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Household Indoor E-Cigarette Use and Frequent or Severe Headache in U.S. Children: A Cross-Sectional NSCH Study

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Abstract

Background

Evidence concerning household indoor e-cigarette use and headache among children is limited. We examined whether caregiver-reported household indoor e-cigarette use was associated with current frequent or severe headache among U.S. children.

Methods

This cross-sectional analysis used 2022–2024 National Survey of Children's Health data for children aged 3–17 years. Survey-weighted modified Poisson regression estimated adjusted prevalence ratios (aPRs), accounting for the complex survey design, survey year, indoor combustible-tobacco use, and prespecified demographic and household covariates. Predictive margins estimated adjusted prevalences and prevalence differences. Six family income-to-poverty ratio implicates were combined using Rubin's rules.

Results

Among 130,077 children, 6,383 (weighted 4.76%) lived in homes with reported indoor e-cigarette use and 3,960 had current frequent or severe headache. Reported indoor e-cigarette use was associated with headache (aPR, 1.75; 95% confidence interval [CI], 1.42–2.16). Adjusted prevalence was 4.56% among exposed children and 2.59% among unexposed children, a difference of 1.97 percentage points (95% CI, 1.04–2.90). There was no evidence of exposure-by-year interaction (P=.276). Among children aged 3–11 years, the estimate was imprecise (aPR, 1.45; 95% CI, 0.97–2.16).

Conclusions

Caregiver-reported indoor e-cigarette use in the home was associated with a higher prevalence of caregiver-reported frequent or severe headache. The cross-sectional data could not establish causality or distinguish secondhand exposure from adolescents' own use.

Background

Headache disorders are common in childhood and adolescence and may interfere with school participation, family functioning, and quality of life. A 2023 systematic review estimated a pooled paediatric migraine prevalence of 11%, although estimates varied by age, diagnostic criteria, and study methods [1]. Nationally representative U.S. data have also identified frequent or severe headache, including migraine, as an important paediatric health problem [2].

Electronic cigarettes generate an aerosol that may contain nicotine, ultrafine particles, volatile organic compounds, flavoring chemicals, and metals. U.S. biomarker data indicate that reported secondhand e-cigarette vapor exposure in children aged 3–11 years corresponds to measurable nicotine absorption, although at lower concentrations than secondhand combustible smoke [3]. Human evidence on secondhand e-cigarette exposure remains limited and has focused mainly on respiratory and biomarker outcomes [4, 5].

Headache has been reported among adolescents and young adults who actively use e-cigarettes [6, 7]. A Canadian population survey associated frequent recurrent headache with active daily vaping among adolescents and with daily household indoor smoking among children [8]. These studies do not answer whether U.S. children living in homes where e-cigarettes are used indoors have a higher prevalence of headache. We therefore evaluated this association in the 2022–2024 National Survey of Children's Health (NSCH), including absolute prevalence differences, annual estimates, an ages 3–11 restriction, and sensitivity analyses.

Methods

Study design and data source

This cross-sectional study used the 2022, 2023, and 2024 NSCH topical public-use data. The NSCH is an annual address-based survey sponsored by the Health Resources and Services Administration Maternal and Child Health Bureau and administered by the U.S. Census Bureau. After a household screener, one resident child is randomly selected for an age-specific questionnaire completed by a parent or caregiver familiar with the child's health [9–12]. Child-level weights account for selection, within-household subsampling, nonresponse, and calibration.

Study population

The annual topical samples included 54,103 children in 2022, 55,162 in 2023, and 51,375 in 2024. We used Child and Adolescent Health Measurement Initiative (CAHMI) Data Resource Center two-year files. Because adjacent releases both contained 2023, we retained 2022 from the 2022–2023 release and 2023–2024 from the 2023–2024 release; all 2023 HHIDs and 21 prespecified fields matched, and each child was included once. We included children aged 3–17 years with valid headache, indoor e-cigarette use, and indoor combustible-tobacco responses. The adjusted sample also required complete sex, race and ethnicity, adult education, family structure, and region data. All eligible records from the prespecified years were used.

