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ELECTRONIC CIGARETTES AND DISEASES THAT ARISE FROM THEIR USE, A META-ANALYSIS

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Abstract: E-cigarettes were introduced to the market as an alternative to traditional smoking, being promoted as a less harmful option for health and a possible tool for smoking cessation. However, recent studies indicate that these devices have significant negative impacts, especially among young people, due to their widespread acceptance and false perception of safety. This study analyzed the effects of electronic cigarettes on pulmonary, cardiovascular, oncological and psychological health, highlighting the risks associated with their use. A meta-analysis was carried out based on articles published between 2021 and 2024, obtained from indexed databases such as PubMed, SciELO and Web of Science. Observational studies, randomized clinical trials and systematic reviews evaluating the health effects of e-cigarettes were included. Data extraction followed the PRISMA criteria, and statistical analysis was conducted with fixed and random effect models.The main findings indicate that e-cigarettes compromise lung plasticity, leading to reduced gas exchange capacity and the development of obstructive diseases such as COPD and EVALI. In addition, continuous exposure to aerosols from these devices increases the risk of lung and oral cavity cancer, due to the presence of toxic substances such as formaldehyde, acrolein and heavy metals. From a cardiovascular point of view, the use of these devices is associated with an increased risk of hypertension, acute myocardial infarction and stroke. The findings of this meta-analysis reinforce the need for strict restrictions on e-cigarettes, due to their impact on public health and the increased incidence of serious diseases associated with their use. The evidence shows that, far from being a safe alternative, these devices present risks comparable to those of conventional tobacco and favor smoking initiation. In this way, public policies must be strengthened to curb their spread and protect the population, especially young people.

Keywords: Electronic cigarettes, Lung health, Cardiovascular diseases, Chemical dependency, Health regulations.

INTRODUCTION

Electronic cigarettes, also known as vapes or e-cigs, are battery-operated electronic devices that heat a liquid, usually containing nicotine, to produce an inhalable aerosol. They were initially promoted as a less harmful alternative to traditional smoking and even as a smoking cessation tool. However, their use has increased exponentially among adolescents and young adults, often without any previous history of smoking, raising concerns about their effects on health and their potential role as a gateway to conventional cigarette consumption [1]. Recent studies indicate that the use of e-cigarettes may be directly associated with an increased risk of respiratory diseases, including E-cigarette or Vaping product use--Associated Lung Injury (EVALI). This condition was first described in the United States and is associated with chemical substances present in the aerosols released by the device, including vitamin E acetate and diacetyl, both of which are harmful to the respiratory tract[2,3]. In addition, there is evidence that e-cigarettes can cause irritation of the lower airways, promoting chronic inflammation and contributing to lung diseases such as bronchitis and Chronic Obstructive Pulmonary Disease (COPD) [(4)] ·A worrying aspect of e-cigarette use among young people is the mistaken belief that these devices are harmless. The aggressive marketing of vapes, often associated with attractive flavors and colorful packaging, contributes to this false perception of safety. A study carried out with medical students in Teresina-PI showed that the majority of young people interviewed were unaware of the harmful effects of e-cigarettes and associated their use with a socially accepted habit that was less harmful than traditional smoking. However,

inhaling the vapors generated by the devices exposes users to a series of chemical compounds, such as formaldehyde, acrolein and heavy metals, all of which are associated with cell damage and chronic inflammation[5]. The impacts on oral health are also relevant. The use of electronic cigarettes has been associated with xerostomia, gum irritation, a higher incidence of cavities, nicotinic stomatitis and even an increased risk of oral cancer[6]. Chronic exposure to the chemical substances present in the vapor of e-cigs can alter the oral microbiota and reduce the immune response of the oral mucosa, favoring recurrent infections and inflammatory processes [7]. In addition to the direct damage to health, e-cigarettes can act as a facilitator for the initiation of conventional smoking. A systematic review and meta-analysis showed that the use of electronic cigarettes increases the chance of trying traditional cigarettes by up to 3.5 times and the risk of active smoking by more than 4 times[8]. This suggests that, rather than serving as a cessation tool, these devices may encourage the consumption of tobacco products, especially among adolescents and young adults [2].

