

Methodology Differences Impacting Prevalence Estimates of Youth Use of Electronic Nicotine Delivery Systems (ENDS) across Waves 5–7 of the Population Assessment of Tobacco and Health *

by

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SUMMARY

Background: The Population Assessment of Tobacco and Health (PATH) is a commonly-used longitudinal survey on nicotine/tobacco product use meant to represent the US population. Accurate surveillance to prevent youth electronic nicotine delivery systems (ENDS) use requires understanding the impact of methodological differences in Wave 6 (~2021), specifically older ages (14–17 vs. usual 12–17) and survey mode (some telephone interviews vs. usual self-completed).

Methods: Changes in past-30-day (P30D) youth ENDS prevalence and patterns of use (i.e., frequency, device type, flavors, and brand) were examined year-over-year and for the 3-year period (2019–2022). Analyses compared combined age groups and survey modes (i.e., among all youth in each wave regardless of methodological differences) with methodologically-comparable subgroups (i.e., same age range and survey mode). The impact of age on point estimates and trends (i.e., interaction with wave) was examined.

Results: Youth P30D ENDS prevalence significantly declined over the prior 3 years, but not year-over-year in either the naïve or methodologically-comparable analyses. However, 14–17-year-olds reported higher prevalence and steeper declines (age-wave interaction $p < 0.0001$) over the past 3 years (12.2% to 7.5%) than 12–13-year-olds (1.7% to 1.2%). Age differences had more modest impacts on patterns of ENDS use.

Discussion: Methodological differences in PATH Wave 6 introduced artifacts in estimates of prevalence, and to a

lesser extent, patterns of youth ENDS use. Waves 5 and 7 are approximately comparable (~95% equivalent) with respect to these differences. Future research examining prevalence trends over these waves should account for differences in survey mode and age range. [Contrib. Tob. Nicotine Res. 35 (2026) 148–156]

KEYWORDS

Adolescents; electronic cigarettes; nicotine; surveillance; trends; methodology; survey artifacts

ZUSAMMENFASSUNG

Hintergrund: Die „Population Assessment of Tobacco and Health“ (PATH) ist eine häufig verwendete Längsschnittstudie zum Konsum von Nikotin- und Tabakprodukten, die repräsentativ für die US-Bevölkerung sein soll. Eine genaue Überwachung zur Prävention des Konsums elektronischer Nikotinabgabesysteme (ENDS) bei Jugendlichen erfordert ein Verständnis der Auswirkungen methodischer Unterschiede in Welle 6 (~2021), insbesondere hinsichtlich älterer Altersgruppen (14–17 Jahre gegenüber den üblichen 12–17 Jahren) und des Erhebungsmodus (teilweise telefonische Befragungen gegenüber den üblichen selbst ausgefüllten Fragebögen). **Methoden:** Veränderungen der Prävalenz des ENDS-Konsums bei Jugendlichen in den letzten 30 Tagen (P30D) sowie der Konsummuster (d. h. Häufigkeit, Ge-

rätetyp, Aromen und Marke) wurden im Jahresvergleich und über den Dreijahreszeitraum (2019–2022) untersucht. In den Analysen wurden kombinierte Altersgruppen und Erhebungsmethoden (d. h. unter allen Jugendlichen jeder Erhebungswelle unabhängig von methodischen Unterschieden) mit methodisch vergleichbaren Untergruppen (d. h. gleiche Altersspanne und Erhebungsmethode) verglichen. Der Einfluss des Alters auf Punktschätzungen und Trends (d. h. Wechselwirkung mit der Erhebungswelle) wurde untersucht.

Ergebnisse: Die Prävalenz des Konsums von ENDS bei Jugendlichen innerhalb der letzten 30 Tage (P30D) ging in den vergangenen drei Jahren signifikant zurück, jedoch nicht im Jahresvergleich, weder in den „naïven“ noch in den methodisch vergleichbaren Analysen. Allerdings berichteten 14- bis 17-Jährige über die letzten drei Jahre hinweg eine höhere Prävalenz und steilere Rückgänge (Wechselwirkung zwischen Alter und Erhebungswelle: $p < 0,0001$) (von 12,2 % auf 7,5 %) als 12- bis 13-Jährige (von 1,7 % auf 1,2 %). Altersunterschiede hatten geringere Auswirkungen auf die Muster des ENDS-Konsums.

