HHS Public Access

Author manuscript

Prev Med. Author manuscript; available in PMC 2022 September 01.

Published in final edited form as:

Prev Med. 2021 September ; 150: 106670. doi:10.1016/j.ypmed.2021.106670.

Longitudinal Trajectories of E-Cigarette Use among Adolescents: A 5-year, Multiple Cohort Study of Vaping with and without Marijuana

Melissa B. Harrell, PhD[1], **Baojiang Chen, PhD**[1], **Stephanie L. Clendennen, DrPH**[1], **Aslesha Sumbe, MPH**[1], **Kathleen R. Case, DrPH**[2], **Anna V. Wilkinson, PhD**[1], **Alexandra Loukas, PhD**[3], **Cheryl L Perry, PhD**[1]

[1]University of Texas Health Science Center at Houston (UTHealth), School of Public Health, Austin, TX

[2]UT Health San Antonio, Center for Research to Advance Community Health, San Antonio, TX

[3]Health Behavior and Health Education in the Department of Kinesiology & Health Education, The University of Texas at Austin, Austin, TX

Abstract

E-cigarette use harms adolescent health, yet it continues to escalate rapidly among teens nationwide. This longitudinal study sought to identify and differentiate between developmental trajectories of past 30-day e-cigarette use with and without marijuana (i.e., liquid THC) across adolescence (11–19 years old). Three population-based cohorts of adolescents (n=3,907; N=461,069) living in major metropolitan areas of Texas (Houston, Dallas-Ft. Worth, San Antonio, Austin) completed up to 9 Waves of an e-cigarette use survey, from 2014 to 2019. Growth curve models (GCMs) were used to identify average trajectories of past 30-day e-cigarette use, by cohort. Growth mixture models (GMMs) were used to investigate developmental patterns in these trajectories, by cohort. Sociodemographic differences in trajectories were also investigated. Stable trajectories of e-cigarette use with and without marijuana were identified, from 11 through 19 years of age. Trajectories varied by age of onset; frequency and escalation in use; and substance used. With one exception, all trajectories of e-cigarette use escalated with age. Moreover, age of

*Corresponding author at: Melissa B. Harrell, PhD MPH, Address: 1616 Guadalupe St. Suite 6.300 Austin, TX 78701, Melissa.B.Harrell@uth.tmc.edu Phone: (512) 391-2526 Fax: (512) 482-6185.

Credit author statement

Melissa B. Harrell: Conceptualization, Methodology Funding acquisition, Supervision, Writing-Original Draft
Baojiang Chen: Formal analysis, Methodology, Writing-Review and Editing
Stephanie L. Clendennen: Project administration, Supervision, Data curation, Writing-Review and Editing
Aslesha Sumbe: Project administration, Data curation, Writing-Review and Editing
Kathleen R. Case: Writing-Original Draft, Writing-Review and Editing
Anna V. Wilkinson: Writing-Review and Editing
Alexandra Loukas: Writing-Review and Editing
Cheryl L Perry: Funding acquisition, Writing-Review and Editing

Conflict of Interest Disclosures

Dr. Harrell is currently a consultant in litigation involving the vaping industry. The other authors have no other potential conflicts of interest to disclose.

onset and progression in use were positively related. The most problematic trajectories, corresponding to more frequent use, were observed among the younger cohorts compared to the oldest. Primary prevention is critical. Interventions to prevent the onset and progression in e-cigarette use among teens must begin early (e.g., in middle school) and be sustained throughout adolescence.

Keywords

Adolescents; e-cigarette use; marijuana use; Tobacco Use

INTRODUCTION

In 2019 alone, over 5 million students nationwide reported using e-cigarettes at least once in the past 30-days, and nearly 1 million used them daily.[1,2] Sustained, substantial use among teens alarms physicians and public health professionals alike,[3,4] as it harms health in many ways.[4–6] A recent outbreak of acute, severe lung injury in 2019 (EVALI; E-cigarette & Vaping Associated Lung Injury) was especially worrisome, as >50% of cases occurred among those under the age of 25.[7–9] While most e-cigarette devices were designed to vaporize and deliver a nicotinized or denicotinized e-liquid, e-cigarettes can also be used to consume liquid THC (Δ-9-tetrahydrocannabinol), the main psychoactive ingredient in marijuana.[10] Use of devices with and without THC were implicated in regards to EVALI.[11] E-liquids and e-cigarette aerosols contain carcinogens (e.g., formaldehyde) and heavy metals (e.g., lead) that damage the lungs and body.[12] Vaping nicotine increases teens' risk for dependence[13] and alters young people's mood, memory, and learning.[14,15] E-cigarette use is also known to predict the onset of cigarette smoking among youth and young adults.[16,17]

Unfortunately, the exponential increase in e-cigarette use among teens observed over the last decade has largely reversed the strong decline in overall tobacco use achieved the decade before.[1,18,19] Therefore, contemporary approaches to comprehensive tobacco control will need to successfully address and reduce e-cigarette use among young people. Constructing effective preventive interventions, however, will require a better understanding of the natural history of e-cigarette use behaviors. To date, most e-cigarette research has been cross-sectional in design[16,20–22] or, if longitudinal, has relied on a limited amount of data time points.[17,23] This, in turn, restricts our ability to fully understand the onset and progression in e-cigarette use behaviors in adolescence. As this developmental stage is often characterized by volatility in health behaviors,[24,25] there is a need to better elucidate stable, persistent patterns in e-cigarette use.[20,26–28] Such an understanding would help identify sustained and especially problematic e-cigarette use, and particular age(s) which it would be most relevant to target, with interventions.

Previous research specific to the natural history of cigarette smoking among young people shows it is possible to identify stable patterns or trajectories of behavior.[29–31] While some studies focus on understanding the average shape or form of a trajectory across adolescence,[32] others identify clusters of trajectories to describe meaningful heterogeneity in developmental patterns of behavior.[29–31] Depending on the population under study, the latter

approach, when applied to cigarette smoking, has identified sub-groups of young people who can be characterized as non-users; triers; erratic and/or occasional users; early escalators; late escalators; or quitters.[29–32] It is unclear whether similar patterns of e-cigarette use exist. The goal of this study, therefore, is to identify and differentiate between developmental trajectories of e-cigarette use, with and without marijuana (i.e., liquid THC). We present analyses of five years (2014–2019) of longitudinal, repeated measures data collected every 6 months specific to past 30-day e-cigarette use. These data span the entirety of adolescence (11–19 years old). This study builds upon emerging evidence-based perspectives on developmental trajectories of e-cigarette use with and without marijuana, given these goals, which are unique in the literature to date.[33–37]

METHODS

Study design, setting, and participants

Data were collected from 3 population-based cohorts of adolescents living in major metropolitan areas of Texas (Houston, Dallas-Ft. Worth, San Antonio, Austin) who were in the 6th (n=1,122, N=148,464), 8th (n=1,322, N=160,083), and 10th (n=1,463, N=152,522) grades at baseline. Each cohort is part of the Texas Adolescent Tobacco & Marketing Surveillance Study (TATAMS).[38] TATAMS used a complex, multi-stage, probability sampling design to recruit and enroll participants. All students in the 6th, 8th, and 10th grades in Fall 2014 in 79 participating schools in these areas were eligible for the study.[38] More details about sampling methodology are found elsewhere.[38] On enrollment, students participated in a web-based survey in school about e-cigarette use, administered via tablet computers.[39] Approximately every 6 months thereafter, participants took the same web-based survey outside of school on their own tablet, computer, or smartphone. Longitudinal, repeated measures data from Wave 1 (Fall, 2014) through Wave 9 (Spring, 2019) are presented here. Retention across Waves ranged from 63–85%, on par with similar longitudinal studies of e-cigarette use among young people nationwide.[40] In our study, retention did not vary by cohort, at any Wave. Active parent consent and student assent were obtained for each participant (HSC-SPH-13-0377). After completing Wave 1, all participants were sent reminder e-mails and text messages about other surveys. To ensure participant retention, incentives were increased from $10 for Waves 1–2 to $25 for Waves 3–9.

The sampling frame for TATAMS included all private, public, and charter schools in these major metropolitan areas to provide a sample representative of student enrollment. Per data from the Texas Education Agency, the Texas Private School Accreditation Commission, and the National Center for Education Statistics, the sampling frame accounted for 97% of 6th, 8th, and 10th grade students in these areas, and more than 40% of all 6th, 8th, and 10th grade students in all of Texas in 2014–15.[38] At Wave 1, the sample was 48.9% female; 54.5% Hispanic, 21.4% non-Hispanic White, and 17.6% non-Hispanic Black; and the average age of each cohort was 11, 13, and 14 years old, respectively.