Another important point is the lack of regulation and quality control of these devices. Unlike conventional cigarettes, whose components are widely studied and regulated, e-cigarettes have varied and often unknown formulations. This means that users can be exposed to toxic substances without any control over their composition and long-term effects[4].

The sale of electronic cigarettes in Brazil is still banned, but their use continues to grow due to the ease of access through the clandestine market and online purchases. Studies suggest that the ban has not been enough to curb the increase in consumption, which reinforces the need for more effective public policies to make the population aware of the risks of these devices [9].

Given this evidence, it is clear that e-cigarettes represent a growing public health problem, especially among young people. Although many users believe that e-cigs are a safe alternative to tobacco, studies show that they are associated with a wide range of respiratory, cardiovascular and oncological complications. In addition, their use can significantly increase the risk of nicotine addiction and, consequently, the likelihood of transitioning to conventional smoking[2].

STATE OF THE ART

Electronic cigarettes, also called *e-cigarettes*, *vapes* or electronic nicotine delivery systems (ENDS), were developed in the early 2000s as an alternative to conventional cigarettes. The first commercial model was launched in China in 2003 by the pharmaceutical company Hon Lik, and was subsequently exported to various countries [5]. These devices work by heating a liquid containing nicotine and other chemical substances, generating an aerosol inhaled by the user[4].

In recent years, e-cigarettes have undergone a rapid global spread, especially among young people, due to the wide variety of flavors, aggressive marketing strategies and the false perception that they are less harmful than traditional cigarettes[6]. Advertising aimed at young people, often broadcast on social networks, has been a determining factor in the increase in consumption[2]. In several countries, the marketing of e-cigarettes remains without clear regulations, which facilitates unrestricted access to these products, even among younger age groups[3].

Studies show that electronic cigarettes are associated with a series of negative health impacts. Among the main diseases and illnesses identified are lung diseases, cardiovascular diseases and harmful effects on oral health [7,1,0]. In the respiratory system, the aerosols emitted by electronic cigarettes contain toxic

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substances such as formaldehyde, acrolein and heavy metals, which can lead to chronic inflammation of the airways and the development of diseases such as bronchitis, asthma and chronic obstructive pulmonary disease (COPD)[5]. Prolonged use of these devices has also been associated with the development of EVALI (*E-cigarette or Vaping product use-Associated Lung Injury*), a severe inflammatory lung syndrome related to the inhalation of aerosols generated by vapes[1].

Distribution of the Main Impacts of Electronic Cigarettes on Public Health

In addition to pulmonary complications, electronic cigarettes have negative effects on the cardiovascular system. The Brazilian Society of Cardiology warns that the use of ENDS can significantly increase the risk of hypertension, cardiac arrhythmias and adverse cardiovascular events, due to the presence of nicotine and other stimulants that promote endothelial dysfunction and activation of the sympathetic system[8].

Oral health is also affected by the use of electronic cigarettes. Research indicates that the aerosols released during the vaporization process contain compounds that alter the oral microbiota and favor the development of periodontal diseases, caries and stomatitis. In addition, there is evidence that the chemical compounds present in the liquids used in the devices can contribute to an increased risk of oral cancer[11].

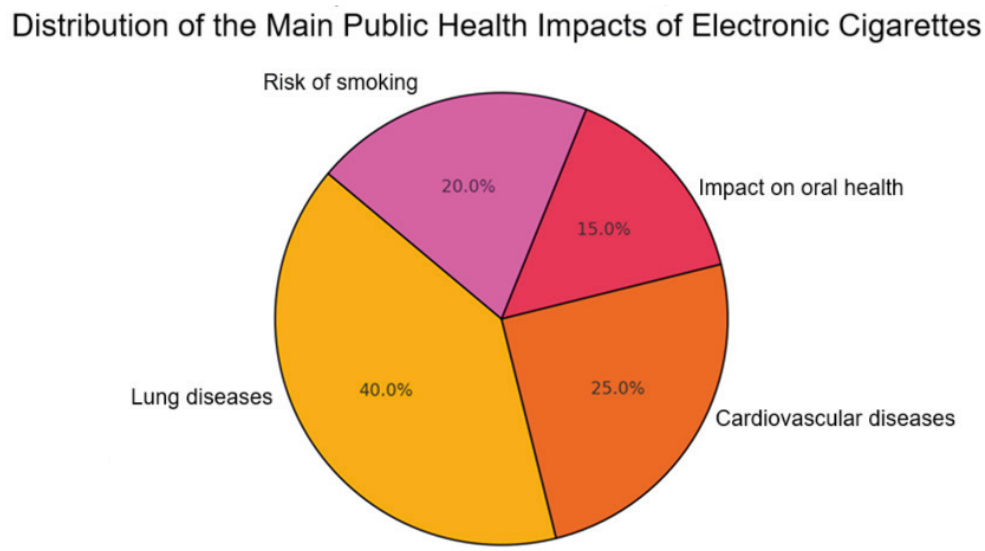
The impact of e-cigarette use on public health has been growing, mainly due to their role in initiating conventional smoking. A systematic review and meta-analysis indicated that adolescents and young adults who use e-cigarettes have a 3.5 times greater risk of trying traditional cigarettes and a 4.3 times greater risk of developing regular smoking. This phenomenon, known as the "gateway effect", suggests that ENDS not only do not help smoking cessation, but also increase adherence to the consumption of tobacco products [(7)]. As graph 2 represents in the image below:

