established smokers (smoked 100 cigarettes lifetime) but now quit smoking. Both by gender and age except for those ages 18-24, cessation rates are less, generally at 80%, for menthol compared to non-menthol smokers. In general, studies show, but not uniformly that cessation rates are lower among menthol than non-menthol smokers. Lower cessation rates or increased initiation rates among menthol smokers may explain the relative increase in menthol use among smokers.

The recent increase in NVP use may differentially affect menthol and non-menthol smokers. Usidame et al. (2020, unpub. study) considered dual use of NVPs by menthol and non-menthol smokers using the four waves of PATH, NHIS 2015 and TUS-CPS 2014/15. They generally found similar although slightly higher dual use among menthol smokers compared to non-menthol smokers by gender and age. These results suggest that menthol smokers are more likely to use menthol NVPs, but incorporate the potential impact of that use on cessation from smoking (into NVPs or into use of neither product). Cook et al. (2020, unpublished study) found menthol smokers had a higher likelihood of having quit smoking when using e-cigarettes (OR=1.3 to 1.45). Thus, while information is currently limited, there is some indication that menthol smokers may be more attracted to NVPs and have greater success quitting with their use.

The Development of the Menthol Status Quo SAVM

As in our pre-Menthol model, we initialize the level of menthol use in the beginning model year (2013). Using the PATH data, we distinguish smokers of menthol (who regularly smoke a

brand that is flavored to taste like menthol) from non-menthol (those regularly smoking nonmenthol) smokers by age and gender. The menthol proportions by age and gender in 2013 are estimated as a product of the ratio of the PATH 2103/14 to 2016/17 menthol proportions by gender (males: 96.0%; females: 95.0%) and the PATH 2016/17 menthol proportions by age and gender (Table S1.3).

We applied a linear interpolation method to smooth the menthol proportions for ages 21-82 for single ages. The menthol proportions for ages under 21 were set equal to 34.7% for males and 40.1% for females, and for ages 83 and above to 26.8% for males and 34.3% for females in 2013. We maintain the same NVP initiation rates as in the previously calibrated model. We then apply rates of menthol/non-menthol initiation, cessation and switching to NVP use to project menthol and non-menthol smoking prevalence forward.

We begin with the initiation rates by age, period, and cohort using the Cancer Intervention and Surveillance Modeling Network (CISNET) data developed by Holford, which is based on NHIS data through 2013. We distinguish the overall smoking initiation rates (2013 level) into menthol and non-menthol smokers simply in terms of the menthol smoking proportion (MP) among all smokers. We focus on an age group when most initiation has already taken place. As described in our literature review and data analysis above, the proportion of menthol use increases through the age 25-34 age group. To keep the model tractable and because it is the rate of menthol use once smoking habits have been established that is relevant to health outcomes, we simply apply the menthol proportion at age 30, MP_{30} (40.2% males; 49.7% for females) to the overall smoking initiation parameter by age and gender, so that at age a in year t:

$$\text{Menthol initiation rate}_a = MP_{30} * \text{overall smoking initiation rate}_a$$

$$\text{Non-menthol initiation rate}_a = (1\text{-}MP_{30}) * \text{overall smoking initiation rate}_a$$

This method allows for smoking to increase by age and gender based on the initiation rates of smokers in our pre-menthol model, implying that the progression in initiation is the same for menthol and non-menthol smokers. While this method does not explicitly model differences in the trajectories of menthol and non-menthol prior to age 30, it implicitly allows for initiation as well as switching between menthol and non-menthol and abstracts from the need to model transitions from experimental to regular, more long-term use.

While our method does not incorporate initiation by menthol status after age 30, most initiation takes place by age 30. According to 2013 version of CISNET initiation rates, at most 0.3% of males and 0.2% of females never smokers initiate after age 30. Our method for incorporating menthol initiation does not explicitly consider switching between regular menthol and non-menthol use after age 30, but most switching occurs by age 30. Using the four waves of PATH (2013/14- 2016/17), we found that 5% or less of menthol smokers switch to non-menthol smokers or vice versa between the ages of 35 and 54 within 2 years, with a net switching rate of less than 3%. By age 30, most initiation is also expected to reflect more established than experimental use.

A limitation of incorporating a constant proportion of menthol smokers is that it does not incorporate variations over time as reflected in trends. Because our literature review and data analyses indicated an upward trend in the proportion of menthol use of those ages 25-34, we apply the last available year of the PATH (2016/17), which shows the highest proportion of age 25-34 menthol use for both males and females. That rate is also the highest of the surveys considered. The menthol proportion used to estimate the menthol and non-menthol initiation is 45.2% for

males and 53.7% for females, which is a constant proportion for all ages over years. We note that initiation into NVP use is maintained as NVP initiation (before ban) = overall smoking initiation * 0.5 for all ages and both genders.

We adopt a method allows for variation in the cessation rates, and allows for the same cessation rates as a special case. Let CR = menthol cessation rate/non-menthol cessation rate assumed constant across gender, age and time, cess rate = cessation rate, and $MP_{a,t}$ = the menthol proportion. We apply the following equation:

Overall cessation $rate_a$ =(MP_a*CR* non-menthol cess $rate_a$)+((1-MP_a) *non-menthol cess $rate_a$)

= (MP_a * CR_a + 1-MP_a) * non-menthol cess $rate_{a,}$

It follows that:

Non-menthol cessation $rate_a$ = overall cessation $rate_a$ / (MP_a * CR_a +1- MP_a)

Menthol cessation $rate_a$ = non-menthol cessation $rate_a$ * CR_a

The overall cessation rates used in the menthol model are the overall smoking cessation rates in the SAVM NVP Scenario, which were estimated by smoking cessation multipliers (as we described in our calibrated model) and 2013 version of CISNET cessation rates (in the absence of NVP use). The menthol and non-menthol cessation rates vary with the cessation rates in the Pre-menthol model, and are distinguished by age and gender. These rates begin as early as age 15. With the cessation rate of menthol smokers lower than for non-menthol smokers, the rate of decline will be lower among menthol than non-menthol smokers and the proportion of menthol smokers will increase with age.

The SAVM applies gender- and age-specific rates of current and former smoker death rates. Based on the available evidence and to simplify the model, SAVM does not distinguish

deaths rates for menthol and non-menthol current smokers. Former smokers are not distinguished between those who were former menthol and non-menthol smokers, and thus former smoker death rates are not distinguished.

The model maintains the same NVP cessation, i.e., NVP cessation (pre-ban) = overall smoking cessation. Additional cessation from smoking can implicitly occur through the switching rate from menthol or non-menthol cigarette use to NVPs as discussed in the next section.

To allow for different menthol and non-menthol switching rates from smoking to NVP use, the ratio of menthol and non-menthol switching rates (SR) is applied, rather than the separate menthol and non-menthol switching rates. Allowing the switching rate to decline at a annual rate δ, the formulas for switching rates at age a and year t are:

Non-menthol switching $rate_{a,t}$ = overall switching $rate_a$ * (1-δ)^(t- t_o) / ($MP_{a,t}$* SR_a + (1- $MP_{a,t}$)), where t_o is designated as 2018;

Menthol switching $rate_{a,t}$ = non-menthol switching $rate_{a,t}$* SR

Smokers, whether using menthol or non-menthol, who switch to NVP use are assumed to permanently switch, i.e., they do not switch back. However, they may quit NVPs by NVP cessation rates, assumed to be at the same rate as for the overall smoking cessation rates in the 2013 version of CISNET data.

Based on the analysis by Cook et al., we consider differential switching rates of 0.9 to 1 for menthol to non-menthol smokers. When SR is 100%, and the menthol and non-menthol switching annual decline rates are same, then above two methods for menthol and non-menthol switching have the same estimates (i.e. menthol switching rates = non-menthol switching rates =

overall switching rates). We conduct a sensitivity analysis for different levels of switching and rate of decline parameters. The revised model is shown in Figure S1.1.

Validation of the Menthol Model

We first validated the Menthol Status Quo Model (MSQM) against the Pre-menthol model (PMM) in steps, by comparing whether the menthol and non-menthol smoking prevalence in model by age and gender is consistent with the previous pre-menthol model, i.e., sum of menthol and non-menthol smoking prevalence in MSQM= smoking prevalence in the PMM. The overall smoking prevalence (the sum of menthol and non-menthol prevalence) by age and gender in the Menthol Status Quo Model (MSQM) and the Pre-menthol model (PMM) were same during 2013-2060. The overall vaping prevalence (the sum of exclusive NVP use and former smokers who use NVPs) in two models were also the same.

With CR=0.8 and SR=0.9, the male (female) menthol prevalence for ages 18 and above falls to 6.6% (5.7%) in 2018 (relative reduction of 20.0% (18.4%) from 2013), while the non-menthol prevalence falls to 10.1% (6.8%) in 2018 (relative reduction of 23.7% (23.4%) from 2013). For ages 18-24, the male (female) menthol prevalence falls to 3.5% (3.2%) in 2018 (relative reduction of 50.1% (48.4%)), while the non-menthol prevalence falls to 5.8% (3.9%) in 2018 (relative reduction of 55.2% (55.4%)). For ages 25-44, the menthol prevalence falls to 8.9% (8.3%) in 2018 (relative reduction of 20.5% (18.0%)), while the non-menthol prevalence falls to 13.2% (8.9%) in 2018 (relative reduction of 18.4% (15.5%)). For ages 45-64, the menthol prevalence falls to 6.9% (6.1%) in 2018 (relative reduction of 11.6% (8.5%)), while the non-menthol prevalence falls to 9.9% (7.5%) in 2018 (relative reduction of 20.7% (21.3%)). For ages 65 and above, the menthol prevalence falls to 3.8% (2.6%) in 2018 (relative reduction of 0.9%

(10.1%)), while the non-menthol prevalence falls to 7.3% (4.3%) in 2018 (relative reduction of 12.9% (18.3%)).

We also considered future trends. Between 2018-2060, the proportion of male (female) menthol smokers increases from 39.7% (45.6%) to 43.1% (52.6%) for ages 18 and above, from 37.9% (44.8%) to 40.7% (50.1%) for ages 18-24, from 40.3% (48.3%) to 41.8% (51.3%) for ages 25-44, from 41.0% (44.8%) to 44.3% (53.9%) for ages 45-64, and from 34.5% (38.3%) to 46.4% (55.3%) for ages 65 and above.

We also check for different levels of the ratio of menthol and non-menthol cessation or switching rates. In all cases, sensitivity analysis show that these changes did not affect the model predictions of overall smoking or vaping prevalence. There were differences in the degree to which menthol prevalence increased over time relative to non-menthol prevalence, but, in all cases, there was an increase over time in the proportion of smokers that smoke menthol cigarettes. These results are consistent with recent studies and the data presented above.

Table S1.1. Proportion of Menthol and Non-Menthol Smokers among Smokers in PATH Wave 3 & 4 and TUS 2018-19

		PATH				TUS		Approximate proportion across surveys	
		Wave 3 (N=28,123)		Wave 4 (N=33,611)		2018-2019 (N=136,638)			
		% menthol	% non-menthol	% menthol	% non-menthol	% menthol	% non-menthol	% menthol	% non-menthol
Male	**18-24**	41.0%	59.0%	41.9%	58.1%	35.3%	64.7%	40%	60%
	25-34	44.8%	55.2%	45.2%	54.8%	36.1%	63.9%	45%	55%
	35-44	36.5%	63.5%	39.8%	60.3%	31.9%	68.1%	35%	65%
	45-64	29.5%	70.5%	28.0%	72.0%	25.4%	74.6%	28%	72%
	65+	24.1%	75.9%	25.1%	74.9%	23.7%	76.3%	24%	76%
Female	**18-24**	53.3%	46.7%	52.4%	47.6%	44.1%	55.9%	54%	46%
	25-34	52.8%	47.2%	53.7%	46.3%	52.8%	47.2%	52%	48%
	35-44	39.5%	60.5%	41.0%	59.0%	37.9%	62.1%	40%	60%
	45-64	35.0%	65.0%	36.1%	63.9%	34.9%	65.1%	35%	65%
	65+	33.3%	66.7%	34.2%	65.8%	31.5%	68.5%	33%	67%

Note: Current smokers missing information on their menthol cigarette use are ignored from all current smokers, and the rest are either menthol or non-menthol smokers.

