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The potential impact of e-cigarettes on the life-years lost from conventional smoking in Georgia: A replication study

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Abstract

Introduction: Smoking remains a significant public health concern in Georgia. Recent efforts to combat smoking have shown some progress, but Georgia's current approach overlooks the potential benefits of harm reduction strategies. Our study aims to estimate the potential impact of e-cigarettes (vaping) on reducing the mortality associated with cigarette smoking in Georgia.

Methods: A US-developed dynamic population simulation model was replicated, adjusting it to simulate Georgia's population across 210 e-cigarette scenarios. These scenarios varied in assumptions regarding e-cigarettes' effects on smoking behavior and health outcomes. Sensitivity analyses were also conducted to affirm the robustness of the study's findings.

Results: Among the 210 e-cigarette scenarios examined, 183 (87.1%) resulted in positive life-years saved (LYS). Estimated LYS by e-cigarettes range from -3.2% to 28.9% of life-years lost (LYL) due to smoking, while the median LYS stood at 7.5% of LYL due to smoking. After 80 years, smoking prevalence in e-cigarette scenarios ranges from 4.9% to 16.5% with a median value of 10.9% compared to 14.1% in the status quo. The results remain robust under sensitivity analysis.

Discussion and Conclusion: Our simulation analysis demonstrates the potential of e-cigarettes to significantly reduce the harm of smoking in Georgia. Future policies should leverage the benefits of e-cigarettes, guided by ongoing research and effective communication about their relative risks. Our findings align with international studies, confirming the life-saving potential of e-cigarettes against traditional smoking.

Take-home message: This study demonstrates that e-cigarettes could significantly reduce the life years lost to smoking-related diseases in Georgia. These findings support the potential of e-cigarettes as a harm-reduction strategy in tobacco control policies.

Keywords: E-cigarettes; tobacco smoking; public health; simulation.

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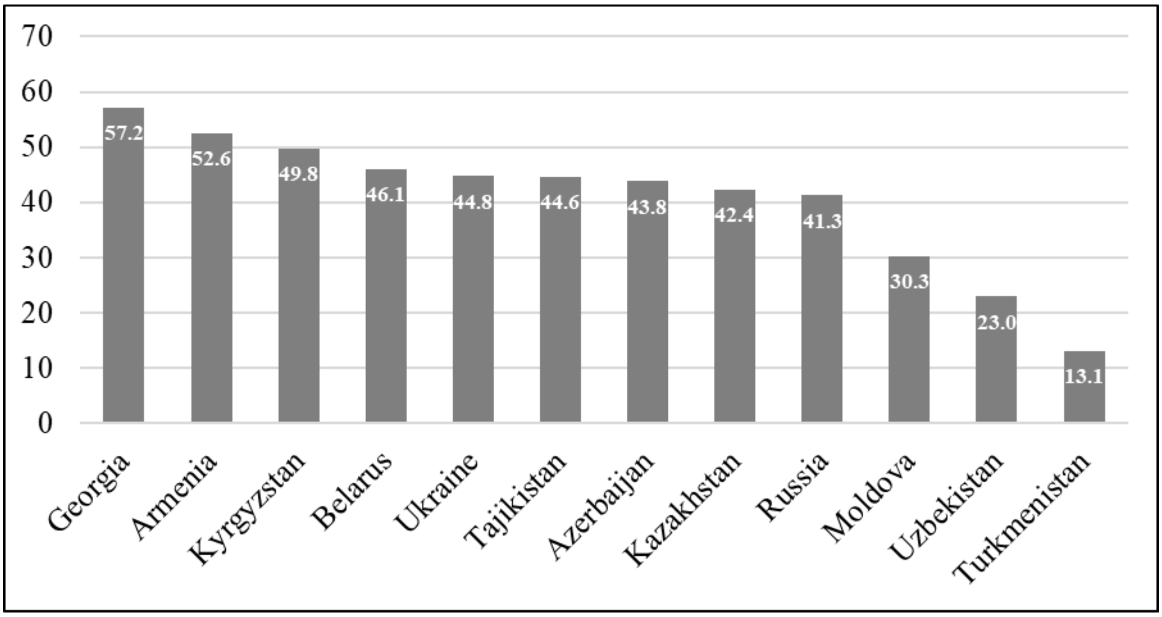
INTRODUCTION

The issue of smoking and its implications for public health is a significant policy concern in Georgia. 31% of the adult population in Georgia was current tobacco smokers in 2016 [1]. This prevalence was particularly alarming among men, 57% of whom were identified as smokers, placing Georgia at the forefront in the WHO Europe region and among Commonwealth of Independent States (CIS) countries [1,2]. Though officially documented at 5.2%, nicotine tests suggest the actual prevalence among women to be around 12.2% [1]. Moreover, the prevalence of tobacco use among youth was concerning, with 12.6% of teenagers aged 13 to 15 engaging in smoking in 2017 [3]. Consequently, the public health burden imposed by smoking was significant, leading to the estimated annual death of 11,400 people (0.4% of the adult population) due to tobacco-related diseases and causing economic costs equivalent to approximately 2.4% of Georgia's annual GDP [4].

