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RESEARCH ARTICLE

The Epidemiology and Social Determinants of Vaping in US Adolescents: Two Decades After the E-Cigarette Invention

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ABSTRACT: Marketed as a safer cigarette and an aid to smoking cessation, nicotine vapes, or e-cigarettes, became popular in the early 2000s. The branding as a safer tobacco product, however, brought in a new generation of users, namely school-aged students and adolescents. This review article tracks a decade of United States (US) data on school-age student vaping and its trends, collating and critiquing publications of social triggers (determinants) of teenage vaping. Noting the impact of non-medical factors like race, socioeconomic status, mental health, and built environment on adolescent vaping rates, this article paves the way for these social determinants of e-cigarette use to be topics for deeper epidemiological analyses. Furthermore, the article calls on pediatricians across the US to be cognizant of the underlying influences that promote e-cigarette use in minors. This way, when vigilant pediatricians come across such youth in their practice for any medical reason, they can identify these "at-risk" teens and effect change.

KEYWORDS: Behavioral Science, Social Psychology, Nicotine, Vaping, E-cigarette, Adolescents, Epidemiology, Social Determinants.

Introduction

Few topics in pediatric public health are as debated as whether vaping is unequivocally injurious to health, or if it is partially beneficial, as it blocks users from a worse form of addiction - conventional (combustible) cigarettes.

Today, vaping is synonymous with Generation Z (those born between the years 1997 and 2012).[1] This population already understands that smoking conventional cigarettes, which contain nicotine within the tobacco leaf, is deleterious to their health,[2] yet paradoxically believes that inhaling vapors of this same nicotine is safe.

In 2003, four centuries after tobacco began to be sold commercially,[3] a Chinese pharmacist, Hon Lik, invented the electronic cigarette (e-cigarette), which was initially intended to be an alternative to the conventional cigarette, for smokers to use as a tool for smoking cessation. Vaping devices are cylindrical structures with a mouthpiece at one end consisting of a battery, an atomizer, and a cartridge containing a liquid solution (referred to as juice) composed of purified nicotine (**Figure 1**).[4,5]

In e-cigarettes, the battery generates the power to heat the liquid nicotine in the cartridge, and the atomizer vaporizes this liquid, emitting it as mist (aerosol) that the user inhales.[6] E-cigarettes, unlike their conventional counterparts, do not rely on the combustion of the tobacco leaf to release nicotine; therefore, they do not need to have certain chemicals called nitrosamines to cure the tobacco leaf and extend its shelf life.[7] Since tobacco-specific nitrosamines are known carcinogens and central to the link between smoking and cancer,[7] e-cigarettes were invented to reduce carcinogens, make smoking safer, and perhaps even aid in smoking cessation.

Paradoxically, the opposite occurred. The notion that "purified" nicotine must be harmless, and the absence of carcinogens must make it "safe," drew a new generation of first-time e-cigarette users: adolescents aged 13-18 years[8] and young adults. Additionally, the use of fruity flavors to mask the bitter stench of concentrated nicotine further resulted in nicotine vapes appealing to youth.[8] A 2018 report that an alarming 85% of young adults (18-29 years of age; **Figure 2A**) had used vape devices at least once stunned public health experts.[9] Aggravating matters, e-cigarette use had even trickled down to teenagers; a 3-year study published in the New England Journal of Medicine demonstrated that its usage doubled between 8th and 12th grade (**Figure 2B**).[10]

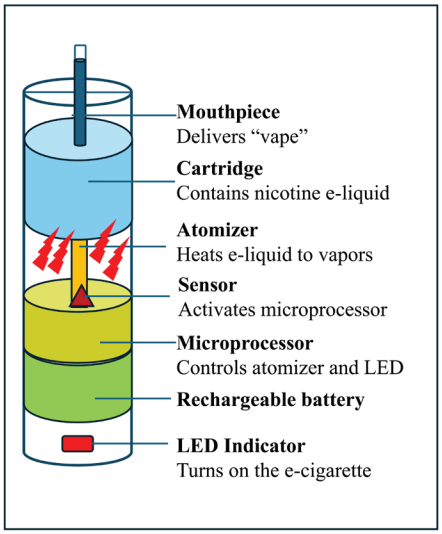

Figure 1: Schematic diagram of an e-cigarette. This figure shows how the vape "pen" works: the battery generates the power to heat the liquid nicotine in the cartridge, and the atomizer vaporizes this liquid, emitting it as mist (aerosol) that the user inhales.

