Introduction

According to the CDC, in 2019, nearly 14 of every 100 US adults aged 18 years or older (14%) currently smoked cigarettes, while more than 16 million Americans live with a smoking-related disease.\(^1\) About 2 of every 100 middle-school students reported smoking cigarettes in the past 30 days, while about 6 of every 100 high-school students (5.8%) reported smoking cigarettes in 2019.\(^2\) The prevalence of smoking was 31.1% among persons below the federal poverty level,\(^3\) so smoking can be considered a health disparity. Fortunately, smoking has declined from 20.9% in 2005 to 13.7% in 2018, and the proportion of ever smokers who have quit has increased.\(^4\) We expect these trends to continue after the United States Congress passed legislation amending the Federal Food, Drug, and Cosmetic Act to raise the federal minimum age of sale of tobacco products from 18 to 21 years old. This law, which we label US Tobacco 21, was passed by Congress and signed by President Trump on December 19, 2019, makes it illegal for a retailer to sell any tobacco product—including cigarettes, cigars, and e-cigarettes—to anyone under 21. This important change in public health policy is part of the Tobacco Endgame, a term used to describe the ending of the tobacco epidemic,\(^5\) that should have received major publicity but was overshadowed by the presidential impeachment proceedings\(^6\) and later by the COVID-19 pandemic.

Nicotine Addiction and Youth Smoking

The United States Department of Health and Human Services shows that about 95% of adult smokers claim that they began smoking before they turned 21 years of age. About three-quarters of adult smokers stated that they first started smoking before the age of 18. 46% of adult smokers become regular smokers, but over 80% of smokers who smoke before they turn 18 will turn into daily regular smokers before they turn 21. Thus, people who smoke before 21 are at high risk to become addicted—daily-smokers.\(^7\)

Strikingly, another survey showed that the median age of smoking initiation was 12.6 years old. Youth, aged 16 and under, primarily used five tobacco products: electronic cigarettes, cigarettes, cigars, smokeless tobacco, and hookah.\(^8\) Youth, which the WHO defines as those under the age of 24,\(^9\) who started using any of these products at or before the age of 13 were much more likely to become current daily users of the above products and developed nicotine dependence.\(^8\)

This evidence of creating youth addiction was further solidified when a researcher from the tobacco company RJ Reynolds stated that “if a man has never smoked by age 18, the odds are three-to-one he never will. By age 24, the odds are twenty-to-one.”\(^10\) Furthermore, a Phillip Morris Company report of January 21, 1986 said “Raising the legal minimum age for cigarette purchaser to 21 could gut our key young adult
market (17–20) where we sell about 25 billion cigarettes and enjoy a 70% market share. Tobacco and e-cigarette companies are notorious for actively targeting the youth since they are the next generation of “money-makers.”

The youth are especially susceptible to nicotine physiologically. Nicotine binds to the nicotinic acetylcholine receptors in the brain and other tissues. In doing so, dopamine release is increased in certain regions of the brain, leading to dependency on dopamine release that leads to nicotine addiction. Research conducted by the Odell group has shown that adolescents display enhanced nicotine reward and reduced withdrawal because they experience short-term positive and reduced aversive effects of nicotine. Furthermore, it has been shown that adolescents do not have physiologically mature brains.

The prefrontal cortex is responsible for executive functions, which include decision making, peer pressure susceptibility, and sensation-seeking impulses and does not develop fully until after the age of 25, thus crippling adolescents from making sound decisions about their health. Because of this, tobacco companies continue working to target youth who are easily manipulated.

E-cigarettes Epidemic and Its Implications Among Youth

E-cigarettes first came to the markets in the mid-2000s. Initially, they were advertised as “safer” alternatives to traditional, combustible cigarettes and an effective tool for quitting cigarette smoking. E-cigarettes are associated with creating a new generation of smokers by causing youth nicotine dependence; they can cause serum nicotine/cotinine levels to be substantially above that of combustible cigarettes, thus facilitating frequent use with their highly addictive content, appealing flavors, and appealing accessibility of use. The CDC reported a 78% increase (from 11.7% to 20.8%) in high-school students’ usage of e-cigarettes by 2018. The Monitoring the Future survey showed that vaping prevalence more than doubled in 12th, 10th, and eighth-grade students from 2017 to 2019; showing that 1 in 4 12th grade students had vaped in the last 30 days. The alarming rate of increase in e-cigarettes use by youth points to the need for policies to limit their purchase.