Figure 1. Prevalence of smoking among men in current and former countries of CIS region in 2015 (age-standardized rate, in %)



In response to the substantial public health challenges linked to smoking, Georgia has introduced stricter tobacco control legislation and taxation measures between 2017 and 2019 [5, 6]. Existing estimations indicate that implementing these measures correlated with a rapid reduction in smoking prevalence [6,7]. However, from 2020 onward, the decrease in smoking prevalence has reached a state of stagnation [7]. Meanwhile, only 1.5% of the adult population used e-cigarettes (vaped) daily in 2022, while 2.4% used them less frequently [8]. The low prevalence of e-cigarettes might be explained by both existing anti-smoking policies, which do not differentiate between cigarettes and safer nicotine products (SNPs), and public perceptions: only 16.8% perceive e-cigarettes as less harmful than cigarettes, while the remainder think the opposite or perceive both as equally harmful [8].

While further reduction in smoking calls for the next increases in excise taxes, which have not changed since 2019, Georgia may consider incorporating a harm reduction strategy in its anti-smoking policy, mirroring the approach taken in an increasing number of nations recognizing the efficacy of granting access to SNPs, including e-cigarettes, as a means of effective harm reduction [9, 10, 11].

Nevertheless, the population health impact of e-cigarettes remains a subject of controversy. While recent literature finds consensus that e-cigarettes are less harmful than cigarettes [11, 12], their impact on smoking cessation and smoking initiation is still debatable. Advocates of e-cigarettes argue that vaping aids smoking cessation among adult smokers [13-17] and that vaping might aid youths in avoiding or quitting smoking [18].

Opponents of e-cigarettes express skepticism about the efficacy of using e-cigarettes for smoking cessation [19-22] while suggesting that e-cigarettes might act as a gateway to smoking (stimulate smoking initiation), particularly among the youth [23].

Recent literature uses simulation analysis to estimate the potential impacts on population health amid these contentious debates. Most models used to estimate the public health effects of e-cigarettes (or SNPs in general) predominantly focus on the US and UK [24]. Lee et al. (2020) reviewed thirteen models by mid-2018 and concluded that introducing SNPs is likely to have a beneficial population health impact [24]. More recent studies conducted in the UK, US, Canada, and Russia also indicated that e-cigarettes could have an important positive public health effect by reducing the harms of smoking [25-29].

To date, such estimates do not exist for Georgia. The only simulation model projecting the effects of tobacco control policies on smoking prevalence and related deaths in Georgia is the abridged SimSmoke tobacco control model developed by Levy et al. (2016) [30]. This model uses smoking prevalence data from the STEPwise approach to surveillance (STEPS) of 2010 in Georgia and simulates the consequences of stricter smoke-free regulations, enhanced cessation services, advertising bans, tobacco packaging warnings, and higher cigarette taxes. According to these simulations, the implementation of combined policies could potentially avert 274,000 smoking-attributable premature deaths and lead to a 60% reduction in smoking prevalence over four decades [31].

The aim of the present study is to estimate the potential population health impact of e-cigarettes on the burden of cigarette smoking in Georgia. This goal is framed within the context of assessing the effectiveness of harm reduction strategies, specifically the use of e-cigarettes, in reducing mortality associated with cigarette smoking. The study seeks to fill a gap in the existing literature by providing simulation analysis estimates for the Georgian context, contrasting with previous models primarily focusing on countries like the US and the UK.