Exposure and outcomes

The focal exposure was a yes response to, 'Does anyone vape or use e-cigarettes inside your home?' The item did not identify the user or measure proximity, frequency, duration, device type, or nicotine content. The primary outcome was caregiver-reported current frequent or severe headache, including migraine. This composite was not a clinician-confirmed migraine diagnosis and did not distinguish headache type. Current moderate or severe headache, defined by the NSCH severity-derived variable, was a secondary population-level outcome.

Covariates

Covariates were selected before formal analysis using a directed acyclic graph and subject-matter knowledge. The primary model included indoor combustible-tobacco use (no household smoker, household smoker who did not smoke indoors, or indoor smoking); child age as a 3-degree-of-freedom natural cubic spline; sex (the NSCH public-use variable SC_SEX, coded as male or female); race and ethnicity; family income-to-poverty ratio; highest education among resident adults; family structure; U.S. Department of Health and Human Services region; and survey year. We did not adjust for potential downstream variables such as sleep, mental health, health-care use, school absence, or headache treatment.

Survey design, pooled weights, and missing data

We specified household identifier (HHID) as the primary sampling unit (PSU) and the interaction of state (FIPSST) and survey stratum (STRATUM) as the stratification variable. The full survey design was constructed before age- or year-domain restriction [12]. Variances were estimated by Taylor linearization. We reconstructed annual weights by multiplying the supplied two-year combined weight by two and divided annual weights by three for the pooled analysis, producing average annual population estimates [13].

NSCH supplies six family income-to-poverty ratio implicates (FPL_I1-FPL_I6). Every model and predictive-margin calculation was fit in each implicate, and coefficients and covariance matrices were combined using Rubin's rules [14]. Records missing other model variables were excluded. Of 132,088 children with valid exposure and outcome data, 2,011 (1.52%) lacked family-structure data; other primary covariates and all poverty implicates were complete. Missingness details are provided in Additional file 1: Table S3.

Statistical analysis

We summarized unweighted counts and survey-weighted means or proportions. A survey-weighted generalized linear model with a log link and quasipoisson variance estimated the adjusted prevalence ratio (aPR) and design-based 95% confidence interval (CI). Survey-weighted quasibinomial models with a logit link estimated predictive margins and prevalence differences using the same adjustment set.

Prespecified supporting analyses included separate annual models, an exposure-by-year interaction, restriction to ages 3–11 years, a complementary ages 12–17 estimate and exposure-by-age-band interaction, the moderate/severe outcome, exclusion of dual indoor e-cigarette and combustible-tobacco exposure, and a four-category joint-exposure model. Wald interaction tests used the Rubin-pooled coefficient vector and total covariance matrix. E-values and a weighted crude nondifferential exposure-misclassification scenario analysis assessed sensitivity to unmeasured confounding and exposure error [15].

Tests were two-sided with alpha=.05. The exposure contrast was the sole primary analysis; supporting analyses were interpreted using CIs, event counts, and omnibus interaction tests without multiplicity adjustment. Reporting followed the STROBE statement [16]. Analyses used R version 4.6.1, survey version 4.5 [17], and mitools version 2.4. Two clean reruns ended normally, and 11 core result files were identical by SHA-256.

Ethics

This study was a secondary analysis of the deidentified public-use 2022–2024 National Survey of Children's Health data. The analysis involved no direct interaction with participants and no access to identifiable private information. Institutional review board approval and additional informed consent were therefore not required. Clinical trial registration was not applicable.

Results

Sample formation and characteristics

The annual files contained 160,640 unique children; 136,195 were aged 3–17 years, and 132,088 had valid outcome and tobacco-exposure responses. After excluding 2,011 children with missing family-structure data, the primary analysis included 130,077 children and 3,960 headache events, representing an average annual U.S. population of approximately 58.5 million children (Additional file 2: Figure S1).

Overall, 6,383 children lived in households with reported indoor e-cigarette use, representing 4.76% of the weighted population. Unadjusted weighted headache prevalence was 5.69% among exposed children and 2.56% among unexposed children. Exposed children were slightly older and more often lived in households with indoor combustible smoking, lower income, lower adult educational attainment, and nonmarried family structures (Table 1).