Impact of a “Tobacco 21” Law in California

Following the e-cigarette epidemic, states began to adopt policies to combat nicotine dependence. In 2014, NYC combated youth initiation and helped reduced the heavy burden of tobacco use on the city and saw rates of adolescent tobacco use decline steadily (from 11.6% to 9.5%). Hawaii raised the legal age for tobacco in 2016, and in data taken from grocery stores from June 2010 compared to February 2017, the average monthly cigarette sales dropped 4.4% and cigar/cigarillos sales dropped 12.1%. Oregon’s law became effective in January 2018, and preliminary data from the first nine months since its passing showed a significant decrease in tobacco use initiation among youth aged 13 to 17 (34% to 25%) and young adults 18 to 20 (23% to 18%).

California’s fight against tobacco usage by underaged individuals began with Proposition 99 in November 1988 which funded the California Tobacco Control Program, which worked to keep tobacco out of the hands of youth, help tobacco users quit, and aimed to ensure that all Californians can live, work, play, and learn in tobacco-free environments. In 1998, 12.8% of middle-school students and 34.8% of high-school students reported smoking cigarettes. By 2002, in California, 16.0% of youth were smoking cigarettes, and in 2016, 10% of high-school students were still smoking. However, with the influx of e-cigarettes in the 2010s and their accessibility, California saw an uptick in e-cigarette usage with almost 28% of high-school students using them in 2018. To combat both cigarette and e-cigarette use by youths, California legislators fought a difficult battle to limit youth tobacco purchase that was challenged by money from tobacco companies amid intense e-cigarette, tobacco industry, and California Association of Retail Tobaccoists opposition. But, lawmakers were able to overcome these obstacles during a special session on health care that allowed the measures to circumvent the normal legislative process. On June 9, 2016, a set of laws raised the minimum legal sale age (MLSA) of tobacco products to 21 years of age, expanded California’s smoke-free workplace laws, broadened California’s tobacco-free school laws to cover all school property at all times, and increased the licensing fees for distributing and selling tobacco products, while also expanding the law to include e-cigarettes. These laws came to be known as CA Tobacco 21.

By 2019, we saw the effects of CA Tobacco 21 although this may also be due to other factors, roughly 2% of high-school students in California were smoking cigarettes, compared to the previous 10% in 2016. Zhang et al found high awareness and support for CA Tobacco 21 law among young adults and tobacco retailers, the two key audiences most affected by the law. Overall, 63.6% of young adults’ ages 18–24 were aware of the law, and awareness was high across all ethnic groups. Interestingly, over 60% of young adult tobacco users agreed that raising the age of tobacco sales to 21 years of age would decrease youth tobacco use. This attitude was significantly stronger among Hispanics and non-Hispanic Blacks than non-Hispanic Whites. However, young adult e-cigarette users were significantly less likely to agree. This may show that e-cigarette users are unaware of the detrimental effects of using these products. This suggests that more campaigns to spread awareness about the law, specifically pertaining to e-cigarettes, are needed to communicate the risks of these products and help people quit.

Seven months after the law was passed, awareness of the law was at 98.6% among tobacco retail owners, managers, and clerks, with more than 60% of them supporting the law. Furthermore, 85.6% of those surveyed agreed that it was easy to
comply with the law, and 90.7% stated that it was easy to train staff to comply with the law.

