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Health Effects of E-Cigarettes and Other Alternative Nicotine Delivery Systems in Sport

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ABSTRACT

In recent years, the popularity of alternative nicotine delivery systems (ANDS)—including electronic cigarettes, heated tobacco products (HTPs), nicotine pouches, snus, and nicotine gums—has rapidly increased, particularly among adolescents and young adults. This review summarizes current literature regarding the composition and toxicity of aerosols generated by e-cigarettes and other ANDS, emphasizing their cytotoxic, oxidative, and inflammatory effects. Researchers increasingly discuss the potential of these products to induce both acute conditions (e.g., EVALI) and chronic respiratory diseases (e.g., chronic obstructive pulmonary disease [COPD], asthma). The review places special focus on the toxicity of flavoring agents and the disproportionate risks faced by vulnerable populations, particularly youth. In Europe, approximately 12–15% of adolescents report regular e-cigarette use, with increasing consumption of other products such as snus and nicotine pouches. While ANDS may reduce certain risks compared to combustible cigarettes, accumulating evidence demonstrates that they are not harmless. Further longitudinal and comparative studies are necessary to comprehensively assess the health impacts of these diverse nicotine delivery products.

Keywords: e-cigarettes, respiratory system, oxidative stress, cytotoxicity, EVALI, adolescents, flavoring substances, alternative nicotine delivery systems, snus, nicotine pouches, athletes, sport performance, pulmonary function, physical activity, ENDS.

1. INTRODUCTION

Despite claims of their "harm reduction", alternative nicotine delivery systems (ANDS) such as electronic cigarettes (e-cigarettes), heated tobacco products (HTPs) and nicotine pouches have seen a rapid uptake amongst adolescents and young adults, in part due to marketing that shows them as less harmful than cigarettes and/or as a means for cessation. Evidence increasingly shows that the constituents of e-cigarette aerosols (e.g., nicotine, aldehydes, heavy metals, flavoring chemicals) can cause oxidative stress, airway inflammation, and impaired respiratory function. We have previously shown that e-cigarette exposure decreases lung function and increases mucus production and, therefore, potentially increases susceptibility to respiratory disease (e.g., asthma, chronic bronchitis). These results call into question the claims of their reduced harm, particularly in physically active individuals and

athletes, for whom performance relies on maximized respiratory capacity (Young et al., 2020).

In view of the increasing popularity of e-cigarettes, HTPs, and nicotine pouches, it is crucial that the physiological effect of ANDS must be studied to provide clear, evidence-based information about potential health and performance risks. This review aims to synthesize current scientific evidence on the health effects of e-cigarettes and other nicotine-containing products. We are looking especially at what it does to your breathing and how it might affect sports performance.

2. REVIEW METHODS

We searched PubMed and Google Scholar for articles until August 2025. We used the following words: "e-cigarettes", "electronic nicotine delivery systems", "vaping health effects", "heated tobacco products", "nicotine pouches", "respiratory toxicity". We also found more articles by looking at references from essential articles and other reviews.

We found n = 748 articles or reviews in total.

After removing n = 312 duplicates, we screened the titles of n = 436 articles.

We did not include n = 274 articles that either did not have enough information on the abstract, did not match our review, or were on other nicotine substances.

We decided to read the full text of the remaining n = 162 articles.

After carefully going through the articles, we did not include n = 106 studies for the following reasons:

- we were unable to extract any outcome data from the studies, as only descriptive results were reported,
- study quality was suboptimal, e.g., isolated case reports with <3 subject(s),
- limited extrapolability, e.g., studies focusing solely on manufacturing features or user behavior,
- review-type articles reporting no new results.

Finally, we included n=28 studies in the qualitative synthesis.

