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RESEARCH BRIEF

Trends in U.S. E-cigarette Sales Measured in Milligrams of Nicotine, 2019−2024

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Introduction: E-cigarette unit sales have been estimated using the number of items typically available in a package to standardize unit sales of each product type. However, recent market changes, such as increases in e-liquid volume and nicotine concentration, challenge the validity of assessing sales according to item count without accounting for product attributes. This study measured nicotine content (mg) in e-cigarettes sold as a function of e-liquid volume (mL) and nicotine concentration (mg/mL), compared with e-cigarette unit sales standardized by item count.

Methods: U.S. e-cigarette retail sales data from Circana (February 2019 to June 2024) were analyzed. Trends in mg nicotine sold were compared with standardized unit sales. Additionally, sales-weighted average e-liquid volume, nicotine concentration, and price per milligram of nicotine were measured by product type. Trends were assessed using Joinpoint regression. Analyses were conducted in 2024.

Results: From February 2020 to June 2024, monthly milligrams of nicotine content sold increased by 249.2% ($p<0.001$)—an increase 7.2 times greater than the 34.7% increase in standardized unit sales. Disposable e-cigarettes experienced the greatest increase in mg nicotine sold, which was largely driven by the rise in e-liquid volume. By June 2024, a disposable device contained 9.0 times more e-liquid than a prefilled cartridge. However, the price per milligram of nicotine in prefilled cartridges was 3.7 times greater than that of disposable devices.

Conclusions: Nicotine is an addictive drug added to most e-cigarettes. Measuring e-cigarette sales in milligrams of nicotine content sold could better account for rapid changes in product attributes and inform policy strategies.

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INTRODUCTION

E-cigarettes are the most commonly used tobacco product among youth.[1] Most e-cigarettes contain nicotine, which is an addictive chemical that can harm brain development through age 25 years.[2−3] Retail scanner data complement survey data for monitoring the e-cigarette landscape. Studies of e-cigarette retail sales typically standardize units to represent the most common number of items per package. Initial studies employed a 1:1 ratio of prefilled cartridges/pods to disposable devices or e-liquid bottles.[4,5] Later studies set 5 prefilled cartridges/pods (the number of pods typically available in a single package) equivalent to 1 disposable e-cigarette or 1 bottle of e-liquid.[6,7] However, e-cigarette products have changed substantially in recent years. The share of disposable e-cigarette sales has more than doubled, from 24.7% in January 2020 to 51.8% in December 2022.[8] Between January 2017 and September 2022,

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average e-liquid volume of disposable e-cigarettes increased from 1.1 to 5.7 mL; average nicotine strength increased from 1.7% to 5%.[9] These changes challenge the validity of current unit standardization approaches, which neglect changes in product attributes. This study compares trends in nicotine content sold with trends in standardized e-cigarette unit sales to assess e-cigarette sales.

METHODS

Study Sample

E-cigarette data are based on custom research by the CDC Foundation using Circana, LLC retail POS (Total U.S. Multi-Outlet + Convenience, February 3, 2019 through June 16, 2024). The data capture sales from brick-and-mortar stores, excluding Internet retailers and vape shops. The data provide information on product type, flavor, e-liquid volume, and nicotine concentration, as stated by manufacturers on the product packaging. Missing information on e-liquid volume (mL) (n=5,829 of 10,230) and nicotine concentration (mg/mL) (n=4,514 of 10,230) was supplemented by an online search. Data are aggregated in 4-week periods (hereafter "months"). E-cigarette accessories and devices sold without e-liquids were excluded.

Measures

The total nicotine content in e-cigarettes sold (mg) was calculated for each product by multiplying the e-liquid volume (mL) by the nicotine concentration (mg/mL) and the unit sales, then summing the results across all products sold. The sum of standardized unit sales was calculated using an approach from previously published studies where one standardized unit equals five prefilled cartridges/pods, one disposable device, or one e-liquid