In a study put forth by the California Department of Public Health, 10.3% of retailers were selling tobacco to youth in 2016, but in 2018, only 5.4% were selling to youth. Furthermore, it was found that tobacco use among all California youth, including cigars, cigarillos, hookah, smokeless tobacco, and other related products, was at dramatically lower levels than they were in 2016, with the only outlier being e-cigarettes.\textsuperscript{25} Tobacco purchase data also showed a significant decline in tobacco sales to younger teens. In fact, 15–16-year-old youth have experienced a 45% reduction in sales of tobacco products. The law included added ID check requirements and penalties to retailers. Furthermore, the law banned retailers from having self-service displays, which allow customers to access items without help from the retailer. This also reduced sales to 15–17-year-olds who may have friends over 18 who could buy them tobacco products, but are unlikely to have friends over 21. These evidences suggest that this law has significantly contributed to reducing illegal tobacco sales to youth under 21 and has achieved widespread retailer compliance.\textsuperscript{27}

Friedman et al, using 2016–2017 data, found that state and local Tobacco 21 laws reduced smoking among 18–20-year-olds who have ever tried cigarettes.\textsuperscript{30} Their data are significant because US Tobacco 21 should result in lower amounts of smoking in under-21-year-olds, and the number of new smokers will continue to drop. Furthermore, data continue to show that Tobacco 21 laws are also preventing large cigar/cigarillo purchases.\textsuperscript{25} More research needs to be gathered to show the decline in other tobacco/nicotine products.

Some studies have modeled the public health impact of raising the minimum age of tobacco sales to 21.\textsuperscript{31,32} Prior to its passage of US Tobacco 21, raising the MLSA was gaining momentum in reducing tobacco use, decreasing negative health outcomes including premature births and chronic diseases, and increasing overall public health, achieving strong compliance in many states\textsuperscript{31} with 19 of the country’s 50 states and Washington, DC already setting 21 as the minimum age.\textsuperscript{34} However, the states that passed the minimal age laws were, for the most part, states with low rates of smoking. Until the passage of US Tobacco 21, states in the “tobacco-belt” still had high rates of smoking and an MLSA of 18 that was often not enforced.

**US Tobacco 21**

This federal age change is part of a comprehensive fight that some states have already begun against tobacco use. The FDA will now oversee the enforcement of the law, including penalizations for retailers who sell to underage customers. It has implemented a ban on selling all tobacco products to military personnel under the age of 21 who were previously exempted. The law also requires states to demonstrate that their retailers are in compliance. In addition to the benefits of restricting sales of tobacco products in underaged Americans, it will create awareness among both retailers and consumers (Table 1). It will help de-normalize tobacco use in society and lead to more tobacco-control campaigns and tobacco-cessation programs. Tobacco 21 may be more readily implemented in the US, where there is already an age 21 limit for alcohol, than in other countries where the alcohol age limit is lower. Passage of US Tobacco 21 will provide multiple benefits.

California smoking rates have decreased 4 times faster than the rest of the US after passing its Tobacco 21 law. They also have the second lowest adult smoking rate in the nation. High-school smoking rates have also dropped significantly. We estimate there will be a 9.4% decline in adult smoking rates in California by 2026.\textsuperscript{35,36} Currently, about 500,000 people die of smoking-related deaths/year, if the nation were to follow California’s trend, this may decrease the rate to 450,000 deaths/year saving 50,000 lives per year.\textsuperscript{37} This is under-estimating the number of lives saved as there will be less second-hand smoke exposure and potentially fewer e-cigarette users going on to cigarette smoking.

| BENEFITS | CHALLENGES |
|----------|-------------|
| Reduction in youth tobacco use and underaged smoking especially in tobacco-belt states\textsuperscript{53} | There are still high numbers of tobacco usage among youth, specifically with e-cigarettes |
| Delaying the age when youth first start smoking | E-cigarette usage is still increasing |
| Reduction in the use of cigars, cigarillos, and flavored products | Shoulder tapping (underaged buyers asking other patrons to buy their products for them) in many retail businesses still exists, as shown in the Zhang et al. study.\textsuperscript{29} There are still illicit dealers and businesses selling to youth illegally |
| Decreased underage attempts to buy tobacco products and in increase in the age gap between adolescents initiating tobacco use and those who can legally provide them with products, “shoulder tapping”\textsuperscript{52} | With youth vapers, many of them turn into adult smokers\textsuperscript{8} |
| Reduction in adult tobacco use and decreased number of new smokers | We must keep up with the ever-evolving market for illicit drug use. THC vapes are gaining traction |
| Increasing awareness of old/new risks of tobacco and e-cigarette usage; the law provides grant funding to states for compliance with the law, pushing states to spread awareness | Actively enforcing the law among both brick and mortar retailers and online retailers. |
| Improved/stricter enforcement of the new US Tobacco 21 law at all levels of government including the military | Reduced adult smoking rates may take years as youth who stop smoking become adults |

