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Title: Health Impacts of E-Cigarettes: A Comprehensive Review of the Evidence and Public Health Implications

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Abstract

Electronic cigarettes, also known as e-cigarettes or Electronic Nicotine Delivery Systems (ENDS), have quickly become a well-liked substitute for conventional tobacco products, especially among teenagers and young people. Despite being marketed as a smoking cessation assistance and harm reduction tool, their safety profile is still being investigated. The health implications of e-cigarette use on the respiratory, cardiovascular, and neurological systems, as well as possible carcinogenic consequences, are examined in this thorough literature analysis. Airway inflammation, elevated cardiovascular risk markers, mental health comorbidities, and biomarkers of DNA damage are only a few of the detrimental health impacts that are now supported by data. The long-term safety of vaping is still unknown, despite some research suggesting lower exposure to dangerous chemicals as compared to combustible tobacco. The necessity of balanced public health measures is emphasized, and global regulatory approaches are also covered. This review

concludes by highlighting the significance of prudent regulation and ongoing research to inform clinical and policy decisions on the use of e-cigarettes.

Key words: E-cigarettes, vaping, electronic nicotine delivery systems, tobacco harm reduction

1. Introduction

Electronic cigarettes, sometimes referred to as electronic nicotine delivery systems (ENDS), have become increasingly popular as substitutes for conventional tobacco products within the last ten years. Marketed as safer options and potential smoking cessation tools, e-cigarettes have seen significant uptake, particularly among adolescents and young people. About 10% of high school students in the United States reported using e-cigarettes as of 2023, and approximately 90% of them preferred flavored products including fruit and candy variants [1].

To create an aerosol that is inhaled into the lungs, e-cigarettes heat a liquid, usually one that contains nicotine, propylene glycol, vegetable glycerin, and flavorings. According to research, this aerosol may contain dangerous materials such as volatile chemical compounds, ultrafine particles, and heavy metals including nickel, lead, and arsenic. These elements raise concerns about the potential health hazards associated with vaping [2].

The scientific community is still divided on the overall health effects of e-cigarettes, despite their increasing popularity. While some studies suggest that switching from traditional cigarettes to e-cigarettes may reduce exposure to certain harmful substances, emerging research indicates that vaping can negatively impact multiple organ systems. A 2024 systematic review, for example, found that e-cigarette use is linked to elevated blood pressure, increased heart rate, and impaired endothelial function—all of which are risk factors for cardiovascular disease. Additionally, a 2023 review found that e-cigarette aerosols contain toxic components capable of inducing oxidative stress, inflammation, and vascular dysfunction, which may contribute to thrombosis [3,4].

The goal of this review is to provide a comprehensive overview of the current knowledge regarding the health effects of e-cigarette use. This article aims to clarify the potential risks and public health implications of vaping by analyzing data from studies on respiratory,

cardiovascular, oncological, and neuropsychiatric outcomes, as well as by examining the regulatory landscape.

2. Metodology

This review was conducted using a structured literature search to identify scientific studies addressing the health effects of e-cigarette use. Articles were selected based on their relevance to various medical fields, including pulmonology, cardiology, oncology, and psychiatry. The inclusion criteria were as follows: publications had to be written in English, and specifically focused on the physiological and clinical consequences of e-cigarette consumption.

Primary sources were obtained through a comprehensive search of the PubMed database, using keywords such as "e-cigarettes," "vaping," "electronic nicotine delivery systems," and "health effects." In addition to database retrieval, a manual search was conducted to identify relevant articles published in high-impact journals. Studies included both observational and experimental research, systematic reviews, meta-analyses, and official health organization statements published between 2019 and 2025.

This approach ensured a broad and multidisciplinary perspective on the health outcomes associated with e-cigarette use, offering a balanced and up-to-date overview of the current scientific evidence.

3. The Potential Health Effects of E-cigarettes on different organs 3.1 Respiratory System

The respiratory system is directly impacted by the aerosol generated from e-cigarettes, which raises significant concerns when assessing the health consequences of vaping. Recent research has focused on both the short-term and long-term effects of e-cigarette consumption on lung function and respiratory well-being [5].

