

# E-Cigarette Use in Teens: Recent Trends and Future Implications

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## ABSTRACT

E-cigarette use has recently surged among youth and teens in the U.S, with retail sales projected to reach \$8.8 billion in 2024. The appeal of sweet, fruity flavors and advancements in e-cigarette technology contribute to the rising prevalence of vaping among teens. This review explores the components and evolution of e-cigarettes, focusing on the increased nicotine potency and addictiveness of modern devices. The analysis includes the impact of flavored e-liquids, nicotine delivery mechanisms, and aerosol temperatures on youth health. Additionally, the paper examines the misconceptions surrounding the safety of vaping and highlights the role of social media and peer influence in promoting e-cigarette use. Finally, the review discusses intervention strategies, including social media campaigns, school-based programs, and policy measures aimed at curbing this growing public health crisis.

## Introduction

E-cigarette use has increased significantly in the United States in the past decade particularly in youth and teens. Between January 2020 and December 2022, e-cigarette unit sales increased by 46.6% (Ali et al., 2023, 1). To quantify this crisis through another lens, as of 2023, the National Youth Tobacco Survey estimated that 7.7% of U.S middle and high school students used e-cigarettes, and among those who had ever used an e-cigarette, 46.7% reported present use (Birdsey et al., 2023, 1175). One of the primary catalysts for these statistics is the availability of sweet, fruity, and candy-like vapes, which appeal to youth due to their vibrant names and flavors (Tsia et al., 2023, 196-200). The U.S Food and Drug Administration's 2020 policy prevents such flavored, cartridge-based e-cigarettes from the market; and yet, this enforcement policy was not as successful as intended (U.S Food and Drug Administration, 2020). Even into 2023, the FDA continued to pursue action against 189 convenience stores, vape shops, and other retailers who did not oblige to the initial ban (The Associated Press, 2023). So, illegally-obtained, flavored vapes continue to be available to adolescents, posing disproportionate harms: a recent study even found that adolescents who vaped e-cigarettes in nontraditional flavors, instead of tobacco, mint, or menthol flavored e-cigarettes, were at greater risk of continued vaping and took on average more puffs per use (Chadi et al., 2019, 7-10). It's not just access to flavors though that poses a risk, it is other advancements in e-cigarette technology that make the use of e-cigarette products more enjoyable and appealing, especially to first time users. When asked why they begin vaping, almost 1 in 3 teens (32.3%) reported that they began because of a friend (*Why Youth Vape | Smoking and Tobacco Use*, 2024). This peer influence as well misconceptions about the safety of vaping need to be addressed.

The aim of this review is to synthesize knowledge on what e-cigarettes are, recent trends in e-cigarette use among young people, and the safety of vaping. The paper concludes with an analysis of intervention and prevention strategies and the role of social media, schooling, and policy in developing such strategies.

## E-Cigarettes 101

There are upwards of 460 e-cigarette brands currently on the market, but despite manufacturing differences, most e-cigarette devices contain some fundamental parts (Zhu et al., 2014, iii3-iii9). The first of these is a cartridge, reservoir, or pod which holds a liquid solution (known as e-liquid or e-juice) usually composed of nicotine, flavorings, and other chemicals. Most e-cigarettes also have a power source, often a battery, to provide energy to the atomizer, so it can aerosolize the liquid solution. The mouthpiece is how e-cigarette users are able to inhale the resulting aerosol (*Vaping Devices (Electronic Cigarettes) DrugFacts*, 2020). At the time of their inception, e-cigarettes largely mimicked combustible cigarettes, and they were marketed as an alternative to smoking or a pathway to quitting smoking entirely (Chadi et al., 2019, 7-10). These ‘first-generation’ e-cigarettes quickly evolved and they no longer looked like traditional combustible devices, but more like pens. As such, ‘second-generation’ devices became characterized by their thin battery that powered an atomizer (Chadi et al., 2019, 7-10). Now, the market is saturated with ‘third generation’ products that have taken the biggest step away from combustible cigarettes. These products are commonly known as ‘vapes,’ and visually bear almost no resemblance to combustible cigarettes. Also, due to the popularity and widespread availability of e-cigarettes and parts, users have been building their own devices (known as “mods”) (Chadi et al., 2019, 7-10). These ‘third-generation’ products offer variability not only in aesthetics, but also in flavors, sensation, and distribution/amount of aerosol particles. While companies exploit this variability to market the uniqueness of their products, such characteristics of vapes could potentially pose the greatest harms.