Table 1

Characteristics of the Primary Analytic Sample, NSCH 2022–2024 Values are survey-weighted percentages unless otherwise noted. Unweighted sample sizes were 123694 without and 6383 with reported household indoor e-cigarette use; total N = 130077.

Characteristic	No reported indoor e-cigarette use	Reported indoor e-cigarette use	Overall
Weighted population, average annual n	55714225	2782231	58496456
Age, weighted mean years	10.18	10.72	10.20
Age 3–11 years	58.1	52.7	57.8
Age 12–17 years	41.9	47.3	42.2
Female sex	48.9	47.1	48.8
Hispanic	27.3	18.8	26.9
Non-Hispanic White	47.4	59.5	47.9
Non-Hispanic Black	12.7	9.7	12.5
Non-Hispanic other/multiple race	12.7	12.0	12.7
Family income-to-poverty ratio < 100%	16.9	22.0	17.1
Family income-to-poverty ratio 100%-199%	19.6	24.9	19.8
Family income-to-poverty ratio 200%-399%	28.5	31.9	28.6
Family income-to-poverty ratio > = 400%	35.1	21.1	34.4
Highest adult education less than high school	8.6	6.3	8.5
High school/GED	18.1	30.1	18.6
Some college/technical school	18.6	30.1	19.1
College degree or higher	54.7	33.5	53.7
Two married parents	65.9	50.2	65.1
Two unmarried parents	6.0	12.4	6.3
Single parent	23.7	30.8	24.1
Grandparent household	3.1	4.3	3.2

Note: Poverty estimates average the six supplied NSCH implicates. Percentages may not sum to 100 because of rounding.

Characteristic	No reported indoor e-cigarette use	Reported indoor e-cigarette use	Overall
Other family structure	1.2	2.3	1.3
No household combustible smoker	89.7	68.1	88.7
Household smoker, not indoors	9.1	21.5	9.7
Indoor combustible smoking	1.2	10.4	1.6
Current frequent/severe headache	2.6	5.7	2.7
Current moderate/severe headache	1.3	2.9	1.4

Note: Poverty estimates average the six supplied NSCH implicates. Percentages may not sum to 100 because of rounding.

[Table 1 about here]

Primary association

Reported household indoor e-cigarette use was associated with a higher prevalence of current frequent or severe headache (aPR, 1.75; 95% CI, 1.42–2.16; P<.001). Adjusted prevalence was 4.56% (95% CI, 3.65%-5.47%) among exposed children and 2.59% (95% CI, 2.41%-2.77%) among unexposed children, a difference of 1.97 percentage points (95% CI, 1.04–2.90; P<.001) (Table 2).

Table 2
Primary Association and Adjusted Absolute Prevalence, NSCH 2022–2024

Exposure contrast	aPR (95% CI)	P value	Adjusted headache prevalence, % (95% CI)	Adjusted difference, percentage points (95% CI)
Reported indoor e-cigarette use: yes vs no	1.75 (1.42–2.16)	< 0.001	4.56 (3.65–5.47) vs 2.59 (2.41–2.77)	1.97 (1.04–2.90)
Household combustible smoker, not indoors vs no household smoker	1.40 (1.10–1.77)	0.005	—	—
Indoor combustible smoking vs no household smoker	1.17 (0.82–1.67)	0.393	—	—

Note: Models adjusted for child age (natural cubic spline), sex, race and ethnicity, family income-to-poverty ratio, highest adult education, family structure, HHS region, survey year, and both tobacco exposure variables. aPR indicates adjusted prevalence ratio; CI, confidence interval.

In the same model, living with a household smoker who did not smoke indoors was associated with headache compared with no household smoker (aPR, 1.40; 95% CI, 1.10–1.77); the indoor combustible-smoking estimate was imprecise (aPR, 1.17; 95% CI, 0.82–1.67). These differently defined exposures were not prespecified for comparative-harm inference.

