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Research Article

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Nicotine-only, THC-only, and dual vaping are not exchangeable: how exposure composition determines the pooled "vaping"–anxiety association (2024 NSDUH)

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Abstract

Introduction. A single "vaping" exposure combines nicotine-only, tetrahydrocannabinol (THC)-only, and dual use. We tested whether their adjusted associations with anxiety symptoms are equal and what a pooled association represents.

Methods. Cross-sectional analysis of 47,299 adults in the 2024 National Survey on Drug Use and Health, the first wave carrying the adult 7-item Generalized Anxiety Disorder scale (GAD-7). Survey-weighted logistic regression estimated adjusted odds ratios (aOR) for moderate-to-severe anxiety symptoms (GAD-7 ≥10) across four mutually exclusive past-month groups.

Pairwise contrasts, a binary any-vaping model, and composition re-weighting were post hoc; serious psychological distress (Kessler-6) provided an internal cross-instrument check.

Results. aORs were 1.65 (95% CI 1.39–1.95) for nicotine-only, 2.45 (1.90–3.15) for THC-only, and 2.23 (1.82–2.73) for dual use; after marijuana and depression adjustment, 1.50, 1.51, and 1.21. The nicotine-only/THC-only ratio was 0.67 (0.50–0.90; p = 0.009), significant at a Bonferroni threshold of 0.017; nicotine-only/dual was 0.74 (0.57–0.96; p = 0.025) and THC-only/dual 1.10 (0.80–1.50; p = 0.54). Any vaping had an aOR of 1.94 (1.69–2.24)—by construction a mixture of the three group-specific associations, weighted by their composition, whose interval overlapped every group-specific interval. Re-weighting to three published compositions yielded 1.93–2.12. The nicotine-only/THC-only difference was reproduced for distress (p = 0.006).

Conclusions. The three vaping groups are not exchangeable. A pooled "vaping" association is a mixture whose value depends on the sample's nicotine:THC:dual composition and should be reported alongside it. These cross-sectional estimates do not establish causation.

Keywords: GAD-7; anxiety; electronic cigarettes; nicotine; tetrahydrocannabinol; compound treatment; NSDUH

Implications

Analyses that treat e-cigarette use as a single exposure estimate a composition-weighted mixture rather than the association for any one group of vapers. Because the nicotine-only and THC-only associations with anxiety symptoms differ—one pairwise difference survived multiplicity correction, two did not—the pooled figure moves—modestly, by about 10% across published

compositions—with the sample's exposure mix. Studies and surveillance reports of vaping and mental health would be more interpretable if the nicotine:THC:dual composition were reported alongside pooled estimates, and if nicotine-only and THC-only use were analysed as distinct exposures where the data permit.

1. Introduction

Anxiety symptoms commonly co-occur with depression and substance use, consistent with shared vulnerability as well as substance-specific pathways. [1-3] The e-cigarette complicates this literature because the device is not the exposure: it may deliver nicotine, THC, or both. Treating all "vaping" as one exposure therefore collapses behaviourally and pharmacologically distinct groups into one category and invites exposure misclassification. [4, 5]

This is an instance of the compound-treatment, or multiple-versions-of-treatment, problem described by Hernán and VanderWeele: a pooled parameter for a compound exposure depends on which versions are present and in what proportions. [6, 7] The principle is well established, and the present estimands are cross-sectional associations rather than causal effects; but the framework clarifies the measurement question. If the nicotine-only, THC-only, and dual associations differ, an any-vaping coefficient necessarily summarises a mixture whose composition can change across samples. To our knowledge, whether they differ has not been tested in a national probability sample with a validated anxiety instrument.

Recent work shows both the value and the limits of separating these exposures. Salinas and colleagues compared dual with single-substance vapers on the GAD-7 in an online convenience sample (N = 492; 40 vaped cannabis only), without a non-vaping comparison group, and did not report the nicotine-only versus cannabis-only contrast. [8] In the National Survey on Drug Use

and Health (NSDUH), Kim and colleagues distinguished exclusive nicotine, exclusive cannabis, and co-vaping among adults aged 18–25, modelling psychological distress as a predictor of vaping type rather than an outcome. [9] Drake and colleagues showed in the PATH study that adults who vape cannabis are frequently misclassified as nicotine vapers, but did not examine a health outcome. [10] Route-of-administration work has similarly shown that collapsing distinct cannabis use patterns obscures heterogeneity in mental-health correlates. [11]