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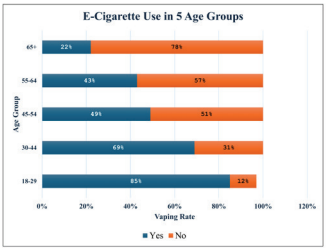

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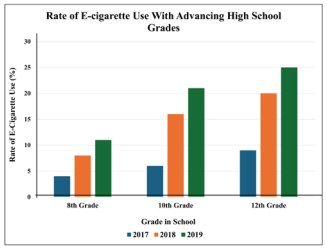

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Figure 2A: Vaping and e-cigarette use by age. Adapted from "Percentage of adults in the U.S. who had used e-cigarettes as of 2018, by age" on Statista.[9] This figure spotlights data from a 2018 survey that 85% of young people (18-29 years old) had used vape devices at least once.

Figure 2B: Uptick in Adolescent Vaping Rates Between 2017 and 2019. Adapted from Miech *et al.*, New England Journal of Medicine.[10] The graphs show a doubling of adolescent e-cigarette users through the course of the high school years between 8th and 12th grade.

Written shortly after the 20th anniversary of the invention of the vape device, this article is one of the few that provide a comprehensive evaluation of the multiple, often interrelated, triggers that lead adolescents towards e-cigarette use. In doing so, the author seeks to examine the "why" of teenage vaping through an epidemiological lens. While causality analyses of each trigger of adolescent vaping are complicated, having reviewed over 100 relevant publications, it became apparent that looking at these factors in isolation is not enough, because "at-risk" teenagers often present with multiple complicating factors. Only by understanding the interplay of the multiple social determinants that impact e-cigarette dependency can health professionals, like pediatricians, flag vulnerable teens and effect sustainable change.

Discussion

Epidemiology and Social Determinants of Adolescent Vaping:

The advent of the e-cigarette saw the rise of a new demographic of users: first-time vapers, often teenagers or young adults.[8]

According to the 2024 annual National Youth Tobacco Survey (NYTS) from the Centers for Disease Control and Prevention (CDC), nicotine e-cigarettes were the most used tobacco product among middle and high schoolers, with 410,000 middle schoolers (3.5% of all US middle schoolers) and 1.21 million high schoolers (7.8% of all US high schoolers) using them nationwide.[11] Of them, 26.3% reported daily vaping, and 38.4% used an electronic cigarette at least 20 of the last 30 days.[11] In contrast, smoking of conventional combustible cigarettes was at an all-time low of 1.4% among middle- and high-school students.[12]

This literature review studies multiple key epidemiological factors and social determinants of health (SDOH) that result in these 1.63 million US middle and high schoolers using e-cigarettes each year.[11] The CDC defines SDOH as all the nonmedical factors that influence health outcomes. These determinants include ethnicity or race, gender, mental health, neighborhood, housing status, food security, family education level, income, and more. By analyzing multiple SDOHs both individually and interconnectedly, our work fills a gap in the literature, as these triggers are often interrelated.

Racial and Cultural Factors:

Racial identity is a noteworthy determinant of e-cigarette usage in adolescents.[13,14] From 2011, when e-cigarette-related questions were introduced into the NYTS, the prevalence of e-cigarette use has always been greater in white adolescents than in teenagers from the Black community. Since vaping costs ranged between $50 and $100 per month, e-cigarettes and nicotine vaping were considered a "vice of the wealthy". The CDC's annual Behavior Risk Factor Surveillance System (BRFSS) demonstrates that race may inform other SDOHs like socioeconomic status, education, income, food (in)security, and social connectedness; hence, its influence on substance dependency in general, and e-cigarette use in this case, cannot be underestimated.[15]

The racial distribution of adolescent vapers in the United States has changed in recent years. The NYTS 2024 data demonstrated that 6.6% of current (past 30-days) e-cigarette-using adolescents in the US identified themselves as multiracial, 5.9% as white, 6.1% as Hispanic or Latino, 7.0% as Black and 11.5 % as American Indian or Alaska Native [(AI/AN); **Figure 3A**].[16]

The NYTS 2024 is unique in the observation that for the first time, vaping rates in African American, Hispanic, and white communities are comparable to each other, whereas in prior years, e-cigarette use was most prevalent among white youth. This outcome could have several potential causes. On the positive side, it may have stemmed from the success of culturally inclusive youth awareness campaigns.