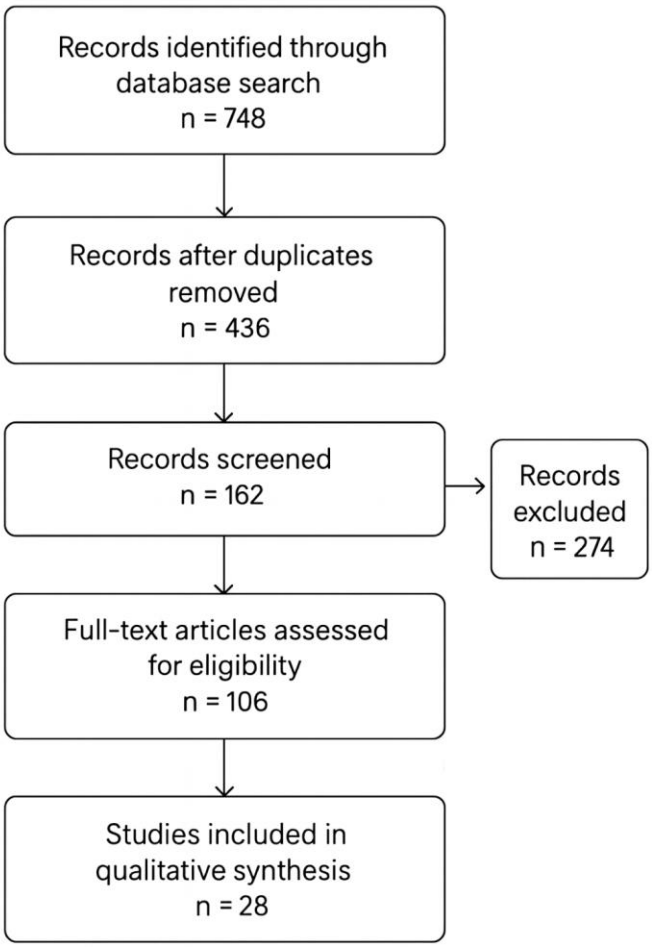

Figure 1. (PRISMA CONSORT chart) illustrates the study selection process.

3. RESULTS & DISCUSSION

E-cigarette aerosol composition and inhalation toxicity

E-cigarette aerosols contain a complex mixture of chemicals, including nicotine, propylene glycol, glycerin, aromatic additives, heavy metals (e.g., nickel and lead), and carbonyl compounds such as formaldehyde and acetaldehyde (Sleiman et al., 2016). These particles are generally less than 2.5 μm aerodynamic diameter, which are deposited in the distal airways and alveolar region (Farsalinos and Polosa, 2014). Many of these constituents have been demonstrated in laboratory and clinical investigations to induce oxidative stress, inflammatory signaling, and bronchial epithelial cell injury, thus resulting in compromised mucociliary clearance and epithelial barrier integrity. Even though some of these chemicals are safe for oral consumption and ingestion, they may have an unexpectedly high level of toxicity when inhaled due to different pharmacokinetics and tissue exposure. Unlike e-cigarettes, a large variety of ANDS, including heated tobacco products (HTPs), oral nicotine pouches and snus, have raised public health concerns. Although these smokeless products are delivered to the oral mucosa, and thus limit the direct pulmonary exposure, chronic use could still provoke systemic inflammation and cardiovascular disturbance due to continuous exposure to nicotine and flavoring chemicals (Berman et al., 2020). The heated tobacco products heat tobacco to make an aerosol that can be inhaled. So, it exposes the people who use it to ultrafine particulate matter and volatile organic compounds. These compounds cause endothelial dysfunction and pulmonary toxicity, however, their concentrations are not as high as those in old fashioned cigarettes (Nabavizadeh et al., 2018).

EVALI – this is a bad lung problem that is mainly caused by vaping

In 2019, some people in the United States got acute lung damage. It was linked to using e-cigarettes. The condition was named EVALI. The symptoms include shortness of breath, cough, fever, chest pain, and hypoxemia. The sickness was closely related to vitamin E acetate found in THC vaping fluids (Blount et al., 2020). But after a review written by Sharma and others, EVALI still happens even after vitamin E acetate was removed from the vaping liquids. So, this could mean that different things in the vaping fluid might also cause EVALI, like other types of solvents and flavoring chemicals (Sharma et al., 2024). When people have EVALI, the symptoms can be confused with other kinds of lung infection like a nasty pneumonia, for example, COVID-19, this can make the EVALI diagnosis wrong and late.