Diskussion: Methodische Unterschiede in der PATH-Welle 6 führten zu Verzerrungen bei den Prävalenzschätzungen und in geringerem Maße auch bei den Mustern des ENDS-Konsums bei Jugendlichen. Die Wellen 5 und 7 sind hinsichtlich dieser Unterschiede in etwa vergleichbar (~95 % äquivalent). Zukünftige Untersuchungen zu Prävalenzrends über diese Wellen hinweg sollten Unterschiede im Erhebungsmodus und im Altersbereich berücksichtigen. [Contrib. Tob. Nicotine Res. 35 (2026) 148–156]

RESUME

Contexte : L'étude « Population Assessment of Tobacco and Health » (PATH) est une enquête longitudinale couramment utilisée sur la consommation de nicotine et de produits du tabac, destinée à refléter la population américaine. Une surveillance précise visant à prévenir la consommation de systèmes électroniques de délivrance de nicotine (ENDS) chez les jeunes nécessite de comprendre l'impact des différences méthodologiques observées dans la vague 6 (~2021), notamment en ce qui concerne les tranches d'âge plus élevées (14-17 ans contre 12-17 ans habituellement) et le mode d'enquête (quelques entretiens téléphoniques contre des questionnaires remplis par les répondants eux-mêmes, comme d'habitude).

Méthodes : Les évolutions de la prévalence de l'utilisation des ENDS chez les jeunes au cours des 30 derniers jours (P30D) et des modes de consommation (c'est-à-dire la fréquence, le type d'appareil, les arômes et la marque) ont été examinées d'une année sur l'autre et sur une période de trois ans (2019–2022). Les analyses ont comparé les groupes d'âge et les modes d'enquête combinés (c'est-à-dire parmi l'ensemble des jeunes de chaque vague, indépendamment des différences méthodologiques) à des sous-groupes méthodologiquement comparables (c'est-à-dire de la même tranche d'âge et du même mode d'enquête). L'impact de l'âge sur les estima-

tions ponctuelles et les tendances (c'est-à-dire l'interaction avec la vague) a été examiné.

Résultats : La prévalence de la consommation d'ENDS chez les jeunes au cours des 30 derniers jours a considérablement diminué au cours des trois dernières années, mais pas d'une année sur l'autre, que ce soit dans les analyses « naïves » ou dans celles comparables sur le plan méthodologique. Cependant, les 14-17 ans ont fait état d'une prévalence plus élevée et de baisses plus marquées (interaction âge-vague, $p < 0,0001$) au cours des trois dernières années (de 12,2 % à 7,5 %) que les 12-13 ans (de 1,7 % à 1,2 %). Les différences d'âge ont eu des effets plus modestes sur les schémas de consommation des ENDS.

Discussion : Les différences méthodologiques de la vague 6 de l'étude PATH ont introduit des artefacts dans les estimations de la prévalence et, dans une moindre mesure, dans les schémas de consommation des ENDS chez les jeunes. Les vagues 5 et 7 sont approximativement comparables (équivalentes à environ 95 %) en ce qui concerne ces différences. Les futures recherches examinant les tendances de prévalence sur ces vagues devraient tenir compte des différences de mode d'enquête et de tranche d'âge. [Contrib. Tob. Nicotine Res. 35 (2026) 148–156]

STATEMENT OF SIGNIFICANCE

Population Assessment of Tobacco and Health (PATH) is the most widely-used national longitudinal survey of nicotine and tobacco product use and is essential for youth surveillance. However, there is at least one known methodological artifact that limits comparability across waves, which is essential for accurate surveillance efforts. We previously documented an artifact in e-cigarette use prevalence resulting from a COVID-related change in survey administration mode (from self-completed to telephone interview). We document an additional artifact in the current manuscript, in which differences in youth age ranges across waves produce spurious differences in prevalence. Specifically, this analysis reports that the methodological differences in PATH indeed complicate the wave-to-wave comparisons of youth e-cigarette use prevalence, leading to an overestimation of prevalence due to a higher age distribution in Wave 6. Its impact on the patterns of e-cigarette use was minimal. These results inform researchers about essential data analysis steps that must be taken for accurate surveillance of youth nicotine and tobacco use.

INTRODUCTION

Ongoing surveillance of youth use of nicotine and tobacco products is a public health priority, especially for the most commonly used product, electronic nicotine delivery systems (ENDS) (1). The nationally-representative Population Assessment of Tobacco and Health (PATH) survey (2) is a main source of data for research on nicotine and tobacco product behavior, including trends over time (3–5).