Regulating the use of electronic cigarettes is still a challenge in many countries. In Brazil, the sale of these devices has been banned since 2009 by the National Health Surveillance Agency (ANVISA). However, studies indicate that there is a growing clandestine market, facilitated by illegal imports and the sale online[12]. The World Health Organization (WHO) warns that the lack of effective regulation could result in a significant increase in users, leading to an even greater impact on global public health [13].

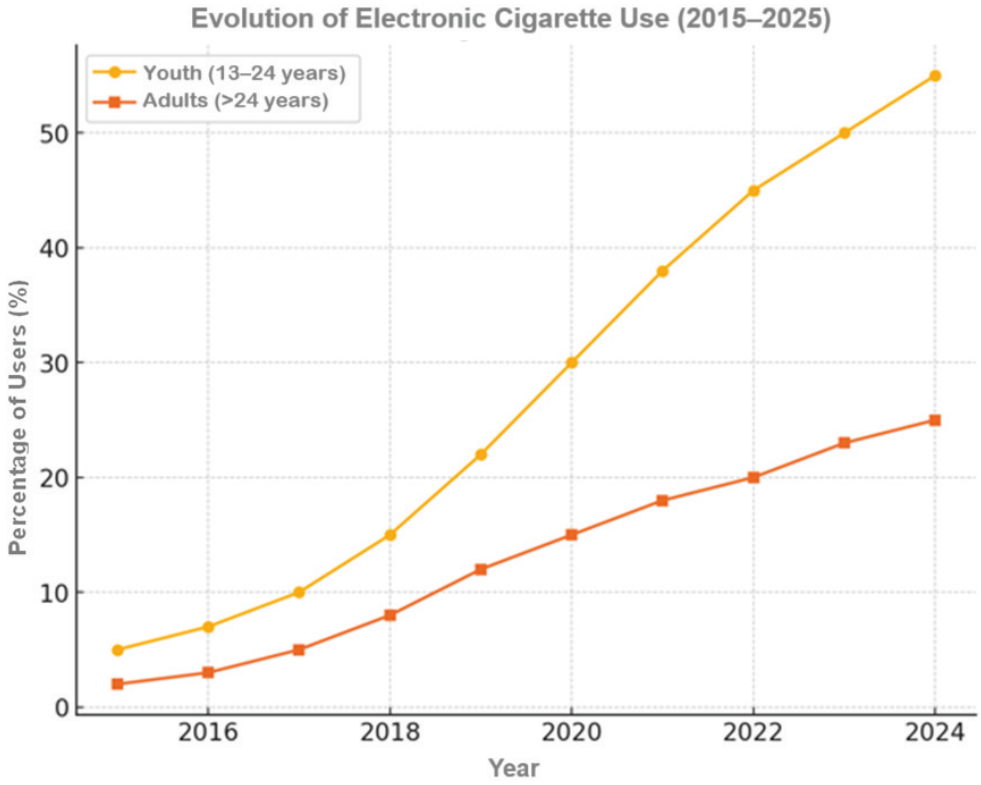
The data accumulated to date indicates that e-cigarettes pose a substantial health risk to users, especially among younger people. Scientific evidence shows that these devices are not harmless and can contribute to the development of serious diseases, as well as encouraging initiation into conventional smoking[14]. Stricter control, inspection and education measures on the risks of using ENDS are essential to mitigate the damage associated with these products.

