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Global youth e-cigarette use: prevalence, risks, and regulatory policy impacts

Edited by
Tammy Chung, Joanna Jacobus and Anita Cservenka

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Global youth e-cigarette use: prevalence, risks, and regulatory policy impacts

Topic editors

Tammy Chung — Rutgers, The State University of New Jersey, United States
Joanna Jacobus — University of California, San Diego, United States
Anita Cservenka — Oregon State University, United States

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Alessandra Maria Passarotti,
University of Illinois Chicago, Chicago, United States

*CORRESPONDENCE
Tammy Chung
tammy.chung@rutgers.edu

†These authors share first authorship

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Editorial: Global youth e-cigarette use: prevalence, risks, and regulatory policy impacts

Anita Cservenka[1†], Joanna Jacobus[2†] and Tammy Chung[3*]

[1]School of Psychological Science, Oregon State University, Corvallis, OR, United States, [2]Department of Psychiatry, University of California San Diego, San Diego, CA, United States, [3]Institute for Health, Health Care Policy and Aging Research, Rutgers, The State University of New Jersey, New Brunswick, NJ, United States

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e-nicotine, e-cigarette, vape, adolescent, young adult

Editorial on the Research Topic
Global youth e-cigarette use: prevalence, risks, and regulatory policy impacts

E-nicotine products, including e-cigarettes and vapes, have emerged as a global health concern, particularly among adolescents and young adults. The rapid rise in e-nicotine use among youth (1) occurs in the context of e-cigarette use rates that have overtaken that of combustible cigarettes in some countries (2). In addressing this significant global public health concern, this Research Topic's twelve articles provide an international perspective on youth e-nicotine use. The articles cover e-nicotine use starting with precursors of use (i.e., susceptibility) through risk and protective factors associated with e-nicotine use at personal (including brain structure), social network, and regulatory policy levels of analysis. The articles showcase the breadth and complexity of the challenges to be addressed in reducing e-nicotine related harms to health.

Prior to initiating e-cigarette use, the beliefs or expectancies that an individual has regarding the positive and negative effects of use (e.g., feeling relaxed or nauseous) robustly predict e-cigarette use (3), and indicate susceptibility (i.e., curiosity, intention, willingness to use) to e-cigarette use. Tarantino et al.'s analyses, reported in this Research Topic, found that adolescents' (aged 12–14) positive and negative e-cigarette expectancies were associated with perceived risk of harm from e-cigarette use, perceived peer disapproval and curiosity about e-cigarettes in the Adolescent Brain Cognitive Development Study conducted in the US (4). Examining susceptibility to e-cigarette use in older adolescents, James et al. found in their survey that over one-third of Oklahoma high-school students who had never used tobacco reported susceptibility to e-cigarette use. Among males in the survey, susceptibility was linked to low perceived e-cigarette harm. Furthermore, among females in the high school survey, psychological distress, lower academic performance, and sexual-minority identity predicted higher susceptibility and risk for e-cigarette use, suggesting important sex differences in risk that can inform interventions tailored to specific subgroups.

In the context of increasing worldwide prevalence of e-nicotine use, several contributions to this Research Topic investigated e-nicotine onset and prevalence

across European, Middle Eastern countries, and Australia. Given the importance of preventing early initiation of e-nicotine use, Al-Naimi et al. conducted a retrospective survey study to identify factors related to early initiation (prior to the age of 18) of vaping. Their survey of 428 regular nicotine vapers (aged 18–60) residing in Middle Eastern countries found that males and adults living in Qatar had the greatest likelihood of early vaping initiation. Extending behavioral findings on early onset, Happer et al. reveal that earlier onset of regular nicotine use and greater craving and reinforcement symptomatology were associated with larger hippocampal volumes in adolescents and emerging adults. The hippocampus, rich in nicotinic acetylcholine receptors, is central to reinforcement learning and memory, suggesting that structural differences in this brain region may contribute to early addiction risk, emphasizing the importance of prevention and early intervention.

Two Research Topic studies, Hejda et al. and Kamoni et al. (5), found higher prevalence of e-nicotine use among males, relative to females. Specifically, male adolescents (aged 12–16) in Poland (Hejda et al.) and male Australian university students (aged 18–25) (5) were more likely to report e-nicotine use. These recent international findings add to the sex-related risk for e-cigarette use reported in adolescence (6). Importantly, since the prevalence of e-nicotine use in youth increases with age (1), Selya et al. observed that prevailing definitions of current e-nicotine use, often operationalized as any use within the past 30 days, may not correlate with clinically meaningful exposure during this developmental period. Their analysis recommends improvements to assessment of e-nicotine use by incorporating frequency, intensity, and persistence metrics to better distinguish transient experimentation from regular use that confers greater health risk.

Effectively reducing risk for e-nicotine use requires understanding the individual, interpersonal or social network, and community-level factors associated with youth e-nicotine use trajectories (6). At the individual level, for example, Kamoni et al. found that Australian university students who reported greater psychological distress, worse academic performance and alcohol use had higher risk for e-cigarette use (5). Similarly, the study by Lanza et al., which involved a regional sample of college students (aged 18–29) in the US, identified polysubstance use trajectories, such as nicotine/tobacco use and binge drinking. The co-occurrence of nicotine/tobacco use with other substance use shows how "syndemics" or co-occurring health conditions, which include overweight (Lanza et al.), can exacerbate the adverse health effects of e-nicotine/tobacco use on health.

Among the risk factors for e-nicotine use, family and peer nicotine/tobacco use robustly predict e-nicotine onset and use. For example, Hatz et al. demonstrate that peer and family nicotine/tobacco product use are the most consistent prospective predictors of emerging adult nicotine/ tobacco product initiation in a US regional sample, even after controlling for baseline use and concurrent cannabis or alcohol consumption. Notably, certain subgroups show protective resistance to peer influence. Specifically, Kozela et al.'s study revealed that women with low socioeconomic status residing in Poland reported being less affected by peer pressure against cigarette smoking and using heated tobacco products, indicating their overall risk for nicotine use may be less susceptible to social influence. Together, these findings align with conceptual models of substance use that emphasize the powerful role of social context and social influence in shaping nicotine use (7), and sex-differences in risk and protection that can inform tailored prevention efforts.

Another robust risk factor addressed in this Research Topic involves youth exposure to e-nicotine advertising, which has been previously linked to youth e-nicotine use (8). For example, Świątkowska et al. found in their sample of over 7,000 Polish adolescents and young adults, that over half reported exposure to e-nicotine advertisements. Specifically, seeing advertisements in club/pub/disco settings was significantly associated with reporting current e-cigarette use (Świątkowska et al.). Similarly, Wang et al. found in their online survey of 724 young adults (aged 18–30) in China that social media exposure to e-cigarettes/ vaping, perceived policy enforcement, and perceived risks and benefits of e-nicotine use were associated with vaping/ e-cigarette use. These studies underscore how youth exposure to e-nicotine marketing, which focuses on the benefits of use, can shape youth perceptions of e-nicotine-related harms to health. In this regard, Hejda et al. found that nearly a third of youth (aged 12–16 years) surveyed in Poland reported that e-nicotine product use was less harmful than combustible cigarette use. These provocative findings emphasize the importance of disseminating accurate information regarding the health harms of e-nicotine use, and the need for effective nicotine/tobacco regulatory policy. To this point, Wang et al. (9) discuss the complexities and challenges in developing and enforcing effective tobacco/e-nicotine regulatory policy.

Across this Research Topic's twelve articles, converging evidence supports multifaceted assessment, and the need for multi-level prevention and intervention strategies: (1) refining measurement standards to capture experimental vs. persistent e-nicotine use; (2) targeting high-risk subgroups, especially those reporting psychosocial distress and social-media exposure and using tailored strength-based approaches to meet specific needs of subgroups and individuals; (3) addressing familial and peer normative influences; and (4) developing effective policy and interventions, particularly to account for the brain's heightened sensitivity to nicotine during adolescence and emerging adulthood (10). Collectively, findings from this Research Topic's articles call for harmonized epidemiologic definitions of nicotine and tobacco use and cross-disciplinary approaches to more effectively mitigate youth nicotine use worldwide.

Author contributions

AC: Conceptualization, Writing – original draft, Writing – review & editing. JJ: Conceptualization, Writing – original draft, Writing – review & editing. TC: Conceptualization, Writing – original draft, Writing – review & editing.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Thivanka Muthumalage,
Purdue University, United States

REVIEWED BY
Mark A. Gottlieb,
Northeastern University, United States
Robert J. Wellman,
UMass Chan Medical School, United States

*CORRESPONDENCE
Shirley A. James
✉ shirley-james@ouhsc.edu

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Susceptibility to e-cigarette use and associated factors in high school youth, Oklahoma Youth Tobacco Survey, 2021–2022

Shirley A. James[1]*, Ashley H. White[1], Fahad F. Kahn[2], Nasir Mushtaq[1], Sixia Chen[1] and Laura A. Beebe[1]

[1]Department of Biostatistics and Epidemiology, Hudson College of Public Health, University of Oklahoma Health Sciences Center, Oklahoma City, OK, United States, [2]Oklahoma State Department of Health, Oklahoma City, OK, United States

Introduction: Susceptibility predicts subsequent uptake of e-cigarettes (EC) by youth. This study identified factors associated with EC susceptibility among high school students who have never used a tobacco/nicotine product.

Methods: The Oklahoma Youth Tobacco Survey was administered to a random sample of 36 Oklahoma High Schools during the 2021–2022 school year (n = 1,220 participating students). Associations between EC susceptibility and covariates were identified using stepwise logistic regression for weighted survey data.

Results: More than one third of Oklahoma high school students who had never used tobacco or nicotine products (36.4%) were susceptible, and males had higher susceptibility than females (38.8 and 33.9%, respectively). In males, EC susceptibility was associated with race (Black, American Indian, and other were less susceptible), psychological distress (aOR = 2.4, 95% CI = 1.1, 4.8), disagreement that all tobacco products are dangerous (aOR = 3.1, 95% CI = 1.2, 7.9), and perception of little/no harm from secondhand vapor (aOR = 3.4, 95% CI = 2.1, 5.3). In females, identifying as gay, lesbian, or bisexual (aOR = 2.1, 95% CI = 1.1, 3.9), poor academic performance (aOR = 4.5, 95% CI = 1.6, 12.6), psychological distress (aOR = 2.6, 95% CI = 1.2, 5.5) and interacting with EC content on social media (aOR = 5.9, 95% CI = 1.9, 18.1) were associated with EC susceptibility.

Conclusion: Males and females had different patterns of susceptibility to EC use. Understanding groups of adolescents most susceptible to using nicotine products can help target prevention efforts at home, in schools, and within communities.

KEYWORDS

susceptibility, electronic cigarettes (e-cigarettes), vaping, youth tobacco prevention, youth tobacco survey

Background/Introduction

Electronic cigarette (EC) use among youth remains problematic and can lead to other forms of nicotine dependence, including smoking (1, 2). Previous research suggests adolescents who regularly used vaping products are up to four times more likely to have smoked in the past 30-days or to have initiated smoking (1). Similarly, there is a strong

association between smoking initiation and regular vaping product use among youth (2).

Most adult tobacco use begins with tobacco experimentation during adolescence (1, 2). Of the wide array of tobacco products available, current high school (HS) students most often choose to experiment with ECs. In 2018, Gentzke and associates reported an adolescent 30-day EC prevalence of 27.7% using data from the National Youth Tobacco Survey (YTS) (3). This prevalence dropped to 19.6% in 2020 (4), 11.3% in 2021, and is currently 14.1% in 2022 (5, 6). While this drop in 30-day prevalence during the last 2 years is encouraging, EC use continues to be a concern, and a significant proportion of adolescents remain susceptible to initiation.

Several research studies have documented factors associated EC use in youth, including identifying as White, using other tobacco products, and having family members who use tobacco of any kind (7). Stress is also associated with both EC and tobacco use and can be related to school grades, peer pressure, gender diversity, and other stressors (7–10). Harm perception or the perception that ECs are less harmful and/or addictive than smoking traditional tobacco products is strongly associated with EC use among youth (8–10), as is exposure to EC advertisement and marketing. Alternatively, television, radio, and social media messaging exposing the dangers associated with tobacco use can increase the perception of harm and decrease susceptibility to tobacco initiation (11, 12).

Preventing initiation is an important step in averting nicotine dependence (1). Susceptibility precedes initiation of tobacco use of any kind (1). EC susceptibility is defined as a lack of firm, decisive, and robust denial of interest in initiating EC use among never users (1, 13, 14). Several studies have reported a strong association between EC susceptibility and initiation within youth (15–17).

A number of studies have evaluated susceptibility to EC use among adolescents, and findings vary based on sampling methods and measures. EC susceptibility has been associated with believing that ECs are less harmful than combustible tobacco products (18–20), believing that ECs are less addictive than combustible tobacco products (21), and having higher affluence (19, 22). Additional factors associated with EC susceptibility include being exposed to EC advertising (22), living in a household where members use ECs (18), and having family members or friends who smoke or vape (21, 22). Conversely, identifying as Black (18), Hispanic (18, 20), and female (18, 20) have been associated with a protective effect with regard to EC susceptibility. Studies limiting the analytic sample to youth who have never used any nicotine product are uncommon. The aim of this study was to determine variables associated with EC susceptibility among high school youth in Oklahoma who have never used any tobacco or nicotine product, including ECs.

Methods

Data

Data for this study were obtained from the Oklahoma Youth Tobacco Survey (OYTS), administered from November 2021 through May 2022. A multi-stage sampling design was used to draw the sample of students. The first stage involved selecting a random sample of public high schools. The second stage involved selecting three classes from each school, using simple random sampling without replacement. Finally, all students in each class were offered the opportunity to take the online survey. The OYTS included a final sample of 36 public high schools with a total sample size of 1,220 students. The analytic sample used in this study was students who never used any tobacco or nicotine product, and with complete information about grade level and age required for accurate weighting ($n = 780$).

Outcome variable

Susceptibility to EC use was defined using the susceptibility index previously developed and validated for smoking susceptibility (1) and determined from the following four questions: "Have you ever been curious about using an e-cigarette?," "Do you think you will try an e-cigarette soon?," "Do you think you will use an e-cigarette in the next year?," and "If one of your best friends were to offer you an e-cigarette, would you use it?" Possible answers included "definitely yes," "probably yes," "probably not," and "definitely not." Students were considered susceptible if they responded with any answer *except* "definitely not" to *any* of those questions.

Measures

Demographic variables

Covariates included ethnicity, categorized as Hispanic or non-Hispanic; race, categorized as American Indian, Black, White, or other; grade level categorized as freshman/sophomore or junior/senior; and sex, categorized as male or female. Finally, students were asked if they spoke a language other than English in the home, with responses dichotomized as yes or no.

Sexual identity

When asked, "Which of the following best describes you?," respondents self-identified into the following categories: straight; gay, lesbian, or bisexual; and unsure.

Grades in school

Respondents were asked, "During the last 12 months, how would you describe your grades in school?" Responses were coded as "As and Bs"; "C's or lower"; and "graded on another scale or unsure." Students graded on another scale were either on a pass/fail grading scale or using an individualized education plan for special education purposes.

Family affluence score

An affluence score was assigned based on four questions; "Does your family own a vehicle?" (no = 0, one = 1, and two or more = 2), "Do you have your own bedroom?" (no = 0 and yes = 1), "How many computers does your family own?" "(none = 0, one = 1, two = 2, and more than two = 3)," and "how many times in the last 12 months have you traveled on vacation with your family?" (Not at all = 0, once = 1, twice = 2, and more than twice = 3). Responses were summed with scores of five or less coded "low affluence," and scores of six or more coded "high affluence," consistent with prior studies (3–6).

Psychological distress

A psychological distress score was assigned based on four questions; "During the past 2 weeks, how often have you been bothered by having little interest or pleasure in doing things?," "During the past 2 weeks, how often have you been bothered by feeling down, depressed, or hopeless?," "During the past 2 weeks, how often have you been bothered by feeling nervous, anxious, or on edge?," and "During the past 2 weeks, how often have you been bothered by feeling like you are not able to stop or control worrying?" Each question was coded not at all = 0, several days = 1, more than half of the days = 2, and nearly every day = 3. Consistent with prior literature, responses were summed with scores of five or less coded "none or low distress," and scores six or more coded "moderate or severe" (3–6).

Harm perception

Four questions were used to determine EC harm perception. First, "How much do you think people harm themselves when they use ECs some days but not every day?" Responses of "No harm" or "a little harm" were combined and compared to "some harm" or "a lot of harm" combined. Next, responses to "Do you believe that ECs are (less addictive, equally addictive, or more addictive) than cigarettes?" were dichotomized as "equally/less/do not know" combined and compared to "more addictive." Third, agreement with the statement "All tobacco products are dangerous" was assessed. Those who responded, "strongly agree" or "agree" were combined and compared to those who responded "disagree" or "strongly disagree." Fourth, Do you think that breathing the vapor from other people's EC causes "no harm," "a little harm," "some harm," or "a lot of harm." Respondents answering, "no harm" or "a little harm" were combined and compared to those who answered, "some harm" or "a lot of harm" (3–6).

Anti-tobacco messaging

Respondents were asked two questions about anti-tobacco messaging. Youth who responded yes to seeing or hearing The Real Cost ads in the past 12 months, and those selecting one or more anti-tobacco names or slogans they may have seen in the past 12 months were considered to have been exposed. Answers were summed and then dichotomized into 0 or 1 and 2 or more (3–6).

EC and tobacco product marketing

Exposure to EC and other tobacco marketing was assessed separately and from questions about four different sources: retail stores; internet; television, streaming services, or movies; and newspapers or magazines. Respondents were asked, "When you are using 'each of these services' how often do you see ads or promotions (for ECs; for cigarettes or tobacco products)?" Respondents could answer never, rarely, sometimes, most of the time, or always. They received one point for each answer of sometimes, most of the time, or always. Answers were summed and then dichotomized into 0 or 1 and 2 or more (2–4).

Social media

Among students responding they use social media, we captured social media exposure based on four questions. First, we asked "How often do you use social media?" Second, we asked "When you use social media, how often do you see posts of content related to e-cigarettes?" To assess interaction with social media, we then asked the following two questions: "When you use social media, how often do you post pictures of yourself or someone else using e-cigarettes?" and "When you use social media, how often have you liked, commented, or shared posts or content related to e-cigarettes?" We dichotomized each question separately, with those responding monthly or more frequently combined and compared to those responding, "less than monthly or never to these questions" (3–6). Those responding that they do not use social media were categorized in the "less than monthly or never" category.

Statistical methods

Data were weighted to adjust for nonresponse and varying probabilities of selection with the underlying population of interest, with extreme weights trimmed. The weighting procedures included base weight, nonresponse adjustment, calibration, and trimming; done to incorporate sampling randomness, reduce nonresponse bias, and improve efficiency. Bivariate associations between covariates and the outcome variable, EC susceptibility, were examined using a Rai-Scott Chi-square test. Weighted multivariable logistic regression was conducted, analyzing the association between EC susceptibility and the series of independent variables using a stepwise selection procedure. Collinearity and interactions were examined in building the final model. Adjusted odds ratios were obtained for the association between EC susceptibility and independent variables. Respondents with missing outcome values were excluded from bivariate and multivariate analysis. Because there was an interaction with sex, all results are presented separately for males and females. All statistical analyses were conducted in SAS® 9.4 (Carey, NC) with an alpha = 0.05. All statistical analyses incorporate design information including final weight, stratification, and clustering. The protocol was approved by Institutional Review Boards at both the Oklahoma State Department of Health (#21–12) and the University of Oklahoma Health Sciences Center (#13847).

Results

Among students who had never used a tobacco or nicotine product, 24% self-identified as American Indian, 11% as Black, 60% as White, and 5% as a member of another race. Most students (82%) self-identified as being "straight" regarding sexual identity, and 78% reported earning A or B grades in school. A high percentage of female students were experiencing psychological distress compared to males (22.1% versus 8.4%). Most students (90%) agreed or strongly agreed that "all tobacco products are dangerous." More than one-third (37%) responded that breathing vapor from other people's ECs causes "little" or "no" harm. About half (48%) had seen two or more anti-tobacco advertisements in the past 12 months, and 92% were exposed to e-cigarette advertising in the past 12 months. Regarding social media, 41% of students had seen EC content on social media "monthly or more often," while 8% had posted pictures, commented on, or shared posts about ECs (Table 1).

Overall, 36% of students were susceptible to EC use: 39% of males and 34% of females. In males, susceptibility to EC use was higher among White students (44%) than Black (24%), or American Indian (36%) students. A higher proportion of students who self-identified as gay, lesbian, or bisexual (53%) were susceptible to EC use compared

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TABLE 1 Characteristics of high school students who have never used tobacco/nicotine products, by sex.

Variable	Total (n = 780)		Males (n = 404)		Females (n = 376)	
	Freq	Weighted % (95% CI)	Freq	Weighted % (95% CI)	Freq	Weighted % (95% CI)
Grade level						
Freshman-Sophomore	476	59.70 (49.98, 69.42)	249	59.46 (49.84, 69.09)	227	59.95 (46.09, 73.80)
Junior–Senior	304	40.30 (30.58, 50.02)	155	40.54 (30.91, 50.16)	149	40.05 (26.20, 53.91)
Race						
American Indian	166	23.91 (17.08, 30.75)	96	26.38 (16.88, 35.88)	70	21.31 (15.68, 26.94)
Black	75	11.41 (562, 17.21)	45	13.90 (6.12, 21.67)	30	8.81 (4.04, 13.57)
White	456	59.73 (52.01, 67.44)	222	54.80 (45.08, 64.52)	234	64.91 (57.70, 72.11)
Other	44	4.95 (1.72, 8.18)	23	4.92 (1.18, 8.67)	21	4.98 (1.60,8.35)
Ethnicity						
Hispanic	226	21.06 (10.25, 31.86)	113	19.83 (9.94, 29.72)	113	22.31 (9.84, 34.78)
Non-Hispanic	547	78.94 (68.14, 89.75)	287	80.17 (70.29, 90.06)	260	77.69 (65.22, 90.16)
Language other than English spoken at home						
Yes	207	23.71 (15.58, 31.84)	109	23.87 (17.34, 30.40)	98	23.54 (12.85, 34.24)
No	520	76.29 (68.16, 84.42)	265	76.13 (69.60, 82.67)	255	76.46 (65.76, 87.15)
Sexual identity						
Gay, lesbian or bisexual	67	8.84 (5.13, 12.54)	22	6.23 (2.01, 10.44)	45	11.51 (6.89, 16.13)
Straight	588	81.97 (78.16, 85.77)	319	85.17 (80.28, 90.07)	269	78.69 (74.83, 82.55)
Not sure	70	9.19 (6.78, 11.61)	33	8.60 (5.24, 11.95)	37	9.80 (7.30, 12.30)
Grades in school						
A's and B's	566	78.01 (70.24, 85.78)	270	70.20 (59.38, 81.02)	296	85.96 (79.96, 91.96)
C's or lower	108	14.82 (9.81, 19.83)	70	20.48 (12.71, 28.24)	38	9.06 (4.19, 13.94)
Another scale/unsure	52	7.17 (3.79, 10.54)	35	9.32 (5.65, 12.99)	17	4.97 (1.22, 8.73)
Family affluence scale						
Low affluence	315	41.86 (34.50, 49.23)	177	47.01 (38.43, 55.59)	138	36.60 (27.81, 45.45)
High affluence	413	58.14 (50.77, 65.50)	198	52.99 (44.41, 61.57)	215	63.37 (54.55, 72.19)
Psychological distress (PHQ-4 scale)						
None or mild	637	84.69 (80.62, 88.77)	356	91.56 (88.65, 94.46)	281	77.61 (71.28, 83.93)
Moderate or severe	124	15.31 (11.23, 19.38)	39	8.44 (5.54, 11.35)	85	22.07 (16.07, 28.71)
Perception of harm when people use e-cigarettes some days but not every day						
Little/no harm	140	18.04 (14.51, 21.57)	81	20.89 (15.99, 25.80)	59	15.12 (9.62, 20.63)
Some/ a lot of harm	621	81.96 (78.43, 85.49)	311	79.11 (74.20, 84.01)	310	84.88 (79.37, 90.38)
Agreement with "all tobacco products are dangerous"						
Disagree/strongly disagree	77	9.74 (6.05, 13.42)	48	11.94 (6.42, 17.47)	29	7.48 (3.56, 11.40)
Agree/strongly agree	678	90.26 (86.58, 93.95)	341	88.06 (82.53, 93.58)	337	92.52 (88.60, 96.44)
Belief that e-cigarettes are less, equally, or more addictive than cigarettes						
Less, equally addictive, unsure	528	68.55 (64.95, 72.14)	279	70.83 (65.96, 75.69)	249	66.24(61.81, 70.67)
More addictive	231	31.45 (27.86, 35.05)	111	29.17 (24.31, 34.04)	120	33.76 (29.33, 38.19)
Belief about the harm from breathing the vapor from other people's e-cigarettes						
Little or no harm	282	37.32 (32.53, 42.11)	149	38.35 (31.79, 44.92)	133	36.27 (28.84, 43.70)
Some or a lot of harm	473	62.68 (57.89, 67.47)	240	61.65 (55.08, 68.21)	233	63.73 (56.30, 71.16)
Anti-tobacco advertising seen in past 12 months						
0–1 ad	399	52.21 (44.24, 60.17)	196	48.49 (40.05, 56.93)	203	56.04 (46.58, 65.50)

(Continued)

TABLE 1 (Continued)

Variable	Total (n = 780)		Males (n = 404)		Females (n = 376)	
	Freq	Weighted % (95% CI)	Freq	Weighted % (95% CI)	Freq	Weighted % (95% CI)
2 or more	381	47.79 (39.83, 55.76)	208	51.51 (43.07, 59.60)	173	43.96 (34.50, 53.42)
E-cigarette advertising						
Not exposed	66	8.43 (6.21, 10.64)	39	10.53 (6.97, 14.10)	27	6.25 (2.95, 9.56)
Exposed	714	91.57 (89.36, 93.79)	365	89.47 (85.90, 93.03)	349	93.75 (90.44, 97.05)
Frequency of seeing e-cigarette-related content in social media posts						
Monthly or more often	312	41.44 (37.54, 45.34)	130	34.02 (2,887, 39.16)	182	49.09 (43.03, 55.16)
Never or less than monthly	468	58.56 (54.66, 62.46)	274	65.98 (60.84, 71.13)	194	50.91 (44.84, 56.97)
Frequency of posting pictures of self or someone else using e-cigarettes, or liking, commenting on, or sharing posts related to e-cigarettes on social media						
Monthly or more often	71	8.44 (5.79, 11.09)	36	8.29 (4.92, 11.67)	35	8.60 (5.52, 11.68)
Never or less than monthly	709	91.56 (88.91, 94.21)	368	91.71 (88.33, 95.08)	341	91.40 (88.33, 94.48)

Oklahoma Youth Tobacco Survey 2021–2022 (n = 780).

to those who self-identified as "straight" (34%). A larger proportion of students earning "C" grades or less were susceptible to EC use (52%) compared to those earning grades of "A" and "B" (34%) grades. More than half of students reporting high levels of psychological distress (53%) were susceptible to EC use compared to those reporting mild or no stress (34%). Overall, a large percentage of students who disagreed or strongly disagreed with the statement that "all tobacco" products are dangerous (51%) were susceptible to EC use compared to those who agreed or strongly agreed (34%). While almost half of all students who thought that "breathing vapor" from other people's vaping products causes "little" or "no harm" were susceptible (46%), susceptibility was higher in males (52%), compared to females (39%). Of students who posted pictures of themselves or someone else using vaping products on social media, or who commented on, or shared posts related to ECs monthly or more often, 62% were susceptible overall (65% of males and 58% of females) (Table 2).

Multivariate analysis results for males and females

Males

When compared to white male students, after adjusting for other variables in the model, the odds of susceptibility to EC use in American Indian and Black male students were lower (aOR = 0.46, 95% CI = 0.23, 0.90 and 0.44, 95% CI = 0.20, 0.96, respectively). In male students, the odds of EC susceptibility were also considerably lower among those who were graded on a different grading scale (aOR = 0.31 with 95% CI = 0.14, 0.70) compared to those who made "A" or "B" grades. After adjusting for other variables in the model, the odds of EC susceptibility in male students who reported moderate or severe levels of psychological stress were more than twice as high as for those reporting mild or no stress (aOR = 2.35, 95% CI = 1.14, 4.81). Likewise, the odds of EC susceptibility among male students who disagreed or strongly disagreed with the statement "all tobacco products are dangerous" were three times higher (aOR = 3.07, 95% CI = 1.19, 7.92) compared to those who agreed or strongly agreed. The odds EC susceptibility among those who perceived little or no harm from breathing vapor from other people's ECs were more than three times higher when compared to those who perceived some or a lot of harm (aOR = 3.35 with 95%CI = 2.12, 5.30) (Table 3).

Females

After adjusting for other variables in the model, the odds of EC susceptibility among females self-identifying as gay, lesbian, or bisexual were two times higher (aOR = 2.10, 95% CI = 1.13, 3.90), and for those who were unsure of their sexual identity, the odds were four times higher (aOR = 4.02, 95% CI = 1.30, 12.38) compared to those who self-identified as "straight." The odds of susceptibility among female students who made "C" grades or lower were more than four times higher than for those making "A" or "B" grades (aOR = 4.50, 95% CI = 1.61, 12.56) and were almost three times higher for those under moderate or severe psychological stress compared to those with mild or no stress (aOR = 2.58, 95% CI = 1.21, 5.53). The odds of susceptibility to EC use in female students who interacted about EC use on social media were almost six times higher than for those who did not (aOR = 5.91, 95%CI = 1.94, 18.10) (Table 3).

Discussion

More than one third of HS students who never used tobacco products were found to be susceptible to EC use. Patterns of susceptibility differed between male and female students. White males were more likely to be susceptible than Black or American Indian males. As reported by others (18, 20), this study found an association between identifying as White and EC susceptibility; however, in our study this only occurred with male students. Male students with low levels of EC/tobacco harm perception were more likely to be susceptible to EC initiation. Females, however, demonstrated an association between susceptibility and both psychological stress, as well as poorer academic performance. Females who interacted in social media about EC products were also more likely to be susceptible to EC initiation. Understanding these differences can assist with focused and evidence-based tobacco/nicotine prevention measures.

TABLE 2 E-cigarette susceptibility among high school students who never used tobacco/nicotine products by sex and variables of interest.