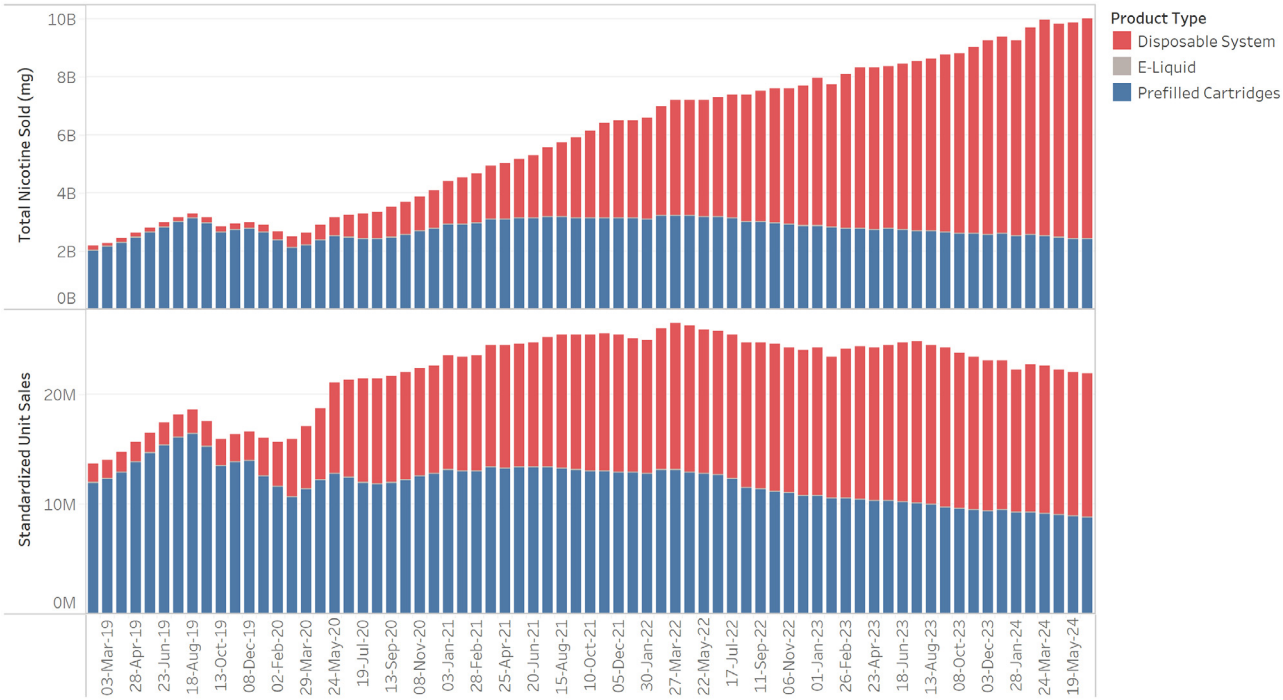

Figure 1. Total nicotine sold (mg) and standardized unit sales (1 disposable=5 pods/prefills) by product type, 4-week periods, 2019 to June 2024. *Notes*: U.S. e-cigarette point-of-sale data are licensed from Circana for convenience stores, gas stations, grocery stores, drug stores or pharmacies, mass merchandiser outlets, club stores, dollar stores, and military sales; Internet and vape shop sales were not recorded. Prefilled cartridges include tanks, cartridges, and pods used in rechargeable and reusable e-cigarette devices. Disposable devices include nonrechargeable and nonreusable e-cigarette devices that are not intended to be refilled with e-liquid after being depleted; the device is disposed once the e-liquid has been consumed. E-liquids are containers of the liquid used in e-cigarette devices, typically containing a humectant (e.g., propylene glycol), nicotine, and flavoring. E-liquid sales usually occur online and are therefore not fully captured by retail sales data. E-cigarette accessories and devices sold without e-liquids were excluded. Total nicotine sold (mg) was calculated as the product of e-liquid volume (mL) and nicotine concentration (mg/mL). The sum of standardized unit sales was calculated such that one standardized unit equals five prefilled cartridges/pods, one disposable device, or one e-liquid bottle.

bottle.[8] Additionally, sales-weighted averages for e-liquid volume, nicotine concentration, and price per milligram of nicotine (calculated as total dollar sales divided by nicotine content in e-cigarettes sold) were measured by product type.

Product flavors were categorized as tobacco, menthol, mint, "clear"/other cooling (products that contain non-menthol coolants),[10] or all other flavors (e.g., fruit, desserts). Product type was categorized as disposable e-cigarettes (with either rechargeable or nonrechargeable batteries), prefilled cartridges/pods, or e-liquid bottles.