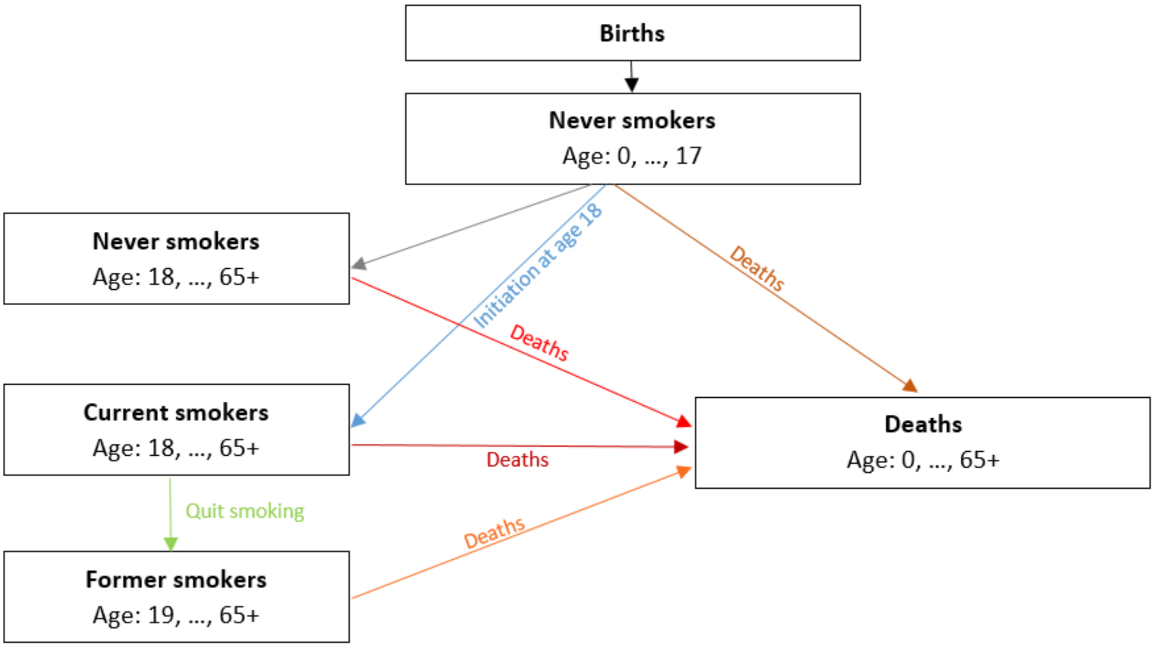
METHODS

Our methodology replicated the one developed by Mendez and Warner (2021) and then used by Mzhavanadze and Yanin (2023) for estimating vaping impacts on public health in the US and Russia, respectively [28, 29]. We simulated the proportion of smoking-induced deaths in Georgia that e-cigarettes could potentially mitigate under the combination of assumptions about the extent to which vaping might influence smoking cessation and initiation and its health impacts, as compared to smokers who quit smoking without the help of e-cigarettes.

Simulation model

A dynamic population simulation model was developed, specifically tailored to analyze tobacco control policies within the Georgian context. The model tracks individuals from ages 0 to 65+ by sex and smoking status: never, current, and former smokers (Figure 2). The detailed specifications of the model are provided in Supplementary Materials.

Figure 2. Schematic representation of the background simulation model.



The model initiates by estimating the baseline population's age, gender, and smoking status. Each year, the model introduces a new birth cohort. Some never-smokers begin smoking at age 18, becoming current smokers, and some current smokers quit, transitioning to former smokers. Additionally, mortality rates, varying by age, sex, and smoking status, affect the entire population.

The baseline year for the model is 2016, as it is the most recent year with available smoking prevalence data. We obtained sex- and age-specific smoking prevalence from Georgian STEPS 2016 (Table A1) [32]. A detailed description of the STEPS 2016 survey is provided in Supplementary Materials.

We attributed people who report currently smoking any combustible tobacco products (such as cigarettes, cigars, or pipes) to current smokers without considering additional information on smoking intensity or the number of cigarettes smoked. In our model, former smokers are individuals who reported smoking tobacco products in the past but currently do not smoke.

Then, by combining smoking prevalence data with corresponding population statistics from the National Statistics Office of Georgia (Table A2) [33], we estimated the population in the baseline year, categorized by age, sex, and smoking status (Table A3).

For the following years, we assumed that the new birth cohort was constant every year – the number of births was kept at the baseline year's level. Also, following Mendez and Warner (2021), we assumed that everyone aged 0-17 is a never-smoker, and smoking initiation happens only at age 18; those who start smoking become current smokers. Starting from age 19, some smokers start quitting smoking, and those who quit become former smokers. We assumed that re-initiation of smoking does not occur.

For model construction, we obtained smoking initiation and cessation rate estimates by sex from STEPS 2016 (Table 1). Smoking initiation rates are estimated as a proportion of current smokers in the population aged 18-24. It should be mentioned that STEPS 2016 data includes former smokers aged 18 - people who started briefly and then quit before they turned 19. We treated these individuals like never smokers as people who were temporarily smokers during their teens are not particularly important for the public health policy. Sex-specific smoking cessation rates are estimated for three age categories (19-34, 35-50, and >50) as a proportion of smokers who quit smoking a year ago.

Table 1. Estimated background smoking cessation and background smoking initiation rates used in the dynamic simulation model (%).

Variable		Men (95% CI)	Women (95% CI)
Background smoking cessation rate (%)	For ages 19-34	2.6 (1.1, 6.4)	6.6 (1.7, 22.6)
	For ages 35-50	3.2 (1.4, 7.0)	0.6 (0.1, 4.5)
	For age >50	3.0 (1.3, 6.7)	0.7 (0.1, 5.1)
Background smoking initiation rate (%)		51.5 (40.9, 61.9)	8.3 (4.4, 15.0)

Then, sex- and age-specific death rates were calculated separately for never smokers, current smokers, and former smokers using the relative risk estimates of adult mortality from smoking-related diseases derived from the US Cancer Prevention Study II (Table A4) [33]. These relative risks were combined with Georgian sex-, age-, and disease-specific mortality data from the National Statistics Office of Georgia. Following Mendez and Warner (2021) we assumed that smoking-related deaths do not occur before age 35, therefore death rates before 35 do not differ by smoking status. Calculated sex- and age-specific smoking status are presented in Table A5. The methodology for the calculation of sex- and age-specific death rates by smoking status is described in Supplementary Materials.

