

Vaping Trends: Analyzing Patterns and Predictive Factors in Electronic Cigarette Use among American Youth

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ABSTRACT

Electronic cigarettes or e-cigarettes, designed originally as a less harmful alternative to traditional tobacco products for addicts, have become increasingly popular among American adolescents, raising substantial public health concerns. This study aims to explore the prevalence, patterns, and health implications of e-cigarette use among youth in America by analyzing data from the National Youth Tobacco Survey (NYTS). The research employs both descriptive and predictive analytical methods to uncover trends and factors influencing e-cigarette use. Our descriptive analysis reveals a high percentage of high school students who use e-cigarettes, with significant influences from ease of access, peer pressure, and social media marketing. The study also identifies a concerning overlap between e-cigarette use and the use of other tobacco products. Predictive modeling highlights critical factors such as social media exposure, misperceptions of e-cigarette safety, and environmental influences that contribute to e-cigarette consumption. The findings underscore the effectiveness of the current regulatory measures and pinpoint gaps in enforcement. Recommendations include implementing stricter advertising and sales restrictions, enhancing public education on the risks of e-cigarettes, and improving regulatory practices to limit youth access. Despite existing regulations, the persistence of e-cigarette use among adolescents indicates ongoing challenges that require a comprehensive approach involving educators, policymakers, and public health professionals to safeguard youth health and prevent addiction.

INTRODUCTION

INTRODUCTION: THE EMERGING CRISIS

E-cigarettes, or electronic cigarettes, are battery-powered devices designed to heat a liquid, often containing nicotine, flavorings, and other chemicals, into an aerosol that users inhale. Unlike traditional cigarettes, they don't burn tobacco, but they still deliver nicotine, which can be addictive. E-cigarettes come in various forms, including vape pens, mods, and pod-based systems. E-cigarettes were initially introduced to help chronic adult smokers switch from traditional cigarettes. The goal was to reduce the harm associated with smoking. However, flashy marketing strategies used to promote e-cigarettes had an unintended consequence. These promotions attracted more students to use e-cigarettes. In the process, the original target population of adult smokers was largely overlooked.

In recent years, the alarming rise in e-cigarette use among American adolescents has sparked widespread concern. Despite regulatory efforts, vaping remains a pervasive and evolving challenge that demands urgent attention. Vaping among American adolescents began in the early 2000s when electronic cigarettes were marketed as a safer alternative to traditional tobacco cigarettes (Sund 2023). In 2015, the release of JUUL, with its aggressive marketing strategies and promotion of flavored e-liquids, targeted adolescents through social media campaigns, leading to a surge in e-cigarette use among youth (Daniel Jr 2018).

Between 2011 and 2015, the National Youth Tobacco Survey (NYTS) reported a staggering 966% increase in e-cigarette use among high school students in the U.S., with current use (defined as use on one or more days in the past 30 days in this case) rising from 1.5% to 16% (Singh 2016) Although there was a brief decline in usage from 2015 to 2017, this trend reversed sharply between 2017 and 2018, with a dramatic 78% rise in e-cigarette use, pushing the rate up to 20.8% among high school students. Meanwhile, e-cigarette use among middle school students also increased, with 4.9% of them reporting current use. This is in line with JUUL's targeted marketing and sales data during this period. In total, this equated to approximately 3.62 million youth e-cigarette users by 2018 (Cullen 2018).

Additionally, the Monitoring the Future (MTF) survey, which has tracked youth substance use for over four decades and began including e-cigarettes in 2015, revealed similar findings. The survey showed a significant spike in e-cigarette use among high schoolers in 2018, with 25% of 12th-graders and 20.3% of 10th-graders reporting nicotine or flavor vaping, up from 15.2% and 12%, respectively, in 2017 (Schulenberg 2017). This marked the largest increase for any substance tracked by the MTF in its 44-year history. The rapid rise in vaping among 10th- and 12th-graders between 2017 and 2018 underscored the growing concern over e-cigarette use among American youth (Miech 2019).

THE APPEAL OF E-CIGARETTES: A DOUBLE-EDGED SWORD

The sleek, tech-inspired designs of e-cigarettes and flavored e-liquids have quickly attracted a much younger demographic. Flavors like mango, mint, and fruit medley were especially popular among teens, masking the harshness of nicotine and making vaping more appealing. Moreover, JUUL's design addressed common drawbacks of traditional smoking, such as unpleasant odors and throat irritation, making these e-cigarettes even more enticing.