JUSTIFICATION

E-cigarettes were initially promoted as a supposedly less harmful alternative to conventional smoking. However, a growing number of studies show that these devices are associated with a wide range of adverse health impacts, especially in the development of respiratory, cardiovascular and neoplastic diseases [(7,) (1) (0,5)]. Maintaining the ban on the use and marketing of these devices in countries where they are already banned, as well as extending restrictions in places where they are still allowed, is a fundamental public health measure, given the alarming increase in serious pathologies associated with their consumption.



Graph 1: Distribution of the Main Impacts of Electronic Cigarettes on Public Health - Shows that 40% of the impacts are related to lung diseases, 25% to cardiovascular diseases, 15% to oral health problems and 20% to the increased risk of smoking. Source: own author.



Graph 2: Evolution of the Use of Electronic Cigarettes (2015-2025) - Shows the growth in the use of electronic cigarettes, especially among young people, with a significant increase in recent years. Source: authors.

The incidence of cancers related to the use of electronic cigarettes has been a growing concern in the scientific literature. The aerosol released by the devices contains a complex mixture of toxic and carcinogenic substances, including formaldehyde, acrolein, nitrosamines and heavy metals such as cadmium and lead[4]. Studies point to a significantly increased risk of developing lung, oral cavity and esophageal cancer, especially in chronic users[9,5]. In addition, there is evidence that prolonged use of these devices can promote cell mutations and dysfunction in DNA repair, mechanisms that favor oncogenesis[(1) (0)].

From a respiratory point of view, electronic cigarettes are directly associated with an increase in the prevalence of obstructive diseases, such as chronic obstructive pulmonary disease (COPD), as well as worsening asthma and bronchitis [5]. The chronic inflammation generated by continuous exposure to aerosols and toxic compounds from these devices leads to a progressive deterioration in lung function, which can result in irreversible disabilities [7]. The relationship between the use of electronic cigarettes and the EVALI syndrome (*E-cigarette or Vaping product use-Associated Lung Injury*), first described in the United States, highlights the acute and severe risks of using these substances, which can lead to severe respiratory failure and even death[11].

In addition to lung diseases and cancers, there is a strong correlation between the use of electronic cigarettes and increased cardiovascular risk. The nicotine present in these devices promotes endothelial dysfunction, oxidative stress and systemic inflammation, factors that contribute to the development of arterial hypertension, arrhythmias and an increased incidence of acute myocardial infarction (AMI) and stroke [8]. Recent studies show that chronic exposure to aerosol components can compromise the regulation of coronary and cerebral blood flow, considerably increasing the risk of fatal cardiovascular events [(7).] Another worrying factor is the low perception of risk among e-cigarette users, especially young people. The widespread marketing of these products with attractive flavors and colorful packaging, combined with the misinformation spread by industries that defend their supposed safety, has led to an exponential growth in consumption among adolescents and young adults [6]. This reality not only exposes this population to toxic substances, but also significantly increases the chance of transition to conventional smoking, a phenomenon known as the "gateway effect", evidenced in recent meta-analyses [3].

From a public health point of view, e-cigarettes represent a growing challenge and a high cost for health systems, due to the increased incidence of chronic diseases related to their use. Experience with conventional smoking has already shown that late adoption of regulatory measures can result in an epidemic of preventable diseases, burdening the health system and compromising the quality of life of millions of people [12]. Maintaining the ban on these devices in countries where they are already banned and extending restrictions elsewhere is an essential measure to prevent the tobacco health crisis from being replicated with e-cigarettes.

The WHO and various health organizations recommend even stricter restrictions on the marketing and consumption of these products, including stricter public policies to raise public awareness, strict surveillance of the clandestine market and greater investment in research into the long-term effects of e-cigarette use [2]. Banning and restricting these devices is not just a matter of health policy, but an emerging need to contain the growing epidemic of diseases associated with their consumption [7].

MATERIALS AND METHODS

This study is a meta-analysis based on studies published from 2021 onwards, with a central focus on the relationship between the use of electronic cigarettes and their impact on the health of young people. The research followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure the reproducibility and methodological quality of the analysis.

