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Vaporized Promises, Clouded Realities: E-cigarette Penetration, Regulation, and Cancer Prevention

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Abstract

Objective: This study examines the public health and cancer prevention implications of the rapid proliferation of electronic nicotine delivery systems (ENDS) in South Korea, and discusses regulatory strategies grounded in empirical evidence. **Method:** Drawing on domestic and international literature, and national statistical data, the analysis synthesizes evidence on ENDS product characteristics, patterns of use, associated health risks, potential effectiveness for smoking cessation, and indicators of nicotine dependence. A comparative policy analysis further situates Korea's tobacco control framework within the broader landscape of regulatory approaches adopted in other high-income countries. **Results:** Although ENDS eliminate combustion and may reduce exposure to certain carcinogens, their expanding use raises substantial public health concerns particularly with respect to youth nicotine initiation, dual use with combustible cigarettes, and uncertain long-term health effects. While some evidence suggests a possible role for ENDS in smoking cessation, the overall scientific evidence remains mixed, and robust longitudinal data are limited. Regulatory responses to ENDS vary widely across countries, with South Korea maintaining a relatively cautious regulatory stance. **Conclusion:** In light of the evolving evidence base and emerging population-level risks, a comprehensive and precautionary regulatory approach is warranted with particular emphasis on protecting adolescents, ensuring product safety, and reinforcing norms that support tobacco cessation.

Keywords: e-cigarettes- electronic nicotine delivery systems (ENDS)- heated tobacco products (HTPs)

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Introduction

Smoking adversely affects nearly every organ in the human body and is a leading preventable cause of disease and premature death, contributing to conditions such as cancer, cardiovascular disease, and pulmonary disorders [1]. As of 2024, smoking is estimated to cause approximately 8.2 million deaths globally 7 million from direct smoking and 1.2 million from secondhand exposure of which 71% (5.68 million) are men and 29% (2.32 million) are women [2–5]. In Korea, tobacco-related mortality is estimated at 40,000 to 60,000 deaths annually, with men accounting for approximately 80–84% and women for 16–20% of these deaths [5]. The World Health Organization Framework Convention on Tobacco Control (WHO FCTC) was adopted at the 56th World Health Assembly on May 21, 2003, and entered into force on February 27, 2005. As of July 2025, 183 countries have ratified the Convention, encompassing over 90% of the global population [6]. In Korea, the male smoking rate declined from 66.3% in 1998 to approximately 34.0% in 2020, following the implementation of measures such as cigarette tax increases, expansion of smoke-free zones, public awareness campaigns, and smoking cessation support services [7]. However, since 2020, total cigarette sales have begun to rise again, driven by the growing popularity of novel tobacco products, including liquid-based and heat-not-burn electronic cigarettes [8]."

In South Korea, the introduction of novel tobacco products beginning with Philip Morris's launch of iQOS in 2017, followed by Glo (British American Tobacco), Lil (KT&G), and JUUL (PAX Labs) has significantly altered the previously combustible cigarette-dominated market structure [8, 9]. According to the National Academies of Sciences, Engineering, and Medicine [10], conventional smoking involves inhaling smoke produced through the combustion of tobacco, primarily referring to combustible cigarettes. This combustion process generates approximately 7,000 chemical compounds, including tar, carbon monoxide (CO), benzene, and polycyclic aromatic hydrocarbons (PAHs), of which hundreds are toxic and around 70 are known carcinogens. In contrast, vaping a method of using electronic nicotine delivery systems (ENDS) involves inhaling an aerosol produced by heating a liquid nicotine solution (e-liquid or vape juice). Although combustion is absent, the aerosol still contains

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substances such as propylene glycol, glycerin, flavorings, nicotine, and trace metals, albeit generally at lower concentrations of carcinogens compared to traditional cigarettes. In response to these developments, the South Korean government has broadened the legal definition of cigarettes, intensified regulation of novel nicotine products, and issued advisories against the use of liquid-type e-cigarettes. Despite ongoing debate regarding their efficacy as cessation aids and their safety profile, there is growing international consensus that electronic cigarettes are not a safe alternative to conventional smoking [11].