The role of social media cannot be overstated, as influencers and viral marketing campaigns rapidly expanded the reach of e-cigarette products (Groner 2015). Platforms like TikTok and Instagram amplified the normalization of vaping among teens, making it not just a habit, but a status symbol. The convenience and ease of use, combined with peer pressure and the perception that vaping was less harmful than smoking, made e-cigarettes an attractive option for adolescents, despite the risks.

THE HEALTH IMPLICATIONS: IMMEDIATE AND LONG-TERM RISKS

While e-cigarettes were marketed as safer than traditional smoking, their health risks—especially for young people—are significant. The outbreak of EVALI (e-cigarette or vaping product use-associated lung injury) in 2019, which primarily affected young adults and adolescents, highlighted the dangers associated with vaping (Adkins 2020). Although EVALI was linked to THC products contaminated with vitamin E acetate, it reinforced concerns about the broader health implications of e-cigarettes (Mendelsohn 2023). In addition to lung injuries, nicotine, the primary ingredient in most e-liquids, is highly addictive and can interfere with adolescent brain development, potentially leading to issues such as anxiety, depression, and cognitive deficits. The Centers for Disease Control and Prevention (CDC) also found that teens who vape are more likely to start smoking traditional cigarettes, exacerbating the public health crisis. Research continues to show that e-cigarettes pose both immediate and long-term risks, masking these dangers under the allure of flavors and sleek designs (Khan 2023).

REGULATORY CHALLENGES AND LOOPHOLES

Regulatory bodies, particularly the FDA, have made efforts to curb youth vaping, banning flavored e-cigarettes and enforcing stricter age restrictions. The FDA's crackdown on JUUL in 2019 included restrictions on marketing tactics and product distribution aimed at minors. Despite these measures, significant challenges remain. Counterfeit and illicit vaping products continue to circulate, often bypassing regulation through online sales that make it easier for minors to access these products. Moreover, social media influencers still promote vaping content to young audiences, further complicating efforts to regulate the spread of e-cigarettes. The constantly evolving landscape of vaping technology, including the development of disposable and pod-based systems, makes regulation an ongoing battle. To effectively combat youth vaping, more stringent measures, greater public awareness campaigns, and enhanced monitoring of both legal and illegal markets are necessary. Addressing these challenges will require a collaborative effort among public health officials, policymakers, and the tech industry to minimize the appeal of e-cigarettes to young people.

OBJECTIVE

The objective of this paper is to examine the prevalence and patterns of vaping among American teens. We aim to investigate the factors influencing vaping initiation and persistence among adolescents, such as peer influence, marketing strategies, and mental health issues. We also study the usage of other tobacco products among youth. This helps in early intervention and thus prevention of chronic vaping in students.

SCOPE

This paper focuses on analyzing vaping data among American adolescents and its health consequences within the United States. The study will examine reasons for vaping, and availability of vape products among students aged 9 to 18 years. Utilizing quantitative methods, the research aims to identify trends, correlations, and associations between vaping behaviors and reasons for initiation and continuing, including ease of access to the products, usage of other tobacco products, and exposure to related content through media consumption. Additionally, the study will explore markers of vaping addiction to provide insights to caretakers to enable early intervention. Overall, the research seeks to help materialize evidence-based strategies for reducing vaping prevalence and promoting adolescent health in the United States.

METHODOLOGY

RESEARCH QUESTIONS

This study examines how sociodemographic factors such as age, environment, and exposure to social media drive e-cigarette use. With this data, we build a predictive model to figure out the trends in e-cigarette usage. We also examine the access to e-cigarette related content on social media, ease of purchase, attitude of peers towards e-cigarettes and how these correlates to usage.

DATA DESCRIPTION

Every year, the FDA and Centers for Disease Control and Prevention (CDC) releases data from the National Youth Tobacco Survey (NYTS) on tobacco usage among the youth in the United States. The NYTS is a self-administered survey on tobacco use among middle school and high school students. A three-stage cluster sampling approach was used to choose a nationally representative sample of children in grades 6-12 from both public and private schools. In 2022, the survey was conducted from January 18 to May 31 and was done online, with 99.3% of students completing it on campus. A total of 28,291 students and 341 schools participated, resulting in an overall response rate of 45.2% (CDC 2022).

The dataset typically includes various demographic and behavioral variables related to tobacco use. This includes information like age, sex, grade, and race, e-cigarette use information along with other products such as traditional cigarettes, bidis, cigars, and more, information on the students' perception and attitude towards e-cigarettes, and other general questions that point to their well-being.