Table S1.2. Smoking Cessation Rates of Menthol and Non-Menthol Smokers, PATH Wave 1-4

	Non-Menthol Smoker Cessation				Menthol Smoker Cessation				Ratio of menthol to non-menthol
	N	%	Lower bound	Upper Bound	N	%	Lower bound	Upper Bound	
Age group									
18-24	50	8.6%	6.1%	11.8%	66	11.0%	8.6%	13.8%	1.28
25-34	68	9.4%	7.0%	12.6%	52	7.4%	6.5%	9.7%	0.79
35-54	93	6.0%	4.8%	7.5%	43	4.5%	3.2%	6.2%	0.74
55+	54	7.2%	5.0%	10.2%	20	5.2%	3.3%	8.1%	0.73
Gender									
Female	128	7.4%	6.2%	8.7%	96	6.5%	5.2%	8.1%	0.88
Male	137	7.2%	5.9%	8.8%	85	6.6%	5.4%	8.1%	0.91

Notes:

(1) All estimates based on current established smokers who report past-30-day use, wave 1 N= 11,209;

(2) menthol prevalence at wave t-1 was included (e.g. wave 3 menthol for wave 4 cessation)

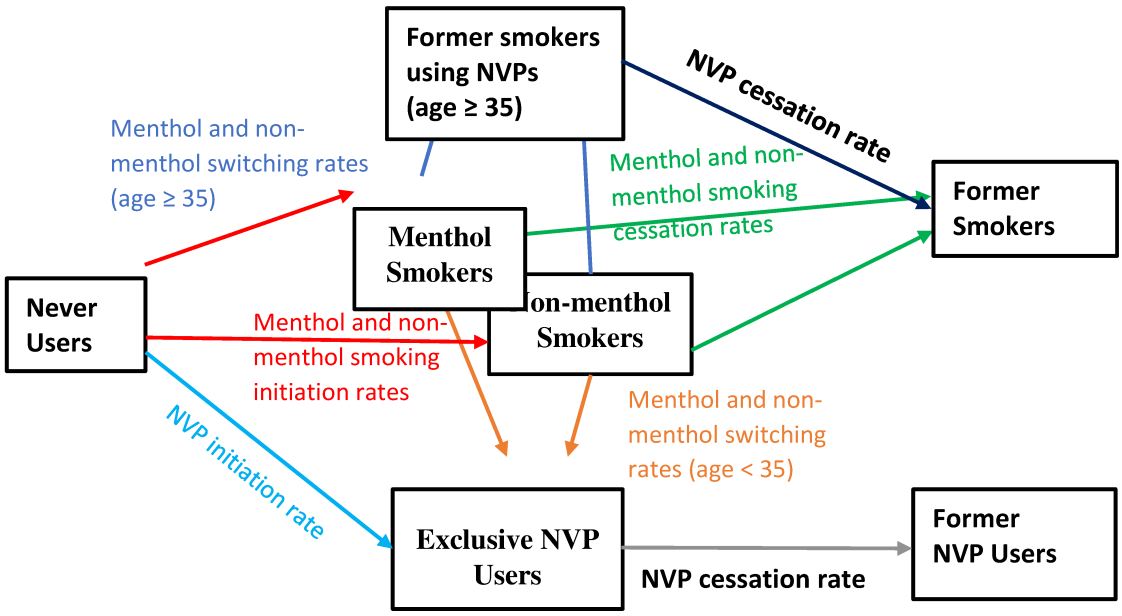
(3) smoking cessation was measured as 'non-current use' at follow-up who reported they 'completely quit smoking cigarettes'

(4) Upper and lower bound are based on 95% confidence intervals.

Table S1.3. The Estimated Menthol Proportions by Age Group and Gender

Age	Male	Female	Mid-age
18-24	34.7%	40.1%	21
25-34	40.2%	49.7%	30
35-44	43.4%	51.0%	40
45-64	38.2%	39.0%	55
65-99	26.8%	34.3%	82

Figure S1.1. Transitions between Smoking and Nicotine Vaping Products (NVPs) Use States in the Menthol Status Quo Scenario



Notes:

1. The overall smoking initiation (menthol + non-menthol) in the Status Quo Scenario is 40% of the smoking initiation rates in the No-NVP Scenario, which was projected using NHIS data before 2013 when no NVP was available, for ages before 25 and 100% for ages after 25. The separation of overall initiation rates to menthol and non-menthol smokers are discussed above.
2. The NVP initiation in the NVP Scenario is 50% of the smoking initiation rates in the No-NVP Scenario for all ages.
3. The overall cessation rate for menthol and non-menthol smokers in the Status Quo Scenario is 80% of the cessation rates in the No-NVP Scenario for all ages, which was projected using NHIS data before 2013 when no NVP was available. Ninety percent of the cessation rate is assumed for females age 25-54 to improve the fitting of the model. The separation of overall cessation rate for menthol and non-menthol smokers are discussed above.
4. The cessation rate for NVP users is the same as the smoking cessation rates in the No-NVP Scenario for all ages.
5. The switching rates from male (female) smokers to NVP use before age 35 or former smokers using NVP after age 35 in the NVP Scenario is 8% (5%) for ages 10-17, 4.0% (2.5%) for ages 18-24, 2.5% (2.0%) for ages 25-34, 2.5% (1.6%) for ages 35-44, 1.3%

(1.4%) for ages 45-54, 1.2% (1.4%) for ages 55-64, and 0.6% (1.0%) for ages 65 and above.

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Supplement 2. The Menthol Ban Scenario

We examine the impact of a menthol ban that is applied to both cigarettes and little cigars, so that substitution from menthol cigarettes to menthol cigars, especially little cigars, is minimal. We rely on a recent expert elicitation,[16] in which experts were asked to estimate the transitions in regular cigarette and NVP use under a menthol cigarette and cigar ban. We developed and pilot tested a questionnaire that focused on tobacco use transitions of current smokers (age 18-24 menthol, age 35-54 menthol, and age 35-54 non-menthol) and potential menthol smokers (age 12-24).

Expert Selection

We adopted a three-pronged approach to the identification of experts. First, we selected lead and senior authors of studies identified in a scoping review on the impact of menthol and flavor bans.[14] Second, we searched Scopus to identify individuals who were among the most published authors on the topic of menthol tobacco. Similar to the method adopted by the FDA for their expert panel,[21] we selected the top 30 authors identified by Scopus and removed those with an H-Index of <20. Finally, we consulted expert advisors of our FDA-sponsored TCORS 2.0 Center (CAsToR) on their recommendations. We sent invitations to the 12 top-ranked experts requesting their participation. All but one invitee agreed to participate, leaving a final sample of 11 experts.

Elicitation Process

First, we asked the experts to review a compilation of background materials. In the first round, experts completed an online questionnaire using the Qualtrics platform. For the second round, we shared the anonymized responses to the questionnaire along with a summary of the group mean, minimum and maximum for each transition with each participating expert. Experts were given the option of

revising their responses, which enabled them to consider others' answers and possibly move toward consensus.[17-19] In addition to their revisions, we also asked experts to indicate their level of confidence for each question (1=not at all to 4=very).

Method Used to Estimate Transitions in the Menthol Ban Scenario

For each age/menthol group, we estimated average net transitions under the ban. Individual net transitions were calculated as the change in use for each product category between the Status Quo and Menthol Ban Scenarios, i.e., the net transitions due to the ban. For example, if an expert indicated that out of 100 menthol smokers, 40 would transition to NNDPs under the status quo and 60 under the menthol ban, then the net transition due to the ban is 20 (=60–40). We then calculated the mean net transition over all 11 experts. While different combustible products were included in the Status Quo and Menthol Ban Scenarios, we aggregated all combustibles (cigarettes and cigars) into a category of total combustibles. Experts were first asked about transitions by those ages 12-24 who would have otherwise initiated into menthol cigarette use. The process allowed for transitions through the age of 30 for initiation. The experts were then asked to estimate the transitions under a ban by menthol smokers at age 18-24 and 35-54, and non-menthol smokers age 35-54 for both genders. The outcomes include "continue to be (illicit) menthol smokers," "switch to non-menthol smoking," "switch to cigar use," "switch to smokeless tobacco use," "switch to NNDP" (novel nicotine delivery products, and "quit" (discontinue any nicotine product use). For the 18-24 and 35-54 years old age groups, experts were asked transitions over a two-year period under the Status Quo (no ban) and under the menthol Ban. In developing the relevant transitions for the model, we use the difference in these transitions for each product category in order to obtain the net change as a result of the ban. In characterizing each of the transitions, illicit menthol cigarette users are retained as menthol smokers, with the same cessation and switching rates as menthol cigarette smokers in the **Menthol Ban Scenario**

We consider transitions into cigar use as non-menthol cigarette use to create a change in combustible use. This is a conservative strategy in that the health impacts are similar or less for cigars compared to cigarettes. Since the experts indicated little impact of menthol ban (?) on smokeless use (2% for ages 18-24 and <1% for ages 35-54), those users are assumed to transfer to non-menthol cigarette use (a conservative strategy). Although the survey also allowed for switching to heated tobacco and HTP risks are similar to NVPs, transfers to NNDP use are assumed to all be into NVP use. While compiling the inputs from 11 experts, one expert gave anomalous response that "most menthol smokers will switch to non-menthol cigarette, NVP and smokeless tobacco in the status quo scenario" and "most menthol smokers will switch to non-menthol cigarettes, and those who would switching to NVPs, smokeless or quit smokers will allow switch to non-menthol cigarette". Since his response deviates greatly from the rest of the experts, his response was removed from the sample.

Based on estimates from the experts for would-be menthol smokers at ages 12-24 in the Menthol Ban Scenario (Table S2.1), we use the mean net transition to model the decomposition of the would-be menthol smokers in the Menthol Ban Scenario (Figure S2.1 below). The transitions are multiplied by the former menthol initiation rate at each age for each gender through age 40, where M1=2.4% become illicit menthol smokers, M2=38.3% (=30.3%+5.6%+2.4%) become non-menthol smokers (including non-menthol cigar users and smokeless users), M3=17.3% become NVP users, and the remaining 42.0% are transferred back to never smokers. Never smokers are kept in a separate permanent never smoker category, so that they do not later initiate into the NVPs use and smoking. This allows for increased initiation of non-menthol smoking and vaping. The same level of transitions of would-be menthol smokers is assumed in all future years after the menthol ban, thus leading to increasing effects of a ban over time.

For transition rates from current menthol smokers (ages 18-24 and ages 35-54) in the Menthol Ban Scenario (see Figure S2.2), we

do not directly apply experts' estimates for the Menthol Ban Scenario because of their dependence on the Status Quo scenario. Instead, we use the difference between experts' estimate in the Status Quo and the menthol ban scenarios to re-distribute would-be menthol smokers in the Menthol Ban Scenario. These transitions are in terms of direct transitions in prevalence. While transitions in the expert elicitation are within a two-year period, we assume the original change in prevalence takes place in the first year for simplicity. That change is maintained over time subject to the cessation rates of the respective products. After the first year of menthol ban when a sudden reduction in the menthol smoking prevalence is incorporated, all the remaining menthol smokers become illicit menthol smokers but their cessation rate and switching rate to NVP use in the following years are assumed to be the same as what were assumed for menthol smokers in the Menthol Status Quo Scenario and no switching to non-menthol smokers anymore. Consequently, a menthol ban continues to have long term effects (in future years) through the increased (Status Quo) cessation rate of non-menthol smokers who have switched from menthol smoking.

Based on the expert data for menthol smokers ages 18-24 (Table S2.2), we estimated the difference between the Status Quo scenario and the Menthol Ban Scenario and computed the increment of each group relative to the diminished menthol cigarette smokers as shown in Figure S.2.2. Based on the expert elicitation, 10.1% switch to illicit menthol cigarettes or cigars, 48.0% (43.8%+0.9%+3.3%) switch to non-menthol cigarettes, 24.2% switch to NVPs and 17.7% quit. These transitions are multiplied by the menthol cigarette smoker prevalence at each age by gender. While the expert elicitation was in terms of ages 18-24, we allowed the transitions to occur through age 30. Thus, the transitions from current menthol smokers ages 18-30 are modelled as a one-time change.

The transition rate for menthol smokers ages 35-54 (Table S2.3) is obtained based on experts' estimates of the difference between

the Status Quo and Menthol Ban Scenario for those ages 35-54. As shown in Table S2.3, 8.8% switch to illicit menthol cigarettes or cigars, 59.2% (54.5%+3.7%+1.0%) switch to non-menthol cigarettes, 17.3% switch to NVPs and 14.7% quit. These transitions are multiplied by the menthol cigarette smokers prevalence by age and gender. While the expert elicitation was in terms of ages 35-54, we allowed the transitions to all menthol smokers above age 30.

For the transition rate from non-menthol smokers age 35-54 in the Menthol Ban Scenario, we allow for no change compared to the rate in the Status Quo Scenario based on the results in Table S2.4.

Table S.2.1. Transitions of Ages 12-24 Who Would Have Initiated as Menthol Smokers under a Menthol Ban, in Percentage Terms (out of 100 age 18-24 menthol smokers in the Status Quo)

Population	**Status Quo**	**Total Population with Menthol Ban**			
Product Type	**Mean/ Median**	**Mean**	**Median**	**Min**	**Max**
Become non-menthol cigarette users (exclusively or with other products)	0	30.3	25.0	1.9	79.0
Become non-menthol cigar users (exclusively or with other products, but not cigarettes)	0	5.6	2.0	0.0	20.0
Become illicit menthol cigarette or cigar user	0	2.4	1.0	0.0	10.0
Total combustible use (status quo all menthol cigarettes)	100	38.3	35.0	3.5	83.0
Become exclusive smokeless tobacco or other oral tobacco product users	0	2.4	2.0	0.0	5.0
Become novel nicotine delivery product users (NNDP), such as e-cigarettes or heated tobacco products (exclusively or in combination with other products, but not cigarettes or cigars)	0	17.3	20.0	3.4	25.0
No tobacco or novel nicotine delivery product use	0	42.0	41.0	6.0	92.3

Table S.2.2. Transitions of age 18-24 Menthol Smokers in the Status Quo and Menthol Ban Scenarios in Percentage Terms (out of 100 age 18-24 menthol smokers in the Status Quo)

Population	Status Quo	Menthol Cigarette and Cigar Ban	Net Effect	Final Transition as a Percent of Menthol Smokers in the Status Quo
Product Type	**Mean**	**Mean**	**Absolute difference**	**Percent of 71.2%**
Continue to be menthol cigarette smokers (exclusively or with other products)	71.2	-	-71.2	
Switch to non-menthol cigarettes (exclusively or with other products, except menthol cigarettes)	5.6	36.8	31.2	43.8% (31.2/71.2)
Switch to cigars, especially little cigars, filtered cigars, or cigarillos (exclusively or with other products, but not cigarettes)	3.4	-	0.7	0.9% (0.7/71.2)
Switch to non-menthol cigars, especially little cigars, filtered cigars or cigarillos (exclusively or with other products, but not cigarettes)	-	4.1		
Switch to illicit menthol cigarette or cigar use	-	7.2	7.2	10.1% (7.2/71.2)
Switch to exclusive smokeless tobacco or other oral tobacco products	1.7	4.1	2.4	3.3% (2.4/71.2)
Switch to novel nicotine delivery products (NNDP), such as e-cigarettes or heated tobacco products (exclusively or in combination with other products, but not cigarettes or cigars)	8.3	25.5	17.2	24.2% (17.2/71.2)

Quit regular use of all tobacco or novel nicotine delivery products	9.8	22.4	12.6	17.7% (12.6/71.2)

Table S2.3. Transitions of Age 35-54 Menthol Smokers in the Status Quo and Menthol Ban Scenarios in Percentage Terms (out of Age 35-54 100 menthol smokers in the status quo)

