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Review Article

Vaping: A Comprehensive and Concise Review Resource Regarding the Beneficial Effects, Indications, Adverse Effects, and Contraindications of Smoking e-Cigarettes on Various Human Body Systems

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Abstract

Vaping is smoking with electronic cigarettes (e-cigarettes). These battery-powered devices help users emulate the smoking experience by inhaling and vaporizing fluid within the device. Although tobacco is not a component of e-cigarettes, nicotine can be present in the form of a liquid solution. Vaping has increased among teens and young adults in recent years, possibly due to its alluring flavors and apparent lack of adverse health consequences compared to traditional cigarettes.

Legalizing nicotine-containing e-cigarettes has dramatically increased access to vaping e-cigarettes among smokers, providing consumers with additional alternatives to quit smoking or ingesting nicotine. However, the health risks and benefits of using electronic cigarettes as an alternative to traditional cigarettes made from combustible tobacco are a matter of contention. Several studies

have reported that vaping with electronic cigarettes can worsen respiratory or cardiovascular conditions. Despite these data, many users believe that vaping is a healthier alternative.

This article reviews the history of vaping, dependence, prevalence, incidence among teenagers and young adults, negative repercussions, medical expenses, and societal financial burden. It also provides readers with a concise and balanced overview of existing evidence on the health effects of vaping e-cigarettes and their effectiveness in quitting smoking compared to conventional smoking.

Keywords: *Breathing Conditions; Cardiovascular Disease; Ocular Health; Second-Hand Smoke; Smoking Devices*

Abbreviations

ATHRA: Australian Tobacco Harm Reduction Association; BP: Blood Pressure; CNS: Central Nervous System; e-cigarettes: Electronic Cigarettes; FDA: US Food and Drug Administration; GATS: Global Adult Tobacco Survey; HR: Heart Rate; MHRA: Medicines and Healthcare Products Regulatory Agency; NASEM: National Academies of Sciences, Engineering and Medicine; NYTS: National Youth Tobacco Survey; PHE: Public Health England; VOC: Volatile Organic Compound; WHO: World Health Organization

Introduction

Vaping history

Vaping is the technique of heating a liquid or wax to create an aerosol (vapor), which is inhaled using an electronic 'smoking' device. The vapor may contain nicotine, other compounds, flavors, and chemicals [1,2].

Vaping can be traced back to Egypt around the 15th century BCE. Herodotus, a renowned historian from ancient Greece, wrote about vaping at that time.

According to historians, ancient Egyptians believed that vaping provided therapeutic benefits to the body and the soul. Therefore, they used vaping for medicinal and religious reasons. A favorable method involved heating hemp seeds with red stones and inhaling the vapors thus generated [3].

About 1500 years ago, vaping was brought to the Middle East. Irfan Sheikh, an Afghan who worked for Mughal King Akbar, created the hookah, allowing users to consume flavor-infused tobacco [4]. Eventually, in the 20th century, vaping was brought to the United States and Europe [3].

Pneumostat, the first electric vaporizer, was created in the 1930s to treat pneumonia. This invention was the first medical device to convert a solution to a vapor using electricity, an essential step for the design of e-cigarettes [5]. The patent granted to Joseph Robinson in 1930 is the first documented reference to an electronic cigarette. Robinson suggested the device produce 'hot medicinal vapor to breathe'. It was called Butane Ignition Vaporizer [6].

In 1963, Herbert Gilbert proposed the idea of vaping; in 1965, he obtained a patent for "a smokeless non-tobacco cigarette". Although not for sale, the non-tobacco cigarette had only flavored steam and no nicotine [7]. Following Gilbert's invention, the vaping device was introduced into the market as smokeless non-tobacco cigarettes.

The first commercially available version of e-cigarettes, which were not electronic, but released nicotine vapor, was developed by Phil Ray and Norman Jacobson in 1979–1980. They were also the pioneers in conducting the initial official study on nicotine administration.

The product was successfully commercialized and made available in famous stores. However, the method for delivering nicotine was never promising. Therefore, the innovators developed a new name, 'vape' [8].