	Overall			Males			Females		
Variable	*n* = 780	Weighted % and 95 CI	*p*-value	*n* = 404	Weighted % and 95 CI	*p*-value	*n* = 376	Weighted % and 95 CI	*p*-value
E-cigarette susceptibility									
Susceptible	303	36.39 (32.89, 39.88)	**<0.0001**	159	38.76 (35.10, 42.42)	**<0.0001**	144	33.94 (29.03, 38.86)	**<0.0001**
Not susceptible	477	63.61 (60.12, 67.11)		245	61.24 (57.58, 64.90)		232	66.06 (61.15, 70.97)	
Grade level									
Freshman-Sophomore	189	37.66 (31.20, 44.12)	0.5629	101	41.00 (35.75, 46.24)	0.2306	88	34.25 (24.47, 44.03)	0.9300
Junior–Senior	114	34.50 (27.93, 41.17)		58	35.47 (28.83, 42.11)		56	33.48 (22.65, 44.31)	
Race									
American Indian	66	36.89 (28.60, 45.18)	0.2350	34	35.95 (26.06, 45.84)	0.0651	32	38.11 (24.05, 52.17)	0.5368
Black	25	26.21 (17.40, 35.01)		14	24.43 (13.14, 35.72)		11	29.16 (12.98, 45.34)	
White	176	37.35 (31.30, 43.39)		95	44.06 (35.76, 52.35)		81	31.39 (23.41, 39.37)	
Other	18	40.33 (29.05, 51.60)		9	35.49 (21.28, 49.70)		9	45.35 (23.43, 67.28)	
Ethnicity									
Hispanic	99	43.74 (38.97, 48.51)	**0.0163**	51	46.27 (36.29, 56.25)	0.1858	48	41.45 (32.55, 50.36)	0.0913
Non-Hispanic	203	34.87 (30.28, 39.46)		108	37.73 (32.42, 43.05)		95	31.86 (25.65, 38.08)	
Language other than English spoken at home									
Yes	90	41.01 (32.81, 49.21)	0.2182	48	42.84 (30.00, 55.68)	0.4313	42	39.13 (29.99, 48.26)	0.2408
No	190	34.64 (29.33, 39.95)		96	36.61 (30.48, 42.75)		94	32.66 (26.06, 39.25)	
Sexual identity									
Gay, lesbian or bisexual	37	52.71 (39.88, 64.54)	**0.0209**	12	50.68 (31.32, 70.05)	0.3513	25	53.83 (35.07, 72.58)	**0.0087**
Straight	210	33.59 (28.83, 38.35)		120	37.76 (32.76, 42.76)		90	28.97 (22.44, 35.50)	
Not sure	32	41.95 (27.33, 56.57)		12	31.71 (14.27, 49.16)		20	51.13 (31.12, 71.15)	
Grades in school									
A's and B's	209	33.72 (29.80, 37.64)	**0.0034**	105	38.54 (32.56, 44.51)	**0.0351**	104	29.71 (25.38, 34.05)	**0.0007**
C's or lower	57	52.02 (38.73, 65.31)		35	47.16 (34.07, 60.25)		22	63.19 (41.19, 85.20)	
Another scale/ unsure	14	30.55 (19.51, 41.59)		6	18.40 (6.40, 30.40)		8	53.73 (30.56, 76.90)	
Family affluence scale									
Low affluence	127	37.16 (32.19, 42.13)	0.6470	69	38.65 (32.43, 44.87)	0.9113	58	35.22 (26.54, 43.90)	0.7386
High affluence	155	35.62 (29.94, 41.30)		77	38.02 (30.19, 45.84)		78	33.58 (27.10, 40.05)	
Psychological distress									
None or mild	230	33.54 (29.41, 37.67)	**0.0030**	132	37.51 (33.60, 41.42)	0.0564	98	28.71 (22.28, 35.13)	**0.0217**
Moderate or severe	65	52.71 (42.39, 63.02)		23	54.36 (38.01, 70.72)		42	52.06 (35.30, 68.83)	
Perception of how much harm people cause themselves when they use e-cigarettes some days but not every day									
Little/no harm	69	49.07 (37.62, 60.52)	0.0191	40	52.41 (40.67, 64.14)	**0.0105**	29	44.36 (26.07, 62.65)	0.1993
Some/a lot of harm	225	33.22 (28.73, 37.72)		113	34.67 (30.21, 39.14)		112	31.84 (26.00, 37.68)	
Agreement with "All tobacco products are dangerous"									
Disagree/ strongly disagree	40	51.22 (43.15, 59.28)	**0.0042**	27	55.59 (36.72, 74.46)	0.0849	13	44.10 (18.57, 69.63)	0.3467
Agree/strongly agree	250	34.14 (29.51, 38.78)		124	35.85 (30.08, 41.62)		126	32.48 (27.15, 37.81)	
Belief that e-cigarettes are less, equally, or more addictive than cigarettes									

(Continued)

TABLE 2 (Continued)

	Overall			Males			Females		
Variable	*n* = 780	Weighted % and 95 CI	*p*-value	*n* = 404	Weighted % and 95 CI	*p*-value	*n* = 376	Weighted % and 95 CI	*p*-value
Less, equally, unsure	201	36.05 (31.66, 40.44)	0.08912	107	38.36 (34.97, 41.75)	0.7787	94	33.56 (26.63, 40.48)	0.9377
More addictive	93	36.61 (29.24, 43.99)		46	39.51 (30.66, 48.34)		47	34.08 (23.50, 44.67)	
Belief about the harm from breathing the vapor from other people's e-cigarettes									
Little or no harm	135	45.59 (38.74, 52.43)	**0.0003**	76	51.57 (44.36, 58.79)	**0.0003**	59	39.14 (27.53, 50.76)	0.2147
Some or a lot of harm	156	30.28 (26.33, 34.23)		76	30.20 (24.72, 35.69)		80	30.36 (23.98, 36.74)	
Anti-tobacco advertising seen in past 12 months									
0–1 ad	145	33.54 (29.10, 37.99)	0.1118	77	38.88 (33.33, 44.43)	0.9625	68	28.79 (22.48, 35.09)	**0.0487**
2 or more	158	39.49 (33.71, 45.27)		82	38.64 (31.66, 45.63)		76	40.51 (31.49, 49.53)	
E-cigarette advertising									
Not exposed	20	32.57 (20.10, 45.04)	0.5644	13	37.79 (20.82, 54.76)	0.9050	7	23.52 (3.97, 43.06)	0.3296
Exposed	283	36.74 (32.60, 40.87)		146	38.87 (34.64, 43.10)		137	34.64 (29.30, 39.98)	
Frequency of seeing e-cigarette-related content in social media posts									
Monthly or more often	142	42.48 (36.60, 48.37)	0.0154	58	43.35 (34.58, 52.11)	0.2173	84	41.87 (31.74, 51.99)	0.0663
Never or less than monthly	161	32.07 (27.18, 36.96)		101	36.39 (31.30, 41.48)		60	26.30 (17.28, 35.32)	
Frequency of posting pictures of self or someone else using e-cigarettes, or liking, commenting on, or sharing posts related to e-cigarettes on social media									
Monthly or more often	42	61.57 (50.18, 72.95)	**0.0002**	21	65.31 (47.07, 83.55)	**0.0088**	21	57.84 (37.41, 78.27)	**0.0129**
Never or less than monthly	261	34.06 (30.23, 37.90)		138	36.36 (32.09, 40.62)		123	31.69 (26.85, 36.54)	

Oklahoma Youth Tobacco Survey, 2021–2022 ($n = 780$). Bolded values indicate statistical significance at the 0.05 level or below.

An important step in tobacco prevention is averting tobacco initiation and susceptibility among youth, especially with popular tobacco products like ECs (1, 2).

Amrock and associates reported a study suggesting that adolescents cannot accurately assess the potential danger of ECs. They noted those who believe ECs are less harmful than combustible tobacco products are more likely to initiate their use (9). In our study, harm perception was only associated with EC susceptibility in male students and in only two of the four harm perception questions, agreeing that "all tobacco products are dangerous," and that "breathing vapor from other's ECs causes some or a lot of harm." Because other authors have reported associations between harm perception and 30-day vaping prevalence (7, 17, 23, 24), continued public health education efforts are warranted. Previous research has reported that heightened harm perception is associated with lower EC susceptibility (with odds ratios between 0.60 and 0.23) (20, 21), while lower levels of harm perception have been associated with increases EC susceptibility (with odds ratios ranging from 2.2 to 4.9) (18).

Students experience a wide variety of stressors during their high school years. In this study, a higher percentage of female students demonstrated psychological distress, which in turn was associated with a higher level of susceptibility to EC use, after controlling for other covariates. Both male and female students experiencing distress had a higher prevalence of susceptibility. Female students demonstrated an association between grades earned in school and susceptibility; and had a higher odds of EC susceptibility when their grades dropped lower than a "B" level. Interestingly, Jha and associates found youth who needed stress relief were more likely to use ECs (13). However, the youth who attempted EC use as a form of stress relief reported higher stress levels after use. Research suggests EC prevention strategies for high school students should focus on stress reduction and healthy coping strategies (9, 22, 25).

While exposure to EC advertising on social media was *not* associated with EC susceptibility in either male or female students, *active interaction* on social media sites *was*. In female students, posting pictures, making comments about, or interacting with others about EC use was highly associated with EC susceptibility. A similar finding was reported by Vogel and associates, who found students who *engaged* in social media on a regular basis demonstrated higher intent to use ECs, along with a lower perception of the danger of EC use (26). This finding warrants further investigation about the potential success of monitoring social media sites in youth at risk for tobacco use, and providing intervention before initiation occurs.

This study adds information not yet published about differences in susceptibility in male and female adolescent

TABLE 3 Factors associated with e-cigarette susceptibility, by sex, crude, and adjusted odds ratios with 95% CIs.

	Males*		Females**	
Variable	Crude odds ratio (95% CI)	Adj odds ratio (95% CI)	Crude odds ratio (95% CI)	Adj odds ratio (95% CI)
Grade level				
Freshman-Sophomore	1.26 (0.85, 1.89)		1.04 (0.46, 2.34)	
Junior–Senior	Referent		Referent	
Race				
American Indian	0.71 (0.39, 1.31)	**0.46 (0.23, 0.90)**	1.35 (0.64, 2.83)	1.75 (0.92, 3.31)
Black	**0.41 (0.19, 0.90)**	**0.44 (0.20, 0.96)**	0.90 (0.37, 2.17)	0.88 (0.34, 2.31)
White	Referent		Referent	
Other	0.70 (0.37, 1.31)	**0.36 (0.16, 0.81)**	1.81 (0.67, 4.88)	2.58 (0.57, 11.76)
Ethnicity				
Hispanic	1.42 (0.82, 2.48)		1.51 (0.92, 2.50)	
Non-Hispanic	Referent		Referent	
Language other than English spoken at home				
Yes	1.30 (0.64, 2.63)		1.33 (0.79, 2.22)	
No				
Sexual identity				
Gay, lesbian or bisexual	1.69 (0.71, 4.03)		**2.86 (1.34, 6.10)**	**2.10 (1.13, 3.90)**
Straight	Referent		Referent	
Not sure	0.77 (0.31, 1.91)		2.57 (0.96, 6.83)	**4.02 (1.30, 12.38)**
Grades in school				
A's and B's	Referent		Referent	
C's or lower	1.42 (0.71, 2.86)	1.65 (0.90, 3.05)	**4.06 (1.65, 9.99)**	**4.50 (1.61, 12.56)**
Another scale/unsure	**0.36 (0.15, 0.87)**	**0.31 (0.14, 0.70)**	**2.75 (1.06, 7.11)**	2.60 (0.79, 8.57)
Family affluence scale				
Low affluence	Referent		Referent	
High affluence	0.97 (0.59, 1.61)		0.93 (0.59, 1.47)	1.67 (0.97, 2.90)
Psychological distress				
None or mild	Referent		Referent	
Moderate or severe	1.99 (0.97, 4.07)	**2.35 (1.14, 4.81)**	2.35 (1.14, 4.81)	**2.58 (1.21, 5.53)**
Perception of harm when people use e-cigarettes some days but not every day				
Little/no harm	**2.08 (1.22, 3.52)**		1.71 (0.72, 4.08)	1.80 (0.88, 3.68)
Some/ a lot of harm	Referent		Referent	
Agreement with "All tobacco products are dangerous"				
Disagree/strongly disagree	2.24 (0.87, 5.76)	**3.07 (1.19, 7.92)**	1.64 (0.55, 4.88)	
Agree/strongly agree	Referent		Referent	
Belief that ECs are less, equally, or more addictive than cigarettes				
Equally, less/do not know	0.95 (0.67, 1.36)		0.98 (0.52, 1.83)	
More addictive	referent		referent	
Belief about the harm from breathing the vapor from other people's e-cigarettes				
Little or no harm	**2.46 (1.63, 3.72)**	**3.35 (2.12, 5.30)**	1.48 (0.78, 2.81)	
Some or a lot of harm	Referent		Referent	
Anti-tobacco advertising seen in past 12 months				
0–1 ad	1.01 (0.65, 1.56)		**0.59 (0.36, 0.99)**	
2 or more	Referent		Referent	

(Continued)

TABLE 3 (Continued)

Variable	Males*		Females**	
	Crude odds ratio (95% CI)	Adj odds ratio (95% CI)	Crude odds ratio (95% CI)	Adj odds ratio (95% CI)
E-cigarette advertising				
Not exposed	Referent		Referent	
Exposed	1.05 (0.47, 2.32)		1.72 (0.56, 5.34)	
Frequency of seeing e-cigarette-related content in social media posts				
Monthly or more	1.34 (0.83, 2.16)		2.02 (0.96, 4.26)	
Never or < monthly	Referent		Referent	
Frequency of posting pictures of self or someone else using e-cigarettes, or liking, commenting on, or sharing posts related to e-cigarettes on social media				
Monthly or more	**3.30 (1.34, 8.08)**		**2.96 (1.21, 7.22)**	**5.91 (1.94, 18.10)**
Never or < monthly	Referent		Referent	

Oklahoma Youth Tobacco Survey, 2021–2022. *Male odds ratios were adjusted for variables retained in the stepwise logistic model: race, grades in school, psychological distress, perceived danger of tobacco products, and vapor harm perception. **Female odds ratios were adjusted for variables retained in the stepwise logistic model: race, sexual identity, grades in school, psychological distress, and social media interaction. Bolded values indicate statistical significance at the 0.05 level or below.

students. Because this study was conducted with students who had never used any type of nicotine or tobacco product, these results are also unique. Limitations of the current study warrant discussion. This is a cross sectional study, and as such, causal inferences are not valid. While this study involved youth in Oklahoma, the sample of high school students never using nicotine and tobacco products was relatively small ($n = 780$) and from a single state; thus, generalizability may be limited. Sample sizes for several sub-groups of interest in this study were small, specifically those involving racial and sexual minority groups. Although weighting procedures intend to account for non-response, the overall response rate of schools and classrooms was less than optimal (44%). Finally, all estimates are based on self-reported data, which might be affected by information bias. As is typical with most surveys, data for all factors likely to be associated with susceptibility were not included.

Understanding EC susceptibility can assist with focused and evidence-based tobacco/nicotine prevention measures. An important step in tobacco prevention is averting tobacco initiation and susceptibility among youth.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the University of Oklahoma Health Sciences Center. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

SJ: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft. AW: Formal analysis, Investigation, Writing – review & editing. FK: Funding acquisition, Supervision, Validation, Writing – review & editing. NM: Formal analysis, Investigation, Supervision, Writing – review & editing. SC: Formal analysis, Software, Supervision, Writing – review & editing. LB: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Susan M. Snyder,
Georgia State University, United States

REVIEWED BY
Vijay Sivaraman,
North Carolina Central University, United States

*CORRESPONDENCE
Arielle Selya
aselya@pinneyassociates.com

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Measures of youth e-cigarette use: strengths, weaknesses and recommendations

Arielle Selya[1]*, Martino Ruggieri[2,3] and Riccardo Polosa[3,4]

[1]PinneyAssociates, Inc., Pittsburgh, PA, United States, [2]Center of Excellence for the Acceleration of Harm Reduction (CoEHAR), University of Catania, Catania, Italy, [3]Unit of Pediatric Clinic, AOU "Policlinico", PO "G. Rodolico", Department of Clinical & Experimental Medicine, University of Catania, Catania, Italy, [4]Department of Clinical & Experimental Medicine, University of Catania, Catania, Italy

This perspective discusses how to best define "e-cigarette use" among youth in a way that is relevant to individual and human health. Commonly-used definitions of youth e-cigarette use have been adapted from measures validated for tobacco cigarette smoking among adults, but may not carry the same meaning for a different product (with a much lower risk profile and very different patterns of use) and a different population (whose use is more often transient and experimental, rather than frequent and persistent). We discuss strengths and weaknesses of different definitions, and recommend improvements in defining youth e-cigarette use. We find that current literature employs a range of definitions of e-cigarette use, from lifetime use ("even a puff") to daily use. More lenient measures capture more potentially at-risk youth, but much of this is transient experimentation that has negligible risks in and itself, if not persistent. More stringent measures such as daily use are more relevant to individual and public health. Future research should examine possible improvements to definitions which include intensity of use (e.g., number of puffs per day) and persistence/duration of use, either via self-report or technology-assisted data capture.

KEYWORDS

adolescents, behavior, e-cigarettes, electronic nicotine delivery systems, nicotine use, surveillance

1 Introduction

E-cigarettes are a lower-risk nicotine product that can benefit adults who smoke and are unlikely to quit entirely (1–4), but there are ongoing concerns about youth e-cigarette use. Continued surveillance of youth e-cigarette use is needed, especially considering that use patterns continue to change with the evolving product market. For example, e-cigarettes were introduced into the US market in 2007, but adult current use prevalence remained low (<2%) through at least 2012 (5), after which it fluctuated through 2018 at approximately 3–4% (6). Retail data broadly corroborate these trends, with low sales prior to 2013, and the e-cigarette market increased with Blu in 2013, Vuse in 2014, and JUUL in 2017 (7). Since 2017, US retail trends (primarily reflecting purchases by adults, who comprise a greater share of the population see (8)); e.g., have shifted toward high-nicotine content e-cigarettes (9), and the most common brands in 2022 (Vuse, JUUL, Elf Bar, NJOY, and Breeze Smoke) (10) utilize nicotine-salt formulations, which provide higher nicotine delivery (11). This is beneficial for adult smokers wanting to switch to e-cigarettes but has raised concerns about these products' addictiveness for youth.

Over this time frame, e-cigarettes have become the most common nicotine product among US youth (12–15) as cigarette smoking reached historic lows (16–20). Youth prevalence of any e-cigarette use in the past 30 days (P30D) peaked in 2019 in the US; this was primarily of JUUL (21, 22). Out of concern over this unacceptably high rate of youth use, Juul Labs, Inc. voluntary discontinued its non-tobacco, non-menthol-flavored products, followed shortly by the U.S. Food and Drug Administration's (FDA's) announcement to prioritize enforcement against non-tobacco, non-menthol-flavored pod/cartridge e-cigarettes (23). Subsequently, youth e-cigarette use shifted to sweet- and fruit-flavored disposable products (21) such as Puff Bar in 2021 and 2022 (24, 25) and more recently, Elf Bar (13). Fortunately, youth P30D use has also fallen substantially has fallen by >60% in 2023, compared to its 2019 peak (22), and correspondingly, youth use of JUUL as usual brand fell from 16.3% of all high school students and 5.7% of all middle school students in 2019[1] (22) to <0.3% of all youth in 2023[2] (13).

Given that cigarettes are at the most harmful end of the continuum of risk (1–4) and evidence that the two products are substitutes (21, 26–28), it is also important to monitor youth cigarette smoking as e-cigarette us trends change. A related concern is dual use, especially with cigarettes, given the possibility of combined exposures to multiple products. However, reassuringly, accompanying the peak-and-decline in P30D youth e-cigarette use, youth P30D cigarette smoking fell to the all-time low of 1.5% (22). Similarly, P30D use of 2+ products has declined along with overall P30D e-cigarette use, among both high school (from 10.2% in 2020 to 3.9% in 2023) and middle school (from 4.0% in 2020 to 2.5% in 2023) students (13, 29). Several other countries also show a concomitant rise in e-cigarette use and a rapid decline in smoking, including Canada, England, New Zealand, and Germany (30–33). Nevertheless, ongoing surveillance of youth nicotine use is warranted, especially for e-cigarettes, as the most commonly-used product currently.

A necessary element of youth surveillance, as well as comparability of research, is defining "e-cigarette use" consistently across studies and using a measure that has external validity (i.e., relevance to public and individual health). There is currently no clear consensus on how best to define "use," and the research field would benefit from explicitly weighing different definitions. Here we discuss trends in different current definitions of "e-cigarette use" and corresponding strengths and weaknesses, and make recommendations.

1.1 Historical context

Commonly-used metrics for measuring e-cigarette use in both youth and adults seem to have been adapted from those used for *cigarette* smoking in adults, which have been validated against both biochemical markers of exposure (e.g., cotinine or carbon monoxide) and clinical health outcomes. Self-reported measures of smoking – especially measures of daily consumption such as cigarettes per day (CPD) – are generally strongly correlated with biochemical markers of exposure (e.g., cotinine or carbon monoxide) in adults (34, 35), which in turn are associated with adverse health outcomes (36–38). Importantly, however, the concordance between self-reported smoking and exposure levels varies widely across studies, and partly depends on how smoking status is defined (34). Specifically, many light and occasional smokers (e.g., <10 CPD) have similar exposure levels to tobacco-naïve individuals (35, 39), prompting recommendations to define positive smoking status using daily-consumption criteria (e.g., 10+ CPD) to prevent misclassification that could obscure the true impact of regular smoking on health (39).

On the other hand, *duration* of smoking and/or cumulative exposure (e.g., pack-years) are more strongly associated with *clinical* outcomes in adults (e.g., lung cancer, coronary artery disease, and severity of chronic obstructive pulmonary disease) than is CPD alone (40). In fact, one study concluded that "*smoking at a lower intensity for longer duration is more deleterious than smoking at a higher intensity for a shorter duration*" (41).

These validated measures of adult cigarette smoking have been adapted in two separate ways without rigorously evaluating whether these adaptations alter their utility: first, to a different product (from cigarettes to e-cigarettes), and second, to a different population (from adults to youth). Regarding the first adaptation – from cigarettes to e-cigarettes – complications may arise from the fact that e-cigarettes have a much lower risk profile than cigarettes (2), which seems to indicate a higher-threshold definition is warranted to measure an equivalent level of health risk. Additionally, e-cigarettes and cigarettes involve different patterns of use (see below), and thus a given definition of use may be incomparable between the products. Additionally, despite the recommendations from the adult smoking literature to measure quantity and/or duration of cigarette smoking (39–41), not all nationally-representative US surveys collect such information for e-cigarette use (42, 43), limiting the available measures to only current use and resulting in a more lenient definition.

Regarding the adaptation from adults to youth, there are additional complications stemming from the fact that youth use is not typically as heavy or prolonged as adult use, and is more often transient and experimental. For example, smoking is likely to be underreported by underage youth – especially when they have privacy concerns when providing survey responses (44) – which may explain why self-reported nonsmoking individuals can have above-threshold exposure levels (39, 45). Another explanation for this type of discrepancy, suggested by a Statistics Canada publication, is that "*smoking initiation or experimentation in this period may have resulted in some cases being inappropriately classified… particularly among respondents aged 12 to 19*" (35) – the implication being that mere initiation or experimentation should *not* be considered as true smoking. Additionally, there are notable exposure differences in *how* one smokes; youth who did not inhale into their lungs more often had below-threshold exposure levels (45).

Despite the importance of accounting for intensity and/or duration when defining "use," youth use is often measured using more loosely, defining "current smoking" as *any* smoking (even a puff) in P30D. This low threshold is likely motivated by the fact that "no amount of smoking is safe" (46), and youth cigarette smoking – even low amounts – can be associated with nicotine dependence (47, 48) and potentially

1 Estimated as: 27.5% of high school students who used e-cigarettes in P30D×59.1% of P30D users who listed JUUL as usual brand; and 10.5% of middle school students who used e-cigarettes in P30D×54.1% who listed JUUL as usual brand (22).

2 Estimated as 7.7% of all youth who used e-cigarettes in P30D×3.4% of P30D users who listed JUUL as usual brand (13).

lead to long-tern use (49, 50). While little to date is known about how often infrequent *e-cigarette* use leads to long-term chronic use, it could plausibly be expected to be less likely for e-cigarettes than cigarettes, considering that dependence on e-cigarettes is lower than on cigarettes (51, 52). Relatedly, youth measures of smoking are typically less stringent than typical measures of *adult* use, in that youth do not (yet) meet the criteria for "established" use (i.e., cumulative 100 cigarettes/lifetime) or daily consumption (e.g., 10+ CPD) typically used among adults (53), since youth have had less time to accrue this level of use. Thus, adopting a "lower bar/threshold" for measuring youth tobacco cigarette use is often considered appropriate.

While surveillance of cigarette and e-cigarette use is often presented equivalently between youth and adults as "current use" (13, 53), the specific questions are different: adult current use is standardly assessed as use on "some days" or "every day" (vs. "not at all") (42, 43, 54, 55) while youth current use is standardly assessed as "any use, even a puff, in the past 30 days (P30D)" (13, 15, 56). The two measures are largely consistent with each other, but there is some notable discrepancy: for example, a comparison of the two metrics in young adults found that the standard youth definition yields higher prevalence estimates than the standard adult definition (34.4% vs. 27.3% for "any use in P30D" vs. "some day or every day use," respectively) (57).

In summary, measures developed and validated for adult cigarette smoking have been adapted in two ways – from cigarettes to e-cigarettes, and from adults to youth – both of which introduce separate sets of complications. These adaptations raise the question of whether these measures remain valid, and call for re-evaluation and, if necessary, improvement of standard metrics for e-cigarette use that are relevant to individual and public health.

1.2 Metrics for measuring youth e-cigarette use

Table 1 presents the common definitions of e-cigarette use, which range from lifetime use (i.e., ever had even a single puff) to daily use. While there is no clear consensus in the literature, the most standard measures in the literature are lifetime use, past-12-month (P12M) use, and P30D use, which are used in several US national youth surveys. Also fairly common are frequency-based measures such as use on 20+ days out of P30D and daily use. The exact measure used is important as it can lead to different interpretations; for example, King cites NYTS data, switching between percentages ("*in 2019, current (past-30-day) e-cigarette prevalence reached a peak among middle-school (10.5%) and high-school (27.5%) students*") and raw numbers ("*nonetheless, in 2021, more than 2 million US middle- and high-school students used e-cigarettes*") (63), which obscures the magnitude of the decline after 2019.

2 Discussion

2.1 Strengths and weaknesses of existing measures of use

Broadly, the main distinction between the common definitions presented in Table 1 is the frequency of use. Note that these measures do not include information on daily consumption/*intensity* of use (e.g., # puffs per day), which is often not captured at all in surveys.

On one hand, lenient definitions (e.g., lifetime use, P12M use) have both conceptual and practical advantages: as noted above for cigarette smoking, the first use of an e-cigarette is not harmful *in and of itself*, but *could* lead to long-term and problematic use (49, 50), which could motivate capturing all youth *potentially* at risk. Practically, lenient definitions capture greater numbers of youth, making statistical analyses easier, as opposed to more stringent definitions yielding too few youth to statistically analyze (Table 2), even in large nationally-representative surveys (59).

The drawback of using lenient definitions of use is that they capture a large fraction of experimental use that does not evolve into long-term use and (if not) poses negligible harms to human health. For example, data from NYTS 2022 and 2023 show that less than half of the youths who *ever* used e-cigarettes *persisted* in using them in the P30D (13, 58). P30D use also includes some level of experimental use, especially if one-time experimentation occurs in the month preceding the survey. Among youths who reported using e-cigarettes in the P30D in NYTS 2023, more (46.1%) used e-cigarettes on only 1–5 days in the P30D period than used them *frequently* (i.e., on 20+ days out of the P30D period; 34.7%) (13). Few used on intermediate number of days (19.1% used on 6–19 days), confirming the bimodal frequency distribution observed for nicotine product use (64). This suggests that *near-daily* (sometimes misleadingly referred to as "daily" use (61)) or *daily* P30D use, rather than *any* P30D use, is more relevant to health risks.

Additionally, *any* P30D use often does not lead to continued/persistent use over time. For example, an analysis of product-use transitions in PATH study showed that approximately one-quarter of youths who exclusively used e-cigarettes in the P30D were not using either e-cigarettes or cigarettes the following year (65). In a more recent study of youth and young adults (ages 15–24) in Ohio, US, very infrequent use (i.e., on ≤5 days in P30D) was found to be highly stable over time, with 76.8% maintaining the same behavior 12 months later (66). In fact, using on ≤5 days in P30D was at least as stable as more frequent use (i.e., on 6+ days in P30D): the probability of maintaining ≤5 vs. 6+ use days over 4 months was 81.5% vs. 73.1%, though the significance of this difference was not tested (66). Definitions that include information on *persistence* or continued use were proposed by Sun et al. (59) in the context of *cigarette* smoking (Table 2), and could reasonably be extended to e-cigarette use. The first definition is rather lenient, capturing initiation in the P12M, and subsequent definitions are increasingly strict. The number of youth captured by each additional criterion drops rapidly; even adding one additional lenient criterion of P12M use 1 year later drops the number of youth meeting criteria for "use" by ~40%. Arguably, the most stringent definition (use at multiple timepoints, leading to established and lifetime use) is the most indicative of problematic patterns of use; however, its prevalence is vanishingly small, comprising only 3% of youth captured by the most lenient definition, and is too few to statistically analyze (59).

Overall, more stringent measures such as daily and persistent use better isolate truly problematic use patterns. The concerns about long-term health effects and nicotine dependence (24, 67) are moot if initial experimentation does not evolve into regular, long-term use. Even for tobacco cigarettes – which pose significantly greater risks than e-cigarettes (1, 2) – stopping smoking before the age of 40 has been shown to substantially reduce risks of dying from smoking-related diseases (62).

TABLE 1 Common definitions of youth e-cigarette use.

