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Original Investigation

A Magic Bullet? The Potential Impact of E-Cigarettes on the Toll of Cigarette Smoking

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Abstract

Introduction: We examine the proportion of US smoking-produced mortality that e-cigarettes might eliminate under assumptions regarding vaping's ability to increase smoking cessation, vaping's health risks, and the possibility that vaping will increase smoking among young people.
Methods: We employ a dynamic population simulation model that tracks individuals from ages 0 to 110, differentiated by gender and smoking status. Using data from the US Census, the National Vital Statistics Reports, Cancer Prevention Study II, and the National Health Interview Survey, we estimate the number of smoking-related life-years lost (LYL) from 2018 to 2100 in a no-vaping scenario. We then compare results for model runs that assess the impact of vaping under a variety of assumptions.
Results: The combination of assumptions produces 360 possible scenarios. 357 (99%) yield positive estimates of life-years saved (LYS) due to vaping by 2100, from 143 000 to 65 million. Most scenarios result in millions of individuals quitting smoking due to vaping. On average, vaping-induced quitters gain an extra 1.2–2.0 years of life compared to smokers who quit without vaping. The impact of vaping is greatest when it most helps smokers who otherwise have the greatest difficulty quitting smoking. While the numbers of LYS are generally large across all scenarios, they often represent a small fraction of the toll of smoking.
Conclusions: Vaping is highly likely to reduce smoking-produced mortality. Still, vaping is not "the" answer to the public health crisis created by smoking. Rather, it may well be a tool to add to the armamentarium of effective tobacco control measures.
Implications: E-cigarettes hold the potential to reduce cigarette smoking's enormous toll. By itself, however, tobacco harm reduction, as embodied in vaping, is no magic bullet. Going forward, tobacco control will require vigilant application of the evidence-based measures that have brought us so much success in combatting smoking. It will require, as well, the search for and adoption of novel means of attacking the remaining problem. Harm reduction can, and many would say should, be a part of the complex formula that will eventually bring about the demise of smoking.

Introduction

E-cigarettes are highly controversial. To supporters, e-cigarettes hold the potential to substantially reduce the toll of smoking. They believe that e-cigarettes pose only a small fraction of smoking's risks, that vaping helps adult smokers to quit smoking, and that it may even assist some youth to avoid or to quit smoking.[1,2] To opponents, e-cigarettes threaten to expand nicotine addiction and renormalize smoking, especially among youth. Opponents note that nicotine can harm young people's developing brains and worry that vaping's health risk substantially exceeds the relatively minor risk touted by supporters. Many opponents do not believe that vaping aids smokers in quitting.[3]

Do e-cigarettes help adult smokers to quit smoking? Recent evidence suggests they do.[1] Population studies have found that vaping has increased smoking cessation in both the United Kingdom and the United States, particularly among frequent vapers.[1,4–10] In both countries, e-cigarettes are now the most commonly used smoking cessation aid.[11,12] A recent randomized trial in three British National Health Service smoking cessation service sites found vaping nearly twice as effective as nicotine replacement products in smoking cessation.[13] Another recent trial in New Zealand found nicotine e-cigarettes, combined with nicotine patch, significantly more effective than either a nicotine-free e-cigarette combined with patch or patches alone[14] (see the supplementary appendix to Hajek et al.[13] for a review of other clinical trials).

Assessment of the magnitude of e-cigarettes' potential contribution to reducing smoking's death toll has been limited. Several studies have simulated the effects of vaping, including a recent paper of our own.[15] Lee and colleagues review the models used in most of those studies, as well as the differences and similarities among them.[16] The unique contribution of the present study (and the model we employ) is that it is the only one that considers variation in all of the following: the risk of vaping relative to that of smoking; how much vaping increases smoking cessation; the impact of vaping on smoking initiation; how e-cigarettes might impact different individuals with dissimilar ability to quit smoking; and patterns of background smoking cessation rates by age (ie, cessation rates independent of vaping). In some instances, this is the first analysis to examine certain questions about vaping. Most notably, it is the first to assess the impacts of vaping's differentially affecting smoking cessation among smokers with greater or less difficulty quitting. The multiple variables we consider, producing 360 distinct scenarios, make this study the most comprehensive analysis to date of the potential consequences of e-cigarettes at the population level.

