POTENTIAL IMPACT OF E-CIGARETTES ON LIFE-YEARS LOST FROM CONVENTIONAL SMOKING IN UKRAINE, A REPLICATION STUDY

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SUMMARY

Objectives: Smoking remains a significant public health concern in Ukraine. Recent efforts to combat smoking have shown some progress, but Ukraine's current approach largely overlooks the potential benefits of harm reduction strategies. Concurrently, the use of e-cigarettes has been on the rise among Ukrainian adults. Our study aims to estimate the potential impact of e-cigarettes on reducing the mortality rate associated with cigarette smoking in Ukraine.

Methods: We conducted a replication study using a dynamic population simulation model initially developed for the US. We ran simulations for 210 e-cigarette scenarios, varying assumptions on how e-cigarettes may affect smoking behaviour and health outcomes. A sensitivity analysis was performed to test the robustness of the results.

Results: A substantial majority of e-cigarette scenarios (88.10%) resulted in positive life-years saved (LYS). The LYS ranged from −1.13 to 13.11 million, with a median of 3.17 million, accounting for 4.55% of the total life-years lost (LYL) due to smoking. Among the most plausible e-cigarette scenarios, the LYS varied from 2.73 to 4.88 million (3.92% to 6.99% of LYL due to smoking). Furthermore, these scenarios demonstrated that the long-term smoking prevalence would stabilize at around 5.56–6.40%.

Conclusions: Our simulation analysis demonstrates the potential of e-cigarettes to significantly reduce the burden of smoking in Ukraine. Most e-cigarette scenarios result in positive LYS, while scenarios with negative LYS are unlikely. These findings support the idea that the benefits of e-cigarettes outweigh potential harm, aligning with previous studies in other countries.

Key words: e-cigarettes, smoking, tobacco harm reduction, public health, simulation analysis

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INTRODUCTION

Smoking remains a significant public health concern in Ukraine. According to the Global Adult Tobacco Surveys (GATS), smoking prevalence stood at 28.8% in 2010 (1). This high smoking prevalence is reflected in substantial social costs, with an estimated 85,000 Ukrainians dying from smoking-related diseases in 2010 (2). Furthermore, smoking causes significant damage to the country economy, resulting in an annual loss of approximately 3.2% of Ukraine GDP due to early disability and healthcare expenditures related to smoking-related diseases (3).

Recently, the country has made progress in tackling smoking, as evidenced by a reduction in smoking prevalence to 22.8% in 2017 (4). Simultaneously, the use of electronic cigarettes (e-cigarettes) or vaping has been on the rise among Ukrainian adults. The prevalence of vaping increased from 1.7% in 2010 to 3% in 2017 (1, 4).

In 2017, to tackle the health and economic burden of smoking Ukraine adopted a plan to annually increase the specific excise tax on cigarettes until 2025 (5). In addition, Ukraine started taxing e-cigarette liquids with and without nicotine in 2021 (6). From July 2023, the country prohibited vaping in public places as well as advertising, sponsorship and promotion of e-cigarettes (7). The law also banned the sale of flavoured e-liquids other than tobacco flavour, while nicotine concentration was limited to 2%.

At the same time, an increasing number of countries are recognizing the effectiveness of harm reduction policies that enable access to non-cigarette alternatives, such as e-cigarettes (8–10). Recent scientific literature has demonstrated that vaping is a less harmful alternative to smoking and can aid in smoking cessation (10–16). Furthermore, studies have indicated that the associations between vaping and smoking initiation are driven by shared risk factors of tobacco use in general, and e-cigarettes may serve as a substitute for combustible cigarettes, thereby reducing smoking initiation among adolescents and young adults (17). Moreover, simulation studies found that reductions in smoking prevalence were most pronounced among younger smokers who are also more likely to use e-cigarettes (18–21).

However, certain previous studies have raised concerns that vaping might encourage non-smoking youth to start smoking, without significantly aiding adult smokers in quitting (22, 23). Additionally, some studies have suggested that smokers who switch to vaping may be less likely to quit smoking altogether potentially increasing the risk of relapse (23–28).

Despite these concerns, the growing evidence shows that smoking prevalence declined at a more rapid rate than projected without e-cigarettes and vaping may provide important public health benefits in terms of reducing cigarette use and smoking-attributable deaths (18–21, 29–32). The literature has primarily focused on the United States, the United Kingdom, and more recently, Canada and Russia. Our study contributes to the field by estimating the potential of e-cigarettes to reduce the mortality rate associated with cigarette smoking, specifically in Ukraine.

MATERIALS AND METHODS

Simulation Analysis

We applied a replication of the methodology initially developed by Mendez and Warner (21) for the United States and subsequently adapted by Mzhavanadze and Yanin (30) for Russia and by Mzhavanadze for Georgia (31).

First, we built the dynamic population simulation model for Ukraine that is tailored towards tobacco control policy analysis. The model tracks individuals from ages 0 to 65+ according to their sex and smoking status (never, current and former smokers).