[Table 2 about here]

Supporting analyses

Annual aPRs were 2.09 (95% CI, 1.44–3.03) in 2022, 1.28 (95% CI, 0.88–1.86) in 2023, and 1.96 (95% CI, 1.39–2.75) in 2024 (Table 3 and Fig. 1). The exposure-by-year interaction was not significant (P=.276).

Table 3
Supporting and Sensitivity Analyses

Analysis or contrast	Analysis N	Focal events	aPR (95% CI)	P value
2022	43382	103	2.09 (1.44–3.03)	< .001
2023	43701	105	1.28 (0.88–1.86)	.203
2024	42994	133	1.96 (1.39–2.75)	< .001
Ages 3–11 years	73317	76	1.45 (0.97–2.16)	.067
Ages 12–17 years	56760	265	1.88 (1.47–2.39)	< .001
Moderate/severe headache	130058	184	1.76 (1.32–2.36)	< .001
Excluding dual exposure	129534	300	1.82 (1.46–2.26)	< .001
E-cigarette only vs neither	5840	300	1.89 (1.53–2.33)	< .001
Indoor smoke only vs neither	1164	61	1.29 (0.84–1.99)	.239
Dual exposure vs neither	543	41	1.52 (0.91–2.52)	.109

Note: Focal events are outcome events among children with reported indoor e-cigarette use or, for the mutually exclusive model, in the named category. Exposure-by-year omnibus P=.276; exposure-by-age-band P=.711. Annual models omitted the year covariate; other adjustments matched the primary model. The reference for mutually exclusive contrasts was neither exposure (N = 122530; 3558 events).

[Figure 1 about here]

Among children aged 3–11 years (N = 73,317; 76 exposed events), the estimate was imprecise (aPR, 1.45; 95% CI, 0.97–2.16; P=.067); adjusted prevalences were 1.79% and 1.23%, a difference of 0.56 percentage points (95% CI, -0.14 to 1.25). Among children aged 12–17 years, the aPR was 1.88 (95% CI, 1.47–2.39), but the exposure-by-age-band interaction was not significant (P=.711).

Indoor e-cigarette use was associated with current moderate or severe headache (aPR, 1.76; 95% CI, 1.32–2.36). Excluding 543 children with dual indoor e-cigarette and combustible-tobacco exposure yielded an aPR of 1.82 (95% CI, 1.46–2.26) and a prevalence difference of 2.13 percentage points (95% CI, 1.14–3.12). In the joint-exposure model, the e-cigarette-only aPR was 1.89 (95% CI, 1.53–2.33); smoke-only and dual-exposure estimates were imprecise (Table 3).

The E-value was 2.90 for the primary estimate and 2.19 for its CI limit closest to the null. Across 30 mathematically valid assumed exposure-classification scenarios, corrected weighted crude risk ratios ranged from 2.26 to 4.52. These unvalidated scenarios did not correct the adjusted aPR or address outcome error, active use, dependent reporting error, or selection (Additional file 1: Tables S2-S4).
[Table 3 about here]

Discussion

In this nationally representative study, caregiver-reported household indoor e-cigarette use was associated with a 75% higher adjusted prevalence of current frequent or severe headache and an absolute adjusted difference of 1.97 percentage points. The association remained after excluding dual indoor tobacco exposure and was observed for the moderate/severe outcome. Annual estimates differed in precision, but the year interaction was not significant.

The ages 3–11 restriction reduced the plausibility that the sampled child was the e-cigarette user. Its estimate was in the same direction, but the CI included the null and should not be interpreted as independent confirmation. The larger adolescent estimate did not establish age modification because the interaction test was null and active vaping could not be excluded.

Our findings extend studies of active use and combustible smoke. Headache has been reported among youth e-cigarette users [6, 7], and a Canadian survey linked frequent recurrent headache with active daily adolescent vaping and daily indoor household smoking [8]. Evidence concerning combustible smoking and headache provides contextual support [18, 19], but products, exposure types, and populations differ. The NSCH item instead recorded use by anyone inside the home without identifying the user.