In the 1990s, a method based on chemical processes was developed. The 'heat-not-burn' device operates in a manner that is halfway between a torched cigarette and a pure nicotine inhaler. During this period, the US Food and Drug Administration (FDA) declined a major US tobacco manufacturer's request to approve a commercialized version of electronic cigarettes [9].

In 2003, Honk Lik, a Chinese pharmacist, created the original e-cigarette released on the market in 2006. Hon Lik filed several patents related to e-cigarettes with various variations over the next few years. Their commercial products ventured offshore for sale in Europe in 2006 and the United States in 2007 [7,10].

In 2008, the World Health Organization (WHO) stated that smoking e-cigarettes could not be considered a helpful aid to quitting smoking. In the same year, the Turkish Health Ministry halted the distribution of e-cigarettes, saying that it is as harmful as traditional cigarettes.

In 2009, Australia outlawed the use and distribution of electronic cigarettes. In 2011, the FDA began to regulate electronic cigarettes under the Food, Drug and Cosmetics Act. Furthermore, in 2015, Public Health England (PHE) concluded that e-cigarettes have the potential to help smokers quit smoking and are comparatively less harmful to health than tobacco cigarettes [8].

Vaping culture

Currently, vaping (e-cigarettes) has gained popularity as an alternative to smoking [11,12]. Its acceptance has increased worldwide, especially among young adults and adolescents.

The availability of different device technologies, sizes, and usability factors have contributed to the increased popularity of vaping [7,13]. These factors had the most significant impact on the decision of users to continue using e-cigarettes [14].

More than 7000 varieties are currently available on the market, and these flavors may also affect vaping [7]. A study discovered that using electronic cigarettes (vaping), color, taste, battery capacity, and other factors affect people's emotions [15]. Other factors that make vaping more popular are detailed in figure 1 [14,16,17].

Discussion

Addiction to vaping e-cigarettes

Vaping has become a popular leisure activity, and individuals from many walks of life are turning to it as an alternative to smoking or purely for pleasure. Initially, vaping was proposed as a method to deliver nicotine without tobacco by heating a mixture containing nicotine, flavoring agents, additives, propylene glycol, or vegetable glycerin [18].

It was also believed to be less compulsive than regular cigarettes. However, there have been reports of individuals developing an addiction to vaping and experiencing withdrawal symptoms [19].

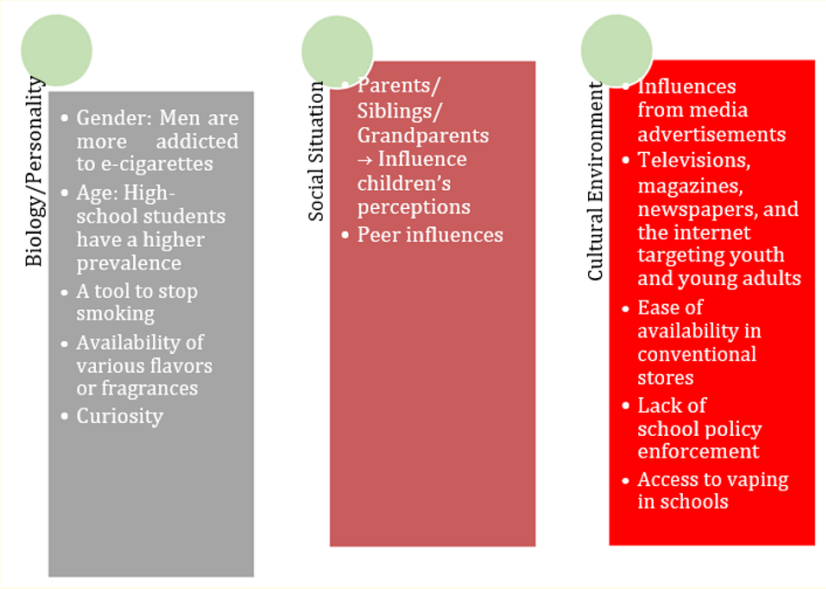

Figure 1: *Factors Influencing vaping.*

Vaping is a typical gateway to tobacco and marijuana use for teenagers and adults [19]. Nicotine, the primary component of regular e-cigarettes, is found naturally in tobacco plants, making vaping highly addictive. The use of e-cigarettes has even been associated with a higher risk of addiction, particularly in those exposed to higher nicotine doses than those who smoke regular cigarettes [20].