In the baseline year, everyone from ages 0 to 17 is considered as never smoker, while from age 18 population is divided into three sub-groups by their smoking status. In the subsequent years the population size and its composition changes: a new birth cohort is introduced in the model, at 18 years old certain never smokers start smoking and become current smokers; some current smokers quit and become former smokers; and everybody is subject to age-, sex-, and smoking status-specific death rates (illustrative representation of the model and detailed model specifications are presented in the Supplementary Materials).

Following Mendez and Warner (21) we also applied the following assumptions to simplify the calculations:

- The new birth cohort remains constant.
- Individuals aged 0–17 are considered never smokers.
- Smoking initiation only occurs at age 18, and those who start smoking at that age are classified as current smokers.
- Some smokers begin to quit the habit starting from age 19, and those who successfully quit become former smokers.
- Initiation does not reoccur in former smokers.
- We assume that smoking-related deaths do not occur before the age of 35; therefore, death rates before age 35 are not influenced by smoking status.

Then we proceed with the simulations of the Ukrainian population for the subsequent 80 years after the baseline. We first simulated the Ukrainian population under two reference scenarios:

- The status quo scenario assumes that baseline smoking initiation and cessation rates will continue unchanged.
- The never-smoking scenario posits a hypothetical situation where no individuals have ever smoked, and no one will initiate smoking in the baseline year or the future.

By comparing these two scenarios, we can estimate the total life-years lost (LYL) due to smoking in the absence of vaping, providing insight into the potential life-saving impact of e-cigarettes as a proportion of smoking-related LYL.

Then we conducted population size simulations for 210 e-cigarette scenarios, which are a combination of various assumptions drawn from Mzhavanadze and Yanin's study (30) on how vaping affects smoking initiation and smoking cessation, and the health risks of vaping for former smokers (Table 1). To account for the existing uncertainties in the literature, these scenarios encompass a broad range of assumptions.

For each year, we calculated the difference in population size between each specific e-cigarette scenario and the baseline scenario. This difference represents the estimated life-years saved (LYS) or LYL due to vaping for that particular year. To determine the cumulative LYS or LYL over the entire 80-year period, we summed these annual estimates. Furthermore, we expressed the cumulative LYS or LYL for each e-cigarette scenario as a percentage of the LYL due to smoking in the baseline scenario. Lastly, we estimated the proportion of individuals who successfully quit smoking due to vaping, referred to as "e-quitters", among the total number of individuals who quit smoking during the entire simulation period.

Data

This study involves secondary data analysis using publicly available data from the Global Adult Tobacco Survey (GATS) and State Statistics Service of Ukraine. The data used in this analysis do not contain any personally identifiable information and are de-identified prior to use. Therefore, this research did not require direct interaction with human participants and did not necessitate institutional review board approval or informed consent.

We selected 2017 as the model's baseline year because it represents the most recent year for which all data necessary for building the simulation model is available.

Sex- and age-specific population statistics were obtained from the State Statistics Service of Ukraine (S Table 1) (33).

To estimate sex- and age-specific smoking prevalence in the baseline year, we used data from the Ukrainian GATS conducted in 2017 (4). The survey focused on individuals aged 15 and older, regardless of citizenship, who considered Ukraine as their primary residence. Population in temporarily occupied regions, including the Autonomous Republic of Crimea, Sevastopol, and specific areas in Donetsk and Luhansk regions, was excluded from the survey. A total of 14,800 households were sampled using a two-stage design. Initially, primary sampling units (PSUs) were identified based on voting precincts established by the Central Election Commission for the 2014 nationwide parliamentary elections. The PSUs were randomly selected using the probability proportional to the size of PSUs method, resulting in 300 PSUs chosen from urban and rural areas. In the subsequent stage, 30 housing units were randomly selected from each PSU in major cities (Kyiv, Dnipro, Lviv, Odesa, and Kharkiv), while 25 housing units were chosen from each PSU in other urban areas and 23 housing units from rural PSUs. The survey utilized two questionnaire modules. First, the household questionnaire collected data on names, birthdates or ages, gender, and tobacco usage status for each household member. Following this, a randomly selected eligible household member from the household roster completed the individual questionnaire, which primarily focused on tobacco-related inquiries. To attain a balanced gender representation in the sample, adult males were deliberately oversampled due to the higher proportion of adult females within the overall population of Ukraine.

We categorized individuals who reported smoking tobacco on a daily or less-than-daily basis as current smokers. Former smokers were defined as individuals who reported smoking in the past but had quit 6–12 months before the survey, while never smokers were those who had never smoked (S Table 2). The population for the baseline year, categorized by age, sex, and smoking status, is a result of combining sex- and age-specific smoking prevalence with relevant population statistics (S Table 3).