One of the prominent simulation studies, by Levy and colleagues, estimated that the nearly complete transition from smoking to e-cigarettes within a decade in the United States could avoid the premature loss of 6.6 million lives and save 86.7 million life-years by the end of the century.[17] The present study complements the work of these analysts. Rather than assuming replacement of smoking by vaping, however, we examine the proportion of US smoking-produced mortality that e-cigarettes might eliminate under a variety of assumptions about how much vaping might increase smoking cessation, along with variation in the other variables just mentioned.

In addition to e-cigarettes, other non-pharmaceutical reduced-risk nicotine delivery products are also being marketed, including heated tobacco products[18] and low-nitrosamine smokeless tobacco products like snus.[19] While we refer to e-cigarettes in this paper, e-cigarettes should be construed as representing the broader category of reduced-risk products, both existent and yet to be introduced.

Methods

Background Simulation Model

We employ a dynamic population simulation model that tracks individuals from age 0 to 110, differentiated by gender and smoking status. The number of individuals of age *a* in year *t* is computed by multiplying the number of people of age *a-1* in year *t-1* by the appropriate age-and-gender-specific survival rate (1 – death rate). Census data provide birth cohort sizes.[20] Age- and-gender-specific death rates come from the National Vital Statistics Reports.[21] We differentiate death rates by smoking status (including, for former smokers, years-quit, up to 30 years) using findings from Cancer Prevention Study II.[22] The model tracks adult population smoking status (with adults defined as age ≥18 years), with initial age- and gender-specific smoking rates drawn from the National Health Interview Survey (NHIS).[23] At age 18, individuals are characterized as current or never smokers. Current smokers have smoked ≥100 cigarettes lifetime and currently smoke some days or every day. After 18, current smokers are estimated as the number of previous-year current smokers who survived to the current year and did not quit smoking. Former smokers are those who were previous-year former smokers and did not die, plus those who were previous-year current smokers, quit smoking, and did not die.

We define the smoking initiation rate (independent of vaping) as the smoking prevalence of 18-year-olds (7.8% in 2018).[24] No initiation after age 18 is considered. Those who become smokers before 18 are included in the 18-year-olds' prevalence (and hence in the initiation rate). The annual smoking cessation rate (independent of vaping), 4.35%, was estimated from a recent application of this model.[25] It is the permanent cessation rate (ie, net of relapse). The model assumes that no smoking-related deaths occur before age 35, consistent with the CDC methodology for computing smoking attributable deaths.[26] We have used the model frequently in previous research.[15,27–32] The model has proven accurate in predicting US smoking prevalence.[29,32]

Simulation Analysis

We first estimate the US population under two reference scenarios: a *status-quo scenario*, assuming no e-cigarette use and maintaining smoking initiation and quit rates at 2017 levels through 2100; and a *never-smoking scenario*, assuming no one ever smoked and hence there was no smoking-related mortality (ie, all individuals are subject to never-smoker death rates). The difference between the never-smoking and status-quo scenarios estimates total life-years lost (LYL) due to smoking in the absence of vaping.

We then estimate e-cigarettes' population health impact as life-years saved (LYS) or lost (LYL) under a variety of assumptions described below. For each combination of assumptions (each combination constituting a single e-cigarette scenario), we project the US population size by smoking status for each year, and every year of age, from 2018 to 2100. The annual difference in population size between each e-cigarette scenario and the status-quo scenario provides that year's estimated vaping-related LYS or LYL. Cumulative LYS or LYL are calculated by adding annual estimates. We estimate cumulative LYS or LYL through 2100. We also express LYS or LYL as fractions of the relevant year's cumulative smoking death toll in the status-quo scenario.