Definitions	Explanation	Examples of surveys and publications	Estimated relevance to human health, and rationale
Lifetime use / ever-use	Ever using an e-cigarette once, even a single puff	Surveys: MTF, NYTS, PATH, YRBS Studies: (13, 24)	Negligible absolute risk; majority of ever-use does not persist even to P30D use (13, 58), let alone to long-term durations that, for more-harmful cigarette smoking, are linked to health outcomes (40, 41).
Past-12-month (P12M) use	Using an e-cigarette at least once in the past 12 months	Surveys: PATH Studies: (59)	Negligible absolute risk; P12M *cigarette* smoking is rarely followed by continued and established use a year later (59), and this may be less likely for e-cigarettes as they are associated with lower dependence (51, 52).
Past-30-day (P30D) use	Using an e-cigarette at least once in the past 30 days	Surveys: MTF, NYTS, PATH, YRBS Studies: (13, 24, 60)	Probably no absolute risk for less frequent (e.g., 1 day in P30D) and less intense (e.g., 1 puff/day) use patterns, as even for more harmful cigarettes, biomarkers of exposure for <10CPD are often indistinguishable from nonsmoking (35, 39); additionally, most P30D use is very infrequent (1–5 days in P30D) (13), indicative of experimentation that is often transient rather than persistent. However, risk increases with more frequent & intense use (35, 39), and with longer durations of use (40, 41).
Frequent use	Using e-cigarettes on 20+ days out of P30D	Surveys: NYTS, PATH Studies: (13, 24)	May pose some risk; but less risk for very light use (e.g., 1 puff/day), as even for more harmful cigarettes, biomarkers of exposure for <10CPD are often indistinguishable from nonsmoking (35, 39). However, risk increases with more frequent & intense use (35, 39), and with longer durations of use (40, 41).
Near-daily use	Using e-cigarettes on 25+ days out of P30D; often sometimes misleadingly referred to as "daily use"	Surveys: TLC Studies: (61)	Likely poses some risk; risk depends on intensity of use (e.g., # puffs per day), just as with more-harmful cigarettes (e.g., <10CPD often produces similar exposure levels as nonsmoking) (35, 39). Risk also depends on how long near-daily use persists (40, 41), just as with more-harmful cigarettes (e.g., quitting before age 40 avoids most of the premature mortality) (62).
Daily use	Using e-cigarettes on every day in P30D	Surveys: MTF, NYTS, PATH Studies: (13, 24)	Likely poses some risk; risk depends on intensity of use (e.g., # puffs per day), just as with more-harmful cigarettes (e.g., <10CPD often produces similar exposure levels as nonsmoking) (35, 39). Risk also depends on how long near-daily use persists (40, 41), just as with more-harmful cigarettes (e.g., quitting before age 40 avoids most of the premature mortality) (62).

MTF, Monitoring the Future; NYTS, National Youth Tobacco Survey; PATH, Population Assessment of Tobacco and Health; TLC, Truth Longitudinal Cohort; YRBS, Youth Risk Behavior Survey.

2.2 Recommendations for future research

Ongoing research is needed on which measures of youth e-cigarette use may best distinguish transient, experimental use from truly problematic patterns of use (i.e., high daily consumption, frequent use, and/or long duration of use). Table 2 shows the importance of assessing continuous e-cigarette use over long time periods; however, many youth surveys are cross-sectional in nature, and cannot prospectively assess persistent use. Future research could examine the accuracy of retrospective self-reported duration or persistent use. Additionally, alternative definitions could include measures of e-cigarette daily use *intensity,* such as number of puffs or puffing sessions per day. Xie et al. recently validated number of puffs per month against cravings and low intention to quit (68); future research is needed to further validate against

TABLE 2 Examples of increasingly stringent measures of use, from Sun et al. (59).

Definition of Cigarette Smoking	# of participants (of 8,671 total)	Weighted % of population
Initiated P12M smoking between Waves 3 and 4	362	4.1%
P12M use at Wave 4 and P12M use at Wave 5	218	2.5%
P12M use at Wave 4 and P30D use at Wave 5	133	1.5%
P12M use at Wave 4 and established use at Wave 5	60	0.8%
P12M use at Wave 4, established use, and use on ≥5 days in P30D at Wave 5	27	0.4%
P12M use at Wave 4, established use, and use on ≥20 days in P30D at Wave 5	12	0.2%

Analysis is based on PATH Waves 3–5. Established use: 100 + cigarettes/lifetime. P12M: past 12-months. P30D: Past 30 days. Source: Sun et al. (59).

dependence scales and subsequent use patterns (especially frequent and persistent use), and on how to most accurately collect intensity data (e.g., self-reports vs. data collected with digital tracking tools).

Another consideration is that use patterns differ between cigarettes and e-cigarettes, which may impact the relevance of different measures of use. For example, a "use occasion" for a cigarette is typically finishing an entire cigarette, but e-cigarettes are often consumed in smaller amounts but more frequently – a pattern that has been described as "grazing" (69, 70). These different use patterns, along with the above inability to consistently distinguish exposure levels of low-level smoking vs. non-use, demonstrate that measures of use should not be assumed to be equivalent across products. Similarly, dependence measures cannot be assumed to be equivalent across products, and in fact in some cases are shown to be incomparable (71).

2.3 Limitations

There are many considerations, sometimes conflicting, in how to best assess "use." For example, validation against biochemical exposures vs. clinical outcomes identifies different self-report variables as important (CPD vs. duration, respectively). Measures of use are probabilistic and imperfect: even daily use (which we identify as likely relevant to health outcomes) will capture some youth who will not persist to established, long-term use; and will miss others who do at a later point in time. Further complications arise from standardizing measures of use across the diversity of e-cigarette products, such as differences in nicotine delivery and possible harmful exposures due to product characteristics (e.g., freebase nicotine vs. nicotine salts, different nicotine concentration, device power, and flavors). Much remains unknown about the validity of different definitions, and pros and cons must be weighed – which we aim here to elucidate.

3 Conclusion

It is regrettable that the metrics currently employed to evaluate youth e-cigarette usage have been directly borrowed from those used for *cigarette* smoking in adults, without re-evaluating whether their validity holds for a different product (with different use patterns and a much lower risk profile) and in a different population (whose use patterns are more often transient and experimental). Definitions of use that are more indicative of truly problematic measures of use must include criteria for continuous use over some time, cumulative lifetime use, and frequent use. Methods offering objective and precise data collection about the intensity of e-cigarette use (e.g., # puffs) like digital tracking tools, mobile applications and sensor technology are likely to be most valuable, though additional validation work is needed. More generally, the wide range of measures currently used has a correspondingly wide range of prevalence estimates; low thresholds have greater "capture" and may evoke emotional responses that are not grounded in quantification of the actual risks to individual and public health. Forthcoming research, therefore, would benefit from providing a "data interpretation guide" that specifies the relevance of each study's selected measure(s) of use to individual and public health.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material; further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements.

Author contributions

AS: Writing – review & editing, Writing – original draft, Project administration, Investigation, Conceptualization. MR: Writing – review & editing. RP: Writing – review & editing, Supervision, Investigation, Conceptualization.

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Conflict of interest

AS is an employee of PinneyAssociates, Inc., which provides consulting services on tobacco harm reduction to Juul Labs, Inc (JLI). AS also individually provides consulting services on behavioral science to the Center of Excellence for the Acceleration of Harm Reduction (CoEHAR) through ECLAT Srl, which received funding from the Foundation for a Smoke-Free World (FSFW). JLI and FSFW had no role in this manuscript. MR is a full tenured professor of Pediatrics at the University of Catania (Italy) and Director of the Pediatric Clinic and the Postgraduate Training Program in Pediatrics at the same University; he is also Director of the Regional Referral Centre for Expanded Newborn Screening (ENS), for Neurometabolic Diseases and for Rare Diseases of the Nervous System in Childhood at the University Hospital of Catania [AOU "Policlinico", PO "G. Rodolico"]; he is also the current President of the Italian Society of Pediatric Neurology (Società Italiana di Neurologia Pediatrica, SINP) and Delegate of the National Council of the Italian Society of Pediatrics (Società Italiana di Pediatria, SIP). He has received grants from the Italian Ministry of Health (PON, POS-T4), the National Institute of Health (Bethesda, US), the Medical Research Council (MRC, Oxford, UK), and the National Health System (NHS, Oxford, UK); he also received grants from Alexion, Sanofi, and Takeda. He received fees, as member of advisory boards and consulting services from Alexion, Sanofi, and Jazz pharma. He received textbooks royalties from Springer Nature Group and Elsevier and from EDRA. He is also a pro bono advisor for the Italian Lay Groups for Neurofibromatosis [ANF, Associazione NeuroFibromatosi, Parma, Italy], Tuberous Sclerosis [AST, Associazione Sclerosi Tuberosa, Rome, Italy], and Sturge-Weber syndrome [Associazione Struge-Weber Italia, Turin, Italy], and for Hypomelanosis of Ito [Ito Foundation, UK]. RP is a full tenured professor of Internal Medicine at the University of Catania (Italy) and Medical Director of the Institute for Internal Medicine and Clinical Immunology at the same University. He has received grants from U-BIOPRED and AIR-PROM, Integral Rheumatology & Immunology Specialists Network (IRIS), Foundation for a Smoke Free World, Pfizer, GlaxoSmithKline, CV Therapeutics, NeuroSearch A/S, Sandoz, Merk Sharp & Dohme, Boehringer Ingelheim, Novartis, Arbi Group Srl., Duska Therapeutics, Forest Laboratories, Ministero dell Universita' e Ricerca (MUR) Bando PNRR 3277/2021 (CUP E63C22000900006) and 341/2022 (CUP E63C22002080006), funded by NextGenerationEU of the European Union (EU), and the ministerial grant PON REACT-EU 2021 GREEN- Bando 3411/2021 by Ministero dell Universita' e (MUR) – PNRR EU Community. He is the founder of the Center for Tobacco Prevention and Treatment (CPCT) at the University of Catania and of the Center of Excellence for the Acceleration of Harm Reduction at the same university. He receives consultancy fees from Pfizer, Boehringer Ingel- heim, Duska Therapeutics, Forest Laboratories, CV Therapeutics, Sermo Inc., GRG Health, Clarivate Analytics, Guidepoint Expert Network, and GLG Group. He receives textbooks royalties from Elsevier. He is also involved in a patent application for ECLAT Srl. He is a pro bono scientific advisor for Lega Italiana Anti Fumo (LIAF) and the International Network of Nicotine Consumers Organizations (INNCO); and he is Chair of the European Technical Committee for Standardization on "Requirements and test methods for emissions of electronic cigarettes" (CEN/TC 437; WG4). These funders had no role in this manuscript.

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EDITED BY
Keryn E. Pasch,
The University of Texas at Austin,
United States

REVIEWED BY
Vijay Sivaraman,
North Carolina Central University,
United States
Marta Kożybska,
Pomeranian Medical University, Poland

*CORRESPONDENCE
Beata Świątkowska
✉ beata.swiatkowska@umed.lodz.pl

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Is e-cigarette advertising associated with e-cigarette use among young people? New survey evidence from Poland

Beata Świątkowska[1]*, Radosław Zajdel[2], Łukasz Balwicki[3] and Dorota Kaleta[1]

[1]Department of Hygiene and Epidemiology, Medical University of Łódź, Łódź, Poland, [2]Department of Informatics in Business and Medicine, University of Łódź, Łódź, Poland, [3]Department of Public Health and Social Medicine, Medical University of Gdańsk, Gdańsk, Poland

Objective: Young people are routinely exposed to e-cigarettes advertising. We examined the impact of e-cigarette advertising on e-cigarette use in a large representative sample of adolescents.

Methods: Data came from cross-sectional sample of the nationwide study on the health effects of tobacco products called PolNicoYouth, which included adolescents aged 15–18 years ($N = 7{,}498$). Data were collected through a detailed questionnaire recommended by international health organizations for monitoring tobacco use by adolescents. Simple and multiple logistic regression analyzes were conducted, adjusting for sex, age, type of school, place of residence, smoking of traditional cigarettes and parental smoking. Frequencies and proportions for descriptive statistics, and adjusted odds ratios with 95% confidence intervals for logistic regression models were reported.

Results: Approximately, 56% of interviewees had noticed some form of e-cigarettes advertising. Exposure to e-cigarette advertising was significantly associated with ever use of e-cigarettes (OR = 1.29; 95% CI: 1.09–1.53). Exposure to e-cigarette advertising via club/pub/disco was significantly associated with current e-cigarette use (OR = 1.58; 95% CI: 1.06–2.36). Adolescents who have ever used e-cigarettes were more likely than never users to report exposure to advertisements on club/pub/disco (OR = 1.57; 95% CI: 1.08–2.30) and internet (OR = 1.22; 95% CI: 1.01–1.47).

Conclusion: Despite the applicable advertising restrictions, the majority of young people declared contact with e-cigarette advertising, which shows the urgent need for more global action. The internet and advertisements in clubs, pubs and discos seem to be the key places of exposure. These forms of exposure need to be urgently addressed given their clear link to e-cigarette use.

KEYWORDS

adolescents, advertising, e-cigarettes, youth, promotional activities

Introduction

Tobacco smoking worldwide, including in Poland, is a significant epidemiological and social problem. Poland is supposed to be a cigarette-free country, i.e., with a smoking rate of less than 5 percent, by 2030, meanwhile the number of tobacco smokers, including alternative tobacco products and e-cigarettes has been increasing since 2021. More and more women and teenagers

are turning to cigarettes. According to the most up-to-date epidemiological study of 2022, 28.8% of the adult population (27.1% of women and 30.8% of men) in Poland already smoked. Of this, as many as 22.9% of women and 26.5% of men declared daily smoking. There were significant differences in the prevalence of daily use of heated tobacco according to age – people from younger age groups were most likely to use the new products (1). The fact that the small percentage of people trying to quit smoking or those who succeeded in quitting is worrying. The market for tobacco products and accessories is constantly changing. The use of electronic devices or heated tobacco is contributing to an increase in the percentage of people using nicotine products (2). The tobacco industry, looking for alternatives to the declining cigarette market, has expanded its product portfolio, introducing new products such as e-cigarettes and heated tobacco. This has contributed to the emergence of new consumer groups for nicotine products, which are most popular among teenagers and young adults.

Young people are less aware of the health risks of e-cigarettes and are more likely to use them than adults. Polish youth have virtually unlimited access to e-cigarettes. The law prohibiting their sale to minors is not enforced because despite the ban on advertising and promotion of tobacco products, these products are available to young people, as evidenced by statistics of their use (3). These regulations need to be updated to adapt them to current challenges, e.g., limiting online advertising or their effective application to alternative tobacco products. There is also a lack of elementary education to warn against the disastrous consequences of addiction. The figures for young people are alarming – 60 percent of all teenagers and almost half of 15-year-olds initiated nicotine use. In recent years there has been a significant increase in the popularity of e-cigarettes especially among young people. Teens are now more likely to choose e-cigarettes over traditional cigarettes (1). In addition, the phenomenon of dual use of tobacco and e-cigarettes is also observed (3). Factors contributing to nicotine initiation include peer pressure (peers, school), availability of tobacco products and exposure to advertising of nicotine products (4). Although e-cigarette advertising is limited in Poland, it plays a significant role in this trend, shaping positive perceptions of e-cigarettes and may play an important role in initiating and sustaining e-cigarette use among young adults.

The prevalence of e-cigarette use among adolescents has increased dramatically worldwide, and there are serious health risks associated with this behavior (5). E-cigarette use among adolescents has harmful effects on many aspects of health (6–8). Despite existing legal regulations prohibiting the advertising of these products, little is known about the real impact of advertising these products to adolescents. This information is essential for establishing effective policies or interventions to reduce e-cigarette use among teens.

This article aims to analyze the problem of youth exposure to e-cigarette advertising and identify the links between exposure to advertising for these products and e-cigarette use among adolescents.

Materials and methods

Study design and population

The study was part of a nationwide study on the health effects of tobacco products, which involved almost 2% of the population of primary and secondary school students aged 15–18, financed by the National Health Program, the Ministry of Health in Poland. The analysis was based on a large cross-sectional study conducted in the first 2 months of 2020 among 15,225 students from 200 Polish upper secondary schools using a random, stratified selection of institutions. This study analyzes data for 7,498 young people who declared ever e-cigarettes smoking.

The study was approved by the National Institute of Public Health PZH—Bioethical Committee of the National Research Institute (Resolution No. 3/2019; 13/11/2019).

Measures

The data necessary for the analysis was collected using an online questionnaire, with the prior consent of the participants, using the Computer-Assisted Web Interview tool, which increases the reliability of data collection and allows to avoid errors that may occur during self-coding or entering data using survey software. The Global Youth Tobacco Survey (GYTS) questionnaire recommended by the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) to monitor youth tobacco use was used (9).

Participants provided information on the following demographic variables: their sex (female, male); age (15–17 years; ≥18 years); type of school (grammar or vocational/technical) and residence (urban or rural). A variable for parental smoking was also taken into account in the analysis (neither of the parents smoke vs. either or both parents smoke). The participants were asked whether they had ever used cigarettes, if they did also about their current smoking habits. Information on smoking traditional cigarettes and e-cigarette use was separately collected. People who never smoked are people who answered "no" to the question: Have you ever tried traditional cigarettes, even once in life?. Those who answered "yes" to this question were categorized as ever smokers. Current smokers were reported to have smoked in the past 30 days. The same type of question was asked to report e-cigarettes behavior. We first asked if they had ever tried an e-cigarettes, using the following item: Have you ever tried e-cigarettes, even once in life? If the participant answered "yes," we assessed current cigarette use with the question: Have you used e-cigarettes at least once in the last 30 days? Adolescents who reported any use in the past 30 days were considered current cigarette smokers.

To assess e-cigarette advertising exposure, participants were asked, "Have you seen an advertisement for e-cigarettes in the last 30 days?." Answer options were yes/no. For respondents who indicated that they had seen or heard an advertisement for e-cigarettes type of exposure to e-cigarette advertising was measured by asking participants about the channels through which they had noticed any e-cigarette advertisements in the previous 30 days: shop, internet and club/pub/disco. Respondents who answered "yes" have been classified as those who were exposed to tobacco advertising. The reference group for advertising exposure was "no exposure."

Statistical methods

In the descriptive analysis, the numbers of each group and their structure indicators are given. An analysis of the significance of differences in the abundance of each subgroup was performed. Statistical correlation analysis was performed using logistic regression, with the odds ratio calculated as a weighted indicator, multivariate logistic regression model assessed the relationship between e-cigarette advertising and (1) ever e-cigarette use and (2) current e-cigarette use.

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The following covariates were included in models: gender, age group, type of high school, type of residence, smoking, and parental smoking. The analysis was performed using the Statistica 13.3 package.

Results

Table 1 summarizes the key characteristics among study population, 7,498 young adult (53.5% men and 46.5% women). Approximately, 56% of interviewees had noticed some form of e-cigarettes Advertising. Among young men, 46.2% reported exposure to e-cigarette advertising This ratio was similar in the group of young women and amounted to 47.0%. In total, 75.5% of the interviewees were averaged 15–17 years, slightly more than half of them (53.0%) have not seen an advertisement for e-cigarettes. The highest proportion of respondents (56.0%) had attained vocational and technical education, 43.5% of these people declared that they were exposed to e-cigarette Advertising. Most of the respondents came from rural areas, but in all groups of residence the percentage of people who were not exposed to e-cigarette advertising was higher.

TABLE 1 Characteristics of study population by status of exposure to e-cigarettes advertising.

Variables *n*	Exposure to e-cigarettes advertising *n* (%)		*p* value
	No	Yes	
Population (overall)			
Male (4014)	2,161 (53.84)	1853 (46.16)	0.000
Female (3484)	1850 (53.10)	1,634 (46.90)	0.000
Age (years)			
15–17 (5658)	2,998 (52.99)	2,660 (47.01)	0.000
≥18 (1840)	1,013 (55.05)	827 (44.95)	0.000
Type of school			
Grammar (3280)	1,631 (49.73)	1,649 (50.27)	0.662
Vocational/technical (4164)	2,352 (56.48)	1812 (43.52)	0.000
Place of residence (number of inhabitants)			
Rural (3352)	1774 (52.92)	1,578 (47.08)	0.000
Cities <20th (1487)	819 (55.08)	668 (44.92)	0.000
Cities 20–99 (1219)	611 (50.12)	608 (49.88)	0.906
Cities 100–500 (817)	425 (52.02)	392 (47.98)	0.103
Cities >500 (292)	157 (53.77)	135 (46.23)	0.068
Smoking (traditional cigarettes)			
Never (2768)	1,360 (49.13)	1,408 (50.87)	0.195
Ever (2058)	1,019 (49.57)	1,039 (50.43)	0.581
Current (2672)	1,632 (61.08)	1,040 (38.92)	0.000
Smoking (e-cigarettes)			
Never (2839)	1,459 (51.39)	1,380 (48.61)	0.036
Ever (1666)	795 (47.72)	871 (52.28)	0.009
Current (2993)	1757 (58.70)	1,236 (41.30)	0.000
Parental smoking			
Traditional cigarettes			
No (3826)	1970 (51.49)	1856 (48.51)	0.009
Yes (3155)	1,694 (53.69)	1,461 (46.31)	0.000
e-cigarettes			
No (6367)	3,336 (52.40)	3,031 (47.60)	0.000
Yes (468)	222 (47.44)	246 (52.56)	0.117

About 27.5% of individuals reported ever smoking, including 36.0% current smokers. The majority of participants were current e-cigarettes users (40.0%); 38.0% of young people reported never e-cigarette use and 22.2% having ever used e-cigarettes, even once in life. Among current e-cigarette users, almost 60% were not exposed to advertising of these products, while among never e-cigarettes users 51.4were those who had no to deal with such exposure. In total, 45.2% of parents were smokers and 54.8% were non-smokers. Only less than 7% of parents used e-cigarettes, Among teenagers whose parents used e-cigarettes, almost 53% were exposed to e-cigarette advertising. Table 2 shows the results of the multivariate regression analysis of the association between exposure to e-cigarettes advertising and ever or current e-cigarette use. As seen exposure to e-cigarette advertising was significantly associated with ever use of e-cigarettes (OR = 1.29; 95% CI: 1.09–1.53) when adjusting for sex, age, type of school, place of residence, smoking of traditional cigarettes and parental smoking. Likewise, e-cigarette advertising exposure was associated with current use of e-cigarettes, although in this case the results were not statistically significant (OR = 1.12; 95% CI: 0.93–1.34). Men were more likely than women to report e-cigarette use, both among ever (OR = 2.07; 95% CI:1.74–2.48) and current e-cigarette smokers (OR = 2.44; 95% CI: 2.01–2.95). In both groups the risk was higher among grammar school students, OR = 1.71 (95% CI: 1.42–2.07) and 1.65 (95% CI: 1.35–2.02), respectively. For respondents who were living in the largest cities, the odds of ever e-cigarette use increased by 1.23, while the odds of current e-cigarette use amounted to OR = 2.28 (95% CI: 1.23–4.20). Individuals who additionally smoked traditional tobacco were over 2.5 times more likely to be ever user of e-cigarettes (OR = 2.60; 95% CI: 2.18–3.09) and more than four times were a current e-cigarette user (OR = 4.22; 95% CI: 3.51–5.08). We also assessed the differences in exposure through specific advertising channels. As shown in Table 3, internet was the most frequently reported source of advertising exposure among study participants. Other channels of exposure included shop and club/pub/disco. Logistic regression models showed that adolescents who have ever used e-cigarettes were more likely than never users to report exposure to advertisements on club/pub/disco (OR = 1.57; 95% CI: 1.08–2.30) and internet (OR = 1.22; 95% CI: 1.01–1.47). Compared to non-e-cigarette over 18 years of age users, younger (from 15 to 17 years of age) users of e-cigarettes were more likely to report e-cigarette use (OR = 1.20; 95% CI: 1.03–1.41). In addition, ever e-cigarettes smoking grammar school students were almost twice (OR = 1.81; 95% CI: 1.52–2.15) more likely to report exposure to e-cigarettes compared to vocational/technical students who had never tried e-cigarettes. A significantly higher risk was found among men with the relative risk being over two times greater in men than women (OR = 2.21; 95% CI: 1.88–2.59). This risk depended also on the place of residence. Thus, for respondents who were lived in big cities to the odds of e-cigarette use increased by 2.25 (OR = 2.25; 95% CI: 1.25–4.06). In the case of additional smoking traditional cigarettes, the risk increases more than 2.5 times (OR = 2.69; 95% CI: 2.29–3.17).

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TABLE 2 Association between e-cigarette use and exposure to e-cigarettes advertising.

Variables	Ever e-cigarette use	Current e-cigarette use
	Adjusted OR (95%CI)	Adjusted OR (95%CI)
Exposure to e-cigarettes advertising		
No (ref)	–	–
Yes	1.29 (1.09–1.53)	1.12 (0.93–1.34)
Male	2.07 (1.74–2.48)	2.44 (2.01–2.95)
Female (ref)	–	–
Age (years)		
15–17	1.11 (0.93–1.34)	1.18 (0.97–1.44)
≥18 (ref)	–	–
Type of school		
Grammar	1.71 (1.42–2.07)	1.65 (1.35–2.02)
Vocational/technical (ref)	–	–
Place of residence (number of inhabitants)		
Rural (ref)	–	–
Cities <20th	1.36 (1.09–1.70)	1.47 (1.16–1.86)
Cities 20–99th	1.55 (1.21–1.98)	1.80 (1.38–2.34)
Cities 100–500	1.41 (1.05–1.84)	1.62 (1.19–2.22)
Cities >500	2.23 (1.24–4.02)	2.28 (1.23–4.20)
Current traditional cigarette use		
No (ref)	–	–
Yes	2.60 (2.18–3.09)	4.22 (3.51–5.08)
Parental smoking		
No (ref)	–	–
Yes	1.02 (0.86–1.21)	1.08 (0.90–1.30)

TABLE 3 Association between e-cigarette use and exposure to e-cigarettes advertising, by source of exposure.

Variables	Ever e-cigarette use	Current e-cigarette use
	Adjusted OR (95%CI)	Adjusted OR (95%CI)
Exposure to e-cigarettes advertising		
No (ref)	–	–
Shop	1.14 (0.90–1.44)	0.97 (0.75–1.24)
Internet	1.22 (1.01–1.47)	0.95 (0.78–1.16)
Club/pub/disco	1.57 (1.08–2.30)	1.58 (1.06–2.36)
Male	2.21 (1.88–2.59)	1.99 (1.68–2.36)
Female (ref)	–	–
Age (years)		
15–17	1.20 (1.03–1.41)	0.94 (0.79–1.12)
≥18 (ref)	–	–
Type of school		
Grammar	1.81 (1.52–2.15)	1.36 (1.13–1.64)
Vocational/technical (ref)	–	–
Place of residence (number of inhabitants)		
Rural (ref)	–	–
Cities <20th	1.42 (1.14–1.76)	1.29 (1.03–1.63)
Cities 20–99th	1.60 (1.26–2.05)	1.59 (1.23–2.06)
Cities 100–500	1.45 (1.09–1.94)	1.43 (1.05–1.94)
Cities >500	2.25 (1.25–4.06)	2.02 (1.10–3.69)
Current traditional cigarette use		
No (ref)	–	–
Yes	2.69 (2.29–3.17)	3.58 (3.01–4.26)
Parental smoking		
No (ref)	–	–
Yes	1.06 (0.90–1.25)	0.92 (0.78–1.10)

As seen Table 3 exposure to e-cigarette advertising via club/pub/disco was significantly associated with current e-cigarette use among young people when adjusting for sex, age, type of school, place of residence, current tobacco use and parental smoking (OR = 1.58; 95% CI: 1.06–2.36). Further, for additional traditional tobacco smoking students' odds of current e-cigarette use increased by 3.58 (OR = 3.58; 95% CI: 3.01–4.26). Again, for participants who were living in big cities the odds ratio of current e-cigarette use increased by 2.02 (95% CI: 1.10–3.69). A lower level of education among current e-cigarette smokers was associated with a higher risk of e-cigarette use (OR = 1.36; 95% CI: 1.13–1.64) compared to youth with vocational/technical education. Men who were current e-cigarette users, had a 2-fold (OR = 1.99; 95% CI: 1.68–2.36) higher risk of e-cigarette use compared to women, who have never used e-cigarettes.

Discussion

The use of a ban on all forms of advertising, promotion and sponsorship of e-cigarettes is one of the main strategies to reduce e-cigarette use among minors and non-smokers introduced by the World Health Organization (5) and this is in line with Article 13 of the Framework Convention on Tobacco Control (10). However, regardless of the regulatory framework in place, young people routinely encounter e-cigarette advertising. The results of our study will contribute to providing scientific evidence assessing the impact of e-cigarette advertising and marketing on e-cigarette use among young people. Regulations prohibiting marketing activities, including e-cigarette advertising, are a key factor in reducing the harms associated with e-cigarette use. Meanwhile, the vast majority (56%), of teenagers, participants in this study, were exposed to e-cigarette advertising in at least one type of media. Exposure rates were particularly high for the Internet. These are alarming data and unfortunately confirm data from other countries (11–13).

Our findings suggest that exposure to e-cigarette advertising was associated with e-cigarette use among young people in Poland. These relationships apply to ever e-cigarette use as well as current e-cigarette use. We further found that later e-cigarette use was related to various e-cigarette-related advertising channels. This is consistent with previous research on the relationship between exposure to e-cigarette advertising and e-cigarette use also. There is limited research on the impact of marketing on the use of e-cigarettes. These studies have found an association between exposure to tobacco product marketing

and with increased likelihood of ever and current e-cigarette use (14–16). Exposure has also been linked to susceptibility to e-cigarette use among those who do not currently use them and as the number of channels of exposure to e-cigarette marketing increased, so did the likelihood of use and susceptibility (17).

E-cigarettes are not a safe substitute for tobacco products (6, 18). A recent large review of 38 studies found that current e-cigarette use is associated with significantly lower quit rates among smokers and smokers are 28% less likely to quit using e-cigarettes than without them (19). According to recent studies, e-cigarettes are not at all associated with any change in the use of traditional cigarettes. Not only are e-cigarettes ineffective as a smoking cessation aid, but they actually promote – especially in adolescents – a descent into nicotine addiction (20, 21). Weak enforcement of the ban on point-of-sale advertising of tobacco products and e-cigarettes gives the tobacco industry a chance to promote its products illegally (22, 23). There is also a lack of prevention messages about e-cigarette use coming from the family, educational and social spheres (24, 25). Young adults are sceptical of the available scientific data on e-cigarette use and by choosing e-cigarettes over cigarettes, young adults believe they are making an informed and healthier choice. Recent results showed that 52.2 and 61.9% of young people, respectively, perceive e-cigarettes and heated tobacco products as less harmful compared to traditional cigarettes. The highest percentage of those who rated these products as less harmful was among current tobacco smokers (69.1%) (26).

Despite a large study group and a standardized survey instrument, our study has some limitations. First, the relationship between frequency of exposure to advertising and the type of advertising messages used and the risk of e-cigarette use was not examined in the study. It is possible that more frequent exposure to marketing activities in this area may be more strongly associated with e-cigarette use. Secondly, we examined the exposure of e-cigarette advertising through the most popular channels such as shop, internet and club/pub/disco. This is related to the introduced restriction on tobacco product advertising, no less advertising may also be related to other channels that may have a potential impact on e-cigarette use among young people. Thirdly, although the survey is representative, it concerns a population of young Poles in whom the problem of e-cigarettes and heated tobacco has emerged relatively recently. In addition, the measures of exposure to e-cigarette advertising and use were self-reported exposures. And we used e-cigarette use in the past 30 days as the outcome variable, which did not fully reflect the intensity of e-cigarette use among young people.

Despite the limitations indicated, the results of our analysis have significant merit indicating the problem of high prevalence of e-cigarette advertising among young people and the factors associated with this relationship. In order to answer the question whether exposure to e-cigarette advertising leads to e-cigarette use, a prospective study is required as a further direction for research. Future research can build on our study and be conducted more broadly, ignoring our limitations.