Population	Status Quo	Menthol Cigarette and Cigar Ban	Net Effect	Final Transition as a Percent of Menthol Smokers in the Status Quo
Product Type	**Mean**	**Mean**	**Absolute difference**	**Percent of 71.2%**
Continue to be menthol cigarette smokers (exclusively or with other products)	71.2	-	-71.2	
Switch to non-menthol cigarettes (exclusively or with other products, except menthol cigarettes)	4.5	43.3	38.8	54.5% (38.8/71.2)
Switch to cigars, especially little cigars, filtered cigars, or cigarillos (exclusively or with other products, but not cigarettes)	1.5	-		
Switch to non-menthol cigars, especially little cigars, filtered cigars or cigarillos (exclusively or with other products, but not cigarettes)	-	4.1	2.6	3.7% (2.6/71.2)
Switch to illicit menthol cigarette or cigar use	0.0	6.3	6.3	8.8% (6.3/71.2)
Switch to exclusive smokeless tobacco or other oral tobacco products	1.9	2.6	0.7	1.0% (0.7/71.2)
Switch to novel nicotine delivery products (NNDP), such as e-cigarettes or heated tobacco products (exclusively or in combination with other products, but not cigarettes or cigars)	8.2	20.5	12.3	17.3% (12.3/71.2)
Quit regular use of all tobacco or novel nicotine delivery products	12.7	23.2	10.5	14.7% (10.5/71.2)

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Table S.2.4. Transitions of Non-Menthol Smokers at Age 35-54 in The Status Quo and Menthol Ban Scenario

Population	Status Quo	Menthol Cigarettes and Cigars Ban	Absolute difference
Product Type	**Mean**	**Mean**	
Switch to be menthol cigarette smokers (exclusively or with other products)	2.3	-	-2.3
Continue to smoke non-menthol cigarettes (exclusively or with other products, except menthol cigarettes)	75.3	76.9	1.6
Switch to cigars, especially little cigars, filtered cigars, or cigarillos (exclusively or with other products, but not cigarettes)	0.8	-	-0.8
Switch to non-menthol cigars, especially little cigars, filtered cigars or cigarillos (exclusively or with other products, but not cigarettes)	-	1.1	1.1
Switch to exclusive smokeless tobacco or other oral tobacco products	1.8	1.7	-0.1
Switch to novel nicotine delivery products (NNDP), such as e-cigarettes or heated tobacco products (exclusively or in combination with other products, but not cigarettes or cigars)	8.4	8.5	0.1
Quit regular use of all tobacco or novel nicotine delivery products	11.4	11.8	0.4

Figure S.2.1: Transitions from Never Smokers in the Menthol Ban Scenario

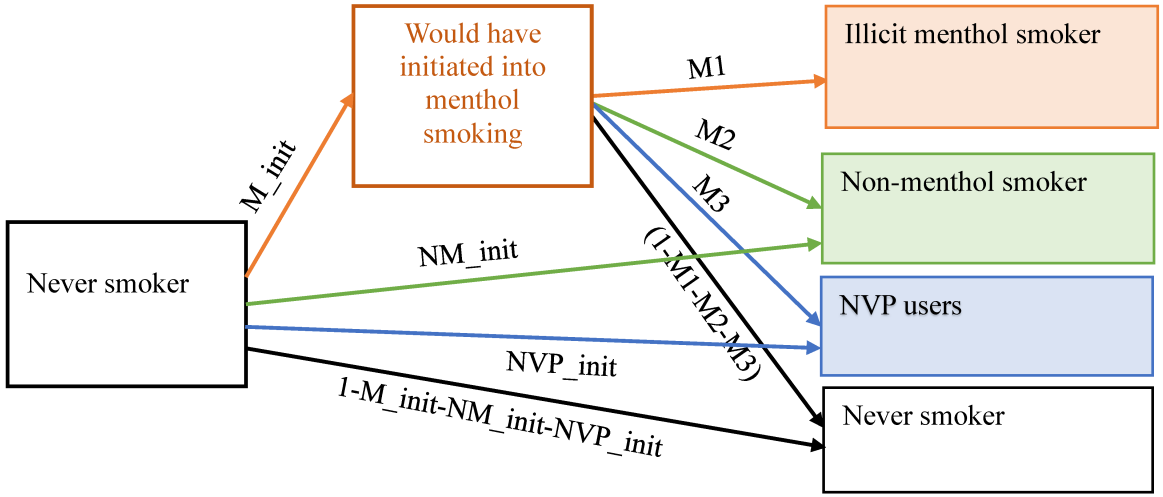
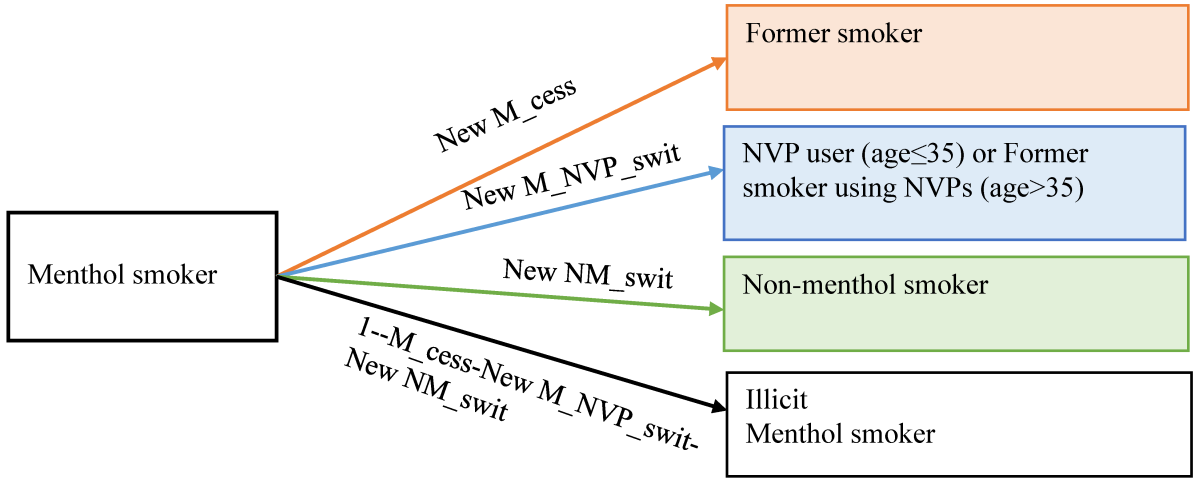


Figure S.2.2 Transitions from Menthol Smoker in the Menthol Ban Scenario



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Supplement 3. Results of the Menthol Status Quo and Menthol Ban Scenarios by Gender

Public Health Impact under the Base Case Status Quo and Menthol Ban Scenarios

Table S3.1 presents the 2021-2080 US menthol and non-menthol smoking and NVP prevalence, deaths, and LYLs for males and females ages 18-99. Results from 2026 and 2080 are presented to display short-term and long-term changes. The results are generally greater in relative terms for females due to their higher rates of menthol cigarette use relative to total cigarette use. Under the Status Quo Scenario, adult (ages ≥18) menthol smoking prevalence declines from 5.8% in 2021 to 4.7% in 2026, 2.5% in 2060, and 2.3% in 2080 for males and from 5.1% in 2021 to 4.3% in 2026, 2.3% in 2060, and 2.1% in 2080 for females, while non-menthol smoking prevalence declines from 8.5% in 2021 to 6.7% in 2026, 3.2% in 2060, and 3.0% in 2080 for males and from 5.8% in 2021 to 4.6% in 2026, 2.1% in 2060, and 1.9% in 2080 for females. The adult (ages ≥18) prevalence of NVP users (both exclusive NVP use who initiated from never users and who switched from current smokers) increases from 4.5% in 2021 to 5.8% in 2026, 7.0% in 2060, and 6.7% in 2080 for males and from 2.7% in 2021 to 3.5% in 2026, 4.6% in 2060, and 4.5% in 2080 for females. Cumulative SVADs by 2080 include 13.3 million males and 5.6 million females, translating to 128.7 million male and 52.1 million female LYLs.

Under the Menthol Ban Scenario, adult menthol smoking prevalence declines to 0.36% in 2026, 0.08% in 2060, and 0.06% in 2080 for males and to 0.32% in 2026, 0.08% in 2060, and 0.05% in 2080 for females, while non-menthol smoking prevalence increases to 9.6% in 2026 and declines to 4.9% in 2060 and 4.7% in 2080 for males and to 7.2% in 2026, 3.6% in 2060, and 3.3% in 2080 for females. The prevalence of NVP users increases from 4.5% in 2021 to 7.0% in 2026, 8.8% in 2060, and 8.7% in 2080 for males and from 2.7% in 2021 to 4.5% in 2026, 6.0% in 2060, and 5.9%

Levy DT, *et al. Tob Control* 2022;0:1–8. doi: 10.1136/tobaccocontrol-2021-056604

in 2080 for females. Cumulative SVADs by 2080 include 12.8 million males and 5.2 million females, translating to 119.9 million male and 46.3 million female LYLs.

Comparing two scenarios by 2080, combined menthol and non-menthol smoking prevalence falls from 5.3% under the status quo to 4.7% with a menthol ban for males (a 12% relative reduction) and from 4.5% to 3.4% for females (a 16% relative reduction). The 2080 NVP prevalence under the status quo and menthol ban are 6.7% and 8.7% for males (a 28% relative increase) and 4.5% and 5.9% for females (a 31% relative increase). Cumulative SVADs are reduced in relative terms by 4.8% (0.5 million males; 0.4 million females), and LYLs are reduced by 8.1% (8.8 million males; 5.9 million females).

Sensitivity analysis by Gender

Table S3.2 contains the sensitivity analysis broken down by gender for 2021-2080. The impacts are of the same sign and similar in magnitude by gender.

Table S3.1. Smoking and NVP Prevalence, Smoking and Vaping Attributable Deaths, Life-Years Lost and Public Health Impact, By Gender, Ages 18 and Above, 2021-2080

Status Quo Scenario									
		MALE				FEMALE			
Category	Category/Year	2021	2026	2080	Cumulative Impact*	2021	2026	2080	Cumulative Impact*
Prevalence	Never smoker	59.7%	62.1%	74.6%	24.8%	68.6%	70.1%	80.6%	17.5%
	Menthol smoker	5.8%	4.7%	2.3%	-60.5%	5.1%	4.3%	2.1%	-58.0%
	Nonmenthol smoker	8.5%	6.7%	3.0%	-64.6%	5.8%	4.6%	1.9%	-67.3%
	All Smokers	14.3%	11.5%	5.3%	-62.9%	10.9%	9.0%	4.0%	-63.0%
	Former smoker	21.3%	19.9%	5.5%	-74.1%	17.6%	17.0%	5.3%	-70.0%
	Exclusive NVP user	3.2%	4.4%	6.7%	107.3%	1.9%	2.6%	4.5%	140.7%
	Former smoker-NVP user	1.2%	1.4%	0.1%	-92.8%	0.8%	0.9%	0.0%	-94.6%
	All NVP users	4.5%	5.8%	6.7%	51.4%	2.7%	3.5%	4.5%	68.6%
	Former NVP user	0.3%	0.7%	7.9%	2701.4%	0.2%	0.4%	5.5%	3276.7%
Smoking and vaping attributable deaths	Menthol smoker	51,083	48,519	14,418	1,890,627	26,372	25,616	9,360	1,121,377
	Nonmenthol smoker	83,797	72,531	15,858	2,394,995	38,445	33,593	6,648	1,092,127
	Former smoker	135,834	144,048	79,873	8,489,954	39,964	45,443	35,047	3,193,375
	Exclusive NVP user	19	121	5,678	161,689	0	7	2,032	49,320
	Former smoker-NVP user	3,595	5,243	1,044	292,867	1,416	1,926	282	89,084
	Former NVP user	0	0	8,471	103,008	0	0	2,012	20,015
	Total	274,328	270,461	125,341	13,333,141	106,198	106,585	55,381	5,565,296
Life-years lost	Menthol smoker	899,390	825,693	247,314	29,925,719	435,860	416,319	137,035	16,755,027
	Nonmenthol smoker	1,353,358	1,149,146	291,808	38,155,336	596,145	506,597	104,072	16,116,945
	Former smoker	1,057,982	1,100,435	353,622	51,734,688	265,265	304,025	136,985	16,846,000
	Exclusive NVP user	809	4,870	100,442	3,892,184	12	301	35,871	1,143,231
	Former smoker-NVP user	64,156	89,255	7,603	3,676,535	21,659	28,449	1,862	1,044,549
	Former NVP user	0	2	69,694	1,291,683	0	0	15,941	223,195
	Total	3,375,694	3,169,401	1,070,483	128,676,145	1,318,941	1,255,691	431,765	52,128,948