Statistical Analysis

Trends in all measures were assessed using Joinpoint regression (version 4.9.1.0; National Cancer Institute). Average 4-week period percentage change (APPC) and p values were calculated for 2019−2024. p values <0.05 were considered statistically significant. Analyses were conducted in October 2024. No IRB approval was required as the study did not involve humans.

RESULTS

Nicotine content in e-cigarettes sold and standardized e-cigarette unit sales increased through August 2019, then decreased through February 2020, when the Food and Drug Administration began prioritizing enforcement against prefilled pods and cartridges in flavors other than tobacco and menthol (Figure 1). From February 2020 to June 2024, total monthly standardized unit sales increased 34.7% (15.7 million to 21.1 million units) (APPC=0.6), whereas nicotine content sales increased 249.2% (2.7 billion to 9.4 billion milligrams) (APPC=2.1) (p<0.001 for all). The increase in nicotine content was 7.2 times larger than the increase in standardized unit sales. From February 2020 to June 2024, standardized disposable unit sales increased 201.3% (versus −23.8% for prefills), while its nicotine content sold increased 2,364.5% (versus 1.3% for prefills). In June 2024, disposable e-cigarettes accounted for 58.1% of standardized unit sales and 74.0% of total nicotine content sold.

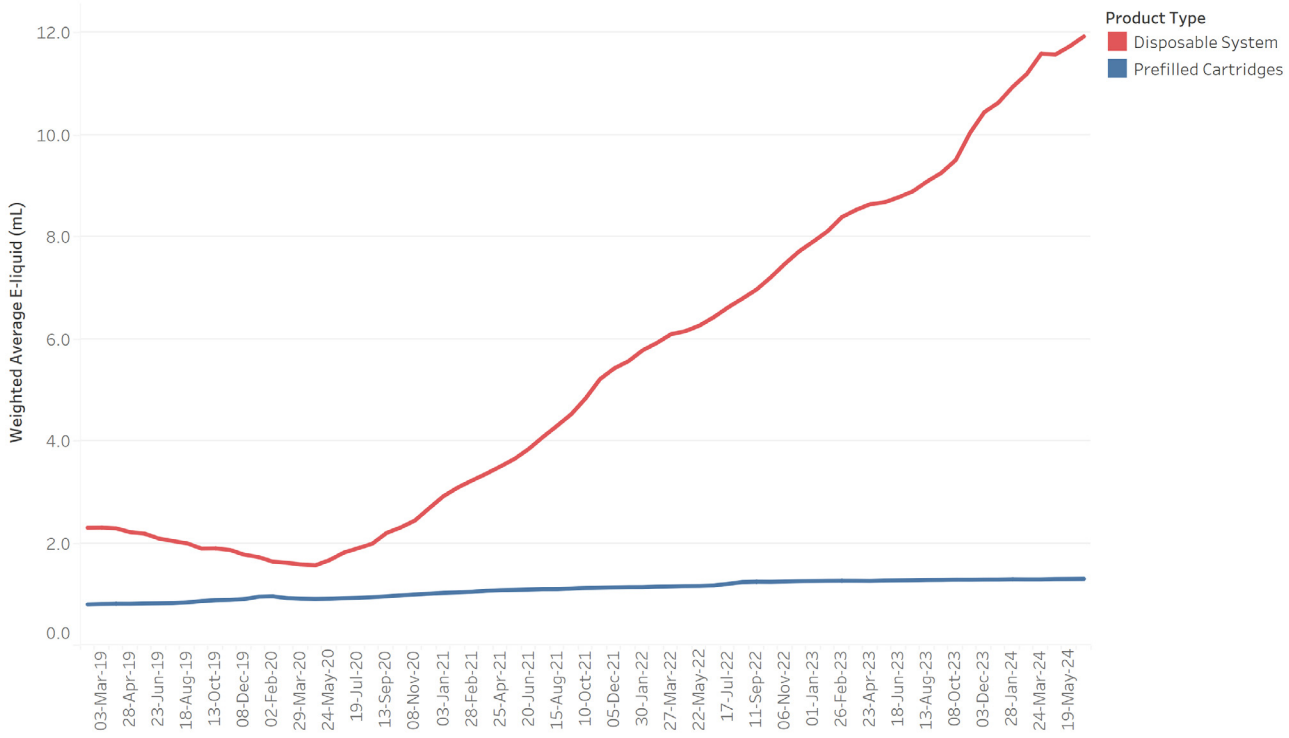

Figure 2. Weighted average e-liquid volume (mL) by product type, 4-week periods, 2019 to June 2024. *Notes*: U.S. e-cigarette point-of-sale data are licensed from Circana for convenience stores, gas stations, grocery stores, drug stores or pharmacies, mass merchandiser outlets, club stores, dollar stores, and military sales; Internet and vape shop sales were not recorded. Prefilled cartridges include tanks, cartridges, and pods used in rechargeable and reusable e-cigarette devices. Disposable devices include nonrechargeable and nonreusable e-cigarette devices that are not intended to be refilled with e-liquid after being depleted; the device is disposed once the e-liquid has been consumed. Weighted average e-liquid volume (mL) is average e-liquid volume per device weighted by unit sales.