Simulation analysis

After building the simulation model, the Georgian population was simulated under two reference scenarios:

1. The status quo scenario: smoking initiation and cessation rates are held constant during the following 80 years after the baseline year.
2. The never-smoking scenario: a hypothetical situation where no individuals have ever smoked, no one smokes in the baseline year, and no one will start smoking in the future.

Comparing these two scenarios, the total life-years lost (LYL) due to smoking in the absence of vaping were estimated. These estimates are then used to provide insights into the potential life-saving impact of e-cigarettes.

Next, the Georgian population was simulated in 210 e-cigarette scenarios, which are a combination of various assumptions drawn from Mzhavanadze and Yanin's study (2023) on how vaping influences smoking cessation and smoking initiation and health risks for former smokers who quit using e-cigarettes (e-quitters) compared to former smokers who quit smoking without e-cigarettes (Table 2) [29].

Table 2. Principal assumptions used in the simulation analysis.

Variable		Values (men)	Values (women)
Variables held constant across all scenarios			
1. Background smoking cessation rate (%)	For ages 19-34	2.6	6.6
	For ages 35-50	3.2	0.6
	For age >50	3.0	0.7
2. Background smoking initiation rate (%)		51.5	8.3

Variables that define unique e-cigarette scenarios	
3. Impact of vaping on smoking cessation rate	Increase background rate by 5%, 10%, 25%, 50%, 100%, or 200%
4. Impact of vaping on smoking initiation rate	Increase the background rate by -20%, -15%, -10%, 0%, 10%, 15% or 20%
5. Health risk of vaping compared to smoking	Reduces former smokers' annual mortality-reduction benefit (compared to continued smoking) by 0%, 2.5%, 5%, 10%, or 20%

To ensure the robustness of our simulation analysis, a sensitivity check was conducted using varying background smoking initiation and cessation rates. Specifically, lower and upper-bound estimates of background smoking cessation and initiation rates were used (Table 1). This sensitivity analysis addressed several potential limitations and uncertainties in our assumptions.

First, smoking initiation might occur before age 18 or after age 24, while we estimated the background smoking initiation rate as the proportion of current smokers in the population aged 18-24. Indeed, we observed that smoking prevalence among the population 25-29 was higher compared to smoking prevalence among 18-24-year-olds (Table A1). Also, the estimates of smoking prevalence are based on self-reported data, which generally tend to underreport bias [35,36]. In the case of Georgia, underreporting was seen among young adults and women in general [37]. In addition, we might overestimate the background cessation rates, as we assumed no relapse in former smokers.

RESULTS

LYL due to smoking

We estimated that in 2016, approximately 3,881 people died prematurely from smoking in Georgia, which is 7.9% of total premature deaths in the 35+ population (Tables 3 and 4). The burden in the case of men is much higher (14.1%) compared to women (1.5%), which is consistent with the prevalence rates.

Table 3. Smoking-attributable deaths in 2016 (in 35+ population).

Cause	ICD 10	Males		Females	
		All deaths	Smoking-Attributable	All deaths	Smoking-Attributable
Malignant neoplasms					
Lip, oral cavity, pharynx	C00–C14	143	116	42	8
Esophagus	C15	40	31	13	3
Stomach	C16	306	101	199	4
Pancreas	C25	124	43	104	7
Larynx	C32	154	134	11	4
Trachea, lung, bronchus	C33–C34	957	871	122	46
Cervix uteri	C53	-	-	183	7
Kidney and renal pelvis	C64–C65	87	41	30	0
Urinary bladder	C67	180	93	42	3
Acute myeloid leukemia	C92.0	35	10	34	1
Cardiovascular diseases					
Coronary heart disease	I20–I25	2,292	638	2,479	88

Other heart disease	I00–I09, I26–I28, I29–I51	1,889	455	1,882	42
Cerebrovascular disease	I60–I69	2,821	643	3,340	102
Atherosclerosis	I70	46	16	65	2
Aortic aneurysm	I71	86	61	27	6
Other arterial disease	I72–I78	62	16	43	2
Respiratory diseases					
Influenza, pneumonia	J10–J11, J12–J18	763	209	643	33
Bronchitis, emphysema	J40–J42, J43	20	18	19	8
Chronic airways obstruction	J44	19	16	10	4
Total					
Total premature deaths from smoking-related causes		10,024	3,512	9,288	370
Total premature deaths from all causes		24,862	3,512	24,131	370

Table 4. Annual smoking-related deaths in the baseline year.