The data set contains 28,291 unique records across 1,334 fields.

DESCRIPTIVE ANALYSIS

Descriptive analysis was performed using SAS On Demand. We chose SAS On Demand as opposed to other tools because of its robust statistical analysis capabilities, user-friendly interface, and extensive built-in procedures tailored for business analytics. Additionally, SAS is widely used in industry, ensuring that the results and methods are aligned with professional standards, and it offers seamless cloud access, making it more convenient for collaboration and data management.

Univariate analysis included identifying common motivations for initiating e-cigarette use, self-reported exposure to e-cigarettes across several social media platforms, prevalent mode of purchasing e-cigarette devices, cartridges, or e-liquid refills, overlap between e-cigarette usage and use of other substances (chewing tobacco, marijuana, nicotine pouches, cigars, snus, bidis etc.)

Bivariate analysis included examining the relationship between mode of purchase of e-cigarettes and the grade level of high-school or middle school students and investigating if reasons for adopting e-cigarette that resulted in continued usage varied between different genders.

Multivariate analysis was performed to check the usage statistics of various tobacco products including e-cigarettes among middle schoolers and high schoolers dividing them into three categories, namely, people who have smoked the product at least once (provided directly in the data set), people who are current smokers (smoked for more than 15 days in the last 30 days as of survey date), and people who are chronic smokers (smoked on all 30 days in the last 30 days as of survey date).

All descriptive analytics results generated on SAS On Demand were then visualized using Microsoft PowerPoint's visualization tool for easier integration into the final paper.

PREDICTIVE MODELING

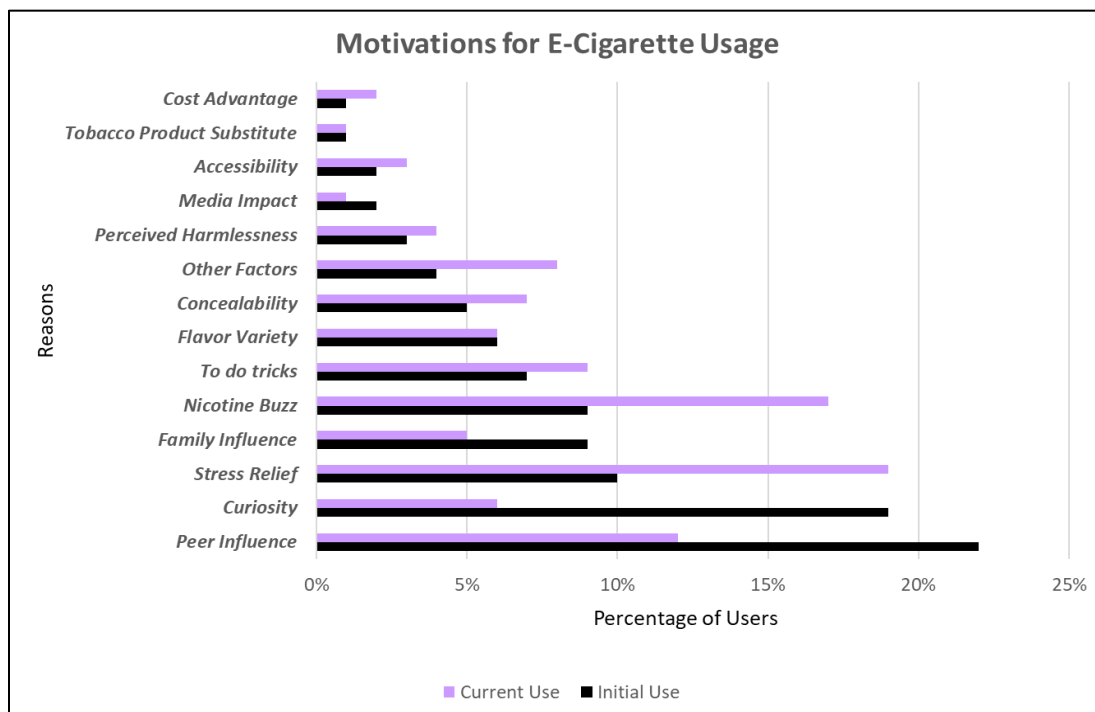
Finally, we developed a predictive model to identify the major factors that influence e-cigarette consumption. To model the problem, we considered multiple outcome variables. For instance, 'Rare smoker', defined as someone who has smoked an e-cigarette ever. Additionally, we derived variables like 'Current smoker' defined as someone who has smoked on at least 15 out of the past 30 days and 'Chronic Smoker' defined as someone who has smoked an e-cigarette on all 30 days. To focus on ongoing e-cigarette users and exclude one-time smokers, we selected 'Current smokers' as our target. Next, we noticed that the distribution of the outcome classes was highly imbalanced with only 1,258 instances consisting of smokers compared to 26,901 instances of non-smokers. To fix this issue, we utilized under sampling wherein we randomly selected subset of instances from the minority class to match the size of the majority class. As a part of feature engineering, we carefully selected only 109 of the most relevant independent variables from the initial list of 1,334 (to prevent overfitting). To select these variables, we relied on domain knowledge and past literature review. By leveraging XGBoost, we built a predictive model with ~84% accuracy that was able to pin down the most key factors influencing youth vaping behavior which is discussed in the result analysis section.