The 2024 NSDUH is the first wave carrying the adult GAD-7, a validated screen for which a score ≥10 denotes moderate-to-severe symptoms, and its design and weights permit population-level estimates. [12-14] We used its adult public-use file to ask two questions: are the adjusted associations of past-month nicotine-only, THC-only, and dual vaping with moderate-to-severe anxiety symptoms statistically distinguishable; and, if they are, what does an analysis that pools them into a single "vaping" exposure estimate, and how does that estimate depend on the sample's exposure composition? Additional adjustment for overall marijuana use and major depressive episode was retained as a sensitivity analysis rather than a primary question. Because the design is cross-sectional, all results are interpreted as associations, not causal effects or temporal sequence.

2. Methods

Data, design, and population. Cross-sectional analysis of the 2024 NSDUH public-use file, representing the U.S. civilian, non-institutionalized population. Adults aged ≥18 years (CATAG6 categories 2–6) were analysed as a survey domain (unweighted n = 47,299). The data are public and de-identified; ethics review and consent were not required. Reporting follows the STROBE guideline; the checklist is provided as supplementary material.

Outcome. Moderate-to-severe anxiety symptoms in the past two weeks, defined as a GAD-7 total score ≥10 (AGADTOTSC; cross-checked against the derived severity variable AGADMODOSEV, with complete agreement). The GAD-7 is a screen, not a diagnosis. The internal robustness outcome was past-month serious psychological distress (SPDPSTMON), a binary indicator derived from the Kessler-6 (K6). The GAD-7 and K6 are related but not fully overlapping measures with different recall windows (two weeks versus one month).

Exposure. Past-month e-cigarette use was classified as none, nicotine-only (NICVAPMON = 1, MJVAPMON = 0), THC-only (MJVAPMON = 1, NICVAPMON = 0), or dual (both = 1); this four-group variable was the primary exposure. A three-group specification combining THC-only and dual into "THC vaping" was retained for comparability with prior literature and for internal calibration. A post-hoc binary indicator combined all three vaping groups as "any vaping".

Covariates. Age category, sex, race/ethnicity, education, poverty level, marital status, health insurance, past-month cigarette use, and past-month alcohol use. Past-month marijuana use of any route (IRMJRC) and past-year major depressive episode (AMDEYR) may confound or lie on the pathway of the vaping–anxiety association, and adding them can induce over-adjustment because THC vaping is contained within overall marijuana use [15]; they were therefore added in pre-specified sensitivity models. Recency, nicotine-vaping frequency, and sex-stratified analyses were pre-specified sensitivity or exploratory analyses.

Primary analysis. Survey-weighted logistic regression used the person-level weight (ANALWT2_C), stratum (VESTR_C), and primary sampling unit (VEREP) with Taylor-series linearization. Crude and adjusted odds ratios were estimated relative to non-vapers, with a joint Wald test for the exposure term. The pre-specified primary estimand was the set of adjusted odds

ratios for the four-group exposure; persistence under marijuana and depression adjustment was a pre-specified sensitivity question. The analysis plan was specified internally but not publicly preregistered, and the group-specific estimates were posted as a preprint before the analyses below were added.

Post-hoc analyses. Three analyses were added after the preprint and are post hoc; each was documented in writing before execution, with a decision rule where one applied, but the group-specific point estimates were already public, so no pre-registration status is claimed. (i) *Pairwise contrasts.* The three contrasts among the nicotine-only, THC-only, and dual coefficients were estimated on the primary model using the full coefficient covariance matrix. All three are reported regardless of direction or significance; uncorrected two-sided p values are shown alongside a Bonferroni threshold for three contrasts ($\alpha = 0.017$). (ii) *Pooled model.* The any-vaping indicator was fitted with the same covariates and design, to obtain the estimate that an analysis treating vaping as one exposure would report. (iii) *Composition re-weighting.* Holding the three group-specific adjusted odds ratios fixed, we computed the pooled odds ratio implied by alternative compositions on the risk scale: with non-vaper prevalence $p_0 = 0.059$, each group's odds ratio O_g was converted to a risk $p_g = O_g p_0 / (1 - p_0 + O_g p_0)$, the risks were averaged with composition weights, and the average converted back to an odds ratio. Compositions were taken from this sample and from three published studies of nicotine and cannabis vapers, applied as arithmetic scenarios rather than as those studies' estimates. [8, 9, 16] Before use, the procedure was checked against an internal benchmark: applied to THC-only and dual with their observed proportions, it reproduced the directly fitted three-group "THC vaping" estimate (2.337 versus 2.34). Sensitivity to p_0 and to the averaging scale is reported in Supplementary Table S6.