One such US teenager-centric educational campaign, "The Real Cost," is credited with reducing e-cigarette initiation in an estimated 444,252 US youth across all races in the 2023-2024 school year.[17] On the negative side, top-selling vape brands may be providing steep discounts to expand their clientele across teenagers from a wider spectrum of racial and socioeconomic backgrounds.[18]

While nicotine vaping rates have been down across all major racial groups in 2024 compared to 2023, their high prevalence (11.5%) in AI/AN youth remains a cause for concern. This is not a sporadic occurrence, as prior years of NYTS have corroborated this finding. The American Indian/Alaska Native (AI/AN) community faces unique stressors compared to other racial groups. The CDC BRFSS reports 31.9% of AI/AN people reporting "lack of support" and social unconnectedness.[15] This state of poor mental health in the community must make its youth more susceptible to e-cigarette dependency (see *Mental Health* section). What is paradoxical, however, is that an expensive habit like vaping is so prevalent in one of America's most impoverished communities, as measured by 21.3% of AI/AN people reporting needing food stamps.[15]

Mental Health:

In an era where great emphasis is placed on feigning perfection (on social media), the mental well-being of youth is undeniably impacted.[19] Nicotine is a highly addictive substance

that binds to nicotinic receptors in the brain to stimulate the release of euphorigenic neurotransmitters like dopamine and norepinephrine in a matter of seconds after inhalation.[20] Thus, teenagers use nicotine vapes hoping that this euphoric sensation will instantly alleviate their stressors of everyday life.[21] In one of the only publications that we think comprehensively addresses multiple SDOHs, Andrea Gentzke and colleagues use primary data from NYTS 2021 to show that school-aged teenagers who were getting D's and F's in classes had an alarming lifetime tobacco use rate of 36.7% and 41.7%, respectively, and 15.6% and 17.3% rate of current usage (**Figure 3B**). Their analysis also revealed that middle and high schoolers who were in moderate and severe psychological distress had 29.3% and 37.8% lifetime tobacco use rates and 11.2% and 14.2% current usage rates, respectively. Similar observations of elevated use of tobacco products were made among teenagers who identified as gay, lesbian, bisexual, or transgender in this survey. 81% of tobacco use in this study was in the form of e-cigarettes. In totality, these data depicted in Figure 3B underscore how academic, social-emotional, orientation-based, and general stressors may bring teenagers to tobacco products, specifically e-cigarettes.[22]

It is likely that these teenagers are misinformed about the adverse repercussions of using vaping devices and believe erroneously that e-cigarettes are a win-win solution: a way to improve mental well-being without deteriorating physical health.[23] However, given the short-lived psychoactive effect of the nicotine as the level of this agent decreases in the brain with time, nicotine cravings or withdrawal symptoms can set in, creating an urge to inhale nicotine again.[24,25] This marks the beginning of dependency; nicotine addiction is rooted in the teenagers need to enhance its positive effects (heightened vigilance, improved mood) on one side and the desire to reduce the negative impact of its absence (withdrawal symptoms such as anxiety, irritability, impaired concentration) on the other. This is the beginning of substance abuse, which can not only result in addiction from a mental health perspective (discussed above) but also acute conditions such as heart disease, stroke, and COPD, from a physical health perspective.[26]

Yet another factor affecting teenagers' mental well-being, and in turn their extent of vaping, is loneliness. In an online survey-based study, John E. Grant and his colleagues concluded that illicit drug or alcohol use, being single, and being an undergraduate student, all of which can cause or exacerbate mental health problems, were statistically significant determinants of e-cigarette use.[27] Once again, they demonstrated nicotine e-cigarette usage to be more prevalent in young adults (18-19 years of age) than older adults in college. Grant's team also reported that students who were current or past year e-cigarette users were more prone to untoward risk-taking behaviors, including their greater susceptibility to non-nicotine substance abuse and higher impulsivity scores. By delineating early undergraduate years and being single (both markers of loneliness) as determinants of e-cigarette usage, Grant's study corroborates Andrea Gentzke[22] analysis that academic and social stressors are relevant mental health precursors to e-cigarette addiction. Looking at how SDOHs can be interconnected, John Grant's work now contextualizes why AI/AN youth, whose community had the highest loneliness rates per the BRFSS,[15] may turn to e-cigarette use.