The annual trends are consistent with monthly trends. From 2020 to 2023, annual nicotine content sales increased 155.1% (43.3 billion to 110.4 billion milligrams), compared with a 17.6% increase in standardized unit sales (264.5 million to 311.2 million units) (Appendix Figure 1). From 2022 to 2023, annual standardized unit sales decreased 4.8% (326.9 million to 311.2 million units), while annual nicotine content sold increased 15.5% (95.6 billion to 110.4 billion milligrams). In 2023, 80.6% of standardized unit sales and 88.2% of nicotine content sold were nontobacco flavored.

E-liquid volume for disposable e-cigarettes increased significantly during this period. From February 2020 to June 2024, monthly weighted average e-liquid volume increased 613.9% (1.6−11.7 mL) (APPC=2.6, $p<0.001$) for disposable e-cigarettes, versus 35.5% (1.0−1.3 mL) (APPC=0.7, $p<0.001$) for prefills (Figure 2). In February 2020, average e-liquid volume for disposable devices to prefills was 1.7:1, increasing to 9:1 by June 2024. From February 2020 to June 2024, sales-weighted average nicotine concentration of disposable devices increased 14.6% (42.3−48.5 mg/mL) (APPC=0.7, $p<0.01$), versus −1.0% for prefills (43.0−42.6 mg/mL) (APPC=−0.0, $p<0.01$) (Figure 3). In February 2020, the disposable versus prefill ratio of average nicotine concentration (mg/mL) was 1:1, increasing to 1.1:1 by June 2024.

Beginning in 2020, the price per milligram of nicotine was lower among disposables (Figure 4). By June 2024, the price ratio was 3.7:1 for prefills ($0.11/mg) versus disposables ($0.03/mg).

DISCUSSION

This study demonstrates the importance of revisiting approaches for measuring e-cigarette sales in a dynamic market. While most cigarettes in the U.S. are sold in packs of 20 sticks, a standard unit for e-cigarettes is less straightforward due to variations in product type (e.g., cartridge, disposable, refillable), volume, and nicotine concentration. Measuring e-cigarette sales by milligrams of nicotine sold better accounts for changes in device volume and nicotine concentration.