Menthol Ban Scenario									
		MALE				FEMALE			
Category	**Category/Year**	**2021**	**2026**	**2080**	**Cumulative Impact ***	**2021**	**2026**	**2080**	**Cumulative Impact ***
Prevalence	**Never smoker**	59.7%	61.7%	71.5%	19.7%	68.6%	69.9%	78.6%	14.5%
	Menthol smoker	5.8%	0.4%	0.06%	-99.0%	5.1%	0.3%	0.05%	-98.9%
	Nonmenthol smoker	8.5%	9.6%	4.6%	-46.0%	5.8%	7.2%	3.3%	-42.7%
	All Smokers	14.3%	9.9%	4.7%	-67.4%	10.9%	7.5%	3.4%	-68.9%
	Former smoker	21.3%	20.6%	5.4%	-74.7%	17.6%	17.6%	5.1%	-71.3%
	Exclusive NVP user	3.2%	5.0%	8.6%	167.4%	1.9%	3.1%	5.9%	215.9%
	Former smoker-NVP user	1.2%	7.0%	0.1%	-93.5%	0.8%	1.4%	0.0%	-95.3%
	All NVP users	4.5%	2.5%	8.7%	94.6%	2.7%	4.5%	5.9%	120.6%
	Former NVP user	0.3%	0.7%	9.8%	3382.3%	0.2%	0.5%	7.1%	4197.3%
Smoking and vaping attributable deaths	**Menthol smoker**	51,083	4,409	593	191,539	26,372	2,383	406	112,181
	Nonmenthol smoker	83,797	102,113	22,792	3,362,569	38,445	49,186	10,546	1,639,431
	Former smoker	135,834	145,339	78,048	8,593,659	39,964	45,759	33,871	3,223,907
	Exclusive NVP user	19	121	6,866	187,603	0	7	2,535	59,603
	Former smoker-NVP user	3,595	7,769	994	366,910	1,416	2,871	287	119,809
	Former NVP user	0	0	9,619	115,086	0	0	2,384	23,325
	Total	274,328	259,751	118,912	12,817,367	106,198	100,206	50,030	5,178,256
Life-years lost	**Menthol smoker**	899,390	73,193	7,609	2,926,131	435,860	38,484	4,655	1,629,769
	Nonmenthol smoker	1,353,358	1,647,004	431,304	53,915,986	596,145	756,752	172,661	24,563,267
	Former smoker	1,057,982	1,117,480	339,399	52,464,097	265,265	307,513	128,309	17,004,012
	Exclusive NVP user	809	4,888	126,185	4,583,213	12	301	45,857	1,394,673
	Former smoker-NVP user	64,156	126,070	6,746	4,504,128	21,659	41,963	1,619	1,397,786
	Former NVP user	0	2	82,415	1,472,556	0	0	19,179	263,239
	Total	3,375,694	2,968,636	993,659	119,866,111	1,318,941	1,145,014	372,281	46,252,745

Difference between Menthol Status Quo and Menthol Ban Scenario									
Relative Reduction in Prevalence**	**Menthol Smoker**	-	-92.5%	97.5%	-	-	-92.5%	97.4%	-
	Nonmenthol Smoker	-	42.1%	52.3%	-	-	54.8%	75.4%	-
	All Smokers	-	-13.6%	12.1%	-	-	-16.0%	15.9%	-
	All NVP users	-	19.3%	-28.48%	-	-	27.8%	-30.8%	-
Gain***	**Averted Deaths**	-	10,710	6,429	515,774	-	6,378	5,352	387,041
	Averted life-years lost	-	200,764	76,824	8,810,034	-	110,676	59,484	5,876,203

Notes: NVP= nicotine vaping product, All smokers = combined menthol and non-menthol smokers. All NVP users= combined exclusive NVP user and Former smoker-NVP. * The cumulative impact is measured in terms of the relative change from 2021-2080 for prevalence rates (i.e., (2080-2021)/2021) and the sum of the smoking and vaping attributable deaths or life years lost over the years 2021 through 2080. ** Relative reduction in prevalence is measured as the relative difference between the menthol status quo scenario and the menthol ban scenario, (i.e. (post ban – pre ban)/pre ban) in year 2026 and 2080. ***The gain is measured as the increase in the averted deaths and life-years lost from menthol status quo scenario to the menthol ban scenario.

Table S3.2. Sensitivity analysis of averted Smoking- and Vaping-Attributable Deaths and Life-Years Lost to NVP relative risks and individual transition parameters, by Gender, All ages, 2021-2080

Case	Description	Male	% change*	Female	% change*
Smoking- and Vaping-Attributable Deaths Averted by Menthol Ban					
1	Base Case with NVP at 15% of cigarette excess mortality risk	515,774	-	387,041	-
2	NVP risk at 5% of cigarette-attributable excess mortality risk	555,890	7.8%	407,128	5.2%
3	NVP risk at 25% of cigarette-attributable excess mortality risk	476,966	-7.5%	367,632	-5.0%
4	Reduce overall smoking initiation rates by 10%	492,456	-4.5%	375,725	-2.9%
5	Increase overall smoking initiation rates by 10%	538,612	4.4%	398,195	2.9%
6	Reduce overall smoking cessation rates by 10%	552,875	7.2%	426,704	10.2%
7	Increase overall smoking cessation rates by 10%	481,478	-6.6%	351,375	-9.2%
8	Menthol cessation rate same as non-menthol rate	365,869	-29.1%	249,117	-35.6%
9	Reduce overall switching rate by 10%	531,301	3.0%	395,418	2.2%
10	Increase overall switching rate by 10%	500,827	-2.9%	378,863	-2.1%
11	Reduce the annual decline in switching rate from 10% to 0%	343,320	-33.4%	276,755	-28.5%
12	Menthol switching rate same as non-menthol rate	497,310	-3.6%	378,583	-2.2%
13	Reduce NVP initiation rates by 10%	516,476	0.1%	387,373	0.1%
14	Increase NVP initiation rates by 10%	515,080	-0.1%	386,711	-0.1%
15	Reduce NVP cessation rates by 10%	511,254	-0.9%	383,725	-0.9%
16	Increase NVP cessation rates by 10%	519,756	0.8%	389,873	0.7%

Smoking- and Vaping-Attributable Life-Years Lost Averted by Menthol Ban					
1	Base Case with NVP at 15% of cigarette excess mortality risk	8,810,034	-	5,876,203	-
2	NVP risk at 5% of cigarette-attributable excess mortality risk	9,612,620	9.1%	6,224,771	5.9%
3	NVP risk at 25% of cigarette-attributable excess mortality risk	8,019,249	-9.0%	5,532,609	-5.8%
4	Reduce overall smoking initiation rates by 10%	8,216,462	-6.7%	5,610,351	-4.5%
5	Increase overall smoking initiation rates by 10%	9,390,532	6.6%	6,137,958	4.5%
6	Reduce overall smoking cessation rates by 10%	9,301,606	5.6%	6,340,918	7.9%
7	Increase overall smoking cessation rates by 10%	8,345,000	-5.3%	5,446,548	-7.3%
8	Menthol cessation rate same as non-menthol rate	6,589,665	-25.2%	4,084,214	-30.5%
9	Reduce overall switching rate by 10%	9,079,730	3.1%	6,002,244	2.1%
10	Increase overall switching rate by 10%	8,550,484	-2.9%	5,753,223	-2.1%
11	Reduce the annual decline in switching rate from 10% to 0%	5,650,284	-35.9%	4,158,632	-29.2%
12	Menthol switching rate same as non-menthol rate	8,456,217	-4.0%	5,737,726	-2.4%
13	Reduce NVP initiation rates by 10%	8,827,421	0.2%	5,884,035	0.1%
14	Increase NVP initiation rates by 10%	8,792,859	-0.2%	5,868,437	-0.1%
15	Reduce NVP cessation rates by 10%	8,730,705	-0.9%	5,829,304	-0.8%
16	Increase NVP cessation rates by 10%	8,881,787	0.8%	5,917,713	0.7%

Notes: NVPs= nicotine vaping products; % change is in terms of the relative difference from the base case, (e.g., (687,209-654,221)/654,221 for case 2 relative to case 1.

Supplementary Appendix 1. Calibration of the Smoking and Vaping Model

A previous version of the Smoking and Vaping Model (SAVM) was developed based on data from the National Health Interview Survey (NHIS) through the year 2013.[1] That model had been shown to validate well overall, but underestimated the decline in smoking rates at younger ages. Due to the importance of these age groups to future smoking rates, we recalibrated model parameters against 2013-2018 NHIS data. We compare 2018 model predictions for smoking and vaping prevalence by gender and age to the 2018 NHIS observed data. Because NHIS and SAVM begin in 2013 with slightly different levels of the smoking prevalence, we compare the relative change in smoking prevalence [(2018 prevalence -2013 prevalence)/2013 prevalence], and then change initiation and/or cessation parameters to recalibrate the model when needed..

Based on comparison of relative changes and confidence intervals, we adjusted the parameters of model until the model predictions were within 10% of the survey estimates for 2018. In our final calibration relative to the initial model,[1] we reduced the smoking initiation rate of those below age 24 by 40% and the switching rate from smoking to NVP use at ages 18-24 was doubled for those below ages 18 in order to calibrate smoking at younger ages. We also reduced the cessation rate by 20% except females ages 25-54 (reduced 10%) to better predict smoking at older ages. To account for the potential reduction in the percent of smokers who switch to NVP (e.g., as those most attracted to NVPs have already switched and technological advance slows), switching rates were reduced by 10% annually starting in 2018 at all ages.

The predictions of smoking prevalence from the re-calibrated SAVM are compared to the NHIS data in Table S1.1. Current smoking is defined as having smoked ≥100 cigarettes during one's lifetime and currently smoking every day or some days. From 2013 to 2018, SAVM adult smoking prevalence for males falls from 21.4% to 16.6% compared reduction from 20.3% (95%

CI: 19.5%-21.2%) to 15.8% (95% CI: 15.0%-16.6%) from NHIS, and for females from 15.9% in 2013 to 12.5% in 2018 compared with 15.4% (95% CI: 14.7%-16.1%) to 12.0% (95% CI: 11.3%-12.6%) from NHIS. While SAVM estimates are above NHIS estimates for both males and females, prevalence in relative terms declines by 22.4% for males compared to 22.2% in NHIS, and by 21.4% for females compared to 22.1% in NHIS. While discrepancies in relative reductions were greater for some age groups (e.g., males ages 18-24, females ages 45-64 and males and females age 65+), the 2018 SAVM predictions were within NHIS CIs except for males and females ages 25-44.

Table S1.1 also shows future predictions. In the calibrated model, male smoking prevalence declines from 16.6% in 2018 to 7.5% in 2040 and 5.7% in 2060, while female prevalence declines from 12.5% in 2018 to 6.0% in 2040 and 4.5% in 2060. Much of reduction results from the reduced initiation rates.

Table S1.2 compares the NVP prevalence with the NHIS NVP rate, measured by those who used e-cigarettes at least 10 days in the last 30 days. We do not examine relative changes from 2012-2018, because the SAVM begins in 2013 with NVP prevalence at 0. The age 18 and above NVP prevalence increases from 3.1% in 2018 to 7.1% in 2060 for males, and from 1.9% in 2018 to 4.6% in 2060 for females. The NVP rates increase from ages 18-24 to 25-44 and then decline with age.

Supplement 1.1. Recalibrated SAVM Smoking Prevalence (%) vs. National Health Interview Survey (NHIS) Estimates with 95% Confidence Intervals (CIs), 2013-2060, By Age and Gender

Age	Source	2013	2014	2018	Relative reduction*	2040	2060
Males							
18+	**SAVM**	21.4	20.4	16.6	-22.4%	7.5%	5.7%
	NHIS	20.3	18.8	15.8	-22.2%	-	-
	95% CI	19.5-21.2	17.9-19.7	15.0-16.6	-	-	-
18-24	**SAVM**	19.9	17.5	9.3	-53.3%	6.9%	6.9%
	NHIS	21.6	18.6	8.5	-60.6%	-	-
	95% CI	18.6-24.6	15.9-21.4	6.4-10.5	-	-	-
25-44	**SAVM**	27.3	26.4	22.1	-19.0%	7.3%	8.4%
	NHIS	23.1	22.9	19.1	-17.3%	-	-
	95% CI	21.6-24.5	21.3-24.4	17.5-20.7	-	-	-
45-64	**SAVM**	20.4	19.6	16.9	-17.2%	10.1%	4.6%
	NHIS	21.6	19.3	18.3	-15.3%	-	-
	95% CI	20.2-23.1	17.7-20.9	16.9-19.7	-	-	-
65+	**SAVM**	12.2	12.0	10.7	-12.3%	5.0%	3.5%
	NHIS	10.6	9.7	9.9	-6.6%	-	-
	95% CI	9.3-12.0	8.4-11.0	8.7-11.1	-	-	-
Females							
18+	**SAVM**	15.9	14.5	12.5	-21.4%	6.0%	4.5%
	NHIS	15.4	13.5	12.0	-22.1%	-	-
	95% CI	14.7-16.1	12.8-14.2	11.3-12.6	-	-	-
18-24	**SAVM**	15.0	11.5	7.1	-52.7%	4.9%	4.9%
	NHIS	15.4	11.1	7.3	-52.6%	-	-
	95% CI	13.0-17.8	9.0-13.3	5.2-9.4	-	-	-
25-44	**SAVM**	20.6	19.3	17.1	-17.0%	6.1%	6.6%
	NHIS	17	15.6	14.2	-16.5%	-	-
	95% CI	15.8-18.2	14.4-16.9	12.9-15.5	-	-	-
45-64	**SAVM**	16.2	15.1	13.6	-16.0%	8.3%	4.0%
	NHIS	18.1	15.8	14.3	-21.0%	-	-
	95% CI	16.8-19.3	14.6-17.1	13.1-15.5	-	-	-
65+	**SAVM**	8.2	7.6	6.9	-15.9%	3.8%	2.7%
	NHIS	7.6	7.6	7.3	-3.9%	-	-
	95% CI	6.6-8.6	6.5-8.6	6.4-8.2	-	-	-

Note: SAVM smoking prevalence of the initiation under age 24 is reduced 40% for both genders and the cessation rate is reduced 20% except 40% for males age above 65 and 10% for females at ages 25-54, and the switching rate is doubled at age 18-24 for those under age 18 for both gender (male: 8% for age under 18, 4.0% for age 18-24; female: 5.0% for age under 18, and 2.5% for age 18-24). *: Relative reduction in prevalence from 2013 to 2018.

Supplement 1.2. Nicotine Vaping Product Prevalence (%), validation SAVM vs. National Health Interview Survey (NHIS) Estimates with 95% Confidence Intervals (CIs), 2018-2060, by Age and Gender

Age	SAVM	NHIS 2018		SAVM	
	2018	mean	95% CI	2040	2060
Males					
18+	3.1%	3.1%	2.7%-3.5%	7.0%	7.1%
18-24	8.0%	6.8%	4.8%-8.8%	9.6%	9.6%
25-44	4.2%	4.7%	3.8%-5.6%	11.8%	10.7%
45-64	1.4%	1.5%	1.0%-1.9%	5.6%	7.1%
65+	0.5%	0.6%	0.3%-0.9%	1.5%	2.3%
Females					
18+	1.9%	1.5%	1.3%-1.8%	4.4%	4.6%
18-24	5.1%	3.1%	1.8%-4.5%	6.5%	6.5%
25-44	2.4%	1.9%	1.4%-2.3%	8.0%	7.5%
45-64	1.1%	1.3%	1.0%-1.7%	3.3%	4.8%
65+	0.4%	0.5%	0.3%-0.7%	0.8%	1.2%

Notes: CI= confidence interval. NVP users from National Health Interview Survey are those who use NVPs at least 10 of the past 30 days.