Accordingly, accurate data analysis and interpretation of findings are paramount to the integrity of ongoing re-

search on youth ENDS use. However, there are important methodological differences that complicate comparisons across waves of PATH. Specifically, previous analyses documented two methodological differences that impact youth ENDS use prevalence estimates in Waves 5.5 (~2020) and 6 (~2021): survey mode and age range (6). Regarding survey mode differences, PATH is typically self-administered by participants in a secure home setting on a laptop with privacy and security features (through Wave 5, ~2020), but due to COVID restrictions, this changed to telephone interviews during Wave 5.5 (~2020; 100% telephone interview) and for some participants in Wave 6 (~2021; approximately two-thirds telephone interviews) (2, 6, 7). Reported ENDS use was significantly lower in telephone interviews than in self-completed assessments, likely due in part to social desirability bias (6). This survey-mode artifact has a substantial impact on the interpretation of youth ENDS use trends: a naïve comparison appears to show a large decline in ENDS use prevalence from Waves 5 to 5.5 followed by an uptick in Wave 6, but analyzing within survey modes shows a more modest decline followed by a plateau (6). That is, the interpretation of youth ENDS use trends qualitatively differs based on whether or not the survey-mode difference is accounted for.

Regarding differences in age range across waves, typically PATH samples participants aged 12–17 for the youth survey (7–8). As PATH is a longitudinal survey, most waves enroll new participants at the younger end of this age range to maintain a similar age range as previous participants age up – either through previously-sampled “shadow” youth or through the Wave 4 and 7 replenishment samples. However, there were very few newly-enrolled youth (~12–13 years) at Waves 5.5 and 6, resulting in an older minimum age (~14–17 years) of the youth sample compared to other waves (6–8). This age difference likely introduces an artifact in estimates of youth ENDS use prevalence, as ENDS use is more common at older ages. That is, youth ENDS use prevalence estimates may be inflated for Waves 5.5 and 6 in analyses that are naïve to the age-range difference; it is unknown whether this artifact could also impact patterns of ENDS use (i.e., frequency, device type, flavor, and brand use).

Previous studies using PATH to assess youth patterns of ENDS use often fall short in fully accounting for methodological differences, such as the age range (9), survey mode (10, 11), or both (12). Previous analysis documenting PATH’s survey mode artifact in Waves 5.5 and 6 touches on the existence of the age-range difference (6); however, it was unable to examine its precise impact on prevalence estimates due to the lack of younger ages (12–13 years) in these waves. The recently released Wave 7 (~2022) affords the opportunity to examine age-related changes in ENDS use prevalence, as it includes a replenishment sample that restores the full youth age range (12–17), making it approximately comparable (~95% similar) to Wave 5 with respect to both survey mode and age range. Specifically, we compare naïve *vs.* methodologically-comparable analyses (i.e., among youth with the same age range and survey mode) of changes in youth ENDS use prevalence and patterns of use over the prior 1 year (i.e., Waves 6–7, ~2021–2022) and 3 years (i.e., Waves 5–7, ~2019–2022).

METHODS

Data

PATH restricted-use files from youth Waves 5 (~2019; N = 11,976), 6 (~2021; N = 5,585), and 7 (~2022; N = 10,650) were analyzed. Wave 5.5 (~2020) was not included in the current analysis as it was 100% telephone interview (7–8), making it fully incomparable with the other waves, as it was previously reported (6). Wave 7 included a replenishment sample and initiated a third survey mode, a web interview (administered to 3.1% of participants). This secondary data analysis was determined exempt from ethical oversight.

Measures

Prevalence of past 30-day ENDS use was assessed as any use of ENDS in the past 30 days (P30D).

Patterns of ENDS use included frequency of use, device type, flavor, and brand. Frequency of ENDS use was derived from the number of days in P30D the participant reported using ENDS, and was categorized here as 1–5, 6–19, and 20+ days in P30D.

Youth reporting P30D ENDS were asked to characterize the device type usually used as “disposable,” “replaceable filled cartridges” (pod/cartridge), “tank,” “mod,” or “something else.” Current analyses combined “mod” and “something else” into a single category due to low endorsement rates. The question structure changed from a single-choice (i.e., the device type used most often) to select-all-that-apply (i.e., any use of each device type, with those using more than one type being asked which was used most often) starting in Wave 6.

ENDS flavor was assessed as check-all-that-apply among youth reporting P30D ENDS use. Wave 5 assessed mint and menthol as a combined category, but these flavors were assessed separately at Waves 6 and 7. Usual/last-used ENDS brand is a PATH-derived variable that assesses usual brand among P30D users who have a usual brand, and last-used brand among those who do not have a usual brand (including those who used ENDS only once). We restricted analyses to the four most common brands at each wave, as well as “no regular brand” and “don’t know”/“refused to answer.”