Finally, we compute the average LYS for vaping-induced quitters (whom we refer to as "e-quitters") in a similar manner but stopping smoking initiation in 2017 and aging the existing population of smokers in 2018 until they are all deceased to capture all the benefit from quitting smoking.

Variables Held Constant Across All E-Cigarette Scenarios

Table 1 identifies the study's principal variables. For the first three, we apply the same values to all e-cigarette scenarios. The annual background smoking cessation rate and the initiation rate (variables 1 and 2, respectively) are held constant through the year 2100. Because vaping might have different smoking cessation effects on different types of smokers, we classify smokers by their inherent ability to quit smoking independent of e-cigarettes (and independent of age)

Table 1. Variables in E-Cigarette Impact Simulations[a]

Variable	Value(s)
1. Overall background smoking cessation rate (independent of vaping)	4.35%
2. Background smoking initiation rate (independent of vaping)	7.8%
3. Ease of quitting smoking without vaping	• Harder than average difficulty (25% of smokers; 2.18% background quit rate) • Average difficulty (50% of smokers; 4.35% background quit rate) • Easier than average difficulty (25% of smokers; 6.53% background quit rate)
4. Impact of vaping on smoking cessation rate	Increase background rate by 10%, 25%, 50%, 100%, or 200%
5. Impact of vaping on smoking initiation rate	Increase the background rate by 0% or 10%
6. Health risk of vaping compared to smoking	Reduces former smokers' annual mortality-reduction benefit (compared to continued smoking) by 0%, 5%, 10%, or 20%
7. Vaping most assists which types of smokers in quitting smoking	Values vary depending on overall impact of vaping on the smoking cessation rate; see text
8. Relationship between smoking cessation rate (without vaping) and age	Rate rises with age, constant across ages, or falls with age

[a]See text for explanation of variables and their values.

(variable 3). For simplification, we categorize 50% of smokers as having an average difficulty quitting smoking ("average-quitters"), 25% finding quitting easier than average ("easy-quitters"), and 25% finding it harder than average ("hard-quitters"). We assign the estimated annual population quit rate to the average-quitters group (4.35%), and increase and decrease that estimate by 50% to obtain the cessation rate values for the easy-quitters and hard-quitters (6.53% and 2.18%, respectively).

Variables That Define Unique E-Cigarette Scenarios

Each unique e-cigarette scenario represents a different combination of the values of variables 4–8 in Table 1:

4. *Impact of vaping on cessation*: Given our interest in the potential public health contribution of vaping, we do not consider that vaping might have no effect on smoking cessation or a negative effect. A 10% cessation rate increase reflects a conservative estimate of what has been achieved to date.[4,5,10,15] Larger increases allow assessment of vaping's potential benefit. In the Results section, we report selected findings for all values except 200% (see Supplementary Table S1 for all values, including 200%). Note that each value represents an increase in the overall population cessation rate. However, only a fraction of smokers use vaping in quit attempts. Vaping will thus boost their cessation rates by more than the indicated rate increase. For example, with a 10% population-wide increase, if a tenth of smokers used e-cigarettes in quit attempts, their cessation rate would increase by 100%, while other quit attempts would be unaffected. A recent controlled trial found that vaping increased the odds of quitting by nearly 100% compared to nicotine replacement products.[13]
5. *Impact of vaping on initiation*: Prospective studies have found that vaping by never-smoking students increases their likelihood of trying cigarettes.[33–35] Half of our e-cigarette scenarios assume an annual initiation increase of 10%, an intentionally very liberal allowance for the possible impact on initiation (the selection of this figure is explained in the Supplementary Material). Because the vaping-smoking initiation relationship may be spurious,[36] and because rapid declines in students' smoking rates during the vaping era are inconsistent with vaping's increasing smoking,[37] the other half of the e-cigarette scenarios assume no impact of vaping on subsequent smoking.
6. *Health risk of vaping compared to smoking*: Because vaping carries some thus far ill-defined risk to health, if likely substantially less than that of smoking,[1] we assume that smokers who quit by vaping incur an elevated mortality risk compared to smokers who quit without vaping. The values we employ are applied to all smokers who quit smoking using e-cigarettes and thus should be construed as the average risk experienced by vaping-aided smoking cessation. It is not the risk associated with vaping for a lifetime instead of smoking for a lifetime. Some smokers who quit by vaping will vape well into the future (possibly for a lifetime); some will vape only briefly. The latter might experience little to no vaping-associated risk, while the former would experience a much higher risk. Thus, for example, a 10% risk in the model represents a much higher risk incurred by long-term vapers (eg, 20%–30%) and a much lower risk for those who quit vaping shortly after quitting smoking. As such, our risk level of 5% represents a considerably higher risk for long-term vapers than does the ≤5% risk identified by UK health authorities, including Public Health England[38] and the Royal College of Physicians.[39] Because we do not believe that vaping is risk-free, in the Results section below we do not present findings associated with a 0% risk. See Supplementary Table S1 for findings associated with no risk.
7. *Vaping most assists which types of smokers in quitting smoking*: For each potential increase in the overall cessation rate, we perform the analysis assuming one of three conditions (in each, average-quitters experience the average cessation increase): (1) vaping benefits hard-quitters but not easy-quitters; (2) all three groups experience the same cessation rate increase; (3) vaping increases easy-quitters' quit rate but not hard-quitters'. The cessation rate increases for hard-quitters in condition (1) and for easy-quitters in condition (3) are selected to preserve the overall cessation rate increase. For details, see the addendum to Supplementary Table S1.
8. *Relationship between smoking cessation rate (without vaping) and age*: Some studies have suggested that the smoking cessation rate increases with age,[27,40] while other research suggests the opposite.[41] The relationship could have changed over time or across cohorts. Thus we test the effects of the cessation rate increasing with age, not varying with age, and decreasing with age. For details, see the addendum to Supplementary Table S1.

Results

LYS assuming no age-related variation in smoking cessation and the vaping-related increase in the smoking cessation rate is the same for all smokers.

Table 2 indicates the life-saving potential, by 2100, of e-cigarettes' increasing smoking cessation by 10%, 25%, 50%, and 100%. Results are given for both the case in which vaping does not affect smoking initiation (columns 3–5) and the case in which it increases initiation by 10% (columns 6–8). Results are presented as LYS (in millions, columns 3 and 6), that number's share (percent) of LYL due to smoking in the absence of vaping (columns 4 and 7), and the number of smokers (in millions) induced to quit by vaping (e-quitters, columns 5 and 8).

Vaping Risk of 5%

The first four rows present findings for a vaping risk of 5% (ie, a 5% reduction in the mortality benefit from quitting smoking without vaping compared to continued smoking). By 2100, a 10% vaping-induced increase in smoking cessation would result in 3.2 million LYS if vaping also increases smoking initiation (first row, column 6) or 5.7 million LYS if vaping does not increase initiation (column 3). These scenarios would reduce smoking's cumulative toll by 2100, which we estimate to be approximately 305 million, by 1.1% or 1.9% (columns 7 and 4, respectively). If vaping increases smoking initiation, 4.1 million smokers will be induced to quit by vaping (column 8). If vaping does not increase initiation, 3.9 million smokers will be e-quitters (column 5). On average, e-quitters from all smokers in 2018 would gain 1.9 years of life compared to smokers who quit without vaping.

In contrast, if vaping increased the smoking cessation rate by 100% (the fourth row), it would generate 37.4 million (column 6) or 39.0 million LYS (column 3), the former if vaping increased smoking initiation, the latter if not. This represents a reduction of smoking's mortality toll of 12.3% or 12.8% (columns 7 and 4, respectively). If vaping increases smoking initiation, 26.9 million smokers will quit by vaping (column 8). With no effect on initiation, 25.7 million smokers will be e-quitters (column 5). E-quitters from all smokers in 2018 would gain 2.0 years of life compared to smokers who quit without vaping.