We obtained smoking cessation and initiation rates by sex from GATS 2017 (4). Sex-specific smoking cessation rates were estimated for three age categories (19–34, 35–50, and > 50). These rates represent the proportion of individuals who reported smoking in the past but quit smoking 6 to 12 months ago and are currently non-smokers (Table 1). Sex-specific smoking initiation rates were estimated as the proportion of current smokers within the population aged 18–24 (Table 2).

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 (S Table 4) (34). These relative risks were combined with sex-, age-, and disease-specific mortality data from Ukraine provided by the State Statistics Service (S Table 5) (33).

Sensitivity Analysis

To assess the robustness of our findings, we conducted a sensitivity analysis by using lower and upper bound estimates of smoking cessation and initiation rates as background rates in our dynamic population simulation model (Table 2). This sensitivity analysis aimed to address several potential limitations and uncertainties in our assumptions.

One concern was related to the estimation of the background smoking initiation rate, which was based on the proportion of current smokers in the population aged 18–24. However, smoking initiation might occur before the age of 18 or after the age of 24. Supporting this argument, we observed that in 2017, smoking prevalence in Ukraine was notably higher among the population aged 25–29 compared to the 18–24 age group (S Table 2). Another consideration was the possibility of underreporting of smoking status, especially among young adults and women, as self-reported data from surveys like GATS may be subject to reporting biases. Furthermore, the estimated background cessation rates might be overestimated due to our assumption that initiation does not occur again among former smokers.

To account for these uncertainties, we utilized the lower and upper bound estimates of smoking cessation and initiation rates as background rates in our simulations.

RESULTS

Life-Years Lost due to Smoking

According to our estimations, in the absence of vaping, approximately 64.68 thousand lives (59.10 for men and 5.58 for women) were lost annually to smoking-related diseases in Ukraine in 2017. These numbers represent 15.54% of total premature

Table 1. *Principal assumptions used in the simulation analysis*

Variable		Values	
		Men	Women
Variables held constant across all scenarios			
Background smoking cessation rate (%)	For ages 19–34	3.48	10.65
	For ages 35–50	2.00	2.83
	For age > 50	1.81	7.86
Background smoking initiation rate (%)		33.28	10.03
Variables that define unique e-cigarette scenarios			
Impact of vaping on smoking cessation rate		Increase background rate by 5%, 10%, 25%, 50%, 100%, or 200%	
Impact of vaping on smoking initiation rate		Increase the background rate by −20%, −15%, −10%, 0%, 10%, 15% or 20%	
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%	

Source: Mzhavanadze and Yanin (30)

Table 2. *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	3.48 (1.72–6.94)	10.65 (5.25–20.42)
	For ages 35–50	2.83 (0.92–4.30)	2.00 (0.93–8.32)
	For age > 50	1.81 (0.92–3.53)	7.86 (1.56–31.43)
Background smoking initiation rate (%)		33.28 (26.84–40.41)	10.03 (5.48–17.65)

Source: Authors' calculations based on GATS 2017 (4) deaths in Ukraine, with a significantly higher toll among men at 30.26% compared to 2.53% among women.

Our estimates are more conservative than the estimate of the Institute for Health Metrics and Evaluation, which reported around 113.56 thousand deaths annually (99.56 for men and 14.00 for women) from smoking-related causes (35). The disparity in the figures arises from differences in methodologies. The Institute for Health Metrics and Evaluation employs its own classification system for smoking-related diseases and uses its estimates relative risks of smoking. Additionally, they assume smoking-related deaths occur from age 30 onwards, while our study considered the corresponding age as 35 onwards.

Furthermore, over 80 years following the baseline, we projected that approximately 69.77 million life-years would be lost due to smoking in the absence of e-cigarettes. The estimated LYL accounted for 3.14% and 20.91% of life-years for the adult population and current smokers, respectively (S Table 6).

Our model indicates that the smoking prevalence in the status quo scenario in Ukraine would decline from 23.30% in 2017 to 17.50% in 10 years and further decrease to 13.48% after 20 years. In the long-term smoking prevalence would stabilize at 8.29%. The notable reduction in smoking prevalence within the status quo scenario can be primarily attributed to the decline in smoking initiation rate in Ukraine, which decreased from 34.06% in 2010 to 22.46% in 2017 (S Table 7).

E-cigarette Scenarios

Summary Results for All 210 E-cigarette Scenarios

Out of the 210 e-cigarette scenarios we analysed, a substantial majority, 185 (88.10%), yielded positive LYS. A summary of the simulation results can be found in Table 3. The calculated LYS ranged from −1.13 to 13.11 million. In relative terms, these estimated LYS values spanned from −1.62% to 18.78% of the LYL due to smoking. The median LYS stood at 3.17 million, constituting 4.55% of LYL due to smoking.