Second distress measure. The primary four-group model was refitted with serious psychological distress as the outcome. This analysis was also post hoc; before it was run, a single criterion was fixed: reproduction meant that the nicotine-only versus THC-only contrast had the same sign as on the GAD-7 with $p < 0.05$.

Degrees of freedom and interval conventions. The design had 50 degrees of freedom; each model's residual degrees of freedom were 50 + 1 − rank(X): 25 for the four-group model and 27 for the any-vaping model. Contrast intervals and p values used t(25); the any-vaping interval used t(27). Confidence intervals for the pre-specified estimates in Table 2 and Supplementary Tables S1–S4 retain the normal-approximation values reported in the preprint; all newly added intervals use the model-specific residual degrees of freedom.

Missing data, E-values, and independent verification. Adjusted models used complete cases within the adult domain (n = 47,163; 136 excluded for missing household income); models including depression used 45,526. Missingness was 0.29%, confined to income, and did not differ across exposure groups (unweighted Pearson χ^2) under either the three-group ($\chi^2 = 1.28$, df = 2, $p = 0.53$) or the four-group ($\chi^2 = 1.28$, df = 3, $p = 0.73$) classification. E-values were computed for the THC-only estimate. [17] Analyses used R (survey package); the analyses added in the present version used R 4.6.0 (survey 4.5). Primary and sensitivity point estimates had earlier been reproduced to two decimal places in a separate Python (statsmodels) implementation. For the analyses added here, Python code implemented the Taylor-linearized sandwich estimator de novo—without calling R or a survey library—retaining the full stratum–PSU structure for domain estimation and the complete coefficient covariance for contrasts; for the primary four-group model (its coefficients and three pairwise contrasts), the pooled any-vaping model, and the descriptive quantities, coefficients, standard errors, residual degrees of

freedom, and design-based p values were reproduced with absolute differences below 1×10^{-4}. The second-instrument, sensitivity, and E-value analyses were run in a single implementation. Generative artificial-intelligence tools were used, under the author's direction, to assist with analysis code and language editing; the full disclosure appears in the declarations.

3. Results

Sample. Among 47,299 adults (weighted ≈ 262 million), 7.4% (95% CI 7.0–7.8) had moderate-to-severe anxiety symptoms; prevalence was 5.9% in non-vapers, 15.8% in nicotine-only, 17.3% in THC-only, and 21.6% in dual users. E-cigarette users were younger and more likely to use cigarettes and alcohol (Table 1).

Group-specific associations (Table 2). Crude odds ratios were 2.99 (95% CI 2.55–3.51), 3.35 (2.68–4.20), and 4.41 (3.70–5.27) for nicotine-only, THC-only, and dual use. After adjustment, aORs were 1.65 (1.39–1.95), 2.45 (1.90–3.15), and 2.23 (1.82–2.73) (joint Wald F = 36.1 on 3 and 25 df, $p = 3.1\times10^{-9}$). Adding past-month marijuana use attenuated THC-only (1.68, 1.27–2.23) and dual (1.55, 1.21–2.00) while leaving nicotine-only largely unchanged (1.60, 1.35–1.90). After further adjustment for major depressive episode—itself strongly associated with the outcome (aOR 14.0, 12.1–16.3)—nicotine-only remained significant (1.50, 1.24–1.80), THC-only attenuated (1.51, 1.06–2.15), and dual was inconclusive (1.21, 0.88–1.65). For comparability with prior literature, the three-group model gave a THC-vaping aOR of 2.34 (Table 2 note); separating the groups showed that the pooled THC estimate was an average of a higher THC-only and a somewhat lower dual estimate.

Are the groups exchangeable? (post-hoc contrasts). The nicotine-only/THC-only ratio of aORs was 0.67 (95% CI 0.50–0.90; p = 0.009), below the Bonferroni threshold of 0.017.