Analyses

Rates of P30D ENDS use and patterns of ENDS use were compared in the prior 1-year (i.e., Waves 6–7, ~2021–2022) and 3-year (i.e., Waves 5–7, ~2019–2022) periods, both naïvely (i.e., in the full youth sample from each wave, without accounting differences in age range and survey modes) as well as among the subgroup of youth who were comparable across all waves, i.e., youth aged 14–17 who self-administered the survey (Table 1).

To examine how age-range differences may impact both point estimates and trends over time, interactions between age group (12–13 *vs.* 14–17) and wave were examined in those interviewed in-person; for these analyses, only the prior 3-year period (Waves 5–7) were analyzed, i.e., excluding Wave 6 which lacked the younger age group.

Table 1. Methodology differences between PATH Waves 5–7.

	Wave 5	Wave 5.5	Wave 6	Wave 7
Dates of administration	Dec 1, 2018 – Nov 30, 2019	July 3, 2020 – Dec 31, 2020	Mar 1, 2021 – Nov 30, 2021	Jan 6, 2022 – April 2, 2023
Survey mode: self-administered	100%	0%	33.9%	95.1%
Survey mode: telephone interview	0%	100%	66.1%	2.8%
Survey mode: Web interview	—	—	—	3.1%
Age range	12–17	Not analyzed	14–17	12–17
Full sample (N)	11,976	Not analyzed	5,585	10,650
Comparable across waves (N). Age 14–17 AND self-administered	8,797	Not analyzed	1,616	6,829
Not comparable across waves (N). Ages 12–13 OR telephone OR web survey	3,179	Not analyzed	3,969	3,821

Note: Wave 5.5 was not analyzed in detail due to incomparability with other waves (i.e., 0% self-administered).

SAS version 9.4 (Cary, NC, USA) was used for all analyses, and the provided weights were used with balanced repeated replication as recommended by the PATH team to adapt a longitudinal survey design to compare cross-sections and to account for the presence of some respondents in more than one wave (8). Listwise deletion was used for missing data. Weighted frequencies are provided to estimate prevalences and Rao-Scott chi-square tests were used to compare differences in these across waves 5, 6 and 7. Logistic regression models were used to study the interaction of age and wave with least squares means used to estimate the prevalence controlling for the interaction. Because significance testing for ENDS flavor and brand was done as a series of dummy-coding (one response *vs.* all others), Bonferroni correction was applied to these *p*-values.