## E-Liquids

Flavorings are one of the most marketable elements of e-liquids, especially to youth and teens. Sweet, fruity, and candy flavors permeated the market, and they are at the core of why young people are introduced to e-cigarettes. In fact, the National Tobacco Youth Survey reported in 2023 that 9 out of every 10 U.S youth who reported current use of e-cigarettes use flavored e-liquids (*Why Youth Vape | Smoking and Tobacco Use*, 2024). “Cherry Crush,” “Vivid Vanilla,” and “Piña Colada” flavored e-liquids are most widely available and they also contain high levels of nicotine (*Outbreak of Lung Injury Associated With the Use of E-Cigarette, or Vaping, Products | Electronic Cigarettes | Smoking & Tobacco Use | CDC*, 2021). The rise of variability and options in e-liquid flavors increases the potential of youth using e-cigarette devices. However, it is not just flavorings that pose a risk to youth, there are an array of additives often found in e-liquids. From essential oils, THC, to multivitamins and traces of medicine, e-liquid cartridges have been found to contain various components (*Vape Flavors and Vape Juice: What You Need to Know*, n.d.). Some of these additives have also had disproportionate impacts. For instance, Vitamin E Acetate has been widely attributed to the prevalence of EVALI (E-cigarette or Vaping Use-Associated Lung Injury) (*Vape Flavors and Vape Juice: What You Need to Know*, n.d.). This potentially life-threatening condition was on the rise in 2019 and 2020 and was even considered an outbreak, with 2807 reported cases as of February 2020 (*Outbreak of Lung Injury Associated With the Use of E-Cigarette, or Vaping, Products | Electronic Cigarettes | Smoking & Tobacco Use | CDC*, 2021). Vitamin E Acetate can be fatal to inhale because it can interfere with the phospholipid bilayer of Pulmonary Surfactants (PS) that line the alveoli (Kamal et al., 2012, 2483-2496). Because Vitamin E Acetate is hydrophobic, it can pass through the membrane of PS and can alter their structure, which hinders the function of the alveoli and proper flow of oxygen into the body (Kamal et al., 2012, 2483-2496). Manufacturers often use Vitamin E Acetate as a diluent to lower costs of production and therefore lower costs of purchase for consumers (Kosarac et al., 2021). Cheaper alternatives could be particularly appealing to youth, who often rely on their parents or low-paying jobs. As such, variability in both flavorings and the presence of additives, both house advantages for e-cigarette manufacturers; however, they can also disproportionately catalyze a cycle of addiction and other health issues for youth and teen users.

## Nicotine Delivery

The user experience is paramount to any manufacturer's decision making. Effective nicotine delivery not only involves the amount of nicotine that is contained within an e-liquid, but also the comfort of users to consume that nicotine. Recent e-cigarette products have frequently seen a shift away from free base nicotine to nicotine salts (Benowitz et al., 2021, s18-s36). Nicotine salts have a lower pH which makes them less irritating for users; nonetheless, they require a high nicotine concentration to achieve a similar level of potency to free base nicotine (Benowitz et al., 2021, s18-s36). Once again, youth and teen users may be more likely to purchase products formulated with nicotine salts because of the less irritating experience, but this means they are also more likely to purchase products that contain higher levels of addictive nicotine. A chemical analysis of JUUL pods (one of the most popular e-cigarette brands) found that nicotine benzoate is the salt that forms when the device is activated (National Academies of Sciences, Engineering, and Medicine, 2018).