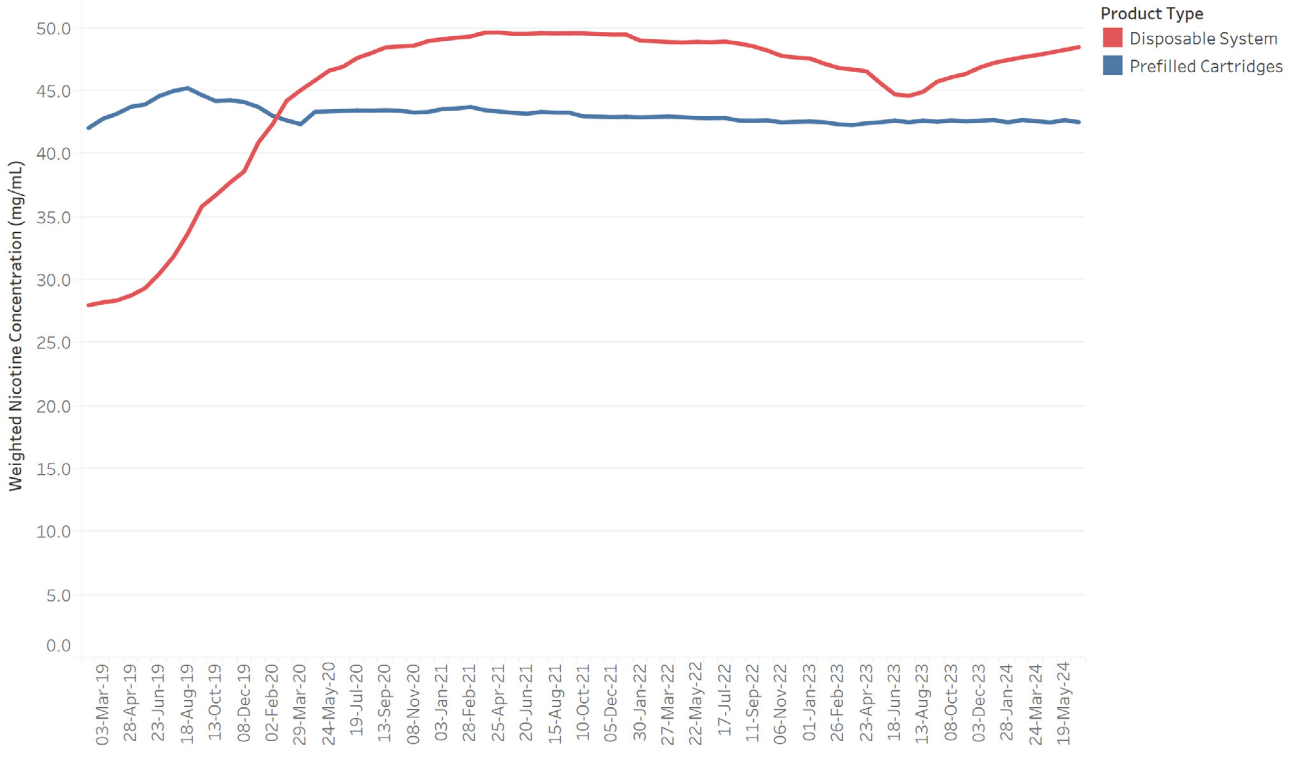

Figure 3. Weighted average nicotine concentration (mg/mL) by product type, 4-week periods, 2019 to June 2024. *Notes*: U.S. e-cigarette point-of-sale data are licensed from Circana for convenience stores, gas stations, grocery stores, drug stores or pharmacies, mass merchandiser outlets, club stores, dollar stores, and military sales; Internet and vape shop sales were not recorded. Prefilled cartridges include tanks, cartridges, and pods used in rechargeable and reusable e-cigarette devices. Disposable devices include nonrechargeable and nonreusable e-cigarette devices that are not intended to be refilled with e-liquid after being depleted; the device is disposed of once the e-liquid has been consumed. Weighted average nicotine concentration (mg/mL) is average nicotine concentration (mg/mL) per device weighted by unit sales.