Conclusion

Despite the advertising restrictions in place, the vast majority of young people said they had been in contact with e-cigarette advertising. The Internet and advertisements for pubs clubs, discos appear to be key exposure sites. These forms of exposure need to be urgently addressed, given their clear connection to e-cigarette use.

E-cigarettes should in any case be considered unhealthy and the arguments about the benefits of electronic cigarettes are unfounded, so their use, especially among young people, should be strongly restricted. As a result of the nicotine industry's marketing efforts, young people are more likely to use e-cigarettes, which can lead to their addiction. The marketing of e-cigarettes is particularly geared toward reaching young people. Advertising of e-cigarettes can make young people see their use as normal and acceptable. Advertisements often portray e-cigarettes as trendy and attractive, which can encourage young people to try them. Advertisements also often overlook or minimize the risks associated with e-cigarette use which can lead to misconceptions about their safety.

Given the ever-increasing importance of e-cigarette use by young people as a global health problem, strengthening prevention strategies including the introduction of stricter restrictions and regulations on e-cigarette marketing and advertising and compliance is key. To reduce exposure to and access to e-cigarettes, the ubiquity of e-cigarette advertising and the persistent challenges of e-cigarette enforcement must be addressed.

Data availability statement

The datasets presented in this article are not readily available because the original contributions presented in the study are included in the article. Requests to access the datasets should be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the National Institute of Public Health PZH—Bioethical Committee of the National Research Institute (Resolution No. 3/2019; 13/11/2019). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

BŚ: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. RZ: Formal analysis, Writing – original draft, Writing – review & editing. ŁB: Resources, Writing – original draft, Writing – review & editing. DK: Conceptualization, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Joanna Jacobus,
University of California, San Diego,
United States

REVIEWED BY
Nilesh Chandrakant Gawde,
Tata Institute of Social Sciences, India
Anita Cservenka,
Oregon State University, United States

*CORRESPONDENCE
Mohammed Al-Hamdani
✉ malhamdani@qu.edu.qa

†These authors have contributed equally to this work

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Sociodemographic characteristics and vaping motives as potential correlates of early vaping initiation

Aisha Al-Naimi†, Fatma Al-Obaidli†, Reem Al-Rashdi†, Fatima Al Zahraa Chokor and Mohammed Al-Hamdani*

Department of Public Health, College of Health Sciences, QU Health, Qatar University, Doha, Qatar

Background: Vaping's popularity has particularly increased among young people, with its prevalence varying across different regions, including the Middle East. The health impacts of vaping, especially when initiated early, are a growing concern.

Aims: This study aimed to investigate the correlates of early vaping initiation (EVI) and explored the sociodemographic characteristics and vaping motives influencing EVI among vapers from Arab countries.

Methods: An online cross-sectional survey recruited 428regular vapers, aged 18–60 who resided in Arab countries at the time of the study. Sociodemographic and vaping motives data were collected. Stepwise logistic regression was used to examine the factors associated with EVI.

Results: The study findings revealed that older participants and expats have lower odds of EVI. Males and vapers from Qatar had around 4–5 times the odds of EVI as compared to females and those from Egypt, respectively.

Conclusion: Targeted social marketing and education campaigns may benefit groups at risk of EVI, including residents of Qatar, males, and those who are strongly influenced by social media or who have friends or family members who vape. Reducing EVI is particularly important, as vaping often begins at an early age, and early intervention is vital to prevent early initiation and subsequent addiction.

KEYWORDS

vaping, sociodemographic variables, early vaping initiation, vaping motives, Middle East

Background

Vaping involves the inhalation and exhalation of vapor generated by an electronic device which heats a flavored fluid, typically enhanced with nicotine, producing a flavored vapor (1). These devices are compact and rechargeable, making them convenient and appealing to the younger generations. Unlike traditional cigarettes, vaping does not produce a strong odour but emits pleasant fruity or sweet aromas (2). Vaping is predominantly perceived as an alternative to smoking cigarettes, perceiving it as a 'safer option' than tobacco (3), despite warnings of its potential for tobacco renormalization and potential harm (4).

The popularity of vaping surged over the years, particularly among younger adolescents globally (5). According to a study, the prevalence of vaping varies across regions. In Europe, prevalence was 14%, one of the highest rates studied. In America, the prevalence was lower at 10% (6). Asia has an 11% prevalence, and Oceania has 6%. In Egypt, a cross-sectional study showed a prevalence of 10.6% among university students (7), while 27.7% of the students in

KSA were regular vapers (8). Another survey conducted in six universities in Palestine showed vaping prevalence of 19.7% (9), while the prevalence of vaping was observed to be 14% among Qatar University students (10).

Motives for vaping among adolescents include peer pressure, curiosity, and social approval (11). Personality traits like spontaneity, thrill-seeking, and anxiety sensitivity also influence decisions to vape (12). Another factor is the availability of different flavors (13). Many adolescents vape to experiment, replace cigarettes, or for entertainment (14). In the US, most vapers have a history of smoking (15), used as a non-toxic alternative to quit smoking (16). Social media platforms, like Twitter, TikTok, and Instagram have influenced vaping habits (17). Moreover, lower education levels correlate with less awareness of vaping harms and, therefore, higher use of vape (18).

Vaping initiation increases the likelihood of cigarette use, leading to nicotine addiction and cancer (19). Early nicotine exposure can impair brain development and affect bone development, lungs, and ocular health (20). Adolescent vapers are more prone to respiratory symptoms, as well as cardiovascular, developmental, and immunologic issues (21, 22). It also poses a risk to children exposed to vaping environments, increasing their chances of experiencing toxic effects like such as nausea, convulsions and respiratory symtoms (23).

Current gaps and study objective

Given the widespread use of vaping and its health risks, it is crucial to examine the factors that are associated with early initiation of vaping. Although previous research has focused adolescents as the target population for EVI, this study takes a retrospective approach, focusing on adults aged 18 and older. By including regular vapers from this age group, we aim to capture individuals who initiated vaping before the age of 18, thus allowing us to explore the factors contributing to EVI. As far as we know, no research has investigated the correlates of EVI in the Arab region. This study, therefore, aims to explore the correlates of early vaping initiation among regular vapers aged 18 and older in a sample of Arab countries.

Methods

Data collection

This study is based on data collected between February and May 2023 by a cross-sectional online survey using the Blue online survey platform. A link to the survey was posted and boosted on social media platforms to reach users.

Study sample

Eligibility criteria for the survey included being a social media user aged 18–60, being a regular vaper who uses any vaping device at least once a week for no less than 3 months and residing in an Arab country. Exclusion criteria were age, under 18 or over 60, not being a regular vaper, or not residing in an Arab country. Participants who completely answered the questions of interest were included in the study.

Ethical approval

The survey received ethical clearance from Qatar University [#QU-IRB 1806-E/23]. An electronic informed consent form, highlighting the study's purpose, potential harms, benefits, confidentiality measures, and data storage procedures was presented in the online survey. Only individuals who agreed to participate after reviewing the consent form were able to take part in the study.

Survey measures

The survey included questions about the respondent's sociodemographic characteristics such as age, country of residence (Qatar, Iraq, Egypt, Other), gender, and residence status (citizen, expat). It also included questions about vaping behaviors such as age at which the respondent started vaping (in years), strongest influence to start vaping (wanting to quit smoking versus friends, family, or social media), using flavored juice when started vaping (yes, no), type of vape juice used when started vaping (with or without nicotine), and smoking before vaping (yes, no) (12).

The Modified Drinking Motives Questionnaire-Revised Short Form scale was used to assess the coping, sensory, cognitive, enhancement, and social motives for starting vaping. The questionnaire, adopted from Davidson et al. (12) and modified from the original Woicik et al. scale (24), presented statements/items related to vaping motives for which participants chose from the scale: 1 "always/almost always," 2 "most of the time," 3 "half of the time/some of the time," and 4 "never/almost never," to indicate how frequently their vaping is motivated by each of the reasons listed. For the analysis of this study, only subscales that showed high reliability were included (enhancement motive and social motive subscales). The survey was pilot-tested on five participants to ensure simplicity and clarity.

Sample size calculation

G*power was conducted to identify the required sample size. A minimum sample size of 308 was needed to detect an odds ratio (OR) $\geq$1.5 at an alpha level of 0.05 and power = 0.8 for a two-tailed logistic regression analysis.

Statistical analysis

The reported age at which the respondent started vaping was categorized into two groups: early initiation of vaping if the age was 18 years or below versus not early initiation of vaping if the age was above 18 years. Descriptive statistics for the respondent's sociodemographic characteristics and vaping motives were presented as medians and interquartile ranges (IQR) for non-normally distributed continuous variables, as well as frequencies and percentages for categorical variables. The normality of continuous variables was assessed through the use of histograms and Q-Q plots. Categorical and continuous variables were compared between participants who initiated

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vaping at an early age versus those who did not use Chi-square tests and the non-parametric test Mann–Whitney U tests, respectively. Binary logistic regression was used to test the correlates of early initiation of vaping (the dependent binary variable defined as yes versus no). The relationships of sociodemographic characteristics, vaping-related characteristics, and vaping motives were further explored using backward stepwise variable selection for a multiple binary logistic regression analysis to identify significant independent correlates of early initiation of vaping. A *p*-value cut-off of 0.1 and 0.2 was set for model entry and removal, respectively. Odds ratio (OR) was used to report the findings along with the 95% confidence interval (CI). To check for multicollinearity among independent variables, we used the variance inflation factor (VIF) cut-off of VIF > 10 as the threshold for collinearity. Data analysis was carried out using StataSE 18. Statistical significance was assessed at an alpha level of 0.05.

Findings

Summary of sample characteristics

Sociodemographic and vaping characteristics are displayed in Table 1 for the total sample by EVI status. The sample consisted of 428 regular vapers aged between 18 and 60 years. The median age for the participants was 26 years; 8.6% were females, and 91.4% were males. Additionally, less than half of the participants (44.9%) were from Egypt, 33.4% from Iraq, 11.9% were from Qatar, and 9.8% were from other countries, including Lebanon, Syria, Jordan, Palestine, Oman,

TABLE 1 Sociodemographic and vaping characteristics of regular vapers by early vaping initiation status.

	No early initiation of vaping (*n* = 331) *N* (%)	Early initiation of vaping (*n* = 97) *N* (%)	Total sample (*n* = 428) *N* (%)	*p*-value*
Age (years)‡	30 (13)	21 (4)	27 (13.5)	<0.001+
Sex				
Female	23 (62.2)	14 (37.8)	37 (8.6)	0.021+
Male	308 (78.8)	83 (21.2)	391 (91.4)	
Country				
Egypt	162 (84.4)	30 (15.6)	192 (44.9)	<0.001+
Iraq	114 (79.7)	29 (20.3)	143 (33.4)	
Qatar	28 (54.9)	23 (45.1)	51 (11.9)	
Others[1]	27 (64.3)	15 (35.7)	42 (9.8)	
Residence				
Citizen	297 (77.6)	86 (22.5)	383 (89.5)	0.763
Expat	34 (75.6)	11 (24.4)	45 (10.5)	
Age of vaping initiation (years) ‡	26 (12)	17 (2)	23 (11)	<0.001+
Strongest influence to start vaping				
Wanting to quit smoking	212 (86.2)	34 (13.8)	246 (57.5)	<0.001+
Friends, family, or social media	119 (65.4)	63 (34.6)	182 (42.5)	
Used a flavored vape juice at initiation				
No	24 (77.4)	7 (22.6)	31 (7.2)	0.991
Yes	307 (77.3)	90 (22.7)	397 (92.8)	
Type of vape juice at initiation				
With nicotine	290 (79.2)	76 (20.8)	366 (85.5)	0.023+
Without nicotine	41 (66.1)	21 (33.9)	62 (14.5)	
Smoking before vaping				
No	56 (60.9)	36 (39.1)	92 (21.5)	<0.001+
Yes	275 (81.9)	61 (18.1)	336 (78.5)	
Enhancement motive scale ‡	2 (2)	2.3 (2.7)	2 (2.3)	0.0651
Social motive scale ‡	3.7 (2)	3.7 (1.7)	3.7 (1.7)	0.3713

**p*-values were obtained from chi-square tests for categorical variables, as applicable or using Mann–Whitney U tests for continuous variables.
‡Continuous variables (age, age of initiation, enhancement motive scale, and social motive scale) are summarized using medians and interquartile ranges.
[1]Others include Lebanon, Syria, Jordan, Palestine, Sudan, Yemen, KSA, Kuwait, UAE, Oman, and Bahrain.
+Significant values.

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Sudan, Yemen, Kuwait, Bahrain, Saudi Arabia, and the United Arab Emirates. Most participants were citizens of their respective countries (89.5%), while 10.5% were expatriates. More than half of the participants (57.5%) reported that "wanting to quit smoking" was their primary reason for vaping initiation. In comparison, 42.5% reported family, friends, and social media as the strongest influence to start vaping. Moreover, 92.8% of the participants used a flavored vaping product when they started vaping, and 14.5% of the participants began to use vaping products without nicotine. Furthermore, 78.5% started smoking before vaping.

Main results

Table 1 also shows that differences were found between those who started vaping at an early age versus those who did not in terms of sex, age, and country of residence. Age distribution was statistically lower among those who initiated vaping at an early age as compared to those who did not ($p < 0.001$). Females had a significantly higher proportion of EVI (37.8%) than males (21.2%). Moreover, participants residing in Qatar had a higher proportion of EVI (45.1%) as compared to those living in Egypt (15.6%) ($p < 0.001$). The median age of vaping initiation across the entire sample was 23 years, with an IQR of 11. Notably, early vaping initiators exhibited significant differences in their age of initiation (median = 17 years) compared to non-early initiators (median = 26 years) ($p < 0.001$). Moreover, as compared to those who started vaping because they wanted to quit smoking, those whose strongest influence to start vaping were friends, family, or social media had significantly higher proportions of EVI ($p < 0.001$).

Further, participants who started vaping using vape juice with nicotine had a significantly lower proportion of EVI (20.8%) compared to those who started using vape juice without nicotine (33.9%) ($p = 0.023$). Similarly, participants who smoked before vaping had a lower prevalence of EVI (18.1%) compared to those who did not smoke before vaping (39.1%) ($p < 0.001$).

Table 2 illustrates the results of logistic regression analyses with the EVI (yes/no) as the dependent variable. One year increase in age is significantly associated with lower odds of EVI by 30% (OR: 0.7, 95% CI: 0.6, 0.8). Males and those residing in Qatar had four times the odds of EVI compared to females and those in Egypt, respectively. Moreover, expats had lower odds of EVI than citizens by 80% (OR = 0.2, 95% CI: 0.1, 0.7). It is worth mentioning that those who reported having friends, family, or social media as the strongest influence to start vaping had approximately two times the odds of EVI as compared to those who started vaping because they wanted to quit smoking (borderline significance). Vaping characteristics and motive scales were not retained in the final model based on the backward stepwise selection.

Sensitivity analyses were applied to the 20–34 years old subsample since they are most impacted by vaping initiation. Another set of analyses were applied to vapers who are citizens only to check whether the convergence of country and residence status impacts vaping initiation. The results of both analyses yielded similar effects to the overall sample concluding that neither a focus on a narrower age group nor the convergence of country and residence status are differentially related to vaping initiation (see Supplemental File).

TABLE 2 Simple and multiple logistic regressions for the correlates of early initiation of vaping among 18–60 years old regular vapers.

	Crude OR (95% CI)	Adjusted OR (95% CI)*
Age (years)	0.7 (0.7, 0.8)	0.7 (0.6, 0.8)
Sex		
Female	Reference	Reference
Male	0.4 (0.2, 0.9)	4.2 (1.4, 12.7)
Country		
Egypt	Reference	Reference
Iraq	1.4 (0.8, 2.4)	0.6 (0.3, 1.3)
Qatar	4.4 (2.2, 8.7)	4.5 (1.2, 16.3)
Others[1]	3.0 (1.4, 6.3)	1.3 (0.5, 3.6)
Residence		
Citizen	Reference	Reference
Expat	1.1 (0.5, 2.3)	0.2 (0.1, 0.7)
Strongest influence to start vaping		
Wanting to quit smoking	Reference	Reference
Friends, family, or social media	3.3 (2.1, 5.3)	1.8 (1.0, 3.3)
Used a flavored vape juice at initiation		
No	Reference	
Yes	1.0 (0.4, 2.4)	
Type of vape juice at initiation		
With nicotine	Reference	
Without nicotine	2.0 (1.1, 3.5)	
Smoking before vaping		
No	Reference	
Yes	0.3 (0.2, 0.6)	
Enhancement motive scale	1.2 (1.0, 1.5)	
Social motive scale	1.1 (0.9, 1.4)	

Significant ORs are displayed in red font.
*Based on backward stepwise selection regression model using likelihood ratio test.
[1]Others include Lebanon, Syria, Jordan, Palestine, Sudan, Yemen, KSA, Kuwait, UAE, Oman, and Bahrain.

Discussion

Our study found that age, sex, country of residence, residence status, and influences from family, friends, and social media (borderline significance) are significantly associated with EVI. These findings align with existing literature, where several studies have reported a higher prevalence of vaping among young adolescents than older ones (25, 26). The lack of understanding and knowledge of the potential health implications of vaping might explain this higher prevalence among the younger ones (27). Moreover, the negative association between age and EVI suggests that younger vapers are more likely to have started vaping earlier compared to older vapers. This could reflect the increasing prevalence of vaping among the younger generation, as vaping has gained popularity in more recent years, coinciding with increased availability and marketing of e-cigarettes. In addition, sex differences in EVI were also observed, with males tending to begin vaping at a younger age than females. This trend is consistent with

previous studies showing historically higher rates of tobacco use among males of all ages (28). Additionally, studies have shown that males are frequently the first to adopt new technologies, and vape products are no exception (29). The increased likelihood of males using vape may be attributed to their lower perception of harm associated with vaping (3, 16).

Further, the country of residence is also associated with EVI, with residents of Qatar showing higher odds of EVI. A previous study reported that 14% of Qatar College undergraduates vape (10). Individuals in higher-income countries are more prone to spending their income on vaping devices and, therefore, have more access to resources (30). Generally, citizens have higher incomes than expatriates, which may explain why citizens are more likely to initiate vaping early (31). Likewise, friends, family, and social media have a borderline significant association with EVI. This finding is consistent with literature indicating that having a family member who vapes increases the likelihood of vaping among adolescents (32). Adults with friends who view vaping positively are more likely to vape (25). Additionally, promotion of vaping on social media has a significant influence on young adolescents (33).

Implications

The results of the current study have several important implications. First, caution should be exercised to prevent EVI, particularly with male adolescents. This can be addressed through parental support or by engaging males in extracurricular activities to develop better coping mechanisms. Engaging them in skill acquisition to refuse vaping products when offered can be crucial in early intervention (34).

Secondly, the higher likelihood of EVI for those residing in Qatar suggests that being cautious about youth spending is necessary to prevent EVI. Parents should consider reducing allowances or buying items for young adolescents rather than giving them money to avert EVI. Additionally, parents can provide gift cards from places that do not sell vaping products, as lower affordability is associated with reduced vaping, particularly among youth (11).

Our study's findings also highlight the need for regulatory measures to restrict the exposure of young social media users to vaping content. This is crucial as past research has shown that social media influences vaping behavior and increases the likelihood of vaping. Therefore, it is prudent to limit the exposure to vaping content for individuals under the age of 18 (19).

Strengths and limitations

To our knowledge, this research addresses an understudied area of vaping literature, which is the correlates of EVI. Our study adds to the scarce literature on vaping control in the Middle East. However, our research has some limitations. The cross-sectional design does not test causal relationships between sociodemographic and vaping motive correlates and EVI. A longitudinal study may be necessary to explore the causal relationships between various correlates and EVI. Additionally, this study included social media users only from a limited number of Arab countries, which limits the generalizability to all regular vapers in the Arab countries. Social media users, especially those who engage in online surveys, may differ from those who do not use these platforms in terms of sociodemographic characteristics (e.g., age, education, socioeconomic status), potentially leading to selection bias. Furthermore, there is a possibility some participants would respond by either underestimating or overestimating their responses, or inaccurately recalling or misreporting their vaping behaviors introducing social-desirability bias. Moreover, because the sample consisted of participants aged 18 and older, the retrospective reporting of vaping initiation before the age of 18 might be subject to recall bias, especially in older respondents. Additionally, the majority of the studied vapers in this study were not early vaping initiators. This limitation can be rectified in future studies via recruiting a larger portion of early vaping initiators in studied samples. It is also important to note that this study grouped vaping initiators into two groups: EVI (<18 years old) and non-EVI (≥18 years). This way of grouping vapers does not distinguish between EVI at different stages of adolescence (early vs. late adolescence) which does not allow for correlating sociodemographic variables with EVI at different stages of adolescence. Future studies can divide EVI by stage of adolescence and compare how each stage differs from non-EVI with respect to sociodemographic correlates to offer more nuanced interpretation. Finally, we examined a limited number of predictors, while other factors such as parent's education level and the presence of mental health disorders may also affect EVI.

Conclusion

This study suggests that sociodemographic characteristics such as sex, country of residence, residence status, and social influences from friends, family, or social media are significantly associated with EVI. Notably, younger age groups had higher odds of EVI, which may highlight emerging trends within younger populations. Future research and policy-making efforts shall, therefore, aim at mitigating the rise of vaping, particularly among younger adults. Further studies are encouraged to explore interventions and preventive measures that address these early initiation trends. Future studies could also expand on these findings by investigating other risk factors and longitudinal patterns, helping to deepen our understanding of vaping behavior in the broader population.

Data availability statement

The datasets presented in this article are not readily available due to the sensitive nature of the data. The anonymized data will only be retained for 5 years from the end date of data collection as this was a condition stated in the informed consent. Requests to access the datasets should be directed to malhamdani@qu.edu.qa.

Ethics statement

The studies involving humans were approved by Qatar University Institutional Review Board (QU-IRB). The studies were conducted in accordance with the local legislation and institutional requirements.

The participants provided their written informed consent to participate in this study.

Author contributions

AA-N: Formal analysis, Writing – original draft. FA-O: Formal analysis, Writing – original draft. RA-R: Formal analysis, Writing – original draft. FC: Formal analysis, Supervision, Writing – review & editing. MA-H: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1484252/full#supplementary-material

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EDITED BY
Gilda Angela Neves,
Federal University of Rio de Janeiro, Brazil

REVIEWED BY
Robert J. Wellman,
UMass Chan Medical School, Division of Preventive and Behavioral Medicine, United States
Laurie A. Solomon,
University of Florida Health Florida Recovery Center, United States
Carlos Llanes,
Boston Children's Hospital, United States

*CORRESPONDENCE
Joanna Jacobus
✉ jjacobus@ucsd.edu

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Substance use and social influence as risk factors for nicotine and tobacco product use in adolescents and young adults who use electronic nicotine delivery systems

Laura E. Hatz[1], Kelly E. Courtney[1], Alexander L. Wallace[1], Natasha E. Wade[1], Rachel Baca[1], Neal Doran[1,2] and Joanna Jacobus[1]*

[1]Department of Psychiatry, University of California San Diego, La Jolla, CA, United States, [2]Psychology Service, Jennifer Moreno Department of Veterans Affairs Medical Center, La Jolla, CA, United States

Background: Nicotine and tobacco product (NTP) use in adolescence and young adulthood is associated with negative health and psychosocial outcomes. This study prospectively tested alcohol use, cannabis use, and peer and family NTP use as predictors of NTP use in adolescents and young adults (AYAs) who were NTP naïve or who primarily used electronic nicotine delivery systems (ENDS).
Method: Participants ($N = 133$) ages 16–22 completed a baseline laboratory visit and follow-up session 1 year later. Participants' baseline alcohol use, cannabis use, and NTP use by peers and family were tested as risk factors for any and moderate to heavy (at least monthly) NTP use at follow-up. Logistic regressions were conducted for the full sample ($N = 133$) and in a subsample of participants reporting no to low NTP use at baseline ($n = 76$).
Results: Baseline alcohol use, cannabis use, and peer and family NTP use were associated with NTP use at 1-year follow-up, over and above baseline NTP use. Peer and family NTP use emerged as the most consistent predictor of AYA NTP use (ORs: 4.059–8.432), while recent cannabis and alcohol use exerted effects (ORs: 1.003–1.021) that varied by NTP use level.
Discussion: A confluence of variables, including prior substance use and social and familial influences, act as risk factors for NTP use in AYAs who primarily use ENDS. Identification of risk and protective factors for NTP use is necessary to inform efforts to decrease NTP use in this developmentally vulnerable population.

KEYWORDS

adolescents, young adults, nicotine, risk factors, alcohol, cannabis

1 Introduction

Nicotine and tobacco product (NTP) use among adolescents and young adults (AYAs) has increased significantly since electronic nicotine delivery systems (ENDS), commonly referred to as e-cigarettes or vaporizers, were introduced in 2004 (1, 2). Despite modest decreases in rates of NTP use among AYAs since the COVID-19 pandemic, NTP use

remains prevalent within this age group, with over 25% of high school seniors and young adults reporting vaping nicotine and about 20% reporting smoking cigarettes within the past year (3, 4). Although ENDS were initially marketed as a smoking cessation aid and lower risk alternative to combustible cigarettes (5), more recent findings have highlighted health risks (6, 7) and potential pathways from nicotine vaping to the use of combustible cigarettes (8–10) and illicit substances (11, 12). Adolescents and young adults are especially vulnerable to NTP use due to nicotine's impacts on neurodevelopment and subsequent alterations in cognitive functioning that may result from nicotine exposure (13). Therefore, identification of risk factors for the initiation and maintenance of NTPs, and especially ENDS, use is needed to inform prevention and intervention efforts targeting AYAs.

Extant literature has identified numerous predictors of NTP use in AYA populations, with a growing emphasis on risk factors for ENDS use. Research on sociodemographic correlates of NTP use indicate that individuals who use combustible NTPs are more likely to be older, have lower socioeconomic status, and have family and peers who smoke (14, 15), whereas individuals who use ENDS are likely to be younger and male, White, and use other NTPs and cannabis (16–20). Several cognitive and affective risk factors for ENDS use have been indentified, including stronger positive and weaker negative expectancies for nicotine's effects (21–24), emotion regulation difficulties (25, 26), and impulsive traits (27, 28). A recent scoping review (29) evaluated modifiable risk factors for ENDS use in children and adolescents (≤age 19) using the Theory of Triadic Influence, which identifies biology and personality, social context, and environmental context factors as determinants of youth tobacco initiation (30). Across 240 studies, youth ENDS use was most frequently significantly associated with biology and personality (e.g., genetics, mental health, attitudes, other substance use) and social context (e.g., peer influence and behavior, family attitudes, cultural context) factors. In line with these findings, the goal of the present study was to replicate prior research by prospectively investigating several candidate risk factors (i.e., AYA cannabis and alcohol use and peer and family NTP use) for NTP use in a sample including NTP naïve AYAs and AYAs who reported regular use of ENDS.

Prior substance use has been associated with NTP initiation and maintenance in AYAs. The Gateway Hypothesis of substance use proposes a developmental sequence of substance use initiation, where use of legal substances (i.e., NTPs and alcohol) precedes involvement with illicit substances, including cannabis (31). However, contemporary theory posits that cannabis, which is increasingly accessible to and common amongst AYAs following legalization in many U.S. states (11) and alcohol may also predict progression to NTP use [i.e., the Reverse Gateway Hypothesis; (32)]. Research supports this latter notion, showing that AYAs who use cannabis, relative to those who do not, are up to four times more likely to initate NTP use and three times more likely to progress to nicotine dependence (33–36). Similarly, alcohol use among AYAs has been identified as a risk factor for later initiation of both NTPs and illicit substances (37, 38). Cannabis and alcohol have also been identified as risk factors for initiation of ENDS use, more specifically, in NTP naïve adolescents (e.g., ages 12–17) in analyses of large, nationally representative longitudinal datasets (39–41). An array of factors may underlie prospective associations between alcohol and cannabis use and later nicotine use, including social and contextual (42, 43) and neurobiological (44–47) factors. Identification of possible contributions of alcohol and cannabis use to initiation and maintenance of NTP and ENDS use is particularly important given the high rates of substance co-use among AYAs (37).

Adolescent and young adult NTP use is also strongly influenced by social contextual factors, particularly exposure to NTPs by family and peers (48). Parental and sibling NTP use and nicotine dependence have been established as predictors of regular cigarette smoking and ENDS use in adolescents (40, 49–53). For instance, adolescents with parents who smoke cigarettes are more likely to experiment with NTPs and to progress to regular NTP use than adolescents whose parents do not smoke (52). As peer socialization becomes increasingly important through adolescence and into early adulthood, perceived social norms (54) and NTP use by friends (55, 56) begin to strongly drive initiation of NTP use, including ENDS (57). Research from the Population Assessment of Tobacco and Health Study (PATH), a nationally representative longitudinal study, support these findings. Analyses of PATH data from nicotine naïve 12–17-year-olds have identified exposure to second hand smoke and tobacco use at home (40, 41, 50) and peer use of ENDS (50) as risk factors for ENDS initiation. Peer influence remains an important predictor of NTP use over time, such that college-aged young adults whose friends use NTPs are significantly more likely to do so themselves (57–59).

In sum, identification of predictors of AYA NTP use is critical given the ubiquity of ENDS and the health and psychosocial consequences of NTP use within a population that is particularly vulnerable to their negative effects. Extant research has proposed AYAs' previous use of alcohol and cannabis and current use by peers and family as risk factors for AYA NTP use, yet many studies test these variables as risk factors for NTP *initiation* and focus on adolescents below age 18 or 19, prior to the age at which NTP use has been found to peak in in emerging adulthood (28), and/or restrict samples to adolescents who are NTP naïve at baseline. Therefore, the present study aimed to replicate prior research in a more heterogeneous sample of AYAs, including those up to age 22 and with diverse substance use histories. Specifically, we tested whether peer and family NTP use and past-year AYA alcohol and cannabis use at baseline (ages 16–22) prospectively predicted NTP use 1 year later in a sample of AYAs including those who were NTP naïve or had limited experience with NTPs at enrollment and those who used NTPs regularly. Consistent with recent trends in the prevalence of AYA NTP use, all participants in the study who used NTPs reported primary use of ENDS. Specifically, we tested these variables as predictors of (1) any NTP use 1 year post-baseline and (2) regular use of NTPs (i.e., at least monthly) 1 year post-baseline in the full sample ($N = 133$) and in a subset of participants ($n = 76$) who reported no or very low NTP use at baseline.

2 Method

2.1 Participants

Data for the present investigation were collected as part of a larger study testing the effects of cannabis and NTP use on adolescent/young adult brain development [e.g., (60)]. Participants were recruited from San Diego County via electronic and physical flyers posted on social media and at high schools, community colleges, universities, and local businesses. Interested individuals completed a telephone screening interview to assess elibigility.