Measures

All questions on the survey were adapted from reliable, valid measures employed in national e-cigarette and marijuana use surveillance studies: the Population Assessment of Tobacco

and Health study (PATH),[41] the National Youth Tobacco Survey,[42] and Monitoring the Future.[43] Primary outcome variables included past 30-day e-cigarette use with and without marijuana (i.e., liquid THC). Questions about e-cigarette use with marijuana were asked before questions without it. Other variables in analysis included age, sex, race/ethnicity, and SES.

Past 30-day E-cigarette Use without Marijuana.—At each Wave, students who reported ever e-cigarette use were asked "During the past 30-days, on how many days did you use an electronic cigarette, vape pen, e-hookah, MOD or tank system? Remember, marijuana DOES NOT count. Please enter the number of days (from 0 to 30 days)." Students that reported 0 days were considered non-users (referent, coded as 0) and those that reported 1 or more days were users (coded as 1). Past 30-day e-cigarette use without marijuana was assessed at all Waves.

Past 30-day E-cigarette Use with Marijuana.—At each Wave, students who reported ever marijuana use in an e-cigarette were asked "During the past 30-days, on how many days did you smoke marijuana (liquid THC) from an electronic cigarette, vape pen, or e-hookah? Please enter the number of days (from 0 to 30 days)." Students that reported 0 days were considered non-users (referent, coded as 0) and those that reported 1 or more days were users (coded as 1). Past 30-day e-cigarette use with marijuana (THC) was only assessed at Waves 3 through 9.

Statistical Analysis

First, we examined average trajectories of past 30-day e-cigarette use for each substance and cohort separately, then evaluated whether these trajectories overlapped at the same age(s) between cohorts. Growth curve models (GCMs) were applied to repeated measures data across all available Waves using generalized estimating equations (GEEs) with a log-link function. Log-linear models were employed, as they fit both e-cigarette use outcome variables best.[44–46] After average trajectories were identified, ageXcohort interaction effects were investigated using procedures described by Miyazaki & Raudenbush.[47] The quasi-likelihood-under-independence-model criterion (QIC) was used to test for differences in trajectories by cohort. If significant overlaps occur, data from multiple age cohorts (like these) could be combined into a single cohort for analysis using a cohort-sequential design.[47] We did not find this to be the case, here.

Next, we investigated whether the average trajectories for each cohort could be "split" into multiple trajectories to describe meaningful sub-groups of adolescents who followed a similar developmental pattern in past 30-day e-cigarette use with increasing age. To do so, growth mixture models (GMMs) were applied. Methods described by Nagin[48–50] and employed by others to identify developmental patterns in young people's cigarette smoking behavior[29–31] were utilized. Models representing 2 to 7 sub-groups were considered; the model with the lowest BIC score and the highest posterior probability was chosen for each variable.[49,50] Multivariate logit models were used to test for differences between these patterns, by sex, race/ethnicity, and SES; the non-user trajectory group served as referent (Table 1, Table 2).

Finally, we illustrated the average trajectories and developmental patterns in trajectories identified in analyses above, using non-parametric methods (Figure 1a, Figure 1b). As age is the primary independent variable in analysis, it is graphed on the x-axis; the number of days of e-cigarette use in the past 30 days (0–30), as the primary dependent variable, is on the y-axis. All methods were applied to all available data across all Waves for all students, providing robust estimates even in the presence of missing data, which was low.[51] Final sample sizes for each cohort, along with a description of missing data are provided in the footnotes of the Tables.

RESULTS

Past 30-day E-cigarette Use without Marijuana

The test of the ageXcohort interaction effect was statistically significant ($p<0.01$), providing evidence that the average trajectory or change in past 30-day e-cigarette use without marijuana with increasing age differed by cohort (Figure 1a, **Panel 1a**). While the trajectory for all cohorts increased with age, this increase occurred at younger ages for younger cohorts (6^{th} grade, 8^{th} grade), compared with the older cohort (10^{th} grade). At the same age (e.g., 16 years old), the frequency of past 30-day e-cigarette use without marijuana was, on average, highest for the 6^{th} grade cohort, followed by the 8^{th} grade and 10^{th} grade cohorts (Figure 1a, **Panel 1a**).

Next, within cohort, we identified sub-groups of adolescents who followed a similar developmental pattern of past 30-day e-cigarette use without marijuana as they aged. A 3-group solution fit the 6^{th} grade cohort best, and a 4-group solution fit the 8^{th} and 10^{th} grade cohorts best (Figure 1a, **Panel 1b**). With the exception of non-users (green pattern), all patterns of past 30-day e-cigarette use without marijuana escalated with increasing age for all cohorts. No declining patterns with increasing age were observed, for any cohort. Patterns included ‘early’ escalators (red pattern), ‘mid’ escalators (blue pattern), and ‘late’ escalators (purple pattern).

For the 6^{th} grade cohort, 9% of participants fell into one of two use patterns: (a) for 4% (‘early’ escalators), past 30-day e-cigarette use began early then escalated rapidly at age 13; while (b) for 5% (‘mid’ escalators), past 30-day e-cigarette use both began and escalated at age 14. By 16 years of age, past 30-day e-cigarette use without marijuana was higher for the ‘early’ escalators ($\bar{x} > 15$ days/month) compared to the ‘mid’ escalators ($\bar{x} < 10$ days/month).

For the 8^{th} grade cohort, 20% of participants fell into one of three use patterns: (a) for 9% (‘early’ escalators), past 30-day e-cigarette use began early then escalated quickly at age 14; (b) for 9% (‘mid’ escalators), past 30-day e-cigarette use began and escalated at age 15; and (c) for 2% (‘late’ escalators), past 30-day e-cigarette use began and escalated just before age 17. By 18 years of age, past 30-day e-cigarette use without marijuana among the ‘mid’ escalators ($\bar{x}$~20 days/month) had surpassed the ‘early’ escalators ($\bar{x}$~15 days/month), while use for ‘early’ and ‘mid’ escalators exceeded that of the ‘late’ escalators ($\bar{x}$~5 days/month).

For the 10^{th} grade cohort, 34% of participants fell into one of three use patterns: (a) for 6% (‘early’ escalators), past 30-day e-cigarette use began early in adolescence, prior to the age

of 14 and escalated thereafter; (b) for 18% ('mid' escalators), past 30-day e-cigarette use began before the age of 15 and escalated more rapidly after the age of 16; and (c) for 10% ('late' escalators), past 30-day e-cigarette use began and escalated at 17 years of age. By 19 years of age, past 30-day e-cigarette use without marijuana was highest among the 'early' escalators ($\bar{x}$~22 days/month), followed by 'mid' ($\bar{x}$~15 days/month) and 'late' ($\bar{x}$~10 days/month) escalator groups.

Finally, we investigated sociodemographic differences in patterns of past 30-day e-cigarette use without marijuana (Table 1a, Table 2a). For the 6th grade cohort, most non-users were in the middle SES group; most 'early' escalators were in the low or middle SES groups; and most 'mid' escalators were in the middle or high SES groups ($p<0.001$). For the 8th grade cohort, most non-users were non-Hispanic White or Hispanic, as were most 'early,' 'mid,' and 'late' escalators ($p<0.001$). For the 10th grade cohort, most non-users were female, while most 'early' escalators were male ($p<0.001$). In addition, more nonusers were Hispanic, while most 'early,' 'mid,' and 'late' escalators were either non-Hispanic White or Hispanic ($p<0.001$). No other statistically significant differences were observed.

Past 30-day E-cigarette Use with Marijuana

The test of the ageXcohort interaction effect was statistically significant ($p<0.01$), providing evidence that the average trajectory or change in past 30-day e-cigarette use with marijuana with increasing age differed by cohort (Figure 1b, **Panel 1a**). While the average trajectory of past 30-day e-cigarette use with marijuana remained relatively flat for the 6th grade cohort, it accelerated with age for the 8th and 10th grade cohorts. At the same age (e.g., 17 and 18 years old), the frequency of e-cigarette use with marijuana was higher in the 8th grade cohort compared to the 10th grade cohort (Figure 1b, **Panel 1a**).

