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E-cigarette Health Effects on Major Body Systems: A Comprehensive Review of Cardiovascular, Respiratory, and Diabetic Implications

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Abstract:

This systematic review examined the health implications of electronic cigarette (e-cigarette) use, focusing on cardiovascular, pulmonary, and metabolic effects through analysis of literature published between 2016 and 2023. The study utilized PubMed and Web of Science databases to identify relevant research, including clinical trials and observational studies. Findings indicate that e-cigarette use is associated with both acute and chronic cardiovascular effects, pulmonary and metabolic impacts. The review concludes that e-cigarette use poses significant health risks, particularly for individuals with pre-existing conditions such as COPD or diabetes, while emphasizing the need for further research into long-term health implications and harm reduction strategies.

Introduction

Vaping products emerged around the mid of 2000. Stirred up debates, within the field promptly after their introduction to the market scene. They were initially promoted as an alternative for nicotine consumption through vaporizing liquids containing nicotine. However, recent studies have shed light on an view regarding their impact on health. Although e-cigarettes may contain fewer chemicals than traditional cigarettes, the potential health risks they pose remain a significant concern. The paced advancements of technology and the plethora of products, on the market make it challenging to determine their effects on our cardiovascular system respiratory health and metabolism. This overview explores our understanding of e-cigarettes influence on well-being by examining findings from medical research and real-life experiences.

Methods

This analysis delved into research on the impact of e-cigarettes on health aspects such as health and metabolic functions while also considering pulmonary outcomes. We undertook a review of literature from 2016 to 2023 focusing on articles published in English using databases like PubMed and Web of Science. The search criteria involved terms like 'electronic cigarettes' 'e cigarettes' 'vaping,' along, with 'health implications' 'heart health,' 'lung function,' 'metabolism,' and 'negative effects.' We incorporated research involving people like trials and observational studies to investigate the impacts of using e cigarettes on health issues such as heart health and lung function as well as metabolism effects. Articles were selected if they reported on cardiovascular, pulmonary, or metabolic effects related to e-cigarette use. We excluded articles that did not focus on these specific health outcomes or were not written in English.

Results:

Based on the analysis of the current evidence, it can be stated that the use of e-cigarettes has a range of negative effects on human health, which affect various organs and systems. Some of the cardiovascular effects are acute and delayed: It causes an increase in heart rate and blood pressure as well as arterial stiffness, endothelial dysfunction, and other vascular effects in the short run while using it in the long run increase the risk of myocardial infarction and coronary heart disease. According to the analysis of National Health Interview Surveys, it was found that the e-cigarette users had a higher probability of having cardiovascular disease than the non-users. As for the pulmonary complications, the research established that exposure to e-cigarettes

for 30 minutes resulted in the elevated levels of serum cotinine (60.6 ng/ml) and reduced lung functions. The odds of developing COPD were 1.30 times higher in e-cigarette users as compared to the never-users. The use of e-cigarette has been linked with poor glycaemic control (HbA1c > 9%) and increased likelihood of diabetic complications in diabetic patients. The nicotine contained in the e-cigarettes has been seen to reduce insulin sensitivity and activate the AMPK enzyme in adipose tissue thus increasing lipolysis and leading to insulin resistance. When exposed to e-cigarette aerosols, diabetic animals suffered from more severe lung injury characterised by increased albuminuria, enhanced oxidative stress and apoptosis of lung cells when compared with non-diabetic controls.

Conclusion:

The current evidence shows that there are numerous negative health impacts of e-cigarette use on the human body. Some of the cardiovascular effects include changes in heart rate, variations in blood pressure and may increase the chances of having heart attacks. Pulmonary impacts show respiratory irritation and lung function impairment while the metabolic impacts suggest an effect on glucose control and insulin sensitivity. These results are even more worrisome for those who suffer from chronic obstructive pulmonary disease or diabetes as they may be at a higher danger of being affected by e-cigarette use. More research must be done in the long run effects and how to contain the harm.