To be eligible to participate in the larger study, participants were required to be between 16 and 22 years old and report either regular (≥2 episodes of use per week, on average) use of cannabis and/or NTPs or very minimal to no past cannabis and/or NTP use (≤15 episodes of use in the past 6 months). Cutoffs for enrollment were defined to ensure variability in recency of substance use but were not the used in analyses for the present study. Potential participants were excluded if they were diagnosed with a current or past DSM-5 psychiatric disorder other than tobacco or cannabis use disorder, reported lifetime illicit substance use (other than cannabis) >10 times, were under the acute influence of alcohol or cannabis at time of testing (confirmed with breathalyzer, urine, and oral fluid toxicology), were taking psychoactive medications, including prescription antidepressants and anxiolytics, reported current major medical issues, or had a history of developmental disability or prenatal substance exposure.

A total of 224 participants enrolled in the larger study and completed a baseline laboratory session. Of the 139 participants who completed a 1-year follow-up session, two were excluded from the present analyses due to missing data. Consistent with AYA trends in NTP use (3) and to ensure a more homogenous sample, we included only participants who endorsed primarily using ENDS in the NTP users. Thus, four participants who reported primary use of combustible NTPs at baseline were excluded. The final sample for the current study consisted of 133 participants who were 16–22 years old with a mean age of 19.4 ($SD = 1.6$) years. Participants were 49.6% female and 50.4% male. Sixty-five (48.9%) reported identifying as White, 34 (25.6%) as Asian, and 27 (20.3%) as more than one race. Forty-six (34.6%) participants identified as Hispanic.

2.2 Measures

2.2.1 Sociodemographics

A demographic and psychosocial interview was conducted to assess background information on socioeconomic status (e.g., income level, maternal education), education, race, ethnicity, and medical history.

2.2.2 Substance use

A modified version of the Customary Drinking and Drug Use Record structured interview [CDDR; (60–64)] was administered to assess use of NTPs, alcohol, and cannabis. At the baseline session, participants indicated how many times they used each substance within the past 30 days, past year and within their lifetime. At the 1-year follow-up session, partcipants reported on past-year substance use. Participants were asked to report number of standard drinks consumed when reporting on alcohol use and the number of full or partial nicotine or cannabis products (e.g., cigarettes, joints) when reporting on combustible product use. When reporting on ENDS or vaporizer use, participants were instructed to report "use occasions" or "episodes," separated by engaging in some other activity after puffing on an ENDS or times the ENDS products were put down and picked up. Episodes of simultaneous use of NTPs and cannabis (e.g., through blunts or spliffs) were assessed separately from isolated NTP use and were not included in the dependent variable in these analyses. Total lifetime use episodes of NTPs at baseline were used to categorize participants by NTP use levels for assessment of baseline group differences and potential covariates for primary analyses. Total NTP use by peers and family, alcohol, and cannabis use episodes in the past year, assessed at baseline, were used as predictors. Total NTP use episodes in the past year assessed at 1-year follow-up was the outcome variable.

2.2.3 Peer and family exposure to nicotine

The Wisconsin Index of Smoking Dependence Motives [WISDM; (65)] was administered. The 68-item measure assesses motivational domains for NTP use and includes an item specific to use of NTPs by peers and family. Participants responded to the item, "A lot of my friends or family use NTPs" on a 7-point scale, where 1 indicates "Not true of me at all" and 7 indicates "Extremely true of me." Prior to analyses, participants' responses were recoded as either endorsement (i.e., a response of 2 or more) or no endorsement (i.e., a reponse of 1, or "Not true of me at all") of this item. This dichotomized item was included as a predictor.

2.3 Procedure

After providing written informed consent (ages 18 and up) or parental consent and participant assent (ages 16–17) in accordance with the University of California, San Diego Human Research Protections Program, participants completed a baseline laboratory visit which included a thorough demographic, psychological, and substance use interview, neurocognitive assessment, and magnetic resonance imaging scan session. Participants were asked to refrain from alcohol use for 24 h and cannabis use for 12 h prior to the appointment, which was verified by oral fluid, urine, and/or breathalyzer. To avoid withdrawal effect contamination during assessment, NTP use was not restricted prior to testing. No participants screened positive for acute alcohol or illicit substance use on breath or oral fluid testing, respectively. One year after the baseline session, participants were invited to complete a telephone follow-up session including interviews and questionnaires administered at baseline.

2.4 Statistical analysis

SPSS Version 28.0 software was used for all analyses. Using data from the CDDR (61), participant NTP use at baseline and 1-year follow-up was categorized as either no/low use, defined as ≤12 uses of NTPs in one's lifetime (at baseline) or in the past year (at 1-year follow-up), or as monthly+ use, defined as >12 uses of NTPs in one's lifetime (at baseline) or in the past year (at 1-year follow-up). Sociodemographic characteristics including age, sex, race, and ethnicity were considered for inclusion as covariates and were compared between participants who reported no/low NTP use and monthly+ NTP use at baseline using independent χ^2 and *t*-tests with a $p < .05$ statistical significance threshold. Only demographic characteristics which significantly differed between the two groups (i.e., age and and sex reported at birth) were ultimately included in the models as covariates.

Among all participants, stepwise binary logistic regression was used to test past-year NTP use, past-year cannabis use, past-year alcohol use, and peer and family use of NTPs, all assessed at baseline, as prospective predictors of NTP use at 1-year follow-up. Two models were tested: (1) a model predicting any NTP use (≥1 use, vs. no use) in the past year, and (2) a model predicting monthly+ NTP use (≥12 uses, vs. <12 uses) in the past year. Baseline NTP use was included in Step 1 of the models to account for the effects of nicotine use prior to follow-up. Additionally, covariates of age and self-reported sex were entered in Step 1. In Step 2, baseline cannabis use, baseline alcohol use, and peer and family NTP use were entered to assess the predictive value of these variables above and beyond baseline NTP use.

Among participants who reported no/low NTP use at baseline, two additional binary logistic regression models were tested. Baseline cannabis use, baseline alcohol use, and peer and family use of NTPs were tested as prospective predictors of (1) any NTP use at 1-year follow-up and (2) monthly+ NTP use at 1 year follow-up. An approximation of the proportion of variance explained for each logistic regression model was quantified using the Cox-Snell R^2, an alternative of the R^2 statistic for ordinary least squares regression (66), often referred to as a pseudo R^2.

3 Results

3.1 Descriptive statistics

At the baseline visit, 57.1% ($n = 76$) of participants reported no/low lifetime NTP use (≤12 uses of NTPs ever) and 42.9% ($n = 57$) reported monthly+ lifetime NTP use (>12 uses of NTPs ever). Differences in demographic characteristics and substance use as a function of NTP use at baseline and 1-year follow-up are displayed in Table 1.

3.2 Risk factors for NTP use at 1-year follow-up

Stepwise logistic regression was used to test which baseline predictors (cannabis and alcohol use; peer and family NTP use), controlling for age and self-reported sex at birth, were significantly associated with (1) any, and (2) monthly+ NTP use at 1-year follow-up, above and beyond baseline NTP use. At 1-year follow-up, 68 (51.1%) of participants reported any NTP use. Baseline cannabis use (OR: 1.002 95% CI: 1.001–1.004, $p = .013$), alcohol use (OR: 1.020, 95% CI: 1.006–1.034, $p = .004$), and peer and family NTP use (OR: 4.403, 95% CI: 1.774–10.933, $p = .001$) were significantly associated with any NTP use at 1-year follow-up, above and beyond baseline NTP use.

Fifty-five (41.4%) participants reported at least monthly NTP use at 1-year follow-up. For this model, baseline cannabis use

TABLE 1 Sample demographics and differences between participants reporting no/low NTP use and moderate to heavy (monthly+) NTP use at baseline and 1-year follow-up.

Variable	Baseline NTP use group [mean (SD) or%]			One-year follow-up NTP Use group [mean (SD) or%]		
	No/low NTP use ($N = 76$)	Monthly+ NTP use ($N = 57$)	*p* value	No/low NTP use ($N = 78$)	Monthly+ NTP use ($N = 55$)	*p* value
Age	19.11 (1.66)	19.86 (1.51)	.008	20.19 (1.68)	20.93 (1.54)	.011
% Male	40.79	63.16	.011	41.03	63.64	.010
Race			.101			.405
% Asian	30.26	19.30		29.49	20.00	
% White	40.79	59.65		42.31	58.18	
% More than one race	21.05	19.30		21.79	18.18	
% Other	7.90	1.75		6.41	3.64	
% Hispanic	26.31	40.79	.082	25.45	41.03	.063
% NTP naïve at baseline	68.42	0.00	<.001	61.54	7.27	<.001
Past year total NTP uses (ENDS and combustible)	0.68 (1.66)	2,779.67 (5,398.18)	<.001	3.92 (2.36)	1,769.60 (2,899.48)	.032
Past 6-month ENDS uses	0.32 (1.07)	1,442.74 (3,482.00)	<.001	53.64 (407.93)	1,419.56 (3,532.21)	<.001
Past year alcohol uses	19.92 (30.61)	65.70 (30.61)	<.001	38.94 (48.23)	71.31 (57.06)	.001
Past year cannabis uses	117.45 (218.59)	344.91 (471.55)	<.001	261.96 (287.15)	297.77 (335.99)	.581

NTP, nicotine and tobacco product; ENDS, electronic nicotine delivery system.

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(OR: 1.002, 95% CI: 1.000–1.003, $p = .043$), baseline alcohol use (OR: 1.018, 95% CI: 1.005–1.032, $p = .006$), and peer and family NTP use (OR: 4.059, 95% CI: 1.616–10.191, $p = .003$) were significantly associated with monthly+ NTP use at 1-year follow-up, above and beyond baseline NTP use. In other words, every ten additional uses of alcohol or cannabis in the past year at baseline was associated with approximately 2% greater odds of NTP use at follow-up. For participants who endorsed peer and family NTP use, the odds of NTP use at follow-up were more than 300% higher compared to those who denied peer and family NTP use. Regression coefficients, Wald statistics, odds ratios (ORs), and 95% confidence intervals (CIs) for the OR for each variable are displayed in Table 2.

Binary logistic regression models, with age and self-reported sex at birth included as covariates, were also run in a subsample of participants who reported no/low NTP use at baseline ($n = 76$) to test potential risk factors for (1) any and (2) monthly+ NTP use at 1-year follow-up. At 1-year follow-up, 18 (17.8%) of participants reported any NTP use and 8 (7.9%) reported at least monthly NTP use. Only baseline cannabis use (OR: 1.003; 95% CI: 1.001–1.006, $p = .017$) and peer and family NTP use (OR: 4.864, 95% CI: 1.192–19.628, $p = .027$) were significantly associated with any level of NTP use at 1-year follow-up. Only peer and family NTP use (OR: 8.432, 95% CI: 1.167–60.935, $p = .035$) was significantly associated with monthly+ NTP use at 1-year follow-up. In other words, for participants who reported no/low NTP use at baseline, each additional ten uses of cannabis within the past 30 days was significantly associated with 3% greater odds of any NTP use at follow-up, whereas endorsement of peer and family NTP use at baseline was associated with over 300% greater odds of any NTP use and 700% greater odds of monthly+ NTP use at follow-up. Regression coefficients, Wald statistics, odds ratios (ORs), and 95% confidence intervals (CIs) for the OR for each variable are displayed in Table 3.

TABLE 2 Logistic regression models estimating effects of baseline NTP use, alcohol use, cannabis use, and peer and family NTP use on any and moderate to heavy (monthly+) NTP use at 1-year follow-up in the full sample ($N = 133$).

Variable	R^2	ΔR^2	*B*	Wald's	Odds ratio	95% CI
Any NTP use						
Step 1	.191					
Age			0.146	1.470	1.157	0.914–1.465
Sex			0.676	3.008	1.948	0.917–4.138
Baseline NTP use			0.001	5.040*	1.001	1.000–1.001
Step 2	.369	.178				
Baseline cannabis use			0.002	6.238*	1.002	1.001–1.004
Baseline alcohol use			0.020	8.079**	1.020	1.006–1.034
Peer/family NTP			1.482	10.209**	4.403	1.774–10.932
Monthly+ NTP use						
Step 1	.247					
Age			0.117	0.839	1.124	0.875–1.443
Sex			0.564	1.910	1.758	0.790–3.911
Baseline NTP use			0.001	7.974**	1.001	1.000–1.002
Step 2	.383	.136				
Baseline cannabis use			0.002	4.076*	1.002	1.000–1.003
Baseline alcohol use			0.018	7.557**	1.018	1.005–1.032
Peer/family NTP use			1.401	8.894**	4.059	1.616–10.191

NTP, nicotine and tobacco product.
*$p < .05$.
**$p < .01$.

TABLE 3 Logistic regression models estimating effects of baseline NTP use, alcohol use, cannabis use, and peer and family NTP use on any and moderate to heavy (monthly+) NTP use at 1-year follow-up in a subsample of participants who reported no to low use of NTPs at baseline ($n = 76$).

Variable	R^2	ΔR^2	*B*	Wald's	Odds ratio	95% CI
Any NTP use						
Step 1	.042					
Age			0.181	1.162	1.199	0.862–1.666
Sex			0.688	1.521	1.989	0.667–5.936
Step 2	.246	.204				
Baseline cannabis use			0.003	5.679*	1.003	1.001–1.006
Baseline alcohol use			0.020	3.410	1.021	0.999–1.043
Peer/family NTP use			1.576	4.864*	4.836	1.192–19.628
Monthly+ NTP use						
Step 1	.034					
Age			0.219	0.887	1.245	0.789–1.963
Sex			0.869	1.229	2.384	0.513–11.079
Step 2	.164	.130				
Baseline cannabis use			0.003	2.399	1.003	0.999–1.006
Baseline alcohol use			0.016	1.333	1.016	0.989–1.044
Peer/family NTP use			2.132	4.464*	8.432	1.167–60.935

NTP, nicotine and tobacco product.
*$p < .05$.

4 Discussion

Rapid increases in the availability and popularity of ENDS have contributed to the increased prevalence of NTP use amongst AYAs over the past decade. The popularity of these devices, combined with their negative effects on AYA health and development (13), highlight the importance of identification of risk factors which can inform efforts to prevent and reduce AYA NTP use. Here, we prospectively tested several likely predictors of NTP use in a sample of AYAs with diverse substance use characteristics. Models including these predictors outperformed baseline models including known covariates, demonstrating that both peer and family NTP use and recent alcohol or cannabis use function as predictors of future NTP use among AYAs, over and above baseline NTP use.

Exposure to NTPs by peers and family emerged as the strongest and most consistent risk factor for later AYA NTP use in our sample. Both within the full sample and among participants who reported no to low baseline NTP use, AYAs who endorsed peer and family NTP use at baseline were at least three times more likely to report NTP use (any and monthly+) at 1-year follow-up than those who did not endorse peer and family NTP use. These findings are consistent with previous research suggesting the importance of social influences on AYA NTP use (67, 68) and

with social learning approaches to the development of youth substance use (69, 70). Based on the item administered in the present study, we cannot disentangle the relative influence of peer vs. family smoking on AYA NTP use. There is also research to suggest that parental influence may differ depending on which parent uses substances and by the AYA's gender (48). Further, there may be cross-substance associations between familial and AYA substance use [e.g., parental use of NTPs increases risk that child will use alcohol (71)]. Future research should include more detailed measures of familial and peer NTP use, parental and peer attitudes towards NTPs, and perceived peer norms, for both NTP use in general and ENDS use, more specifically.

Findings also suggest that baseline alcohol and cannabis use may act as prospective risk factors for NTP use among AYAs. Within the full sample, both alcohol and cannabis use were associated with any NTP use at 1-year follow-up, while only cannabis was associated with moderate NTP use. For participants reporting no to low NTP use at baseline, only cannabis use predicted any level of NTP use 1 year later. These results are consistent with prior research demonstrating associations between cannabis and ENDS use among AYAs (28); yet, it is important to note that the effects observed in the present study, especially for cannabis use, were small, with odds ratios close to 1. One possible reason for the size of these effects is the prevalence of alcohol and cannabis within the full sample, which was recruited for a larger study focusing on NTP and cannabis use, relative to the prevalence of NTP use. Upon enrollment, participants reported an average of 1,191.68 (SD = 3,777.32) uses of NTPs within the past year, but only 214.93 (SD = 366.40) uses of cannabis and 39.54 (SD = 48.13) uses of alcohol. The low prevalence rates of alcohol and cannabis use in the sample, relative to NTP use, may be due to study recruitment strategies and/or the young age of some participants, which may limit their access to some substances. Alternatively, NTP uses may be significantly higher because ENDS can be used more frequently and discretely throughout the day with minimal disruption to school or work, vs. alcohol or cannabis products. Comprehensively testing use of other commonly used substances as risk factors for nicotine, and especially ENDS, use among AYAs is a priority for future research, particularly given increasingly high rates of substance co-use among young people (11, 37).

Given the continued popularity of ENDS, development and application of intervention and prevention efforts are necessary to continue the downward trend in AYA NTP use observed in recent years (4, 11). The present study focused on prospective, modifiable risk factors for NTP use, and the results have implications for prevention and intervention campaigns to decrease AYA NTP use. Peer and family use of NTPs emerged as a significant risk factor for NTP use in the present study, suggesting its importance as a potential target for interventions. Consistent with this finding, prior research has identified parental monitoring (72) and involvement [e.g., anti-smoking communication by parents to adolescents; (73)] as an important and modifiable factor which may prevent NTP use among AYAs. Therefore, efforts targeting reducing parental use of NTPs and increasing parents' knowledge and communication regarding NTP risks are promising avenues for preventing and decreasing AYA NTP use. Prior research also suggests that frequent exposure to friends' use of substances is associated with decreased perceptions of harm associated with substance use and that AYAs tend to overestimate peer involvement with substance use (54). Therefore, school-based psychoeducational campaigns targeting normative beliefs, teaching substance refusal skills, and providing information about the harms of NTPs (74) and vaping, which is often viewed as a safer alternative to cigarettes (5, 75), would likely be of benefit to AYAs who endorse high rates of peer NTP use.

The findings of the present research should be considered in the context of its limitations. Although the sample for this study included participants ranging from adolescence to early adulthood, the size of the sample ($N = 133$) is small in comparison to the large, nationally representative studies of thousands of participants (e.g., PATH study) which have identified numerous risk factors for NTP and ENDS use in childhood and adolescence. Many of these studies focus on late childhood/early adolescent predictors of NTP initiation, while fewer include follow-up through early adulthood [e.g., (76)]. Because NTP use often peaks in young adulthood [i.e., ages 18–25; (28)], future analyses of large cohort study datasets should include follow-up data collected beyond the adolescent years, whenever possible, to capture trajectories of substance use including peak periods. In addition, the sample for this study included AYAs with a variety of substance use behaviors, ranging from individuals who did not use subtances at baseline to those who reported regular use of NTPs, cannabis, and alcohol. While this variability in substance use patterns increases generalizability to real-world use patterns, it may have resulted in a restricted range of alcohol and cannabis use. In combination with a modest sample size, this feature of the sample may have resulted in limited power to detect small effects. Future investigations should test these effects within larger AYA populations with heavier alcohol and cannabis use to determine if results persist with heavier earlier use.

In addition, several features of the study may limit generalizability of findings. The present study's analyses grouped participants who were NTP naïve (i.e., reported zero lifetime uses of NTPs) with participants who reported very minimal (i.e., <12 lifetime uses) of NTPs. Despite the low cutoff for lifetime NTP use, it is possible that participants with very minimal exposure to NTPs differed from NTP naïve participants in ways which may limit generalizability of our findings. Potential participants were excluded if they were diagnosed with a DSM-5 psychiatric condition, other than cannabis or nicotine use, or if they were currently taking psychoactive medictions including antidepressants or anxiolytics. Therefore, results may not generalize to individuals with concurrent substance use and other psychiatric disorders. Participants were also predominantly White. Although race was not significantly associated with baseline nicotine use in the sample, extant literature demonstrates racial disparities in substance use (77) and results may not generalize to more racially or socioeconomically diverse samples. Finally, although the prospective design was a strength of the study, participant follow-up only occurred at 1-year post-enrollment, and over 30% of enrolled participants were lost to follow-up. Following participants for a longer period of time, during the transition from adolescence

to early adulthood, and implementing strategies to enhance participant retenton is an important future direction for research aimed at identifying risk factors for NTP use.

The results of the present study replicate a growing body of literature identifying risk factors for NTP and ENDS use in a sample of AYAs with heterogeneous substance use histories. Here, we demonstrated that baseline peer and family NTP use was a significant risk factor for NTP use, both in general and at least monthly use, 1 year later among a sample of AYAs ranging in age from 16 to 22. In addition, we found that even modest baseline alcohol and cannabis use exerted effects on later NTP use, despite the relatively limited sample size. Together, these findings suggest that a confluence of risk factors contribute to NTP initiation and continued use amongst AYAs, and identification of these risk factors in larger samples following participants through early adulthood may promote more efficacious intervention and prevention efforts for preventing NTP and ENDS use.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were approved by UC San Diego Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by participants or the participants' legal guardians/next of kin.

Author contributions

LH: Formal Analysis, Writing – original draft, Writing – review & editing. KC: Conceptualization, Formal Analysis, Writing – original draft, Writing – review & editing. AW: Writing – original draft, Writing – review & editing. NW: Conceptualization, Writing – original draft, Writing – review & editing. RB: Investigation, Project administration, Writing – original draft, Writing – review & editing. ND: Writing – original draft, Writing – review & editing. JJ: Conceptualization, Funding acquisition, Resources, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EDITED BY
Anita Cservenka,
Oregon State University, United States

REVIEWED BY
Landhing Moran,
National Institute on Drug Abuse (NIH), United States
Jacob Rohde,
RTI International, United States
Kristina Zierold,
University of Alabama at Birmingham, United States

*CORRESPONDENCE
Chris Barton
✉ Chris.barton@monash.edu

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E-cigarette use and health information needs among a university student population in Melbourne, Australia

Tasneem Kamoni[1], Melis Selamoglu[1], Christian Osadnik[2], Sanduni Madawala[3], Susan Kotwas[4], Kim Turudia[4] and Chris Barton[1]*

[1]Department of General Practice, School of Public Health and Preventive Medicine, Monash University, Melbourne, VIC, Australia, [2]Department of Physiotherapy, School of Primary and Allied Health Care, Monash University, Melbourne, VIC, Australia, [3]Respiratory Research at the Alfred Hospital, Melbourne, VIC, Australia, [4]University Health Services, Monash University, Melbourne, VIC, Australia

Objective: We explored e-cigarette use, e-cigarette knowledge, attitudes, intentions to use and access to e-cigarette health information among young adults enrolled at an Australian university.

Methods: Respondents completed a survey about e-cigarette use and health resources about vaping. Data were analyzed using SPSS Version 28.0.

Results: Responses were received from *n* = 1,094 students aged 18–25 years. Current e-cigarette use was reported by 13.1% of respondents, daily use 7.6% and ever use 26.8%. Prevalence was greater among men, those reporting more psychological distress, alcohol use and worse academic performance. More than half (51.2%) perceived e-cigarette use as common among their peers and one-third were curious to try an e-cigarette in the future. Domestic and international student e-cigarette use was similar, however, international students tended to access less reputable sources for health information about vaping.

Conclusion: Tailored strategies for domestic and international student groups are needed to address e-cigarette use among university cohorts. Universities provide a setting in which health information and cessation support can be provided to a well-defined group, by dedicated and well-resourced health and wellbeing teams. These results provide a rich resource to guide health promotion, prevention and cessation activities on campus.

KEYWORDS

e-cigarette, university student, health beliefs and attitudes, health information sources, knowledge, intentions

Introduction

E-cigarette use has grown rapidly in Australia in the past 5 years. An estimated 1.5 million Australian's reported current e-cigarette use in 2022–2023 (1), most of whom were young people aged 18–24. Young adults in Australia tend to use e-cigarettes they know contain nicotine (72%), buy them from retail stores (80%), and vape when feeling stressed or anxious (29%) (2). These trends in Australia align with global patterns (3), which indicate that younger adults have the highest likelihood of trying e-cigarettes (4).

A growing body of literature outlines health harms associated with e-cigarette use (5). Non-smokers and young people are most vulnerable to e-cigarette events and are disproportionately affected by risks such as addiction, poisoning, toxicity from inhalation, and increased smoking uptake (5). A key known harm for young people is addiction to nicotine. The effects of nicotine on the developing brain are well established (6) and there is likely a bi-directional relationship between psychological distress and nicotine use (7). Nicotine exposure during periods of active brain development has been linked to long-term cognitive and behavioral deficiencies (6). Students experiencing psychological distress may use e-cigarettes as a coping mechanism, strengthening addiction, which impacts concentration and academic performance, creating further stress. Preventing young people from using e-cigarettes to avoid developing nicotine dependence is important, as is supporting them to quit and mitigate the risk of potential long-term negative health impacts (8, 9).

Colleges and Universities are one setting where there is a large concentration of young people. There is a long standing practice of health promotion on university campuses and they are seen as important settings for health promotion and public health (10). The prevalence of ever vaping among college and university students across the US, Europe, Asia and NZ ranges from 21.2–50% (11–19). Current smoking, alcohol use, white race and gender have been identified as predictors of e-cigarette use from US samples. Studies from campuses in Europe and Asia further identify binge drinking and cigarette smoking, perceived social norms, and curiosity as potential predictors of e-cigarette use among university students.

Australian data on e-cigarette use among university students is limited. Data from one study of almost 5,000 students at the University of Queensland (UQ) reported a prevalence of ever, current and daily vaping of 20.9, 1.8% and 0.7% (20) which is well below more recent estimates of prevalence among young people (1). In the UQ study, people who used e-cigarette or tobacco cigarette were more likely to believe that e-cigarettes were less harmful, and there were important differences between domestic and international students in prevalence (higher among domestic students) and perceptions of e-cigarettes as less harmful, which has important implications for health promotion and cessation services on campus.

University campuses provide unique opportunity for health promotion and prevention activities targeting young adults through health and well-being programs. They provide students accessible youth-oriented health services many of which are free of charge. This is particularly important for international student cohorts, who are navigating an unfamiliar health system and may not have the same information and supports available to them while studying abroad. University health services need to be properly equipped to provide information on vaping and are well positioned to provide health promotion, prevention, and cessation services to students.

Considering the rapid changes in the use of e-cigarettes that have occurred in the past 5 years, the aims of this study were to (i) provide an updated estimate of the prevalence of e-cigarette use among domestic and international university students at a major Australian university; (ii) identify intentions of students to use e-cigarettes in the future related to their knowledge, attitudes and perceptions of e-cigarettes and (iii) identify preferences for accessing health information about e-cigarettes to inform future health interventions in these groups.

Methods

Design and setting

A cross-sectional survey was completed by young adults aged between 18 and 25 years, from Monash University in Melbourne, Australia. Monash is Australia's largest public university by student population and approximately one in three students are enrolled as international students (21). Recruitment was primarily undertaken in person on university campuses by student peers in public spaces such as university greens, libraries and cafeteria common areas, as well as via closed university student groups and noticeboards, and at University Health Service clinics.

Participation was voluntary, not tied to any course credits or requirements, and responses were anonymous. Participants were offered the chance to enter a prize draw to win 1 of 10 gift card prizes upon completion of the survey. The response rate could not be estimated as this was a convenience sample.

Data collection

The survey was developed using Qualtrics™ (see Supplementary material) and accessed by scanning a QR code on their smartphone, or, via links in digital advertisements. Data collection occurred between September and November 2023. We checked Internet Protocol addresses to identify and remove duplicate entries ($n = 11$) to minimize the risk of multiple entries from a single respondent.

The survey was designed specifically to appeal to young adults through the flow and design of the survey, brevity, and the use of popular culture memes and references that encouraged completion. The survey was pilot tested prior to distributing the survey with students within the Department of General Practice who matched the inclusion criteria for the study. They were asked to provide feedback on their experience including identifying any grammatical or typographical errors, flow or skip errors, and ensuring response options were appropriate for this population. Pilot testing suggested the survey could be completed in less than 5 min which was important to increase engagement and completion of the survey in this context.

The selection of items for the survey was informed by the needs of the university health services and guided by the Theory of Planned Behavior and the Health Belief Model (22–25). The TPB compromises three domains: attitudes, subjective norms and the influence of social pressure and, perceived behavioral control (26). The Health Belief Model comprises four concepts: perceived severity, perceived susceptibility, perceived benefits, and perceived barriers toward e-cigarettes (22).

Assessment of e-cigarette use and smoking status

Frequency of e-cigarette and smoking were classified based on the Population Assessment of Tobacco and Health study definitions (27, 28). We asked "How often do you currently vape or use e-cigarettes?" Response options included daily, at least once a week, less than weekly, not at all now but has been a regular e-cigarette user in the past, not at all now but has been an infrequent e-cigarette user in the past, or not at all and I have never been a regular e-cigarette user. We classified

"Current use" as people who reported using e-cigarettes either daily, at least once a week, or less than weekly. "Past use" was classified as not using e-cigarettes at all now but regular e-cigarette use in the past or; not at all now but infrequent e-cigarette use in the past. "Never used" were respondents who had never used e-cigarettes.

We asked respondents to indicate situations they were likely to vape/use e-cigarettes with five different situations they could select, or they could select "other times" (see Supplementary material for full list).

For traditional cigarettes, we asked "How often do you now smoke cigarettes, pipes or other tobacco products (do not include e-cigarettes or vapes)?" Response options and categorization of use was the same as those for e-cigarettes. We used this information to identify dual use.

Assessment of e-cigarette knowledge, attitudes and beliefs, and perceived social norms

E-cigarette knowledge was assessed using five items drawn from existing e-cigarette knowledge scales (29, 30). Responses options included yes/no/unsure. These items asked about different aspects of e-cigarettes, including the content of e-cigarettes (3 items), mechanism of action of e-cigarettes (1 item), and health risks of e-cigarette use (1 item). Attitudes and beliefs (8 items) were assessed using questions from previously published scales (29, 31, 32) and were answered on a five-point Likert-scale (strongly disagree to strongly agree). We asked if participants felt vaping is common among their peer group and their concern about the use of e-cigarettes "by others in the community," "by people they are close to," and "own use of e-cigarettes or vaping."

Intention to use e-cigarettes in the future

Susceptibility to e-cigarette initiation was assessed in people who had not used e-cigarettes. Three items, adapted for use with e-cigarette initiation as described previously (33–35) were used—"Have you ever been curious about using e-cigarettes," "Do you think you will try an e-cigarette soon?" and "If one of your best friends were to offer you an e-cigarette, would you use it?." Participants responded on a four-point Likert-scale ranging from "definitely not" to "definitely yes." Respondents who answered "not at all curious" to question (i) and "definitely not" to questions (ii) and (iii) for each tobacco product were considered non-susceptible, and any other combination of responses were considered susceptible.