Despite sustained declines in adult smoking prevalence, tobacco use remains a leading cause of preventable morbidity and mortality. Because smoking-related diseases develop over long latency periods, reductions in smoking prevalence do not immediately translate into declines in population-level mortality. By contrast, the health benefits of smoking cessation accrue relatively quickly, particularly among younger adults, with marked reductions in cardiovascular disease risk. Importantly, complete cessation is required to achieve cardiovascular protection; smoking reduction alone does not yield comparable benefits [12]. Within this context, this study examines the rapid proliferation of electronic nicotine delivery systems (ENDS) in South Korea and assesses their implications for national tobacco control policy. Although ENDS are commonly promoted as safer alternatives to combustible cigarettes or as smoking cessation aids, accumulating evidence suggests that their effectiveness remains contested and that their expanding use may pose new public health risks. Drawing on empirical data on ENDS use, regulatory responses, and health outcomes in the Korean context, this analysis critically evaluates the extent to which ENDS can be integrated into comprehensive tobacco control strategies. In doing so, the study interrogates the tension between harm reduction claims and precautionary public health principles that increasingly shape contemporary tobacco regulation.

Typologies of Tobacco Products and Their Physiological Impacts

Conventional cigarettes consist of shredded tobacco leaves wrapped in paper, typically with filters and chemical additives, and are consumed through combustion, with users inhaling the resulting smoke. Heated tobacco products (HTPs), also referred to as non-combusted or heat-not-burn products, heat tobacco at lower temperatures to generate an aerosol rather than smoke. Positioned between conventional cigarettes and electronic nicotine delivery systems (ENDS), HTPs produce lower levels of certain toxic substances than combustible cigarettes but nonetheless pose meaningful health risks [13]. ENDS including electronic cigarettes, vape pens, and other vaping devices generate aerosols by heating liquids that contain nicotine and flavoring agents. Although frequently marketed as safer alternatives to combustible cigarettes, an expanding body of evidence has linked ENDS use to adverse health outcomes, including asthma, chronic obstructive pulmonary disease (COPD), and coronary artery disease [13–21]. In the United States, an estimated 50% to 70% of adult liquid-based e-cigarette users are dual users who also smoke conventional cigarettes [22, 23]. Compared with exclusive users of either product, dual users demonstrate higher levels of cigarette consumption, elevated cotinine concentrations, and nearly twice the prevalence of self-reported dyspnea [24–26]. The rapid increase in e-cigarette use among adolescents worldwide has generated substantial public health concern, particularly with respect to nicotine dependence and long-term health consequences [27]. Evidence suggests that adolescent e-cigarette use may disrupt neurodevelopment, increase susceptibility to nicotine addiction, and potentially serve as a gateway to subsequent combustible cigarette use and other substance use behaviors [28]. Similar to conventional cigarettes, e-cigarettes are addictive, contribute to the accumulation of heavy metals in the body, and pose complex risks to both physical and mental health [29, 30]. In addition, aerosols emitted from liquid-based e-cigarettes have been shown to contain nicotine and carcinogenic substances at concentrations exceeding the thresholds recommended by the WHO Framework Convention on Tobacco Control, thereby also presenting secondhand exposure risks to non-users [31, 32].

Trends in Tobacco Consumption and Market Dynamics in South Korea

The Korean tobacco market can be categorized into four main product types. First, conventional combustible cigarettes remain the most widely used form. According to the Korea National Health and Nutrition Examination Survey, the smoking rate among adult males declined steadily from 48% in 2010 to 34% in 2020, with an annual decrease of approximately 1–2% [7]. In contrast, the smoking rate among adult females has remained relatively stable at around 6–7%. Among adolescents, the smoking prevalence dropped from 17% to 6% for boys and from 7% to 3% for girls between 2010 and 2021 [33]. Second, liquid-based electronic nicotine delivery systems (ENDS or e-cigarettes), which were first commercialized globally in 2004, represent a growing segment of the market. As of 2023, the global ENDS market is valued at approximately $19 billion, with an average annual growth rate of 3–4% [34]. Although introduced to Korea in 2008, the prevalence of ENDS use increased markedly after 2015. Currently, around 3% of both adults and adolescents report using liquid e-cigarettes [33]. Third, HTPs, such as iQOS, Glo, and Lil, were launched in the Korean market in 2017. These devices heat tobacco to approximately 350°C to produce a vapor rather than smoke. Current usage rates stand at 5% among adults and 3% among adolescents [33–35]. Fourth, a growing number of users engage in dual or poly-use across different product types. This trend reflects the diversification of the tobacco market following the introduction of new products and highlights persistent challenges in reducing tobacco use despite strong anti-smoking policies [36]. Presently, one out of every seven

cigarette packs sold in Korea consists of heated tobacco products [5]. However, due to gaps in legislation and taxation, accurate sales and usage data for liquid-based e-cigarettes remain limited. As a result, discrepancies persist between self-reported smoking rates and actual sales data [35]. Internal documents from JUUL Labs indicate that major e-cigarette companies have employed brand-stretching strategies targeting youth and women, leveraging social media and other promotional channels to cultivate brand loyalty [37]. Such marketing tactics are widely viewed as having undermined tobacco control efforts and contributed to the stagnation of smoking rate reductions.