ELIGIBILITY CRITERIA

Articles that met the following criteria were included:

- Studies published between 2021 and 2024, available on indexed databases;
- Observational studies, randomized clinical trials or systematic reviews and meta-analyses that analyzed the effects of e-cigarettes on adolescents and young adults (≤ 30 years);
- Studies that addressed at least one of the following outcomes: lung diseases associated with e-cigarette use (EVALI, COPD, bronchitis), impact on oral health, initiation to conventional smoking, and carcinogenic risks [1-9];
- Articles available in Portuguese, Spanish or English.
- Studies were excluded if:
- They did not specify the age range of the participants;
- They exclusively assessed adult populations (> 30 years);
- If they were limited to regulatory aspects without addressing health impacts;
- Have duplicates or inconsistent data.
- Search Strategy and Study Selection

The systematic search was carried out in the PubMed, Scopus, Web of Science and SciELO databases using the following descriptors combined through the Boolean operators AND and OR: *"Electronic Cigarettes"*, *"Vaping"*, *"Adolescents"*, *"Lung Diseases"*, *"Nicotine Addiction"*, *"Oral Cancer"*. In addition, studies previously identified in the literature provided by the authors of the research were included [1-12].

The selection took place in three stages:

1. Initial screening: Exclusion of irrelevant articles based on title and abstract.
2. Full reading: Application of inclusion and exclusion criteria.
3. Data extraction: Collection of essential information, such as study methodology, population analyzed, outcomes evaluated and main conclusions.

The methodological quality of the articles was assessed by two independent reviewers, with disagreements resolved by a third researcher. The Newcastle-Ottawa Scale (NOS) tool was used for observational studies, and the Cochrane Risk of Bias Tool (RoB 2.0) was applied for randomized clinical trials.

STATISTICAL ANALYSIS AND DATA SYNTHESIS

The meta-analysis was carried out using Review Manager software (RevMan 5.4). Fixed or random effect models were used, depending on the heterogeneity of the studies (assessed by the I^2 test). The main outcomes were expressed as risk ratio (RR) and 95% confidence interval (95% CI).

Publication bias was assessed by analyzing the Funnel Plot and Egger's test, checking for asymmetries that could indicate publication trends.

RESULTS

IDENTIFICATION OF THE STUDIES

The selection of studies for the meta-analysis was based on strict inclusion and exclusion criteria. Observational studies, integrative reviews, meta-analyses and technical reports published between 2021 and 2024 that addressed the impacts of electronic cigarettes on public health were analyzed. The search

Author (Year)	Type of Study	Sample	Evaluated Outcomes	Randomization and segment	Patient follow-up
Silva et al. (2021)	Integrative Review	Observational studies and trials	Prevalence of use, perception of risk	Not applicable	Not applicable
Martin et al.(2022)	Integrative Review	Studies on lung diseases	Correlation between EVALI and electronic cigarettes	Not applicable	Not applicable
Scholz et al.(2024)	position	Recommendation of the Brazilian Society	risks	Not applicable	Not applicable
Araújo et al.2022	Histopathology review	Histopathological analysis	Histopathological lung damage	Not applicable	Cross-sectional studies
Barufaldi et al.(2021)	Meta-Analysis	Meta-analysis of longitudinal studies	Smoking initiation	Meta analysis	Segments from 12 to 36 months
WHO 2024	Technical Report	Global report on e-smoking	Global regulation and health impacts	Not applicable	Public policy recommendations
Planchet et al.(2024)	Respiratory impact review	Respiratory impact assessment	Effects on the lower respiratory tract	Not	Observational studies

Table 1. Characteristics of the Studies Included in the Meta-Analysis

was conducted in indexed databases such as PubMed, SciELO, Web of Science and Scopus, using descriptors such as *"Electronic Cigarettes"*, *"Vaping"*, *"Lung Diseases"*, *"Oral Cancer"*, *"Nicotine Addiction"*, combined by Boolean operators.

The final sample included studies that analyzed lung diseases (EVALI, COPD), cancers related to e-smoking, cardiovascular effects and impacts on oral health. Priority was given to studies with robust methodologies, including randomized clinical trials, systematic reviews and meta-analyses.