Sources of e-cigarette health information

We asked respondents to nominate whether they would access information about the health effects of e-cigarettes from nine different sources (a GP, a pharmacist, university health service, government reports/websites, websites from non-government health organizations, social media, friends or family, e-cigarette retailers, and e-cigarette manufacturers). Respondents indicated yes, no, or maybe for each source.

Finally, we asked respondents to indicate where they would advise their friend or family member to seek help if they asked for help to quit vaping (see Supplementary material for full list of response options).

Sociodemographic characteristics, wellbeing, and academic performance

Participants demographic characteristics, including age, gender, cultural and ethnic identification and enrolment status (domestic or international) were collected together with questions to assess psychological distress (K6) (36), alcohol use (AUDIT-C) (37) and self-reported academic performance. The six items to assess psychological distress were summed to produce a total score with a possible range of 6–30. Serious psychological distress (SPD) was defined as a score of 19 or more and has been associated with the occurrence of probable serious mental illness (36). Alcohol use frequency was categorized as less than weekly and weekly or more. Academic performance was categorized as high (self-reported weighted average mark (WAM) 70 or greater) or low (less than 70).

Data analysis

Survey responses were downloaded to SPSS (Version 28.0) [IBM Corp. (2020) for analysis]. Frequencies were used to determine proportions of respondents using traditional tobacco products including cigarettes, pipes or other tobacco products; e-cigarette use was categorized as daily, current (defined as daily, weekly, or less than weekly), past, and never use. Flavors and type of pods used, whether students believed they contained nicotine, and the situations they were most likely to use e-cigarettes are summarized.

Chi-squared tests and Analysis of Variance (ANOVA) were used to explore differences in sociodemographic characteristics, SPD, alcohol use frequency, and WAM, between student's e-cigarette use daily or current, and past or never use. Differences in the settings that domestic and international students used e-cigarettes were compared using chi-squared tests. Independent samples *t*-tests were used to test differences in knowledge scores.

We compared attitudes and beliefs, perceived behavioral control and perceived norms for accessing e-cigarette health information between current use and never used with logistic regression, controlling for socio-demographic factors [age, gender (man/woman) and enrolment status (domestic vs. international student)].

Intention to use e-cigarettes in the future and susceptibility to use were dichotomised (yes/no) and a logistic regression performed to identify independent predictors of intention and susceptibility to e-cigarette use among those who had never used e-cigarettes. Covariates in the logistic regression model included variables from the univariate analysis comparing current and never use with a *p*-value less than 0.05 or with specific theoretical relevance to the analysis. As items assessing attitude to e-cigarette were correlated only one item was included "e-cigarettes are a gateway to smoking."

For all tests a two-sided $p < 0.05$ was considered statistically significant.

Results

A total of $n = 1{,}094$ responses were available for analysis. Eighteen respondents indicated their gender as gender diverse/non-binary ($n = 18$, 2.1%), the majority of respondents identified as woman ($n = 536$, 62.5%) and a small number preferred not to say ($n = 13$, 1.5%). Demographic characteristics and e-cigarette use among participants are presented in Table 1. International students (25% of the sample) were observed to be older than domestic students.

E-cigarette use was more prevalent than cigarette use. The proportion of people who use e-cigarettes daily ($n = 80$, 7.6%) did not

TABLE 1 Prevalence of e-cigarette use by demographic factors, serious psychological distress, alcohol use frequency, and weighted average mark.

		E-cigarette use			
	N	Daily	Current#	Past user	Never used
All participants	1,094	*N* = 80 (7.6%)	*N* = 138 (13.1%)	*N* = 145 (13.7%)	*n* = 772 (73.2%)
Age					
Mean (SD)	20.4 (1.9)	20.8 (1.9)*	20.8 (2.0)**	20.7 (2.0)*	20.3 (1.8)
Gender^					
Woman	536	*N* = 26 (4.9%)	*N* = 49 (9.1%)	*N* = 75 (14.0%)	*N* = 412 (76.9%)
Man	290	*N* = 33 (11.4%)**	*N* = 53 (18.3%)**	*N* = 34 (11.7%)	*N* = 203 (70.0%)
International student					
No	563	*N* = 35 (6.2%)	*N* = 71 (12.6%)	*N* = 77 (13.7%)	*N* = 415 (73.7%)
Yes	192	*N* = 15 (7.8%)	*N* = 22 (11.5%)	*N* = 23 (12.0%)	*N* = 147 (76.6%)
Serious psych distress					
No	829	*N* = 52 (6.3%)	*N* = 92 (11.1%)	*N* = 102 (12.3%)	*N* = 635 (76.6%)
Yes	117	*N* = 15 (12.9%)	*N* = 24 (20.7%)**	*N* = 18 (15.5%)	*N* = 74 (63.8%)
Alcohol use					
<Weekly	835	*N* = 47 (5.6%)	*N* = 77 (9.2%)	*N* = 88 (10.6%)	669 (80.2%)
>Weekly	191	*N* = 28 (14.7%)***	*N* = 52 (27.2%)***	*N* = 48 (25.1%)	91 (47.6%)
WAM##					
High (70+)	627	*N* = 35 (5.6%)	*N* = 66 (10.5%)	*N* = 26 (13.3%)	*N* = 473 (75.4%)
Low (<69)	195	*N* = 24 (12.3%)**	*N* = 39 (20.0%)**	*N* = 88 (14.0%)	*N* = 130 (66.7%)

#Daily, at least once a week, less than weekly. ##Self-reported Weighted Average Mark. ^Analyzed as a binary due to small *n* of genders other than woman/man. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

differ between domestic and international students; however, men were more likely than women to report use of e-cigarettes (Table 1). Approximately 1 in 7 students (13.6%) reported current use (either daily, weekly or monthly use) of e-cigarettes and just over one quarter reported "ever use" of an e-cigarette (26.8%). E-cigarette use was greater among men, those reporting serious psychological distress, who used alcohol more frequently, and reported lower academic performance (Table 1).

Fruity flavored vapes were most commonly used (*n* = 104, 77.0%) followed by menthol/mint (*n* = 18, 13.0%). Nearly all people who reported current use, used e-liquids they believed contained nicotine (*n* = 110, 79.7%). Two thirds of students who used e-cigarettes daily reported using an e-cigarette on waking (*n* = 53, 66.3%).

Among all people who reported current use of e-cigarettes, the most common situations to use e-cigarettes were when hanging out with friends (81.2%), when drinking alcohol (60.9%) or when feeling stressed or anxious (56.5%) (Table 2). There were no differences between men and women respondents for situations where they would use e-cigarettes (data not shown); domestic students were more likely than international students to report using e-cigarettes at a party or club (Table 2).

Daily use of cigarettes, pipes or other tobacco products was uncommon (*n* = 34, 3.3%) although just more than 1 in 10 indicated they currently used any cigarettes (*n* = 120, 11.6%) with most use being among those who smoked less than weekly (*n* = 72, 7.0%). Dual use was common among people who used tobacco products daily (27/34, 79.4%) but less common among people who used e-cigarettes daily (27/76, 35.5%).

Knowledge, attitudes and beliefs, social norms and self-efficacy

Mean e-cigarette knowledge was modest [3.02/5 (St Dev 1.10)] and there was no difference in knowledge between man and woman respondents ($p = 0.426$). Domestic students and people who used e-cigarettes currently tended to have higher scores for knowledge about e-cigarettes but these differences were not statistically significant.

More than half of respondents (51.2%) felt e-cigarette use was common within their peer groups however attitudes toward e-cigarettes and their impacts on health were predominantly negative (Table 3). Differences for seven out of nine statements about attitudes and social norms were found between people who reported current use compared to those who reported never use of e-cigarettes (Table 3).

Intention to use e-cigarettes

Among people who reported never using e-cigarettes, just under 1 in 4 respondents (*n* = 164, 22.8%) said they would use an e-cigarette if offered by a friend; 1 in 3 were curious about using e-cigarettes (*n* = 227, 31.5%) and *N* = 78 (10.8%) said they think they will try an e-cigarette soon. Nearly two in five [*n* = 279 (38.9%)] were considered susceptible to future use.

Results of logistic regression to determine independent predictors of intention to use e-cigarettes and susceptibility to use in the future is summarized in Table 4. Weekly or greater alcohol use (OR 4.805,

TABLE 2 Situations where students are likely to use e-cigarettes.

	Current e-cigarette use *N* = 138	Domestic student *N* = 71^	International student *N* = 22^	*p*-value
	n (%)	*n* (%)	*n* (%)	*n* (%)
When hanging out with friends	112 (81.2%)	64 (90.1%)	16 (72.7%)	$p = 0.040$
When drinking alcohol	84 (60.9%)	51 (71.8%)	12 (54.5%)	$p = 0.130$
When I feel stressed or anxious	78 (56.5%)	46 (64.8%)	14 (63.6%)	$p = 0.921$
When I am bored or out of habit	68 (49.3%)	37 (52.1%)	10 (45.5%)	$p = 0.585$
In the morning when I first wake up	59 (42.8%)	29 (40.8%)	9 (40.9%)	$p = 0.996$
Other times	21 (15.2%)	10 (14.1%)	6 (27.3%)	$p = 0.152$
Preferred flavors				
Fruity	104 (77.0%)			
Menthol/mint	18 (13.0%)			
Tobacco	4 (2.9%)			
Coffee	1 (0.7%)			
Dessert/Creams	3 (2.2%)			
Other	5 (3.6%)			

^Numbers do not total 100% due to missing data.

2.411–9.576) and low self-efficacy (OR 2.531, 1.061–6.037) were the strongest predictors of intention to use e-cigarettes among never users (Table 4). Women, participants reporting greater psychological distress, worse academic performance, or those with more positive attitudes toward e-cigarettes, and perception that vaping is common in their peer group were significant predictors of intention to use e-cigarettes in the future (Table 4).

E-cigarette health information sources

Students predominantly reported they sought health information about vaping from reputable, non-government health websites (77.3%), government reports/websites (72.9%), general practitioners (GPs) (67.9%), university health services (61.3%), or pharmacists (53.4%). Less reputable sources such as social media (30.7%), e-cigarette retailers (14.3%) and manufacturers (13.2%) were rarely nominated, however, those who did nominate them were significantly more likely to be an international student.

Most students indicated they would recommend friends or family members concerned about e-cigarette use to access reputable online resources such as Quit Victoria or Cancer Council Australia ($n = 250$, 27.7%) or their GP ($n = 204$, 22.6%). International students were least confident where to direct a family member or friend (15.9% selected "could not offer advice") but the university health service was the most common reported service among international students (18.0%).

Discussion

The prevalence of e-cigarette use in this cohort was much higher than previous studies of Australian university cohorts, but in line with increased community prevalence of e-cigarette use among young adults in Australia observed in community samples in the past 5 years. Current e-cigarette use was highest among those experiencing serious psychological distress, using alcohol more frequently, and with lower self-reported academic performance – all attributes that are likely to bring students into contact with university health services. Prevalence did not differ between domestic and international student groups which contrasts with a previous survey of Australian university students, and emphasizes the need to consider the needs of international students in health promotion or health service provision on campuses. More than one in three people who reported they had "never used" e-cigarettes were considered susceptible to future use and 1 in 10 intended to try an e-cigarette in the future. Levels of knowledge about e-cigarettes were modest. Mostly, students sourced information about health impacts of e-cigarettes from reputable online resources, or their GP, however, international students tended to rely more frequently on less reputable information sources including e-cigarette retailers and manufacturers and lacked confidence to direct friends or family who were concerned about e-cigarette use to appropriate supports.

Australia has seen a rapid increase in the use of e-cigarettes among adolescents in the past 5 years (1). This increase in community prevalence is reflected in the greater proportion of university students using e-cigarettes we identified compared with an earlier study of an Australian university cohort (20). Changes to the accessibility of e-cigarettes in Australia could impact upon use among university cohorts and the wider young-adult population more generally (38). Just under one in 10 of our respondents used e-cigarettes daily and provided indicators of addiction such as using e-cigarettes on waking. Care must be taken by the government as they adjust regulatory settings, to ensure this group are supported to quit use of nicotine, and not merely substitute nicotine from e-cigarettes to nicotine from other forms of tobacco products (39).

E-cigarette use in our sample was associated with a range of psychosocial and academic risks that may bring them into contact with health services consistent with previous reports (7, 40–42). In particular, psychological distress was more common among people who used e-cigarettes in our sample who also tended to use alcohol more frequently and reported worse academic performance which is consistent with findings from general population surveys of

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TABLE 3 Perceived social norms, attitudes and beliefs toward e-cigarettes of participants.

	All participants	Current e-cigarette user	Never e-cigarette user	Test statistic	95%CI
	N = 1,094 (%)	*N* (%)	*N* (%)	(Exp(B))	
Vaping is common among my peer group					
Strongly disagree/disagree	368 (38.1%)	16 (13.2%)	352 (41.7%)	**REF**	
Neither/nor	103 (10.7%)	12 (9.9%)	91 (10.8%)	**3.027**	**1.231–7.441**
Agree/strongly agree	495 (51.2%)	93 (76.8%)	399 (47.5%)	**4.547**	**2.389–8.655**
E-cigarettes lower the risk of tobacco-related diseases					
Strongly disagree/*disagree*	503 (55.2)	51 (44.7%)	452 (56.6%)	REF	
Neither/nor	200 (21.9)	25 (21.9%)	175 (21.9%)	1.202	0.644–2.242
Agree/strongly agree	209 (22.9)	38 (33.3%)	171 (21.4%)	**2.445**	**1.455–4.109**
E-cigarettes are safer than regular cigarettes					
Strongly disagree/*disagree*	461 (50.9)	48 (42.5%)	413 (52.1%)	REF	
Neither/nor	196 (21.7)	27 (23.9%)	169 (21.3%)	1.442	0.794–2.619
Agree/strongly agree	248 (27.4)	38 (33.6%)	210 (26.5%)	**1.736**	**1.022–2.950**
E-cigarettes are less harmful to health than regular cigarettes					
Strongly disagree/*disagree*	484 (53.4)	48 (42.5%)	436 (55.0%)	REF	
Neither/nor	186 (20.5)	25 (22.1%)	161 (20.3%)	1.401	0.751–2.613
Agree/strongly agree	236 (26.0)	40 (35.4%)	196 (24.7%)	**2.247**	**1.334–3.784**
E-cigarettes are less harmful to the environment than regular cigarettes					
Strongly disagree/*disagree*	456 (50.2)	64 (56.6%)	392 (49.3%)	REF	
Neither/nor	241 (26.5)	26 (23.0%)	215 (27.0%)	0.671	0.380–1.185
Agree/strongly agree	211 (23.2)	23 (20.4%)	188 (23.6%)	0.751	0.424–1.330
E-cigarette aerosol is harmful for people in the vicinity of the user					
Strongly disagree/*disagree*	157 (17.3)	33 (29.2%)	124 (15.6%)	REF	
Neither/nor	210 (23.1)	31 (27.4%)	179 (22.5%)	0.610	0.322–1.156
Agree/strongly agree	541 (59.6)	49 (43.4%)	492 (61.9%)	**0.366**	**0.205–0.656**
E-cigarettes are a gateway to smoking					
Strongly disagree/*disagree*	184 (20.2)	37 (32.5%)	147 (18.4%)	REF	
Neither/nor	197 (21.6)	23 (20.2%)	174 (21.8%)	**0.510**	**0.263–0.989**
Agree/strongly agree	532 (78.4)	54 (47.4%)	478 (59.8%)	**0.401**	**0.233–0.690**
E-cigarettes are an effective way for smokers to decrease the number of cigarettes smoked (but not quit)					
Strongly disagree/*disagree*	227 (24.9)	21 (18.4%)	206 (25.9%)	REF	
Neither/nor	198 (21.8)	26 (22.8%)	172 (21.6%)	1.604	0.760–3.385
Agree/strongly agree	485 (44.3)	67 (58.8%)	418 (52.5%)	1.664	0.889–3.116
E-cigarettes are an effective way for people who smoke cigarettes to quit smoking					
Strongly disagree/*disagree*	398 (43.7)	34 (30.1%)	364 (45.7%)	REF	
Neither/nor	223 (24.5)	28 (24.8%)	195 (24.5%)	1.781	0.949–3.344
Agree/strongly agree	289 (31.8)	51 (45.1%)	238 (29.9%)	**2.372**	**1.371–4.104**

Model adjusted for gender (man/woman), age, international student status. Bolded figures indicate statistically significant differences between groups.

Australian adults (43). This highlights the importance of asking all students who present at health services about their smoking and vaping habits and discussing the associated harms. Many students may not voluntarily disclose their vaping use, despite using e-cigarettes as a coping strategy to manage stress (7). Students seeking support for stress, academic performance, or other general health counseling should be asked about e-cigarette use at every opportunity, and evidence-based treatments offered to these students together with behavioral support and referral where appropriate.

Addressing curiosity (44) and de-normalizing e-cigarette use, particularly in social activities, is crucial, and targeted public health campaigns that raise awareness of the potential harms of vaping could

TABLE 4 Logistic regression model of predictors of intention to use e-cigarettes and susceptibility to use of e-cigarettes in the future (never used).

	Intention to use			Susceptibility to use		
	Intention to use Yes (*N* = 78)	Exp(B)	95% CI for Exp(B)	Susceptibility to use Yes (*N* = 279)	Exp(B)	95% CI for Exp(B)
Alcohol use						
<Weekly	*N* = 55 (8.7%)	Ref		*N* = 232 (36.8%)	Ref	
Weekly or more	*N* = 23 (26.1%)	4.805	2.411–9.576	*N* = 47 (53.4%)	1.724	1.016–2.926
Self-efficacy						
High	*N* = 11 (4.8%)	Ref		*N* = 61 (26.8%)	Ref	
Low	*N* = 66 (13.6%)	2.531	1.061–6.037	*N* = 214 (44.3%)	1.509	0.999–2.281
Gender^						
Man	*N* = 17 (8.4%)	Ref		*N* = 73 (36.1%)	Ref	
Woman	*N* = 51 (12.4%)	2.329	1.154–4.700	*N* = 172 (41.8)	1.353	0.922–1.986
Attitude—e-cigarettes are a gateway to smoking						
Strongly agree/agree	*N* = 36 (8.8%)	Ref		*N* = 150 (36.8%)	Ref	
Neutral	*N* = 22 (14.5%)	2.288	1.77–4.864	*N* = 67 (44.4%)	1.512	0.922–2.480
Strongly disagree/disagree	*N* = 16 (13.7%)	2.057	1.040–4.067	*N* = 48 (41.0%)	1.364	0.879–2.117
WAM						
High	*N* = 44 (9.3%)	Ref		*N* = 184 (39.1%)	Ref	
Low	*N* = 22 (16.9%)	2.031	1.084–3.804	*N* = 59 (45.4%)	1.218	0.794–1.868
Vaping is common in my peer group						
[Less common (1)—more common (5)]	Mean = 3.40			Mean = 3.11		
	St Dev = 1.33	1.318	1.061–1.636	St Dev = 1.41	1.188	1.051–1.343
Kessler 6 total score						
	Mean = 14.07			Mean = 12.93		
	St Dev = 4.73	1.127	1.062–1.197	St Dev = 5.16	1.086	1.047–1.127

%, percentage within row. ^Analyzed as a binary due to small *n* of genders other than man/woman.

be effective in reducing intention to use e-cigarettes. The participants in this study overwhelmingly indicated they would source health information about e-cigarettes from reputable, online resources, however, international students, who make up approximately one third of the university student population, tended to rely on less reputable sources including social media, retailers, and manufacturers. Ensuring these students are aware of, and have access to, reputable sources of health information about e-cigarettes is important for this group and targeted strategies may be required for international students at Australian universities. Cultural variations in tobacco and nicotine consumption norms, as well as exposure to different nicotine control policies in their country of origin may impact upon their attitudes and beliefs to e-cigarette use (45, 46).

Strengths and limitations

This study provides valuable insights into e-cigarette use among Australian university students and the health information sources young-adults use to inform their health decisions about vaping. International students comprised approximately one third of our sample and this is the first study to specifically consider their behaviors and health needs in relation to e-cigarettes. While our sample was over represented by women, the participation of international students was proportionally similar to, albeit it a little lower than, the general university student population.

Several limitations should be considered when interpreting the results of this study. The cross-sectional design means causal relationships between e-cigarette use and outcomes cannot be determined. We did not identify the degree/courses students were enrolled in so it is unclear if students with a greater health focus tended to participate, or whether the sample is broadly reflective of the range of course offerings available. Additionally, Monash University campuses are designated as smoking and vaping free, a policy that is known to be effective in reducing pro-tobacco beliefs, the acceptability of smoking, and decreases positive attitudes toward smoking (47). Among the respondents who used tobacco products we did not differentiate between those who smoked cigarettes, pipes or other tobacco products. Dual use as such, includes use of any of these types of tobacco products. Further, we did not ask about smokeless tobacco which can cause cancer, or nicotine pouches which are being increasingly promoted to young people in Australia by social media influencers.

About one third of the participants who started the survey did not complete it. We did not use imputation for missing data as there was no evidence of differences in prevalence of e-cigarette use between those who completed the survey and those who did not. Finally, *p*-values have

not been adjusted for multiple comparisons, and so care should be taken in interpreting outcomes where there is risk of type 1 error.

Conclusion

This study provides valuable and timely information about e-cigarette use and intentions to use e-cigarettes at a major Australian university. The high prevalence of e-cigarette use among both domestic and international students in our sample, and our finding that more than one in three respondents who had never used e-cigarettes were susceptible to future use, signals a need to address this issue with proactive preventive practices. Routine screening for e-cigarette use among young people who come in contact with university health services may be one appropriate example of this. Further research to understand how university students engage with health promotion messaging relating to e-cigarettes, the nature and forms of messaging most relevant to this group, including international student groups, is needed, to further inform future activities seeking to address e-cigarette use among university student cohorts.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Monash University Human Research Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional guidelines.

Author contributions

TK: Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. MS: Conceptualization, Methodology, Supervision, Writing – review & editing. CO: Conceptualization, Methodology, Supervision, Writing – review & editing. SM: Data curation, Methodology, Writing – review & editing. SK: Methodology, Resources, Writing – review & editing. KT: Resources, Writing – review & editing. CB: Conceptualization, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2025.1563117/full#supplementary-material

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EDITED BY
Joanna Jacobus,
University of California, San Diego,
United States

REVIEWED BY
Siti Munira Yasin,
MARA University of Technology, Malaysia
Dongxia Ye,
University of Rochester, United States

*CORRESPONDENCE
Hualin Zhang
✉ richard_zhl@szu.edu.cn

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Examining the impact of social media on youth vaping behavior in China: an analysis of the mediating role of perceptions of policy enforcement

Tong-Chen Lucas Wang[1,2], Mei-Juan Zhang[1] and Hualin Zhang[3]*

[1]School of Media and Communication, Shenzhen University, Shenzhen, China, [2]Institute of Global Communication, Shenzhen University, Shenzhen, China, [3]Division of Arts, Shenzhen University, Shenzhen, China

Introduction: Research has established that exposure to media and the perceived enforcement of policies can influence outcomes related to (un)healthy behaviors. However, little is known about the underlying processes that may mediate the relationship. The Knowledge-Attitude-Practice (KAP) model serves as an important framework for examining health cognition and behavior change. It asserts that knowledge underpins beliefs, attitudes drive motivation, and practices reflect behaviors. In the realm of e-cigarette cessation, this study investigates the influence of media exposure on perceptions of policy enforcement, which in turn affects risk-benefit evaluations and behavioral outcomes.

Methods: Data for this study were collected in 2024 from an online questionnaire survey ($N = 724$) conducted in Guangdong China, with participants aged 18 to 30. We primarily employ methods such as mediating effect testing and regression analysis to conduct our data analysis.

Results: The findings suggest that social media exposure, perceived policy enforcement, and perceptions of risks and benefits collectively influence youth vaping behaviors through various mediating pathways. Specifically, the results indicate that exposure to social media has a positive effect on the perceived enforcement of tobacco control policy. This perception, in turn, positively affects both risk and benefit perceptions, thereby either decreasing the likelihood of vaping through heightened perceived risks or increasing it through enhanced perceived benefits.

Discussion: The study highlights the impact of social media content concerning e-cigarettes, noting that both ambiguous advertising and health education materials can enhance the perceived enforcement of tobacco control policy. Furthermore, we investigate the impact of information shared across various social media platforms on vaping behaviors and perceptions of tobacco control policy enforcement. Implications and limitations are discussed.

KEYWORDS

youth vaping, e-cigarettes control policy, social media exposure, perceived enforcement of tobacco control policy, risk and benefits perception

1 Introduction

The Electronic Nicotine Delivery System (ENDS), invented in China in 2003, utilizes battery-operated devices to aerosolize liquid that contains nicotine (1, 2). Initially promoted as safer alternatives to traditional cigarettes, e-cigarettes are now subject to increasing global scrutiny due to their associated toxicity risks, particularly among young people. Research indicates that their acute toxicity may surpass that of conventional

cigarettes, with nicotine exposure contributing to heightened addiction and subsequent tobacco use, thereby increasing the risks of cardiovascular diseases, chronic obstructive pulmonary disease (COPD), cancer, and premature death (3, 4).

Internationally, the implementation of smoke-free policies—including bans, health warnings, advertising restrictions, and taxation—has led to a decrease in both traditional cigarette smoking and e-cigarette usage (5, 6). Although China has recently enacted regulations concerning e-cigarettes (1), its tobacco control measures are still less rigorous compared to those in Singapore and Hong Kong, resulting in a slower decline in smoking rates. From 1990 to 2019, the reduction in China's smoking rate was notably behind the global average (7). Alarmingly, the prevalence of smoking among youth remains significant, with rates of 27.7% for males and 2.0% for females, and 56.2% of youth initiating smoking by the age of 18 (9). This situation highlights the urgent need for policies targeting youth within global public health initiatives.

This study employs the Knowledge-Attitude-Practice (KAP) model (10) to examine the interactions between young people's perceptions of tobacco policy enforcement, their exposure to social media, and their evaluations of risks and benefits. The KAP framework, widely utilized in health behavior research (11–14), elucidates the influence of social media on perceptions of policy enforcement in our research. Mediation analyses reveal indirect effects, demonstrating that perceived enforcement can affect vaping behavior by modifying risk-benefit assessments.

Existing research in health communication in China has explored various aspects, including policy implementation (15, 16), public attitudes (17, 19), and drivers of perception (20). However, a significant gap exists in the literature, as most studies have concentrated on policy design and public attitudes while largely overlooking perceptions of enforcement efficacy. This research seeks to fill this gap by investigating perceived enforcement as both an independent variable and a mediator. The findings indicate that variations in perceptions of enforcement are predictive of the likelihood of vaping, thereby contributing to the enrichment of the KAP model and bolstering advocacy for enhanced tobacco control measures.

2 Literature review

2.1 The Knowledge, Attitude, Practice model

The Knowledge, Attitude, Practice (KAP) model provides a framework for understanding the development of health-related behaviors through the processes of knowledge acquisition, attitude formation, and behavioral practices (10). This model has been extensively utilized in the context of vaping research, with various studies indicating that an increase in knowledge is associated with negative attitudes toward vaping and a greater likelihood of cessation (21–24). Furthermore, demographic variables such as gender (25, 26), older age (27, 28), lower educational attainment (29), and socioeconomic status (30) have been identified as predictors of vaping behaviors. Nevertheless, current literature has not sufficiently examined the underlying mechanisms that influence attitudes toward vaping.

A significant gap exists in understanding the inadequate awareness among vapers regarding the risks associated with e-cigarettes, which contributes to continued usage (31–34). For example, a lack of awareness about the potential harms and skepticism toward regulatory measures have impeded efforts to reduce vaping among Chinese middle school students (35). While previous research has focused on perceived risks and benefits of vaping, it has largely overlooked the perceptions surrounding policy enforcement.

This study aims to apply the KAP model to investigate youth vaping behavior, with an emphasis on the influence of social media on exposure to information about e-cigarettes (K), the perceptions of risks and benefits as well as policy enforcement (A), and the resultant behavioral practices (P). The research seeks to elucidate how social media shapes the psychological perceptions that affect vaping behaviors.

2.2 Perceived enforcement of tobacco control policy

Perceived Policy Enforcement (PPE) refers to individuals' assessments of the effectiveness of policies (36) and plays a significant role in shaping tobacco-related behaviors through two main aspects: the strictness of policies and perceptions of enforcement. Research has shown that PPE is essential in decreasing youth smoking rates, particularly through school policies (37, 38) and state-level initiatives (39, 40). Studies indicate that adolescents' views on the enforcement of local regulations are inversely related to smoking prevalence, with anti-smoking norms acting as a mediating factor (41). Furthermore, the media plays a crucial role in enhancing PPE through the dissemination of information, as social media transforms public discussions and perceptions of enforcement (42–45). This phenomenon aligns with the KAP model, where media influences PPE, which in turn affects youth behaviors.

While existing research primarily focuses on traditional cigarettes, there are significant gaps in understanding the implications for e-cigarettes. Three key research priorities emerge: (1) Examining indirect mechanisms: Understanding how PPE mediates vaping behaviors could enhance the KAP model and inform policy modifications. (2) Investigating risk-benefit perceptions: Misunderstandings regarding the safety of e-cigarettes (46–50) may interact with PPE, necessitating further investigation. (3) Exploring the role of social media: Given its significance as a primary source of information for youth (51–53), the impact of social media on PPE and vaping requires empirical scrutiny.

Additionally, PPE influences broader health behaviors, with stronger perceptions of enforcement linked to healthier choices, including lower smoking rates (54, 55). In the context of vaping, PPE may discourage e-cigarette use by shaping public attitudes. Within the KAP framework, PPE acts as an attitudinal factor that connects knowledge to practices. While media significantly shapes PPE (56–60), the mediating variables between PPE and behaviors remain largely underexplored. Investigating these pathways could enhance the predictive capabilities of the KAP model and guide targeted interventions. This study aims to thoroughly explore the

antecedent factors (such as social media) and subsequent mediators to clarify the role of PPE in youth vaping behaviors.

2.3 Social media and perceived enforcement of tobacco control policy

In modern information environments, social media plays a crucial role in engaging young people with content related to policies, influencing their views on enforcement through both active participation and algorithm-driven exposure (61). For example, platforms such as Weibo contribute to increasing public awareness of environmental policies (62). This research specifically investigates the context of e-cigarette regulation in China, aiming to fill existing gaps in understanding how different types of social media platforms affect perceptions of tobacco control enforcement. Previous studies have indicated that social media enhances the understanding of norms and perceptions regarding smoking (63, 64), yet they often overlook the unique dynamics and content attributes of specific platforms that contribute to these effects. This study will explore the variations among platforms and the characteristics of content that influence perceptions of enforcement within Chinese social media.