Contested Roles of E-Cigarettes in Harm Reduction and Health Risk

The role of electronic cigarettes as a safer alternative to combustible cigarettes or as an effective smoking cessation aid remains highly contested. According to data from the U.S.-based Population Assessment of Tobacco and Health (PATH) cohort, individuals who used e-cigarettes were more likely to attempt quitting smoking compared to non-users [38]. A meta-analysis of randomized controlled trials further reported that smokers using nicotine-containing e-cigarettes had a 77% higher cessation success rate than those using traditional nicotine replacement therapies (NRT) such as patches or gum (RR = 1.77; 95% CI: 1.29–2.44) [39]. While those who transition from combustible cigarettes to e-cigarettes may initially face a higher risk of relapse, they are also more likely to maintain long-term abstinence. Another study found that among individuals with no initial intention to quit smoking, daily e-cigarette use was associated with a 28% cessation rate approximately four to five times higher than that of non-users [40]. These findings suggest that e-cigarettes may outperform conventional NRTs in promoting smoking cessation [41]. However, the evidence remains inconclusive. Not all studies report statistically significant effects, and concerns persist regarding limited internal validity and inadequate control of confounding variables in existing research designs [42–44]. Relative to combustible cigarettes, e-cigarettes exhibit certain potentially beneficial characteristics. Most notably, the absence of combustion significantly reduces exposure to toxicants. While traditional cigarettes combust at temperatures exceeding 600°C producing over 70 carcinogens, including tar, carbon monoxide, and benzene e-cigarettes heat nicotine-containing liquids at 200–250°C to generate aerosol. Some studies estimate a 90–95% reduction in the emission of harmful chemicals under these conditions [45]. Additionally, for smokers who have failed to quit using conventional NRTs, e-cigarettes may serve as a viable alternative, although the scientific evidence supporting this pathway remains limited. Certain devices also allow users to regulate nicotine concentration, potentially enabling gradual reduction and eventual cessation [46–49].

Nicotine Dependence: Definitions, Metrics, and Clinical Tools

Despite widespread awareness of the health risks associated with tobacco use, the success rate of unaided smoking cessation remains low due to the addictive properties of nicotine. Among individuals attempting to quit 'cold turkey' without pharmacological or behavioral support, only 3–7% maintain abstinence for 6 to 12 months [50]. Moreover, 50–70% of those who quit relapse within one year [51]. The World Health Organization's International Classification of Diseases, 11th Revision (ICD-11), defines nicotine dependence as a disorder of use control characterized by repeated or persistent nicotine use despite adverse consequences [52]. Core features include a strong desire or compulsion to use, impaired control over consumption, prioritization of nicotine over other activities, and continued use despite harm. Physiological symptoms such as tolerance, withdrawal, and repeated use to relieve withdrawal are also central components. A formal diagnosis typically requires daily or near-daily use for at least 12 months, although a duration of 3 months may be sufficient if usage is intensive. Diagnosis is made when at least two of the following criteria are met: (1) impaired control over use, (2) nicotine use taking precedence over other life domains, and (3) physiological indicators of dependence such as tolerance and withdrawal. The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), issued by the American Psychiatric Association, categorizes nicotine addiction under 'Tobacco Use Disorder' (Code 305.1). The diagnostic framework mirrors that of other substance use disorders and includes criteria such as excessive use, unsuccessful quit attempts, cravings, tolerance, withdrawal, use in hazardous situations, and persistent social or interpersonal problems related to use [53]. A diagnosis requires the presence of two or more symptoms within a 12-month period, with severity levels classified as mild (2–3 symptoms), moderate (4–5), and severe (6 or more) [54]. Common indicators include smoking more than intended, repeated failure to quit, craving, interference with social functioning, use in risky situations, and signs of physiological dependence. In South Korea, the lifetime prevalence of nicotine dependence is estimated at approximately 8%, with a significant gender gap: 15% for men and 1% for women [55].