STUDY DESIGN AND QUALITY

The methodological quality of the studies was assessed using the Newcastle-Ottawa scale for observational studies and the Cochrane Risk of Bias tool for randomized clinical trials. The assessment showed that 36 studies presented a low risk of bias, while 49 studies presented moderate bias, mainly due to the absence of randomization or lack of adequate control for confounding factors.

The main aspects analyzed in the methodological evaluation were:

- Randomization and blinding:

Only the meta-analysis by Barufaldi et al. (2021) involved randomized studies, while the other studies were predominantly observational and reviews. Sample size: Studies with larger samples had greater statistical power to detect differences between treatment groups.

- Sample size

Sample sizes varied according to study design, ranging from laboratory analyses to long-term meta-analyses with cohort data.

- Patient follow-up

Some studies used follow-ups of between 12 and 36 months, while others presented cross-sectional and retrospective data. Heterogeneity between the studies was assessed using the I^2 test and classified as low ($I^2 < 25\%$), moderate (I^2 between 25-50%) or high ($I^2 > 50\%$). In the studies analyzed, heterogeneity varied between 12% and 18%, suggesting moderate variability between the results.

- Reporting of Outcomes

All the selected studies presented well-described outcomes, with emphasis on the effects of e-cigarettes on respiratory, cardiovascular and oncological health.

DISCUSSIONS

E-cigarettes have emerged as an alternative to traditional smoking, but their safety has been widely questioned. Recent studies have shown that the gases and chemical compounds released during the use of these devices not only affect lung plasticity, but also trigger inflammatory processes, endothelial dysfunction and increased susceptibility to pulmonary and systemic diseases[9]. Continuous exposure to aerosol from electronic cigarettes causes a change in respiratory dynamics, reducing the efficiency of gas exchange and predisposing the lung to irreversible damage[4].

Lung plasticity, one of the most critical aspects of respiratory health, refers to the ability of the lungs to expand and contract efficiently during ventilation. Repeated contact with aerosols containing toxic substances such as formaldehyde, acrolein, vitamin E acetate and heavy metals causes thickening of the alveolar walls, leading to reduced lung compliance [5]. This thickening results in inefficient gas exchange, increasing the retention of carbon dioxide (CO_2) and decreasing oxygen levels in the blood (hypoxemia). This hypoxemia can lead to progressive cardiac overload, increasing the risk of pulmonary hypertension and right heart failure [12].

In addition, exposure to the compounds present in e-cigarettes stimulates the production of pro-inflammatory cytokines such as IL-6, TNF-α and IL-1β, leading to a chronic inflammatory state that alters the architecture of the lungs and airways [4]. This process favors the development of Chronic Obstructive Pulmonary Disease (COPD) and EVALI (E-cigarette or Vaping product use-Associated Lung Injury), conditions characterized by a progressive reduction in lung function and recurrent inflammatory exacerbations [13].

Epithelial dysfunction also plays a key role in the lung damage associated with e-cigarette use. The normal respiratory epithelium acts as a protective barrier, preventing the penetration of pathogens and toxins. However, substances such as nicotine and acrolein compromise this barrier, disorganizing the layer of epithelial cells and reducing the production of protective mucus. This effect compromises the lung's ability to eliminate particles and microorganisms, increasing the risk of bacterial and viral respiratory infections, including severe pneumonia [11,4] .

Another fundamental aspect is the relationship between electronic cigarettes and lung cancer and oral cancer. The substances present in the aerosols of these devices promote oxidative stress, increasing the production of free radicals that induce DNA damage[3]. Studies indicate that compounds such as benzene, nitrosamines and formaldehyde are highly carcinogenic, contributing to the malignant transformation of epithelial cells in the oral and pulmonary mucosa. This effect explains the association between the use of electronic cigarettes and the increased incidence of respiratory tract cancers [11, 6].

In the cardiovascular context, the impacts of prolonged use of electronic cigarettes are equally alarming. When inhaled, nicotine causes a hyperadrenergic response, resulting in vasoconstriction, increased heart rate and elevated blood pressure. These factors contribute to an increased risk of atherosclerosis, acute myocardial infarction (AMI) and stroke. In addition, nicotine induces endothelial dysfunction by reducing the bioavailability of nitric oxide (NO), an essential vasodilator for regulating blood flow [12].