EVALI is mainly linked to substances breathed in. But it shows the general dangers of different ways to deliver nicotine. Some examples of these are nicotine gums and lozenges. They are thought to be less risky and are used as nicotine replacements. But more long-term studies are needed to know how safe they are, especially for the heart and addiction. Other tobacco products that do not require burning, like snus, are also marketed. Snus is a damp, powdered tobacco placed under the lip. It does not need to be breathed in, so it is less likely to cause lung problems like EVALI. But studies have shown it can cause more pancreatic cancer and heart problems (Luo et al., 2007). Packets with a lot of nicotine and other kinds that are eaten are becoming more popular. Some of them are said not to have tobacco, which can be misleading. But researchers are worried that teens will get addicted to these and that other chemicals in them could poison people (Breland et al., 2017). New devices that are for vaping, like pod devices that can be thrown away, can have a lot more nicotine concentration in the shape of salts. They could make people depend on them even more and bring more harm to the body, especially if other unknown chemicals are added. So, even if not every nicotine product has the same lung dangers as e-cigarettes shown in EVALI, they are not entirely safe. We need more research and rules for them.

Flavorings are used to attract users, but they can harm the lungs

For example, Diacetyl, a buttery-tasting chemical that is OK in food, can cause a bad lung disease that does not go away. Some flavorings can also cause immune cell reactions and make diseases worse. They set off chemicals in the body (interleukin-6, interleukin-8) that can cause swelling and irritation in the airways. This can stop the cilia, the small helpers that clear mucus and particles from the lungs, from doing their job. Recently, a study has shown that some flavors are dangerous to airway cells. Especially, cinnamon (cinnamaldehyde) and fruit flavors show the highest levels of toxicity and stress. E-liquids flavored with cinnamon have been found to harm mitochondria and raise inflammation more than other flavors tested. Some fruit flavors may also increase oxidative damage and damage the lining of airway cells (Gerloff et al., 2020). These results show that flavored chemicals have different levels of toxicity, so they need more rules.

Also, other nicotine products, HTPs, snus, and oral nicotine pouches have a lot more flavoring chemicals. Even though snus and oral nicotine pouches are not inhaled, these flavoring toxic chemicals can affect our body through the mouth. Recent studies show that sweet or mint-flavored nicotine pouches may change the oral cells by causing stress and inflammation. Flavored HTPs used in the long

term have been linked to lung inflammation and dysfunction. These results show that flavoring toxicity is not only harmful in the airway but also must be examined in every form of nicotine product.

E-cigarettes and oxidative stress

Scientists are still learning about e-cigarettes and how they affect the body. They have found many ways that e-cigarettes are harmful for cells. One way is that the nicotine vapor made by e-cigarettes can increase oxidative stress in the body. It can also lower a protein called glutathione that helps protect the body from damage. These things cause the cell to try and stop the damage. Misfolded proteins build up in a part of the cell called the ER. They attach to another protein, BiP. This activates certain factors called ATF4, CHOP, XBP1, and IRE1α. ATF4 makes a lot of genes that can help stop some of the stress. CHOP stops another protein from fighting cell death, so the cell dies more easily. IRE1α also turns on a lot of XBP1, which makes PDI, a protein that helps with folding proteins. If the ER cannot fix all the problems, the cell dies.

E-cigarette exposure can also stimulate other molecular pathways like NF-κB to modulate cytokines such as IL-6, CXCL-8 and IL-10, as well as growth factors, e.g., transforming growth factor-beta (TGF-β), and hepatocyte growth factor (HGF). TGF-β in particular is associated with metabolic dysregulation, induction of epithelial-mesenchymal transition (EMT) and deposition of extracellular matrix. All of these are involved in fibrosis and cancer. The SMAD signaling cascade, which is mainly mediated by Smad2 and Smad3, enhanced tumor-related mechanisms by stimulating the production of the pro-angiogenic factor thrombospondin-4 (TSP-4). Stimulation of the HGF/c-MET pathway has been shown to alter cellular metabolism by upregulating glycolysis, and promoting tumor progression by enhancing cellular proliferation, invasiveness and neovascularization (Hartmann et al., 2016; Ha et al., 2019).