Nicotine-only/dual was 0.74 (0.57–0.96; p = 0.025), significant before but not after correction. THC-only/dual was 1.10 (0.80–1.50; p = 0.54); no difference was detected for that pair. The evidence therefore does not support treating the three coefficients as interchangeable, but neither does it establish that every pair differs.

What the pooled exposure estimates. The directly fitted any-vaping aOR was 1.94 (95% CI 1.69–2.24). It is by construction a mixture of the three group-specific associations, weighted (approximately, on the risk scale) by their composition, rather than an estimate for any one of them, and its interval overlapped every group-specific interval (1.39–1.95, 1.90–3.15, 1.82–2.73). Re-weighting the group-specific estimates to this sample's own weighted composition gave 1.96, within 1% of the directly fitted value. Holding the group estimates fixed and applying three published compositions moved the implied pooled value from 1.93 (adults aged 18–25) to 2.12 (a convenience sample in which 71% of vapers were dual users)—a 9.9% range, smaller than the multiplicative width of any group-specific interval; the theoretical range from all-nicotine-only to all-THC-only is 1.65 to 2.45 (Table 3).

Second distress measure. For serious psychological distress, aORs were 1.48 (95% CI 1.24–1.76), 2.13 (1.67–2.70), and 2.70 (2.09–3.50) for nicotine-only, THC-only, and dual use (joint F = 24.5 on 3 and 25 df, $p = 1.3\times10^{-7}$). The criterion fixed in advance was met: nicotine-only differed from THC-only in the same direction as on the GAD-7 (−0.36 log-odds; p = 0.006). The ordering of the THC-containing groups differed between instruments—THC-only highest on the GAD-7, dual highest on distress—but neither THC-only/dual contrast was significant (p = 0.54 and 0.068), so the ordering difference is not statistically established (Supplementary Table S5).

Other pre-specified analyses. Associations were consistent across past-year and lifetime windows and strongest for past-month use (Supplementary Table S1). Among nicotine vapers, more vaping days showed an increasing gradient (aOR 1.17 per ordinal category; p = 0.028), not strictly monotonic (Supplementary Table S2). Associations were stronger in women, with a significant exposure-by-sex interaction (p = 0.012), but sex-specific intervals overlapped (Supplementary Table S3). E-values for THC-only were 2.51 (point) and 2.10 (limit) before, and 1.92 and 1.51 after, marijuana adjustment (Supplementary Table S4).

4. Discussion

Using the first NSDUH wave with the adult GAD-7, we compared past-month nicotine-only, THC-only, and dual e-cigarette use with moderate-to-severe anxiety symptoms in a nationally representative sample. All three groups were associated with higher adjusted odds (THC-only 2.45, dual 2.23, nicotine-only 1.65). The central finding is that these associations are not interchangeable: nicotine-only and THC-only differed even after multiplicity adjustment, nicotine-only and dual differed only before it, and the two THC-containing groups could not be distinguished. This describes the exposure structure; it is not a claim about mechanism.

Separating THC-only from dual use is where the structure becomes visible. A three-group classification folds pure-THC and nicotine/THC dual users into a single "THC vaping" category; here, roughly half of that category was dual use. Once separated, the THC-only estimate was slightly higher than the pooled THC estimate—so dual use was not artificially inflating the pooled association; rather, the lumped category obscured potentially distinct patterns for THC-only and dual users. Notably, although dual users had the highest unadjusted symptom prevalence (21.6%), their adjusted odds ratio (2.23) was not the highest of the three vaping

groups, because dual users also carried more of the adjusted covariates (e.g., cigarette and alcohol use); covariate adjustment therefore attenuated the dual estimate more than the THC-only estimate. Exposures labelled identically as "THC vaping" may therefore contain groups differing in motives, co-used substances, and mental-health background.

What the lumped category obscures can be quantified, and the issue is clearest when all three groups are compressed into "any vaping". Any such analysis estimates, by construction, a mixture of the group-specific associations whose weights are the sample's exposure composition (approximately a weighted average on the risk scale; see Limitations). [6, 7] Here that average was 1.94. Applied to the exposure mixes reported by three other studies—an NSDUH sample aged 18–25, adults who use tobacco products in five New England states, and an online convenience sample—the same arithmetic gave 1.93 to 2.12 (Table 3). Two things follow. First, the pooled coefficient is not the coefficient for nicotine vapers, THC vapers, or dual users; it is a property of the sample's mix and should be read as such. Second, the movement induced by realistic compositional differences was modest—about 10%, less than the sampling uncertainty around any one group estimate—and the pooled interval overlapped every group-specific interval. The compositional dependence therefore concerns the interpretation of the pooled parameter, not the reliability of existing pooled estimates. We do not claim that published estimates are wrong or mutually incomparable. A testable implication for future meta-analysis is that studies should report the nicotine:THC:dual composition alongside pooled estimates and, as studies accrue, examine composition as a study-level moderator; that is a hypothesis from this application, not evidence that an existing synthesis would change.