1. Levy DT, Tam J, Sanchez Romero LM, et al. The Public Health Implications of Vaping in the U.S.: The Smoking and Vaping Model. available as preprint2020.

Supplement 2. The Menthol SAVM Model

Background

According to a recent study, approximately 40% of US smokers prefer menthol over non-menthol cigarettes.[1] According to 2004-2010 data from the National Surveys on Drug Use and Health (NSDUH),[2] the proportion of menthol smokers is higher among youth (ages 12-17 years) and young adult (ages 18-25 years) smokers (56.7% and 45.0% respectively, vs. 30.5%-34.7% among older age groups); among women (39.6% vs. 31.4% among men); and among African Americans (88.5% vs. 25.7% among Caucasians). Similar results were reported by Villanti et al.[1] extending to later years and by Mattingly et al.[3] using the NHIS. In the latter study, proportion of menthol smokers in 2015 was 28% for males and 37% for females, and by age group: 18-24 (35-44%), 25-34 (40%), 35-54 (29%) and 55+ (27%).

For the percent menthol and non-menthol smokers among smokers in the base year (2013), we also examine data from the Population Assessment of Tobacco and Health (PATH) in wave 3 (2015/16) and 4 (2016/17) and the Tobacco Use Supplement to the Current Population Survey (TUS-CPS) in 2018/19. Both PATH and TUS-CPS measured current smokers by those who smoked ≥100 cigarettes in their lifetime and now smoke cigarettes every day or some days. Among those current smokers, menthol and non-menthol smokers were defined by those who regularly smoked each type. Those current smokers missing menthol use information were classified as unknown current smokers, account for 3%-7% by age group and gender, and are excluded in estimating the proportion of menthol and non-menthol smokers, as shown in Table S2.1.

In PATH wave 4, menthol smokers accounted for 38.9% of all smokers age 18+ (36.1% among males and 42.2% among females). Distinguishing by age, menthol smokers accounted for 65.1% among those age 15-17, 46.2% among those age 18-24, 48.7% among those age 25-34,

35.3% among those age 35-54, and 32.5% among those age 55+. The menthol smoking prevalence was higher among females than males and increased with age from 18-24 to 25-34 and then declined with age. The percentage change in proportion of menthol smokers between Wave 3 and Wave 4 is less than 1% (38.3% vs. 38.9%) overall as well as by gender and age. We also considered PATH Waves 1 and 2 (2013/14 and 2014/15) by age and did not find major differences.

In TUS-CPS 2018/19, menthol smokers accounted for 29.4% among male smokers age 18+ and 38.8% among female smokers age 18+. By age, menthol smokers accounted for 35.3% among males age 18-24 and 44.1% among females age 18-24, 36.1% among males age 25-34 and 52.8% among females age 25-34, 31.9% among males age 35-44 and 37.9% among females age 35-44, 25.4% among males age 45-64 and 34.9% among females age 45-64, and 23.6% among males age 65+ and 31.5% among females age 65+. We also considered the TUS-CPS 2014/15 and found similar patterns, but the TUS-CPS 2018/19 at each age were still below, but closer to the PATH wave 3 and wave 4 estimates. We also considered the 2012 and 2018 NSDUH. Different from the PATH and TUS-CPS (regular use), NSDUH measured menthol smokers by those current who smoked menthol cigarettes in the past 30 days. In 2018, menthol smokers accounted for 38.9% of all smokes age 18+ (35.1% for males and 43.5% for females). The 2018 NSDUH estimates were generally below, but closer to PATH waves 3 and 4 than the TUS-CPS.

We also considered studies of recent trends in menthol vs. non-menthol use. Although the prevalence of non-menthol cigarette use is decreasing, the prevalence of menthol cigarette use has either increased or remained unchanged.[1,2,4] Data from the NSDUH showed that the prevalence of menthol cigarette use stayed constant from 2004 to 2010 among adults aged 26+ years but increased among adults aged 18-25 from 14.0% to 16.3%.[2] Similar increases were observed in a

later study.[1] Among past-30 day cigarette smokers, the proportion of menthol cigarette use increased between 2004 and 2014 for ages 12-17 (42% to 53%), ages 18-25 (32% to 51%) and age 26+ (29% to 37%).[1] Most of the increase was between 2004 and 2010, although a reduction from 55% to 53% was observed for ages 12-17 from 2010-2014.[1] Mattingly et al.[3] found that the prevalence of non-menthol cigarette use generally fell by gender and age in 2005-2010 and 2010-2015 using NHIS. However, menthol use increased between 2005 and 2010, but fell during 2010 to 2015. These latter reductions were most prominent among males and those ages 18-24 and 25-34. Our calculations using Matting et al. estimates indicated increases from 2005 to 2015 in the proportion of smokers using menthol by males (21.5% to 28%), females (32% to 36.5%), ages 18-24 (30.5% to 35.5%), 25-34 (24% to 40%), 35-54 (27% to 29%) and 55+ (23% to 27%), with generally stable trends from 2010 to 2015 except among those 18-24 (from 44% to 35.5%).

In general, while non-menthol use has clearly fallen in the last 15 years, menthol use appears to have been relatively stable, and thus making up a larger percent of overall cigarette use. These tendencies are most pronounced among younger smokers, except possibly for those ages 18-24 from 2010-2015 in NHIS. Most apparent is the increase among those ages 25-34, ages when regular use is often established. The relative increase in menthol use is also confirmed by Delnevo et al.[5] They examined consumption data (reflecting quantity and prevalence) and found that since 2009 (at the time of the Tobacco Control Act), menthol cigarette sales increased from 25.9% in 2010 to 35.4% of the cigarette market in 2018.

We also examined recent trends in the proportion menthol use from the PATH, TUS-CPS and NSDUH surveys. Between 2013/4 and 2016/7, PATH had an increase from 35% for males and 40% for females to 36% for males and 42% for females. The TUS-CPS had larger increases from 2010/11 to 2014/5 compared to 2014/5 to 2018/9. The largest increases were for those age

25-34 (45% to 49%) and 35-54 (32% to 35%). According to NSDUH, the proportion of menthol use rose slightly from 33.5% male and 42% female in 2013 to 35% male and 43.5% female in 2018. Notably, the largest 2013-2018 increase was among those ages 25-34 (44% to 48%) and 35-49 (31% to 38%). Thus, trends show increases in the use of menthol relative to non-menthol smoking, with the largest increase among those ages 25-34. These results suggest that initiation rates have been increasing and cessation rates have been declining among menthol relative to non-menthol smokers.

A recent review by Villanti et al.[6] finds that smoking initiation often occurs with menthol use and that those initiating menthol smoking often progress to more established levels of either menthol or switching to non-menthol smoking. This latter result suggests the need to gauge initiation into regular use. They also note the increase in the proportion of menthol use over time by youth and young adults. These results are consistent with our review of levels and trends in menthol use in the relevant age groups.

A large literature also examines whether smoking cessation rates differ between menthol and non-menthol smokers. While most studies indicate some difference, the results are mixed regarding whether the differences are significant. Four earlier reviews have summarized findings across a heterogeneous literature and concluded that, despite mixed evidence, menthol cigarette use is probably associated with a lower likelihood of smoking cessation.[6-9] A recent meta-analysis[10] did not obtain a significant association between menthol use and cessation; however, menthol users were significantly less likely to quit among African American smokers (OR = 0.88). A recent study[11] using PATH (2013/4-2016/7) found that daily menthol smokers were less likely to quit compared to non-menthol smokers (OR=0.76 [0.63, 0.91]), but no differences was found for non-daily smokers nor in relapse rates. Schneller et al[12] found no significant

differences after adjusting for sociodemographic characteristics in the longitudinal association menthol status and smoking cessation over two one-year intervals (PATH Waves 1 and 2). Cook et al. (2020, unpublished study) found menthol smokers generally had a lower likelihood of having quit smoking (OR =0.8). Two studies[13,14] also found indications of higher levels of dependence among menthol compared to non-menthol smokers, as discussed also by Villanti et al.[6] We also considered PATH data Waves 1-4, and found that cessation rates were similar for males and females, but that cessation rates among menthol smokers were about 80% that of non-menthol smokers for ages 25 and above, although were below those of menthol smokers for those ages 18-24 (11% vs. 8.6%). Table S2.2 shows cessation rates from PATH for waves 1-4, where cessation is measure as those who were established smokers (smoked 100 cigarettes lifetime) but now quit smoking. Both by gender and age except for those ages 18-24, cessation rates are less, generally at 80%, for menthol compared to non-menthol smokers. In general, studies show, but not uniformly that cessation rates are lower among menthol than non-menthol smokers. Based on these results, we will conduct sensitivity analysis with menthol cessation rates between 80% and 100% that of non-menthol smokers. Lower cessation rates or increased initiation rates among menthol smokers may explain the relative increase in menthol use among smokers.

The recent increase in NVP use may differentially affect menthol and non-menthol smokers. Usidame et al. (2020, unpub. study) considered dual use of NVPs by menthol and non-menthol smokers using the four waves of PATH, NHIS 2015 and TUS-CPS 2014/15. They generally found similar although slightly higher dual use among menthol smokers compared to non-menthol smokers by gender and age. These results suggest that menthol smokers are more likely to use menthol NVPs, but incorporate the potential impact of that use on cessation from

smoking (into NVPs or into use of neither product). Cook et al. (2020, unpublished study) found menthol smokers had a higher likelihood of having quit smoking when using e-cigarettes (OR=1.3 to 1.45). Thus, while information is currently limited, there is some indication that menthol smokers may be more attracted to NVPs and have greater success quitting with their use.

The Development of the Menthol Status Quo SAVM

As in our pre-Menthol model, we initialize the level of menthol use in the beginning model year (2013). Using the PATH data, we distinguish smokers of menthol (who regularly smoke a brand that is flavored to taste like menthol) from non-menthol (those regularly smoking nonmenthol) smokers by age and gender. The menthol proportions by age and gender in 2013 are estimated as a product of the ratio of the PATH 2103/14 to 2016/17 menthol proportions by gender (males: 96.0%; females: 95.0%) and the PATH 2016/17 menthol proportions by age and gender (Table S2.3).

We applied a linear interpolation method to smooth the menthol proportions for ages 21-82 for single ages. The menthol proportions for ages under 21 were set equal to 34.7% for males and 40.1% for females, and for ages 83 and above to 26.8% for males and 34.3% for females in 2013. We maintain the same NVP initiation rates as in the previously calibrated model. We then apply rates of menthol/non-menthol initiation, cessation and switching to NVP use to project menthol and non-menthol smoking prevalence forward.

We begin with the initiation rates by age, period, and cohort using the Cancer Intervention and Surveillance Modeling Network (CISNET) data developed by Holford, which is based on NHIS data through 2013. We distinguish the overall smoking initiation rates (2013 level) into menthol and non-menthol smokers simply in terms of the menthol smoking proportion (MP) among all smokers. We focus on an age group when most initiation has already taken place. As

described in our literature review and data analysis above, the proportion of menthol use increases through the age 25-34 age group. To keep the model tractable and because it is the rate of menthol use once smoking habits have been established that is relevant to health outcomes, we simply apply the menthol proportion at age 30, MP_{30} (40.2% males; 49.7% for females) to the overall smoking initiation parameter by age and gender, so that at age a in year t:

$$\text{Menthol initiation rate}_a = MP_{30} * \text{overall smoking initiation rate}_a$$

$$\text{Non-menthol initiation rate}_a = (1-MP_{30}) * \text{overall smoking initiation rate}_a$$

This method allows for smoking to increase by age and gender based on the initiation rates of smokers in our pre-menthol model, implying that the progression in initiation is the same for menthol and non-menthol smokers. While this method does not explicitly model differences in the trajectories of menthol and non-menthol prior to age 30, it implicitly allows for initiation as well as switching between menthol and non-menthol and abstracts from the need to model transitions from experimental to regular, more long-term use.

While our method does not incorporate initiation by menthol status after age 30, most initiation takes place by age 30. According to 2013 version of CISNET initiation rates, at most 0.3% of males and 0.2% of females never smokers initiate after age 30. Our method for incorporating menthol initiation does not explicitly consider switching between regular menthol and non-menthol use after age 30, but most switching occurs by age 30. Using the four waves of PATH (2013/14- 2016/17), we found that 5% or less of menthol smokers switch to non-menthol smokers or vice versa between the ages of 35 and 54 within 2 years, with a net switching rate of less than 3%. By age 30, most initiation is also expected to reflect more established than experimental use.

A limitation of incorporating a constant proportion of menthol smokers is that it does not

incorporate variations over time as reflected in trends. Because our literature review and data analyses indicated an upward trend in the proportion of menthol use of those ages 25-34, we apply the last available year of the PATH (2016/17), which shows the highest proportion of age 25-34 menthol use for both males and females. That rate is also the highest of the surveys considered. The menthol proportion used to estimate the menthol and non-menthol initiation is 45.2% for males and 53.7% for females, which is a constant proportion for all ages over years. We note that initiation into NVP use is maintained as NVP initiation (before ban) = overall smoking initiation * 0.5 for all ages and both genders.