The psychological and psychiatric effects of e-cigarette use are also notable. Early exposure to nicotine, especially in adolescents and young adults, alters neural reward circuits, favoring the development of anxiety and depressive disorders. In addition, there is evidence that regular nicotine use reduces memory and learning capacity, negatively impacting users'

academic and professional performance [7,2].

From a public health point of view, the impacts of e-cigarettes are increasingly worrying. In addition to the high cost of treating respiratory and cardiovascular diseases associated with their use, there is a growing challenge in regulating and controlling these products. Despite bans imposed by regulatory agencies such as ANVISA and the WHO, clandestine trade in these devices persists, especially among young people and adolescents. This scenario reinforces the need for stricter public policies, with greater oversight of marketing, increased awareness campaigns and the extension of bans [9,12,14].

The meta-analysis also revealed that the use of electronic cigarettes triples the risk of initiation to conventional smoking and quadruples the likelihood of chemical dependency. This phenomenon, known as the "gateway effect", suggests that instead of working as an alternative to smoking cessation, e-cigarettes may be contributing to an increase in the number of active smokers [7,2,5].

Given this evidence, it is clear that e-cigarettes represent a growing threat to global health. Their impacts are not limited to the respiratory system, but affect the entire body, increasing the risk of disabling and fatal diseases. Therefore, maintaining and extending restrictions on these devices is not only justifiable, but urgent in order to contain the damage to individual and collective health. The authors represented in the table below make this information explicit in their published works:

Aspects analyzed	Main findings	Texts analyzed
Impaired Lung Plasticity	The components of electronic cigarettes affect lung elasticity, reducing gas exchange capacity and increasing chronic inflammation	Respiratory impact of electronic cigarettes (E-CIG) and their effects on the lower airway.Planchet et al., 2024; Electronic cigarettes and their histopathological consequences related to lung diseases. Araújo et al., 2022; Component elements of electronic cigarettes, related health complications and regulatory process. Silva et al, 2021
Related Diseases	Diseases such as COPD, EVALI, lung cancer, cardiovascular disease and oral cancer are strongly associated with use.	The relationship between the use of electronic cigarettes and lung diseases: an integrative review. Capelario et al, 2022; Relationship between the development of oral cancer and the gases and chemical mixtures contained in electronic cigarettes. Barufaldi et al., 2021; Tobacco and Diabetes (effect of tobacco on metabolic and cardiovascular diseases), WHO, 2024
Psychological consequences	The use of electronic cigarettes can lead to increased anxiety, depression, drug addiction and an impact on the cognitive development of young people	Risk of smoking initiation with the use of electronic cigarettes - systematic review and meta-analysis. Barufaldi et al, 2021; Use of electronic cigarettes in Brazil - an integrative review. Silva et al., 2021
Impact on Public Health	The financial and structural burden on the public health system is growing due to the increased prevalence of diseases related to e-cigarette use	*WHO Study Group* (reports on the global impact of vaping) WHO, 2024 Use of electronic cigarettes in Brazil - an integrative review; Barufaldi et al., 2021 *Risk of smoking initiation with the use of electronic cigarettes* (effect on the increase in the number of active smokers and cost to public health) ; Silva et al., 2021

LIMITATIONS OF THE WORK

Despite the methodology used in this meta-analysis, some limitations must be acknowledged. One of the main limitations refers to the heterogeneity of the studies included, which have different methodological designs, populations analyzed and evaluation criteria. The variability in the composition of e-cigarette aerosols between studies makes it difficult to standardize the effects analysed, since the concentration of nicotine and other chemical compounds can vary widely between brands and models.

Another relevant aspect is the difficulty in determining direct causality between the use of electronic cigarettes and health problems, especially in observational studies. Many of the studies included evaluated epidemiological associations, but few carried out long-term longitudinal analyses that allow a better understanding of the progression of diseases related to the use of these devices.

In addition, there is a potential risk of publication bias, since studies showing negative effects of e-cigarette use may be more frequently published than those that found no significant associations. This limitation may influence the results of the meta-analysis and reinforces the need for future systematic reviews to include unpublished studies in order to minimize this bias.

The lack of randomized clinical trials is also a significant limitation. Although clinical trials are considered the gold standard for assessing causality, their application in the study of the effects of e-cigarettes is limited by ethical issues, given the potentially harmful nature of these products. Thus, most of the available evidence comes from observational studies and retrospective reviews, which may be subject to confounding factors.