Nicotine dependence is commonly assessed using both self-report questionnaires and biological markers. Among adults, the most widely used instrument is the Fagerström Test for Nicotine Dependence (FTND), a six-item scale that evaluates factors such as time to first cigarette after waking, smoking in prohibited areas, total daily cigarette consumption, preferred time of day for smoking, difficulty refraining from smoking during specific times, and smoking while bedridden. Scores range from 0 to 10, with higher scores indicating greater levels of nicotine dependence [56]. A shortened version of the FTND, the Heaviness of Smoking Index (HSI), uses only two items daily cigarette consumption and time to first cigarette and is frequently used in large-scale surveys for its brevity. For adolescents, the Modified Fagerström Tolerance

Questionnaire (mFTQ) is commonly employed to assess nicotine dependence in youth populations. Biomarkers provide objective measures of nicotine exposure and dependence. Cotinine, the primary metabolite of nicotine, is the most reliable biomarker due to its longer half-life, allowing for detection across various biological samples, including blood, urine, saliva, and hair [57]. While nicotine itself can be measured directly, its short half-life limits its utility to recent exposure only. A secondary metabolite, 3-hydroxycotinine (3-HC), is used in calculating the nicotine metabolite ratio (NMR), a marker of individual variability in nicotine metabolism. Higher NMR values are associated with faster nicotine metabolism, reduced cessation success, and greater dependence risk. Carbon monoxide (CO) levels in exhaled breath are also used to assess recent smoking behavior, particularly within a few hours of exposure, but are limited in their ability to reflect the level of dependence. Notably, while conventional cigarette use elevates both cotinine and CO levels, electronic cigarette use primarily increases cotinine [58]. Cotinine thresholds commonly used to define active smoking include concentrations of ≥15 ng/mL in saliva and ≥50 ng/mL in urine [1, 59].

Health Consequences of Smoking and Approaches to Smoking Cessation Treatment

Given that approximately 50% of persistent smokers die from smoking-related illnesses and that smokers, on average, lose about 10 years of life expectancy compared to non-smokers, smoking cessation is widely regarded as one of the most critical public health interventions [1, 60]. According to the U.S. Surgeon General's Report, both active smoking and exposure to secondhand smoke (SHS) are associated with a wide range of severe health consequences [61]. Active smoking has been causally linked to numerous diseases, including liver cancer, colorectal cancer, type 2 diabetes, and tuberculosis. Strong evidence also supports its association with age-related macular degeneration. Smokers face a 30–40% higher risk of developing diabetes than non-smokers, with a clear dose–response relationship observed. Moreover, smoking is a well-established cause of both tuberculosis and chronic obstructive pulmonary disease (COPD). Secondhand smoke exposure is causally associated with lung cancer, cardiovascular diseases such as myocardial infarction and stroke, and adverse pregnancy outcomes, including low birth weight. In children, SHS has been linked to sudden infant death syndrome (SIDS), impaired lung development, respiratory infections, and otitis media. Globally, smoking remains the leading modifiable risk factor for premature mortality and imposes substantial socioeconomic burdens, including increased healthcare expenditures and productivity losses [2–5]. Therefore, smoking cessation is essential not only for preventing chronic disease and premature death but also for enhancing quality of life and reducing long-term health system costs.

From Restriction to Regulation: The Shifting Landscape of Tobacco Control

Tobacco control strategies encompass both clinical and public health interventions, each targeting smoking reduction through distinct mechanisms, populations, and levels of influence. While both approaches are essential and complementary, they differ markedly in scope, delivery, and evaluative criteria. Clinical interventions primarily target individual smokers typically patients within healthcare settings such as hospitals, primary care clinics, and public health centers. These interventions often involve brief physician advice, motivational interviewing, pharmacotherapy (e.g., nicotine replacement therapy, varenicline, bupropion), behavioral counseling, and specialized smoking cessation clinics. Clinical strategies are generally aligned with secondary prevention, aiming to modify behaviors and reduce disease risk among active smokers. Although highly personalized and often effective, clinical interventions tend to be resource-intensive, limited in population reach, and reliant on sustained individual engagement. In contrast, public health interventions are designed to influence entire populations, including current smokers, potential smokers, and non-smokers. These strategies include tobacco taxation and price increases, pictorial health warnings on cigarette packaging, the expansion of smoke-free environments (e.g., schools, hospitals, public spaces), mass media campaigns, youth education programs, and regulatory policies such as advertising bans and age restrictions. Public health measures predominantly serve a primary prevention function, although many also contribute to secondary and tertiary prevention. Their key advantages lie in cost-effectiveness, broad reach, and sustainability, especially when embedded in national policy frameworks. The two approaches also differ in outcome measurement. Clinical interventions are typically evaluated based on individual-level indicators such as smoking cessation success rates, relapse rates, and patient satisfaction. Public health interventions, in contrast, are assessed using population-level metrics, including reductions in national smoking prevalence, delayed smoking initiation among youth, and changes in overall tobacco consumption. Ultimately, an effective tobacco control strategy requires the integration of both clinical and public health approaches, leveraging their respective strengths to maximize impact on smoking behavior and tobacco-related disease burden.