**Table 1.** Benefits and challenges of the Tobacco 21 law.
In 2015, a report from the Institute of Medicine found that increasing the minimum age of sale for tobacco products to 21 years of age would have a significant impact on the amount of youth smoking nationally. It projected a 12% decrease in tobacco product use prevalence in adults. Furthermore, it reported that close to 4700 young people under the age of 21 try their first cigarette every day, 1400 of them will become regular smokers, and roughly 50% will die from smoking-related diseases. However, it found that a new law would reduce smoking by 25% among 15–17 year-olds and 15% among those 18–20 years old. This could prevent roughly 223,000 fewer premature deaths nationwide, 50,000 fewer deaths from lung cancer, and 4.2 million fewer years of life lost among people born between 2000 and 2019. As California has shown, US Tobacco 21 will help break this cycle of death and disease by discouraging/preventing generations of youth from smoking. US Tobacco 21 may be one of the most important public health laws passed, as it has the potential to save a large number of lives and along with other policies, reduce cigarette use in the USA.

**Future Steps to Reduce Cigarette and E–Cigarette Use Among Underaged Youths**

Though we have seen success with CA Tobacco 21 and in other parts of the nation and expect to see even more success with US Tobacco 21, policymakers should take steps to combat the new vaping epidemic using the newly passed US Tobacco 21 law in a comprehensive approach:

1. Publicize the positive effects of raising the tobacco purchase age to 21.
   (1) California’s Department of Public Health shows cigarette smoking in youth is at an all-time low.
   (2) The vaping epidemic can follow suit and be taken under control with enforcement of the law.
2. Push for enforcement of the new law.
   (1) In California, over 5% of retailers still sell e-cigarette products to youth.
   (2) Shut down businesses that sell tobacco products including e-cigarettes to underage patrons.
3. Push for taxation of e-cigarettes.
   (1) It is well documented that taxation of combustible cigarettes drastically leads to decreased sales.
   (2) The taxation on e-cigarettes will lead to decreased sells, but should not be higher than on cigarettes, otherwise e-cigarette users may switch to cigarettes.
4. Push for much tighter regulation of online sales.
   (1) If you go to some e-cigarette websites, it simply “asks” a purchaser if they are 21 without verification.
   (2) There is existing technology (such as used by Juul) that would require documentation of age prior to online purchase of electronic cigarettes that should be implemented.
5. Push for the ban of all flavored vaping products.
   (1) Brands now emphasize consumer choice in models and flavors.
   (2) Research has shown that flavored products appeal to the underaged and make up the majority of electronic products used by youth.
   (3) President Trump initially supported a federal ban on all flavored products but scaled back after pressure from the industry and risk of political fallout.
6. Spread awareness of how dangerous all tobacco products including e-cigarettes are.
   (1) There have been 60 nationwide vaping-related deaths (EVALI).
   (2) Many of the patients presenting with EVALI are reporting use of THC or purchasing products from illicit dealers.
   (3) Vapor from electronic cigarettes contains carcinogenic compounds. Flavoring compounds have been shown to cause cell cytotoxicity.
   (4) Nicotine products have been shown to have many detrimental effects on health, including metabolic syndrome and gut microbiota.

Ultimately following these six steps, along with other measures and programs set forth by the WHO Framework Convention on Tobacco Control (WHO FCTC), will help push e-cigarettes usage on a downward trend similar to cigarette smoking. If we want this new law to effectively reduce e-cigarette usage as much as it has reduced cigarette smoking usage among both adults and youth, we must publicize both the data and the law itself. Nonetheless, US Tobacco 21 is a substantial victory for America’s public health at a time when the vaping epidemic is sweeping across the nation that is likely to save hundreds of thousands of lives and push us one step closer toward reaching a tobacco endgame.