Additionally, social media messaging has a direct effect on health behaviors (18, 65–67, 69, 70). In the context of vaping, exposure to e-cigarette advertisements has been shown to significantly increase the likelihood of usage (71–74). However, prior research has not effectively identified which types of messages across different platforms exert the strongest influence on behaviors. This study seeks to examine the connections between different Chinese social media platforms and adolescent vaping in order to identify the most impactful characteristics of both the platforms and the messages, thereby enhancing the understanding of how digital media influences policy perceptions and behavioral outcomes.

2.4 The role of perceived risks/benefits

Risk perception pertains to an individual's evaluation of health risks associated with specific behaviors, whereas benefit perception relates to an individual's recognition of the positive outcomes of those behaviors (75). Existing research indicates contrasting effects of these perceptions: risk perception tends to decrease engagement in unhealthy behaviors (76–78), while benefit perception tends to encourage such behaviors (79–81). The role of social media is critical, as it exacerbates these perceptions by presenting both positive and negative information regarding behaviors such as vaping (82–85). This research proposes that risk and benefit perceptions play distinct roles in youth vaping behaviors and highlights the significant impact of social media on shaping these perceptions.

Additionally, perceived policy enforcement influences evaluations of risk and benefit. Previous studies in public policy (86), climate initiatives (87), and health regulations (54) have established a link between the effectiveness of policies and risk perception. Likewise, a stronger perception of policy enforcement is associated with an increased perception of benefits from compliant behaviors, such as farmland protection (8).

In the context of vaping, more stringent enforcement of tobacco policies may diminish perceived benefits by indicating a higher level of harm, while simultaneously elevating risk perceptions. Within the framework of KAP model in China, this study introduces a mediation model (see Figure 1) that illustrates how social media exposure can directly and indirectly influence the likelihood of vaping among youth, with perceived policy enforcement, risk, and benefit perceptions serving as mediators. These mediators provide insight into how external factors translate into behavioral outcomes.

2.5 Hypothesis and research questions

Drawing upon theoretical frameworks and existing research, as well as considering the context of perceptions regarding policy implementation and the social media usage in this study, we develop our research hypotheses and questions. Initially, concerning the direct association between PPE and youth vaping, we propose:

> *H1: The level of perceived enforcement of tobacco control policy exerts a negative influence on the vaping behaviors of young people.*

Secondly, we consider social media to be an essential source of information and propose a hypothesis regarding its influence on PPE and vaping behavior. In this context, we also develop two research questions that specifically examine the effects of social media on these two variables. They are:

> *H2: The frequency of social media exposure to vaping positively influences young people's perceptions of tobacco control policy enforcement.*
> *H3: The frequency of social media exposure related to vaping increases the likelihood of adolescent vaping behavior.*
> *RQ1: Which types of Chinese social media impact young people's perceptions of tobacco control policy enforcement, and what are the characteristics of the information disseminated on these platforms?*
> *RQ2: Which types of Chinese social media most significantly influence adolescent vaping behavior, and what are the characteristics of the pertinent social media messages?*

The two variables previously mentioned not only exert independent effects on vaping behavior but also contribute to the formation of individuals' beliefs concerning electronic cigarettes. In this context, we investigate two critical beliefs—perceived benefits and perceived risks—and their impact on vaping behavior, thereby establishing pertinent research hypotheses. Furthermore, this research aims to establish hypotheses that investigate the direct relationship between these two beliefs and the perception of policy enforcement. In addition, we seek to explore potential mediating effects through specific research questions. Accordingly, we present the following research hypotheses and questions:

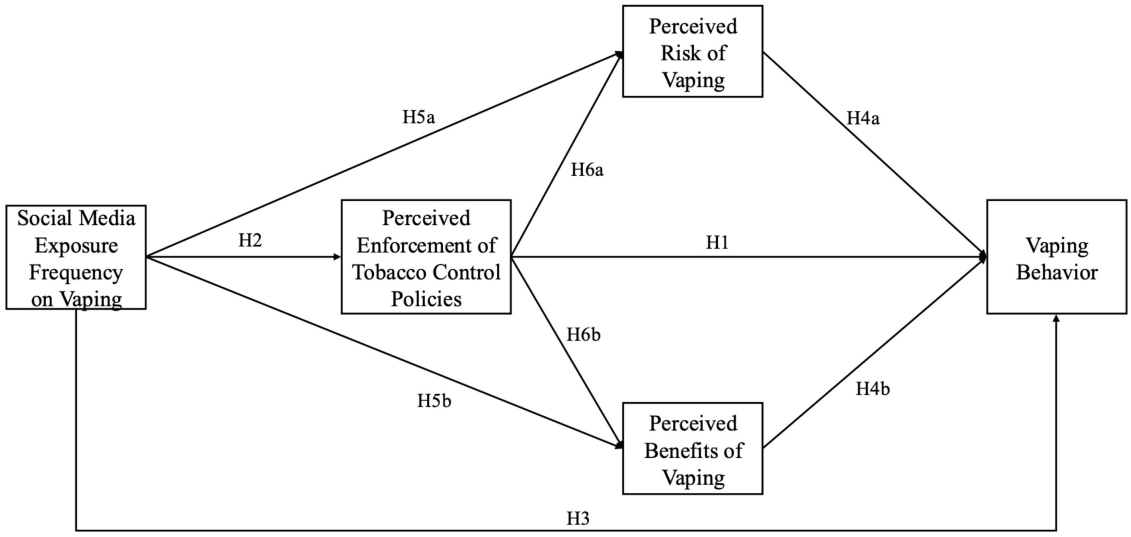

FIGURE 1
Conceptual framework.

H4: A higher level of (a) perceived risk/(b) perceived benefits associated with vaping among youth will correlate with (a) a lower/(b) higher likelihood of engaging in vaping behavior.
H5: The frequency of youth's exposure to vaping-related content on social media may (a) negatively affect their perceived risk of vaping, and (b) positively affect their perceived benefits of vaping.
H6: A high level of perceived enforcement of tobacco control policies among youth (a) positively influences the perceived risk of vaping and (b) negatively influences the perceived benefits of vaping.
RQ3: Do the perceived enforcement of tobacco control policies and the perceived risks and benefits of vaping act as mediators in the relationship between social media exposure and vaping behavior?

3 Methods

3.1 Data and sample

Based on a study investigating the prevalence of e-cigarette usage in China (68), we utilized G*Power software to determine the necessary sample size. This computation was performed with thorough consideration to essential parameters, such as the proportion of e-cigarette users, the acceptable margin of error, and the probability of committing a Type I error, etc. Consequently, we concluded that the sample size should not be <478 participants. The sample must consist of individuals who are at least 18 years of age, as this is the legal age at which Chinese citizens are permitted to purchase e-cigarettes. The current study involved a sample of 724 participants, recruited through random sampling from a population of young individuals aged 18–30 in Guangdong Province, China. Recruitment took place via an online survey administered by *Jishuyun Big Data*, a data service provider, during the period from July to September 2024. The recruitment process utilized various methods, including telephone calls, emails, WeChat QR codes, and website invitations, while initially gathering basic demographic information to ensure the sample's representativeness and validity. Once the representative sample was established, participants were invited to anonymously access the survey website using their mobile devices and complete the questionnaire. Before completing the questionnaire, it was necessary for all participants to carefully read and sign an informed consent form. Following the submission of their responses, participants were provided with information regarding the purpose of the research. It is important to note that, due to privacy considerations, the study did not collect data concerning individuals' mental health or other substance use. Detailed demographic information about the sample is presented in the results section.

3.2 Measurements

3.2.1 Dependent variable

Vaping Behavior was measured by asking participants whether they smoked e-cigarettes (1 = yes, 0 = no) (88) ($M = 0.515$, $SD = 0.500$).

3.2.2 Perceived enforcement of tobacco control policy

Perceived policy enforcement was measured by a single-item, in which respondents were instructed to indicate their subjective perception of policy enforcement of Tobacco Control Policy within their respective geographical areas (89). Response options ranging from 0 = not at all, 5 = moderate, 10 = very strict ($M = 6.350$, $SD = 2.192$).

3.2.3 Social media exposure frequency on vaping

Social Media Exposure Frequency was measured by eleven questions adapted from previous research (90). The eleven items include: Over the past 6 months, how frequently have you consumed information or advertisements pertaining to e-cigarettes on (1) Weibo, (2) Wechat moments (posted or forwarded by other friends), (3) WeChat official account, (4) WeChat Channels, (5) REDnote, (6) Tiktok, (7) Kwai, (8) Bilibili, (9) Zhihu, (10) Baidu Tieba, (11) Social Media Outside China (e.g., Facebook, YouTube, Instagram, X)? Responses were scored on a five-point scale (1 = I never have, 2 = Monthly, 3 = Every few weeks, 4 = Weekly, 5 = Daily) ($M = 1.503$, $SD = 0.846$, Cronbach's alpha = 0.883).

3.2.4 Perceived risk of vaping

Perceived risk was measured by fourteen questions, drawn from prior research (91). A 7-point Likert scale was used as the response format, ranging from 1 ("totally disagree") to 7("totally agree"), with 4 representing "neither agree nor disagree." Based on the actual situation in China, we eliminated items within the scale that were incongruent with the Chinese context, subsequently retaining fourteen questions post-deletion. The fourteen items include: (1) E-cigarettes contain toxic chemicals. (2) The nicotine in liquid cartridges for e-cigarettes is toxic to small children and pets. (3) E-cigarettes heat a mixture of propylene glycol, nicotine, and flavoring. (4) E-cigarettes contain some of the same toxins as regular cigarettes, such as formaldehyde. (5) There is risk in inhaling the hot mix of chemicals (propylene glycol, glycerin, and nicotine) contained in e-cigarettes. (6) Nicotine is addictive, regardless of whether ingested through e-cigarettes or regular cigarettes. (7) Dual use of regular cigarettes and e-cigarettes places the smoker/vaper at risk for heart problems, lung problems, and cancer. (8) Many people who start vaping smoke cigarettes as well. (9) There are more effective ways to quit smoking than e-cigarettes. (10) Kids who use e-cigarettes are more likely to continue smoking. (11) Children and pets can become seriously ill if they drink or touch e-cigarette fluid. (12) Many local communities have started to ban the use of e-cigarettes wherever tobacco cigarettes are prohibited. (13) Liquid cartridges for e-cigarettes contain nicotine. (14) "Vaping" (smoking e-cigarettes) can lead to smoking more regular cigarettes ($M = 4.724$, $SD = 0.888$, Cronbach's alpha = 0.827).

3.2.5 Perceived benefits of vaping

Perceived benefits was measured by nine questions derived from previous research (91). A 7-point Likert scale was used as the response format, ranging from 1 ("totally disagree") to 7("totally agree"), with 4 representing "neither agree nor disagree." Based on the actual context in China, we eliminated the items within the scale that were incongruent with the Chinese context, and retained nine questions subsequent to the deletion process. The nine items include: (1) E-cigarettes are less harmful than regular cigarettes. (2) E-cigarettes are an effective way to quit smoking regular cigarettes. (3) E-cigarettes contain fewer chemicals than regular cigarettes. (4) Kids who use e-cigarettes are more likely to quit smoking. (5) E-cigarettes can be used anywhere even indoors. (6) E-cigarette users exhale only water vapor that contains no toxins. (7) Compared to second-hand smoke from regular cigarettes, there are no known risks to second-hand vapor from e-cigarettes. (8) E-cigarettes are safe. It's tobacco-not nicotine-that makes regular cigarettes dangerous. (9) E-cigarettes do not have the same adverse effect as regular cigarettes after smoking (i.e., mouth and throat irritation, nausea/headache and dry cough) ($M = 4.192$, $SD = 1.233$, Cronbach's alpha = 0.861).

3.2.6 Control variables

Control variables included respondents' age (self-report), gender (1 = male, 0 = female), education (1 = Junior high school and below, 2 = Senior high school, 3 = college diploma, 4 = bachelor's degree, 5 = master's degree, 6 = doctoral degree), annual household income (ranging from 1 = ¥0 to ¥10,000, 14 = ¥200,000 or more).

3.3 Data analysis

SPSS29.0 was used for data analysis. First, to investigate the direct impacts of four independent variables—namely, the frequency of exposure to social media concerning electronic cigarettes, the perceived enforcement of tobacco control policies, the perceived risks of vaping, and the perceived benefits of vaping—on the dependent variable, vaping behavior, a binary logistic regression analysis was carried out. Second, to assess the mediation models, we utilized Model 81 from the SPSS PROCESS macro (92) to produce bootstrapped confidence intervals (CIs). Third, to identify the specific social media platforms or combinations thereof that affected perceptions of tobacco control policy enforcement and vaping behavior, we conducted linear regression analyses for perceived enforcement of tobacco control policies and logistic regression analyses for vaping behavior, utilizing varying frequencies of social media exposure as independent variables.

4 Results

Socio-demographic characteristics are summarized in Table 1. The participants in this study are primarily within the age range of 18–30 years, exhibiting a mean age of 25.45 years. The sample is comprised of 88.4% males ($N = 640$) and 11.6% females ($N = 84$), which closely corresponds to the overall male-to-female ratio of 9:1 observed in the smoking population of China (93). Notably, 51.5% of the participants ($N = 373$) reported using electronic cigarettes. Additionally, a significant majority of the sample, 83.2%, possesses either an associate degree or a bachelor's degree. Furthermore, the annual income of the participants primarily ranges from ¥40,001 to ¥90,000, encompassing 77.5% of the sample.

To evaluate the hypothesis of the negative association between perceived tobacco control enforcement and vaping (H1), we performed a binary logistic regression analysis. The results of the Hosmer and Lemeshow Test for the regression model indicated a satisfactory fit, with χ^2 (8) = 13.357 and $p = 0.10$. The detailed results are displayed in Table 2. The findings reveal that the perceived enforcement of the Tobacco Control Policy did not have a statistically significant impact on youth vaping behavior

TABLE 1 Sample Characteristics ($N = 724$).

Demographic characteristics	*M* (SD) or *N* (%)
Age	25.45 (1.98)
Sex	
Male	640 (88.4%)
Female	84 (11.6%)
Education	
Less than collage	112 (15.5%)
College undergraduate	602 (83.1%)
College graduate and Higher	10 (1.4%)
Annual income	
<¥50,000 ($7,000)	200 (27.6%)
¥50,001 to ¥100,000($14,000)	444 (61.3%)
¥100,001 to ¥150,000($21,000)	61 (8.4%)
>¥150,000	19 (2.7%)

The conversion of RMB to USD is an approximation.

TABLE 2 Binary logistic regression on vaping.

Variables	Model 1			Model 2		
	B	Exp(B)	*SE*	B	Exp(B)	*SE*
Block 1: demographics						
Sex	−0.06	0.94	0.24	0.18*	1.20	0.26
Age	−0.01	0.99	0.03	0.01	1.01	0.03
Income	0.11***	1.12	0.03	0.10**	1.11	0.04
Education	0.21*	1.23	0.11	0.18	1.19	0.12
Δ *Pseudo* $R^2 = 0.039$						
Block 2: independent variables						
Social media exposure				−0.23*	0.80	0.10
Perceived policy effectiveness				−0.02	0.98	0.04
Perceived risk				−0.47***	0.63	0.10
Perceived benefits				0.34***	1.40	0.07
Δ *Pseudo* $R^2 = 0.118$						
Total Pseudo $R^2 = 0.157$						
−2 Log likelihood = 912.228						

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

($B = -0.023$, OR = 0.977, $SE = 0.040$, 95% CI: [0.904, 1.056]). Consequently, the result does not establish a negative relationship between the perceived enforcement of tobacco control measures and vaping behavior.

To investigate the positive influence of social media exposure on perceived policy enforcement (H2), we developed a mediation model (see Table 3 and Figure 2). The findings revealed that exposure to vaping content on social media had a significant impact on the perceived enforcement of tobacco control policies ($\beta = 0.464$, $SE = 0.096$, $p < 0.001$). These results suggest that increased exposure to social media content concerning

TABLE 3 Results of mediation effect test.

	b	*SE*	95%CI
Social Media -> Enforcement -> Vaping	−0.011	0.020	[−0.052, 0.026]
Social Media -> Risk-> Vaping	0.040	0.025	[−0.004, 0.095]
Social Media -> Benefit->Vaping	0.006	0.020	[−0.035, 0.095]
Social Media -> Enforcement->Risk-> Vaping	−0.011	0.006	[−0.026, −0.002]
Social Media -> Enforcement->Risk-> Vaping	0.013	0.006	[0.004, 0.029]

e-cigarettes correlates with a heightened perception of the enforcement of tobacco control policies among young individuals. Thus, the data support the assertion that exposure to social media has a favorable impact on individuals' perceptions of policy enforcement.

Subsequently, we evaluate whether sustained exposure to social media content pertaining to vaping substantially enhances the probability of engaging in vaping behavior (H3). The results from both the logistic regression analysis (Table 2) and the mediation analysis (Table 3 and Figure 2) indicate that for each additional unit of exposure to social media content on vaping among adolescents, the probability of engaging in vaping behavior increased by a factor of 1.257 ($B = 0.229$, OR = 1.257, $SE = 0.103$, 95% CI: [0.904, 1.056]), indicating that social media exposure serves as a significant predictor of adolescent vaping.

We propose the hypothesis that a low perception of risks associated with vaping, in conjunction with a high perception of its benefits, may increase the likelihood of vaping behavior among adolescents (H4). Results presented in Table 2 illustrate that as the perception of risk related to vaping increases, the likelihood of engaging in vaping decreases ($B = -0.465$, OR = 0.628, $SE = 0.095$, 95% CI: [0.521, 0.757]). Conversely, an increase in the perception of benefits associated with vaping correlates with a heightened likelihood of vaping (B = 0.338, OR = 1.403, $SE = 0.073$, 95% CI: [1.216, 1.618]). Thus, empirical support has been identified indicating that risk perception negatively affects vaping behavior (H4a), while benefit perception exerts a positive influence on such behavior (H4b).

This study posits that frequent exposure to vaping-related content on social media may variably shape individuals' perceptions regarding the risks and benefits linked to vaping (H5). As depicted in Table 3 and Figure 2, increased exposure of adolescents to social media content pertaining to vaping correlates with a decreased perception of the risks involved ($\beta = -0.086$, $SE = 0.042$, $p < 0.05$). However, the data failed to prove an increase in the perception of benefits ($\beta = 0.017$, $SE = 0.055$, $p = 0.761$). As a result, there exists a negative correlation between exposure to social media and the perceived risks (H5a), while a positive relationship is identified between social media exposure and the perceived benefits of vaping (H5b).

We further investigate the impact of perceived enforcement of Tobacco Control Policy on individuals' perceptions of risk and benefit (H6). As illustrated in Table 3 and Figure 2, the findings indicated a positive relationship between both perceived

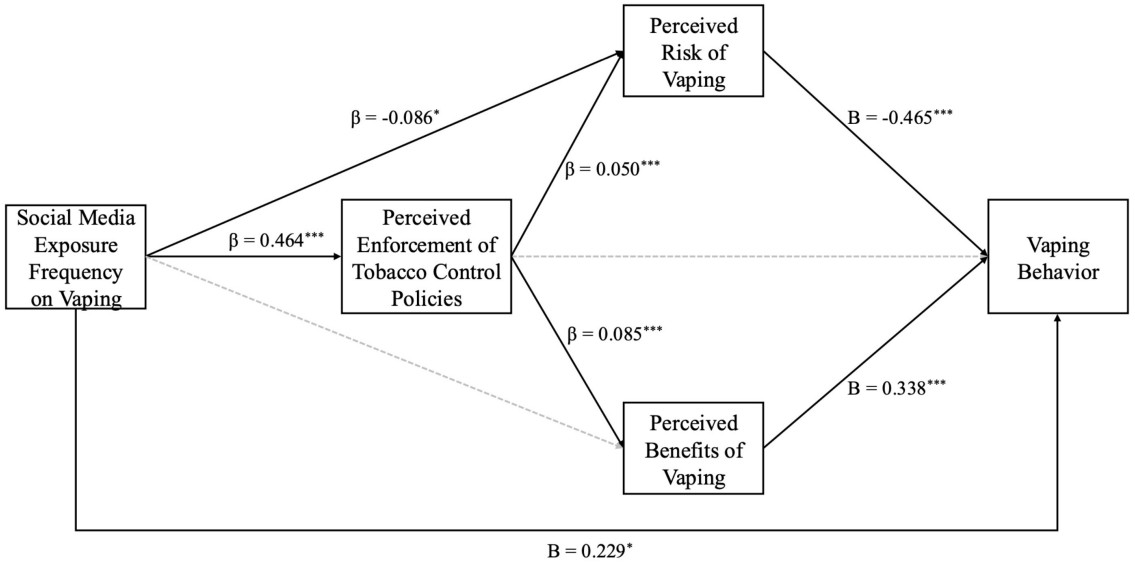

FIGURE 2
Model results. *$p < 0.05$, ***$p < 0.001$.

TABLE 4 Regression analysis of different types of social media on policy enforcement perception and vaping prevalence.

	Model 1 (linear regression of perceived enforcement of tobacco control policy)				Model 2 (binary logistic regression on vaping)			
Social Media	*β*	*SE*	*t*	95%CI	B	*SE*	OR	95%CI
Weibo	−0.082	0.084	−1.812	[−0.317, 0.013]	−0.07	0.081	0.932	[0.796,1.092]
Wechat moments	0.114	0.076	2.516	[0.042, 0.339]	0.031	0.073	1.032	[0.895,1.189]
WeChat official account	0.001	0.084	0.026	[−0.162, 0.166]	0.038	0.08	1.039	[0.888,1.216]
WeChat Channels	0.034	0.086	0.698	[−0.109, 0.229]	−0.206	0.083	0.814	[0.691, 0.958]
REDnote	0.094	0.079	2.107	[0.011, 0.321]	0.079	0.076	1.082	[0.933,1.254]
Tiktok	0.012	0.075	0.273	[−0.127, 0.167]	−0.02	0.072	0.98	[0.852,1.128]
Kwai	−0.087	0.082	−1.775	[−0.307, 0.015]	−0.018	0.079	0.982	[0.842,1.146]
Bilibili	−0.047	0.083	−1.025	[−0.248, 0.078]	0.128	0.08	1.136	[0.972,1.328]
Zhihu	0.026	0.083	0.549	[−0.117, 0.208]	−0.008	0.08	0.992	[0.848,1.159]
Baidu Tieba	0.169	0.085	3.505	[0.132, 0.467]	0.212	0.083	1.236	[1.051,1.454]
Social Media Outside China (e.g., Facebook, Youtube, Instagram, X)	0.083	0.079	2.011	[0.004, 0.315]	0.025	0.076	1.025	[0.882,1.191]
$R^2 = 0.08$					*−2 Log likelihood = 982.08*			
$F(11,712) = 5.536$					*pseudo* $R^2 = 0.04$			

risks and perceived benefits concerning the perceived enforcement of Tobacco Control Policy, thereby supporting that positive correlation between perceived enforcement and risk perception (H6a) ($\beta = 0.050$, $SE = 0.016$, $p < 0.01$). Nevertheless, the anticipated negative correlation between perceived enforcement and benefit perception (H6b) was not substantiated by the findings ($\beta = 0.085$, $SE = 0.021$, $p < 0.001$). The results indicate that the perceived enforcement of Tobacco Control Policy positively influences the perceived benefits of vaping, thereby contradicting the initial hypothesis.

The primary focus of the present study is to investigate the effectiveness of different types of social media in shaping perceptions of the enforcement of Tobacco Control Policy (RQ1) and their impact on vaping behaviors (RQ2) within the context of China. In this analysis, we designated the frequency of exposure to different forms of social media as the independent variable, while the perceived enforcement of Tobacco Control Policy served as the dependent variable for the linear regression analysis (see Model 1 in Table 4). The findings suggest that increased exposure to e-cigarette-related information on social media platforms, including

(1) WeChat Moments ($\beta = 0.114$, $SE = 0.076$, $p < 0.05$), (2) REDNote ($\beta = 0.094$, $SE = 0.079$, $p < 0.05$), (3) Baidu Tieba ($\beta = 0.169$, $SE = 0.85$, $p < 0.001$), and (4) International Social Media Outside China($\beta = 0.083$, $SE = 0.079$, $p < 0.05$), correlates with a heightened perception of Tobacco Control Policy enforcement.

Additionally, we employed the frequency of exposure to various social media types as the independent variable and vaping behavior as the dependent variable in a binary logistic regression analysis (see Model 2 in Table 4). The results indicate two key trends: (1) a higher frequency of exposure to e-cigarette-related content on WeChat Video Channel is associated with a decreased likelihood of youth engaging in vaping behavior ($B = -0.206$, OR = 0.098, 95% CI: [0.691, 0.985]), and (2) increased exposure to e-cigarette-related content on Baidu Tieba correlates with an increased likelihood of youth participating in vaping activities ($B = 0.212$, OR = 1.236, 95% CI: [1.051, 1.454]).

The present study also examined the mediating roles of perceptions regarding policy enforcement and evaluations of the risks and benefits associated with vaping (RQ3). As illustrated in Table 3, the frequency of social media exposure to vaping significantly influences the occurrence of vaping behavior through two indirect pathways: (1) in path a, perceived enforcement of Tobacco Control Policy and perceived risk function as mediators ($b = -0.013$, $SE = 0.006$, 95% CI: [−0.028, −0.004]); and (2) in path b, perceived enforcement of Tobacco Control Policy and perceived benefits serve as mediators ($b = 0.011$, $SE = 0.006$, 95% CI: [0.002, 0.027]). Both pathways are found to be significant. This suggests that exposure to information related to e-cigarettes on social media can shape young individuals' perceptions regarding the enforcement of Tobacco Control Policy, which in turn affects their perceptions of both risks and benefits. Such perceptions may subsequently either enhance or diminish the likelihood of engaging in vaping behavior.

5 Discussion

5.1 The mediating role of perceived policy enforcement

This research examines the factors influencing vaping behavior among Chinese adolescents, focusing on the perceived enforcement of policies. Previous studies indicate that China is the world's largest consumer of tobacco products, and there is a concerning trend of decreasing age at which individuals initiate smoking, especially among the youth demographic, as highlighted by multiple sources (94–98). Also, the recent proliferation of social media has stimulated public discourse by disseminating and sharing various content, thereby altering public understanding and attitudes. This transformation, in turn, influences individuals' perceptions of policy enforcement (42–45). Therefore, a deeper understanding of how vaping behavior is influenced by social media and tobacco control policies, particularly the psychological mechanisms involved in this process, is crucial for effectively utilizing social media platforms and related policies to control smoking, especially in reducing youth vaping. The findings of this study reveal that daily exposure to vaping-related content on social media can have both direct and indirect effects on individuals' vaping behaviors. Specifically, the frequency of exposure to such content positively affects perceptions of the enforcement of Tobacco Control Policies. This perception, in turn, primes individuals' awareness of the risks and benefits associated with vaping, ultimately increasing or decreasing the likelihood of engaging in vaping behavior. Identifying this mediating pathway offers valuable insights into the psychological factors influencing youth vaping and introduces new approaches for health communication strategies aimed at intervening vaping behaviors. Additionally, framed within the KAP theory, the mediating model provides strong empirical support and theoretical contributions. The following sections will discuss the research results and their theoretical and practical implications in detail.

This study reveals that the perceived enforcement of Tobacco Control Policy does not have a significant direct effect on the likelihood of youth engaging in vaping behavior. Instead, it influences vaping through the mediation of perceived risks and perceived benefits. Specifically, the perception of effective enforcement of Tobacco Control Policy positively affects perceived risk, which in turn decreases the likelihood of vaping. Conversely, it also positively affects perceived benefits, thereby increasing the likelihood of vaping. This pathway is consistent with prior research indicating that perceptions of policy, including its effectiveness and enforcement strength, shape individuals' cognitions and attitudes, ultimately influencing their behaviors (99, 100). The interplay between perceived risk and perceived benefits, which should theoretically be opposite in terms of both causing and being caused by other variables, manifests in the pathways through which these perceptions influence vaping behavior. However, when influenced by the perceived enforcement of Tobacco Control Policy, both perceptions exhibit a positive impact. China's tobacco control policies may reflect a dual conceptualization distinguishing traditional and e-cigarettes, potentially shaping public perceptions and regulatory outcomes. When policies are perceived as strictly enforced, individuals associating regulations primarily with traditional cigarettes might view e-cigarettes as possible substitutes, which may amplify perceived benefits and possibly encourage vaping adoption. Conversely, activating policy concepts related to e-cigarettes could heighten risk perceptions, potentially discouraging their use (101, 102). This pattern may align with China's historical focus on regulating traditional cigarettes. Recent efforts to address e-cigarettes risks appear to integrate vaping governance into existing tobacco frameworks rather than establishing separate policies.

5.2 A potential explanation of the psychological mechanism: cognitive dissonance

From the perspective of psychological mechanisms, tobacco control policies may generate dual perceptions of e-cigarettes: awareness of health risks and belief in their substitution benefits for conventional cigarettes. This duality could create cognitive dissonance as users navigate conflicting cognitions—risk vs. benefit. When an individual's actions are at odds with both the risk perception emphasized by policies (e.g., health hazards)

and the perception of e-cigarettes as beneficial (e.g., as a tool for quitting traditional cigarettes), psychological tension may arise from the inability to reconcile these conflicting beliefs. This dissonance may motivate individuals to resolve the tension through various strategies, such as altering their behavior (e.g., quitting e-cigarettes or exclusively using e-cigarettes without reverting to traditional cigarettes), selectively reinforcing one side of the cognition (e.g., emphasizing harm reduction or amplifying risks), or seeking external justification from policy authority (e.g., interpreting the policy as only requiring the cessation of traditional cigarettes, thereby rendering individual e-cigarette use permissible and rational). These strategies aim to reconcile contradictions and regain cognitive consonance. While this framework proposes explanatory psychological mechanisms, their operation along these pathways remains subject to empirical validation.

Based on the findings of this study, two practical implications emerge. First, it is crucial to strengthen the enforcement of tobacco control policies to enhance the perceived authority of these regulations concerning e-cigarettes, thereby reducing unhealthy behaviors. Second, policies should explicitly delineate the risks associated with electronic cigarettes and the relevant regulatory provisions, with the objective of maximizing public awareness regarding the potential dangers posed by e-cigarettes. It is essential to recognize that tobacco control is a comprehensive concept rather than one specifically targeting traditional cigarettes or e-cigarettes only; thus, when mention tobacco control invoke two distinct concepts—e-cigarettes and traditional cigarettes—which differentially influence risk and benefit perceptions.

5.3 The role of social media and its theoretical explanations

This study also examined the impact of social media exposure on vaping behavior. The results suggest that exposure to e-cigarette-related content on social media significantly enhances vaping behavior. Additionally, this exposure indirectly influences vaping through perceived enforcement of Tobacco Control Policies and the perception of risks and benefits associated with vaping. Within the framework of the KAP model, social media exposure is categorized as knowledge, which subsequently increases the likelihood of adopting specific practices. In the context of vaping, a higher frequency of exposure to e-cigarette information or advertisements on social media correlates with an increased likelihood of vaping. Typically, individuals who frequently encounter such social media content—whether through active searches, passive algorithmic feeds, or casual scanning—demonstrate heightened attention to e-cigarettes, thereby increasing their propensity to engage in vaping behavior. This direct relationship is consistent with findings from prior research (71, 103–105).