The scenario with the lowest LYS combines assumptions where vaping increases smoking cessation by 5%, elevates smoking initiation by 20%, and individuals who quit smoking due to vaping (e-quitters) face a 20% heightened mortality risk. Conversely, the scenario with the highest LYS is characterized by vaping increasing smoking cessation by 200%, reducing smoking initiation by 20%, and having no adverse health impacts on former smokers who quit using e-cigarettes.

The distribution of e-cigarette scenarios based on LYS ranges is presented in Figure 1. The largest number of scenarios (42) fell within the LYS range of 2% to 4%, followed by 32 scenarios in the 0% to 2% range, and 29 scenarios in the 4% to 6% range. Conversely, 25 e-cigarette scenarios in our simulations resulted in negative LYS, with the minimum reaching −1.62%. Detailed results for each e-cigarette scenario are available in S Table 8.

Table 3. *Summary of all e-cigarette scenario simulations (N = 210)*

	Minimum value	Maximum value	Median value
LYS (in millions)	−1.13	13.11	3.17
LYS by vaping as a share of LYL due to smoking (%)	−1.62	18.78%	4.55
Number of scenarios with positive LYS, n (%)	185 (88.10)		

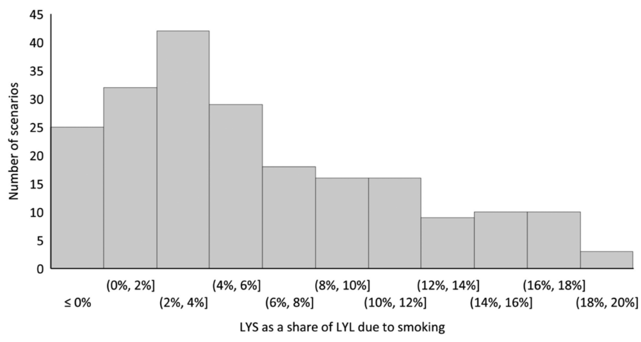

Fig. 1. *Distribution of e-cigarette scenarios by LYS by vaping over the 80 years as a share of LYL due to smoking.*

E-cigarette Scenarios with a Negative Impact on Life-years

Among the 210 e-cigarette scenarios examined, 25 (11.90%) scenarios demonstrate a negative impact on life-years. These scenarios are a result of combinations where vaping increases smoking cessation by 5% or 10% and smoking initiation by 10%, 15%, or 20%. Additionally, elevated health risks of vaping ranging from 0% to 20% are assumed in these scenarios.

However, it is important to note that we consider these scenarios unlikely. As previously mentioned, recent research indicates that the association between vaping and smoking in youth is attributable to shared risk factors of tobacco use (17). Furthermore, adolescents who initially experiment with e-cigarettes are less inclined to start smoking compared to their peers with similar characteristics (17). Consequently, it is more likely that e-cigarettes decrease smoking initiation rather than increase it.

Furthermore, considering the documented effectiveness of vaping in aiding smoking cessation, which is twice as effective as nicotine replacement therapy, our assumption that a 5% or 10% increase in the overall cessation rate due to vaping implies that, on average, only a small fraction of smokers will opt for e-cigarettes as a cessation tool over the next 80 years from the baseline (13, 14). This assumption does indeed align with the current vaping landscape in Ukraine, where only 3.3% of adults reported using e-cigarettes in 2023 (36). However, it is worth noting that if more smokers use e-cigarettes for smoking cessation, then considering a 5% or 10% increase in the population-wide cessation rates would be regarded as a conservative assumption.

Selected E-cigarette Scenarios

Following the insights provided by Mzhavanadze and Yanin (30) and Mzhavanadze (31), and considering our earlier discussion regarding the potential impact of vaping on both quitting and starting smoking, we have identified four e-cigarette scenarios as particularly relevant for Ukraine (Table 4). These scenarios are built on assumptions of a 25% and 50% increase in the background smoking cessation rate, along with a corresponding 10% reduction in the background smoking initiation rate. To account for the

Table 4. 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 reducing smoking initiation by 10%		
		LYS (millions)	LYS as a share of LYL due to smoking (%)	E-quitters as a share in all quitters (%)
5	25	3.02	4.33	19.21
	50	4.88	6.99	32.14
10	25	2.73	3.92	19.09
	50	4.36	6.25	31.96

LYS – life-years saved; LYL – life-years lost; E-quitters – individuals who successfully quit smoking due to vaping

potential risks associated with vaping, we have also factored in vaping risks of 5% or 10% in these scenarios.

These scenarios result in positive cumulative LYS over the 80 years, indicating the potential of e-cigarettes in preventing smoking-related deaths. In these scenarios, LYS ranges from 2.73 to 4.88 million life years in absolute terms and constitutes 3.92% to 6.99% as a share of LYS attributed to vaping in LYL due to smoking (Fig. 2). Furthermore, the potential share of e-quitters among all quitters is estimated to be between 19.09% and 31.96%.