Furthermore, e-cigarette exposure, both with, and without nicotine, stimulated the production of mucins - mainly mucin 5AC (MUC5AC) in the airways, most likely by propylene glycol. The overproduction of MUC5AC results in thick mucus that is harder to clear from the airways (Lachowicz-Scroggins et al., 2016). This promotes their obstruction, inflammation, and recurrent infections. Overproduction of mucins has been associated with respiratory conditions such as chronic obstructive pulmonary disease (COPD), cystic fibrosis and asthma (Horsley et al., 2014; Kirkham et al., 2008).

Cytotoxic effect

Oxidative stress can harm the cells. Many scientists have found that the chemicals in e-cigarette vapor can hurt cells. E-liquids can damage cells and DNA in the nose and throat tissues. E-liquids with fruit flavorings are more damaging than non-flavored ones. This might be because fruit flavors need more kinds of chemicals to make them taste good (Welz et al., 2016; Putzhammer et al., 2016). But regular cigarette smoke is way more damaging than e-cig vapor when it comes to harming cells. High levels of nicotine did not damage cells in the mouth, but they did make the cilia not work as well. Still, this was better cilia activity than after exposure to smoke from a regular cigarette. If your cilia are not working, your mucus gets backed up and can not clear pathogens. When mucus can not clear like it should, you are more likely to get respiratory infections (Möller et al., 2006; Ito et al., 2015).

Long-term effects of use

Studies show that using e-cigarettes can often harm the lungs. This harm includes breathing out less air, having trouble with airflow, and a higher chance of chronic bronchitis (McConnell et al., 2017). When people often breathe in e-cigarette vapor, the immune system in the nose and throat also becomes less active (Reidel et al., 2018). There are other products related to this issue, called alternative nicotine delivery systems (ANDS), such as heated tobacco products (HTPs), nicotine pouches, snus, and nicotine gums. These also risk your breathing and overall health. HTPs release dangerous chemicals you can also find in e-cigarette vapor. These chemicals seem to cause harm to the lungs (Farsalinos & Polosa, 2014). While people do not breathe in snus and nicotine pouches, they can still cause problems with inflammation in the body and heart issues (Berman et al., 2020; Nabavizadeh et al., 2018). All these facts show that we need to closely check all ANDS to better write rules and keep people healthy.

Young people and vulnerable groups at risk

Teenagers and young people are using e-cigarettes more often. This is especially true in Western countries. Many teenagers choose e-cigarettes because they like the different flavors. They also think e-cigarettes do not hurt them. These young people are often still growing, so their lungs are not fully ready to handle the chemicals in e-cigarettes. The substances might damage their lungs forever. Data shows that many young people use e-cigarettes. In Poland, a study found that about 80% of teenagers use e-cigarettes. About half

of those teenagers use e-cigarettes because they like the flavors. Other countries also have many teenagers using e-cigarettes. The World Health Organization said that 32% of 15-year-olds in Europe have used e-cigarettes. About 20% have used an e-cigarette in the past month. Many teenagers who use e-cigarettes later use regular tobacco cigarettes.

E-cigarettes might lead young people to nicotine addiction

They are not just a healthy replacement for smoking. At the same time, young people are using more heated tobacco products, nicotine pouches, and snus. These products are said to be less risky. They come in nice flavors and are easy to use in secret. This makes them more popular with teenagers (Leigh et al., 2018). HTPs are less harmful than cigarettes because they are not burned. But they still have unsafe chemicals that can hurt young people's lungs. These chemicals can cause swelling in the body. Young people cannot fight them off because they are still growing (Huang et al., 2017). Nicotine pouches, and snus are not as bad because you do not breathe them in. Yet, they can still make young people addicted to nicotine and their moods can change (Goriounova & Mansvelder, 2012). There are many kinds of ANDS which come in different flavors such as menthol, fruit, and candy flavors. Young people love these flavors. They also think that they cannot get addicted (Huang et al., 2017).