Vaping Risk of 10% or 20%

The four middle rows present equivalent figures for a vaping risk of 10%, the last four rows for a 20% risk. Within each risk category, LYS are higher when vaping does not increase smoking initiation and LYS rise as the vaping-induced increase in smoking cessation increases. For all sets of cessation/initiation assumptions in the table, LYS is highest for the lowest vaping risk (5%) and lowest for the highest vaping risk (20%). All combinations of assumptions in this table yield positive LYS. All scenarios involve millions of e-quitters (3.9–26.9 million). For all the scenarios in the table, on average e-quitters from all smokers in 2018 would gain from 1.2 to 2.0 years of life compared to smokers who quit without vaping.

The table holds two assumptions constant: The background smoking cessation rate does not vary by smokers' ages, and the vaping-related increase in the smoking cessation rate is the same for all smokers regardless of their general difficulty quitting smoking.

LYS Assuming Variation in Smokers' Difficulty Quitting Smoking

Table 3 presents results for cases that vary the type of smoker most assisted by vaping in quitting smoking. While the overall cessation

Table 2. Net Effects of Vaping on Mortality and Smoking Cessation by 2100

		Vaping does not increase smoking initiation			Vaping increases smoking initiation by 10%		
Vaping risk (% of cigarettes)[a]	Annual cessation rate increase due to vaping (%)	Life-years saved (LYS) (millions)	LYS as % of life-years lost (LYL) due to smoking in scenario in which e-cigarettes never existed	E-quitters (millions)	LYS (millions)	LYS as % of LYL due to smoking in scenario in which e-cigarettes never existed	E-quitters (millions)
5	10	5.7	1.9	3.9	3.2	1.1	4.1
	25	13.2	4.3	9.0	11.0	3.6	9.4
	50	23.6	7.7	15.9	21.7	7.1	16.6
	100	39.0	12.8	25.7	37.4	12.3	26.9
10	10	4.9	1.6	3.9	2.5	0.8	4.1
	25	11.5	3.8	9.0	9.2	3.0	9.4
	50	20.5	6.7	15.9	18.5	6.1	16.6
	100	33.8	11.1	25.7	32.1	10.5	26.9
20	10	3.5	1.2	3.9	1.0	0.3	4.1
	25	8.2	2.7	9.0	5.8	1.9	9.4
	50	14.6	4.8	15.9	12.4	4.1	16.6
	100	23.9	7.8	25.7	21.9	7.2	26.9

Assumptions: (1) The background smoking cessation rate does not vary by the age of the smoker. (2) The vaping-related increase in the smoking cessation rate is the same for all smokers regardless of their difficulty quitting smoking without vaping.

[a]Decrease in former smokers' annual mortality-reduction benefit (compared to continued smoking).

Table 3. Impact of Type of Smoker Vaping Most Assists in Quitting Smoking by 2100

		Vaping does not increase smoking initiation			Vaping increases smoking initiation by 10%		
Group of smokers most benefiting from vaping-related cessation rate increase	Annual cessation rate increase due to vaping (%)	Life-years saved (LYS) (millions)	LYS as % of life-years lost due (LYL) to smoking in scenario in which e-cigarettes never existed	E-quitters (millions)	LYS (millions)	LYS as % of LYL due to smoking in scenario in which e-cigarettes never existed	E-quitters (millions)
Smokers with greatest difficulty quitting otherwise	10	7.1	2.3	4.6	4.7	1.6	4.8
	25	15.8	5.2	10.1	13.6	4.5	10.5
	50	26.3	8.6	16.5	24.4	8.0	17.2
	100	39.1	12.8	24.3	37.6	12.3	25.4
All smokers benefit equally	10	4.9	1.6	3.9	2.5	0.8	4.1
	25	11.5	3.8	9.0	9.2	3.0	9.4
	50	20.5	6.7	15.9	18.5	6.1	16.6
	100	33.8	11.1	25.7	32.1	10.5	26.9
Smokers with least difficulty quitting otherwise	10	4.0	1.3	3.5	1.5	0.5	3.7
	25	9.1	3.0	8.0	6.8	2.2	8.3
	50	15.9	5.2	13.8	13.7	4.5	14.4
	100	25.1	8.2	21.5	23.1	7.6	22.5