Key words: e-cigarette, cardiovascular, pulmonary, vaping, diabetes, pre-diabetes, electronic cigarettes, heart, lungs

E-cigarette Aerosol Composition and Toxicity

E-cigarette devices come with a number of components that use liquids which are also known as ‘e-liquids’ or ‘vape juices’ which are vaporized and then inhaled by the user. Although these solutions can have different components, the common ones include nicotine, propylene glycol, vegetable glycerin and flavors. The available evidence indicates that exposure to e-cigarette aerosols may present users with a number of risks including particulate matter,

volatile organic compounds and heavy metals. Recent findings have shown that e-cigarette aerosols may cause oxidative stress, a pathological mechanism that leads to tissue damage and impaired function. [2]

Propylene glycol and vegetable glycerin are the basic ingredient of e-cigarette liquids, usually making up the majority of their volume. They serve as carriers for nicotine and flavoring substances, and when heated, they create visible vapor. While generally recognized as safe for ingestion, the effects of chronic inhalation of propylene glycol remain poorly understood, with some studies suggesting potential respiratory irritation and inflammation. [1]

Although the harmful impact of nicotine on human health is well-documented, the effects of nicotine delivery via e-cigarettes may differ from traditional tobacco products due to variations in nicotine content, absorption, and patterns of use.

Using e-cigarettes involves exposure to heavy metals like copper, nickel or silver that may come from the heating coil of the atomizer. These metals have been associated with a number of negative health impacts including cardiovascular and respiratory diseases. [3][4]

Also, most of the e-cigarette liquids have flavors which when ingested can be safe but their effects when inhaled after being heated are still unknown.

The effects of e-cigarette use on the cardiovascular and pulmonary systems have been the focus of much research in recent years. [1] [2]

Cardiovascular Effects

The use of e-cigarette has been linked with short- and long-term cardiovascular consequences. Although e-cigarettes are marketed as a way of reducing the risks of smoking tobacco products, the current literature demonstrates that e-cigarette use has numerous cardiovascular consequences including acute physiological changes and possibly increased risks of cardiovascular diseases in the long run.

Short term changes

A number of research have conducted observational research and found that e-cigarette use is associated with higher heart rate, blood pressure and arterial stiffness which may have implications for the cardiovascular system. These findings from the studies mentioned above can be explained by the exposure to nicotine and other compounds present in the e-cigarette aerosols which are known to have an impact on the cardiovascular system through vasodilation, increased heart rate and impaired endothelial function. [1] [2]

When inhaled, nicotine triggers several cardiovascular effects through its interaction with nicotinic acetylcholine receptors (nAChRs). It activates sympathetic nervous system by binding to nAChRs in the adrenal medulla and stimulating the release of catecholamines - primarily epinephrine and norepinephrine. Catecholamines act on alpha-1 adrenergic receptors in blood vessels, causing vasoconstriction. Epinephrine and norepinephrine simultaneously stimulate beta-1 adrenergic receptors in the heart, increasing both heart rate and contractility. Nicotine has also immediate vascular effects. Nicotine directly activates nAChRs on vascular smooth muscle cells. This activation leads to endothelial dysfunction and reduced nitric oxide production. The result is increased peripheral vascular resistance. This causes to increased blood pressure and pulse rate, as well as decreased heart rate variability. [2]

The increase in blood pressure is a result of both increased cardiac output due to higher heart rate and contractility and increased peripheral vascular resistance because of vasoconstriction. [3][4]

Remote changes

The advent of electronic cigarettes has introduced new concerns regarding cardiovascular health, as emerging evidence suggests their use is associated with significant remote pathophysiological changes in the cardiovascular system. Long-term exposure has been linked to an increased risk of myocardial infarction through multiple mechanisms, including enhanced platelet reactivity, endothelial dysfunction, and accelerated atherosclerotic plaque formation. The oxidative stress induced by e-cigarette constituents promotes inflammatory responses within vessel walls, contributing to the development and progression of atherosclerosis. Furthermore, studies have demonstrated that e-cigarette use is associated with increased arterial stiffness, impaired endothelial-dependent vasodilation, and elevated markers of systemic inflammation – all of which are established precursors to cardiovascular disease. The presence of metal particulates in e-cigarette aerosols, including nickel, chromium, and lead, may further exacerbate these pathological processes through direct toxic effects on vascular tissues.

Usage of e - cigarettes affects damage of endothelial cell structure and function, as nicotine, the main component in e-cigarette liquids causes increase level of adrenaline, which leads to elevated heart rate and blood pressure, triggering vasoconstriction and impair vasodilation of blood vessels. Chronic endothelial dysfunction, driven by persistent nicotine exposure, can initiate and accelerate the progression of atherosclerosis. The resulting impairment in nitric oxide production and increased oxidative stress fosters a pro-inflammatory

environment within the arterial wall, attracting immune cells and promoting the formation of atherosclerotic plaques. Over time, these plaques can restrict blood flow, leading to an elevated risk of cardiovascular events such as myocardial infarction and stroke. Furthermore, the persistent inflammatory state contributes to vascular remodeling, characterized by increased arterial stiffness and reduced elasticity, further exacerbating cardiovascular risk. [3][4][5]