A population-average association for "any vaping" remains a legitimate estimand for a clearly defined target population. The point is narrower: when the components differ, the average is

specific to the population that produced it and does not answer the question most readers bring to it—whether nicotine or THC vaping is more strongly associated with anxiety symptoms.

Sensitivity analyses give a more conservative reading of the group-specific estimates. After additional adjustment for past-month marijuana use, the THC-only association attenuated from 2.45 to 1.68 and dual from 2.23 to 1.55, while nicotine-only was essentially unchanged. After further adjustment for past-year major depressive episode, the nicotine-only association remained near 1.5 and statistically significant, the THC-only association attenuated markedly, and the dual-use estimate became inconclusive—consistent with the established link between smoking/nicotine and anxiety [18], and with a substantial part of the THC-vaping burden being shared with overall marijuana use, itself associated with anxiety [19], and with depression comorbidity.

This attenuation should not be read as "THC vaping has no association." THC vaping is a component of marijuana use (THC vaping $\subseteq$ marijuana use), so adjusting the THC-vaping estimate for overall marijuana use is, by construction, an over-adjustment: it conditions on a superset of the exposure itself, and much of the association is removed as a mathematical consequence rather than as evidence against an effect. [15] The marijuana-adjusted THC-only estimate (aOR 1.68) should therefore be read as an extreme conservative lower bound, not a refutation. The internal consistency of the models supports this interpretation: the nicotine-only estimate is essentially unchanged under the same adjustment, because nicotine vaping is not part of the marijuana-use construct. Anxiety and depression are likewise highly comorbid, so adjustment for major depressive episode may similarly over-control. We present these adjustments to show how the association changes as overall marijuana use and depression comorbidity are added in turn, not to prove a mechanism. The entanglement of anxiety,

depression, and substance use seen here is consistent with a transdiagnostic, internalizing-spectrum view of shared liability; a cross-sectional analysis cannot adjudicate this, but longitudinal work could test it.

The second-instrument check adds limited but useful internal robustness. The nicotine-only versus THC-only contrast retained its direction on a related but not fully overlapping distress measure, which argues against the pattern being an artefact of the GAD-7 alone. This is an internal cross-instrument check, not external validation: the same respondents completed both measures in the same interview, the instruments share item content, and the prior probability of agreement was therefore high. The highest point estimate changed from THC-only on the two-week GAD-7 to dual use on the one-month distress measure; different constructs and recall windows are plausible explanations, both THC-only versus dual tests were non-significant, and the apparent ordering change cannot support a substance-specific interpretation without a formal outcome-by-exposure interaction test, which was not planned.

Our results extend rather than contradict earlier work. Salinas and colleagues provided GAD-7 data among vapers but could not compare nicotine-only with cannabis-only or either with non-users at the population level. [8] Kim and colleagues used the four-group taxonomy in NSDUH for young adults, with distress as a predictor of vaping type. [9] Drake and colleagues showed how often cannabis vapers are counted as nicotine vapers; the present analysis carries that exposure-definition concern into an anxiety association. [10] Chung and colleagues separated cannabis smoking, cannabis vaping, and their dual use—a different decomposition axis that likewise shows why broad product labels need explicit component definitions. [11] Clendennen and colleagues examined the reverse temporal direction, with symptoms predicting subsequent nicotine and THC vaping among adolescents and young adults. [20] We place nicotine-only,

THC-only, dual use, and non-users in a single population-level frame, test whether the groups differ, and show what pooling them estimates.

For clinicians and surveillance, vaping status alone may be insufficient: ascertaining whether a patient vapes nicotine, THC/marijuana, or both is a screening point, not a causal claim.