We adopt a method allows for variation in the cessation rates, and allows for the same cessation rates as a special case. Let CR = menthol cessation rate/non-menthol cessation rate assumed constant across gender, age and time, cess rate = cessation rate, and $MP_{a,t}$ = the menthol proportion. We apply the following equation:

Overall cessation $rate_a$ =(MP_a*CR* non-menthol cess $rate_a$)+((1-MP_a) *non-menthol cess $rate_a$)

= (MP_a * CR_a + 1-MP_a) * non-menthol cess $rate_a$,

It follows that:

Non-menthol cessation $rate_a$ = overall cessation $rate_a$ / (MP_a * CR_a +1- MP_a)

Menthol cessation $rate_a$ = non-menthol cessation $rate_a$ * CR_a

The overall cessation rates used in the menthol model are the overall smoking cessation rates in the SAVM NVP Scenario, which were estimated by smoking cessation multipliers (as we described in our calibrated model) and 2013 version of CISNET cessation rates (in the absence of NVP use). The menthol and non-menthol cessation rates vary with the cessation rates in the Pre-menthol model, and are distinguished by age and gender. These rates begin as early as age 15. With the cessation rate of menthol smokers lower than for non-menthol smokers, the rate of

decline will be lower among menthol than non-menthol smokers and the proportion of menthol smokers will increase with age.

The SAVM applies gender- and age-specific rates of current and former smoker death rates. Based on the available evidence and to simplify the model, SAVM does not distinguish deaths rates for menthol and non-menthol current smokers. Former smokers are not distinguished between those who were former menthol and non-menthol smokers, and thus former smoker death rates are not distinguished.

The model maintains the same NVP cessation, i.e., NVP cessation (pre-ban) = overall smoking cessation. Additional cessation from smoking can implicitly occur through the switching rate from menthol or non-menthol cigarette use to NVPs as discussed in the next section.

To allow for different menthol and non-menthol switching rates from smoking to NVP use, the ratio of menthol and non-menthol switching rates (SR) is applied, rather than the separate menthol and non-menthol switching rates. Allowing the switching rate to decline at a annual rate δ, the formulas for switching rates at age a and year t are:

Non-menthol switching $rate_{a,t}$ = overall switching $rate_a$ * $(1-\delta)^{(t- t_o)}$ / ($MP_{a,t}$* SR_a + (1- $MP_{a,t}$)), where t_o is designated as 2018;

Menthol switching $rate_{a,t}$ = non-menthol switching $rate_{a,t}$* SR

Smokers, whether using menthol or non-menthol, who switch to NVP use are assumed to permanently switch, i.e., they do not switch back. However, they may quit NVPs by NVP cessation rates, assumed to be at the same rate as for the overall smoking cessation rates in the 2013 version of CISNET data.

Based on the analysis by Cook et al., we consider differential switching rates of 0.9 to 1 for menthol to non-menthol smokers. When SR is 100%, and the menthol and non-menthol switching annual decline rates are same, then above two methods for menthol and non-menthol

switching have the same estimates (i.e. menthol switching rates = non-menthol switching rates = overall switching rates). We conduct a sensitivity analysis for different levels of switching and rate of decline parameters. The revised model is shown in Figure S2.1.

Validation of the Menthol Model

We first validated the Menthol Status Quo Model (MSQM) against the Pre-menthol model (PMM) in steps, by comparing whether the menthol and non-menthol smoking prevalence in model by age and gender is consistent with the previous pre-menthol model, i.e., sum of menthol and non-menthol smoking prevalence in MSQM= smoking prevalence in the PMM. The overall smoking prevalence (the sum of menthol and non-menthol prevalence) by age and gender in the Menthol Status Quo Model (MSQM) and the Pre-menthol model (PMM) were same during 2013-2060. The overall vaping prevalence (the sum of exclusive NVP use and former smokers who use NVPs) in two models were also the same.

With CR=0.8 and SR=0.9, the male (female) menthol prevalence for ages 18 and above falls to 6.6% (5.7%) in 2018 (relative reduction of 20.0% (18.4%) from 2013), while the non-menthol prevalence falls to 10.1% (6.8%) in 2018 (relative reduction of 23.7% (23.4%) from 2013). For ages 18-24, the male (female) menthol prevalence falls to 3.5% (3.2%) in 2018 (relative reduction of 50.1% (48.4%)), while the non-menthol prevalence falls to 5.8% (3.9%) in 2018 (relative reduction of 55.2% (55.4%)). For ages 25-44, the menthol prevalence falls to 8.9% (8.3%) in 2018 (relative reduction of 20.5% (18.0%)), while the non-menthol prevalence falls to 13.2% (8.9%) in 2018 (relative reduction of 18.4% (15.5%)). For ages 45-64, the menthol prevalence falls to 6.9% (6.1%) in 2018 (relative reduction of 11.6% (8.5%)), while the non-menthol prevalence falls to 9.9% (7.5%) in 2018 (relative reduction of 20.7% (21.3%)). For ages 65 and above, the menthol prevalence falls to 3.8% (2.6%) in 2018 (relative reduction of 0.9%

(10.1%)), while the non-menthol prevalence falls to 7.3% (4.3%) in 2018 (relative reduction of 12.9% (18.3%)).

We also considered future trends. Between 2018-2060, the proportion of male (female) menthol smokers increases from 39.7% (45.6%) to 43.1% (52.6%) for ages 18 and above, from 37.9% (44.8%) to 40.7% (50.1%) for ages 18-24, from 40.3% (48.3%) to 41.8% (51.3%) for ages 25-44, from 41.0% (44.8%) to 44.3% (53.9%) for ages 45-64, and from 34.5% (38.3%) to 46.4% (55.3%) for ages 65 and above.

We also check for different levels of the ratio of menthol and non-menthol cessation or switching rates. In all cases, sensitivity analysis show that these changes did not affect the model predictions of overall smoking or vaping prevalence. There were differences in the degree to which menthol prevalence increased over time relative to non-menthol prevalence, but, in all cases, there was an increase over time in the proportion of smokers that smoke menthol cigarettes. These results are consistent with recent studies and the data presented above.

Supplement 2.1. Proportion of Menthol and Non-Menthol Smokers among Smokers in PATH Wave 3 & 4 and TUS 2018-19

		PATH				TUS		Approximate proportion across surveys	
		Wave 3 (N=28,123)		Wave 4 (N=33,611)		2018-2019 (N=136,638)			
		% menthol	% non-menthol	% menthol	% non-menthol	% menthol	% non-menthol	% menthol	% non-menthol
Male	**18-24**	41.0%	59.0%	41.9%	58.1%	35.3%	64.7%	40%	60%
	25-34	44.8%	55.2%	45.2%	54.8%	36.1%	63.9%	45%	55%
	35-44	36.5%	63.5%	39.8%	60.3%	31.9%	68.1%	35%	65%
	45-64	29.5%	70.5%	28.0%	72.0%	25.4%	74.6%	28%	72%
	65+	24.1%	75.9%	25.1%	74.9%	23.7%	76.3%	24%	76%
Female	**18-24**	53.3%	46.7%	52.4%	47.6%	44.1%	55.9%	54%	46%
	25-34	52.8%	47.2%	53.7%	46.3%	52.8%	47.2%	52%	48%
	35-44	39.5%	60.5%	41.0%	59.0%	37.9%	62.1%	40%	60%
	45-64	35.0%	65.0%	36.1%	63.9%	34.9%	65.1%	35%	65%
	65+	33.3%	66.7%	34.2%	65.8%	31.5%	68.5%	33%	67%

Note: Current smokers missing information on their menthol cigarette use are ignored from all current smokers, and the rest are either menthol or non-menthol smokers.

Supplement 2.2. Smoking Cessation Rates of Menthol and Non-Menthol Smokers, PATH Wave 1-4

	Non-Menthol Smoker Cessation				Menthol Smoker Cessation				Ratio of menthol to non-menthol
	N	%	Lower bound	Upper Bound	N	%	Lower bound	Upper Bound	
Age group									
18-24	50	8.6%	6.1%	11.8%	66	11.0%	8.6%	13.8%	1.28
25-34	68	9.4%	7.0%	12.6%	52	7.4%	6.5%	9.7%	0.79
35-54	93	6.0%	4.8%	7.5%	43	4.5%	3.2%	6.2%	0.74
55+	54	7.2%	5.0%	10.2%	20	5.2%	3.3%	8.1%	0.73
Gender									
Female	128	7.4%	6.2%	8.7%	96	6.5%	5.2%	8.1%	0.88
Male	137	7.2%	5.9%	8.8%	85	6.6%	5.4%	8.1%	0.91

Notes:

(1) All estimates based on current established smokers who report past-30-day use, wave 1 N= 11,209;

(2) menthol prevalence at wave t-1 was included (e.g. wave 3 menthol for wave 4 cessation)

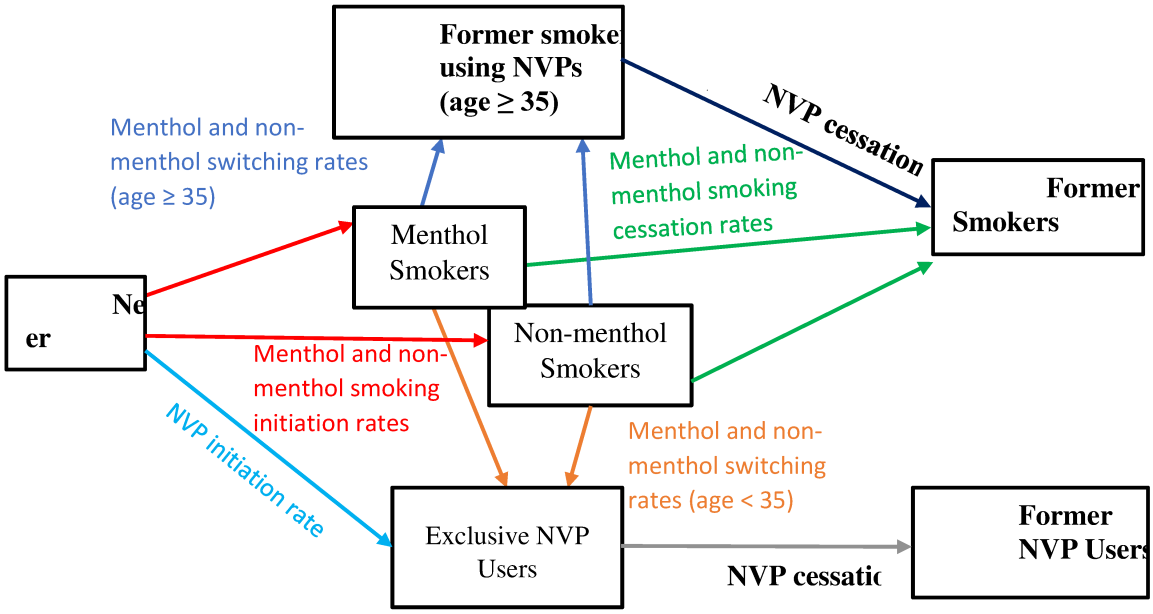
(3) smoking cessation was measured as 'non-current use' at follow-up who reported they 'completely quit smoking cigarettes'

(4) Upper and lower bound are based on 95% confidence intervals.

Supplement 2.3. The Estimated Menthol Proportions by Age Group and Gender

Age	Male	Female	Mid-age
18-24	34.7%	40.1%	21
25-34	40.2%	49.7%	30
35-44	43.4%	51.0%	40
45-64	38.2%	39.0%	55
65-99	26.8%	34.3%	82

Supplement 2.1. Transitions between Smoking and Nicotine Vaping Products (NVPs) Use States in the Menthol Status Quo Scenario



Notes:

1. The overall smoking initiation (menthol + non-menthol) in the Status Quo Scenario is 40% of the smoking initiation rates in the No-NVP Scenario, which was projected using NHIS data before 2013 when no NVP was available, for ages before 25 and 100% for ages after 25. The separation of overall initiation rates to menthol and non-menthol smokers are discussed in the Supplement 2.
2. The NVP initiation in the NVP Scenario is 50% of the smoking initiation rates in the No-NVP Scenario for all ages.
3. The overall cessation rate for menthol and non-menthol smokers in the Status Quo Scenario is 80% of the cessation rates in the No-NVP Scenario for all ages, which was projected using NHIS data before 2013 when no NVP was available. Ninety percent of the cessation rate is assumed for females age 25-54 to improve the fitting of the model. The separation of overall cessation rate for menthol and non-menthol smokers are discussed in the Supplement 2.
4. The cessation rate for NVP users is the same as the smoking cessation rates in the No-NVP Scenario for all ages.
5. The switching rates from male (female) smokers to NVP use before age 35 or former smokers using NVP after age 35 in the NVP Scenario is 8% (5%) for ages 10-17, 4.0% (2.5%) for ages 18-24, 2.5% (2.0%) for ages 25-34, 2.5% (1.6%) for ages 35-44, 1.3% (1.4%) for ages 45-54, 1.2% (1.4%) for ages 55-64, and 0.6% (1.0%) for ages 65 and above.

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Supplement 3. The Menthol Ban Scenario

We consider the impact of a menthol ban that is applied to both cigarettes and little cigars, so that substitution from menthol cigarettes to menthol cigars, especially little cigars, is minimal. We rely on a recent expert elicitation,[1] in which experts were asked to estimate the transitions in regular cigarette and NVP use under a menthol cigarette and cigar ban. We developed and pilot tested a questionnaire that focused on tobacco use transitions of current smokers (age 18-24 menthol, age 35-54 menthol, and age 35-54 non-menthol) and potential menthol smokers (age 12-24).

Expert Selection

We adopted a three-pronged approach to the identification of experts. First, we selected lead and senior authors of studies identified in a scoping review on the impact of menthol and flavor bans.[14] Second, we searched Scopus to identify individuals who were among the most published authors on the topic of menthol tobacco. Similar to the method adopted by the FDA for their expert panel,[21] we selected the top 30 authors identified by Scopus and removed those with an H-Index of <20. Finally, we consulted expert advisors of our FDA-sponsored TCORS 2.0 Center (CAsToR) on their recommendations. We sent invitations to the 12 top-ranked experts requesting their participation. All but one invitee agreed to participate, leaving a final sample of 11 experts.