Next, within cohort, we again identified sub-groups of adolescents who followed a similar developmental pattern of past 30-day e-cigarette use with marijuana as they aged. A 2-class solution fit all cohorts best: 7%, 8%, and 12% of the 6th, 8th, and 10th grade cohorts fell into one e-cigarette use pattern (red; Figure 1b, **Panel 1b**), while the rest (green pattern) remain non-users. Past 30-day e-cigarette use with marijuana consistently escalated with increasing age for the 8th and 10th grade cohorts; but, for the 6th grade cohort, it peaked at age 15 then declined somewhat. On average, the use of marijuana in these devices never exceeded 10 days/month.

We also investigated sociodemographic differences in patterns of past 30-day e-cigarette use with marijuana (Table 1b, Table 2b). For the 6th grade cohort, most non-users were in the middle SES group ($p<0.021$). No other statistically significant differences were observed.

DISCUSSION

This is the first study to describe developmental trajectories of past 30-day e-cigarette use across adolescence, from 11 to 19 years of age. Importantly, it demonstrates that stable trajectories of e-cigarette use with and without marijuana (i.e., liquid THC) do exist, which has important implications for interventions. Our analysis described meaningful trajectories that occur 'on average' and include subgroup variation. Trajectories varied by cohort; age of

onset; frequency and escalation in use; and substance used. With only one exception, all trajectories of e-cigarette use escalated with age. Moreover, age of onset and progression in use were positively related. That is, the younger one started, the more one used later, providing support for primary prevention as an important component of comprehensive tobacco control efforts that focus on e-cigarette use. Interventions to prevent the onset and progression in e-cigarette use among youth must begin early (i.e., in middle school) and be sustained throughout adolescence.

E-cigarette use without marijuana was more prevalent than e-cigarette use with it, consistent with differences in national prevalence estimates, at present (i.e., 2019).[3,52] While marijuana use never exceeded 5–10 days per month, use of e-cigarettes without marijuana, at its peak, ranged from 10 to 20+ days per month. Our measure of the latter was not specific to quantity of nicotine used, which is difficult to disentangle in research. Most e-cigarette products are not clearly labeled in regards to their nicotine content, suggesting self-reports of use may be biased.[53,54] Future research that examines differences by device type or brand may be able to differentiate between trajectories with higher or lower/no nicotine, as certain brands (e.g., JUUL) and device types (e.g., vape pens, mods) are known to contain higher levels of nicotine than others.[55–57] Use of any e-cigarette product, with or without these substances, still confers risk.[15] Our data suggest marijuana use in these devices may be highest for non-Hispanic Blacks, while use of nicotinized or denicotinized e-liquids is most common for non-Hispanic Whites. Notably, few differences by socioeconomic status were noted, and no differences by sex were observed.

While vaping nicotine and marijuana are distinct behaviors that have differential legal consequences, there are many similarities in risk factors for use, and their use patterns can be strongly linked.[58] Importantly, smoking combustible THC is still the most common mode of using marijuana among adolescents, followed by edibles, and vaping.[59] Conversely, vaping is now the preferred method for using nicotine among youth, having eclipsed cigarette smoking in 2014.[60] While a recent California study of trajectories of nicotine vaping and cannabis vaping across late adolescence into early adulthood showed similarities between trajectories,[35] our study from Texas showed differences. This contrast in findings may lie in differences between substances and/or contexts, particularly specific to legalization of these products.[61] For example, THC vaping products may be more accessible (albeit still not legal to purchase) for adolescents in states like California where adults can purchase these products legally – and less accessible in states like Texas, where they are illegal to purchase for both adolescents and adults. Texas recently raised the legal age of tobacco use to 21,[62] yet recreational marijuana (i.e., THC) use remains illegal in the state of Texas for everyone. Studies show marijuana (i.e., THC) use rates among youth vary between states that do and do not prohibit marijuana use among adults.[63–65]

Cost may also be a factor in understanding differences in e-cigarette use trajectories by substance. Youth are more price sensitive than adults as they do not have as much disposable income as older age groups.[67] The cost of a 2-pack of JUUL (a popular brand of e-cigarette) cartridges is roughly $10,[62] while a 1-gram cartridge of marijuana can cost over $50.[68] Ultimately, these differences may explain why youth in our sample report less frequent use

of e-cigarettes with marijuana (max 5–10 days per month) as compared to nicotine (10 to 20+ days per month).

E-cigarettes were first introduced to the marketplace in the United States in 2007,[69] while monitoring and surveillance of its use among youth began in 2011.[6] As prevalence escalated quickly for this vulnerable sub-group as a whole, few explicit comparisons have been made to determine whether introduction of this tobacco product may have differentially impacted younger or older youth. Unfortunately, our analyses suggest younger cohorts have and may continue to bear the brunt of this epidemic, as it continues to unfold over time. Onset of use occurred at earlier ages for younger cohorts (i.e., 6th and 8th grade cohorts) and progressed more quickly to more frequent use, compared to the oldest cohort (i.e., 10th grade). This is worrisome, as earlier onset of substance use (e.g., alcohol use, tobacco use, marijuana use) often predicts worse health outcomes.[32,70,71] Future research is needed to determine what risk factors differentially predict these trajectories, across age groups. Early adolescence may simply be a developmental period characterized by more susceptibility to ENDS use, or other factors may be responsible for this finding, such as product characteristics (e.g., flavors, device type), industry advertising, or social media that may be especially appealing to young adolescents. Alternatively, young people's perceptions of the harm or addictiveness of these products may differ by age and/or cohort or secular trends in ENDS use across this period (2014–19) may be responsible for findings.[72,73] Continued longitudinal research is also needed to track adolescents into young adulthood, to determine how e-cigarette use trajectories unfold over time. Trajectories, by definition, confer momentum. Young adulthood is the developmental period during which use of tobacco products stabilizes and becomes established, behaviorally speaking.[74–78] It is yet unclear whether these trajectories of e-cigarette use identified in adolescence will escalate, stabilize, and/or decline in young adulthood.

Limitations of this study include its reliance on self-report data from regional cohorts. At the time of study (2014–19), both marijuana (i.e., liquid THC) and nicotine (i.e., e-cigarette and other tobacco product use) were illicit substances for youth under the age of 18 in the state of Texas. Generalizability of findings may be limited to major metropolitan areas in Texas, though the prevalence of e-cigarette use behaviors reported here are comparable to national studies.[78] Findings specific to marijuana use, however, may not generalize to other places where medicinal and/or recreational use are no longer illegal among adults over the age of 21.

CONCLUSION

This longitudinal study provides 5 years of follow-up data (2014–19) across adolescence (11–19 years old). Comparisons are made not only between substances vaped, but also between cohorts, thereby differentiating between trajectories in early (i.e., 11–15 years old), middle (i.e., 13–17 years old), and late (i.e., 15–19 years old) adolescence, adding to emerging evidence-based perspectives on developmental trajectories of e-cigarette use with and without marijuana.[33–37] Stable trajectories of past 30-day e-cigarette use with and without marijuana do exist among young people, may be most problematic among younger cohorts of adolescents, and escalate with age. Interventions to re-direct the most problematic

trajectories of e-cigarette use among adolescents are urgently needed and must start early in the life course.

Funding

Research reported in this paper was supported by grants [1 P50 CA180906 and 1R01 CA239097] from the National Cancer Institute (NCI) and the FDA Center for Tobacco Products (CTP).

Role of Funder

The NCI, NIH or FDA had no role in the design and conduct of the study. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH (NCI) or the FDA.