## Aerosol Temperature

When the heating power is too high, e-cigarette users can experience a sensation called "dry hit." Dry hits can occur if the e-liquid is not ignited properly, resulting in a burnt taste and a vaporless hit (Narimani et al., 2020). This is why an optimal temperature of the aerosol plays such a crucial role in e-cigarette manufacturing. Overtime, e-cigarette manufacturers have perfected their design to minimize dry hits and make the vaping experience more enjoyable even for first-time users, youth, and teens. However, even with these advancements, there is still some concern among scientists that the high temperatures that vaping devices reach could be associated with the prevalence of EVALIs. It has been considered that vaping induced pyrolysis of Vitamin E Acetate may result in the production of ketene, a potentially toxic gas (Wu et al., 2020). Again, as companies have adapted products to make them more pleasurable, the scientific community has raised concerns about the short and long term health implications.

## Quantifying E-Cigarette Use Among Youth and Teens

As of 2023, the National Youth Tobacco Survey estimated that 7.7% of U.S middle and high school students used e-cigarettes, and among those who have ever used an e-cigarette 46.7% reported present use (Birdsey et al., 2023, 1175). This statistic comes as the prevalence of combustible cigarette smoking has decreased beginning in 2012, and especially in 2017 when e-cigarettes entered the market (Meza et al., 2020). As such, in 2017, e-cigarettes were the most common first tobacco product used (Glantz et al, 2022). Modern vapes seem to contain more nicotine than ever before and JUUL compatible pods (14) and JUUL knock off devices (39) were identified to contain equal or more nicotine than JUUL's high-nicotine products ( $\geq 5\%$ ) (Jackler et al, 2019, 623-628). The same study found that more than 70 e-liquid brands present with high-levels of nicotine in bulk ( $\geq 30$  mL) that is equivalent to more than 40 packs of combustible cigarettes. Staggering levels of nicotine, therefore, are becoming popular among youth and teens. Most youth and teens are attracted by the appeal of sweet flavors. Among current e-cigarette users, 84.9% reported using sweet or fruity flavors (*Why Youth Vape | Smoking and Tobacco Use*, 2024). Others report beginning e-cigarette use due to social media and advertising. About 3 out of every 4 students (74%) who use social media reported seeing an e-cigarette related post or content (*Why Youth Vape | Smoking and Tobacco Use*, 2024). For young users, however, the most common introduction into e-cigarettes was through friends (32.3%); another 31.7%, though, purchased the products themselves (*Why Youth Vape | Smoking and Tobacco Use*, 2024). The combination of these causes as well as the belief that vaping is a safer alternative to smoking culminated in e-cigarette use among youth and teens. When considering ways to address e-cigarette use in this demographic, it is necessary to consider why they begin usage and to implement preventionary methods in addition to providing support for current users. As for parents who are grappling with the crisis in their own lives, a recent study found that parents know less than they perhaps should. Most

parents were cognizant that nicotine is dangerous, but many also did not know that JUUL pods contain nicotine. And while most parents were worried about general e-cigarette use in youth and teens, only 2 in 5 parents were worried about their own child using e-cigarette products (Jones et al, 2020, 56-58).

## Smoking vs. Vaping

Many U.S youth use e-cigarettes as they believe that vaping is a safer alternative to smoking; in fact, a 2017 survey of 786 high schoolers found that 40.36% considered e-cigarettes as a method of cessation, and 43.13% considered e-cigarettes safer than combustible cigarettes (Gorukanti et al, 2016). Tobacco cigarettes could be more harmful as compared to e-cigarettes, however there are many unknown health consequences of e-cigarette use. Early evidence also suggests that vaping may serve as a gateway into other nicotine products, as many young people who vape are also dual-users of other tobacco products (*E-Cigarette Use Among Youth | Smoking and Tobacco Use*, 2024). The CDC reports that approximately a third of high school students (36.8%) and a half of middle school students (49.0%) who vaped also used another tobacco product (Leventhal et al, 2015, 700-707). A study found that high school students who had reported e-cigarette use in the last month were approximately 7x more likely to also report combustible cigarette and other smokable tobacco product use in the next 6 months compared to non e-cigarette users (Weaver et al, 2018).. These studies taken together suggest that teens using e-cigarettes are at increased risk for smoking cigarettes. Even among those who reported using vapes as a means of quitting smoking, one study reports limited success: a study of 800 smokers who reported vaping to stop smoking, only 9% reported quitting smoking after a year (Janowski et al, 2019). It seems that rather than a method of cessation, vaping is a method of introduction to greater tobacco usage. It is certainly dangerous to youth and teens to be consuming any nicotine at all, let alone nicotine from multiple tobacco products.