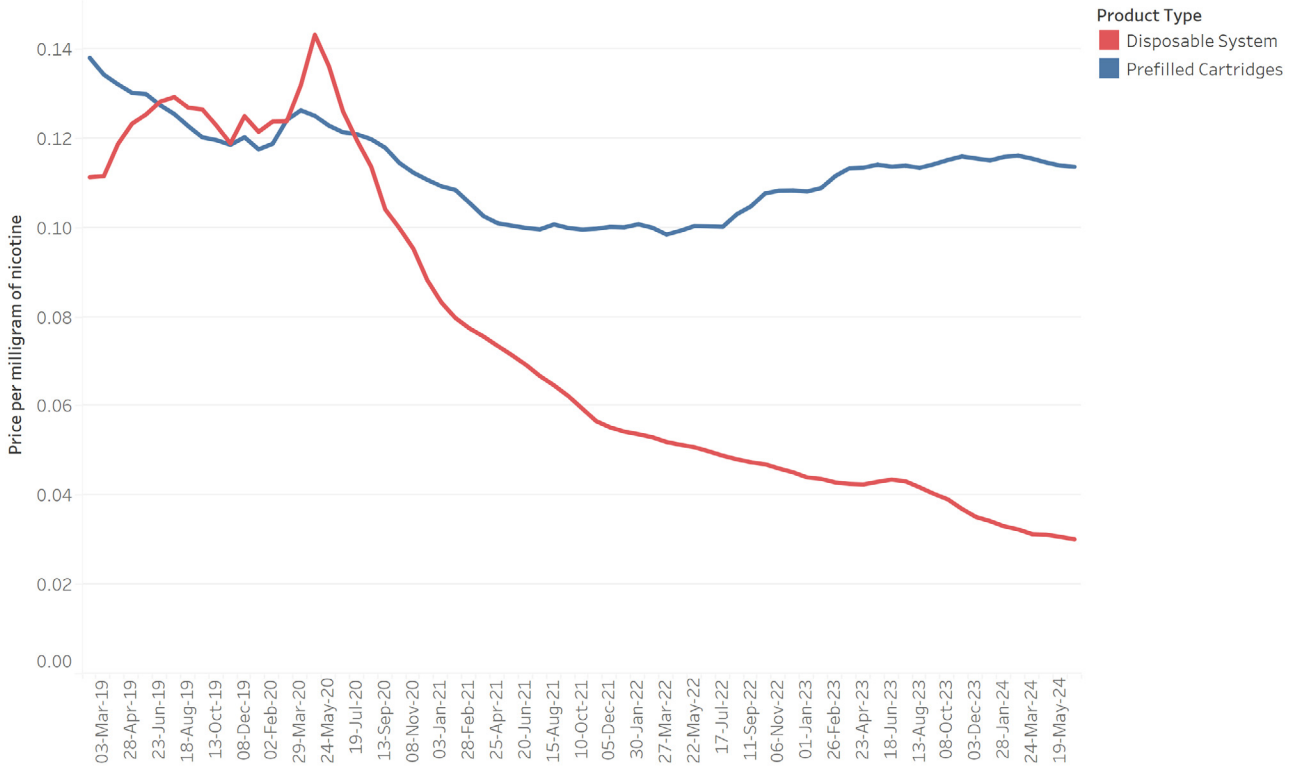

Figure 4. Weighted average price ($) per milligram of nicotine by product type, 4-week periods, 2019 to June 2024. *Notes*: U.S. e-cigarette point-of-sale data are licensed from Circana for convenience stores, gas stations, grocery stores, drug stores or pharmacies, mass merchandiser outlets, club stores, dollar stores, and military sales; Internet and vape shop sales were not recorded. Prefilled cartridges include tanks, cartridges, and pods used in rechargeable and reusable e-cigarette devices. Disposable devices include nonrechargeable and nonreusable e-cigarette devices that are not intended to be refilled with e-liquid after being depleted; the device is disposed of once the e-liquid has been consumed. Weighted Average price per milligram of nicotine was calculated by dividing total dollar sales revenues by total nicotine content in unit sales.

Nicotine content in e-cigarettes sold increased from 2022 to 2023, while standardized unit sales decreased. Nearly 90% of nicotine content sold in 2023 was flavored to taste like something other than tobacco. Furthermore, by June 2024, e-liquid volume in a disposable device was 9.0 times that of a prefilled cartridge, up from 1.7 in February 2020. This study adds to previous findings of a declining price of nicotine in disposables[9] by showing that nicotine is cheaper in disposable e-cigarettes compared to prefilled cartridges. This raises concerns; youth are particularly price-sensitive, and disposable e-cigarettes are the most popular e-cigarette product among youth[1].

Limitations

This study has several limitations. Vape shops and internet sales are not available; sales in these channels may differ from tracked channels. Additionally, nicotine content labeled on packaging may not reflect actual product measurements. Further, back-coding of missing information on e-liquid volume and nicotine concentration might be subject to misclassification. To mitigate this, two trained, independent analysts conducted the search, and a third analyst reviewed their codes and resolved any discrepancies. Finally, estimates are based on data released by Circana at the time of analysis. Newly released data may differ.

CONCLUSIONS

Nicotine is the addictive chemical that perpetuates tobacco product use. Measuring e-cigarette sales in milligrams of nicotine content sold could account for rapid changes in product attributes. Complemented with behavioral survey data, these data help explain changes in nicotine consumption due to policy changes and other factors.

CREDIT AUTHOR STATEMENT

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visualization, writing—review and editing, supervision. Megan C. Diaz: Conceptualization, methodology, investigation, writing—original draft, writing—review and editing. Brian S. Armour: Conceptualization, investigation, writing—original draft, writing—review and editing. Elisha Crane: Validation, investigation, data curation, software, writing—review and editing. Michael A. Tynan: Investigation, writing—original draft, writing—review and editing. Kristy L. Marynak: Conceptualization, methodology, investigation, writing—original draft, writing—review and editing, supervision.

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2025.02.007.

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