	Total deaths	Share in total premature deaths	Share in current smokers' deaths
Total	3,881	7.9%	0.5%
Men	3,512	14.1%	0.5%
Women	370	1.5%	0.4%

It should be mentioned that our estimates show more conservative figures compared to the existing literature. According to UNDP et al. (2018), 11,418 people die annually from smoking-related diseases, of which 2,093 result from exposure to second-hand smoke [4]. In their estimations, the authors use the list of 27 smoking-related diseases compared to 19 used in our estimates. In addition, the study does not provide details on the relative risks of smoking used in calculations. The Institute for Health Metrics and Evaluation (IHME) reported around 7,172 deaths annually from smoking in Georgia in 2019 [38]. IHME uses its own classification and list of smoking-related diseases and its own estimates of the relative risks of smoking. Also, IHME assumes that smoking-related deaths occur starting from age 30.

Then, the cumulative LYL attributable to smoking in Georgia was estimated in the absence of e-cigarettes for 80 years after the baseline year (Table 5). This calculation resulted in 3.4 million LYL, accounting for 7.6% of current smokers' life-years and 1.4% of adult life-years. This model also projected that in the status quo, the smoking prevalence in Georgia would decline by 5.8 percent points in 10 years and 9.5 percent points in 20 years. In the long term, smoking prevalence would stabilize at 14.1%.

Table 5. LYL due to smoking in the following 80 years.

	Total	Share in current smokers' life-years	Share in adults' life-years
Total	3.4 million	7.6%	1.4%
Men	2.9 million	7.6%	2.6%
Women	0.4 million	7.7%	0.3%

LYS by e-cigarettes

Among the 210 e-cigarette scenarios examined, 87.1% (183 out of 210) resulted in positive LYS. (Table 6). Estimated LYS by vaping ranges from -0.1 (-3.2% of LYL due to smoking) to 1 million

(28.9% of LYL due to smoking), while the median LYS stood at 0.3 million, which is 7.5% of LYL due to smoking. After 80 years, smoking prevalence in e-cigarette scenarios ranges from 4.9% to 16.5% with a median value of 10.9%. The detailed outcomes for each e-cigarette scenario are presented in Table A6.

Table 6. Summary of all e-cigarette scenario simulations.

	Minimum value	Maximum value	Median value
LYS (in millions)	-0.108	0.970	0.252
LYS by vaping as a share of LYL due to smoking	-3.2%	28.9%	7.5%
Smoking prevalence (after 80 years)	4.9%	16.5%	10.9%
Number of scenarios with positive LYS		183 (out of 210)	

Naturally, the combination of assumptions where vaping increases smoking cessation by 5%, increases smoking initiation by 20%, and elevates health risks for e-quitters by 20% produces an e-cigarette scenario with the lowest LYS. The e-cigarette scenario with the highest LYS is a scenario where we assumed a 200% increase in smoking cessation a 20% reduction in smoking initiation, and vaping has no adverse health impacts for e-quitters compared to former smokers who quit smoking without e-cigarettes.

When comparing the life-saving potential of vaping under the scenarios presented in Mendez and Warner (2021) for the US and Mzhavanadze and Yanin (2023) for Russia, our estimates showed comparable results (Table 7) [28,29]. These are scenarios that are based on the assumption that vaping increases background smoking cessation rates by 10%, 25%, 50%, and 100% and has no effect on background smoking initiation or increases it by 10%. Additionally, the health risk of vaping for former smokers is at 5%, 10%, and 20% - indicating the reduction in the mortality benefit from quitting smoking without vaping compared to quitting with vaping. Almost all combinations of these assumptions (except one) resulted in positive cumulative LYS over the 80 years, ranging from -0.4% to 16.3% as a proportion of LYS by vaping in LYL due to smoking. All scenarios include a considerable number of e-quitters, with a share in all quitters ranging from 8.9% to 49.7%.

Table 7. Effects of vaping on mortality and smoking cessation (cumulative over 80 years): E-cigarette scenarios for which assumptions on smoking cessation, initiation, and health risks of vaping are replicated from Mendez and Warner (2021).