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**REFERENCES**

1. Centers for Disease Control and Prevention. *Current Cigarette Smoking Among Adults in the United States*. National Center for Chronic Disease Prevention and Health Promotion; Office on Smoking and Health, 2018.
2. Centers for Disease Control and Prevention. *National Center for Chronic Disease Prevention and Health Promotion; Office on Smoking and Health; Youth and Tobacco Use*, 2019.
3. *Vital signs: non-smokers’ exposure to secondhand smoke—United States, 1999–2008*. MMWR Morb Mortal Wkly Rep. 2010;59(35):1141-1146.
4. Creamers MR, Wang TW, Babic S, et al. Tobacco product use and cessation indicators among adults—United States, 2018. MMWR Morb Mortal Wkly Rep. 2019; 68(45):1013-1019.
5. McDaniel PA, Smith EA, Malone RE. The tobacco endgame: A qualitative review and synthesis. Tob Control. 2016;25(5):594-604.
6. Sullivan M. Get used to it: The ‘I-word’—Impedance—Is about to Dominate Trump Coverage. Perspective. The Washington Post; 2019.
7. United States Department of Health and Human Services. Substance Abuse and Mental Health Services Administration: Center for Behavioral Health Statistics and Quality. National Survey on Drug Use and Health; 2014.
8. Sharapova S, Reyes-Guzman C, Singh T, Phillips E, Marynak KL, Agaku I. Age of tobacco use initiation and association with current use and nicotine dependence among US middle and high school students, 2014–2016. Tob Control Jan 2020;29(1):49-54.
9. Organization WH. Adolescent Health. World Health Organization; 2021.
10. Oyston J. A fresh approach to tobacco control: Raising the minimum legal age for access. CMJ. 2017;189(8):E293-E294.
11. Bach L. Increasing the Minimum Legal Sale Age for Tobacco Products to 21: Campaigns for Tobacco-Free Kids, 2020.
12. Berry KM, Fetterman JL, Benjamin EJ, et al. Association of electronic cigarette use with subsequent initiation of tobacco cigarettes in US youths. JAMA Netw Open. 2019;2(2):e187794.
13. Padon AA, Maloney EK, Cappella JN. Youth-targeted E-cigarette marketing in the US. Tob Regul Sci. 2017;3(1):95-101.
14. Yuan M, Haque M, Johal L, et al. Maturation of the adolescent brain. Neuropharmacology. 2009;56(suppl 1):263-278.
15. Padon AA, Maloney EK, Cappella JN. Youth-targeted E-cigarette marketing in the US. Tob Regul Sci. 2017;3(1):95-101.
16. Sullivan M. A psychobiological framework of the substrates that mediate nicotine use during adolescence. Neuropharmacology. 2009;56(suppl 1):263-278.
17. Sullivan M. The tobacco endgame: A qualitative review and synthesis. Tob Control. 2016;25(suppl 1):S397-S412.
18. O'Dell LE. A psychobiological framework of the substrates that mediate nicotine use during adolescence. Neuropharmacology. 2009;56(suppl 1):263-278.
19. Arain M, Haque M, Johal L, et al. Maturation of the adolescent brain. Neuropharmacology. 2009;56(suppl 1):263-278.
20. Goriouanova NA, Manwelder HD. Short- and long-term consequences of nicotine exposure during adolescence for prefrontal cortex neuronal network function. Cold Spring Harb Perspect Med. 2012;2(12):a012120.
21. Farrel M, Lebowitz J, Marci CN, Perry C. Flavored tobacco product use among youth and adult smokers: What if flavors didn’t exist?. Tob Regul Sci. 2017;3(2):168-172.
22. Drummond MB, Upson D. Electronic cigarettes. Potential harms and benefits. Am J Prev Med. 2014;47(12):236-242.
23. Glantz SA, Barchet DW. E-Cigarettes: Use, effects on smoking, risks, and policy implications. Annu Rev Publ Health. 2018;39:215-235.
24. Shao XM, Friedman TC. Pod-Mod vs. Conventional E-cigarettes: Nicotine chemistry, pH and health effects. J Appl Physiol. 2020;128:1056-1058.
25. Cullen KA, Ambrose BK, Gentles AS, Apelberg BJ, Jasul A, King BA. Notes from the field: Use of electronic cigarettes and any tobacco product among middle and high school students-United States, 2011-2018. MMWR. Morb Mortal Wkly Rep. 2018;67(45):1276-1277.