Independent computation strengthens the methods application: for the four-group model, its pairwise contrasts, and the pooled model, a de novo Python Taylor-linearization estimator reproduced point estimates, standard errors, residual degrees of freedom, and design-based p values to below 1×10^{-4}. This does not remove model misspecification or measurement bias, but it makes a software-specific inferential error less likely and made explicit the distinction between design and residual degrees of freedom. Further strengths are the large, nationally representative sample; the validated GAD-7 with its standard threshold; the separation of THC-only from dual use; and the written documentation of the post-hoc analyses, with their decision rules, before they were run.

5. Limitations

The cross-sectional design cannot establish whether vaping preceded anxiety symptoms, whether symptoms influenced vaping, or whether shared causes produced both. [3] The primary outcome covers two weeks, exposure covers 30 days, and the K6 covers one month; these mismatched windows limit temporal interpretation and offer a competing explanation for the cross-instrument ordering. Exposure, covariates, and outcomes were self-reported; respondents may not know what their devices contained, so the nicotine/THC classification may be misclassified—if non-differential, this would generally attenuate group contrasts. The GAD-7 and K6 are screening measures rather than diagnoses; they are related, not independent, and robustness across them

within the same survey is not external replication. Past-month cigarette use was adjusted as binary, leaving possible confounding by smoking intensity and former smoking. Trauma, other psychiatric conditions, substance-use-disorder severity, use motives, product dose, and device type were unavailable. Because the outcome was not rare, odds ratios exceed the corresponding prevalence ratios. Only one NSDUH wave includes the adult GAD-7, preventing within-NSDUH replication. Sex-stratified THC-only and dual cells were moderate in size.

The pairwise contrasts, pooled model, and composition re-weighting are post hoc; their decision rules were documented before execution, but the point estimates were already public. The composition calculations have additional restrictions. Adjusted odds ratios are non-collapsible, so risk-scale re-weighting is an interpretable approximation rather than an algebraic reconstruction of a marginal logistic coefficient; the close internal checks—2.337 versus the fitted 2.34 for pooled THC vaping, and 1.96 versus the directly fitted 1.94 for any vaping—bound the discrepancy in this dataset but do not remove it. Re-weighting also assumes that the three group-specific odds ratios transport across populations; the exposure-by-sex interaction ($p = 0.012$) shows that they are not constant even within this sample, so transportability cannot be assumed. Table 3 deliberately fixes the group estimates to isolate the composition channel; it is not a prediction of what the cited studies would have estimated, and none of those studies reported a pooled vaping-versus-non-user estimate. The three published compositions are illustrative, not a systematic sample.

6. Conclusions

In the first NSDUH wave carrying the adult GAD-7, nicotine-only, THC-only, and dual past-month e-cigarette use were each associated with higher odds of moderate-to-severe anxiety

symptoms, with the nicotine-only association least attenuated by adjustment for marijuana use and depression (1.65 to 1.50, versus 2.45 to 1.51 and 2.23 to 1.21). The nicotine-only and THC-only associations differed even after Bonferroni correction; the two THC-containing groups did not differ detectably. Because the groups are not exchangeable, pooling them yields an aOR—here 1.94—that is by construction a composition-weighted mixture, corresponds to none of the groups, and yet cannot be statistically distinguished from any of them; its value depends on the sample's nicotine:THC:dual mix. Reporting that composition alongside pooled vaping–mental-health estimates, and analysing nicotine-only and THC-only use as distinct exposures where the data permit, would make such estimates more interpretable. These cross-sectional associations do not establish causation or temporal order.

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Declaration of Interests

None. No funding from, financial relationship with, or other interest involving the tobacco, alcohol, cannabis, pharmaceutical, or gambling industries or organisations supported by them; no constraints on publication; no payments, financial support, or other financial interests in the past 36 months.

Data Availability

The 2024 NSDUH public-use file is available from the Substance Abuse and Mental Health Services Administration at https://www.datafiles.samhsa.gov/. The R analysis code and the

independent Python verification code will be made openly available through GitHub and archived with a persistent identifier upon publication.