Analysis of the National Health Interview Surveys (NHIS) from 2016 and 2017 demonstrated that cigarette smoking is strongly associated with the occurrence of myocardial infarction (MI) and coronary heart disease (CHD). Importantly, the study found that the use of e-cigarettes was also linked to an increased risk of these cardiovascular outcomes, independent of traditional cigarette smoking. All smoking patterns (daily, several days per week, and former smokers) were significantly associated with coronary heart disease. Moreover, former smokers who quit smoking more than 6 years ago had lower odds of developing coronary heart disease compared to those who quit smoking within the last 6 years. The study by Alzahrani et al., based on NHIS data, found that daily cigarette smoking is associated with a 2.72-fold higher probability of myocardial infarction compared to never-smokers, after adjusting for other risk factors. Occasional smoking or past smoking history was also associated with an increased risk of myocardial infarction. The study by Oh et al., analyzing smoking history in 5,462 individuals with metabolic syndrome and 12,194 control subjects, demonstrated that increased risk of metabolic syndrome was associated with smoking one pack of cigarettes for 20 years or longer. In the Bermudez et al. study, smokers had a 1.54-fold higher risk of developing metabolic syndrome compared to non-smokers.[6][7]

In summary, current evidence consistently indicates a strong association between e-cigarette use and cardiovascular effects, including increased risk of myocardial infarction, coronary heart disease, and metabolic syndrome. However, it should be noted that most of these studies are observational in nature, which makes it difficult to definitively establish causal relationships. Additional longitudinal and experimental studies are needed to fully understand the long-term cardiovascular implications of e-cigarette use.

Pulmonary effects

While much research has been focused on the cardiovascular effects of the e-cigarette, the respiratory effects cannot be overlooked either. Recent research also shows that e-cigarettes may result in adverse impacts on the pulmonary system including inflammation of the lungs, compromised lung capacity and respiratory disorders. [8]

Immediate adverse impacts on pulmonary function have been observed with e-cigarette use. The study by Flouris et al. revealed that using e-cigarettes actively for 30 minutes will raise cotinine level in serum to 60. 6 ng/ml. Cotinine is a metabolite of nicotine and its presence in the body is an indication that one has been exposed to nicotine. This short-term exposure was also found to lead to a considerable reduction in the lung function as measured by forced expiratory volume in one second.

E-cigarette aerosols contain a number of substances, metals and nanoparticles and their inhalation may cause airway irritation and inflammation of the lungs. Research evidence has established that e-cigarette use is correlated with an elevated levels of inflammatory markers including neutrophils, interleukin-6 and tumor necrosis factor-alpha even if the user does not smoke traditional cigarettes. [9]

The use of e-cigarettes has related to respiratory disorders, including chronic obstructive pulmonary disease and asthma. According to a study by Wills et al., e-cigarette use among children and adolescents was correlated with an increased probability of having asthma and asthma attacks after adjusting for combustible cigarette smoking. A cross-sectional study by Osei et al also revealed that adults who used e-cigarettes had higher odds of developing COPD than non-users regardless of their smoking status. [10]

This is supported by recent epidemiological research that extends the knowledge on the effects of e-cigarette use on the lungs. The conclusions of Bhatta and Glantz showed that the e-cigarette users had 1.30 times higher chances of getting COPD than the never-users even after adjusting for other risks factors including smoking of conventional cigarettes.

The potential for e-cigarettes to induce lung injury is further emphasized by the outbreak of e-cigarette, or vaping, product use-associated lung injury in the United States in 2019-2020. This severe respiratory illness, characterized by acute respiratory distress, pneumonia, and even death, was linked to the use of e-cigarette or vaping products, particularly those containing tetrahydrocannabinol or vitamin E acetate. [11]

In conclusion, while vaping is less harmful than traditional cigarettes, the use of e-cigarette aerosols is also dangerous to the respiratory system. The current research shows that the use of e-cigarette can have negative impacts on the lungs, trigger inflammation of the lungs and may lead to serious respiratory conditions including COPD and asthma. These findings support the need to control the e-cigarette devices and raise awareness of the general public on the pulmonary hazards of using such products.

Impacts on Diabetic Patients

Besides the cardiovascular and pulmonary effects, the use of e-cigarettes is also dangerous to diabetics. Diabetes is a metabolic disorder which is defined by the inability to regulate the blood glucose level, and if not managed well can result to other complications like cardiovascular disease, kidney disease and nerve damage.