Oral nicotine products can be used secretly. This makes it easy for students to use them at home or school. It is hard for parents and teachers to notice early on and step in.

We need to be careful about nicotine products that are not e-cigarettes, too. There needs to be regulation and public health education about alternative nicotine products. If we don't regulate it, products will continue to be normalized and more vulnerable populations will become nicotine dependent (Nabavizadeh et al., 2018; Leigh et al., 2018).

The Risks of Nicotine Use in Athletes and Physically Active Individuals

Although the health risks of nicotine Alternatives have been generally discussed in the general population, new evidence suggests a significant health risk to Athletes and physically active populations. Chronic exposure to aerosols containing aldehydes, heavy metals, flavoring compounds can lead to compromised pulmonary function. This appears to indicate reduced exercise tolerance and endurance. This is especially concerning in sports that require exercise tolerance and endurance. Studies have shown that e-cigarette use can cause airway inflammation and decreased forced expiratory volume in 1 second (FEV1), which may translate into impaired performance (Young et al., 2020).

ENDS stands for Electronic Nicotine Delivery Systems

It is a fancy term for things you may know as e-cigarettes, e-cigs, vaporizers, vape pens, Juuls, or dab pens. Developed in China, e-cigs became available in the U.S. in 2006. ENDS are non-combustible, battery-powered products often reusable. Not all e-liquids or devices are created equal. ENDS typically have a battery, a heating element, and a cartridge or tank containing e-liquid. E-liquid solutions are generally made of propylene glycol or vegetable glycerin with nicotine and can include flavorings. Nicotine content ranges from 1.7–4.8%. One product that stands apart from the others is the USB-shaped Juul device that uses a proprietary salt nicotine formula at 5% concentration, providing a nicotine kick similar to traditional combustible cigarettes (TRCs). A single Juul pod contains 40mg— roughly the same amount of nicotine as a pack of cigarettes. The U.S. Food and Drug Administration (FDA) only regulates ENDS hardware— not yet the contents of e-liquid solutions, which can contain a variety of potentially harmful constituents.

ENDS became the most popular nicotine product amongst U.S. high school (20.8%) and middle school (4.9%) students in 2018 – a skyrocketing increase from 2011. The rise in use has been partially attributed to the ability to conceal use and the high nicotine content of products such as Juul. Data from 2014 to 2016 showed that although an increasing number of adults reported using ENDS, only 12–14% continued daily use. Data among athletes is more limited. Some report using nicotine in an effort to control weight and/or stress, with others citing the potential to enhance reaction times or focus. Use is seen more often in skill sports versus power or endurance sports. In 2019, the World Anti-Doping Agency (WADA) was monitoring but had not banned nicotine use in sports. NCAA data from that same year showed that 8% of student athletes reported use of ENDS compared with 11% use of cigarettes and 17% who smoked cigars once in a while. ENDS use risk was higher in sports like baseball, softball, and wrestling, and playing sport was not protective against their use (Young et al., 2020).

ENDS-Related Harmful Effects Beyond Addiction and Lung Injury, Negative Impact on Injury Recovery and Future Research Directions

Since 2017, thermal burns, and shrapnel wounds secondary to ENDS (e.g., explosion) have accounted for >800 injuries with men <45 years old experiencing the most significant risk. In addition to burns and shrapnel, unintentional or intentional ingestion of e-liquids may cause significant gastrointestinal toxicity. Symptoms may include vomiting, altered mental status, and tachycardia but can escalate to seizures, acidosis, or cardiac arrest. Sleep quality and duration are key drivers of athletic recovery and exposure to nicotine and other substances found in ENDS suppresses REM sleep, increases sleep onset, and fragments sleep cycles. Moreover, dual-use (i.e., ENDS and TRC) and female sex amplify these adverse effects on sleep. TRC use is also associated with impaired musculoskeletal healing, and preclinical studies have found that nicotine exposure can delay both tendon and bone healing. Thus, nicotine, and other substance exposure from ENDS may yield similar adverse effects on musculoskeletal recovery, but this has primarily been shown in animal models (Young et al 2020).