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Table 1. Weighted sample characteristics by past-month e-cigarette group (column %), with unweighted n

	Overall	Non-vaper	Nicotine-only	THC-only	Dual
Unweighted n	47,299	38,656	4,824	1,873	1,946
Weighted n (millions)	262.3	227.6	18.8	8.6	7.3
Age 18–25 (%)	13.3	11.1	28.7	17.6	39.5
Female (%)	51.3	52.2	47.6	41.1	44.5
Past-month cigarette (%)	14.3	11.4	35.4	22.1	40.6
Past-month alcohol (%)	50.2	48.0	60.0	70.8	71.5
GAD-7 ≥ 10 (%)	7.4	5.9	15.8	17.3	21.6

Unweighted GAD-7 ≥ 10 counts: non-vaper 2,998/38,656; nicotine-only 837/4,824; THC-only 356/1,873; dual 471/1,946. The three-group "THC vaping" category is the union of THC-only and dual. Dual users were the youngest and the heaviest cigarette and alcohol users; this contributes to their lower adjusted odds ratio despite their highest crude symptom prevalence.

Table 2. Adjusted odds ratios for moderate-to-severe anxiety symptoms by past-month e-cigarette group

Exposure	Crude OR (95% CI)	Primary aOR (95% CI)	+ Marijuana use	+ Depression	+ Marijuana + depression
Nicotine-only	2.99 (2.55–3.51)	1.65 (1.39–1.95)	1.60 (1.35–1.90)	1.52 (1.26–1.83)	1.50 (1.24–1.80)
THC-only	3.35 (2.68–4.20)	2.45 (1.90–3.15)	1.68 (1.27–2.23)	1.94 (1.40–2.69)	1.51 (1.06–2.15)
Dual	4.41 (3.70–5.27)	2.23 (1.82–2.73)	1.55 (1.21–2.00)	1.53 (1.19–1.97)	1.21 (0.88–1.65)
Model n	47,163	47,163	47,163	45,526	45,526

Outcome: moderate-to-severe anxiety symptoms (GAD-7 ≥ 10); reference = non-vapers. Crude odds ratios are unadjusted survey-weighted estimates computed with the same survey design in the same complete-case sample as the adjusted models; estimates in the full adult domain (n = 47,299) were essentially identical. The crude, primary, and +marijuana models include 47,163 adults; models adjusting for depression include 45,526 (a further 1,637 excluded for missing past-year major depressive episode). The primary model adjusts for age, sex, race/ethnicity, education, poverty, marital status, insurance, past-month cigarette use, and past-month alcohol use; the joint Wald test was $F = 36.1$ (df 3, 25), $p = 3.1\times10^{-9}$. Past-year major depressive episode was itself strongly associated with anxiety symptoms (aOR 14.0, 95% CI 12.1–16.3). For the three-group measure (in which the "THC vaping" category is the union of THC-only and dual), the crude nicotine-only OR was 2.99 (2.55–3.51) and the crude THC-vaping OR was 3.82 (3.30–4.44); the adjusted nicotine-only aOR was 1.65 (1.39–1.96) and the THC-vaping aOR was 2.34 (1.96–2.78), attenuating to 1.62 (1.29–2.02) after marijuana adjustment. Post-hoc pairwise contrasts on the primary model are reported in the Results (residual df = 25; t-based intervals); confidence intervals in this table use a normal approximation.

Table 3. Pooled "any vaping" adjusted odds ratio implied by alternative exposure compositions

Composition source	Nicotine-only (%)	THC-only (%)	Dual (%)	Implied pooled aOR
This sample, survey-weighted	54.2	24.9	21.0	1.96
This sample, unweighted	55.8	21.7	22.5	1.95
NSDUH 2022–2023, adults aged 18–25 [9]	56.3	15.1	28.5	1.93
Adults who use tobacco products, five New England states [16]	37.5	22.0	40.5	2.05
Online convenience sample of vapers [8]	21.1	8.1	70.7	2.12
Directly fitted pooled model, this sample	—	—	—	*1.94 (95% CI 1.69–2.24)*

Group-specific inputs are the primary adjusted odds ratios in Table 2 (1.65, 2.45, 2.23), held fixed across rows; the risk-scale procedure and its sensitivity to the reference risk and averaging scale are described in the Methods and Supplementary Table S6. The theoretically attainable range, from 100% nicotine-only to 100% THC-only, is 1.65 to 2.45. Compositions in rows 3–5 are taken from the cited studies' reported group sizes or prevalences; none of the three reported a pooled vaping-versus-non-user estimate for anxiety (the New England study modelled vaping type as the outcome, with anxiety as a predictor). The values shown are what a pooled estimate would be if the group-specific associations were as observed here; the calculation isolates the composition channel and does not estimate results for the cited studies (see Limitations).

Supplementary Files

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