RESULT ANALYSIS

DESCRIPTIVE OVERVIEW: IDENTIFYING KEY TRENDS

Out of the 5,808 students who reported trying e-cigarettes at least once, about 1,154 reported vaping for more than 15 days in the previous 30 days as of the survey date, indicating a conversion rate of around 20%. Of these 88% were high school students and the remaining 12% were students in middle school. We also found that 4,189 students specifically mentioned using THC products contaminated with oils which was the major reason for the EVALI outbreak (Adkins 2020).

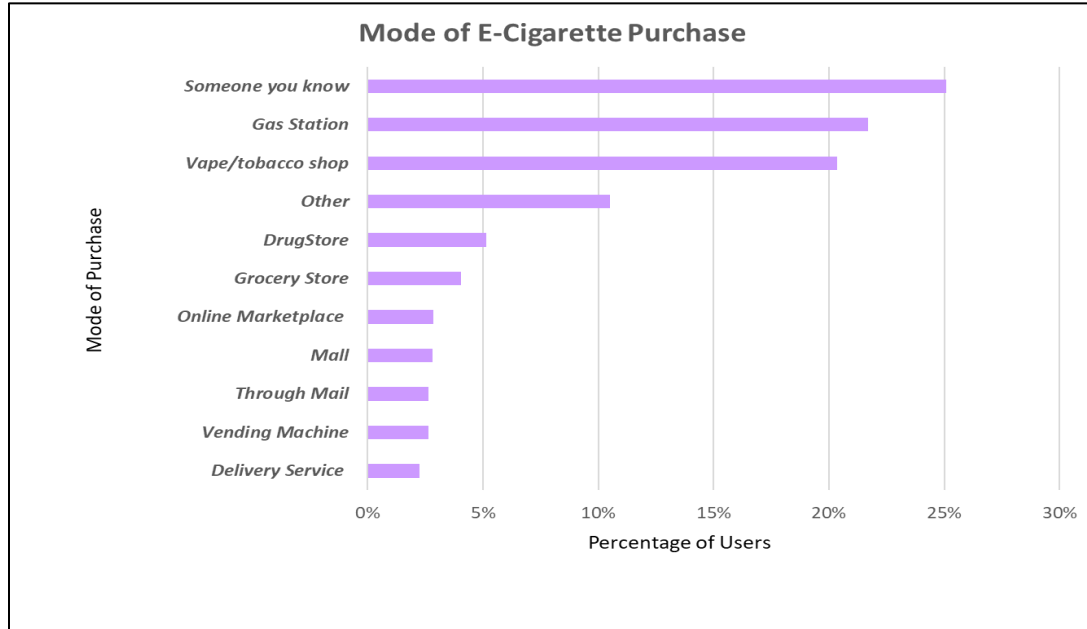
When asked why these 1,154 students continued to smoke, 596 respondents stated that they felt anxious, stressed, or depressed. This was closely followed by 578 respondents who expressed a desire for a high or buzz from nicotine (the values are not mutually exclusive). Figure 1 shows the motivations behind E-cigarette use.