Socioeconomic Status, Housing, and Neighborhood:

Family income and socioeconomic status play a powerful role in adolescents' vaping in the US, but there is conflicting evidence on whether it is poverty or affluence that promotes e-cigarette use in minors.

Treating housing status as a proxy for socioeconomic stratum (SES), a paper by Patricia Simon and coworkers from Yale University surveyed 3473 urban and suburban Connecticut high schoolers to demonstrate a positive correlation between SES and prevalence of vape use: the higher the SES, the greater the rate of teenage vapers. Although the direct correlation between SES and e-cigarette use narrowly missed statistical significance ($p=0.07$), what was significant was a correlation between SES and exposure to advertising ($p<0.001$), which in turn had a significant ($p=0.05$) correlation with e-cigarette use (**Figure 3C**).[28] Another study, a secondary analysis of social determinants from NYTS 2021 by Andrea Gentzke, claimed otherwise showing no correlation of family affluence with tobacco and e-cigarette use (**Figure 3D**).[22]

In complete contrast, an analysis of the California Healthy Kids Survey by Jennifer Felner and colleagues concluded that the likelihood of vaping among youth living in transitional homes or shelters was 1.53-1.88 times greater than those residing in permanent homes, and these results were statistically significant.[29] Felner's work also showed that teens from a lower social class have a greater susceptibility to e-cigarette use. Since vaping nicotine is an expensive habit, costing $50 to $100 each month, Felner and colleagues' observation that the lower the SES, the greater the chance of vaping, is paradoxical.[29]

These contradictions underscore the central goal of this paper, which is to look at the matrix of SDOHs both individually and collectively. Perhaps that paradox can be explained by delving deeper into the neighborhood in which a teenager's home is located. Patricia Simon's[28] work has already demonstrated the direct impact of advertisement on adolescent e-cigarette use. Extrapolating it forward, the area in which one's permanent or even transitional home is located may perhaps have a triggering effect on e-cigarette use through the continuous vape shop advertising that a teenager sees around them in the community.

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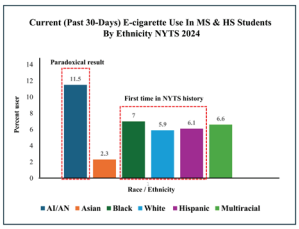

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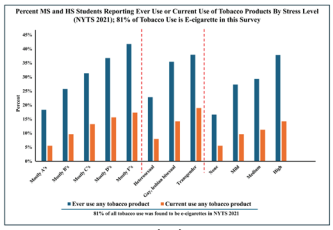

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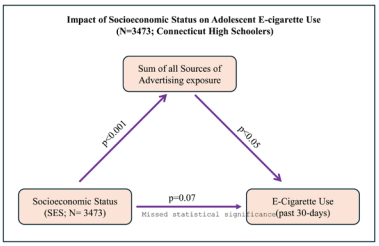

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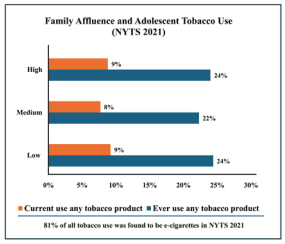

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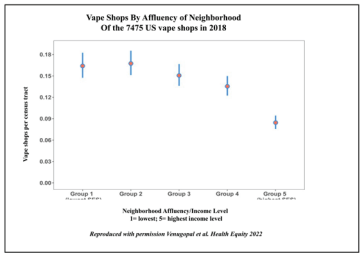

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Figure 3A: Current (30 days) e-cigarette use in middle school (MS) and high school (HS) by student ethnicity. Adapted from Jamal *et al.*, NYTS 2024.[16] The figure depicts the racial representation of current adolescent e-cigarette users from NYTS 2024 and analyzes it as a percentage of all US middle and high schoolers of the same ethnicity.