The nicotine concentration in vaping products may differ from what is stated on the label. Even products with a nicotine-free label can contain nicotine traces [21]. The compound is a stimulant of the central nervous system (CNS).

When smoking an e-cigarette, nicotine is quickly passed into the bloodstream from the lungs. As soon as it enters the bloodstream, it causes the adrenal glands to produce epinephrine. This production activates the CNS, increasing blood pressure (BP), heart rate (HR), and breathing rates, and also stimulates the reward circuits in the brain and increases dopamine levels (a neurotransmitter that promotes rewarding actions).

Nicotine's connection with the reward circuit causes some people to use nicotine repeatedly, despite the harm to their health, safety, and well-being [22,23]. Young adults who use electronic cigarettes and develop nicotine addiction are more likely to use other tobacco products later [21].

The promotion of e-cigarettes and other vaping forms is also primarily a result of the tobacco industry's marketing strategies. The tobacco industry has portrayed vaping emissions as 'water vapor' and a healthy substitute for people who want to reduce cigarette use or are looking for a smoking cessation tool. Furthermore, they have hailed the fact that e-cigarettes allow consumers to smoke in public areas [24,25].

Acceptable level of e-cigarette consumption

Because e-cigarettes contain fewer toxic compounds than regular cigarettes, they are considered less harmful to the user's health [26]. However, the "acceptable" daily (or in a month or a year) consumption of e-cigarette vaping use varies according to lifestyle choices, biological parameters, or from person to person [27,28].

Additionally, e-cigarettes allow more variance in puffs in quantity and length, making it more challenging to compare such among users [28]. According to a study, a typical puff volume of an e-cigarette is between 96.81 and 133.92 ml [29], while another study showed that a standard puff volume is between 331.2 and 519.6 ml [30].

The puff volume, length of the inhalation, degree of dilution with ambient air, and tempo and intensity of puffing affect how much nicotine is released in each puff. The nicotine content will increase if one takes a long pull from the vaporizer.

Therefore, the solution is not straightforward [31].

According to Directive 2014/40/EU of the European Parliament and the European Union Council, the maximum nicotine concentrations in e-cigarettes must range from 0 (0%, nicotine-free option) to 20 mg/mL (2.0%).

Despite this regulation, some market e-liquids contain nicotine contents substantially higher than these limits—nearly 54 mg/mL in some instances. Based on the release of around 1 mg of nicotine every 5 minutes, e-cigarettes with a nicotine content of 20 mg/mL are more similar to traditional cigarettes [32].

Incidence and prevalence of cigarette vaping

The use of vaping e-cigarettes is widely considered a global health concern. In 2011, international e-cigarette use reached 7 million users. In 2018, it increased to 41 million [33]. Jerzynski., *et al*. (2021) conducted research in 2021 to assess the global consumption of e-cigarettes. They evaluated the average incidence of vaping for each WHO region. They reported approximately 68 million e-cigarette users globally in 2020, estimated to increase to 86.1 million by 2023 [34].

In the United Kingdom, the prevalence of vaping e-cigarettes ranges from 1.7% to 7.1% [34]. In the United States, approximately 2.3% of the population vapes [35]. In Eastern Europe, Slovakia had a vaping rate of 34.3%, while Lithuania had a vaping rate of 55.7% [36].

In Malaysia, a cross-sectional study using the global adult tobacco survey (GATS) methodology found that 40.2% of participants do both traditional smoking and vaping, and 74.8% do only vaping [37].

A study conducted at different medical institutions in Lahore indicated that 6.2% of people smoked e-cigarettes [38], and another study featuring college students in Saudi Arabia reported incidence values ranging from 10.7% to 27.6% [39].