Vaping risk	**Annual cessation rate increase due to vaping**	**Vaping does not increase smoking initiation**				**Vaping increases smoking initiation by 10%**			
		LYS (million)	**LYS as a share of LYL due to smoking**	**E-quitters as a share in all quitters**	**Smoking prevalenc e (after 80 years)**	**LYS (million)**	**LYS as a share of LYL due to smoking**	**E-quitters as a share in all quitters**	**Smoking prevalenc e (after 80 years)**
5%	**10%**	0.080	2.4%	9.0%	13.3%	0.014	0.4%	9.0%	14.7%
	25%	0.186	5.5%	19.8%	12.3%	0.123	3.7%	19.8%	13.5%
	50%	0.333	9.9%	33.1%	10.8%	0.275	8.2%	33.1%	11.9%
	100%	0.547	16.3%	49.7%	8.7%	0.495	14.8%	49.7%	9.5%
10%	**10%**	0.071	2.1%	9.0%	13.3%	0.005	0.1%	9.0%	14.7%
	25%	0.166	4.9%	19.8%	12.3%	0.102	3.1%	19.8%	13.5%
	50%	0.297	8.8%	33.0%	10.8%	0.237	7.1%	33.0%	11.9%
	100%	0.485	14.5%	49.6%	8.7%	0.431	12.9%	49.6%	9.5%
20%	**10%**	0.054	1.6%	8.9%	13.3%	-0.013	-0.4%	8.9%	14.7%
	25%	0.126	3.8%	19.6%	12.3%	0.061	1.8%	19.7%	13.5%
	50%	0.225	6.7%	32.8%	10.8%	0.163	4.9%	32.9%	11.9%
	100%	0.364	10.9%	49.4%	8.7%	0.306	9.1%	49.4%	9.6%

Concerning the e-cigarette scenarios (27 out of 210) with a negative impact on life-years, these scenarios are a result of combinations where:

1. Vaping leads to a 5% increase in smoking cessation while simultaneously resulting in a 10%, 15%, or 20% increase in smoking initiation, irrespective of the assumed health risks associated with vaping.
2. Vaping leads to a 10% increase in smoking cessation, coupled with a 15% or 20% increase in smoking initiation, again, regardless of the assumed health risks associated with vaping.
3. Vaping leads to a 25% increase in smoking cessation and a 20% increase in smoking initiation and assumes a 20% health risk related to vaping.

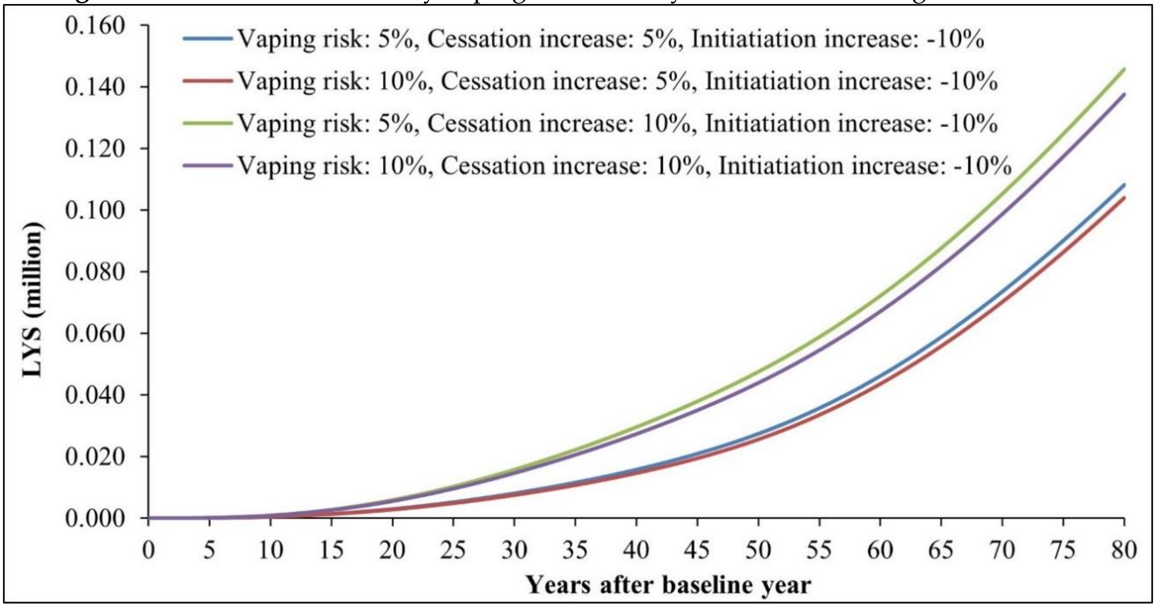
E-cigarette scenarios considered the most plausible for Georgia were selected. These selections were based on the current prevalence of e-cigarette use, existing policies, and the documented impact of vaping on health, smoking cessation, and initiation, as outlined in recent literature. These scenarios are the combination of assumptions where vaping increases population-wide smoking cessation by 5% or 10% and decreases smoking initiation by 10% while having 5% or 10% of elevated health risks for e-quitters (Table 8).

Table 8. Effects of vaping on mortality and smoking cessation (cumulative over 80 years): Selected e-cigarette scenarios.