Figure 3B: Percent of middle (MS) and high school (HS) students reporting ever use or current use of tobacco products analyzed by stressors of life. Adapted from Gentzke *et al.*, NYTS 2021.[22] (Note: 81% of all tobacco use was as e-cigarettes). This graph shows the impact of academic grades, sexual or gender orientation, and general mental health status of a teenager on their tobacco use.

Figure 3C: Association analysis of family socioeconomic status (SES) with e-cigarette consumption either directly or through advertising exposure. Adapted from Simon *et al.*[28] Using a Yale University survey conducted in Connecticut high schools, this schematic representation shows both a direct correlation between SES and current e-cigarette use and a more robust indirect correlation through the extent of exposure to advertising.

Figure 3D: Adolescent tobacco use (current or ever) by family affluence. Adapted from Gentzke *et al.*, NYTS 2021.[22] This graph demonstrates a lack of correlation between family affluence level (self-reported) and use of tobacco products (ever or current) from the NYTS 2021 dataset. (Note: 81% of all tobacco use was as e-cigarettes)

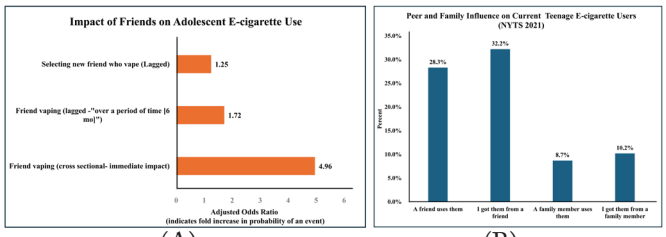
Figure 3E: US geospatial mapping of specialty vape shops analyzed as a function of SES of the neighborhood. Group 1 = lowest SES, group 5 = highest SES. Reproduced with permission from Dr. D Venugopal.[31] This diagram shows that the lower the SES level of an area, the higher the number of vape shops located there.

A spatial analysis of Tobacco Retail Outlets (TROs) and Vape Shop Outlets (VSOs), entitled "Neighborhood Disadvantage and Tobacco Retail Outlet and Vape Shop Outlet Rates," was published in April 2020 by David C. Wheeler and colleagues. This study concluded that the socioeconomic level of a neighborhood had a clear negative correlation with the number of TROs and VSOs in that area; on average, a low-income neighborhood had 63% more TROs and 64% more VSOs than an affluent one. This study also reported strong positive associations between the dependent variable of TRO/VSOs and independent variables such as percentage of renter-occupied housing versus owner-occupied homes, and percent vacant housing units.[30] This correlation supports the thesis that living in neighborhoods with several itinerant households, devoid of long-term ties within one's community, predisposes teenagers in those families to nicotine vaping. The authors suggest that, conversely, neighborhoods with entrenched multi-year, multi-generational families may likely create robust local laws that deter TROs and VSOs from springing up in the first place. Perhaps it is now possible to contextualize why Felner and colleagues saw the increased odds of vaping in teens living in transitional homes, as they would gravitate to the high number of VSOs in their area and get initiated into vaping.

Bringing our analysis a full circle, at the height of the adolescent vaping crisis in 2018-2019, a team from the Food and Drug Administration (FDA), Venugopal and colleagues performed geospatial mapping of US VSO's and analyzed their abundance in an area as a function of the SES of that neighborhood determined from census data. This data corroborated Wheeler's findings and showed an inverse proportionality between SES and number of vape shops (**Figure 3E**).[31] Together, the cited works establish the complexity of evaluating SES alone, and the value of studying it in the context of other SDOHs like housing, neighborhood and built environment to quantify its true impact on adolescent e-cigarette use.

Interpersonal Influences: Peer Pressure and Family Dynamics:

Interpersonal influences, specifically peer pressure, are a powerful predictor of the likelihood of nicotine vaping in American adolescents. In 2023, a paper entitled "Social Network Influences on Adolescent E-cigarette Use," by Valente and colleagues, analyzed the role this SDOH plays in adolescent e-cigarette use by interviewing 1,208 students in a Midwestern school district and asking them about exposure to vaping among their circle of friends. Valente's team concluded that both seeing e-cigarette use among a pre-existing (friendship duration ≥6 months) circle of friends (**Figure 4A**; "lagged" data) and selecting new friends (Figure 4A; "immediate" data) who vape were both positively correlated with one's own vaping initiation. In fact, new friends who vape dramatically increased the likelihood (4.96-fold) of a teenager initiating e-cigarette use (Figure 4A). This marked the first prospectively defined epidemiological study to quantify the impact of peer pressure and social dynamics on teenage e-cigarette initiation.