Pan., *et al*. (2022) used GATS data 2022 to investigate the prevalence of e-cigarette use in 14 countries: China, Ethiopia, Ukraine, Bangladesh, Uruguay, India, Mexico, Philippines, Romania, Russia, Senegal, Costa Rica, Turkey, and Vietnam.

The researchers found that the crude prevalence of current e-cigarette use ranged from 0.02% in India in 2016-2017 to 3.5% in Russia in 2016. On the contrary, the average prevalence rates were 0.8% in the Philippines in 2015 and 0.9% in China in 2018.

Current e-cigarette vaping use prevalence was 1% in 9 of the 14 countries studied: Bangladesh, China, Ethiopia, India, Mexico, the Philippines, Senegal, Uruguay, and Vietnam [26].

Gender differences also exist in vaping e-cigarettes. Men are more likely than women to be current smokers due to the reporting of smoking and the preference for e-cigarettes over traditional cigarettes [40]. Schoenborn and Gindi (2015) discovered that men (4.1% vs. 3.4% of women) were likelier to have tried an e-cigarette. The researchers also found that ≥ 20% of people aged 18 – 24 had performed vaping and that its use decreased with age.

E-cigarette use among students is also a worldwide issue [24]. According to National Youth Tobacco Survey (NYTS) statistics, vaping among students increased from 9.0% in 2004 to 13.7% in 2014 [41]. The 2019 data show that this number increased to 40.5% [42].

Consequences of cigarette vaping

The number and concentration of toxic compounds in e-cigarette aerosol are lower than those in tobacco smoke; however, long-term exposure to e-cigarette vapor can promote nicotine dependence and increase the likelihood of respiratory and cardiovascular health consequences [43].

In addition, a growing body of data demonstrates that vaping is hazardous. Figure 2 details the hazards and causes associated with the direct vaping of electronic cigarettes [17,24,40,44].

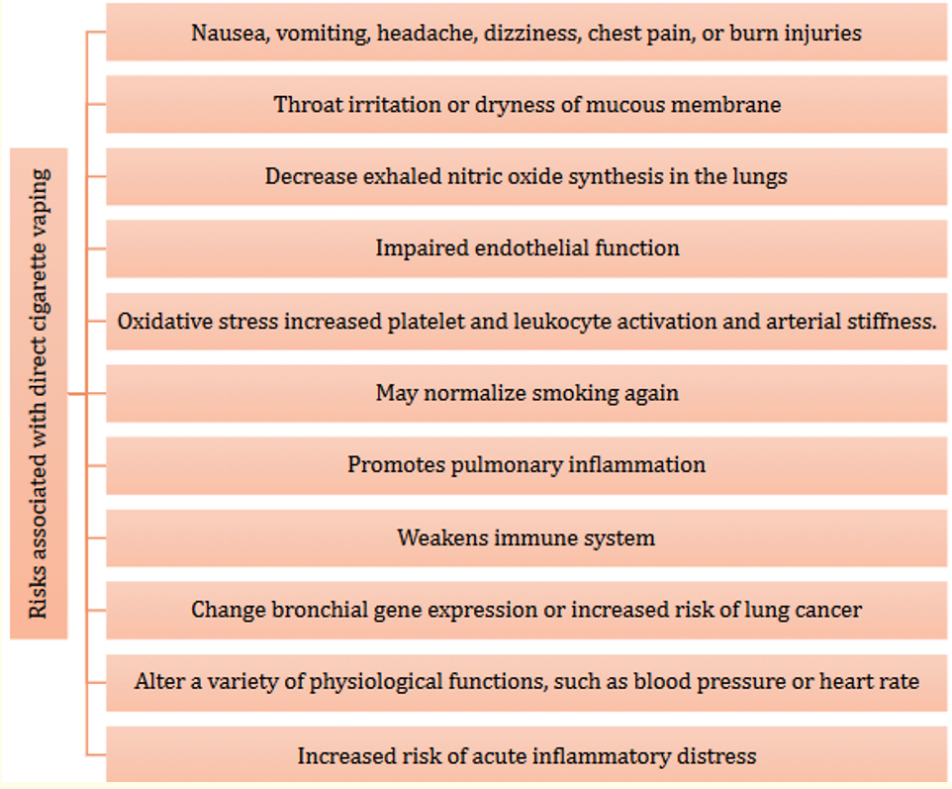

Figure 2: *Risks associated with direct smoking.*

Passive (second-hand) e-cigarette smoking

Passive e-cigarette smoke is less hazardous than passive cigarette smoke. However, second-hand vapor is still a type of air pollution that may harm health.