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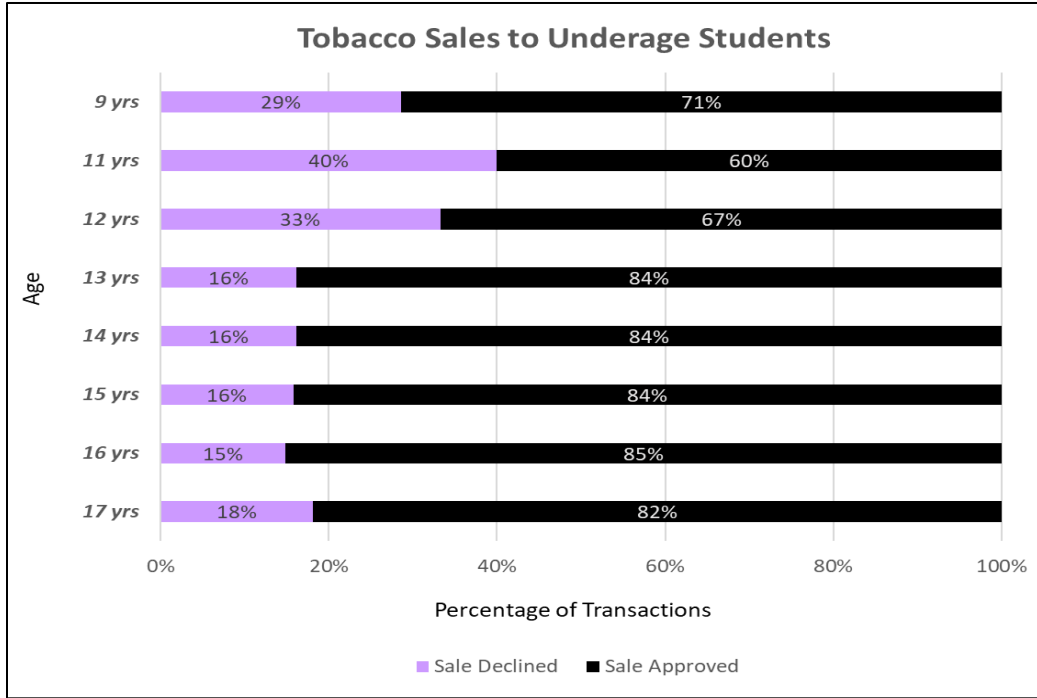
It is interesting to note that a concerning number of students cited peer influence and curiosity as their reasons for trying e-cigarettes for the first time. Additionally, trends show that their continued use is motivated either by the need to relieve stress or by the urge for the buzz from nicotine.

Next, we focus on how minors, despite being legally banned from acquiring e-cigarettes, were able to obtain them. Over 22% of students who smoke mentioned that they purchased their vape from a gas station or tobacco shop pointing to violations of the FDA regulations. Figure 2 depicts the purchase distribution of e-cigarettes.



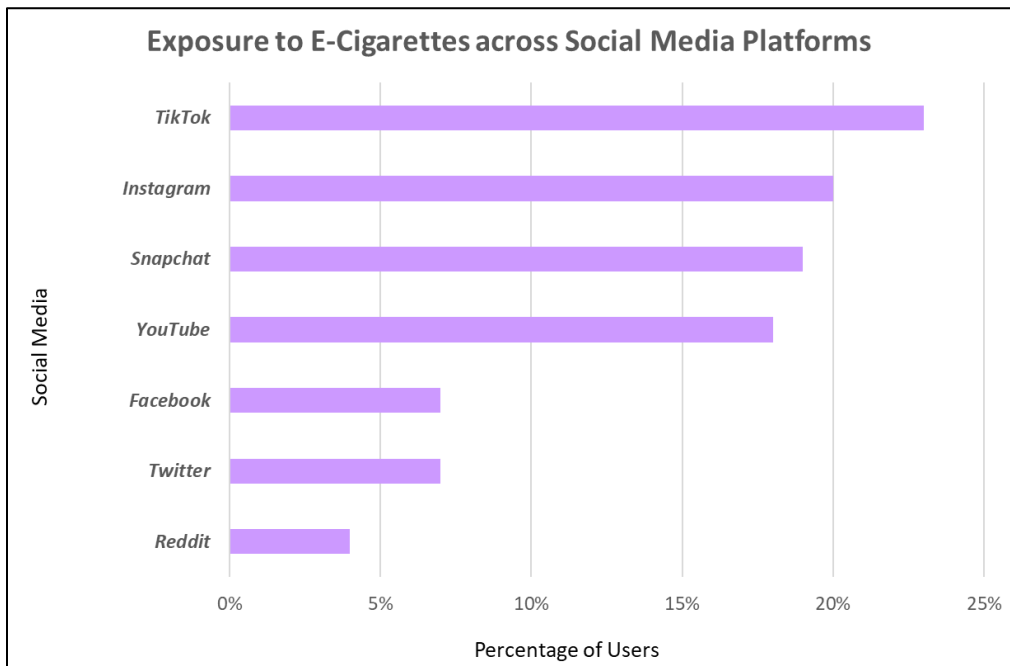
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To further investigate, we examined the refusal rate of tobacco sales by age. We explored the responses to the question "In the past 30 days, has anyone refused to sell you tobacco products due to your age?". Focusing on students who responded conclusively with either 'Yes' or 'No' to this question, we observed a trend – older students faced less resistance when purchasing tobacco products despite being underage. Figure 3 depicts the rate of refusal to sell tobacco ordered by age.