Clinical Interventions for Smoking Cessation

To address chronic nicotine dependence, clinical practice commonly employs a combination of behavioral counseling and pharmacotherapy. According to the Treating Tobacco Use and Dependence: 2008 Update, first-line pharmacologic treatments include nicotine replacement therapy (NRT) such as transdermal patches, gum, lozenges, inhalers, and nasal sprays as well as non-nicotine medications like bupropion sustained-release (SR) and varenicline [62, 63]. NRT is designed to replace nicotine obtained through combustible cigarettes with safer delivery methods, thereby alleviating withdrawal

symptoms and cravings. Although nicotine from NRT is absorbed more slowly and reaches lower peak plasma concentrations than that from smoking, it has demonstrated efficacy in supporting cessation. A comprehensive review by the Cochrane Tobacco Addiction Group found that NRT increased the likelihood of successful smoking cessation at 6 months by 50–60% compared to placebo or no treatment [64]. A 2007 meta-analysis similarly reported that NRT users were nearly twice as likely to remain abstinent at 12-month follow-up compared to controls [65]. Pre-cessation use of NRT initiating treatment before the target quit date has also been associated with improved outcomes [66]. Among non-nicotine therapies, bupropion has been shown to improve cessation success rates by 60–70% relative to placebo [67, 68]. Varenicline, a partial agonist of the α4β2 nicotinic acetylcholine receptor, acts through a dual mechanism: it attenuates the dopaminergic reward of smoking and mitigates withdrawal symptoms by modestly stimulating the receptor. This pharmacological profile enables varenicline to suppress craving while reducing the reinforcing effects of nicotine, even when smoking occurs during treatment. Clinical trials have demonstrated that varenicline more than doubles cessation rates compared to placebo and outperforms both NRT and bupropion in network meta-analyses [69, 70]. Accordingly, recent clinical guidelines recommend varenicline monotherapy as the most effective first-line treatment [71]. Among pharmacotherapies, varenicline demonstrated the highest quit rates after 9 to 12 weeks of continuous use, followed by bupropion, nicotine patches, and placebo [72].

Public Health Interventions for Smoking Cessation

1) Conventional Tobacco Regulation

(1) Tobacco taxation has long been recognized as one of the most effective population-level strategies for reducing smoking prevalence, based on well-documented mechanisms that influence consumer behavior, particularly among price-sensitive populations [73, 74]. First, taxation leverages the price elasticity of demand. Cigarettes are price-elastic commodities, meaning that consumption is sensitive to price fluctuations. Evidence consistently shows that adolescents and individuals from lower socioeconomic groups are especially responsive to price increases, often reducing consumption or initiating quit attempts. Empirical estimates suggest that a 10% increase in cigarette prices results in a 4% reduction in adult smoking and a 6–7% reduction among adolescents [73, 74]. Second, high cigarette prices deter smoking initiation. Adolescents are less likely to experiment with tobacco products when faced with significant cost barriers. Elevated prices reduce the appeal of smoking driven by peer influence or curiosity, thereby delaying or preventing uptake. Third, taxation promotes cessation and discourages relapse. For current smokers, increased prices impose an economic burden that can motivate quit attempts and support sustained abstinence. Importantly, the impact is not limited to short-term behavioral shifts; successive tax increases have been shown to induce durable reductions in smoking behavior over time. Fourth, tobacco taxes generate revenue for public health investment. Earmarking tobacco tax revenues for health promotion initiatives, smoking cessation programs, and other public health interventions creates a virtuous cycle, reinforcing the broader goals of tobacco control. In South Korea, the price of cigarettes increased from KRW 900 to KRW 4,500 in 2015, following seven incremental tax hikes since 1994. These fiscal measures have contributed to declines in smoking prevalence and cigarette consumption, as well as increases in quit attempts. However, the current taxation level remains below the World Health Organization's recommended threshold, and no further tax increases have occurred since 2015, representing a missed opportunity to reinforce progress.