Assumptions: (1) Risk of vaping compared to smoking = 10%. (2) The background smoking cessation rate does not vary by the age of the smoker.

rate increase is as indicated in column 2, different vaping-induced increases could apply to easy-quitters and hard-quitters. The first four rows assume that vaping most assists hard-quitters. The middle rows assume that all smokers have the same vaping-related smoking cessation rate increase. The last four rows assume that vaping most helps easy-quitters. This table holds the vaping risk constant at 10% and assumes that the background cessation rate (without vaping) does not vary with age.

Vaping saves the most life-years when most assisting hard-quitters. For example, if vaping does not increase smoking initiation, a 25% increase in the smoking cessation rate generates 15.8 million LYS when vaping most assists hard-quitters (second row, column 3), 11.5 million LYS when affecting all smokers equally (sixth row), and 9.1 million when most assisting easy-quitters (10th row). These represent, respectively, 5.2%, 3.8%, and 3.0% of LYL due to smoking assuming the absence of e-cigarettes (column 4). Comparable figures for the case in which vaping increases smoking initiation are found in the same rows in columns 6 and 7. As in the previous table, for every level of smoking cessation increase, when vaping increases smoking initiation LYS is lower than when vaping has no effect on initiation, but remains positive and sizable. LYS increases as the vaping-related boost to smoking cessation increases.

Variation in the Age-Related Background Smoking Cessation Rate (Independent of Vaping)

The one variable for which we do not show results in text tables is how the background smoking cessation rate (independent of vaping) varies with age (rising, remaining constant, falling). As seen in Supplementary Table S1, this variable produces the least variation in LYS. For example, assuming a 10% vaping risk, no differences across smoker types regarding ease of quitting smoking, and no vaping-related increase in smoking initiation, LYS for a 10% vaping-related increase in the annual cessation rate varies across the three assumptions from 4.3 to 4.9 million. For a 100% vaping-related cessation rate increase, LYS varies from 30.8 to 33.8 million. These are much smaller differences than observed in Tables 2 and 3.

Summary Results for All 360 Scenarios

Combined, all the possible values of this study's assumptions, in Table 1, yield 360 unique cases. All can be found in Supplementary Table S1. Three hundred fifty-seven cases (99%) produce positive LYS ranging from 143 000 to 65 million (The latter assumed no harm from vaping and a 200% cessation rate increase. With 5% harm and a 100% cessation rate increase, the top estimate was 44 million LYS.). Of the three cases with LYL (negative LYS), all assumed that vaping increases smoking initiation, vaping increases cessation by 10%, and the background cessation rate increases with age. For 2, vaping's risk is 20%; it is 10% for the other. LYL in the 3 cases ranged from 464 000 to 1.6 million. All three registered positive LYS (life-years gained) through 2070.

Discussion

If vaping increases smoking cessation, vaping is highly likely to produce net LYS gains through the end of the century, reducing smoking's toll by as much as a fifth. Smaller contributions reflect conservative assumptions. The largest impacts reflect highly optimistic assumptions, including a 200% vaping-produced increase in smoking cessation and little to no vaping-related health risk (Supplementary Table S1). The most optimistic assumptions in

Table 2—a vaping-produced doubling of the cessation rate, no impact on smoking initiation, and a 5% vaping-related risk—would reduce smoking's toll by 12.8% (fourth row, column 4), a very significant contribution to public health. The same outcome would be achieved with a 10% vaping-related risk if vaping most aided smokers with the greatest difficulty quitting smoking in their cessation attempts (Table 3, fourth row, column 4). Even a small percentage impact would constitute a genuine contribution, given the magnitude of the mortality attributable to smoking. Still, our findings indicate that vaping is unlikely to be "the" solution to the problem of smoking in America.