Due to higher cessation rates and lower initiation rates, smoking prevalence in these selected e-cigarette scenarios declines more rapidly compared to the status quo scenario. In the long term, smoking prevalence stabilizes at 5.56% (when the impact of vaping on cessation is 50%) and 6.40% (when the impact of vaping on cessation is 25%) (Fig. 3).

Sensitivity Analysis

After using the lower bound estimates of smoking cessation and initiation rates, the simulation analysis produced 184 (87.62%) scenarios with positive LYS. Similarly, using the upper bound estimates resulted in 178 (84.76%) scenarios with posi-

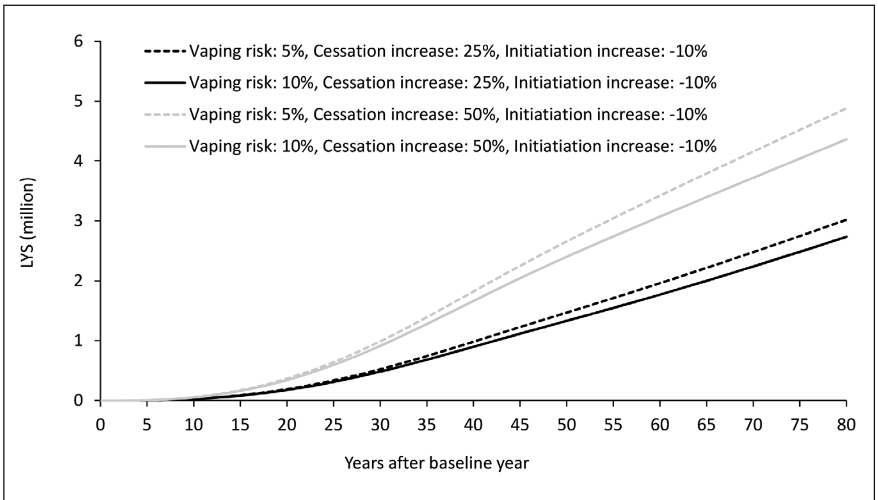

Fig. 2. The cumulative LYS by vaping over the 80 years in selected e-cigarette scenarios.

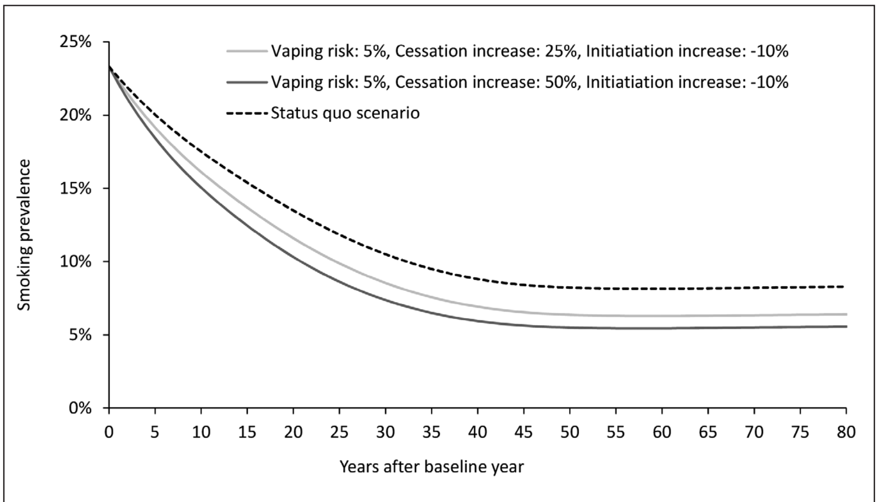

Fig. 3. Smoking prevalence in selected e-cigarette scenarios and status quo over the 80 years.

Table 5. *Effects of vaping on mortality and smoking cessation (cumulative over 80 years)*

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	LYS (million)	LYS as a share of LYL due to smoking	E-quitters as a share in all quitters
5%	10%	1.00	1.43%	8.74%	0.284	0.41%	8.76%
	25%	2.34	3.35%	19.28%	1.654	2.37%	19.33%
	50%	4.23	6.07%	32.24%	3.591	5.15%	32.32%
	100%	7.11	10.19%	48.55%	6.521	9.35%	48.66%
10%	10%	0.87	1.25%	8.67%	0.157	0.22%	8.70%
	25%	2.04	2.93%	19.15%	1.354	1.94%	19.21%
	50%	3.70	5.31%	32.07%	3.047	4.37%	32.15%
	100%	6.22	8.91%	48.36%	5.606	8.03%	48.48%
20%	10%	0.63	0.90%	8.55%	-0.090	-0.13%	8.58%
	25%	1.48	2.12%	18.92%	0.776	1.11%	18.98%
	50%	2.68	3.84%	31.74%	1.999	2.86%	31.83%
	100%	4.49	6.44%	48.00%	3.839	5.50%	48.12%

LYS – life-years saved; LYL – life-years lost; E-quitters – individuals who successfully quit smoking due to vaping
E-cigarette scenarios for which assumptions on smoking cessation, initiation and health risks of vaping are replicated from Mendez and Warner (21).

tive LYS. Summarized results of these sensitivity analyses are provided in S Table 9 and S Table 10, and detailed outcomes can be found in S Table 11 and S Table 12.