(A) (B)

Figure 4A: The likelihood (odds) of an adolescent vaping by immediate (cross-sectional) and 6-month (lagging) impact of their friends using e-cigarettes. Adapted from Valente *et al.*[32] Using data from a Midwest school district, this graph shows how having existing friends who vape impacts the likelihood of a teenager initiating e-cigarette use themselves. This impact is far greater (4.96-fold) when a teenager makes new friends who vape.

Figure 4B: The role of friends and family members who vape on adolescent e-cigarette use. Adapted from Gentzke *et al.*, NYTS 2021.[22] This data graphically represents student responses from the NYTS 2021, demonstrating the influence of friends and family members who vape on teenage e-cigarette users, including their role in sourcing the first vape for the adolescent.

Valente's data also corroborates the elegant analysis of the NYTS 2021 by Andrea Gentzke demonstrating that an 28.3% of current vapers indicated that they had a "friend who was using them" and 32.3% of the current vapers indicated that it was a friend who had "got it for them" (**Figure 4B**).[22] While overall nicotine vaping rates among school-aged youth have reduced since the time of this analysis (2021), the triggering influence of friends remains undeniable.

Not all pressure is peer pressure; a child's elders using e-cigarettes would likely increase their own affinity for vaping.[33] In fact, data mining of individual responses from the teenagers polled for the NYTS 2021 revealed 18.7% lifetime e-cigarette users, and 8.7% of current users admitted to family members using them at home. Far more concerning was that 10.2% of all current vapers indicated that they actually developed the habit because a family member actually "got it for them" (**Figure 4B**).[22] Similarly, in a 2018 meta-analysis, Jian-Wei Wang and her research team compiled 21 studies analyzing the effect of observing family members vape on a teenagers own e-cigarette usage and reported a positive correlation between teen vaping and e-cigarette usage in both family members and in friends. Adolescents are 1.47 times more likely to vape if their family members do so.[34]

Social Media and Tactical Marketing:

Valente's work already shows the dangerous (4.96-fold) impact of new friends on teenage e-cigarette initiation.[32] But not just physical friends, cyber peers also play a role in enticing adolescents towards e-cigarettes. A 2023 publication by Hopkinson and colleagues concluded that those spending 1-3 hours per day on social media are 92% more likely to vape, and those spending greater than 7 hours per day on social media increase their likelihood of smoking or vaping by nearly five-fold.[35] Once again, just like VSOs are an example of physical advertisements, Hopkinson's work ties back to Simon *et al.*,[28] that increased exposure to advertising (see Figure 3C), in this case e-advertisements through social media, correlates with a higher incidence of nicotine vaping.

The impact of tactical social media marketing by "big tobacco" companies is central to the US adolescent e-cigarette epidemic. The success of the two oldest corporations in the US vaping landscape, JUUL Labs (makers of the popular pod-based vape product, JUUL) and RJ Reynolds (the makers of Vuse, the rechargeable vape), monopolizing the nicotine e-cigarette market (through 2023), stemmed from their ability to convincingly market nicotine vaping products to adolescents through social media. Showcasing the fruit and candy flavorings in the vape through social media convinced adolescents that they are only inhaling fun flavors, when in reality, they are breathing in nicotine.[36] In their 2018 annual earnings release, JUUL reported expenses of $73 million on targeted teenage branding and marketing campaigns highlighting the breadth of flavors in which their vapes were available.[37] Not surprisingly hence that in the following year, the 2019 NYTS data demonstrated that 69.3% of American teenagers reported exposure to e-cigarette marketing directed at them.[38] Furthermore, in 2019 and every year since, > 8 out of 10 youth initiate their tobacco addiction with a flavored product, and 72% of high school students who vape regularly have expressed a preference for flavorings in their electronic cigarettes.[12]