The 10% vaping-related cessation increase, the lowest we considered, is a conservative estimate of experience to date.[3,4,9,28] Higher rates might well be achieved with supportive regulatory policies, dissemination of accurate information on the relative risks of vaping, accrual of positive experience with vaping, and continually improving products. To date, policies in the United States have not been supportive of vaping, and the public grossly overestimates vaping's risks compared to those of smoking. This includes smokers.[42]

In the vast majority of the cases, we considered, vaping will account for millions of people quitting smoking. On average, "e-quitters" from all smokers in 2018 will gain from 1.2 to 2.0 LYS compared to smokers who quit without vaping. This range of extra LYS per e-quitter may strike some readers as low, especially given the fact that the average life-long smoker loses 10 years of life expectancy. The numbers reflect, in part, former smokers' retaining significant smoking-related mortality risk years after quitting. For example, from our model a smoker who quits (without e-cigarettes) at age 50 gains 4.3 of the 10 LYL from a lifetime of smoking. Further, many e-quitters would have quit without vaping in the future anyway, many in the near future. These individuals would have gained much of the benefit they derive by quitting earlier with e-cigarettes, without the health risk associated with vaping.

The health risk associated with vaping matters. For each level of vaping-related increase in smoking cessation, the number of LYS at a vaping risk level of 5% is substantially greater than the number of LYS at a risk level of 20%. However, even at a risk level of 20%, vaping produces a large number of LYS.

As explained earlier, our risk levels represent averages of much higher risks for people who vape for many years and much lower risks for people who vape only a few months or years. Thus, the lowest risk we considered in the results presented in the paper, 5%, is not comparable to the 5% that British health authorities consider the maximum risk associated with vaping.[38,39] Rather, it reflects, for example, a risk of perhaps 10%–15% for long-term vapers and much less than 5% for short-term vapers. Our 20% risk thus represents a relative risk of perhaps 40% or more for long-term vapers.

Whom vaping most helps to quit smoking matters as well. The impact of vaping is greatest if vaping most helps those who otherwise have the greatest difficulty quitting smoking. Determining which kinds of smokers vaping most assists will be challenging, as it has been for other quitting methods.

Overall, our findings suggest that e-cigarettes represent a meaningful if thus far modest public health contribution and could represent a more substantial one. Still, it would fall short of that envisioned by Levy and colleagues' scenario of vaping's replacing smoking in a decade.[17] Under their optimistic assumptions, vaping would avoid the loss of 35% of projected smoking-produced LYL. Even under our most extreme assumptions, including a 200% increase in smoking cessation, the largest contribution we find would reduce projected LYL by 21%. Regarding both studies, however, it is important to note that it is impossible to avoid all future smoking-produced LYL. Some of that toll reflects the residual risk carried by former smokers throughout their lives. Elsewhere we estimate that approximately two-thirds of the smoking LYL by 2100 are attributable to smoking that occurred prior to 2018. Only the remaining third of the LYL can be avoided.[43]

Limitations

This study's most important limitation relates to its core assumption that vaping increases smoking cessation. If it does not—or, worse, if it decreases cessation[3]—there is no benefit and, indeed, a clear cost. As discussed above, we believe the evidence increasingly supports the notion that vaping and other reduced-risk products can and do increase quitting. In the most dramatic display of reduced-risk products' potential to replace cigarettes, from 2016 to 2019 heated tobacco products attained a 23.5% share of Japan's nicotine market, which was previously 100% cigarettes. In the preceding 3-year period, prior to the introduction of heated tobacco products, cigarette sales fell 7.3%, an average of 2.4% per year. The 2016–2019 decline in cigarette consumption—30.4%, an average of 10.1% per year—is certainly one of the largest decreases in any country since the beginning of the global smoking epidemic.[44] An important question, however, is whether it represents a comparable drop in smoking prevalence (ie, many heated tobacco product consumers may be dual users)[45] and whether the decrease can be sustained.