Interestingly, the sensitivity analysis revealed that the additional scenarios with negative LYS were primarily driven by the combination of assumptions where vaping had a positive impact on cessation by 10%, 25%, or 50%, but simultaneously increased initiation by 15% or 20%, along with elevated health risks for e-quitters by 20%. However, the resulting range of LYS across 210 e-cigarette scenarios remained largely unchanged, with median LYS being slightly lower in both cases compared to the main results. Moreover, in the case of selected e-cigarette scenarios, the sensitivity analysis produced results that were consistent with the main findings (S Table 13 and S Table 14).

The sensitivity analysis enhances the robustness of our conclusions, demonstrating that the potential impact of e-cigarettes remains significant across a range of plausible assumptions. Although uncertainties exist, the positive outcomes observed in the majority of scenarios indicate that e-cigarettes have the potential to play a vital role in mitigating the burden of smoking-related deaths in Ukraine.

DISCUSSION

Our simulation analysis highlights the significant potential of e-cigarettes to reduce smoking-related mortality in Ukraine. The majority of the 210 scenarios we examined showed positive LYS, suggesting that e-cigarettes could play a crucial role in reducing the public health burden of smoking in the country. The results indicate that under the current policy landscape, e-cigarettes could save between 3.92% and 6.99% of LYL due to smoking.

Our findings closely align with similar simulation analyses conducted internationally, reinforcing the validity and generalizability of the modelling approach. Across scenarios assuming increases in smoking cessation rates of 10%, 25%, 50%, and 100%, combined with either no effect or a 10% increase in smoking initiation and relative risks of vaping set at 5%, 10%, or 20%, our estimates ranged from 0.4% to 10.2% LYS as a proportion of smoking-related LYL (Table 5). Mendez and Warner (21) estimated that in the United States, e-cigarette use could reduce smoking-related LYL by 1.1% to 12.8%. Similarly, in the Russian context, Mzhavanadze and Yanin (30) projected savings of 0.5% to 11.08% of smoking-related LYL, while in Georgia, estimates by Mzhavanadze (31) ranged from 0.4% to 16.3%, closely mirroring our results in relative terms. In Australia, Levy et al. projected that replacing restrictive vaping policies with more permissive access could reduce smoking-related deaths by 7.7% and life-years lost (LYL) by 17.3%, assuming vaping carries 5% of the mortality risk of smoking (32). Even with a higher assumed risk (40%), the reductions of 5.4% in deaths and 10.6% in LYL were observed.

We acknowledge several key limitations inherent in our study design. First, our model assumes constant birth cohorts and excludes initiation of smoking below age 18 or among former smokers, potentially underestimating smoking initiation and cessation dynamics. Second, the long-term mortality risks associated with vaping remain uncertain; while we incorporated a wide range of assumptions and sensitivity analyses, definitive evidence on long-term health outcomes is still lacking. Third, reliance on self-reported data from surveys such as GATS may introduce reporting bias, particularly underestimating smoking prevalence and initiation rates among women and youth.

A major strength of our study lies in its comprehensive sensitivity analyses, which incorporated a wide range of plausible assumptions on initiation and cessation rates, as well as health risks associated with vaping. These robustness checks consistently affirmed our central finding – most scenarios predict substantial positive public health impacts. Additionally, using publicly available and high-quality nationally representative survey data enhances the credibility and reproducibility of our modelling outcomes.

Our study also identified a small subset (11.90%) of scenarios that yield negative LYS. These scenarios occur under assumptions combining minimal cessation benefits from vaping, substantial increases in smoking initiation, and significantly elevated mortality risks for vaping former smokers. However, such scenarios appear unlikely under realistic conditions, given growing evidence that vaping is effective for cessation (often double that of conventional nicotine replacement therapies), and that it is more likely to substitute for, rather than promote, youth smoking initiation (13, 14, 17).

CONCLUSIONS

The findings from our simulation analysis provide strong evidence that e-cigarettes could significantly reduce the burden of smoking-related diseases in Ukraine. With most scenarios indicating positive life-years saved, our study suggests that the inclusion of harm reduction strategies could enhance the effectiveness of Ukraine's tobacco control policies.

However, the potential risks associated with e-cigarettes, particularly regarding youth initiation and the health impacts on former smokers, should not be overlooked. These risks highlight the importance of implementing comprehensive regulatory frameworks that maximize the public health benefits of e-cigarettes while minimizing potential harms.

In conclusion, while the debate on e-cigarettes continues, our study contributes to the growing body of evidence suggesting that e-cigarettes could play a pivotal role in reducing smoking prevalence and preventing smoking-attributable deaths in Ukraine.