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From our literature review, we had identified that social media impact was a major factor that attributed to the rapid popularity of e-cigarettes. We investigated students' exposure to e-cigarettes across different social media platforms, identifying TikTok as the major platform where e-cigarette related content was shared. It was closely followed by Instagram, Snapchat, and YouTube. Figure 4 depicts how exposure to e-cigarettes is distributed across different social media platforms.



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Furthermore, we considered an overlap analysis of e-cigarettes versus other tobacco products (like cigarettes, chewing tobacco, snuff, hookah etc.). We saw that about 41% of smokers used e-cigarettes as well as some other tobacco products. This could point to e-cigarettes motivating these students to try other tobacco products that are more harmful in nature or vice versa. This is depicted in Table 1.

Used an e-cigarette?	Used another tobacco product?	Percentage of users
No	Yes	21%
Yes	No	38%
Yes	Yes	41%

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We also performed a comparative analysis of e-cigarette and other tobacco products' usage among middle schoolers and high schoolers.as broken down by their status: one-time smoker, current smoker or a chronic smoker as shown in Table 2.

Product	Status	Percentage of Middle Schoolers	Percentage of High Schoolers
E-cigarette	Ever Smoked	4.4%	16.1%
	Current Smoker	0.5%	4.0%
	Chronic Smoker	0.2%	2.3%
Cigarette	Ever Smoked	2.4%	6.5%
	Current Smoker	0.1%	0.4%
	Chronic Smoker	0.1%	0.2%
Cigars, cigarillos or little cigars	Ever Smoked	1.1%	4.7%
	Current Smoker	0.1%	0.4%
	Chronic Smoker	0.1%	0.3%
Chewing tobacco, snuff or dip	Ever Smoked	1.3%	2.8%
	Current Smoker	0.1%	0.3%
	Chronic Smoker	0.1%	0.2%
Hookah or water pipe	Ever Smoked	0.8%	2.6%
	Current Smoker	0.1%	0.2%
	Chronic Smoker	0.1%	0.1%
Roll-Your-Own Cigarettes	Ever Smoked	0.7%	1.7%
	Current Smoker	0.1%	0.2%
	Chronic Smoker	0.0%	0.1%
Pipes filled with tobacco	Ever Smoked	0.4%	1.1%
	Current Smoker	0.0%	0.1%
	Chronic Smoker	0.0%	0.1%
snus	Ever Smoked	0.3%	1.1%
	Current Smoker	0.0%	0.2%
	Chronic Smoker	0.0%	0.1%
Dissolvable tobacco products	Ever Smoked	0.2%	0.5%
	Current Smoker	0.0%	0.1%
	Chronic Smoker	0.0%	0.1%
Bidis	Ever Smoked	0.3%	0.8%
	Current Smoker	0.0%	0.1%
	Chronic Smoker	0.0%	0.1%
Heated tobacco product	Ever Smoked	0.6%	1.1%
	Current Smoker	0.1%	0.2%
	Chronic Smoker	0.0%	0.2%
Nicotine Pouch	Ever Smoked	0.4%	1.9%
	Current Smoker	0.1%	0.3%
	Chronic Smoker	0.0%	0.2%