According to a 2018 NAP study, passive vapors contain particulate matter and volatile organic compounds (VOCs), such as nicotine, in amounts higher than the recommended values [45].

Research has shown that passive inhalation of e-cigarette vapors (second-hand smoke) elevates blood levels of cotinine (a nicotine metabolite), identical to passive exposure to traditional cigarettes [19].

Moreover, second-hand vape aerosol contains flavoring agents. One of them is diacetyl, a substance that can damage the functionality of the cilia in the airways and increase the likelihood of complaints of bronchitis, cause asthma episodes, or induce breathing difficulties [46].

All are affected by passive vape aerosol, but some groups may be more susceptible to its harmful effects. For example, infants and young children may be vulnerable to the potentially dangerous effects of chemicals in the aerosol of e-cigarettes because of their smaller size and growing respiratory systems.

Nguyen., *et al*. (2017) found that exposure to second-hand nicotine in vulnerable developmental stages, from the embryonic to adolescent stage, can have multiple adverse health effects, including impaired brain and lung development [47].

Vaping devices compared to traditional cigarettes

The equipment used for vaping comes in various sizes, forms, and names, including *vape boxes, e-cigars, vapes, e-hookah, hookah pens, hookah sticks, shisha sticks, Juul, vape pens, mechanical mods, tank systems, and e-pipes* [21].

The early vaping products were made to look similar to a typical store-bought cigarette. Most of them were intended to be used only once. They contained a cell, a cartridge (a reservoir or pod that contains electronic liquid with variable amounts of nicotine, flavors, and other compounds), an atomizer (a thermal element), and a mouthpiece.

The development of second-generation devices led to 'vape pens', rechargeable, refillable items that purposely vary from cigarettes in appearance. More modular variants (third generation) have since been developed, consisting of detachable and interchangeable parts that the user may switch out to create a unique product.

Fourth-generation e-cigarettes—also known as PODs—are frequently used by young people new to e-cigarettes. The fourth-generation is similar to first-generation sealed devices in that they include a limited-capacity battery and a disposable 'pod' that contains a highly concentrated liquid loaded with nicotine and in contact with a coil.

In vaping devices, puffing frequently ignites the battery-operated heat source, which vaporizes the liquid in the cartridge. Subsequently, the person inhales the resulting aerosol or vapor [48–50].

When comparing inhaling vape smoke to smoking combustible cigarettes, vaping is a less dangerous method of smoking nicotine [43]. The FDA approved the commercialization of 3 e-cigarette products in 2021, highlighting, in particular, their potential to aid smokers in quitting smoking [44].

To determine whether e-cigarette use is associated with cessation of cigarette use among smokers who originally never intended to stop, Kaza., *et al*. (2021) researched 1600 individuals. They found that daily use of e-cigarettes among tobacco users can increase their chances of quitting by 8 times [51].

Furthermore, a randomized control study by Hakel., *et al*. (2019) revealed that daily use of e-cigarettes is associated with nearly twice as high an incidence of smoking cessation as other nicotine replacement therapies after a year [52].

Because it is a safer option, its benefits outweigh the risks from a public health-harm reduction point of view. However, teenagers or young people increasingly use e-cigarettes, some of whom have never smoked. They are exposed to avoidable health hazards associated with using e-cigarettes, making it a public health concern [53]. Additionally, long-term research indicates that adult smokers who use nicotine-containing e-cigarettes may be more susceptible to addiction than those who smoke regular cigarettes [44].