Electronic Supplementary Materials

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Conflicts of Interest

None declared

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REFERENCES

1. Andreeva T, Kharchenko N, Krasovsky K, Korol N, Lea V, Lee J, et al. Global Adult Tobacco Survey (GATS), Ukraine 2010 [Internet]. [cited 2023 Jun 15]. Available from: https://www.kiis.com.ua/materials/pr/2010/REPORT/GATS%20Ukraine%202010%20Report%20ENG.pdf.
2. Peto R, Lopez AD, Pan H, Boreham J, Thun M. Mortality from smoking in developed countries 1950-2000 [Internet]. Oxford: Oxford University, CTSU; 2015 [cited 2023 Jun 15]. Available from: http://gas.ctsu.ox.ac.uk/tobacco/.
3. Goodchild M, Nargis N, Tursan d'Espaignet E. Global economic cost of smoking-attributable diseases. Tob Control. 2018 Jan;27(1):58-64.
4. Andreeva T, Bazyka D, Dudin O, Fuzik M, Korol N, Rymarenko K, et al. Global Adult Tobacco Survey, Report Ukraine 2017 [Internet]. Kyiv: Ministry of Health of Ukraine; 2017 [cited 2023 Jun 15]. Available from: https://kiis.com.ua/materials/pr/20180214_GATS/Full%20Report%20GATS%20Ukraine%202017%20ENG.pdf.
5. [Act No. 2245-VII on amendments to the tax code of Ukraine and some legislative acts of Ukraine on ensuring balance of budgetary revenues in 2018]. Vidomosti Verkhovnoyi Rady. 2018;(8):46. Ukrainian.
6. [Law No. 466-IX on amendments to the tax code of Ukraine on improving tax administration, eliminating technical and logical inconsistencies in tax law]. Vidomosti Verkhovnoyi Rady. 2020;(32):227. Ukrainian.
7. [Law No. 1978-IX on amendments to certain laws of Ukraine on public health protection from the harmful effects of tobacco]. Vidomosti Verkhovnoyi Rady. 2023;(7):20. Ukrainian.
8. Stratton KR. Kwan LY, Eaton DL, editors. Public health consequences of e-cigarettes. Washington (DC): The National Academies Press; 2018.
9. Shah A, Britton J, Bogdanovica I. Developing a novel e-cigarette regulatory and policy control scale: results from the European Union. Drugs (Abingdon Engl). 2021 Aug 12;29(6):719-25.
10. Office for Health Improvement and Disparities. Nicotine vaping in England: an evidence update including health risks and perceptions [Internet]. London: Office for Health Improvement and Disparities; 2022 [cited 2023 Jun 15]. Available from: https://www.gov.uk/government/publications/nicotine-vaping-in-england-2022-evidence-update/nicotine-vaping-in-england-2022-evidence-update-main-findings.
11. Banks E, Yazidjoglou A, Brown S, Nguyen M, Martin M, Beckwith K, et al. Electronic cigarettes and health outcomes: umbrella and systematic review of the global evidence. Med J Aust. 2023 Apr 3;218(6):267-75.
12. Chambers MS. Effect of vaping on past-year smoking cessation success of Australians in 2019-evidence from a national survey. Addiction. 2022 Aug;117(8):2306-15.
13. Hartmann-Boyce J, Lindson N, Butler AR, McRobbie H, Bullen C, Begh R, et al. Electronic cigarettes for smoking cessation. Cochrane Database Syst Rev. 2022 Nov 17;11(11):CD010216. doi: 10.1002/14651858.CD010216.pub7.
14. Hajek P, Phillips-Waller A, Przulj D, Pesola F, Myers Smith K, Bisal N, et al. A randomized trial of e-cigarettes versus nicotine-replacement therapy. N Engl J Med. 2019 Feb 14;380(7):629-37.
15. Lindson N, Theodoulou A, Ordóñez-Mena JM, Fanshawe TR, Sutton AJ, Livingstone-Banks J, et al. Pharmacological and electronic cigarette interventions for smoking cessation in adults: component network meta-analyses. Cochrane Database Syst Rev. 2023 Sep 12;9(9):CD015226. doi: 10.1002/14651858.CD015226.pub2.
16. Kasza KA, Edwards KC, Anesetti-Rothermel A, Creamer MR, Cummings KM, Niaura RS, et al. E-cigarette use and change in plans to quit cigarette smoking among adult smokers in the United States: Longitudinal findings from the PATH Study 2014-2019. Addict Behav. 2022 Jan;124:107124. doi: 10.1016/j.addbeh.2021.107124.
17. Shahab L, Beard E, Brown J. Association of initial e-cigarette and other tobacco product use with subsequent cigarette smoking in adolescents: a cross-sectional, matched control study. Tob Control. 2021 Mar;30(2):212-20.
18. Levy DT, Sánchez-Romero LM, Li Y, Yuan Z, Travis N, Jarvis MJ, et al. England SimSmoke: the impact of nicotine vaping on smoking prevalence and smoking-attributable deaths in England. Addiction. 2021 May;116(5):1196-211.
19. Levy DT, Sánchez-Romero LM, Travis N, Yuan Z, Li Y, Skolnick S, et al. US nicotine vaping product SimSmoke simulation model: the effect of vaping and tobacco control policies on smoking prevalence and smoking-attributable deaths. Int J Environ Res Public Health. 2021 May 3;18(9):4876. doi: 10.3390/ijerph18094876.
20. Levy DT, Cadham CJ, Yuan Z, Li Y, Gravely S, Cummings KM. Comparison of smoking prevalence in Canada before and after nicotine vaping