RESULTS

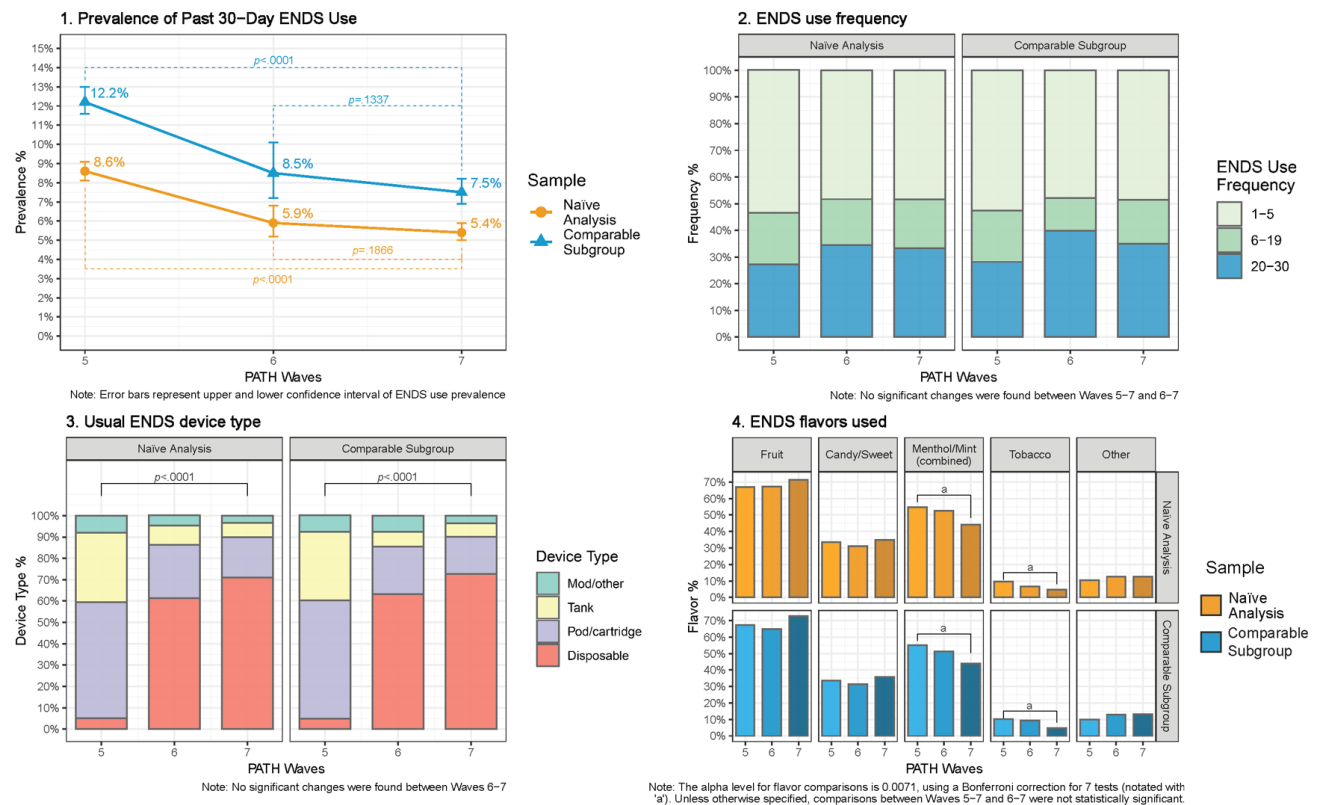
The survey-mode and age-range differences primarily affect PATH Wave 6 (Table 1); since Wave 7 returned nearly entirely (~95%) to self-administration and the newly-enrolled replenishment sample restored the typical age range of 12–17, Waves 5 and 7 are approximately comparable with respect to these methodological differences. The small percentage of web and telephone interviews did not appreciably change the overall Wave 7 estimates (see [Supplementary Table 1](#) using PATH W7 public-use data).

Prevalence of youth ENDS use

Figure 1 shows the naïve *vs.* methodologically-comparable estimates of youth P30D ENDS use and use patterns over Waves 5–7. Results showed a statistically-significant decline in P30D youth ENDS use over the prior 3 years for both the naïve (8.6% to 5.4%, $p < 0.0001$) and comparable-subgroup analyses (12.2% to 7.5%, $p < 0.0001$; see Figure 1, Panel 1); a significant decline between Waves 5–6 has been previously reported (6). In the prior 1-year period (Waves 6–7), P30D ENDS use declined, but not significantly, according to both analyses (naïve analysis: 5.9% to 5.4%, $p = 0.1886$; comparable-subgroup analysis: 8.5% to 7.5%, $p = 0.1337$). However, point estimates were considerably higher in the comparable-subgroup analysis at all time points.

For the rates of P30D ENDS use, the interaction between age and wave over the prior 3 years was significant ($p < 0.0001$). Specifically, P30D ENDS use was significantly more common among youth aged 14–17 compared to those aged 12–13 in both Waves 5 and 7 (Wave 5: 12.2% *vs.* 1.2%; Wave 7: 7.5% *vs.* 1.7%, $p < 0.0001$). However, compared to youth aged 14–17 participating in Wave 5, the comparable age group in Wave 7 reported decreased rates of P30D ENDS use (12.2% in Wave 5 to 7.5% in Wave 7), while it was modestly increased among cohorts aged 12–13 in each wave (1.2% to 1.7%). Controlling for this interaction resulted in a net non-significant main effect of wave, $p = 0.3214$.

Figure 1. Youth ENDS use prevalence and patterns of use, PATH Waves 5–7.



Patterns of ENDS use

Frequency of ENDS use (Figure 1, Panel 2) did not significantly change over the prior 1-year or 3-year periods in either analysis and point estimates were generally similar across the naïve vs. comparable-subgroup analyses (differences of ~5.0 percentage points or less; same rank order of frequency groups). With respect to device type (Figure 1, Panel 3), there was a large shift over the prior 3 years away from pod/cartridge and tank devices and towards disposable devices, which largely occurred during the first of those 3 years (i.e., Waves 5–6), as previously reported (13). Device type patterns were approximately stable over the prior 1 year in both the naïve and comparable-subgroup analyses (differences < 2.0 percentage points). Use of fruit- and candy/sweet-flavored ENDS were fairly consistent across all waves analyzed, reported by 70% and 33% of youth reporting P30D ENDS use, in both naïve and comparable-subgroup analyses (Figure 1, Panel 4). However, there were significant changes in the use of other flavors over the prior 3 years: use of menthol/mint significantly decreased (from ~55% to ~44%, in both naïve and comparable-subgroup analyses) and the use of tobacco flavor, which was uncommon, fell by approximately half (from ~10% to ~5%, $p < 0.0001$). These declines in use of menthol/mint and tobacco flavors appear to have continued over the prior year, though the comparisons did not reach statistical significance, possibly due to lower sample size in Wave 6 (see Table 1).