A systematic review conducted by Honeycutt and colleagues in 2022 examined eight studies investigating the influence of e-cigarette usage on lung function. The review revealed that although vaping may heighten airway resistance, it does not seem to have a significant effect on forced expiratory volume in one second (FEV1), forced vital capacity (FVC), or the FEV1/FVC ratio. Nevertheless, the authors pointed out that the studies were

limited in both number and size, with most concentrating on short-term effects, highlighting the necessity for additional research on long-term respiratory outcomes [5].

Alongside functional changes, there have been raised concerns regarding the link between ecigarette usage and respiratory illnesses. In their integrative review, Wills et al. in 2021 merged findings from epidemiological and laboratory studies, determining that e-cigarette consumption correlates with a higher risk of asthma and chronic obstructive pulmonary disease (COPD). The review emphasized that the evidence fulfills established standards for consistency, magnitude of effect, and biological feasibility, highlighting the possible public health consequences [6].

Furthermore, a study by Bhatta and Glantz in 2020 utilizing data from the Population Assessment of Tobacco and Health (PATH) study found that e-cigarette users had a 1.3 times higher risk of developing respiratory diseases compared to non-users. The risk was even

higher among dual users of e-cigarettes and traditional cigarettes, emphasizing the compounded risks associated with concurrent use [7].

One of the most severe and well-documented outcomes of e-cigarette usage is EVALI (Ecigarette or Vaping Product Use-Associated Lung Injury). In their comprehensive pathological and radiological analysis, Smith et al. in 2020 described EVALI as a type of acute lung injury characterized by histological features of diffuse alveolar damage, organizing pneumonia, and acute fibrinous and organizing pneumonia (AFOP). From a radiological perspective, patients typically exhibited bilateral ground-glass opacities along with regions of consolidation. The research highlighted that the injury patterns are not linked to a singular toxic substance but may arise from various components present in e- liquids, including vitamin E acetate. The authors concluded that healthcare providers and pathologists should stay alert in recognizing vaping-related lung injuries because of their possible severity and diagnostic intricacies [8].

The results indicate that although e-cigarettes might carry lower risks compared to conventional cigarettes, they still present considerable concerns for respiratory health. Existing evidence highlights the necessity for caution and the importance of additional longitudinal studies to comprehensively assess the long-term impacts of e-cigarette consumption on respiratory health [6].

3.2 Cardiovascular System

The cardiovascular system is one of the organ systems most severely impacted by nicotine products, such as e-cigarettes. While vaping is frequently viewed as a less harmful option compared to conventional smoking, new research reveals its capacity to induce considerable negative effects on cardiovascular health [9].

A systematic review and meta-analysis conducted by Kundu and co-authors in 2025 evaluated the effects of e-cigarette consumption on cardiovascular health indicators, such as heart rate, blood pressure, endothelial function, and arterial stiffness. The researchers discovered that immediate e-cigarette use led to temporary rises in heart rate and systolic blood pressure. Furthermore, multiple studies included in the review indicated reduced flow-mediated dilation (FMD), suggesting compromised endothelial function — an important precursor to atherosclerosis and cardiovascular issues [9].

A comparative analysis conducted by Yayan et al. in 2024 examined cardiovascular biomarkers in users of e-cigarettes compared to traditional cigarette smokers. Although e-cigarette users showed lower levels of carbon monoxide exposure, they still had heightened levels of inflammatory markers (such as CRP and IL-6) and increased platelet reactivity, both of which are linked to the development of thrombosis and atherosclerosis. These results imply that while vaping may lower certain risks when compared to combustible tobacco, it is not without risks regarding cardiovascular health [10].

Crucially, the long-term effects of e-cigarette usage on cardiovascular morbidity and mortality are still not fully understood due to the relative newness of these products. Nonetheless, the growing body of short- and mid-term evidence indicates a concerning trend, especially among younger users and those with existing cardiovascular risk factors [9].