REFERENCES

1. Wang TW, Gentzke AS, Creamer MR, et al. Tobacco product use and associated factors among middle and high school students—United States, 2019. MMWR Surveillance Summaries. 2019;68(12):1.
2. Cullen KA, Gentzke AS, Sawdey MD, et al. E-cigarette use among youth in the United States, 2019. Jama. 2019;322(21):2095–2103. [PubMed: 31688912]
3. Murthy VH. E-cigarette use among youth and young adults: a major public health concern. JAMA pediatrics. 2017;171(3):209–210. [PubMed: 27928577]
4. King BA, Jones CM, Baldwin GT, Briss PA. The EVALI and youth vaping epidemics—implications for public health. New England Journal of Medicine. 2020;382(8):689–691.
5. Marcellin L. What are the potential harms and benefits of e-cigarettes? Elsevier Connect 2019; https://www.elsevier.com/connect/what-are-the-potential-harms-and-benefits-of-e-cigarettes#:~:text=%20E-cigarettes%20have%20many%20potential%20dangers%3A%20%201,can%20sensitize%20adolescents%20to%20cocaine%20and…%20More%20. Accessed July 24, 2020.
6. Health UDo, Services H. E-cigarette use among youth and young adults: A report of the Surgeon General. 2016.
7. Rao DR, Maple KL, Dettori A, et al. Clinical features of e-cigarette, or vaping, product use–associated lung injury in teenagers. Pediatrics. 2020.
8. Perrine CG, Pickens CM, Boehmer TK, et al. Characteristics of a multistate outbreak of lung injury associated with e-cigarette use, or vaping—United States, 2019. Morbidity and Mortality Weekly Report. 2019;68(39):860. [PubMed: 31581168]
9. Adkins SH, Anderson KN, Goodman AB, et al. Demographics, Substance Use Behaviors, and Clinical Characteristics of Adolescents With e-Cigarette, or Vaping, Product Use–Associated Lung Injury (EVALI) in the United States in 2019. JAMA Pediatrics. 2020:e200756–e200756. [PubMed: 32421164]
10. Brown CJ, Cheng JM. Electronic cigarettes: product characterisation and design considerations. Tobacco control. 2014;23(suppl 2):ii4–ii10. [PubMed: 24732162]
11. Blount BC, Karwowski MP, Shields PG, et al. Vitamin E acetate in bronchoalveolar-lavage fluid associated with EVALI. New England Journal of Medicine. 2020;382(8):697–705.
12. Eaton DL, Kwan LY, Stratton K, National Academies of Sciences E, Medicine. Toxicology of E-Cigarette Constituents. Public Health Consequences of E-Cigarettes: National Academies Press (US); 2018.
13. Case KR, Mantey DS, Creamer MR, Harrell MB, Kelder SH, Perry CL. E-cigarette-specific symptoms of nicotine dependence among Texas adolescents. Addictive behaviors. 2018;84:57–61. [PubMed: 29627634]
14. Know the Risks of E-cigarettes for Young People: Know the Risks: E-cigarettes & Young People: U.S. Surgeon General's Report. . https://e-cigarettes.surgeongeneral.gov/knowtherisks.html. Accessed July 24, 2020.
15. CA TF. The Effects Of Nicotine On The Adolescent Brain. 2020; https://tobaccofreeca.com/e-cigarettes/the-effects-of-nicotine-on-the-adolescent-brain/. Accessed July 24, 2020.

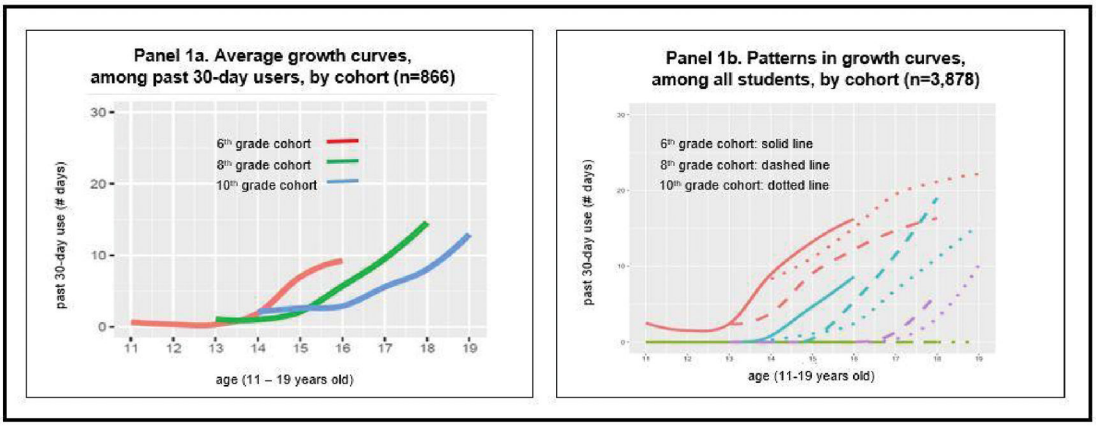
16. Odani S, Armour BS, King BA, Agaku IT. E-Cigarette Use and Subsequent Cigarette Initiation and Sustained Use Among Youth, US, 2015–2017. Journal of Adolescent Health. 2020;66(1):34–38.
17. Soneji S, Barrington-Trimis JL, Wills TA, et al. Association between initial use of e-cigarettes and subsequent cigarette smoking among adolescents and young adults: a systematic review and meta-analysis. JAMA pediatrics. 2017;171(8):788–797. [PubMed: 28654986]
18. Miech R, Keyes KM, O'Malley PM, Johnston LD. The great decline in adolescent cigarette smoking since 2000: consequences for drug use among US adolescents. Tobacco Control. 2020.
19. Miech RA, Patrick ME, O'Malley PM, Johnston LD, Bachman JG. Trends in reported marijuana vaping among US adolescents, 2017–2019. Jama. 2020;323(5):475–476. [PubMed: 31848566]
20. Villanti AC, Pearson JL, Glasser AM, et al. Frequency of youth e-cigarette and tobacco use patterns in the United States: Measurement precision is critical to inform public health. Nicotine & Tobacco Research. 2017;19(11):1345–1350. [PubMed: 28013271]
21. Lanza ST, Russell MA, Braymiller JL. Emergence of electronic cigarette use in US adolescents and the link to traditional cigarette use. Addictive behaviors. 2017;67:38–43. [PubMed: 27988415]
22. Chen X, Yu B, Wang Y. Initiation of electronic cigarette use by age among youth in the US. American journal of preventive medicine. 2017;53(3):396–399. [PubMed: 28372920]
23. Leventhal AM, Stone MD, Andrabi N, et al. Association of e-cigarette vaping and progression to heavier patterns of cigarette smoking. Jama. 2016;316(18):1918–1920. [PubMed: 27825000]
24. Hair EC, Romberg AR, Niaura R, et al. Longitudinal tobacco use transitions among adolescents and young adults: 2014–2016. Nicotine and Tobacco Research. 2019;21(4):458–468. [PubMed: 29452385]
25. Niaura R, Rich I, Johnson AL, et al. Young adult tobacco and e-cigarette use transitions: examining stability using multistate modeling. Nicotine and Tobacco Research. 2020;22(5):647–654. [PubMed: 30820566]
26. Schneider S, Diehl K. Vaping as a catalyst for smoking? An initial model on the initiation of electronic cigarette use and the transition to tobacco smoking among adolescents. Nicotine & Tobacco Research. 2016;18(5):647–653. [PubMed: 26386472]
27. Cherng ST, Tam J, Christine P, Meza R. Modeling the effects of e-cigarettes on smoking behavior: implications for future adult smoking prevalence. Epidemiology (Cambridge, Mass). 2016;27(6):819.
28. Amato MS, Boyle RG, Levy D. How to define e-cigarette prevalence? Finding clues in the use frequency distribution. Tobacco control. 2016;25(e1):e24–e29. [PubMed: 26085124]
29. Chassin L, Presson CC, Pitts SC, Sherman SJ. The natural history of cigarette smoking from adolescence to adulthood in a midwestern community sample: multiple trajectories and their psychosocial correlates. Health Psychology. 2000;19(3):223. [PubMed: 10868766]
30. Bernat DH, Erickson DJ, Widome R, Perry CL, Forster JL. Adolescent smoking trajectories: results from a population-based cohort study. Journal of Adolescent Health. 2008;43(4):334–340.
31. Dutra LM, Glantz SA, Lisha NE, Song AV. Beyond experimentation: Five trajectories of cigarette smoking in a longitudinal sample of youth. PloS one. 2017;12(2):e0171808. [PubMed: 28182748]
32. U.S. Department of Health and Human Services. Preventing Tobacco Use Among Youth and Young Adults: A Report of the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, 2012.
33. Boyd CJ, Veliz P, Evans-Polce R, Eisman AB, McCabe SE. Latent class trajectories: US adolescents' nicotine use and its association with nicotine dependence. Addictive Behaviors Reports. 2020;12:100303. [PubMed: 33364312]
34. Kwon E, Adams Z, Seo D-C. Trajectories and determinants of adolescents' nicotine product use risk among US adolescents in a nationally representative sample of longitudinal cohort. Addictive Behaviors. 2021;116:106812. [PubMed: 33421749]
35. Lanza HI, Barrington-Trimis JL, McConnell R, et al. Trajectories of Nicotine and Cannabis Vaping and Polyuse From Adolescence to Young Adulthood. JAMA network open. 2020;3(10):e2019181–e2019181. [PubMed: 33021651]