Contraindications and potential side effects of e-cigarette vaping

Vaping is highly discouraged or contraindicated in individuals with alcohol allergies, cardiovascular disease, hypertension, or respiratory disorders. Additionally, breastfeeding and pregnant women should not use vaporizers [44,54,55].

Vapor from e-cigarettes may include several volatile chemical compounds and nitrosamines often present in conventional tobacco products. These chemicals disrupt the metabolism of various psychiatric drugs (including antipsychotic medications, antidepressants, hypnotics, and anxiolytics), lowering their blood levels. Thus, people using these drugs should avoid smoking e-cigarettes [56]. Figure 3 details the potential repercussions of e-cigarette vaping on biological systems [21,44,57].

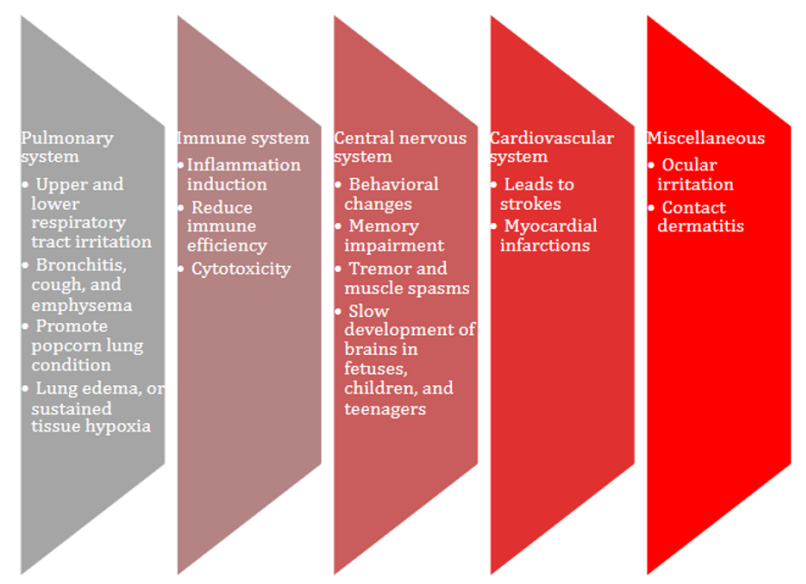

Figure 3: *Potential adverse effects of e-cigarettes on biological systems.*

Vaping device industry profits

In light of the growing popularity of e-cigarette vaping, sales of vaping devices have taken markets worldwide by storm. The United States, the United Kingdom, and France are the largest vaping markets.

In 2018, vapers in these three nations spent more than $10 billion on tobacco-free and vaping items. In 2019, the vaping industry was worth $19.3 billion worldwide [58]. According to Grand View Research, Inc., electronic cigarettes revenue is expected to reach $22.82 billion by the end of 2022, and according to recent government research, by 2030, electronic cigarettes revenue will reach $182.84 billion, showing a CAGR of 30.0% from 2022 (Figure 4) [59,60].

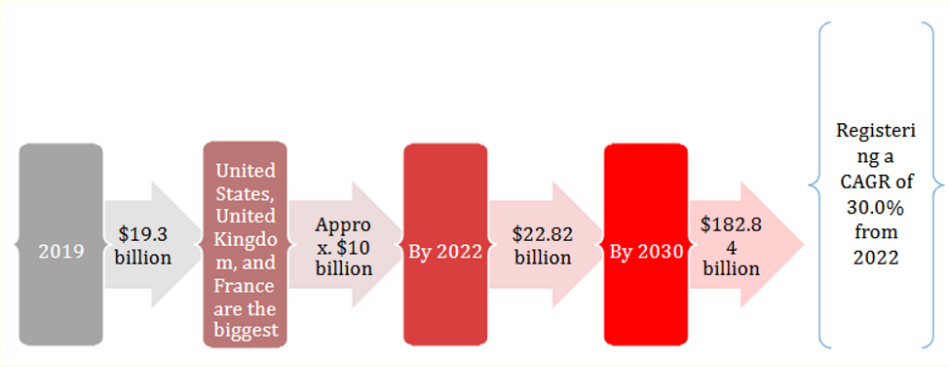

Figure 4: *Global estimation of the vaping market.*

Vaping costs to a smoker and its financial burden on society

Vaping is less expensive than regular tobacco cigarettes, but it is still not inexpensive. The cost of vaping is determined by the type of vaping device used (high-upfront vaping devices are more expensive than combustible tobacco products) and the amount of vaping. Compared to the price of cigarette packs, vaping cartridges and e-liquids are often less costly, making them an attractive long-term option. It costs about 7 packs of 20 tobacco cigarettes to cover the cost of a vaping product; thus, buying a rechargeable device may pay for itself in 9 - 10 days [61].