A second limitation is that we hold the annual smoking initiation and background cessation rates constant over time. Given the remarkable decreases in the initiation rate in recent years, as well as increases in the cessation rate, it is possible, even likely, that further changes will occur in the coming years, although the direction of such changes is not certain (One hopes and expects that changes, if any, will continue in the desirable direction.). The effects of some changes are predictable, while others are not. For example, if the initiation rate continues to decline, the 10% increase in the initiation rate that we attribute to vaping in half of the 360 scenarios would add fewer smokers in future years. That would increase the net LYS by vaping.

A third limitation is that we treat a given vaping-related increase in the cessation rate as applying equally to all ages. Currently, the prevalence of vaping is inversely related to age, so one might expect vaping to increase cessation more among younger smokers (which seems likely to have been happening, given the dramatic recent reductions in smoking prevalence among young adults). As such, our estimates can be considered conservative. For example, our assumption of a 10% vaping-induced increase in cessation—consistent with population study data (if conservative)—might reflect higher increases at younger ages and lower increases at older ages, averaging out to 10%. Such a distribution would produce higher estimates of LYS attributable to vaping than we report in this study. For the future, if e-cigarette manufacturers and vendors shifted their marketing toward middle-aged and older smokers, we might observe a change in the prevalence of vaping by age.

Another limitation is that we ignore potential negative health implications of vaping other than those directly affecting vapers who quit smoking. It is conceivable, if unlikely, that dual use—vaping and smoking—could introduce additional health risks. Vaping certainly would introduce health risks for people who otherwise would not have been smoking.

On the other side of the equation, some youthful smokers or former smokers (under 18 years old) may be using vaping to quit smoking.[2] Nearly all the attention to date has focused on the notion that vaping by never-smoking young people may increase their trial

of cigarettes.[33–35] However, the studies producing this finding have important limitations.[36] Further, the rise of youth vaping has been accompanied by an accelerated decrease in youth smoking.[37]

This said, an important omission from the study is consideration of the potential costs of a subset of young vapers who have never used tobacco becoming addicted to nicotine, even if they do not progress to smoking. Those costs include potential impacts on their developing brains, as well as the simple fact of addiction itself.[46] Fortunately, among US high school students in 2018, only 8.4% of never-tobacco users had vaped in the past 30 days, only 1% of those had vaped frequently (≥20 days in the past 30), and small percentages showed any signs of nicotine dependence (eg, only 3.8% reported craving and 3.1% reported wanting to vape within 30 minutes of waking).[47]

Remaining limitations primarily reflect uncertainties concerning the study's variables. These uncertainties recommend a partial research agenda, with our analysis providing context for the relative importance of the various uncertainties.

Concluding Thoughts

Worldwide, e-cigarettes have generated simultaneously an intensity of enthusiasm and a level of dread never previously experienced in tobacco control. The debate is heated, driven as much by emotions and philosophies as by facts. One hopes that the debate will move to an evidence-based discussion as research fleshes out the factual basis for evaluating the roles of these novel products.[48]

We find that e-cigarettes hold the potential to contribute significantly to reducing cigarette smoking's enormous toll. By itself, however, tobacco harm reduction, as embodied in vaping, is no magic bullet. Going forward, tobacco control will require vigilant application of the evidence-based measures that have brought us so much success in combatting Public Health Enemy Number One. It will require, as well, the search for and adoption of novel means of attacking the remaining problem. Harm reduction can, and many would say should, be a part of the complex formula that will eventually bring about the demise of smoking.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at https://academic.oup.com/ntr.

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Declaration of Interests

None declared.

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