We still do not know a lot about how ENDS use affects athletic performance. ENDS use on strength, sprint, and endurance performance has not been evaluated. The effect of the timing of ENDS use before, during, and after exercise is unclear. It is unknown if ENDS use could improve or worsen performance. The long-term health outcomes of ENDS use in amateur and elite athletes, including the effects of passive ENDS use and the chronic inhalation of heated vapor and its various constituents on the pulmonary health of athletes are unknown. Future research should focus on these areas and focus on clear, evidence-based risk communication specific to the athletic community (Young et al., 2020). Current strong evidence support e-cigarettes, which are often advertised as a "safer" alternative to regular tobacco smoking, have a significant biological impact on respiratory health. Preclinical and clinical studies have shown mechanisms including oxidative stress, airway epithelial barrier disruption, impaired mucociliary clearance, and mucin production, leading to chronic airway inflammation, airway remodeling, and increased susceptibility to respiratory infection.

Interestingly, the rise of EVALI cases makes us realize the sudden breathing problems that some e-cigarette ingredients can cause, especially vitamin E acetate found in some illegal THC vaping products during the time of the EVALI outbreak. Yet, the fact that lung issues like EVALI are still around even after vitamin E acetate was removed from these products shows us that there are still other toxins in vaping aerosol that haven't been found yet. On top of that, new studies have discovered that e-cigarette exposure can cause some changes in human genes through epigenetic modifications, which can make people more prone to diseases after using vaping products for an extended period. Finally, flavoring additives need special attention because some have shown strong power to cause cell death and inflammation in airway epithelial cells, such as cinnamaldehyde and some fruit flavors. This is especially concerning because flavored products are sold to adolescents on purpose, enticing them to use ENDS and start using nicotine products. Other ANDS devices like nicotine gums, snus, and nicotine pouches should also be mentioned as contributing to the current nicotine epidemic, and all of them, like ENDS, have their own health risks and can increase systematic oxidative stress and cause inflammatory responses. These products differ from each other and reach the body in different ways, but all are harmful to human health. Therefore, ANDS should be regulated. These regulations should include stringent chemical controls on the composition of e-liquids and nicotine products, stringent restrictions on flavors, and enhanced measures to reduce youth access and appeal. E-cigarettes may have a role in tobacco harm reduction for established adult smokers but the uncontrolled proliferation of these products, particularly among youth, and non-smokers, represents a significant threat to public health and respiratory health. Future work should prioritize longitudinal and mechanistic studies to better understand the long-term effects of e-cigarettes and other ANDS on respiratory and systemic health to inform future evidence-based policy and clinical recommendations. To clarify product specific risks, Table 1 briefly describes the key differences between e-cigarettes, heat-not-burn products and traditional tobacco cigarettes.

Table 1. Comparison of E-Cigarettes, Heat-Not-Burn Products and Traditional Cigarettes

Feature	E-Cigarettes	Heat-Not-Burn (HTP)	Traditional Cigarettes
Source of aerosol/smoke	Heated and vaporized liquid,	Heated tobacco sticks	Combustion of tobacco
Nicotine delivery	Variable, user-dependent,	More stable and consistent	High and rapid
Primary toxicants	Aldehydes, metals, flavorings,	Tobacco-derived toxicants	Full spectrum of combustion toxins
Typical health risks	Airway irritation, inflammation, altered mucins,	Endothelial dysfunction, exposure to TSNAs	Cancer, COPD, cardiovascular disease
Youth appeal	Very high (flavors, accessibility, social influence),	Low–moderate	Generally lower than e-cigarettes

4. CONCLUSION

Evidence shows that electronic nicotine delivery systems (ENDS) are likely to have fewer long-term health and performance risks than traditional cigarettes. But the rise of vaping-associated lung injury (VALI), which is linked to THC products, is a significant public health problem for athletes and everyone else. In addition, new science findings do not support the idea that ENDS and related products, such as heated tobacco products (HTPs), snus, and nicotine pouches, are safer. Aerosols and chemicals in these products, especially flavoring compounds, including cinnamaldehyde and fruit flavors, have been shown to cause respiratory toxicity, including harming mitochondria, epithelial barrier disruption, and inflammation. Even non-inhaled nicotine delivery systems can add to oxidative stress and inflammation from the mouth of the user to the rest of the body.