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PREDICTIVE INSIGHTS: IDENTIFYING AT-RISK GROUPS

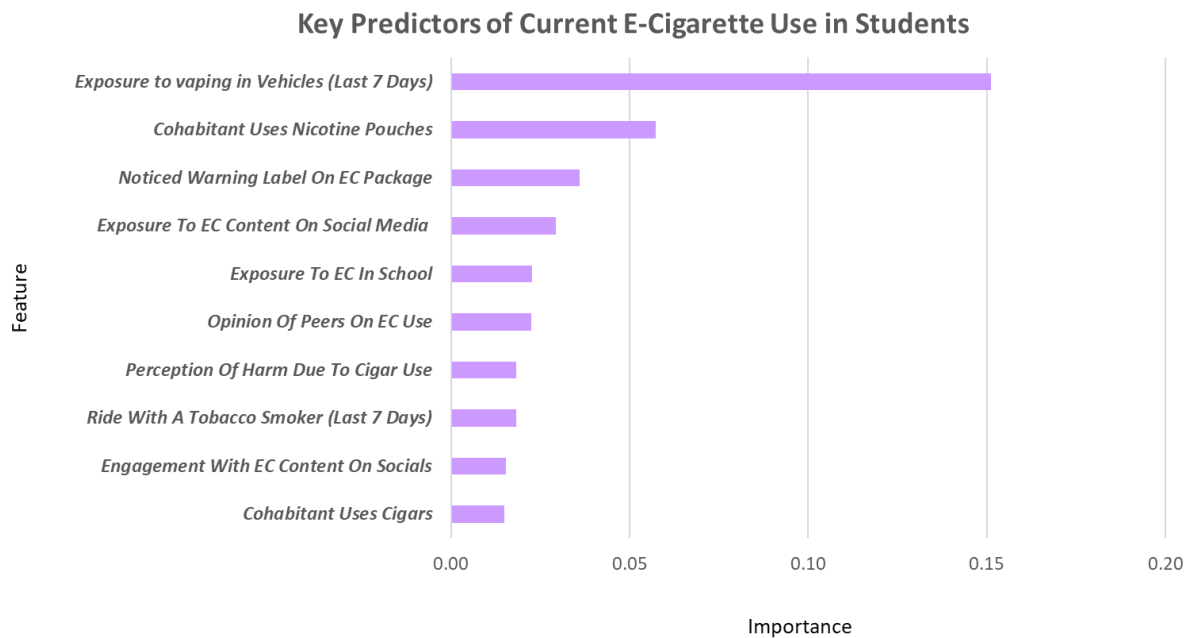
We examined several performance metrics to understand the effectiveness of our model. The key metrics considered include precision, recall, F1-score and accuracy as detailed in Table 3.

	Precision	Recall	F1-Score	Accuracy
Not a Current Smoker	0.82	0.84	0.83	0.84
Current Smoker	0.85	0.83	0.84	0.84

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We then identified key factors influencing e-cigarette usage among these students based on the feature importance generated by the XGBoost model we built. The top 10 features are shown below in Fig 6. We discuss more on these features and direct recommendations to combat these specific factors in a later section (Section 5.1).

We can see here that direct exposure by riding in the same vehicle or by living with smokers, social media impact, peer influence, and misconceptions regarding the amount of harm e-cigarettes or smoking causes were key predictors in identifying the at-risk groups of students. Figure 6 depicts the top 10 features identified the XGBoost and their respective importances.



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DISCUSSIONS

RECOMMENDATIONS

To address the observed usage patterns of e-cigarettes among the youth, a multi-faceted approach should be considered. Efforts to raise awareness, implement prevention strategies, and promote cessation programs must account for reducing the prevalence of e-cigarette use. In the following section, we'll explore the primary factors influencing e-cigarette usage, propose strategies to mitigate this, and discuss the potential short-term and long-term outcomes of implementing these recommendations.

Environmental Exposure and Peer Influence

- Key Drivers:
 - Exposure to vaping in vehicles (76.3% of current smokers rode with an E-cigarette smoker for at least one day of the week, compared to 16.9% of non-users)
 - Exposure at home to nicotine products (6.1% of current users live with someone using nicotine pouches compared to 1.6% of non-users)
- Recommendations:
 - *Vehicle Smoke-Free Policies*: Regulatory authorities should advocate for the expansion of smoke-free laws to include vaping in vehicles when minors are present. Creating public service announcements that highlight the risks of vaping in closed environments should also contribute positively to curb vaping.
 - *Home-based Interventions*: Bodies like CDC or NIH should promote cessation programs for families with minors. This would educate parents about the impact their nicotine use has on youth vaping. Encouraging families to create tobacco-free and vape-free home environments (e.g., tax credits, community recognition) could also be a viable option.
 - *Community Outreach*: Advocacy groups can partner with schools, pediatricians, and local organizations can offer resources and education to parents, targeting families where children are regularly exposed to vaping.
- Expected Impact:
 - Short-term: Reduced exposure to vaping in environments like cars and homes, which would minimize passive normalization and peer pressure.
 - Long-term: A decline in vaping initiation among youth, as they are less likely to be exposed to vaping behaviors in their immediate environment.