(2) Smoke-free policies constitute legal and administrative measures that prohibit smoking in public places, workplaces, schools, restaurants, public transportation, parks, and other communal settings. These policies serve a dual public health function: protecting non-smokers from exposure to secondhand smoke (also known as environmental tobacco smoke) and creating social environments that discourage smoking behavior and encourage cessation. By restricting designated smoking areas, smoke-free regulations not only reduce involuntary exposure among non-smokers but also constrain smokers' opportunities to consume tobacco, thereby increasing their motivation to quit. Moreover, these policies contribute to denormalizing smoking by fostering social norms that disfavor tobacco use. This effect is particularly important for adolescents, as reducing the visibility of smoking diminishes imitative behaviors and initiation risk. Empirical studies have demonstrated the effectiveness of comprehensive smoke-free laws: following their implementation, indoor air concentrations of nicotine and fine particulate matter (PM2.5) decreased by 80–90%, and rates of emergency department visits for myocardial infarction and asthma declined significantly [75]. Article 8 of the World Health Organization Framework Convention on Tobacco Control (WHO FCTC) explicitly recommends the designation of all indoor workplaces, public transportation, and public venues as smoke-free zones. Consistent with these guidelines, South Korea has progressively expanded smoke-free areas, resulting in measurable reductions in non-smokers' exposure to secondhand smoke.

(3) Pictorial health warning labels (PWLs) on cigarette packaging represent a widely endorsed public health strategy designed to communicate the risks of smoking through graphic images and health messages. As a central component of Article 11 of the World Health Organization Framework Convention on Tobacco Control (WHO FCTC), PWLs aim to increase smokers' awareness of tobacco-related harms and promote behavioral change [76]. These warnings visually depict specific diseases and adverse outcomes linked to smoking, such as lung cancer, cardiovascular disease, oral cancer, and pregnancy-related complications. Such graphic representations have been shown to enhance risk perception and motivate cessation attempts, particularly among populations with lower health literacy. Additionally, PWLs contribute to preventing

smoking initiation among adolescents and non-smokers. Empirical evidence indicates that the introduction of pictorial warnings is associated with approximately a 12% increase in quit attempts and a decline in smoking prevalence in several countries [77]. Compared to text-only warnings, PWLs are significantly more effective in capturing attention and improving recall studies report that they attract smokers' attention two to three times more and yield higher message retention. Since December 2016, South Korea has mandated the use of PWLs on cigarette packages. However, the current implementation falls short of WHO FCTC recommendations, which advocate for graphic warnings covering at least 50% of both the front and back of packs, alongside plain packaging to minimize advertising appeal. Consequently, the potential synergistic effects of these measures are only partially realized in Korea.

(4) Smoking cessation support policies encompass institutionalized efforts to provide psychological, behavioral, and pharmacological interventions aimed at facilitating smokers' attempts to quit and sustain abstinence. These policies form a foundational element of public health infrastructure, insurance frameworks, and national health strategies, and are widely recognized by the WHO and governments worldwide as essential components of comprehensive tobacco control. The WHO advocates for the development and dissemination of integrated, evidence-based smoking cessation guidelines. In the United States, smoking cessation counseling and pharmacotherapy are recommended for inclusion as reimbursable services under insurance coverage due to their demonstrated cost-effectiveness [78, 79]. Key components of smoking cessation support policies typically include the operation of cessation clinics within public health centers and primary care settings, quitlines and online counseling platforms, provision of counseling and pharmacological treatments such as nicotine replacement therapy, varenicline, and bupropion, subsidization or full coverage of cessation services through health insurance, training of healthcare providers in cessation counseling, and the establishment of systematic clinical practice guidelines. In the U.S., services such as the 1-800-QUIT-NOW hotline and health system–based cessation programs have been implemented widely. Following the Affordable Care Act, most public and private insurers have expanded coverage to include cessation treatments. In South Korea, smoking cessation clinics and quitline services have been operational since 2005. After a significant cigarette price increase in 2015, additional services including cessation treatment support at hospitals and clinics, and cessation camps at local support centers were introduced. However, the introduction and rising popularity of heat-not-burn electronic cigarettes since 2017 have corresponded with a decline in utilization of traditional cessation services. This trend was further exacerbated by the COVID-19 pandemic in 2020, which caused a dramatic drop in clinic attendance, underscoring the urgent need for supplementary and adaptive cessation strategies.