Vaping risk	**Annual cessation rate increase due to vaping**	**Vaping reduces smoking initiation by 10%**			
		LYS (millions)	**LYS as a share of LYL due to smoking**	**E-quitters as a share in all quitters**	**Smoking prevalence (after 80 years)**
5.0%	**5%**	0.108	3.2%	4.7%	12.3%
	10%	0.146	4.3%	9.0%	12.0%
10.0%	**5%**	0.104	3.1%	4.7%	12.3%
	10%	0.138	4.1%	9.0%	12.0%

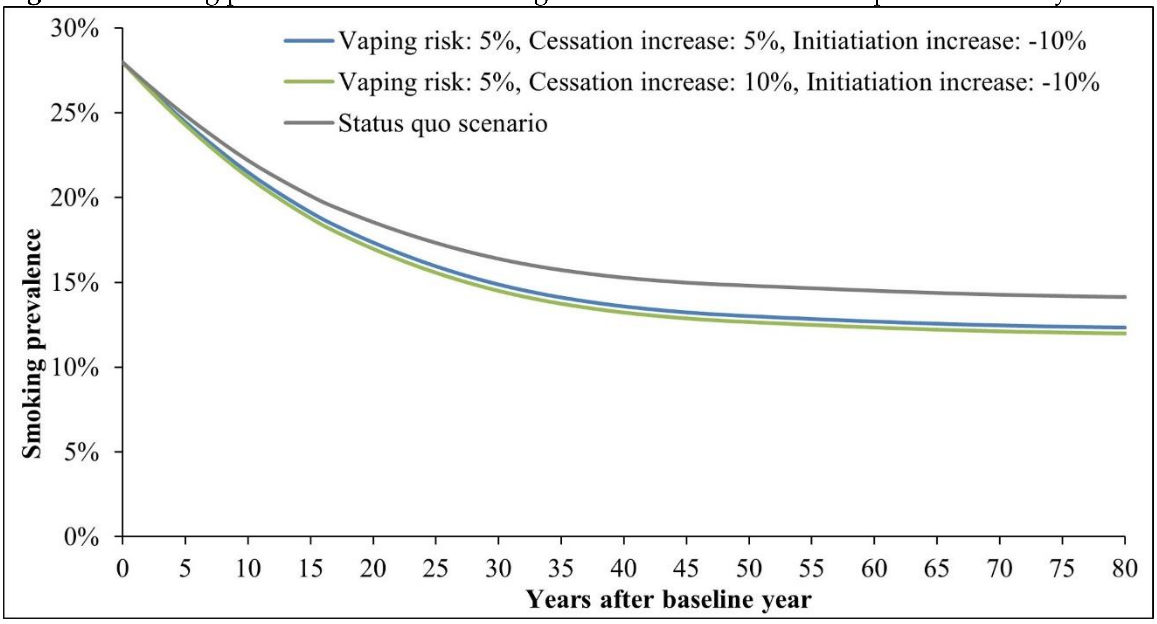
In these scenarios, LYS by vaping ranges from 3.1% to 4.3% as a share of LYL due to smoking. The cumulative LYS by vaping over the 80 years in selected e-cigarette scenarios are presented in Fig. 3. Furthermore, the potential share of e-quitters among all quitters is estimated to be between 19.1% and 32.1%.

Figure 3. The cumulative LYS by vaping over the 80 years in selected e-cigarette scenarios.



Due to higher smoking cessation rates and lower smoking initiation rates, smoking prevalence in these selected e-cigarette scenarios declines more rapidly compared to the status quo scenario (Fig. 4). Long-term smoking prevalence varies between 12% (when the impact of vaping on the population-wide cessation rate is 5%) and 12.3% (when the impact of vaping on the population-wide cessation rate is 10%).

Figure 4. Smoking prevalence in selected e-cigarette scenarios and status quo over the 80 years



Sensitivity analysis

When we applied the lower bound estimates for background smoking cessation and initiation rates, our simulation analysis produced 176 (83.8%) and 169 (80.5%) e-cigarette scenarios with positive LYS, respectively.

The range of LYS across the 210 e-cigarette scenarios remained consistent with the primary results. In simulations employing the lower bound estimates, it spanned from -3.2% to 24.2%, while simulations with the upper bound estimates showed a range from -4% to 22%. The median LYS in both cases was lower compared to the primary results, measuring 5.3% and 5%, respectively. A summary of the sensitivity analysis results can be found in Tables A7 and A8, while detailed outcomes are provided in Tables A9 and A10. Concerning the selected e-cigarette scenarios, the sensitivity analysis produced results in line with the primary findings (Tables A11 and A12).

The additional e-cigarette scenarios with negative LYS (in comparison to the main results) were scenarios in which vaping increases smoking initiation by 10%, 15%, or 20% while assuming a vaping risk of 20%.

DISCUSSION

The potential public health impacts of vaping (the reduction of LYL due to smoking in our simulations) depend on its efficacy in promoting smoking cessation. Should vaping fail to aid smokers in quitting, the simulations predict adverse outcomes in scenarios where it was assumed that vaping increases smoking initiation. The assumptions about vaping's impact on smoking initiation and its adverse health impacts on former smokers who quit with vaping's aid also affect simulation outcomes, albeit to a lesser extent than assumptions about vaping's impact on smoking cessation.