36. Park E, Livingston JA, Wang W, Kwon M, Eiden RD, Chang Y-P. Adolescent E-cigarette use trajectories and subsequent alcohol and marijuana use. Addictive behaviors. 2020;103:106213. [PubMed: 31862618]
37. Westling E, Rusby JC, Crowley R, Light JM. Electronic cigarette use by youth: prevalence, correlates, and use trajectories from middle to high school. Journal of Adolescent Health. 2017;60(6):660–666.
38. Pérez A, Harrell MB, Malkani RI, et al. Texas adolescent tobacco and marketing surveillance system's design. Tobacco regulatory science. 2017;3(2):151–167. [PubMed: 29098172]
39. Delk J, Harrell MB, Fakhouri TH, Muir KA, Perry CL. Implementation of a Computerized Tablet-Survey in an Adolescent Large-Scale, School-Based Study. Journal of School Health. 2017;87(7):506–512.
40. Cantrell J, Hair EC, Smith A, et al. Recruiting and retaining youth and young adults: challenges and opportunities in survey research for tobacco control. Tobacco Control. 2018;27(2):147–154. [PubMed: 28432211]
41. Hyland A, Ambrose BK, Conway KP, et al. Design and methods of the Population Assessment of Tobacco and Health (PATH) Study. Tobacco control. 2017;26(4):371–378. [PubMed: 27507901]
42. Prevention. CfDCa. National Youth Tobacco Survey (NYTS). https://www.cdc.gov/tobacco/data_statistics/surveys/nyts/index.htm. Accessed July 24, 2020.
43. Bachman JG, Johnston LD, O'Malley PM, Schulenberg JE. The Monitoring the Future Project After Thirty-Two Years: Design and Procedures. Monitoring the Future Occasional Paper 64. Online Submission. 2006.
44. Grimm KJ, Ram N, Hamagami F. Nonlinear growth curves in developmental research. Child development. 2011;82(5):1357–1371. [PubMed: 21824131]
45. Cudeck R, Harring JR. Analysis of nonlinear patterns of change with random coefficient models. Annu Rev Psychol. 2007;58:615–637. [PubMed: 16953795]
46. Biesanz JC, Deeb-Sossa N, Papadakis AA, Bollen KA, Curran PJ. The role of coding time in estimating and interpreting growth curve models. Psychological methods. 2004;9(1):30. [PubMed: 15053718]
47. Miyazaki Y, Raudenbush SW. Tests for linkage of multiple cohorts in an accelerated longitudinal design. Psychological methods. 2000;5(1):44. [PubMed: 10937322]
48. Reinecke J, Seddig D. Growth mixture models in longitudinal research. AStA Advances in Statistical Analysis. 2011;95(4):415–434.
49. Nagin DS, NAGIN D. Group-based modeling of development. Harvard University Press; 2005.
50. Nagin DS. Analyzing developmental trajectories: a semiparametric, group-based approach. Psychological methods. 1999;4(2):139.
51. Schafer JL, Graham JW. Missing data: our view of the state of the art. Psychological methods. 2002;7(2):147. [PubMed: 12090408]
52. Miech R, Johnston L, O'Malley PM, Bachman JG, Patrick ME. Trends in adolescent vaping, 2017–2019. New England Journal of Medicine. 2019;381(15):1490–1491.
53. Buonocore F, Gomes ACM, Nabhani-Gebara S, Barton SJ, Calabrese G. Labelling of electronic cigarettes: regulations and current practice. Tobacco control. 2017;26(1):46–52. [PubMed: 26790924]
54. Marynak KL, Gammon DG, Rogers T, Coats EM, Singh T, King BA. Sales of nicotine-containing electronic cigarette products: United States, 2015. American journal of public health. 2017;107(5):702–705. [PubMed: 28323467]
55. Initiative T. How much nicotine is in JUUL? 2019; https://truthinitiative.org/research-resources/emerging-tobacco-products/how-much-nicotine-juul. Accessed July 24,, 2020.
56. Talih S, Salman R, El-Hage R, et al. Characteristics and toxicant emissions of JUUL electronic cigarettes. Tobacco control. 2019;28(6):678–680. [PubMed: 30745326]
57. Jackler RK, Ramamurthi D. Nicotine arms race: JUUL and the high-nicotine product market. Tobacco control. 2019;28(6):623–628. [PubMed: 30733312]
58. Dai H, Catley D, Richter KP, Goggin K, Ellerbeck EF. Electronic cigarettes and future marijuana use: a longitudinal study. Pediatrics. 2018;141(5).

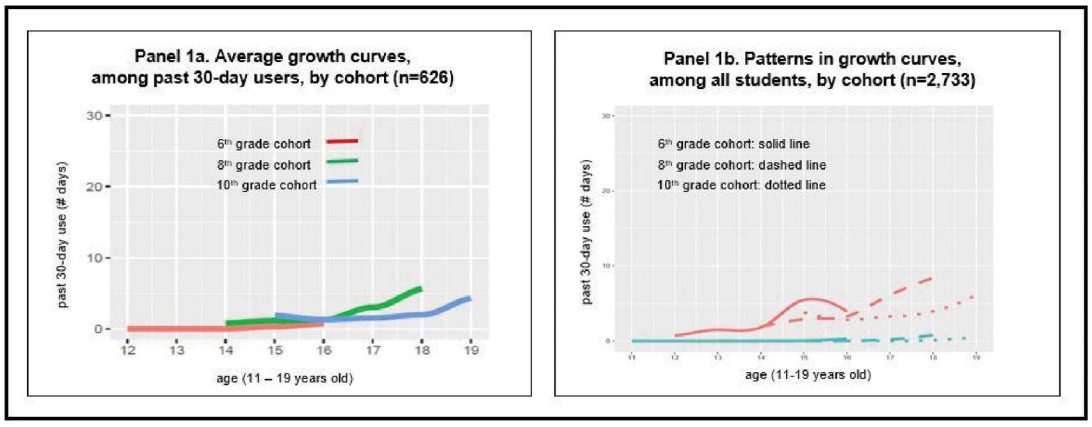
59. Knapp AA, Lee DC, Borodovsky JT, Auty SG, Gabrielli J, Budney AJ. Emerging trends in cannabis administration among adolescent cannabis users. Journal of Adolescent Health. 2019;64(4):487–493.
60. Gentzke AS, Creamer M, Cullen KA, et al. Vital signs: tobacco product use among middle and high school students—United States, 2011–2018. Morbidity and Mortality Weekly Report. 2019;68(6):157. [PubMed: 30763302]
61. Borodovsky JT, Lee DC, Crosier BS, Gabrielli JL, Sargent JD, Budney AJ. US cannabis legalization and use of vaping and edible products among youth. Drug and alcohol dependence. 2017;177:299–306. [PubMed: 28662974]
62. https://www.juul.com/shop/pods. Accessed February 22, 2021.
63. Wen H, Hockenberry JM, Cummings JR. The effect of medical marijuana laws on adolescent and adult use of marijuana, alcohol, and other substances. Journal of health economics. 2015;42:64–80. [PubMed: 25863001]
64. Coley RL, Hawkins SS, Ghiani M, Kruzik C, Baum CF. A quasi-experimental evaluation of marijuana policies and youth marijuana use. The American journal of drug and alcohol abuse. 2019;45(3):292–303. [PubMed: 30764656]
65. Pacula RL, Powell D, Heaton P, Sevigny EL. Assessing the effects of medical marijuana laws on marijuana use: the devil is in the details. Journal of Policy Analysis and Management. 2015;34(1):7–31. [PubMed: 25558490]
66. Wagner AC, Parks MJ, Patrick ME. How do high school seniors get marijuana? Prevalence and sociodemographic differences. Addictive Behaviors. 2021;114:106730. [PubMed: 33234360]
67. Chaloupka FJ, Cummings KM, Morley CP, Horan JK. Tax, price and cigarette smoking: evidence from the tobacco documents and implications for tobacco company marketing strategies. Tobacco Control. 2002;11(suppl 1):i62–i72. [PubMed: 11893816]
68. Firth CL, Davenport S, Smart R, Dilley JA. How high: differences in the developments of cannabis markets in two legalized states. The International journal on drug policy. 2020;75:102611. [PubMed: 31786435]
69. Lichtenberg K. E-cigarettes: current evidence and policy. Missouri Medicine. 2017;114(5):335. [PubMed: 30228625]
70. Brook JS, Stimmel MA, Zhang C, Brook DW. The association between earlier marijuana use and subsequent academic achievement and health problems: A longitudinal study. American Journal on Addictions. 2008;17(2):155–160.
71. Poudel A, Gautam S. Age of onset of substance use and psychosocial problems among individuals with substance use disorders. BMC psychiatry. 2017;17(1):1–7. [PubMed: 28049496]
72. Johnston LD, Miech RA, O'Malley PM, Bachman JG, Schulenberg JE, Patrick ME. Monitoring the Future National Survey Results on Drug Use, 1975–2018: Overview, Key Findings on Adolescent Drug Use. Institute for Social Research. 2019.
73. Wang TW, Neff LJ, Park-Lee E, Ren C, Cullen KA, King BA. E-cigarette use among middle and high school students—United States, 2020. Morbidity and Mortality Weekly Report. 2020;69(37):1310. [PubMed: 32941408]
74. Berg CJ, Haardörfer R, Lanier A, et al. Tobacco use trajectories in young adults: Analyses of predictors across systems levels. Nicotine & Tobacco Research. 2020.
75. Johnson AL, Collins LK, Villanti AC, Pearson JL, Niaura RS. Patterns of nicotine and tobacco product use in youth and young adults in the United States, 2011–2015. Nicotine and Tobacco Research. 2018;20(suppl_1):S48–S54. [PubMed: 30125012]
76. Rath JM, Villanti AC, Abrams DB, Vallone DM. Patterns of tobacco use and dual use in US young adults: the missing link between youth prevention and adult cessation. Journal of environmental and public health. 2012;2012.
77. Arnett JJ. The developmental context of substance use in emerging adulthood. Journal of drug issues. 2005;35(2):235–254.
78. Perry CL, Pérez A, Bluestein M, et al. Youth or young adults: which group is at highest risk for tobacco use onset? Journal of Adolescent Health. 2018;63(4):413–420.