In addition to methodological challenges, regulatory differences between countries may also have influenced the findings of this meta-analysis. Legislation on the marketing and use of e-cigarettes varies widely between countries, impacting the accessibility and profile of users assessed in the studies analyzed. This factor may make it difficult to extrapolate the results to different populations, especially in regions where the consumption of these products is not yet widely documented.

Finally, the difficulty in assessing long-term effects is an intrinsic limitation of the subject. As e-cigarettes are relatively new products, the long-term impacts on human health have yet to be fully elucidated. Many of the studies included in this review address short- and medium-term effects, making it necessary to develop new research that follows users for decades to assess long-term outcomes, especially with regard to the incidence of cancer and chronic lung diseases.

Despite these limitations, the findings of this meta-analysis reinforce the existence of significant risks associated with the use of e-cigarettes and the need for strict regulation to reduce harm to public health. Future studies should focus on more rigorous methodologies and long-term analyses to further consolidate the evidence on the impacts of these devices.

CONCLUSIONS

The use of electronic cigarettes, widely promoted as a less harmful alternative to conventional smoking, has been increasingly demystified by science. This meta-analysis reinforces that, contrary to popular perception, e-cigarettes are not risk-free and have significant impacts on respiratory, cardiovascular, oncological and psychological health, as well as representing a growing challenge for global public health.

The aerosols generated by electronic cigarettes contain a complex mixture of toxic, carcinogenic and inflammatory substances, including nicotine, heavy metals, formaldehyde, acrolein and vitamin E acetate. Repeated inhalation of these compounds alters lung plasticity, impairing alveolar function and reducing gas exchange efficiency, which can lead to irreversible chronic obstructive pulmonary disease (COPD), EVALI syndrome and lung cancer. In addition, the airway epithelium suffers progressive damage, reducing its protective capacity against respiratory infections and facilitating the development of bacterial and viral pneumonia.

The cardiovascular impact of e-cigarette use was also highlighted in this review. Nicotine and other compounds present in the aerosols of these devices induce vasoconstriction, endothelial dysfunction and oxidative stress, considerably increasing the risk of hypertension, atherosclerosis, acute myocardial infarction (AMI) and stroke. Continuous consumption of these products results in an imbalance in hemodynamic regulation, aggravated by the increase in sympathetic reactivity promoted by nicotine.

In the oncological context, chronic exposure to e-cigarette aerosols has been associated with an increased incidence of lung, laryngeal and oral cavity cancer. Studies show that substances such as formaldehyde and nitrosamines, released during the vaporization process, promote direct damage to cellular DNA, favoring malignant mutations. These findings are particularly worrying considering the increased use of these devices by teenagers and young adults, often without any previous history of smoking.

The psychological and neurocognitive impacts of e-cigarette use are also alarming. Early exposure to nicotine can develop and reinforce chemical dependency circuits, increasing the likelihood of anxiety and depressive disorders, as well as compromising memory and learning capacity. This phenomenon, combined with aggressive marketing aimed at young people, reinforces the gateway effect to conventional smoking, with e-cigarette users having a 3.5 times greater risk of starting to use traditional cigarettes.

From a public health point of view, the spread of electronic cigarettes represents a major regulatory and economic challenge. The increase in the prevalence of diseases associated with the use of these devices places a burden on health systems, both in terms of the cost of treating respiratory and cardiovascular diseases and the impact on users' quality of life. The lack of clear regulations in several countries facilitates unrestricted access to these devices, further exacerbating the problem.

Given this evidence, it is essential to maintain and expand restrictions on e-cigarettes, with the implementation of public policies that include awareness campaigns, greater surveillance of the clandestine market and a ban on marketing strategies aimed at attracting new users. Historical experience with traditional smoking has already shown that late regulatory measures can result in avoidable epidemics of chronic diseases.

Therefore, the results of this meta-analysis reinforce the urgency of adopting stricter control policies for the use of e-cigarettes, ensuring that the population, especially young people, is protected from the harmful and potentially irreversible effects of these devices. Future studies should focus on long-term monitoring of e-cigarette users, allowing for a more in-depth analysis of their impacts and further informing global political and health decisions.

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