In conclusion, existing research suggests that e-cigarettes can negatively impact the cardiovascular system through mechanisms such as sympathetic activation, vascular dysfunction, and inflammation. While they may provide harm reduction for some smokers, their use is not without danger, and requires careful observation and further research in long-term prospective studies [9,10].

3.3 Nervous System and Mental Health

Recent studies have increasingly pointed out the possible mental health effects linked to ecigarette usage. A study by Lee et al. in 2024 identified significant connections between current e-cigarette users and higher levels of depression, anxiety, and stress in young adults, indicating that vaping could worsen pre-existing mental health issues [11].

In an extensive umbrella review, Al-Hamdani and co-authors in 2023 explored the connection between e-cigarette use and mental health conditions in children. The research concluded that both current and former e-cigarette users displayed higher instances of depression and suicidality compared to those who do not use e-cigarettes, highlighting the necessity for focused interventions in this age group [12].

Moreover, a systematic review conducted by Becker and colleagues in 2021 evaluated the overlap between electronic cigarette usage and mental health disorders among adolescents and young adults. The review revealed that e-cigarette use is linked to heightened mental health issues, including increased symptoms of depression and anxiety, emphasizing the need to factor mental health into vaping prevention efforts [13].

These results highlight the intricate relationship between e-cigarette usage and mental health, especially among younger individuals. They indicate that strategies aimed at curbing vaping in adolescents and young adults should also tackle the underlying mental health challenges to enhance their effectiveness [13].

3.4 Cancer Risk

The potential for e-cigarettes to cause cancer is still an area of ongoing research. While ecigarettes do not create the wide array of combustion-related carcinogens present in traditional tobacco smoke, they still contain harmful or potentially harmful constituents (HPHCs). New evidence indicates that prolonged exposure to certain e-cigarette aerosols may heighten cancer risk, particularly due to oxidative stress, DNA damage, as well as exposure to nitrosamines and heavy metals [14].

A systematic review conducted by Kundu et al. in 2025, published in Tobacco Induced Diseases, offers one of the most recent and thorough assessments on this topic. The researchers concluded that although there is still limited epidemiological data regarding

cancer rates among people who exclusively use e-cigarettes—due to their relatively recent rise in popularity—biomarkers of exposure and early DNA damage are already detectable. The review emphasized that carcinogens such as formaldehyde, acetaldehyde, and acrolein can be found in e-cigarette aerosols, especially when used at higher power levels and with flavored variants. Additionally, certain metal components from e-cigarette devices have been shown to leach into the aerosol, introducing toxic substances like nickel, chromium, and lead. [14]

Laboratory research has further corroborated these concerns. Studies conducted in vitro and in animal models have shown that e-cigarette vapor can cause DNA strand breaks, diminish repair capacity, and foster mutations—characteristics that are indicative of cancer development. For instance, research by Tellez et al. in 2023 found that long-term exposure to e-cigarette aerosols resulted in increased oxidative stress and the upregulation of oncogenes in bronchial epithelial cells [15].

Nevertheless, it is crucial to recognize that, as of now, no extensive, long-term epidemiological research has definitively linked exclusive e-cigarette usage to a specific type of cancer in humans. Yet, the detection of precancerous biological alterations and carcinogenic elements in vape aerosols strongly suggests that extended use could pose significant oncological dangers, particularly with ongoing and frequent exposure [14].

In conclusion, even though e-cigarettes might present a reduced cancer risk compared to regular tobacco, they are not without risk. The existing evidence clearly indicates a pressing requirement for caution, regulation, and additional long-term studies to fully grasp the cancercausing potential of vaping products [14].