Elicitation Process

First, we asked the experts to review a compilation of background materials. In the first round, experts completed an online questionnaire using the Qualtrics platform. For the second round, we shared the anonymized responses to the questionnaire along with a summary of the group mean, minimum and maximum for each transition with each participating expert. Experts were given the option of revising their responses, which enabled them to consider others' answers and possibly

Levy DT, *et al. Tob Control* 2021;0:1–8. doi: 10.1136/tobaccocontrol-2021-056604

move toward consensus.[2-4] In addition to their revisions, we also asked experts to indicate their level of confidence for each question (1=not at all to 4=very).

Method Used to Estimate Transitions in the Menthol Ban Scenario

For each age/menthol group, we estimated average net transitions under the ban. Individual net transitions were calculated as the change in use for each product category between the Status Quo and Menthol Ban Scenarios, i.e., the net transitions due to the ban. For example, if an expert indicated that out of 100 menthol smokers, 40 would transition to NNDPs under the status quo and 60 under the menthol ban, then the net transition due to the ban is 20 (=60–40). We then calculated the mean net transition over all 11 experts. While different combustible products were included in the Status Quo and Menthol Ban Scenarios, we aggregated all combustibles (cigarettes and cigars) into a category of total combustibles. Experts were first asked about transitions by those ages 12-24 who would have otherwise initiated into menthol cigarette use. The process allowed for transitions through the age of 30 for initiation. The experts were then asked to estimate the transitions under a ban by menthol smokers at age 18-24 and 35-54, and non-menthol smokers age 35-54 for both genders. The outcomes include "continue to be (illicit) menthol smokers," "switch to non-menthol smoking," "switch to cigar use," "switch to smokeless tobacco use," "switch to NNDP" (novel nicotine delivery products, and "quit" (discontinue any nicotine product use). For the 18-24 and 35-54 years old age groups, experts were asked transitions over a two-year period under the Status Quo (no ban) and under the menthol Ban. In developing the relevant transitions for the model, we use the difference in these transitions for each product category in order to obtain the net change as a result of the ban. In characterizing each of the transitions, illicit menthol cigarette users are retained as menthol smokers, with the same cessation and switching rates as menthol cigarette smokers in the

Menthol Ban Scenario

We consider transitions into cigar use as non-menthol cigarette use to create a change in combustible use. This is a conservative strategy in that the health impacts are similar or less for cigars compared to cigarettes. Since the experts indicated little impact of menthol ban (?) on smokeless use (2% for ages 18-24 and <1% for ages 35-54), those users are assumed to transfer to non-menthol cigarette use (a conservative strategy). Although the survey also allowed for switching to heated tobacco and HTP risks are similar to NVPs, transfers to NNDP use are assumed to all be into NVP use. While compiling the inputs from 11 experts, one expert gave anomalous response that "most menthol smokers will switch to non-menthol cigarette, NVP and smokeless tobacco in the status quo scenario" and "most menthol smokers will switch to non-menthol cigarettes, and those who would switching to NVPs, smokeless or quit smokers will allow switch to non-menthol cigarette". Since his response deviates greatly from the rest of the experts, his response was removed from the sample.

Based on estimates from the experts for would-be menthol smokers at ages 12-24 in the Menthol Ban Scenario (Table S3.1), we use the mean net transition to model the decomposition of the would-be menthol smokers in the Menthol Ban Scenario (Figure S3.1 below). The transitions are multiplied by the former menthol initiation rate at each age for each gender through age 40, where M1=2.4% become illicit menthol smokers, M2=38.3% (=30.3%+5.6%+2.4%) become non-menthol smokers (including non-menthol cigar users and smokeless users), M3=17.3% become NVP users, and the remaining 42.0% are transferred back to never smokers. Never smokers are kept in a separate permanent never smoker category, so that they do not later initiate into the NVPs use and smoking. This allows for increased initiation of non-menthol smoking and vaping. The same level

of transitions of would-be menthol smokers is assumed in all future years after the menthol ban, thus leading to increasing effects of a ban over time.

For transition rates from current menthol smokers (ages 18-24 and ages 35-54) in the Menthol Ban Scenario (see Figure S3.2), we do not directly apply experts' estimates for the Menthol Ban Scenario because of their dependence on the Status Quo scenario. Instead, we use the difference between experts' estimate in the Status Quo and the menthol ban scenarios to re-distribute would-be menthol smokers in the Menthol Ban Scenario. These transitions are in terms of direct transitions in prevalence. While transitions in the expert elicitation are within a two-year period, we assume the original change in prevalence takes place in the first year for simplicity. That change is maintained over time subject to the cessation rates of the respective products. After the first year of menthol ban when a sudden reduction in the menthol smoking prevalence is incorporated, all the remaining menthol smokers become illicit menthol smokers but their cessation rate and switching rate to NVP use in the following years are assumed to be the same as what were assumed for menthol smokers in the Menthol Status Quo Scenario and no switching to non-menthol smokers anymore. Consequently, a menthol ban continues to have long term effects (in future years) through the increased (Status Quo) cessation rate of non-menthol smokers who have switched from menthol(?) smoking.

Based on the expert data for menthol smokers ages 18-24 (Table S3.2), we estimated the difference between the Status Quo scenario and the Menthol Ban Scenario and computed the increment of each group relative to the diminished menthol cigarette smokers as shown in Figure S.3.2. Based on the expert elicitation, 10.1% switch to illicit menthol cigarettes or cigars, 48.0% (43.8%+0.9%+3.3%) switch to non-menthol cigarettes, 24.2% switch to NVPs and 17.7% quit. These transitions are multiplied by the menthol cigarette smokers prevalence at each age by gender.

While the expert elicitation was in terms of ages 18-24, we allowed the transitions to occur through age 30. Thus, the transitions from current menthol smokers ages 18-30 are modelled as a one-time change.

The transition rate for menthol smokers ages 35-54 (Table S3.3) is obtained based on experts' estimates of the difference between the Status Quo and Menthol Ban Scenario for those ages 35-54. As shown in Table S3.3, 8.8% switch to illicit menthol cigarettes or cigars, 59.2% (54.5%+3.7%+1.0%) switch to non-menthol cigarettes, 17.3% switch to NVPs and 14.7% quit. These transitions are multiplied by the menthol cigarette smokers prevalence by age and gender. While the expert elicitation was in terms of ages 35-54, we allowed the transitions to all menthol smokers above age 30.

For the transition rate from non-menthol smokers age 35-54 in the Menthol Ban Scenario, we allow for no change compared to the rate in the Status Quo Scenario based on the results in Table S3.4.

Table S.3.1. Transitions of Ages 12-24 Who Would Have Initiated as Menthol Smokers Under a Menthol Ban, in Percentage Terms (out of 100 age 18-24 menthol smokers in the Status Quo)

Population	**Status Quo**	**Total Population with Menthol Ban**			
Product Type	**Mean/ Median**	**Mean**	**Median**	**Min**	**Max**
Become **non-menthol cigarette** users (exclusively or with other products)	0	30.3	25.0	1.9	79.0
Become **non-menthol cigar** users (exclusively or with other products, but not cigarettes)	0	5.6	2.0	0.0	20.0
Become **illicit menthol cigarette or cigar user**	0	2.4	1.0	0.0	10.0
Total combustible use (status quo all menthol cigarettes)	100	38.3	35.0	3.5	83.0
Become exclusive **smokeless tobacco or other oral** tobacco product users	0	2.4	2.0	0.0	5.0
Become novel nicotine delivery product users **(NNDP),** such as e-cigarettes or heated tobacco products (exclusively or in combination with other products, but not cigarettes or cigars)	0	17.3	20.0	3.4	25.0
No tobacco or novel nicotine delivery product **use**	0	42.0	41.0	6.0	92.3

Table S.3.2. Transitions of age 18-24 Menthol Smokers in the Status Quo and Menthol Ban Scenarios in Percentage Terms (out of 100 age 18-24 menthol smokers in the Status Quo)

Population	**Status Quo**	**Menthol Cigarette and Cigar Ban**	**Net Effect**	**Final Transition as a Percent of Menthol Smokers in the Status Quo**
Product Type	**Mean**	**Mean**	**Absolute difference**	**Percent of 71.2%**
Continue to be menthol cigarette smokers (exclusively or with other products)	71.2	-	-71.2	
Switch to non-menthol cigarettes (exclusively or with other products, except menthol cigarettes)	5.6	36.8	31.2	43.8% (31.2/71.2)
Switch to cigars, especially little cigars, filtered cigars, or cigarillos (exclusively or with other products, but not cigarettes)	3.4	-	0.7	0.9% (0.7/71.2)
Switch to non-menthol cigars, especially little cigars, filtered cigars or cigarillos (exclusively or with other products, but not cigarettes)	-	4.1		
Switch to illicit menthol cigarette or cigar use	-	7.2	7.2	10.1% (7.2/71.2)
Switch to exclusive smokeless tobacco or other oral tobacco products	1.7	4.1	2.4	3.3% (2.4/71.2)
Switch to novel nicotine delivery products (NNDP), such as e-cigarettes or heated tobacco products (exclusively or in combination with other products, but not cigarettes or cigars)	8.3	25.5	17.2	24.2% (17.2/71.2)
Quit regular use of all tobacco or novel nicotine delivery products	9.8	22.4	12.6	17.7% (12.6/71.2)

Table S3.3. Transitions of Age 35-54 Menthol Smokers in the Status Quo and Menthol Ban Scenarios in Percentage Terms (out of Age 35-54 100 menthol smokers in the status quo)

Population	Status Quo	Menthol Cigarette and Cigar Ban	Net Effect	Final Transition as a Percent of Menthol Smokers in the Status Quo
Product Type	**Mean**	**Mean**	**Absolute difference**	**Percent of 71.2%**
Continue to be menthol cigarette smokers (exclusively or with other products)	71.2	-	-71.2	
Switch to non-menthol cigarettes (exclusively or with other products, except menthol cigarettes)	4.5	43.3	38.8	54.5% (38.8/71.2)
Switch to cigars, especially little cigars, filtered cigars, or cigarillos (exclusively or with other products, but not cigarettes)	1.5	-		
Switch to non-menthol cigars, especially little cigars, filtered cigars or cigarillos (exclusively or with other products, but not cigarettes)	-	4.1	2.6	3.7% (2.6/71.2)
Switch to illicit menthol cigarette or cigar use	0.0	6.3	6.3	8.8% (6.3/71.2)
Switch to exclusive smokeless tobacco or other oral tobacco products	1.9	2.6	0.7	1.0% (0.7/71.2)
Switch to novel nicotine delivery products (NNDP), such as e-cigarettes or heated tobacco products (exclusively or in combination with other products, but not cigarettes or cigars)	8.2	20.5	12.3	17.3% (12.3/71.2)
Quit regular use of all tobacco or novel nicotine delivery products	12.7	23.2	10.5	14.7% (10.5/71.2)

Table S.3.4. Transitions of Non-Menthol Smokers at Age 35-54 in The Status Quo and Menthol Ban Scenario

Population	Status Quo	Menthol Cigarettes and Cigars Ban	Absolute difference
Product Type	**Mean**	**Mean**	
Switch to be menthol cigarette smokers (exclusively or with other products)	2.3	-	-2.3
Continue to smoke non-menthol cigarettes (exclusively or with other products, except menthol cigarettes)	75.3	76.9	1.6
Switch to cigars, especially little cigars, filtered cigars, or cigarillos (exclusively or with other products, but not cigarettes)	0.8	-	-0.8
Switch to non-menthol cigars, especially little cigars, filtered cigars or cigarillos (exclusively or with other products, but not cigarettes)	-	1.1	1.1
Switch to exclusive smokeless tobacco or other oral tobacco products	1.8	1.7	-0.1
Switch to novel nicotine delivery products (NNDP), such as e-cigarettes or heated tobacco products (exclusively or in combination with other products, but not cigarettes or cigars)	8.4	8.5	0.1
Quit regular use of all tobacco or novel nicotine delivery products	11.4	11.8	0.4

Figure S.3.1: Transitions from Never Smokers in the Menthol Ban Scenario

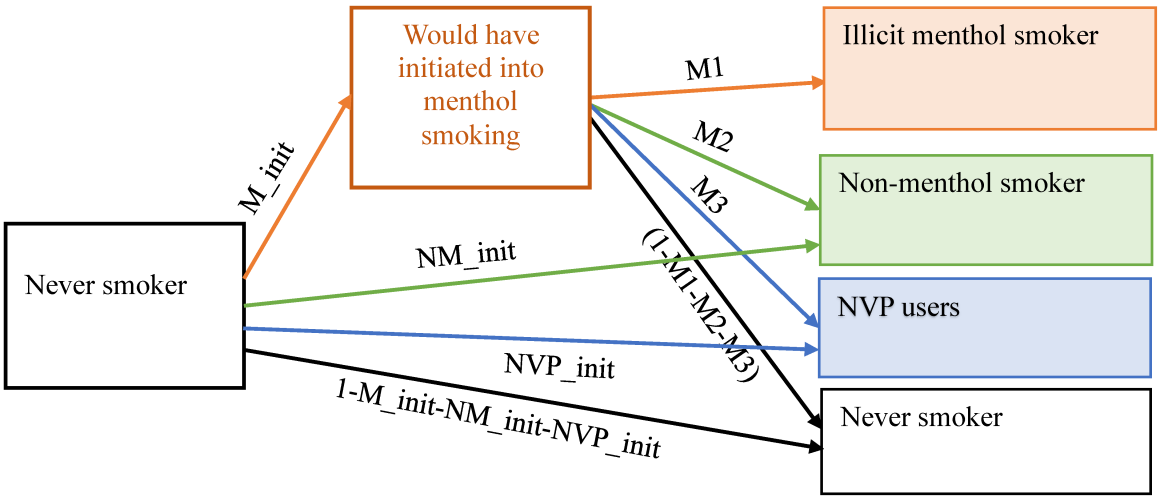
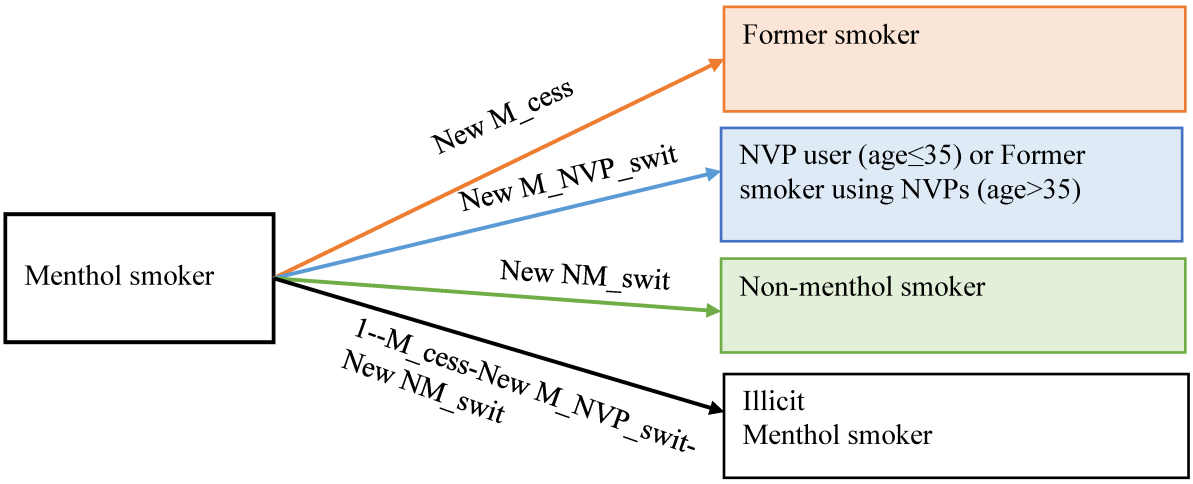