HIGHLIGHTS

- Identifies trajectories of e-cigarette use across adolescence (11–19 years old)
- Trajectories are modeled separately for use with and without marijuana (i.e., liquid THC)
- Trajectories vary by age of onset; frequency and escalation in use; substance use
- Primary prevention of e-cigarette use among younger adolescents is especially critical



a. Past 30-day E-cigarette Use without Marijuana



b. Past 30-day E-cigarette Use with Marijuana

Figure 1.

Stable trajectories of past 30-day e-cigarette use with and without marijuana, by cohort; the Texas Adolescent Tobacco and Marketing Surveillance System (TATAMS), Waves 1–9, 2014–2019

Table 1.

Differences in developmental patterns of e-cigarette use, by cohort and sociodemographic factors[b–f]; the Texas Adolescent Tobacco and Marketing Surveillance System (TATAMS), Waves 1–9, 2014–2019

Table 1a. Past 30-day E-cigarette Use without Marijuana **(Waves 1–9, 2014–2019; n=3,878)**

	Pattern 1 Non-users		**Pattern 2 'Early' escalators**		**Pattern 3 'Mid' escalators**		**Pattern 4 'Late' escalators**		
	%[a]	**95% CI**	**%[a]**	**95% CI**	**%[a]**	**95% CI**	**%[a]**	**95% CI**	**p-value**
6th grade cohort									
n	*1013*	--	*28*	--	*68*	--			
% of cohort	91%		3%		6%				
Gender									0.533
Female	60.5	(57.4 – 63.5)	50.0	(30.6 – 69.4)	60.3	(47.7 – 72.0)			
Male	39.5	(36.5 – 42.6)	50.0	(30.6 – 69.4)	39.7	(28.0 – 52.3)			
Race/ethnicity									0.196
Non-Hispanic White	30.2	(27.4 – 33.1)	25.0	(10.7 – 44.9)	42.6	(30.7 – 55.2)			
Non-Hispanic Black	13.6	(11.6 – 15.9)	10.7	(2.3 – 28.2)	4.4	(0.9 – 12.4)			
Hispanic	40.9	(37.8 – 44.0)	42.9	(24.5 – 62.8)	38.2	(26.7 – 50.8)			
Other	15.3	(13.1 – 17.7)	21.4	(8.3 – 41.0)	14.7	(7.3 – 25.4)			
SES									<0.001
Low	11.8	(9.9 – 14.0)	46.4	(27.5 – 66.1)	11.8	(5.2 – 21.9)			
Middle	63.1	(60.0 – 66.1)	42.9	(24.5 – 62.8)	55.9	(43.3 – 67.9)			
High	25.1	(22.4 – 27.9)	10.7	(2.3 – 28.2)	32.4	(21.5 – 44.8)			
8th grade cohort									
n	*1025*		*108*	--	*146*	--	*34*	--	
% of cohort	78%		8%		11%		3%		
Gender									0.598
Female	54.0	(50.8 – 57.0)	52.8	(42.9 – 62.5)	48.6	(40.3 – 57.0)	58.8	(40.7 – 75.4)	
Male	46.0	(43.0 – 49.2)	47.2	(37.5 – 57.1)	51.4	(43.0 – 59.7)	41.2	(24.6 – 59.3)	
Race/ethnicity									<0.001
Non-Hispanic White	33.6	(30.7 – 36.5)	30.6	(22.1 – 40.2)	52.7	(44.3 – 61.1)	44.1	(27.2 – 62.1)	
Non-Hispanic Black	15.9	(13.7 – 18.3)	13.9	(8.0 – 21.9)	4.1	(1.5 – 8.7)	0.0	(0.0 – 10.3)	
Hispanic	36.1	(33.2 – 39.1)	41.7	(32.3 – 51.5)	28.8	(21.6 – 36.8)	32.4	(17.4 – 50.5)	
Other	14.4	(12.3 – 16.7)	13.9	(8.0 – 21.9)	14.4	(9.1 – 21.1)	23.5	(10.7 – 41.2)	
SES									0.747
Low	14.3	(12.2 – 16.6)	13.9	(8.0 – 21.9)	13.0	(8.0 – 19.6)	11.8	(3.3 – 27.5)	

Table 1a. Past 30-day E-cigarette Use without Marijuana **(Waves 1–9, 2014–2019; n=3,878)**

	Pattern 1 Non-users		**Pattern 2 'Early' escalators**		**Pattern 3 'Mid' escalators**		**Pattern 4 'Late' escalators**		
	%[a]	**95% CI**	**%[a]**	**95% CI**	**%[a]**	**95% CI**	**%[a]**	**95% CI**	**p-value**
Middle	61.6	(58.5 – 64.6)	57.4	(47.5 – 66.9)	56.8	(48.4 – 65.0)	64.7	(46.5 – 80.3)	
High	24.1	(21.6 – 26.9)	28.7	(20.4 – 38.2)	30.1	(22.8 – 38.3)	23.5	(10.7 – 41.2)	
10th grade cohort									
n	*966*		*90*	--	*246*	--	*154*	--	
% of cohort	66%		6%		17%		11%		
Gender									<0.001
Female	58.5	(55.3 – 61.6)	34.4	(24.7 – 45.2)	50.4	(44.0 – 56.8)	55.2	(47.0 – 63.2)	
Male	41.5	(38.4 – 44.7)	65.6	(54.8 – 75.3)	49.6	(43.2 – 56.0)	44.8	(36.8 – 53.0)	
Race/ethnicity									
Non-Hispanic White	24.0	(21.4 – 26.8)	45.6	(35.0 – 56.4)	30.9	(25.2 – 37.1)	33.8	(26.4 – 41.8)	<0.001
Non-Hispanic Black	22.7	(20.1 – 25.4)	14.4	(7.9 – 23.4)	13.0	(9.1 – 17.9)	14.3	(9.2 – 20.8)	
Hispanic	39.3	(36.2 – 42.5)	31.1	(21.8 – 41.7)	43.1	(36.8 – 49.5)	35.7	(28.2 – 43.8)	
Other	14.0	(11.8 – 16.3)	8.9	(3.9 – 16.8)	13.0	(9.1 – 17.9)	16.2	(10.8 – 23.0)	
SES									0.238
Low	17.3	(14.9 – 19.8)	24.4	(16.0 – 34.6)	21.1	(16.2 – 26.8)	24.7	(18.1 – 32.3)	
Middle	64.1	(61.0 – 67.1)	60.0	(49.1 – 70.2)	61.0	(54.6 – 67.1)	60.4	(52.2 – 68.2)	
High	18.6	(16.2 – 21.2)	15.6	(8.8 – 24.7)	17.9	(13.3 – 23.3)	14.9	(9.7 – 21.6)	