The Australian Tobacco Harm Reduction Association (ATHRA) states that vaping is 90% less expensive than smoking. In addition, according to ATHRA, the annual smoking budget for a pack-a-day smoker (20 cigarettes) is $10,580, whereas the cost of vaping is $1,150 per person per year (with a refillable tank) [62]. Although vaping is less expensive than smoking regular cigarettes,

These expenses can increase the cost of life and health insurance and contribute to the high medical expenses caused by diseases. For example, the health care expenditures associated with vaping use in the United States are $15 billion annually. Furthermore, a study by scientists at the San Francisco School of Nursing of the United Nations reveals a $ 2,000 increase in health care expenses per person who vape [63].

Medically-recognized vaping devices

The FDA has not authorized e-cigarette vaping devices as smoking cessation tools [44,64]. On the contrary, the Medicines and Healthcare Products Regulatory Agency (MHRA) has issued new guidelines that allow healthcare practitioners to prescribe authorized vaping products to tobacco smokers. Its tobacco control plan will be released shortly [65].

PHE, an institution that promotes health and eliminates health disparities, commissioned independent research that favored e-cigarette vaping over traditional smoking. According to PHE, vaping is 95% less harmful than conventional cigarettes and, when combined with behavioral intervention, can help most users quit smoking altogether [64].

Also, the PHE supports reasonable regulation to ensure high product safety and efficacy and marketing restrictions to ensure vaping is positioned to assist adult smokers in quitting.

The National Academies of Sciences, Engineering and Medicine (NASEM) also endorsed the notion that vaping can help quit smoking. They stated that transitioning entirely to electronic cigarettes from regular use of combustible tobacco cigarettes has fewer short-term ill health outcomes in multiple organ systems, and the degree of risk and dependence for vaping is lower than that for combustible tobacco cigarettes [55].

Vaping's future

Over time, the establishment of effective tobacco product laws that resulted in successful reductions in cigarette consumption has always been intertwined with scientific advances providing compelling information on the negative health consequences of smoking.

Thus, evidence-based laws and scientifically driven vaping recommendations will be more effective, rational, and enforceable and reduce/eliminate the danger of unexpected consequences, such as unwittingly converting e-cigarettes into *prohibitos autem fructum* (e.g., forbidden fruit).

While scientific data on the harmful biological effects of e-cigarette use accumulate, information on the usefulness of vaping coupled with behavioral treatment is also developing to help smokers stop smoking.

Vaping has the potential to provide a comprehensive and affordable solution to reduce smoking among more disadvantaged sections of the community, where smoking prevalence is higher [64,66].

Moreover, PHE has issued one of the most substantial official endorsements of vaping: e-cigarette vaping "may one day be offered as a regulated prescription as an alternative to anti-smoking treatments such as patches" [64].

Conclusion

Vaping using e-cigarettes has revolutionized public health, especially by lowering the severe health disparities from smoking. Adults using e-cigarettes can provide several reasons for continuing the habit, such as that it helps them stop smoking cigarettes and allows them to consume nicotine in places where smoking is not permitted.

Studies further support the idea that vaping can help to quit smoking. Contrary to traditional smoking, vaping poses fewer risks but is not entirely risk-free. More toxicological research, particularly studies on the long-term consequences of vaping, stricter sales controls, adequate industry oversight, and taste limitations, are warranted.

Conflict of Interest Statement

The authors declare that this paper was written without any commercial or financial relationship that could be construed as a potential conflict of interest.

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