Figure S.3.2 Transitions from Menthol Smoker in the Menthol Ban Scenario



Supplement 4. Results of the Menthol Status Quo and Menthol Ban Scenarios by Gender

Public Health Impact under the Base Case Status Quo and Menthol Ban Scenarios

Table S4.1 presents the 2021-2060 US menthol and non-menthol smoking and NVP prevalence, deaths, and LYLs for males and females ages 18-99. Results from 2026 and 2060 are presented to display short-term and long-term changes. The results are generally greater in relative terms for females due to their higher rates of menthol cigarette use relative to total cigarette use.

Under the Status Quo Scenario, adult (ages $\geq$18) menthol smoking prevalence declines from 5.8% in 2021 to 4.7% in 2026 and 2.5% in 2060 for males and from 5.1% in 2021 to 4.3% in 2026 and 2.3% in 2060 for females, while non-menthol smoking prevalence declines from 8.5% in 2021 to 6.7% in 2026 and 3.2% in 2060 for males and from 5.8% in 2021 to 4.6% in 2026 and 2.1% in 2060 for females. Cumulative SVADs include 10.0 million males and 4.2 million females, translating to 102.1 million male and 41.2 million female LYLs.

Under the Menthol Ban Scenario, adult menthol smoking prevalence declines to 0.4% in 2026 and 0.1% in 2060 for males and to 0.3% in 2026 and 0.1% in 2060 for females, while non-menthol smoking prevalence increases to 9.6% in 2026 and declines to 4.8% in 2060 for males and to 7.2% in 2026 and 3.6% in 2060 for females. Cumulative SVADs include 9.7 million males and 3.9 million females, translating to 95.2 million male and 36.8 million female LYLs.

By 2060, combined menthol and non-menthol smoking prevalence falls from 5.7% under the status quo to 4.9% with a menthol ban for males (a 13% relative reduction) and from 4.5% to 3.7% for females (17% reduction). The 2060 NVP prevalence under the status quo and menthol ban are 6.7% and 8.5% for males (25% increase) and 4.5% and 5.8% for females (28% increase). Cumulative SVADs are reduced in relative terms by 4.6% (0.4 million males; 0.3 million females),

and LYLs are reduced by 7.9% (6.9 million males; 4.4 million females).

Sensitivity analysis by Gender

Table S4.2 contains the sensitivity analysis broken down by gender. The impacts are of the same sign and similar in magnitude by gender.

Supp 4..1. Smoking and NVP Prevalence, Smoking and Vaping Attributable Deaths, Life-Years Lost and Public Health Impact, By Gender, Ages 18 and Above, 2021-2060

Status Quo Scenario									
		MALE				FEMALE			
Category	Category/Year	2021	2026	2060	Cumulative Impact*	2021	2026	2060	Cumulative Impact*
Prevalence	Never smoker	59.7%	62.1%	72.2%	20.9%	68.6%	70.1%	78.3%	14.2%
	Menthol smoker	5.8%	4.7%	2.5%	-57.3%	5.1%	4.3%	2.3%	-53.9%
	Nonmenthol smoker	8.5%	6.7%	3.2%	-61.8%	5.8%	4.6%	2.1%	-63.9%
	All Smokers	14.3%	11.5%	5.7%	-60.0%	10.9%	9.0%	4.5%	-59.2%
	Former smoker	21.3%	19.9%	9.5%	-55.4%	17.6%	17.0%	8.9%	-49.6%
	Exclusive NVP user	3.2%	4.4%	6.7%	109.6%	1.9%	2.6%	4.5%	140.7%
	Former smoker-NVP user	1.2%	1.4%	0.3%	-74.4%	0.8%	0.9%	0.2%	-79.5%
	All NVP users	4.5%	5.8%	7.0%	58.3%	2.7%	3.5%	4.6%	73.3%
	Former NVP user	0.3%	0.7%	5.5%	1868%	0.2%	0.4%	3.7%	2132.0%
Smoking and vaping attributable deaths	Menthol smoker	51,083	48,519	23,865	1,522,092	26,372	25,616	15,554	880,187
	Nonmenthol smoker	83,797	72,531	26,320	1,990,971	38,445	33,593	11,602	918,274
	Former smoker	135,834	144,048	138,524	6,212,810	39,964	45,443	53,843	2,288,041
	Exclusive NVP user	19	121	3,985	60,509	0	7	1,228	14,897
	Former smoker-NVP user	3,595	5,243	4,630	241,155	1,416	1,926	1,190	75,546
	Former NVP user	0	0	1,512	11,600	0	0	204	1,212
	Total	274,328	270,461	198,836	10,039,137	106,198	106,585	83,621	4,178,156
Life-years lost	Menthol smoker	899,390	825,693	343,306	24,361,382	435,860	416,319	212,825	13,485,248
	Nonmenthol smoker	1,353,358	1,149,146	409,599	31,561,363	596,145	506,597	172,211	13,560,658
	Former smoker	1,057,982	1,100,435	780,242	40,765,617	265,265	304,025	270,173	12,730,946
	Exclusive NVP user	809	4,870	99,586	1,814,641	12	301	30,921	433,456
	Former smoker-NVP user	64,156	89,255	39,988	3,302,218	21,659	28,449	10,747	944,031
	Former NVP user	0	2	28,428	254,156	0	0	3,682	24,560
	Total	3,375,694	3,169,401	1,701,148	102,059,376	1,318,941	1,255,691	700,559	41,178,899

Menthol Ban Scenario									
		MALE				FEMALE			
Category	**Category/Year**	**2021**	**2026**	**2060**	**Cumulative Impact ***	**2021**	**2026**	**2060**	**Cumulative Impact ***
Prevalence	**Never smoker**	59.7%	61.7%	70.0%	17.2%	68.6%	69.9%	76.9%	12.1%
	Menthol smoker	5.8%	0.4%	0.1%	-98.5%	5.1%	0.3%	0.1%	-98.4%
	Nonmenthol smoker	8.5%	9.6%	4.8%	-42.9%	5.8%	7.2%	3.6%	-38.3%
	All Smokers	14.3%	9.9%	4.9%	-65.4%	10.9%	7.5%	3.7%	-66.3%
	Former smoker	21.3%	20.6%	9.6%	-55.0%	17.6%	17.6%	8.9%	-49.4%
	Exclusive NVP user	3.2%	5.0%	8.5%	164.7%	1.9%	3.1%	5.8%	210.9%
	Former smoker-NVP user	1.2%	7.0%	8.8%	-73.5%	0.8%	1.4%	6.0%	-77.4%
	All NVP users	4.5%	2.5%	0.3%	98.2%	2.7%	4.5%	0.2%	122.6%
	Former NVP user	0.3%	0.7%	6.6%	2260.8%	0.2%	0.5%	4.5%	2663.1%
Smoking and vaping attributable deaths	**Menthol smoker**	51,083	4,409	1,515	172,510	26,372	2,383	1,043	98,958
	Nonmenthol smoker	83,797	102,113	37,211	2,790,339	38,445	49,186	18,167	1,367,181
	Former smoker	135,834	145,339	141,001	6,303,873	39,964	45,759	54,744	2,316,726
	Exclusive NVP user	19	121	4,578	68,087	0	7	1,466	17,568
	Former smoker-NVP user	3,595	7,769	5,295	310,429	1,416	2,871	1,520	103,390
	Former NVP user	0	0	1,662	12,641	0	0	233	1,369
	Total	274,328	259,751	191,262	9,657,880	106,198	100,206	77,173	3,905,192
Life-years lost	**Menthol smoker**	899,390	73,193	18,326	2,695,009	435,860	38,484	12,230	1,479,148
	Nonmenthol smoker	1,353,358	1,647,004	575,978	44,419,838	596,145	756,752	265,542	20,506,821
	Former smoker	1,057,982	1,117,480	791,117	41,581,500	265,265	307,513	274,077	12,949,902
	Exclusive NVP user	809	4,888	116,538	2,056,349	12	301	37,215	513,526
	Former smoker-NVP user	64,156	126,070	43,145	4,129,424	21,659	41,963	12,905	1,288,841
	Former NVP user	0	2	31,561	278,770	0	0	4,257	28,071
	Total	3,375,694	2,968,636	1,576,663	95,160,891	1,318,941	1,145,014	606,226	36,766,308

Difference between Menthol Status Quo and Menthol Ban Scenario									
Relative Reduction in Prevalence**	**Menthol Smoker**	-	-92.5%	-96.5%	-	-	-92.5%	-96.5%	-
	Nonmenthol Smoker	-	42.1%	49.6%	-	-	54.8%	70.7%	-
	All Smokers	-	-13.6%	-13.4%	-	-	-16.0%	-17.3%	-
	Exclusive NVP user	-	19.3%	25.2%	-	-	27.8%	28.5%	-
Gain***	**Averted Deaths**	-	10,710	7,575	381,257	-	6,378	6,448	272,964
	Averted life-years lost	-	200,764	124,484	6,898,485	-	110,676	94,333	4,412,592

Notes: NVP= nicotine vaping product, All smokers = combined menthol and non-menthol smokers. All NVP users= combined exclusive NVP user and Former smoker-NVP * The cumulative impact is measured in terms of the relative change from 2021-2060 for prevalence rates (i.e., (2060-2021)/2021) and the sum of the smoking and vaping attributable deaths or life years lost over the years 2021 through 2060. ** Relative reduction in prevalence is measured as the relative difference between the menthol status quo scenario and the menthol ban scenario, (i.e. (post ban – pre ban)/pre ban) in year 2026 and 2060. ***The gain is measured as the increase in the averted deaths and life-years lost from menthol status quo scenario to the menthol ban scenario.

Table S4.2. Sensitivity analysis of averted Smoking- and Vaping-Attributable Deaths and Life-Years Lost to NVP relative risks and individual transition parameters, by Gender, All ages, 2021-2060

Smoking- and Vaping-Attributable Deaths Averted by Menthol Ban					
Case	**Description**	**Males**	**% change***	**Females**	**% change***
1	Base Case	381,257		272,964	-
2	5% instead of 15% NVP risk	401,885	5.4%	285,324	4.5%
3	25% instead of 15% NVP risk	361,376	-5.2%	261,049	-4.4%
4	Increase overall smoking cessation rates by 50%	279,726	-26.6%	180,033	-34.0%
5	Reduce overall smoking initiation rates by 50%	355,050	-6.9%	262,526	-3.8%
6	Increase non-menthol cessation rates annually by 10%	490,326	28.6%	355,647	30.3%
7	Menthol cessation rate same as non-menthol rate	278,416	-27.0%	182,589	-33.1%
8	Increase NVP cessation rates by 50%	389,592	2.2%	279,174	2.3%
9	Increase NVP initiation rates by 100%	379,671	-0.4%	272,445	-0.2%
10	Menthol switching rate same as non-menthol rate	369,610	-3.1%	267,287	-2.1%
11	Increase overall switching rate by 50%	334,455	-12.3%	246,839	-9.6%
12	Reduce the annual decline in switching rate from 10% to 0%	286,893	-24.8%	217,731	-20.2%
Smoking- and Vaping-Attributable Life-Years Lost Averted by Menthol Ban					
1	Base Case	6,898,485		4,412,592	-
2	5% NVP risk	7,302,214	5.9%	4,621,900	4.7%
3	25% NVP risk	6,501,249	-5.8%	4,206,515	-4.7%
4	Increase overall smoking cessation rates by 50%	5,354,899	-22.4%	3,135,741	-28.9%
5	Decrease overall smoking initiation rates by 50%	6,039,512	-12.5%	4,090,267	-7.3%
6	Increase non-menthol cessation rates annually by 10%	8,512,072	23.4%	5,503,745	24.7%
7	Menthol cessation rate same as non-menthol rate	5,376,649	-22.1%	3,200,564	-27.5%
8	Increase NVP cessation rates by 50%	7,036,248	2.0%	4,500,279	2.0%
9	Increase NVP initiation rates by 100%	6,845,769	-0.8%	4,395,641	-0.4%
10	Menthol switching rate same as non-menthol rate	6,656,080	-3.5%	4,313,941	-2.2%
11	Increase overall switching rate by 50%	5,967,457	-13.5%	3,971,355	-10.0%
12	Reduce the annual decline in switching rate from 10% to 0%	5,049,036	-26.8%	3,478,404	-21.2%

Notes: NVPs= nicotine vaping products, % change is in terms of the relative difference from the base case, (e.g., (687,209-654,221)/654,221 for case 2 relative to case 1.

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