There are some health problems. These include lung injury linked to e-cigarette use. It also includes chronic bronchitis, asthma, and early signs of COPD. More teens and young adults are using ENDS. This increases these health issues. Strong regulation is needed. This should include rules on what is in ENDS. It should also ban flavors. It should not allow ads aimed at teens. We do not know if ENDS is safe. We need to know the effects on teens and athletes. Doctors, coaches, and others need to teach the risks. We must keep on researching ENDS. We need to find out what it does over time. We need to find out how it affects our health. This will help us make rules about ENDS use.

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Data and materials availability

All data associated with this study will be available based on reasonable request to the Corresponding Author.

REFERENCES

1. Berman ML, Glasser AM, Edwards KC, Johnson AL, McLellan A. Exploring the respiratory health effects of novel nicotine delivery products: a systematic review of the literature. Tob Induc Dis 2020;18:99. doi:10.18332/tid/129279
2. Blount BC, Karwowski MP, Shields PG, Morel-Espinosa M, Valentin-Blasini L, Gardner M, Braselton M, Goniewicz ML, Wang L, Urbina T. Vitamin E Acetate in Bronchoalveolar-Lavage Fluid Associated with EVALI. N Engl J Med 2020; 382(8):697-705
3. Breland A, Soule E, Lopez A, Ramôa C, El-Hellani A, Eissenberg T. Electronic cigarettes: what are they and what do they do? Ann N Y Acad Sci 2017;1394(1):5-30. doi:10.1111 /nyas.12977
4. Farsalinos KE, Polosa R. Evaluation of Electronic Cigarette Use and Exposure to Nicotine and Other Chemicals: A Systematic Review. Int J Environ Res Public Health 2014;11 (11):11179-11195
5. Gerloff J, Sundar IK, Freter R, Sekera E, Friedman AE, Samsuzzaman M, Rahman I. Inflammatory Response and Mitochondrial Dysfunction Induced by E-Cigarette Flavorings in Human Airway Epithelial Cells. Toxicol Sci 2020;176(2):267-278. doi:10.1093/toxsci/kfaa045
6. Goriounova NA, Mansvelder HD. Short- and long-term consequences of nicotine exposure during adolescence. Cold Spring Harb Perspect Med 2012;2(12):a012120. doi:10.1101/ cshperspect.a012120
7. Ha T-AN, Madison MC, Kheradmand F, Myerburg MM, Parikh M, Brune KA. Laryngeal inflammatory response to smoke and vape in a murine model. Am J Otolaryngol 2019;40:89-92. doi:10.1016/j.amjoto.2018.10.001
8. Hartmann S, Bhola NE, Grandis JR. HGF/Met Signaling in Head and Neck Cancer: Impact on the Tumor Microenvironment. Clin Cancer Res 2016;22:4005-4013. doi:10.1158/1078-0432.CCR-16-0951
9. Horsley A, Rousseau K, Ridley C, Syk J, O'Neil D, McDowell C, Brown C. Reassessment of the importance of mucins in determining sputum properties in cystic fibrosis. J Cyst Fibros 2014;13:260-266. doi:10.1016/j.jcf.2013.11.002
10. Huang LL, Baker HM, Meernik C, Ranney LM, Richardson A, Goldstein AO. Impact of non-menthol flavours in tobacco products on perceptions and use among youth, young adults and adults: a systematic review. Tob Control 2017;26(6):709-719. doi:10.1136/tobaccocontrol-2016-053196
11. Ito JT, Ramos D, Lima FF, Claudino RS, Souza H, Saldiva PH, Mauad T. Nasal Mucociliary Clearance in Subjects with COPD After Smoking Cessation. Respir Care 2015;60:399-405. doi: 10.4187/respcare.03266