A 2019 study that used the Fagerstrom Test for Nicotine Dependence (FTND) to quantify the nicotine dependence to quantify the nicotine dependence of participants found that exclusive e-cigarette users had FTND scores over two times higher than those of traditional tobacco smokers (*Instrument: Fagerstrom Test for Nicotine Dependence (FTND)*, n.d.). The FTND is a self-reported questionnaire that asks participants questions such as “How soon after you wake up do you smoke your first cigarette,” “How many cigarettes per day do you smoke,” and “Do you find it difficult to refrain from smoking in places where it is forbidden” (Buu et al, 2020, 610-615). This means that exclusive e-cigarettes users exhibited nicotine dependence at high levels compared to traditional tobacco smokers, and the study’s authors conclude, therefore, that young people who use e-cigarettes are at high risk of addiction. The study also found that dual users often used e-liquids with greater concentrations of nicotine and consumed a greater volume of e-liquid per day. This data coupled with higher FTND scores among dual users indicate that they have the highest nicotine dependence when compared with exclusive e-cigarette users and exclusive combustible cigarette users. This data suggests that e-cigarette may actually be more addictive than combustible cigarettes and potentially even more addictive when multiple products are consumed. While the data that was collected from this study contrasted with the findings of previous studies, this study offers the most recent findings and collects data that is applicable to third-generation devices that offer more effective nicotine delivery to users and focuses its findings on young people aged  $22.4 \pm 2.2$  years old (Buu et al, 2020, 610-615).

With e-cigarettes serving many times as starting points into further nicotine usage and findings that support the conclusion that e-cigarettes may be more addictive than traditional products, youth and teens should be wary of e-cigarette use. In actuality, ~33% of e-cigarette users say they are “not at all addicted” to nicotine, despite most indicating at least one symptom of addiction (*Social Media and Teens*, n.d.). While e-cigarettes may offer a pathway to smoking cessation for some, they are not safe to consume and are still highly addictive products for use and inhalation.

## Addressing Vaping in Youth and Teens

### Intervention Through Social Media

When considering ways to address the staggering rates of e-cigarette usage in the U.S among youth and teens, along with combating misinformation and misconceptions, social media may be a necessary tool to capitalize on. For teens aged 13-17, 75% report having at least a single active social media account, and over 1 in every 2 teens (51%) report visiting a social media site at least daily (Truth Initiative, n.d.). Social media is also a place where young people are introduced to vaping and exposed to peer pressure. This means the potential of social media for vaping intervention cannot be underestimated.

In 2019, the Truth Initiative launched their *This is Quitting (TIQ)* campaign. TIQ is an automated and interactive text-based intervention program to help young people overcome addiction (Graham et al, 2021, 923-930). The messages are tailored for young people and are meant to serve as nonjudgmental and supportive resources for users. From December 2019 to November 2020, a clinical trial was conducted among young adult users who had reported past 30-day e-cigarette use and were interested in quitting in the next month (Lyu et al, 2022). After the 7 month period with the TIQ program, among the 2588 users, 24.1% of the text-message intervention participants and 18.6% of control group participants (those who only reported their usage but were not a part of the TIQ program) reported abstinence (Lyu et al, 2022). This study demonstrated a statistically significant difference in e-cigarette cessation between those who used the intervention program and those who did not. However, a limitation of this trial was that results of the reports were not biochemically verified. This work serves as a stepping stone and offers hope for future interventions via social media and online platforms. There is one ongoing study of e-cigarette intervention that hopes to utilize daily Facebook and weekly live counseling chats with a trained counselor (Liu et al, 2023, 589-600). Participants will be randomly assigned to a control group or an intervention group, where the control group will not see the posts, but will be directed to a chatline if they seek it out. The study will biochemically verify reports and also measure secondary outcomes such as users' confidence in their ability to quit smoking, commitment to abstinence, and desire to quit. This study may avoid some of the limitations of the TIQ program as it does biochemically verify data for more accurate findings and uses trained counselors opposed to automated messages to tailor to the needs of participants. In the future, social media could be a crucial resource to continue intervention and also prevent young people from beginning to use e-cigarettes in the first place.