Public Awareness and Perception

- Key Drivers:
 - Misperception of harm (9.86% of current users think e-cigarettes are harmless compared to 2.90% of non-users)
 - Social media influence (63.5% of current engage with e-cigarette content on social media while 43.6% users see content posted by someone they know)
- Recommendations:
 - *Educational Campaigns*: Implement targeted public health campaigns that address misconceptions about the safety of e-cigarettes. These can be disseminated through schools, social media, and healthcare providers.
 - *Social Media Monitoring*: Collaborate with social media platforms to reduce the visibility of pro-vaping content. We can also create counter-narratives and digital literacy programs in schools that educate youth on the dangers of e-cigarette use and the tactics used by vape companies to market their products.
 - *Engagement with Influencers*: Recruit influencers and public figures who resonate with youth to spread awareness about the risks of vaping and promote alternative, healthier behaviors.
- Expected Impact:
 - Short-term: A reduction in misperception about the safety of vaping and lower engagement with pro-vaping social media content.
 - Long-term: As perception shifts and peer norms change, youth may become less likely to experiment with or continue using e-cigarettes. Social pressure to vape would decrease as it becomes less socially acceptable.

Regulation & Policy Enforcement especially for Minors

- Key Drivers:

- Low refusal rate of sales to minors (82.8% of minors who ever tried to purchase an e-cigarette were able to do so)
- Recommendations:
 - *Marketing and Advertising Restrictions*: Implement stricter regulations around the advertising of vaping products, particularly near schools, parks, and other youth-centric locations. Strategically placing ban e-cigarette ads from places where youth are likely to encounter them can be beneficial (e.g., convenience stores).
 - *Point-of-Sale Limitations*: Place limits on the visibility of vaping products at the point of sale, requiring that products are not displayed in prominent places in stores where youth are likely to shop.
- Expected Impact:
 - Short-term: Decreased visibility of vaping products and advertisements in public spaces, leading to reduced curiosity and exposure among youth.
 - Long-term: As marketing restrictions tighten and products become less appealing and accessible, youth initiation rates are likely to drop. A decrease in peer normalization of vaping could also contribute to a reduction in use.

LIMITATIONS

One of the major limitations of our work is the data set used. While it is the best available data set on tobacco usage trends among American youth, it is still survey data and therefore will have sampling bias and self-reporting bias. The sampling strategy used may not represent the entire youth population of the country. The self-reported nature of survey dataset renders it susceptible to factors like social desirability bias causing students to not provide the complete truth or even memory recall errors. There is also the issue that a good percentage of the values are missing.

There are not enough fields that could help us check the correlation of e-cigarette usage against health factors, both mental and physical. This makes it harder to identify the extent of the harm caused by e-cigarettes.

FUTURE RESEARCH

With more data regarding the mental and physical health of the respondents, we could identify the health issues caused by e-cigarette usage to a better extent. This could help educate the young generation on the harmful effects of nicotine.

Research can also be done in the longer-term trends of e-cigarette usage among youth and whether the regulations imposed over time have helped control the usage. Furthermore, e-cigarette sales need to be investigated in parallel to counter the self-reporting bias of the data set.

CONCLUSION

Although initially introduced as a product intended to help adult smokers in transitioning from traditional cigarettes and thereby reduce the harm entailed, studies show that the marketing strategies of the e-cigarette companies resulted in the widespread popularity among youth rather than their intended adult demographic (Kramarow 2023). What makes it even more tragic is how statistics show that cigarette usage was at an all-time low among American adolescents for longer than the past decade (Delnevo 2023). Therefore, it is safe to say that a lot of adolescents who were never interested in nicotine before, became enraptured by the enticing array of flavors, sleek designs, and social media marketing methodology of vape products and turned nicotine addicts. This is clear from the surge in e-cigarette usage among adolescents until 2019 which only leveled out after the FDA regulations were imposed in

the same year to ban selling vaping products to minors. Additionally, this could also be attributed to the post-pandemic lockdown and the fear caused by the EVALI outbreak.

Studies show how nicotine addiction can impact mental health manifesting in symptoms like depression, anxiety, impulsivity, and more related issues that inhibit the ability of an adolescent to learn and grow as a capable individual in society. Our study shows how a lot of minors are still able to acquire and use these products despite the legislative efforts. It is vital that parents, educators, store owners, healthcare professionals, and the government all work together to take the necessary steps to save our young generation from the destructive grip of nicotine addiction.

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