4. Comparisons and Regulatory Perspectives

4.1 E-cigarettes vs Traditional Cigarettes

The evaluation of e-cigarettes in relation to traditional combustible cigarettes is crucial for understanding their role in tobacco harm reduction strategies. Although e-cigarettes are often promoted and perceived as a safer option than regular smoking, increasing scientific evidence reveals that they also pose health risks. Various comparative studies indicate that e-cigarettes expose users to significantly lower levels of harmful toxicants related to combustion, such as tar, carbon monoxide (CO), and polycyclic aromatic hydrocarbons

(PAHs), which are key contributors to lung cancer and heart disease among conventional smokers. For example, Yayan in 2024 performed a systematic analysis and found that while users of e-cigarettes displayed lower levels of CO and other combustion-related substances, they still showed heightened markers of systemic inflammation (e.g., C- reactive protein and IL-6) and increased platelet aggregation—biomarkers linked to cardiovascular and thrombotic issues [16].

Recent research has emphasized the differences in harmful substance exposure between those who exclusively use e-cigarettes and traditional cigarette smokers. A study in Scientific Reports from 2019 revealed that exclusive users of electronic nicotine delivery systems (ENDS) had significantly lower levels of biomarkers indicating exposure to harmful chemicals compared to traditional smokers. Specifically, 16 out of 18 non-nicotine biomarkers were notably lower in ENDS users, with 9 biomarkers showing no significant difference from

non-users. This implies that exclusive e-cigarette use might decrease exposure to particular harmful substances associated with diseases related to smoking [17].

Nevertheless, it is crucial to recognize that e-cigarette use carries its own risks. A study in Scientific Reports from 2022 found that e-cigarette users had higher levels of inflammatory and cancer risk biomarkers compared to non-smokers, indicating that e-cigarettes could increase the risk of developing systemic diseases, even though the risk is lower than that posed by traditional cigarettes. This highlights that while e-cigarettes might be a less dangerous alternative for current smokers who switch entirely, they remain unsafe for non-smokers, particularly among adolescents and young adults [18].

In summary, while e-cigarettes may lower certain health risks in comparison to traditional cigarettes, especially for those who have quit smoking, they are not without harm. The phenomenon of dual-use, uncertainties regarding long-term safety, and the growing prevalence among youth suggest the necessity for careful public health messaging and robust regulatory measures [16].

4.2. Public Health and Regulation

The swift increase in e-cigarette consumption, particularly among teenagers and young adults, poses a complicated challenge for global health authorities and regulatory agencies. While some experts advocate for e-cigarettes as a harm reduction strategy for adult smokers who struggle to quit, the rising incidence of vaping among never-smokers,

especially youth, has sparked serious concerns regarding nicotine addiction, potential long-term health effects, and the normalization of smoking habits [19,20].

Organizations like the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) have adopted a cautious position. They recognize that e- cigarettes may pose less harm than traditional tobacco products, but they strongly advise against their use among non-smokers, young people, pregnant women, and those with existing cardiovascular or respiratory issues. The WHO particularly cautions that the long- term repercussions of using e-cigarettes are largely unknown, and these products should not be regarded as a safe option [19,20].

Tackett et al. in 2020 highlighted the sensitive balancing act needed in the regulation of ecigarettes. They contend that excessively strict regulations could hinder the potential for harm reduction among adult smokers, while a too lenient stance could lead to a new generation developing a nicotine addiction. They propose that effective regulation should be based on continuous scientific assessment, clear standards for products, and strong public education initiatives [21].

To conclude, the regulatory framework for e-cigarettes is still in flux and very dynamic. Public health strategies must keep adapting in response to new scientific findings, striving to reduce harm for current smokers while also preventing the initiation of use among youth and non-smokers [21].

5. Discussion

This extensive literature review sought to consolidate current findings on the health effects of e-cigarette usage, emphasizing organ-specific consequences, mental health considerations, cancer risks, and regulatory viewpoints. The results present a complex scenario: although e-cigarettes typically expose users to a lower level of harmful substances compared to traditional combustible tobacco, they are not without risks and raise significant health concerns of their own [3,4].