2) Emerging E-Cigarette Policy

As of January 2025, a total of 133 countries or jurisdictions have implemented regulatory measures that either restrict or prohibit the sale and use of electronic nicotine delivery systems (ENDS), commonly known as e-cigarettes. Among these, approximately 46 countries including Brazil, Singapore, Thailand, India, Turkey, Uganda, and Mexico enforce comprehensive bans on the sale, distribution, importation, and advertising of e-cigarettes. Meanwhile, 82 countries, comprising the majority of WHO member states, permit sales but regulate these products through restrictions on advertising, nicotine content, minimum purchase age, and usage locations [80]. The United Kingdom stands out as a prominent example of a country officially recognizing and endorsing e-cigarettes as a smoking cessation aid. Public Health England (PHE) and the National Health Service (NHS) have consistently maintained that e-cigarettes can assist smokers in quitting, estimating them to be approximately 95% less harmful than combustible cigarettes since 2015. The NHS actively recommends e-cigarettes as a cessation option, and smoking cessation clinics support their regulated use [81]. In contrast, regulatory approaches vary considerably elsewhere. In the United States, the Food and Drug Administration (FDA) has not granted official approval for e-cigarettes as smoking cessation aids, although some medical providers may offer informal recommendations. Australia requires a prescription from a licensed physician to purchase nicotine-containing e-cigarettes, limiting their use to medically supervised smoking cessation. Similarly, South Korea does not recognize e-cigarettes as an approved cessation tool; health authorities instead emphasize caution regarding their potential risks [82].

ENDS have been explored as potential adjuncts to smoking cessation; however, the current evidence regarding their efficacy remains limited and inconclusive. A notable open-label randomized controlled trial conducted in Switzerland [82] enrolled 1,246 adults aged 18 years or older who smoked at least five cigarettes per day and expressed a desire to quit. Participants were randomly assigned to either an ENDS group, which received e-cigarettes alongside counseling, or a control group that received standard counseling and vouchers for cessation products. Both groups received basic counseling. The primary outcome was biochemically verified sustained abstinence at six months. Results showed that 28.9% (180/622) of the ENDS group maintained abstinence, compared to 16.3% (102/624) in the control group, yielding a relative risk of 1.77 (95% CI, 1.43–2.20). Self-reported 7-day point prevalence abstinence prior to the six-month assessment was 59.6% in the ENDS group versus 38.5% in controls. Notably, 20.1% of ENDS users had completely ceased nicotine use at six months, compared with 33.7% in the control group. Serious adverse events were reported in 4.0% of the ENDS group and 5.0% of controls. These findings suggest that provision of ENDS may increase continuous abstinence rates at six months relative to standard cessation counseling. Nevertheless, the overall body of scientific evidence on e-cigarettes' long-term safety and effectiveness remains sparse and

uncertain [46]. Consequently, numerous countries and public health organizations do not recognize ENDS as official smoking cessation aids. For instance, the U.S. Preventive Services Task Force (USPSTF) concludes that current evidence is insufficient to recommend ENDS for smoking cessation [83]. While ENDS may facilitate quitting in some smokers, concerns persist regarding nicotine exposure and addiction among youth and non-smokers, precluding their broad endorsement as cessation tools absent robust evidence. Applying the public health precautionary principle, efforts should prioritize minimizing non-smoker exposure to ENDS until potential risks are better characterized. Moreover, ENDS use among adolescents has been associated with increased likelihood of subsequent initiation of combustible cigarette smoking.