### Intervention in Schools

Schools are essential educational institutions to spread awareness and house resources for youth and teens. A survey conducted across Massachusetts schools between November 2020 and January 2021, depicts the concerns of teachers, administrators, and school nurses when it comes to e-cigarette use in their students (*E-Cigarettes, Vapes, and Other Electronic Nicotine Delivery Systems (ENDS)*, 2024). Out of the 162 survey participants, the most common ways to address vaping in their student body were education (n = 47), progressive discipline (n = 35), and school policies (n = 27). Among these respondents, the most desired resources were further education and treatment programs (*E-Cigarettes, Vapes, and Other Electronic Nicotine Delivery Systems (ENDS)*, 2024). This survey was also coupled with interviews for data collection, during which participants highlighted mental health declines after Covid-19 and the need for cessation programs to emphasize mental wellbeing. Interviews also emphasized the importance of peer led support and minimizing misinformation. These findings are helpful, particularly the most desired resources among the school staff. As local and state governments and boards of education work to implement intervention and cessation programs in schools, it will be important to continue to tailor health curricula away from generic standards to focus on the dangers of e-cigarette, drug, and alcohol use. It may also be worthy to explore Alternative to Suspension programs for schools to implement, as this will take away the fear of a punitive reaction from schools for students who

may want to reach out for help. Lastly, as teachers and counselors are provided training, it may be useful to provide them guidance and expertise on how to best help their students and educate parents. The school system has the potential to make a big impact on the current rates of e-cigarette use among young people. With the implementation of greater education, training, and alternatives to traditional punitive measures, students' wellbeing, health, and recovery can and should be prioritized.

## Treatment

There are numerous resources available for youth and teens seeking treatment for e-cigarette use. The reader is referred to the CDC Resources to Help Youth Reject or Quit Vaping (*Resources to Help Youth Reject or Quit Vaping*, 2024). This site outlines many mobile-friendly quitting programs that allow users to set, track, and adapt their quitting goals and provide either virtual or human support (*Resources to Help Youth Reject or Quit Vaping*, 2024). It also provides further resources and guidance for both parents and educators. Despite the vast number of existing resources, healthcare providers also have a responsibility to provide treatment to youth e-cigarette users. The American Academy of Pediatrics recommends that physicians implement the A.C.T (Ask-Counsel-Treat) Model, whereby they foster a supportive environment for youth to discuss their e-cigarette use, conduct motivational interviewing, inform youth of the consequences of nicotine consumption, and follow up on quitting goals overtime (*AAP Youth Tobacco Cessation Case Studies*, 2024). Physicians could also consider using nicotine replacement therapy as a form of treatment.

## Overall Policy

The U.S government has continued to make policy strides when it comes to regulating the e-cigarette market. In 2020, a federal ban on flavored cartridge-based e-cigarettes was enacted (*E-Cigarettes, Vapes, and Other Electronic Nicotine Delivery Systems (ENDS)*, 2024). This was important, as these flavors are a large allure to young users. Then, in 2022, an omnibus spending bill gave the Food and Drug Administration the authority to regulate synthetic nicotine products as tobacco products (*E-Cigarettes, Vapes, and Other Electronic Nicotine Delivery Systems (ENDS)*, 2024). There have also been various local and statewide policies that have been implemented such as flavor bans, special taxes and incentives, and smoke-free public spaces. Future policy should focus on effectively exercising existing regulatory powers, while continuing to oversee the marketing of manufacturers and reforming the health education system across the country.

## Conclusion

As e-cigarette manufacturers continue to make new advancements to appeal to users and market their products, it is essential that action is taken. This paper addresses the misconception that vaping is safe and outlines potential actions to be taken by various stakeholders. The issue at hand is multifaceted, so in order to provide help to as many young people as possible, every stakeholder must contribute. Whether it be through greater public education and awareness, social media campaigns, or school resources, the present rates of the e-cigarette use in youth and teens can be reduced.

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