Products like the Elf Bar have recently risen to prominence in 2023-2024 by savvy marketing of their fruit flavors, colorful packaging, easy disposability (single use), and their unique social media strategy targeting teenagers on TikTok.[18] In fact, 36.1% of all adolescent nicotine e-cigarette users surveyed in the NYTS 2024 used this product (**Figure 5**).[11] Since TikTok involves individuals disseminating their own videos, it is reported that Shenzhen iMiracle Technologies from China, the makers of Elf bars, pay teenage influencers to put out the Elf Bar content while remaining incognito themselves. [39] In this way, the company has been able to circumvent US regulations regarding marketing to minors. Similarly, the colorful packaging and cartoon characters on Elf Bars serve as both a ploy to import these products into the US as battery-operated toys, obfuscating US Customs enforcement, and as their fun-filled youth marketing strategy.

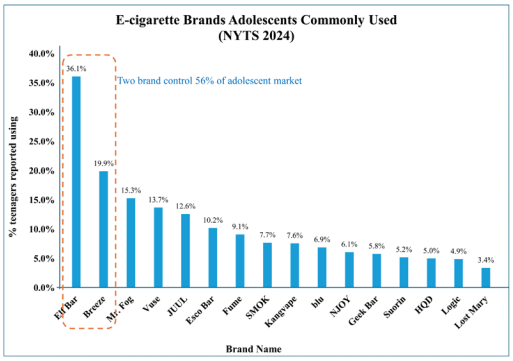


Figure 5: Best-selling nicotine vape brands among adolescent users in 2024. Adapted from NYTS 2024.[11] The bar graph compiles student responses from NYTS 2024 about what are the brand(s) of vape products they use routinely. Percentages cumulate to > 100% as the same student may use multiple products.

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Legislation and Enforcement:

One of the most powerful SDOHs of teenage vaping is, in fact, extrinsic to the teenagers themselves and in the hands of policymakers. Past 30-day e-cigarette usage rates among high school students have declined from 27.5% in 2019 to 10% in 2023 to 7.8% in 2024 (**Figure 6**).[40]

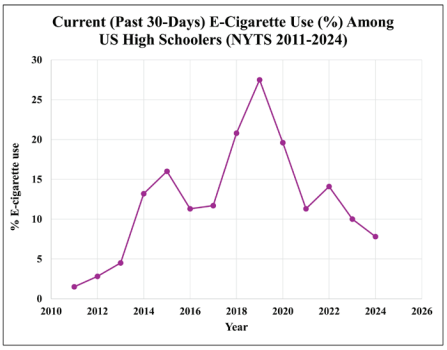

Figure 6: Past 30-day e-cigarette use from 2011-2024. Adapted from NYTS 2011-2023.[40] This graph shows the evolution of current e-cigarette use among teenagers over 14 years (2011-2024). E-cigarette use peaked in 2019 and has been trending downwards since. Yet, with 1.6 million adolescents using e-cigarettes in 2024, vaping remains a very serious pediatric public health crisis.

One of the most foundational reasons for this steady decline in adolescent e-cigarette use in the 2020-2024 period is the enactment and enforcement of diverse sets of legislation that restrict the actions of the major corporations in the vaping industry. **Table 1** lists five of the most consequential pieces of legislation related to e-cigarette use passed in the last 15 years, and details their ramifications.

Table 1: Existing e-cigarette-related federal legislation passed since 2009. The table shows the robust body of legislation passed in the last 15 years to regulate e-cigarette manufacturers selling products in the US markets, aimed specifically at blocking their sales to teenagers.

Name of Law/Month and Year of passage	Consequences of the legislation
Family Smoking Prevention and Tobacco Control Act June 2009	Allow the executive branch of the government to restrict and regulate sale and distribution of tobacco products to promote public health Restricts promotion of tobacco products by preventing tobacco brands from sponsoring social events (such as sports, entertainment, etc.)[41]
Deeming Rule May 2016	Extends the definition of "tobacco products" in Family Smoking Prevention and Tobacco Control Act to include electronic nicotine delivery systems and e-cigarettes.[42]
Tobacco 21 Dec. 2019	Raises the minimum age for purchasing tobacco and nicotine products from 18 to 21.[43]
Preventing Online Sales of E-Cigarettes to Children Act July 2020	This legislation subject's e-cigarette sales to taxation Requires US Postal Service to prevent mailing of nicotine e-cigarette products. Requires National Institutes of Health (NIH) to conduct a study on health impacts of nicotine vape usage.[44]
Premarket Tobacco Product Application (PTMA) Guidelines Amended 2021	Requires companies selling tobacco to submit clinical studies to the FDA that demonstrate that their products are not more injurious to public health than conventional cigarettes. In these reports, corporations must also prove that they are marketing tobacco products in an accurate and veracious manner.[45]