Measurable serum cotinine among nonusing children with reported secondhand vapor exposure supports the plausibility of nicotine uptake [3], but it does not validate the present exposure measure or prove mediation. Prospective research has also associated household secondhand vaping with respiratory symptoms [20], whereas reviews emphasize limited, heterogeneous evidence and substantial risk of bias [4, 5]. Nicotine, aerosol irritants, and inflammatory or neurovascular responses are possible pathways, but the NSCH data contain no biomarkers or temporal measurements.

Combustible-tobacco use was included as a coexposure and contextual benchmark, not as a head-to-head comparison. Indoor smoking was uncommon, and the smoking and e-cigarette items did not measure equivalent frequency or dose. The nonsignificant indoor-smoking coefficient does not show absence of harm, and the numerically larger e-cigarette coefficient does not establish greater harm.

Strengths include three unique annual samples, correct handling of the overlapping 2023 release, full complex-survey and domain methods, pooled weights representing an average annual population, and Rubin-rule combination of six poverty implicates. We reported relative and absolute estimates, interaction tests, event counts, age and coexposure restrictions, and sensitivity analyses. Two clean analytic runs produced identical core outputs.

Several limitations are central. Cross-sectional measurement prevents establishing temporality or causality. The exposure was a caregiver-reported household-use proxy and did not establish inhalation by the child, identify the user, or measure proximity, frequency, ventilation, device characteristics, or nicotine dose. The outcome was caregiver reported, combined frequent or severe headache with migraine, and was not clinically characterised. Shared caregiver reporting could produce dependent error in either direction.

NSCH did not measure the sampled child's active vaping, so active use could not be excluded among adolescents. Residual confounding may remain from parental headache susceptibility, household stress, sleep, other indoor pollutants, cannabis aerosol, fragrances, or unmeasured socioeconomic factors. Complete-case exclusion for nonpoverty covariates and modest survey response rates may introduce selection bias despite weighting. Results generalise to U.S. noninstitutionalized children living in households during 2022–2024, not necessarily to other settings or current product markets.

Reported indoor nicotine-product use may be relevant when describing a child's environmental history, but these data do not show that screening for or changing household vaping would reduce headache. Longitudinal studies should identify the household user, distinguish adolescents' own use, measure aerosol or biomarkers repeatedly, and use validated paediatric headache diagnoses and disability measures.

Conclusions

Caregiver-reported household indoor e-cigarette use was associated with a higher prevalence of caregiver-reported frequent or severe headache among U.S. children. The study could not establish causality or distinguish secondhand exposure from adolescents' own use, and the ages 3–11 estimate was imprecise.

Abbreviations

aPR
adjusted prevalence ratio

CAHMI
Child and Adolescent Health Measurement Initiative
CI
confidence interval
FPL
family income-to-poverty ratio
HHS
U.S. Department of Health and Human Services
HHID
household identifier
NSCH
National Survey of Children's Health
PSU
primary sampling unit.

Declarations

Ethics approval and consent to participate

Ethics approval and consent to participate were not required for this secondary analysis of deidentified, publicly available 2022–2024 NSCH data because the investigators had no direct interaction with participants and no access to identifiable private information.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

CQ conceptualized the study, developed the methodology, conducted the formal analysis, and drafted the manuscript. CY contributed to conceptualization and methodology, supervised the work, reviewed and edited the manuscript. GC curated the data, prepared the visualization, and reviewed and edited the

manuscript. YS, QC, JX, and YF reviewed and edited the manuscript. LZ supervised the work, administered the project, and reviewed and edited the manuscript, and served as guarantor.All authors read and approved the final manuscript and accept accountability for the work.

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Availability of data and materials

The deidentified public-use 2022–2024 NSCH datasets and accompanying documentation analysed during the current study are available from the U.S. Census Bureau at https://www.census.gov/programs-surveys/nsch/data/datasets.html [21].