Table 1b. Past 30-day E-cigarette Use without Marijuana **(Waves 3–9, 2015–2019; n=2,733)**

	Pattern 1 Non-users		**Pattern 2 Escalators**		
	%[a]	**95% CI**	**%[a]**	**95% CI**	**p-value**
6th grade cohort					
n	*729*	--	*36*	--	
% of cohort	95%		5%		
Gender					0.236
Female	58.0	(54.3 – 61.6)	69.4	(51.9 – 83.7)	
Male	42.0	(38.4 – 45.7)	30.6	(16.3 – 48.1)	
Race/ethnicity					0.168
Non-Hispanic White	33.9	(30.4 – 37.4)	30.6	(16.3 – 48.1)	
Non-Hispanic Black	11.5	(9.3 – 14.1)	2.8	(0.1 – 14.5)	
Hispanic	36.9	(33.4 – 40.5)	52.8	(35.5 – 69.6)	

Table 1b. Past 30-day E-cigarette Use without Marijuana (Waves 3–9, 2015–2019; n=2,733)					
	Pattern 1 Non-users		Pattern 2 Escalators		
	%[a]	95% CI	%[a]	95% CI	p-value
Other	17.7	(15.0 – 20.7)	13.9	(4.7 – 29.5)	
SES					0.021
Low	13.9	(11.4 – 16.6)	30.6	(16.3 – 48.1)	
Middle	64.3	(60.7 – 67.8)	50.0	(32.9 – 67.1)	
High	21.8	(18.9 – 25.0)	19.4	(8.2 – 36.0)	
8th grade cohort					
n	*835*		*78*	--	
% of cohort	91%		9%		
Gender					0.657
Female	54.4	(50.9 – 57.8)	57.7	(46.0 – 68.8)	
Male	45.6	(42.2 – 49.1)	42.3	(31.2 – 54.0)	
Race/ethnicity					0.507
Non-Hispanic White	37.8	(34.5 – 41.2)	37.2	(26.5 – 48.9)	
Non-Hispanic Black	13.2	(11.0 – 15.7)	9.0	(3.7 – 17.6)	
Hispanic	32.6	(29.4 – 35.9)	39.7	(28.8 – 51.5)	
Other	16.4	(14.0 – 19.1)	14.1	(7.3 – 23.8)	
SES					0.597
Low	16.2	(13.8 – 18.9)	19.2	(11.2 – 29.7)	
Middle	64.7	(61.4 – 68.0)	59.0	(47.3 – 70.0)	
High	19.1	(16.5 – 21.9)	21.8	(13.2 – 32.6)	
10th grade cohort					
n	*931*		*124*	--	
% of cohort	88%		12%		
Gender					0.171
Female	58.5	(55.3 – 61.7)	51.6	(42.5 – 60.7)	
Male	41.5	(38.3 – 44.7)	48.4	(39.3 – 57.5)	
Race/ethnicity					0.455
Non-Hispanic White	26.2	(23.4 – 29.2)	29.8	(22.0 – 38.7)	
Non-Hispanic Black	20.3	(17.8 – 23.0)	14.5	(8.8 – 22.0)	
Hispanic	39.0	(35.8 – 42.2)	39.5	(30.9 – 48.7)	
Other	14.5	(12.3 – 16.9)	16.1	(10.1 – 23.8)	
SES					0.099
Low	23.5	(20.8 – 26.3)	24.2	(17.0 – 32.7)	
Middle	65.9	(62.7 – 68.9)	58.9	(49.7 – 67.6)	
High	10.7	(8.7 – 12.8)	16.9	(10.8 – 24.7)	

[a]Column percentages represent prevalence within pattern and stratum (e.g., % female in Pattern 1).

[b]3907 participants were enrolled in TATAMS at Wave 1. After excluding those not 11–19 years of age across Waves 1–9 (n=4), there were 1119 participants in 6th Grade Cohort, 1322 participants in 8th Grade Cohort and 1462 participants in 10th Grade Cohort. Participants were further

excluded from each cohort if they did not complete the survey at Wave 1, leaving 1109 participants in 6th Grade Cohort, 1313 participants in 8th Grade Cohort and 1456 participants in 10th Grade Cohort (n=3878) for the final analysis sample.

[c]To assess Cohort, participants were asked 'What Grade are you in?'. The response options at Wave 1 were '6th', '7th', '8th', '9th', '10th', '11th' and '12th'. All 7th, 11th, and 12th grade students were removed and all 9th grade students were classified as 10th grade. 6th, 8th and 10th Grade students were retained in the survey (n=3907) and followed longitudinally as '6th grade cohort,' '8th grade cohort' and '10th grade cohort.'

[d]To assess Gender, participants were asked 'What is your gender?' and response options were 'Male' and 'Female.'

[e]To assess Race/ethnicity, participants were asked 'Are you Hispanic or Latino/a?' and 'What race or races do you consider yourself to be?' respectively. The response options (Hispanic, White, Black or African American, Asian, American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander and Other) were used to derive the measure of race/ethnicity (Non-Hispanic White, Non-Hispanic Black, Hispanic, Other).

[f]To assess SES, participants were asked 'In terms of income, what best describes your family's standard of living in the home where you live most of the time?' and the response options provided were 'Very well off,' 'Living comfortably,' 'Just getting by,' 'Nearly poor' and 'Poor.' 'Very well off' was categorized as 'High SES.' 'Living comfortably' was categorized as 'Middle SES' and 'Just getting by.' 'Nearly poor' and 'Poor' were combined to derive 'Low SES.'

[a]Column percentages represent prevalence within pattern and stratum (e.g., % female in Pattern 1).

[b]3907 participants were enrolled in TATAMS at Wave 1. After excluding those not 11–19 years of age across Waves 1–9 (n=4), there were 1119 participants in 6th Grade Cohort, 1322 participants in 8th Grade Cohort and 1462 participants in 10th Grade Cohort. Participants were further excluded from each cohort if they did not complete the survey at Wave 1, leaving 1109 participants in 6th Grade Cohort, 1313 participants in 8th Grade Cohort and 1456 participants in 10th Grade Cohort (n=3878) for the final analysis sample.

[c]To assess Cohort, participants were asked 'What Grade are you in?'. The response options at Wave 1 were '6th', '7th', '8th', '9th', '10th', '11th' and '12th'. All 7th, 11th, and 12th grade students were removed and all 9th grade students were classified as 10th grade. 6th, 8th and 10th Grade students were retained in the survey (n=3907) and followed longitudinally as '6th grade cohort,' '8th grade cohort' and '10th grade cohort.'

[d]To assess Gender, participants were asked 'What is your gender?' and response options were 'Male' and 'Female.'

[e]To assess Race/ethnicity, participants were asked 'Are you Hispanic or Latino/a?' and 'What race or races do you consider yourself to be?' respectively. The response options (Hispanic, White, Black or African American, Asian, American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander and Other) were used to derive the measure of race/ethnicity (Non-Hispanic White, Non-Hispanic Black, Hispanic, Other).

[f]To assess SES, participants were asked 'In terms of income, what best describes your family's standard of living in the home where you live most of the time?' and the response options provided were 'Very well off,' 'Living comfortably,' 'Just getting by,' 'Nearly poor' and 'Poor.' 'Very well off' was categorized as 'High SES.' 'Living comfortably' was categorized as 'Middle SES' and 'Just getting by.' 'Nearly poor' and 'Poor' were combined to derive 'Low SES.'

as 'Middle SES' and 'Just getting by.' 'Nearly poor' and 'Poor' were combined to derive 'Low SES.'

Table 2.