Research from respiratory studies suggests that e-cigarette usage is linked to airway inflammation, reduced lung function, and, in severe cases, acute lung injuries such as EVALI (E-cigarette or Vaping product use-Associated Lung Injury) [5]. While long-term epidemiological insights are still under development, short- and mid-term investigations

clearly show that contact with e-cigarette aerosols can lead to biological changes indicative of pulmonary damage [6,7].

Cardiovascular research also raises alarms. Numerous studies have indicated immediate elevations in heart rate and blood pressure, along with markers of endothelial dysfunction and systemic inflammation among e-cigarette users [3,4]. Although these effects may be less severe than those associated with traditional smoking, the occurrence of such changes—particularly in young, otherwise healthy individuals—merits careful scrutiny. Furthermore, the combined use of e-cigarettes and conventional cigarettes could heighten cardiovascular risks, negating any possible benefits of harm reduction [10].

The mental health implications are becoming increasingly acknowledged, particularly among adolescents. Evidence points to a two-way relationship: individuals with prior mental health issues tend to have a higher likelihood of using e-cigarettes, while nicotine exposure may worsen anxiety, depression, and sleep disorders. The influence of flavors and social media marketing on youth vaping initiation further complicates the public health narrative [11-13].

In terms of cancer risk, although no direct association has been found between sole ecigarette use and cancer incidence in humans, several studies reveal carcinogenic substances in e-cigarette vapor and early indicators of DNA damage in users [3]. Animal and in vitro studies additionally suggest that e-cigarette aerosols can trigger molecular and cellular alterations related to carcinogenesis, highlighting the necessity for long-term cohort investigations [14,15].

From a regulatory perspective, countries have implemented highly varied approaches, ranging from harm reduction strategies (e.g., the UK) to complete or partial prohibitions (e.g., India and Australia). This global disparity illustrates the challenge of balancing potential public health advantages for adult smokers with the critical need to shield youth from nicotine dependency. The debated role of flavorings and the shifting positions of organizations like the WHO and CDC demonstrate that regulations must adapt to new scientific findings [1,2].

The limitations of this review include the relatively brief period since the introduction of ecigarettes to the market, which restricts the availability of long-term health outcome information. Additionally, the variability in study designs, target populations, and e-cigarette devices complicates the process of direct comparisons and generalizability [14]. In summary, e-cigarettes may provide a less harmful alternative to traditional smoking for current smokers if used exclusively and short-term. However, their rising appeal among non-smokers and young individuals, combined with accumulating evidence of negative health effects, justifies a cautious and evidence-driven approach. Ongoing research, particularly longitudinal and mechanistic studies, is crucial to thoroughly understand the long-term health consequences of vaping [14,21].

6. Conclusions

E-cigarettes are a quickly evolving class of nicotine delivery devices that continue to spark important debates in the fields of science and public health. They nevertheless pose health hazards even though recent evidence suggests they may be less harmful than conventional combustible tobacco products, especially when used only by adult smokers.

According to this review, using e-cigarettes is associated with adverse effects on a number of organ systems. Concerns include alterations in the cardiovascular and pulmonary systems, markers of inflammation and oxidative stress, and mounting data of effects on mental health. Furthermore, although conclusive long-term epidemiological study is currently lacking, laboratory studies and biomarker data suggest a possible risk of cancer.

The growing trend of teens and non-smokers using e-cigarettes, which is frequently encouraged by enticing flavors and aggressive marketing campaigns, is especially concerning. Public health efforts to prevent nicotine addiction and the risks associated with it face significant obstacles as a result of this trend.

In light of these findings, it is imperative that regulatory actions strike a suitable balance between implementing robust protections to discourage use among at-risk groups and assisting adult smokers in quitting traditional cigarettes through harm reduction techniques. These regulations must be informed by ongoing research, particularly long- term studies that concentrate on real usage patterns and health impacts.

E-cigarettes should therefore be subjected to the same level of scientific scrutiny as traditional tobacco when definitive longitudinal data are available, especially in regulatory and clinical decision-making situations.

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9. Conflict of Interest

The authors declare that they have no conflict of interest.

10. Supplementary Materials

None.

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