Since 2009, the US government, and specifically organizations like the FDA, have passed substantial legislation to combat the vaping epidemic in American adolescents. The implementation of these laws has also improved meaningfully in the last 5 years. For example, under the aegis of the Family Smoking Prevention and Tobacco Control Act of 2009 and the Deeming Rule of 2016, the FDA was able to launch an investigation on Juul in 2019, resulting in the first leg of the removal of some of its fruity flavored vapes from the market that same year.[46] The 2021 amendment of the PTMA Guidelines resulted in both Juul and Vuse receiving marketing denial orders (MDOs) for their PTMAs from the FDA that year.[47] Although both Juul and Vuse have been reinstated in US markets in 2024, the scope of their product offerings has been curtailed, and no longer contains any candy or fruit flavored vapes whatsoever.[48] Knowing that >80% of adolescents across all NYTSs report favoring fruity vapes, this legal enforcement was likely a primary contributor to the reduction in adolescent vaping since 2020.

With strong and proven legislation already in place, now it is behooved of the government agencies to galvanize their implementation even further by working with local level city law enforcement (police) to combat the sales of the remaining fruit flavored vape products like Elf Bar and Breeze, that together make up 56% of all e-cigarettes sold to US teenagers. One reason that these two brands have been able to avoid the national ban on fruit flavored vapes that Juul and Vuse were forced to comply with is that both are imported products brought in from China, hence able to circumvent the PTMA law relevant only for US-domiciled manufacturers.

■ Conclusion

Public health research is often confounded by the multifactorial nature of human decision-making. The epidemic of e-cigarette use among US adolescents is one such public health emergency where the unequivocal cause and effect as to what drives a teenager to their first vape is hard to establish. A matrix of life events may create conditions that entice teens to vape. Therefore, studying these triggering factors individually may leave unanswered questions. In this paper, race and ethnicity, socioeconomics, housing, neighborhood, peer-pressure, family dynamics, mental health, governmental legislation, and its implementation are all studied as determinants of teenage e-cigarette use. Throughout the paper, we have highlighted how understanding one SDOH may be impacted by clarifying the role of another. An example of the power of triangulation of information from various SDOHs is the case of minors in shelter and transitional homes, affording vapes when they have no money for food; a paradox when one looks at it as just an SES question. Looking through the multi-SDOH lens, we see their dilapidated neighborhood, potentially with high numbers of VSOs reinforcing vaping, in turn impacting their newfound peer group, perhaps family members with substance abuse, or their falling grades from moving to a transitional home, together taking a final toll on their mental health. Another unique aspect of our work was to show how seemingly unconnected things like VSOs and social media marketing can both serve as positive reinforcers to e-cigarette dependency; one physical, another digital.

One SDOH for future analysis is the impact of urban, suburban, or rural school settings on teenage vaping in the US. All the papers found were pre-pandemic, predating the social

media surge, or devoid of a dependable trendline. What we gleaned cursorily was that nicotine vaping can be high in both extremely rural and ultra-urban environments. As a future step, the authors intend to approach the CDC (under the Freedom of Information Act) for the zip codes of the roughly 300 schools that are chosen each year for NYTS, and the rate of current e-cigarette use by that school's zip code. A five-year lookback of such zip code level information, when cross-matched with census assignment of that area (rural, suburban, or urban), will shed light on the SDOH of the school setting.

Through this work, the authors also want to reach out to adults who interact with teenagers, including teachers, guidance counselors, coaches, and above all, pediatricians in community practices, to carefully evaluate adolescents through the multi-SDOH lens studied in this paper. By being cognizant of the interplay of underlying triggering causes that promote e-cigarette use in adolescents, vigilant pediatricians and educators can identify these "at-risk" teens quickly and effect change.

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