With respect to usual/last-used brand (Table 2), JUUL declined over the prior 3 years as reported previously (13) as Vuse, Hyde, and Puff Bar increased; brand use was

similar over the 1 year prior to Wave 7. Neither brand endorsement rates nor changes over time were materially different across naïve vs. comparable-subgroup analyses. Additional interaction analyses examined how age-range differences may be associated with trends in patterns of use over the prior 3 years. For most flavors, there was no interaction between age range and wave, with the sole exception of tobacco flavor, where the mean effects of age group and wave were significant as was their interaction ($p < 0.05$ for all with a Bonferroni correction of 5 flavor comparisons), reflecting the fact that the effect of age on use of tobacco-flavored ENDS varied by wave, while the effects on use of other flavors use did not.

With respect to device type, an interaction of age range and wave was found only with trends in pod/cartridge ENDS products: while there was no main effect on use of cartridges overall (i.e., across waves), there was an interaction between age and wave ($p = 0.0055$) such that youth aged 14–17 showed larger declines in use of cartridges over the prior 3 years (55.6% to 17.5%) than youth aged 12–13 (30.8% vs. 24.8%, respectively). Age was not significantly associated with endorsement rates in other device types or their trends over time.

Finally, with respect to JUUL as usual/last-used brand, there were strongly significant main effects of both age and wave as well as their interaction ($p < 0.0001$ for all) on estimates of JUUL as usual/last-used ENDS brand. Specifically, at Wave 5, youth aged 12–13 (vs. 14–17) were more likely to report JUUL as their usual/last-used brand (29.2% vs. 23.7%, respectively). However, in addition to an overall decline in use of JUUL as usual/last-used brand over the prior 3 years ($p < 0.0001$), this age difference reversed in Wave 7 ($p < 0.0001$ for interaction

Table 2. Usual/last-used ENDS brand, naïve analysis and comparable-subgroup analysis, PATH Waves 5–7.

		Wave 5 (~2019)	Wave 6 (~2021)	Wave 7 (~2022)	p-value ^{c,d} (W5→7)	p-value ^{c,d} (W6→7)
Naïve analysis ^a	No regular brand	62.4%	45.3%	44.2%	NA ^e	NA
Naïve analysis	Most common named brands	JUUL: 23.9% Blu: 3.0% SMOK: 1.8% E-Swisher: 1.5%	Hyde: 10.0% Vuse: 7.8% JUUL: 6.5% Puff: 9.3%	Hyde: 12.1% Vuse: 6.1% JUUL: 4.8% Puff: 4.8%	Hyde: NA Vuse: < 0.0001 JUUL: < 0.0001 Puff: NA	Hyde: 0.4041 Vuse: 0.2746 JUUL: 0.2924 Puff: 0.0126
Naïve analysis	All other listed brands	1.9%	4.1%	5.6%	NA	NA
Naïve analysis	Other brand (not listed)	3.2%	11.6%	10.8%	< 0.0001	0.6954
Comparable subgroup ^b	No regular brand	62.7%	51.3%	43.2%	NA	NA
Comparable subgroup	Most common named brands	JUUL: 23.7% Blu: 3.1% SMOK: 1.9% Vuse: 0.4%	Hyde: 12.5% Vuse: 9.4% JUUL: 7.8% Puff: 6.5%	Hyde: 13.0% Vuse: 6.2% JUUL: 5.5% Puff: 5.1%	Hyde: NA Vuse: < 0.0001 JUUL: < 0.0001 Puff: NA	Hyde: 0.8863 Vuse: 0.2338 JUUL: 0.3579 Puff: 0.5216
Comparable subgroup	All other listed brands	1.8%	2.4%	5.1%	NA	NA
Comparable subgroup	Other brand (not listed)	3.1%	3.7%	10.5%	< 0.0001	0.0128

^a Naïve analysis includes all youth participants, regardless of methodological differences between waves.