26. Meirch R, Johnston L, O'Malley PM, Bachman JG, Patrick ME. Trends in adolescent vaping, 2017-2019. N Engl J Med. 2019;381(15):1490-1491.
27. Moreland-Russell S, Combs T, Schroth K, Luke D. Success in the city: The road to tobacco control in New York City. Tob control. 2016;25(suppl 1):s6-s9.
28. Oregon Health Authority. Oregon's Tobacco 21 Law: Impact Evaluation; 2019.
29. California Department of Public Health; California Tobacco Control Program. California Tobacco Facts and Figures; 2018.
30. California Department of Public Health CTPP. California Tobacco 21 Law; 2019.
31. Texas, VA, NY, MD, PA. Tobacco 21 laws and youth adult smoking: Quasi-experimental evidence. Addiction. 2019;114(10):1816-1823.
32. Berman ML. Raising the tobacco sales age to 21: Surveying the legal landscape. Public Health Rep. 2016;131(2):378-381.
33. Tian J, Levy DT, Jiang Y, et al. Projecting the effects of tobacco control policies in the USA through microsimulation study protocol. BMJ Open. 2018;8(3):e019169.
34. Bombi R, Stratton K, Kwan LY, eds. Committee on the Public Health Implications of Raising the Minimum Age for Purchasing Tobacco P, Board on Population H, Public Health P, Institute of M. Public Health Implications of Raising the Minimum Age of Legal Access to Tobacco Products: National Academies Press (US)All rights reserved.; 2015. Copyright 2015 by the National Academy of Sciences.
35. California Tobacco Facts and Figures; 2019.
36. Oregon Department of Human Services. Tobacco 21. Federal Tobacco 21: The Laws of Land. 2019.
37. Sajjad A. The cost-effectiveness of raising the legal smoking age in California. Mod Decis Making. 2005;25:330-340.
38. Institute of Medicine. Tobacco 21. Federal Tobacco 21: The Laws of Land. 2019.
39. California Department of Public Health. Minimum Age of Legal Access to Tobacco Products. 2019.
40. Sajjad A. The cost-effectiveness of raising the legal smoking age in California. Mod Decis Making. 2005;25:330-340.
41. Sindelar JL. Regulating vaping-policies, possibilities, and perils. N Engl J Med. 2020;382(20):e54.
42. Bader P, Boisclair D, Ferrence R. Effects of tobacco taxation and pricing on smoking behavior in high risk populations: A knowledge synthesis. Int J Environ Res Public Health. 2011;8(11):4118-4139.
43. Cohen JE, Sarabia V, Ashley MJ. Tobacco commerce on the internet: A threat to comprehensive tobacco control. Tob Control. 2001;10(4):364-367.
44. Baumgaertner E. Tobacco commerce on the internet: A threat to comprehensive tobacco control. Tob Control. 2001;10(4):364-367.
45. Kalinsky A, Bach CT, Nacca NE, et al. E-cigarette, or vaping, product use associated lung injury (EVALI): case series and diagnostic approach. Lancet Respir Med. 2019;7(12):1017-1026.
46. Goniewicz ML, Knysak J, Gawron M, et al. Levels of selected carcinogens and toxicants in vapour from electronic cigarettes. Tob Control. 2014;23(2):133-139.
47. Bellas CS, Den UE, Phillips LM, et al. Cytotoxicity and genotoxicity of E-cigarette generated aerosols containing diverse flavoring products and nicotine in oral epithelial cell lines. Toxicol Sci. 2021;179(2):220-228.
48. Wang Y, Wang J, Yang R, et al. Decreased 11 expression in the kidney may contribute to nicotine/smoking-induced blood pressure elevation in mice. Proc Natl Acad Sci U S A. 2015;112(6):1992-1996.
49. Martinez JE, Kahana DD, Ghuman S, et al. Unhealthy lifestyle and gut dysbiosis: A better understanding of the effects of poor diet and nicotine on the intestinal microbiome. Front Endocrinol (Lausanne). 2021;12:667066.
50. Bader P, Boisclair D, Ferrence R. Effects of tobacco taxation and pricing on smoking behavior in high risk populations: A knowledge synthesis. Int J Environ Res Public Health. 2011;8(11):4118-4139.