In the most optimistic scenario, in which we assume a 200% increase in the smoking cessation rate, no health risks associated with vaping, and a 20% reduction in smoking initiation, vaping is projected to yield substantial public health benefits, potentially saving 28.9% of LYL due to smoking. However, this scenario is an upper limit of potential benefits that may be unrealistic, as it assumes the adoption of vaping among all smokers for cessation purposes and a tripling of the cessation rate - a phenomenon not yet supported by empirical evidence.

It is important to note that 12.9% of our e-cigarette scenarios resulted in a negative impact on life-years. These scenarios assume minimal effects of vaping on smoking cessation and an increase in smoking initiation rates due to vaping. Nevertheless, we consider these scenarios as highly unlikely, given recent literature suggests that the association between vaping and smoking in youth is far smaller than those reported in cohort studies and is insufficient to establish a gateway effect [17,38]. Furthermore, this association is attributable to shared risk factors of tobacco use [18,39-41]. At the same time, adolescents who initially experiment with e-cigarettes are less inclined to start smoking compared to their peers with similar characteristics [18,40].

Furthermore, recent observational studies point to the correlation between vaping and a faster-than-expected decline in smoking prevalence [42]. Therefore, it is more likely that e-cigarettes and combustible cigarettes are substitutes, and vaping decreases smoking initiation rather than increases it. Consequently, our assumptions about the increase in background smoking initiation rate by 10%, 15%, or 20% may be excessively pessimistic.

In e-cigarette scenarios considered the most plausible for Georgia, a 5% or 10% increase in population-wide cessation rates was assumed due to vaping. Considering the growing evidence of the effectiveness of vaping in aiding smoking cessation [13-15], these assumptions imply that, on average, only a small fraction of smokers will turn to e-cigarettes for smoking cessation over the next 80 years. This aligns with the current vaping prevalence in Georgia - 1.5% daily usage and 2.4% less frequent usage. However, the popularity of vaping among smokers could shift in the future [8]. This evolution depends on policy and perceptions of the relative harms of e-cigarettes compared to combustible cigarettes among smokers. If, over 80 years, more smokers increasingly use vaping for smoking cessation, then our initial assumption of a 5% or 10% increase in background cessation rates would be highly conservative, translating into higher public health benefits than suggested in Table 8 (4.3% reduction in LYL due to smoking).

Study limitations

Our study has several limitations. Firstly, we maintained constant smoking initiation rates at the 2016 level. Research suggests that smoking initiation has been declining in recent decades in both developed and developing countries [43-45]. Therefore, our simulations might overestimate the impact of vaping on smoking-related mortality in Georgia, potentially lowering the "true" values of LYS by vaping. Nonetheless, from 2010 to 2016, smoking initiation rates did not show significant changes. Utilizing STEPS 2010 data, we estimated smoking initiation rates in Georgia to be 45.2% (95% CI: 38.2 - 52.3) among men and 5.0% (95% CI: 3.0 - 8.3) among women, figures that are actually lower than those reported in 2016 (Table 1).

Another limitation is that we only considered elevated vaping-related health risks for people who successfully quit smoking. The simulation does not incorporate changes in health risks for dual users - smokers who tried to quit vaping but failed and continued both smoking and vaping. Existing literature shows, albeit with low certainty, that dual use is at least as harmful, if not more so, than exclusive smoking [46]. Such considerations would diminish the simulated positive public health impacts of vaping in Georgia.

Moreover, our estimations do not account for the role of innovation and technological advances in addressing the health consequences of smoking, such as developing new methods for smoking cessation, early diagnosis, and more effective treatments for cancers, chronic obstructive pulmonary disease, and heart disease. Such progress reduces premature deaths from smoking, as well as from other risk factors. Consequently, advancements in medical technology alone are expected to decrease LYL due to smoking, which would, in turn, lessen the projected positive public health impact of vaping.

CONCLUSION

This study underscores the potential for public health improvement in Georgia by adopting e-cigarettes as a harm reduction strategy. Our modeling of various scenarios has shown that e-cigarettes could save a considerable number of life-years otherwise lost to smoking-related diseases, supporting the case for integrating harm reduction into tobacco control policies alongside traditional tobacco control measures.

The favorable outcomes linked with vaping, especially in scenarios highlighting increased cessation and decreased initiation rates, show that e-cigarettes could be instrumental in the fight against the smoking epidemic in Georgia. Therefore, future policies should consider the nuanced benefits of e-cigarettes, supported by continuous research to address evolving concerns. Implementing policies that encourage smokers to switch to e-cigarettes, coupled with careful communication about the relative risks of e-cigarettes compared to traditional cigarettes, will amplify the public health benefits of e-cigarettes by significantly lowering the smoking-related death toll.

Our results are in line with earlier simulation studies from the UK, US, Canada, and Russia, consistently demonstrating the life-saving capacity of e-cigarettes in the face of traditional smoking challenges.

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