^b Comparable subgroup analysis includes only youth participants aged 14–17 who self-administered the survey.

^c An overall significance test was not possible due to different lists of most common brands across waves; thus, separate significance tests were performed for each brand vs. all others.

^d The alpha level for brand comparisons is 0.01, using a Bonferroni correction for 5 tests.

^e NA = not applicable

between age and wave), when no 12–13-year-olds reported JUUL use (vs. 5.4% of 14–17-year-olds).

DISCUSSION

This analysis extends previous analyses (6) documenting methodological artifacts in PATH that impact estimates of youth ENDS use prevalence, here focusing on the impact of Wave 6 youth being older than usual (14–17 vs. 12–17), in combination with the previously-reported survey-mode difference. Estimated rates of P30D ENDS use differ substantially between naïve analyses and comparable-subset analyses, with higher prevalence among self-interviewed and older (ages 14–17) youth. In addition to age group having an effect on estimated rates of P30D ENDS use, it also had an effect on age-specific trends (i.e., an interaction between age and wave) such that older youth showed larger declines over the prior 3 years. Methodological differences generally impacted patterns of ENDS use (including frequency of use, device type, flavors, and usual brand) to a lesser degree, in that both patterns of use and trends over time were similar across naïve vs. comparable-subgroup analyses. Age range did, however, impact both point-estimates and trends across time in the use of tobacco-flavored ENDS, use of JUUL as usual/last-used brand (such that 12–13-year-olds had larger declines in JUUL use over the prior 3 years), and

use of pod/cartridge device types (such that 14–17-year-olds had larger declines in pod/cartridge use).

These analyses are consistent with prior work in PATH (6) and NYTS (National Youth Tobacco Survey) (14, 15) showing that COVID-related changes in survey methodology introduce artifacts that complicate comparisons across waves. The survey-mode artifact seems to be at least partly explained by social desirability bias (6, 14), as youth who interact with a live person to give their responses are less likely to report on sensitive behaviors including ENDS use (16, 17). The current analysis extends this work to highlight the impact of an age-range difference which further complicates prevalence comparisons, as Wave 6's relative absence of younger participants (~12–13 years) who are less likely to use ENDS, may result in higher apparent rates of P30D ENDS use, all else (including survey mode) being equal. On the other hand, patterns of ENDS use are not substantially impacted by methodological changes across waves, suggesting that among youth who use ENDS, those who are willing to disclose that behavior in the survey also go on to also report their detailed patterns of use in similar fashion. That is, social desirability may impact the initial reporting of ENDS use but does usually appear to bias responses to more detailed questions on patterns of use once the participant has initially disclosed ENDS use.

A similar phenomenon may apply to age, whereby older youth (14–17 *vs.* 12–17) are more likely to use ENDS, but among those who do use ENDS, patterns of use are similar. There were some exceptions, notably use of tobacco flavor (but no other flavors), use of JUUL as usual/last-used brand (though other brands could not be evaluated), and use of pod/cartridge ENDS (but not other device types). The reason why age impacted the rates of P30D ENDS use and trends of these specific patterns of use is unclear, but could be due to the diversification of the ENDS market: younger youth (12–13) may have initiated after the proliferation of non-tobacco flavors and disposable devices, explaining their lower use of tobacco flavor and pod/cartridge ENDS (and accordingly, use of JUUL, a brand that sells pod/cartridge products) over the prior year. Similarly, migrating to flavors also explains the steeper decline in use of tobacco flavor and pod/cartridge devices among older youth (14–17).

Trends in patterns of use over time are consistent with other analyses of US youth. In particular, there has been a large shift away from pod/cartridge devices and towards disposable device types since 2020 (10, 13, 18), and the current analysis shows that this trend continues in PATH Wave 7. Use of common brands has changed accordingly, *i.e.*, away from JUUL in Wave 5 to Puff and Hyde in Waves 6 and 7 (brands that sell disposables). Use of fruit and candy/sweet flavors remains consistently high. Frequency continues to be bimodally distributed—with approximately 33–40% (across analyses) using frequently (*i.e.*, 20+ days in P30D), just under half using on only 1–5 days per week, and few using on an intermediate number of days—consistent with youth use of nicotine/tobacco products in general (19).