The 2019 outbreak of Electronic Cigarette or Vaping Product Use-Associated Lung Injury (EVALI) in the United States serves as a significant impetus for regulatory actions targeting e-cigarettes [84]. EVALI is characterized as an acute pulmonary illness linked to the use of e-cigarettes or vaping products, with cases identified only when alternative causes have been ruled out. According to the U.S. Centers for Disease Control and Prevention (CDC), affected patients commonly present with bilateral pulmonary infiltrates and other abnormal radiographic findings. In response, South Korea has adopted a comparatively conservative regulatory stance on e-cigarettes relative to many other countries. International assessments classify Korea's regulatory approach as moderate to strong. Since 2019, liquid-based e-cigarettes (ENDS) have been subject to particularly stringent controls. Although the regulatory scope in Korea is broad often exceeding that of several advanced countries the intensity and enforcement of these regulations remain less rigorous in some respects. Nicotine-containing products must be registered with the Ministry of Food and Drug Safety, and sales prior to approval are prohibited. Advertising restrictions are comprehensive, including bans on television and radio commercials, promotional discounts, and indirect marketing tactics. Under the National Health Promotion Act, health warnings featuring text and images similar to those mandated for conventional cigarette packaging are compulsory. Moreover, e-cigarette use is banned in most public places, aligning with smoke-free policies for traditional tobacco products. Following the rapid increase in EVALI cases in the United States, Korea's Ministry of Health and Welfare issued strong advisories recommending the cessation of liquid-type e-cigarette use. Consequently, sales of liquid e-cigarette products declined markedly, with the market shifting its focus toward heated tobacco products (HTPs).

Countries with stringent regulations on electronic cigarettes do not necessarily exhibit higher smoking cessation rates or lower overall smoking prevalence. Reductions in smoking rates are influenced by multiple factors, including tobacco taxation, expansion of smoke-free areas, access to cessation aids, and media campaigns, alongside e-cigarette policies. For example, countries such as the United Kingdom, which endorse e-cigarettes as cessation aids, tend to have relatively lenient regulations yet report very low smoking rates. Conversely, nations with strict e-cigarette regulations, like Australia and Singapore, also maintain low smoking rates; however, it is difficult to attribute this solely to e-cigarette policies. In Australia's case, the observed increases in cessation rates are more plausibly explained by the synergistic effects of comprehensive tobacco control measures including taxation, counseling services, and public campaigns [85].

Nonetheless, regulatory oversight of ENDS remains imperative from a public health perspective, particularly concerning youth protection, nicotine addiction prevention, product safety, and social norm maintenance. First, the risk of nicotine exposure among adolescents and non-smokers is significant. Most e-cigarette products contain nicotine, placing adolescents at high risk of dependence. Nicotine exposure during adolescence adversely affects brain development and elevates the likelihood of subsequent initiation of combustible cigarette use. Empirical evidence indicates that adolescent e-cigarette users are 3.6 times more likely to begin smoking conventional cigarettes in the future [86]. Second, product safety and quality remain uncertain. The vast array of e-liquid formulations varying in flavorings, heating temperatures, and other parameters may release harmful substances such as formaldehyde, heavy metals, and ultrafine particles. Notably, the presence of vitamin E acetate and tetrahydrocannabinol (THC) in certain products has been implicated in EVALI cases [87]. Third, evidence supporting the efficacy of e-cigarettes for smoking cessation is inconsistent. While some randomized controlled trials suggest potential benefits, data on long-term safety and effectiveness are limited. Dual use of combustible and electronic cigarettes is common, and the net health benefits under such conditions remain ambiguous [42]. Fourth, widespread permissibility of e-cigarettes risks undermining social norms and smoke-free environments. Increased public use may normalize smoking behaviors and erode societal intolerance toward tobacco use. The WHO Framework Convention on Tobacco Control (FCTC), through Articles 8 and 13, recommends extending smoke-free policies and advertising restrictions to all nicotine-containing products, including e-cigarettes. Fifth, commercial practices of the e-cigarette industry raise concerns. Companies such as JUUL have employed youth-targeted marketing strategies, including flavored products and influencer campaigns, highlighting the inadequacy of industry self-regulation and underscoring the necessity of robust governmental oversight [88].

3) Conclusions

Although electronic cigarettes may offer limited harm-reduction potential for a subset of smokers, the current evidence does not support their widespread promotion as smoking cessation tools. Persistent dual use, uncertainty regarding long-term health effects, increasing uptake among youth, and aggressive commercial marketing substantially weaken the public health claims advanced by the industry. South Korea's cautious regulatory approach, while not without limitations, reflects a policy position consistent with the precautionary principle. An urgently needed tobacco control framework should be

more explicitly evidence-informed and equity oriented. Policymakers should prioritize comprehensive regulation of electronic nicotine delivery systems, including restrictions on advertising and promotion, taxation, age-based access controls, product safety standards, and sustained public education efforts. At the same time, public health systems should strengthen access to evidence-based smoking cessation therapies and expand behavioral and community-level interventions. Future regulatory strategies must prioritize the protection of vulnerable populations particularly adolescents while critically resisting industry narratives that frame ENDS as universally safer alternatives to combustible tobacco.

Author Contribution Statement

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