Adjusted odds ratios testing for differences in developmental patterns of e-cigarette use, by cohort and sociodemographic factors[b–e]; the Texas Adolescent Tobacco and Marketing Surveillance System (TATAMS), Waves 1–9, 2014–2019

Table 2a. Past 30-day E-cigarette Use without Marijuana **(Waves 1–9, 2014–2019; n=3,878)**						
	Pattern 2 ('Early' escalators) vs. Pattern 1 (Non-users)		**Pattern 3 ('Mid' escalators) vs. Pattern 1 (Non-users)**		**Pattern 4 ('Late' escalators) vs. Pattern 1 (Non-users)**	
	AOR[a]	**95% CI**	**AOR[a]**	**95% CI**	**AOR[a]**	**95% CI**
6th grade cohort						
Gender						
Female	REF		REF		n/a	n/a
Male	1.567	(0.725 – 3.384)	0.942	(0.566 – 1.568)	n/a	n/a
Race/ethnicity						
Non-Hispanic White	REF		REF		n/a	n/a
Non-Hispanic Black	0.738	(0.183 – 2.985)	0.235	(0.070 – 0.789)	n/a	n/a
Hispanic	1.106	(0.420 – 2.911)	0.664	(0.381 – 1.159)	n/a	n/a
Other	1.592	(0.516 – 4.908)	0.683	(0.324 – 1.440)	n/a	n/a
SES						
Low	REF		REF		n/a	n/a
Middle	0.167	(0.074 – 0.378)	0.829	(0.375 – 1.830)	n/a	n/a
High	0.103	(0.028 – 0.371)	1.143	(0.490 – 2.664)	n/a	n/a
8th grade cohort						
Gender						
Female	REF		REF		REF	
Male	1.060	(0.711 – 1.579)	1.215	(0.854 – 1.727)	0.815	(0.405 – 1.638)
Race/ethnicity						
Non-Hispanic White	REF		REF		REF	
Non-Hispanic Black	1.006	(0.528 – 1.917)	0.168	(0.071 – 0.395)	0.000	(0.000 – Inf)
Hispanic	1.344	(0.826 – 2.186)	0.518	(0.342 – 0.785)	0.662	(0.294 – 1.490)
Other	1.094	(0.574 – 2.084)	0.647	(0.383 – 1.093)	1.203	(0.495 – 2.924)
SES						
Low	REF				REF	
Middle	0.989	(0.545 – 1.794)	0.926	(0.540 – 1.587)	1.246	(0.419 – 3.705)
High	1.324	(0.681 – 2.574)	1.073	(0.591 – 1.948)	1.012	(0.291 – 3.521)
10th grade cohort						
Gender						
Female	REF		REF		REF	
Male	2.666	(1.687 – 4.213)	1.382	(1.042 – 1.834)	1.126	(0.798 – 1.591)
Race/ethnicity						

Table 2a. Past 30-day E-cigarette Use without Marijuana (Waves 1–9, 2014–2019; n=3,878)						
	Pattern 2 ('Early' escalators) vs. Pattern 1 (Non-users)		Pattern 3 ('Mid' escalators) vs. Pattern 1 (Non-users)		Pattern 4 ('Late' escalators) vs. Pattern 1 (Non-users)	
	AOR[a]	95% CI	AOR[a]	95% CI	AOR[a]	95% CI
Non-Hispanic White	REF		REF		REF	
Non-Hispanic Black	0.325	(0.168 – 0.628)	0.440	(0.279 – 0.695)	0.425	(0.249 – 0.727)
Hispanic	0.394	(0.235 – 0.661)	0.827	(0.588 – 1.164)	0.602	(0.396 – 0.915)
Other	0.308	(0.139 – 0.681)	0.701	(0.439 – 1.119)	0.781	(0.462 – 1.322)
Socioeconomic status						
Low	REF		REF		REF	
Middle	0.614	(0.360 – 1.048)	0.762	(0.531 – 1.094)	0.645	(0.425 – 0.979)
High	0.492	(0.239 – 1.012)	0.738	(0.466 – 1.172)	0.501	(0.284 – 0.884)

Table 2b. Past 30-day E-cigarette Use with Marijuana (Waves 3–9, 2015–2019; Waves 3–9, 2015–2019; n=2,733)		
	Pattern 2 (Escalators) vs. Pattern 1 (Non-users)	
	AOR[a]	95% CI
6th grade cohort		
Gender		
Female	REF	
Male	0.687	(0.327 – 1.443)
Race/ethnicity		
Non-Hispanic White	REF	
Non-Hispanic Black	0.238	(0.030 – 1.886)
Hispanic	1.462	(0.672 – 3.180)
Other	0.853	(0.288 – 2.530)
SES		
Low	REF	
Middle	0.362	(0.164– 0.798)
High	0.428	(0.159 – 1.157)
8th grade cohort		
Gender		
Female	REF	
Male	0.866	(0.541 – 1.388)
Race/ethnicity		
Non-Hispanic White	REF	
Non-Hispanic Black	0.711	(0.301 – 1.679)
Hispanic	1.246	(0.718 – 2.162)
Other	0.863	(0.417 – 1.785)
SES		
Low	REF	
Middle	0.798	(0.428 – 1.486)

Table 2b. Past 30-day E-cigarette Use with Marijuana (Waves 3–9, 2015–2019; Waves 3–9, 2015–2019; n=2,733)		
	Pattern 2 (Escalators) vs. Pattern 1 (Non-users)	
	AOR[a]	95% CI
High	1.038	(0.486– 2.216)
10th grade cohort		
Gender		
Female	REF	
Male	1.336	(0.915 – 1.951)
Race/ethnicity		
Non-Hispanic White	REF	
Non-Hispanic Black	0.676	(0.370 – 1.232)
Hispanic	0.964	(0.605 – 1.534)
Other	1.014	(0.563 – 1.826)
Socioeconomic status		
Low	REF	
Middle	0.854	(0.542 – 1.344)
High	1.531	(0.827 – 2.834)

[a]Models are adjusted for all sociodemographic variables (gender, race/ethnicity, SES).

[b]To assess Cohort, participants were asked ‘What Grade are you in?’. The response options at Wave 1 were ‘6th’, ‘7th’, ‘8th’, ‘9th’, ‘10th’, ‘11th’ and ‘12th’. All 7th, 11th, and 12th grade students were removed and all 9th grade students were classified as 10th grade. 6th, 8th and 10th Grade students were retained in the survey (n=3907) and followed longitudinally as ‘6th grade cohort,’ ‘8th grade cohort’ and ‘10th grade cohort.’

[c]To assess Gender, participants were asked ‘What is your gender?’ and response options were ‘Male’ and ‘Female.’

[d]To assess Race/ethnicity, participants were asked ‘Are you Hispanic or Latino/a?’ and ‘What race or races do you consider yourself to be?’ respectively. The response options (Hispanic, White, Black or African American, Asian, American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander and Other) were used to derive the measure of race/ethnicity (Non-Hispanic White, Non-Hispanic Black, Hispanic, Other).

[e]To assess SES, participants were asked ‘In terms of income, what best describes your family’s standard of living in the home where you live most of the time?’ and the response options provided were ‘Very well off,’ ‘Living comfortably,’ ‘Just getting by,’ ‘Nearly poor’ and ‘Poor.’ ‘Very well off’ was categorized as ‘High SES.’ ‘Living comfortably’ was categorized as ‘Middle SES’ and ‘Just getting by.’ ‘Nearly poor’ and ‘Poor’ were combined to derive ‘Low SES.’

[a]Models are adjusted for all sociodemographic variables (gender, race/ethnicity, SES).

[b]To assess Cohort, participants were asked ‘What Grade are you in?’. The response options at Wave 1 were ‘6th’, ‘7th’, ‘8th’, ‘9th’, ‘10th’, ‘11th’ and ‘12th’. All 7th, 11th, and 12th grade students were removed and all 9th grade students were classified as 10th grade. 6th, 8th and 10th Grade students were retained in the survey (n=3907) and followed longitudinally as ‘6th grade cohort,’ ‘8th grade cohort’ and ‘10th grade cohort.’

[c]To assess Gender, participants were asked ‘What is your gender?’ and response options were ‘Male’ and ‘Female.’

[d]To assess Race/ethnicity, participants were asked ‘Are you Hispanic or Latino/a?’ and ‘What race or races do you consider yourself to be?’ respectively. The response options (Hispanic, White, Black or African American, Asian, American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander and Other) were used to derive the measure of race/ethnicity (Non-Hispanic White, Non-Hispanic Black, Hispanic, Other).

[e]To assess SES, participants were asked ‘In terms of income, what best describes your family’s standard of living in the home where you live most of the time?’ and the response options provided were ‘Very well off,’ ‘Living comfortably,’ ‘Just getting by,’ ‘Nearly poor’ and ‘Poor.’ ‘Very well off’ was categorized as ‘High SES.’ ‘Living comfortably’ was categorized as ‘Middle SES’ and ‘Just getting by.’ ‘Nearly poor’ and ‘Poor’ were combined to derive ‘Low SES.