Additionally, the youth ENDS use trends in this analysis broadly align with those of other nationally-representative surveys of US youth, including NYTS and Monitoring the Future (MTF), which also show a substantial decline in youth ENDS use since 2019–2020 (20, 21) and a shift towards disposable ENDS and away from pod/cartridge-based ENDS (22, 23). However, it is important to note that while trends are consistent across surveys, point estimates vary due to methodology differences (sampling strategy, survey mode, *etc.*). For example, PATH's estimates of youth P30D ENDS use prevalence are consistently lower than NYTS's (8.6% *vs.* 20.0%, respectively, in the 2019 peak; and 5.4% *vs.* 9.4% in W7/2022 (24–25). Thus, cross-survey inference should not seek to reconcile small discrepancies in estimates but rather focus on trends and approximate estimates (provided survey methodology is consistent over time).

Though the current findings are specific to the U.S. with respect to specific trends in youth ENDS use, the methodological implications are relevant to youth surveillance efforts globally. Namely, these findings highlight the importance of maintaining the same survey methodology over different waves so that trends can be derived accurately. If changes in survey methodology do occur, this can create artifacts that could be misinterpreted as changing trends, *e.g.*, different prevalence due to non-equivalent age ranges of participants as shown here, or due to COVID-related changes to survey mode in PATH (6) and NYTS (14–15). Thus, it is essential for the study team to test for, and document, any artifacts due to survey

administration so that researchers can account for them when analyzing data. However, even when the study team has documented methodology changes that prevent direct comparisons across waves – such as the COVID-related change to survey mode in NYTS 2021 (14–15) and several large changes to Canadian youth surveillance surveys (26) – researchers sometimes fail to account for these and inappropriately infer trends (27–28). Researchers, therefore, also have a responsibility to be cognizant of, and account for, such artifacts when analyzing data from these surveys.

Limitations include the self-reported nature of data, which may be inaccurate due to recall bias and (as discussed above) social desirability bias. Additionally, there is the possibility of a self-selection bias in the survey mode in Wave 6, as some participants who were eligible for in-person self-administered survey completion nevertheless elected a telephone interview. Unfortunately, there is no data indicating which telephone-interviewed participants elected *vs.* were assigned a telephone interview. Regardless of this possible self-selection, however, there remains a significant difference in ENDS use prevalence by survey mode that future research should take into account.

CONCLUSIONS

Methodological differences in survey mode and age range complicate comparisons of youth ENDS use prevalence in PATH Waves affected by COVID-related changes and, generally to a lesser extent, patterns of ENDS use (*i.e.*, frequency of use, usual device type, flavors, and brands). Future analyses of PATH trends in youth ENDS use behaviors that include Waves 5.5 and 6 must account for survey mode and age; or alternatively, only directly compare Waves 5 and Wave 7, which are approximately equivalent.

SUPPLEMENTARY INFORMATION

This publication contains supplementary material available [on the Journal's website](#).

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ETHICAL APPROVAL AND INFORMED CONSENT

This is a secondary analysis of the anonymized PATH data. The PATH study was conducted by Westat, Inc. and approved by Westat's institutional review board. This secondary data analysis of PATH data was determined exempt from IRB oversight by a qualified IRB. All analyses were performed in accordance with the relevant guidelines and regulations.

DECLARATION OF INTEREST

Through Pinney Associates (PA), authors AS, SK, and MH consult to Juul Labs, Inc (JLI) on nicotine vapor products to advance tobacco harm reduction. Additionally, AS serves as a scientific advisor to the Global Forum on Nicotine (GFN) in exchange for travel support to the annual GFN conference and a small honorarium. In the past 3 years, PA has also consulted to Philip Morris International (PMI) solely on US regulatory pathways for non-combustible, non-tobacco nicotine products. PA does not consult on combustible tobacco products. In the past 3 years, AS has also consulted on behavioral science to the Center of Excellence for the Acceleration of Harm Reduction (CoEHAR), which received funding from the Global Action to End Smoking (GA). Neither PMI, GFN, CoEHAR, nor GA had any role in, or oversight of, this manuscript.

DATA AVAILABILITY

The restricted-use data files from the Population Assessment of Tobacco and Health (PATH) Study were used: <https://www.icpsr.umich.edu/web/NAHDAP/studies/36231>. Researchers may obtain access to the restricted-use data by submitting an application to the Inter-University Consortium for Political and Social Research (ICPSR).

CREDIT STATEMENTS

AS: Conceptualization, Investigation, Project administration, Writing - original draft, Writing - review and editing; MJH: Data curation, Formal analysis, Methodology, Software, Writing - review and editing; SK: Conceptualization, Investigation, Visualization, Writing - review and editing; SS: Supervision, Investigation, Methodology, Writing - review and editing.

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