A systematic review by Nayak et al. found that e-cigarette use was associated with a higher prevalence of diabetes compared to non-users [12].

For patients with pre-existing diabetes, e-cigarette use can make diabetes even harder to manage and increase the risk of developing diabetes-related complications. E-cigarette use has been associated with suboptimal glycaemic control, increased likelihood of diabetic ketoacidosis and augmented risk of diabetes-related hospital admissions. In addition, the use of e-cigarettes in diabetic patients may result in worse health status, for instance, increased frequency of cardiovascular events and progression of diabetic neuropathy, nephropathy and retinopathy.

Nicotine which is present in e-cigarettes has been known to have negative impacts on the blood sugar and insulin levels. Research indicates that nicotine intake hinders glucose regulation, enhances insulin insensitivity and increases the likelihood of getting type 2 diabetes. In addition, the use of e-cigarettes has been linked with an increased rate of metabolic syndrome which is a group of conditions that include high blood pressure, high blood sugar, and abdominal obesity and all of these are associated with an increased risk of diabetes and cardiovascular disease.

A study by Yingst et al**.** found that e-cigarette users with diabetes were more likely to experience poor glycemic control, defined as having an HbA1c level greater than 9%, compared to non-users. Nicotine has been known to decrease the sensitivity of receptors to insulin, which may result in worse glucose management and higher chances of diabetic complications. Moreover, it stimulates releasing stress hormones like adrenaline, noradrenaline and cortisol, which can also impact blood sugar levels. Nicotine activates AMPK enzyme in adipose tissue, which accelerate lipolysis. This causes increase of free fatty acids, contributing to insulin resistance and diabetic complications. A review by a review by Ghosh and Drummond showed that e-cigarette use may lead to the development of diabetic ketoacidosis which is a severe condition of diabetes that results in the buildup of ketones in the blood. [12][13] [14][15]

Nicotine has been known to suppress the tissue sensitivity to insulin, which in turns increase the chances of getting type 2 diabetes. Nicotine enhances the levels of hormones that

are antagonistic to insulin such as catecholamines and cortisol. Some experimental works on animals have demonstrated that nicotine is able to activate AMP-dependent protein kinase in adipose tissue and thus enhances lipolysis and leads to insulin resistance. [16]

The study also revealed that individuals with diabetes are sensitive to the adverse impact of e-cigarettes on the lungs. Research done on animals with type II diabetes revealed that e-cigarette exposure results in more severe lung injury as compared to non-diabetic ones. Higher levels of albumin, oxidative stress and apoptosis of lung cells were also noticed, suggesting that diabetic patients with poor glycaemic control are even more susceptible to e-cigarette induced damage. [17]

These studies underscore the significant risks that e-cigarette use poses for individuals with diabetes.

Limitations:

Though there is an increasing amount of research highlighting the health effects of e cigarettes there are still some constraints, within the existing studies.

- Most studies have focused on short-term effects, with limited data on the long-term consequences of e-cigarette use.
- Most of the research works have been based on self-reports which may be inaccurate due to recall bias. [16]
- The diversity of e-cigarette products, nicotine strength, flavors, and device types, makes it difficult to extrapolate the results to all the categories of e-cigarette users. [14] [1] [18]
- The effects of the concomitant use of e-cigarettes and conventional cigarettes on health outcomes is not well known.

Although much has been said about the e-cigarettes, there is still a lot of uncertainty regarding the specific pathways through which the devices may affect the cardiovascular, pulmonary, and metabolic systems.

Conclusion

Current evidence indicates significant health effects of e-cigarette use across multiple organ systems. Cardiovascular impacts include altered heart rate, blood pressure changes, and

potential increased risk of myocardial infarction. Pulmonary effects demonstrate respiratory irritation and altered lung function, while metabolic effects suggest possible interactions with glucose regulation and insulin sensitivity. These findings are particularly concerning given that individuals with pre-existing conditions, such as lung disease or diabetes, may be at disproportionately higher risk for adverse outcomes associated with e-cigarette use.

Initially promoted as a method to help people quit smoking e-cigarettes are now seen as fueling nicotine dependency and hindering smoking cessation efforts.

Despite the increasing evidence of health implications associated with it there are still research deficiencies that exist regarding e cigarettes. The extended consequences are not fully comprehended yet. It remains a challenge to establish uniformity among e cigarette devices and exposure procedures, for research purposes. As the e-cigarette industry continues to evolve, ongoing surveillance, robust research, and evidence-based policymaking will be critical to address the public health implications of these emerging nicotine delivery products.

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