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Figures

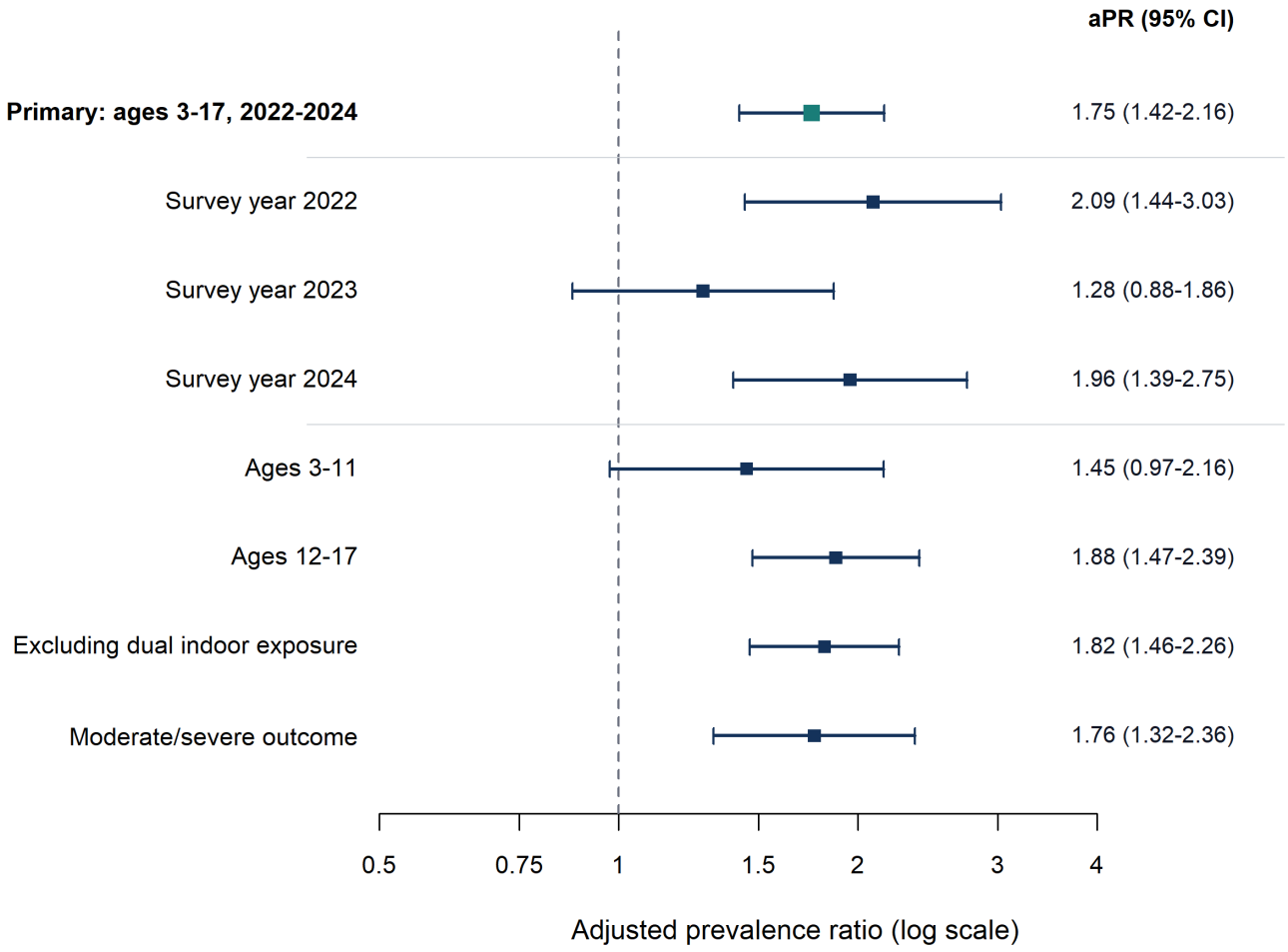


Figure 1

Adjusted prevalence ratios for reported household indoor e-cigarette use and current frequent or severe headache. Squares indicate aPRs and horizontal lines indicate 95% confidence intervals. All models incorporated the complex survey design and six poverty implicates. The moderate/severe row uses the population-level secondary outcome; the no-dual row excludes children with both reported indoor e-cigarette use and indoor combustible smoking.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- 03AdditionalFile1SupplementaryTables.docx
- AdditionalFile2StudyFlow.tif