12. Kirkham S, Kolsum U, Rousseau K, Donaldson SH, Singh D, Knox AJ, Holloway JW. MUC5B is the major mucin in the gel phase of sputum in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2008;178:1033-1039. doi: 10.1164/ rccm.200803-391OC
13. Lachowicz-Scroggins ME, Yuan S, Kerr SC, Dunican EM, Glickman S, Solberg OD, Hansen J, Choy DF, Cardet JC, Fahy JV. Abnormalities in MUC5AC and MUC5B Protein in Airway Mucus in Asthma. Am J Respir Crit Care Med 2016;194:1296-1299. doi:10.1164/rccm.201603-0526LE
14. Leigh NJ, Lawton RI, Hershberger PA, Goniewicz ML. Chemical constituents involved in the inflammatory, oxidative and pro-fibrotic responses induced by heated tobacco products and e-cigarettes in lung epithelial cells. Toxicol In Vitro 2018;52:254-262
15. Luo J, Ye W, Zendehdel K, Adami HO, Adami J, Boffetta P. Oral use of Swedish moist snuff (snus) and risk for cancer of the mouth, lung, and pancreas in male construction workers. Lancet 2007;369:2015-2020. doi:10.1016/S0140-6736(07)60678-3
16. McConnell R, Barrington-Trimis JL, Wang K, Urman R, Lien A, Berhane K, Cruz TB, Pentz MA, Samet JM. Electronic Cigarette Use and Respiratory Symptoms in Adolescents. Am J Respir Crit Care Med 2017;195(8):1043-1049
17. Möller W, Häußinger K, Ziegler-Heitbrock L, Heyder J, Meyer T, Gehr P, Bischof W. Mucociliary and long-term particle clearance in airways of patients with immotile cilia. Respir Res 2006;7:10. doi:10.1186/1465-9921-7-10
18. Nabavizadeh P, Liu J, Havel CM, Springer ML, Hecht SS, O'Connor R, Siu CO. Vascular endothelial function is impaired by aerosol from a single IQOS HeatStick to the same extent as by cigarette smoke. Tob Control 2018;27(Suppl 1):s13-s19. doi:10.1136/tobaccocontrol-2018-054325
19. Putzhammer R, Doppler C, Jakschitz T, Heinz K, Förste J, Danzl K, Messner B, Bernhard D. Vapours of US and EU Market Leader Electronic Cigarette Brands and Liquids Are Cytotoxic for Human Vascular Endothelial Cells. PLoS One 2016;11:e0157337. doi:10.1371/journal.pone.0157337
20. Reidel B, Radicioni G, Clapp PW, Ford AA, Abdelwahab S, Rebuli ME, Haridass P, Alexis NE, Jaspers I, Kesimer M. E-cigarette use causes a unique innate immune response in the

lung, involving increased neutrophilic activation and altered mucin secretion. Am J Respir Crit Care Med 2018;197(4):492-501

21. Sharma A, Bennett D, Quaife M, Agarwal R, Chopra K. EVALI: Diagnostic Challenges Amidst COVID-19 Pandemic. Cureus 2024;16(2):e51956. doi:10.7759/cureus.51956
22. Sleiman M, Logue JM, Montesinos VN, Russell ML, Litter MI, Gundel LA, Destaillats H. Emissions from Electronic Cigarettes: Key Parameters Affecting the Release of Harmful Chemicals. Environ Sci Technol 2016;50(17):9644-9651
23. Welz C, Canis M, Schwenk-Zieger S, Bruchhage KL, Schick B, Poetschke C, Schmitz D. Cytotoxic and Genotoxic Effects of Electronic Cigarette Liquids on Human Mucosal Tissue Cultures of the Oropharynx. J Environ Pathol Toxicol Oncol 2016;35:343-354. doi:10.1615/JEnvironPatholToxicolOncol.2016016652
24. Young SE, Henderson CA, Couperus KS. The Effects of Electronic Nicotine Delivery Systems on Athletes. Curr Sports Med Rep 2020;19(4):146-150. doi:10.1249/JSR.0000000000000705