product access using the SimSmoke model. Can J Public Health. 2023 Dec;114(6):992-1005.
21. Mendez D, Warner KE. A Magic bullet? The potential impact of e-cigarettes on the toll of cigarette smoking. Nicotine Tob Res. 2021 Mar 19;23(4):654-61.
22. Soneji S, Barrington-Trimis JL, Wills TA, Leventhal AM, Unger JB, Gibson LA, et al. Association between initial use of e-cigarettes and subsequent cigarette smoking among adolescents and young adults: a systematic review and meta-analysis. JAMA Pediatr. 2017 Aug 1;171(8):788-97.
23. Watkins SL, Glantz SA, Chaffee BW. Association of noncigarette tobacco product use with future cigarette smoking among youth in the Population Assessment of Tobacco and Health (PATH) Study, 2013-2015. JAMA Pediatr. 2018 Feb 1;172(2):181-7.
24. Weaver SR, Huang J, Pechacek TF, Heath JW, Ashley DL, Eriksen MP. Are electronic nicotine delivery systems helping cigarette smokers quit? Evidence from a prospective cohort study of U.S. adult smokers, 2015-2016. PLoS One. 2018 Jul 9;13(7):e0198047. doi: 10.1371/journal.pone.0198047.
25. Miller CR, Smith DM, Goniewicz ML. Changes in nicotine product use among dual users of tobacco and electronic cigarettes: findings from the Population Assessment of Tobacco and Health (PATH) Study, 2013-2015. Subst Use Misuse. 2020;55(6):909-13.
26. Glantz SA, Bareham DW. E-cigarettes: use, effects on smoking, risks, and policy implications. Annu Rev Public Health. 2018 Apr 1;39:215-35.
27. Dai H, Leventhal AM. Association of electronic cigarette vaping and subsequent smoking relapse among former smokers. Drug Alcohol Depend. 2019 Jun 1;199:10-7.
28. Baenziger ON, Ford L, Yazidjoglou A, Joshy G, Banks E. E-cigarette use and combustible tobacco cigarette smoking uptake among non-smokers, including relapse in former smokers: umbrella review, systematic review and meta-analysis. BMJ Open. 2021 Mar 30;11(3):e045603. doi: 10.1136/bmjopen-2020-045603.
29. Lee PN, Abrams D, Bachand A, Baker G, Black R, Camacho O, et al. Estimating the population health impact of recently introduced modified risk tobacco products: a comparison of different approaches. Nicotine Tob Res. 2021 Feb 16;23(3):426-37.
30. Mzhavanadze G, Yanin D. The Potential impact of e-cigarettes on the life-years lost from conventional smoking in the Russian Federation. J Consum Policy (Dordr). 2023;46(2):253-74.
31. Mzhavanadze G. The potential impact of e-cigarettes on the life-years lost from conventional smoking in Georgia: a replication study. J Health Soc Sci. 2024;9(1):155-69.
32. Levy DT, Gartner C, Liber AC, Sánchez-Romero LM, Yuan Z, Li Y, et al. The Australia smoking and vaping model: the potential impact of increasing access to nicotine vaping products. Nicotine Tob Res. 2023 Feb 9;25(3):486-97.
33. State Statistics Service. Population statistics. State Statistics Service of Ukraine; 2021.
34. National Center for Chronic Disease Prevention and Health Promotion (US), Office on Smoking and Health. The health consequences of smoking: 50 years of progress. Atlanta (GA): Centers for Disease Control and Prevention (US); 2014.
35. Institute for Health Metrics and Evaluation (IHME). Global Burden of Disease Study 2019 (GBD 2019) results [Internet]. Seattle (WA): IHME; 2020 [cited 2023 Jun 15]. Available from: https://vizhub.healthdata.org/gbd-results/.
36. Advocacy center Life. Consumption of tobacco and nicotine products in Ukraine: sociological survey results among adults aged 18+ [Internet]. Kyiv: Advocacy center Life [cited 2023 Sep 26]. Available from https://center-life.org/wp-content/uploads/2023/07/FACT-SHEET_FINAL_VZHYVANNYA_TYUTYUNOVYKH_TA_NYKOTYNOVYKH_VYROBIV_VUKRAINI-1.pdf.

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