The selective exposure theory suggests that individuals shape their information environment based on their existing behaviors, which may create a reverse causal relationship that contradicts this paper's argument. For instance, young people who are inclined to use e-cigarettes might actively seek out related content on social media. This self-selection means that media exposure may result from their behavioral tendencies rather than cause them. Furthermore, this active engagement may create a reinforcing loop: individuals may strengthen their perceived rationality of the behavior through information filtering (e.g., favoring pro-e-cigarette content), social validation (e.g., interacting with like-minded users), or emotional resonance (e.g., associating e-cigarettes with being 'cool' or 'fashionable'). Thus, a loop may form where behavioral inclination leads to media exposure, which in turn reinforces that behavior. Additionally, there may be a bidirectional dynamic relationship between media exposure and behavior: initial behavioral tendencies might drive selective exposure, while the encountered information (e.g., product glorification, peer modeling) might reduce perceived behavioral costs (e.g., others' use is harmless), potentially driving the implementation or continuation of the behavior. This complex interplay requires further validation through longitudinal data or instrumental variable analysis to potentially distinguish the antecedents and consequences of media exposure.

Moreover, young adults exposed to e-cigarette-related information on social media tend to perceive a stronger enforcement of Tobacco Control Policies. This is particularly evident in the context of China, where direct e-cigarette advertisements are prohibited on social media platforms. Users often modify keywords associated with e-cigarettes to present advertising content more subtly. Such exposure to relatively discreet information fosters the perception that regulatory policies are actively governing e-cigarette use, thus enhancing their sense of enforcement. Additionally, much of the content available on social media regarding e-cigarettes comprises health-related information and discussions of tobacco control policies. Engagement with this type of content increases users' awareness of the harmful effects of e-cigarettes and their understanding of current policy measures, thereby reinforcing their perception of enforcement. Through this process, as previously noted, social media exposure shapes young adults' perceptions of risks and benefits, subsequently influencing their vaping behavior. This mediating effect elucidates a mechanism by which policy enforcement relates to social media's role in shaping vaping behavior, offering new avenues for intervention strategies targeting vaping through social media platforms.

5.4 The impact of information sources on different social media platforms

Our research has uncovered various direct and indirect pathways through which different types of social media information impact individuals' vaping behaviors. Specifically, exposure to e-cigarette-related content on two distinct Chinese social media platforms—WeChat Video Channels (negative impact) and Baidu Tieba (positive impact)—has been found to significantly influence the vaping behaviors of young individuals, albeit in contrasting ways. Analysis of the content on these platforms indicates that: (1) WeChat Video Channels primarily

disseminate health education and policy-related information regarding the dangers of e-cigarettes, devoid of any advertising. Consequently, increased exposure to such content tends to diminish the likelihood of vaping; (2) In contrast, Baidu Tieba is characterized by a higher prevalence of advertising-oriented information about e-cigarettes, often presented in a manner that lacks health education. Users frequently employ ambiguous terminology to promote e-cigarettes in order to circumvent online censorship, which, in turn, heightens the likelihood of vaping among those frequently exposed to such content. Furthermore, the study reveals that greater exposure to e-cigarette-related information across four accessible social media platforms—WeChat Moments, REDNote, Baidu Tieba, and various international social media outside China—reinforces young people's perception of the enforcement of Tobacco Control Policies in China. Notably, platforms such as Baidu Tieba and REDNote contain a substantial number of e-cigarette advertisements, often rephrased with ambiguous keywords to evade censorship. On the one hand, exposure to these rephrased messages primes users' understanding of regulatory frameworks, heightening their perception of policy enforcement. On the other hand, the presence of e-cigarette advertisements, particularly those from international social media outside China that utilize more explicit content, may further amplify users' perception of strong policy enforcement when they encounter such information across different platforms. We contend that numerous Chinese social media platforms continue to inadequately regulate this obfuscated and homophonic content, thereby increasing the likelihood of exposure to these advertisements among young people, which subsequently influences their vaping behaviors through both direct and indirect psychological mechanisms. Therefore, the timely identification and warning of harmful health information on social media, along with the enhancement of information regulation, represent effective administrative strategies for mitigating vaping behaviors.

5.5 Theoretical implications

This study investigates various critical factors that influence vaping behavior, uncovering the fundamental mechanisms involved, which carry significant theoretical implications. Initially, we enhance the KAP model related to youth vaping, specifically exploring how perceptions regarding the enforcement of tobacco control policies impact individuals' views on associated risks and benefits. This enhancement broadens the pathways linked to attitudes, thereby offering new frameworks for understanding vaping behavior. Second, the study underscores the confusion that arises when applying conjoint behavioral concepts, such as tobacco control, to distinct behaviors such as e-cigarette use vs. traditional cigarette smoking. This confusion may result in different outcomes in individual decision-making processes due to the activation of various behavioral constructs. In terms of agenda-setting in health policy communication, the precise definition of concepts and the priming mechanisms are vital for influencing individuals' cognition, attitudes, and behaviors at a micro level.

5.6 Practical implications

This study presents practical implications in two significant dimensions. First, tobacco control policies must not only raise public awareness through a well-rounded conceptual framework but also involve targeted advocacy efforts tailored to specific behaviors and contextual factors. In the case of China, the existing tobacco control policies demonstrate extensive reach and comprehensive regulation; however, there is a pressing need to enhance enforcement mechanisms. This enhancement is essential for effectively shaping public perceptions regarding the risks associated with e-cigarette use and for mitigating vaping behaviors. Second, given that social media platforms serve as vital sources of information for young individuals, it is crucial to manage health-related information with precision. This includes minimizing ambiguity and coded messaging and improving the scope and depth of health science information dissemination. Such strategies are intended to enhance public risk perception and rectify the widespread misconception that e-cigarettes pose no harm to human health.

6 Conclusion and limitations

This study examines the underlying mechanisms that influence vaping behavior, focusing on factors such as exposure to social media content, the perceived enforcement of Tobacco Control Policy, perceived risks, and perceived benefits. The results demonstrate that exposure to e-cigarette-related information and advertisements on social media enhances the perceived enforcement of Tobacco Control Policy. This enhancement subsequently affects both the perceived risks and perceived benefits, thereby shaping the vaping behavior among youth. The mediating mechanisms identified in this research contribute to the expansion of the KAP theory. Furthermore, the study investigates the role of Chinese social media platforms in relation to youth vaping behavior and the perceived enforcement of Tobacco Control Policy. It finds that platforms featuring more ambiguous and coded information regarding e-cigarettes exert a more pronounced influence on youth vaping behavior compared to those with clearer content. Consequently, the regulation of information on social media platforms and the reinforcement of policy enforcement emerge as vital strategies for mitigating vaping behavior in China.

It is essential to acknowledge the limitations inherent in this study. First, the investigation into exposure to e-cigarette-related information on social media did not sufficiently differentiate among various types of content, such as specific inquiries about exposure to advertisements, health knowledge, or introductions to regulatory policies. Such distinctions would greatly enhance the understanding of the priming effects of different concepts within a precise analytical framework. Subsequent research should aim to address this differentiation. Second, this research investigates the vaping behaviors among the younger generation in China. However, due to the considerable regional differences in both economic conditions and cultural practices across this vast

nation, it is essential to integrate insights from the fields of economic geography and cultural geography to provide a more nuanced understanding of the research subjects. Third, while this study utilized a cross-sectional design, it is important to note that the fluctuating rates of e-cigarette use and varying levels of public awareness regarding the hazards associated with e-cigarettes render cross-sectional surveys inadequate for establishing causal relationships. Consequently, future studies could benefit from the application of longitudinal data to elucidate the causal pathways connecting social media exposure, perceived policy enforcement, and vaping behaviors. Fourth, the study's sample was predominantly male, which, although reflecting the statistical characteristics of smoking populations in China, limits the generalizability of the findings to female users. The vaping behaviors of women, their perceptions of tobacco control policies, and their attitudes toward secondhand and thirdhand smoke may differ from those of men. A more gender-balanced sample could potentially produce different outcomes. Therefore, future research should investigate the gender disparities that influence vaping behaviors in greater depth. Last, this research did not consider mental health functioning and additional substance use as covariates, presenting a limitation. Future studies should investigate the interplay of these factors in shaping youth vaping behaviors.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

T-CW: Conceptualization, Data curation, Methodology, Software, Writing – original draft, Writing – review & editing. M-JZ: Project administration, Visualization, Writing – review & editing. HZ: Funding acquisition, Project administration, Supervision, Writing – review & editing, Software.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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EDITED BY
Joanna Jacobus,
University of California, San Diego,
United States

REVIEWED BY
Kelly A. Correa,
University of California, San Diego,
United States
Neal Doran,
University of California, San Diego,
United States

*CORRESPONDENCE
John Tarantino
jpt134@rwjms.rutgers.edu

†These authors share first authorship

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Understanding racial/ethnic differences in e-cigarette outcome expectancies among early adolescents: findings from the Adolescent Brain Cognitive Development Study

John Tarantino[1*†], Tammy Chung[1,2†], Nicole Kennelly[2], Shawn J. Latendresse[3], Margret Z. Powell[3] and Carolyn E. Sartor[1,2]

[1]Department of Psychiatry, Rutgers Robert Wood Johnson Medical School, Piscataway, NJ, United States, [2]Institute for Health, Heath Care Policy and Aging Research, New Brunswick, NJ, United States, [3]Department of Psychology and Neuroscience, Baylor University, Waco, TX, United States

Introduction: E-cigarette expectancies, which may differ by race/ethnicity, play a crucial role in shaping youth e-cigarette use. Observed differences by race/ethnicity, however, may reflect racial/ethnic variations in social determinants of health, such as socioeconomic status (SES). This study examined the extent to which race/ethnicity was uniquely associated with youths' positive and negative e-cigarette expectancies, after adjusting for SES and neighborhood disadvantage, and individual, family, and peer risk factors.
Methods: Analyses included 8,814 Black (15.0%), Latinx (22.8%), and White (62.2%) 12 to 14-year-old participants in the Adolescent Brain Cognitive Development Study. Applying a three-stage analytic approach, hierarchical regression analyses examined associations of positive and negative e-cigarette expectancies with race/ethnicity in three blocks, with age and gender in block 1, adding SES and neighborhood disadvantage in block 2, and individual, family, and peer risk factors in block 3.
Results: Black and Latinx (relative to White) race/ethnicity and Latinx (relative to Black) race/ethnicity were associated with positive expectancies ($p < 0.001$) in blocks 1 and 2 but were non-significant in block 3. Black and Latinx (relative to White) race/ethnicity and Latinx (relative to Black) race/ethnicity were associated with lower negative expectancies ($p < 0.001$) in block 1, but were no longer significant after adding SES and neighborhood indicators in block 2. Perceived risk, perceived peer disapproval, and curiosity about e-cigarettes were associated with positive and negative expectancies.
Discussion: The results highlight the importance of considering associations of race/ethnicity with e-cigarette expectancies in the context of social determinants and individual and interpersonal factors in e-cigarette prevention.

KEYWORDS

e-cigarette, adolescent, positive expectancies, negative expectancies, race, ethnicity

1 Introduction

The use of electronic cigarettes (e-cigarettes) among youth poses significant health risks, including possible progression to nicotine dependence and combustible cigarette use (1, 2), delays in brain development (3), and respiratory injury (4). According to the 2023 national Monitoring the Future survey, approximately one in seven 8th graders has tried e-cigarettes, with some modest variations in prevalence across racial/ethnic groups (5). By 12th grade, however, trends in prevalence diverge, with Black and Latinx youth reporting a higher lifetime prevalence of e-cigarette use relative to White youth (45% and 31% vs. 25%, respectively) (5). These findings underscore the importance of examining precursors to e-cigarette use, particularly among Black and Latinx youth at younger ages, to inform tailored prevention efforts.

Substance use outcome expectancies—beliefs about the anticipated effects (positive and negative) of substance use—consistently predict youth initiation of alcohol, cannabis, combustible cigarettes, and e-cigarette use (6–10). Expectancies exist even before an individual has direct experience with a substance (11) and can change after use has started (6, 12), which makes expectancies a key target for prevention. Positive e-cigarette expectancies include enjoyment or pleasure, reduced stress, appearing older, and improved social status, while negative e-cigarette expectancies involve, for example, concerns about potential addiction and adverse health effects (6, 13). Notably, a national survey of adolescents and young adults found that high positive e-cigarette expectancies were associated with an increased risk of e-cigarette initiation, while high negative e-cigarette expectancies protected against initiation of e-cigarette use (6).

A socio-ecological model of substance use initiation (14) suggests that multiple interconnected factors operating at individual, family, peer, and neighborhood levels can influence the development of e-cigarette expectancies and use among adolescents. Demographic characteristics such as gender and race/ethnicity may be associated with e-cigarette expectancies and use patterns. One study found that among youth with no vaping experience, girls had higher negative and positive e-cigarette expectancies relative to boys (15). Regarding race/ethnicity, research on expectancies is scarce. For example, higher positive e-cigarette expectancies have been observed among Black, relative to White and Latinx, high school students (15). In line with this finding, some studies have reported a higher lifetime prevalence of e-cigarette use among Black youth relative to their White peers (16, 17). One recent study found a higher prevalence of e-cigarette use among Latinx and White youth relative to Black youth, but found increasing rates of e-cigarette use among Black youth (18). In considering the implications for prevention, it is important to keep in mind that racial/ethnic differences in e-cigarette expectancies may be confounded by socioeconomic status (SES) and neighborhood factors, given the overrepresentation of Black and Latinx families in low-resource neighborhoods (19, 20).

We are unaware of prior research examining the association of SES with e-cigarette expectancies. However, some research suggests that, unlike combustible cigarettes, which are more prevalent in individuals from lower SES backgrounds (21), youth from higher SES households may be at greater risk of e-cigarette initiation regardless of race/ethnicity (22). It is important to note that the study by Hitchman et al. (21) focused on an older age group (18–24 years), which may limit its applicability to adolescent populations. Neighborhood conditions, including high exposure to e-cigarette products as a function of a high density of retailers in disadvantaged neighborhoods (23), may increase the risk of e-cigarette initiation (24) and potentially also e-cigarette expectancies. The current analyses examine unique associations of SES and neighborhood conditions with e-cigarette expectancies.

Beyond demographic and neighborhood factors, psychosocial factors at the individual, family, and peer levels of the socio-ecological model could contribute to e-cigarette expectancies and use in youth. Key predictors of e-cigarette use include personal attitudes toward use, peer influence, and parental use of e-cigarettes (25). For example, youth who perceive e-cigarettes as less harmful than combustible cigarettes are more likely to initiate use, underscoring the role of harm perceptions in shaping behaviors (25). Furthermore, exposure to family members and peers who use e-cigarettes significantly increases the likelihood of use (25). In addition, given that e-cigarette use itself can shape expectancies, leading to more favorable anticipated effects (6, 12) and the previously noted variation by race/ethnicity in the prevalence of e-cigarette use, it is critical to consider prior e-cigarette use when examining expectancies.

This secondary analysis of data from the Adolescent Brain Cognitive Development (ABCD) Study (26) explored demographic characteristics (race/ethnicity, gender identity, and age); SES and neighborhood conditions; and individual, family, and peer factors as predictors of e-cigarette positive and negative expectancies in youth. We addressed three research questions using a hierarchical regression modeling approach to evaluate the contribution of these constructs, entered in blocks, to predict e-cigarette expectancies above and beyond previously entered blocks of predictors. First, analyses examined how race/ethnicity, age, and gender related to expectancies. We tested the hypothesis, consistent with the relative prevalence of youth e-cigarette use by race/ethnicity (5), that the highest positive and lowest negative expectancies (indicative of greatest liability to e-cigarette use) would be reported by Black youth, followed by Latinx youth, with the lowest positive and highest negative expectancies observed in White youth. Second, indicators of SES and neighborhood disadvantage were added to the analysis to evaluate whether race/ethnicity continued to uniquely predict e-cigarette expectancies after adjusting for SES and neighborhood conditions (that is, to examine their potential confounding effects with race/ethnicity), given the disproportionate representation of Black and Latinx families in lower SES and disadvantaged neighborhoods (19, 20). Third, analyses examined whether race/ethnicity remained a unique predictor of e-cigarette expectancies after additionally adjusting for individual, family, and peer risk factors.

This three-step hierarchical regression analysis approach permitted evaluation of how structural factors (e.g., SES and

neighborhood conditions) and individual and interpersonal (i.e., family and peer) risk factors contribute to observed race/ethnicity differences in e-cigarette expectancies. We hypothesized that associations of race/ethnicity with e-cigarette expectancies would be reduced after adjusting for SES and neighborhood conditions —social determinants of health that disproportionately impact people of color (27, 28). By examining these factors sequentially, in a hierarchical regression modeling approach, the current study aimed to provide a more nuanced understanding of the complex interplay between social determinants of health and youth perceptions of e-cigarette effects, offering novel insights into the correlates of e-cigarette health disparities.

2 Materials and methods

2.1 Data source

The ABCD Study (abcd.org) is an ongoing multi-site longitudinal study of adolescent health and cognitive development in the US (26). Details of the study design have been previously reported (29, 30).

Briefly, from 2016 to 2018, the study recruited youths ($N = 11,875$) aged 9–10 years, primarily through schools. Enrollment targets were derived using the National Center for Education Statistics and US Census data.

At annual assessments, youths and their primary caregivers (parents) completed a comprehensive assessment of mental and physical health, including a wide range of substance use-related factors, as well as cultural and environmental factors (31–33). Parents also reported demographic information (e.g., parental education level, youth race/ethnicity) and health information. Data for the current study were drawn mainly from Follow-up Year 3, release 5, the most recent data available at the time of analysis. In addition, data from baseline and prior follow-ups were used for specific variables, as detailed in the Measures section.

2.2 Participants

Our analysis included Black, Latinx, and White youth, the three largest racial/ethnic groups represented in the ABCD Study. Other racial/ethnic groups were excluded due to limited numbers, which would have resulted in insufficient statistical power. We used ABCD Study-defined race/ethnicity categories based on parent-reported youth ethnicity (Latinx/Hispanic or Non-Hispanic/Latinx) and youth race (in separate questions). Under this definition, all individuals endorsing Latinx/Hispanic were categorized as Latinx. Thus, "White" refers to Non-Latinx ethnicity and White race and "Black" as Non-Latinx Black/African American. Race/ethnicity was represented in the model using contrast coding, with one variable representing Black and Latinx race/ethnicity relative to White race/ethnicity and a second representing Latinx relative to Black race/ethnicity, thus allowing us to directly compare Black and Latinx youth. Youths' self-reported gender identity, which was assessed with the question, "What is your current gender identity?" Response options were "boy," "girl," and "another gender (e.g., nonbinary)."

The analysis sample included 8,814 Black, Latinx, and White youths who completed all items in the ENDS Expectancies questionnaire at Follow-up 3 ($M_{age} = 12.94$, $SD < 0.01$; 53.07% self-identified as "boy," 45.01% as "girl," and 1.92% as "other gender;" 62.19% White, 15.03% Black, and 22.78% Latinx). The majority of parents reported an educational level of bachelor's degree or higher (71.18%), and nearly half (48.88%) reported a household income of $100,000 or above. Detailed demographic characteristics of the sample are reported in Table 1.

2.3 Measures

2.3.1 SES indicators

The primary caregivers reported on their education level with the question, "What is the highest grade or level of school you have completed or the highest degree you have received?" Consistent with prior ABCD publications (34), education level was collapsed into five categories: less than high school, high school, some college, bachelor's degree, and post-bachelor's degree. Education was represented in models with four dichotomous variables, using "some college" as the reference group.

Household income was categorized, consistent with prior ABCD publications (35), as low (less than $50,000), medium ($50,000–$99,999), and high ($100,000 or more), represented in the models with two dichotomous variables, using medium income as the reference group.

The Area Deprivation Index (ADI) was calculated by the ABCD Study by linking geocoded data from the parent-reported youth residence at baseline to census-tract data. The ADI is a widely used measure of neighborhood disadvantage, incorporating a variety of factors such as employment, household utilities, and housing values (36). ADI values are expressed as population-level (national) percentiles (ranging from 1 to 100), with higher values indicating greater disadvantage. For this study, the common approach of analyzing ADI quartiles was employed: 1 = ≤25th, 2 = 26th–50th, 3 = 51st–75th, and 4 = ≥76th percentiles. ADI was represented in models using three dichotomous variables, with the most advantaged (first ADI quartile) serving as the reference group.

2.3.2 Individual, family, and peer risk factors

All risk factors other than e-cigarette use in the household were assessed via the youths' report.

Lifetime e-cigarette use was assessed at baseline by asking, "Have you ever tried electronic cigarettes, vape pens, or e-hookah at any time in your life?" At subsequent follow-ups, youths were asked, "Have you had a puff of an e-cigarette, vape pen, or hookah since the last time we saw you?" These items were coded dichotomously (yes = 1, no = 0) and combined into a lifetime e-cigarette use variable (yes = 1, no = 0).

E-cigarette users in the household were assessed by asking the primary caregiver, "Did anyone use electronic nicotine or vaping products such as e-cigarettes, vape pens or Juuls inside the house

TABLE 1 Sample demographic characteristics by race/ethnicity.

Variable	Total		White		Black		Latinx		% missing
N (%)	8,814 (100.00)		5,481 (62.19)		1,325 (15.03)		2,008 (22.78)		0.00
	N or *M*	% or *SE*	*N* or *M*	% or *SE*	*N* or *M*	% or *SE*	*N* or *M*	% or *SE*	%
Age	12.94	>0.01	12.96	0.01	12.93	0.02	12.90	0.02	0.00
Gender identity									1.41
Girl	3,911	45.01	2,393	44.18	640	49.12	878	44.57	
Boy	4,612	53.07	2,907	53.66	649	49.81	1,056	53.60	
Other	167	1.92	117	2.16	14	1.07	36	1.83	
Caregiver education level									0.01
Less than high school	381	4.32	36	0.66	80	6.04	265	13.02	
High school	1,001	11.36	253	4.62	377	27.72	381	18.97	
Some college	1,158	13.14	645	11.77	218	16.47	295	14.69	
Bachelor's degree	2,545	28.88	1,970	33.94	189	14.27	386	19.22	
Post-bachelor's degree	3,728	42.30	2,577	47.02	470	35.50	681	33.50	
Yearly household income									1.65
<$50,000	2,169	25.02	522	9.63	775	60.50	872	44.40	
$50,000–99,999	2,263	26.10	1,360	25.07	308	24.04	595	30.30	
>$100,000	4,237	48.88	3,542	65.30	198	15.46	497	25.31	
Area Deprivation Index									6.89
First quartile	2,900	35.34	2,205	42.83	130	10.98	565	30.13	
Second quartile	2,951	35.96	1,979	38.44	218	18.41	754	40.21	
Third quartile	1,281	15.61	675	13.11	275	23.23	331	17.65	
Fourth quartile	1,075	13.10	289	5.61	561	47.38	225	12.00	

M, mean SE, standard error.

when your child was home or in a vehicle your child was in?" (1 = "yes", 0 = "no").

Perceived risk of regular e-cigarette use was assessed by asking, "How much do you think people risk harming themselves (physically or in other ways) if they use e-cigarettes regularly?" The response options included "no risk," "slight risk," "moderate risk," "great risk," and "don't know." Due to the low percentage (as expected at this age) selecting "no risk" (2.62%), it was combined with "slight risk." Three binary variables were included in the model: "no/low risk" (1 = "no/slight risk," 0 = all other responses), "moderate risk," and "don't know." "Great risk" served as the reference. This recoding addresses sparsely populated response categories and increases interpretability and statistical power by focusing on key distinctions in response options.

Perceived peer disapproval of e-cigarette use was assessed by the question, "How do you think your close friends feel (or would feel) about you using e-cigarettes regularly?" Possible responses included "not disapprove," "disapprove," "strongly disapprove," and "don't know." For ease of interpretation, "disapprove" and "strongly disapprove" were combined and used as the comparison group. Two binary variables were included in the model: "not disapprove" (1 = "yes," 0 = all other responses) and another indicating "don't know" (1 = "yes," 0 = all other responses). Combining these categories reduces sparse data for some response categories by focusing on meaningful distinctions and improving statistical power, reflecting the overall high degree of disapproval in this developmental period.

Curiosity about e-cigarettes was assessed with the question, "Have you ever been curious about using an electronic nicotine or vaping product?" Possible responses included "not at all curious," "a little curious," "somewhat curious," "very curious," and "don't know." Due to the small number of participants indicating any curiosity, responses were collapsed into a dichotomous variable: 1 = "a little curious," "somewhat curious," "very curious," and "don't know" vs. 0 = "not at all curious" (the reference group), to enhance interpretability, highlight meaningful distinctions, and improve statistical power.

2.3.3 Outcomes

E-cigarette outcome expectancies: Positive and negative outcome expectancies regarding e-cigarette use were assessed at follow-up 3 using the eight-item revised Youth E-cigarette Outcome Expectancies measure (37). The measure queries four positive (e.g., feeling relaxed) and four negative (e.g., looking awkward) e-cigarette expectancies (rated 0 = unlikely to experience the effect and 9 = likely to experience the effect). After adjustment for measurement equivalence with respect to race/ethnicity, sex assigned at birth, and the intersection of race/ethnicity and sex [see Chung et al. (38) for details on measurement equivalence methods], the positive and negative expectancy scales yielded continuous scores for each subscale. These scores were used as the outcome measures in the analysis.

2.4 Analysis plan

Analyses were conducted in SAS version 8.3 using SAS SURVEY procedures to accommodate the ABCD Study's complex

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TABLE 2 Hierarchical regression model predicting adjusted positive e-cigarette expectancies.

Variable	Block 1		Block 2		Block 3	
	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*
Age	0.011	<0.001	0.011	<0.001	0.007	<0.001
Gender identity						
Girl	0.033	0.114	0.033	0.105	0.035	0.080
Other gender identity	0.436	<0.001	0.439	<0.001	0.252	<0.001
Race/ethnicity						
Black/Latinx vs. White	−0.073	0.001	−0.058	0.033	−0.025	0.338
Latinx vs. Black	0.129	<0.001	0.122	0.001	0.069	0.067
Caregiver education level						
Less than high school			0.015	0.808	0.062	0.298
High school			−0.009	0.830	0.015	0.723
Bachelor's degree			−0.027	0.465	0.024	0.487
Post-bachelor's degree			0.012	0.739	0.051	0.122
Yearly household income						
<$50,000			−0.058	0.070	−0.059	0.055
>$100,000			−0.027	0.284	0.012	0.610
Area Deprivation Index						
Second quartile			−0.056	0.021	−0.065	0.005
Third quartile			−0.031	0.345	−0.067	0.032
Fourth quartile			−0.040	0.286	−0.081	0.028
Lifetime e-cigarette use						
Yes					0.137	0.103
Use of e-cigarettes in home						
Yes					0.136	0.001
Perceived risk of regular e-cigarette Use						
No risk/slight risk					0.313	<0.001
Moderate risk					0.333	<0.001
Don't know					0.049	0.300
Perceived peer disapproval						
Not disapprove					0.315	<0.001
Don't know					0.009	0.845
Curiosity about e-cigarettes						
At least a little curious					0.448	<0.001
Model R^2	0.019		0.021		0.135	
ΔR^2 (relative to prior model)			0.002		0.114	

Hierarchical regression analyses were conducted to quantify potential changes in the magnitude of associations as additional sets of variables were added to the model. Model coefficients are standardized. Block 1 included only demographic variables, such as race/ethnicity, gender identity, and age. Block 2 incorporated SES and neighborhood conditions and block 3 added potential individual, family, and peer factors related to e-cigarette use. The sample size for the analyses was 8,814.

sample ascertainment design. Analyses accounted for clustering within the family and the study site. For the hierarchical regression analyses, standard ABCD Study sample weights were applied per ABCD Study analysis guidelines (39). Prior to finalizing regression analyses, collinearity diagnostics were conducted; they did not support the exclusion of any explanatory variables. Regression analyses (SURVEYREG) fitted a general linear model to the data in three steps (or three blocks), separately for positive (Table 2) and negative (Table 3) e-cigarette expectancies. The SURVEYREG procedure calculates coefficient estimators (standardized coefficients are reported) using generalized least squares estimation via elementwise regression (40) and uses Taylor series to estimate the sampling errors of estimators (40). The first block included only race/ethnicity, gender, and age. Race/ethnicity was represented in the model (and subsequent models) using contrast coding, with two variables, one representing the contrast between Black and Latinx relative to White youth and one representing the contrast between Latinx and Black youth. The second block added SES and neighborhood indicators: parental education, household income, and ADI. The third block added the individual, family, and peer risk factors (e.g., lifetime e-cigarette use, perceived risk of regular use of e-cigarettes). Note that, as hierarchical regression analysis was used to disaggregate unique explanatory contributions of elements within a model testing a single, albeit complex, hypothesis, there was no need to account for possible Type 1 error inflation, as would be the case with multiple testing.

3 Results

Note that adjustment for measurement equivalence in the expectancies subscales resulted in continuous factor scores with a

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TABLE 3 Hierarchical regression model predicting adjusted negative e-cigarette expectancies.

Variable	Block 1		Block 2		Block 3	
	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*
Age	−0.003	0.024	−0.003	0.013	−0.001	0.685
Gender identity						
Girl	0.012	0.571	0.011	0.612	−0.010	0.642
Other gender identity	−0.278	<0.001	−0.268	<0.001	−0.133	0.047
Race/ethnicity						
Black/Latinx vs. White	−0.102	<0.001	0.002	0.933	0.011	0.673
Latinx vs. Black	0.099	0.005	0.039	0.298	0.038	0.326
Caregiver education level						
Less than high school			−0.197	<0.001	−0.213	<0.001
High school			−0.123	0.008	−0.108	0.022
Bachelor's degree			−0.013	0.738	−0.054	0.145
Post-bachelor's degree			−0.054	0.134	−0.072	0.040
Yearly household income						
<$50,000			0.006	0.845	0.018	0.583
>$100,000			0.068	0.012	0.032	0.220
Area Deprivation Index						
Second quartile			−0.012	0.630	0.003	0.892
Third quartile			−0.043	0.194	−0.013	0.704
Fourth quartile			−0.201	<0.001	−0.135	0.001
Lifetime e-cigarette use						
Yes					−0.131	0.063
Use of e-cigarettes in home						
Yes					−0.071	0.088
Perceived risk of regular e-cigarette use						
No risk/slight risk					−0.589	<0.001
Moderate risk					−0.383	<0.001
Don't know					−0.580	<0.001
Perceived peer disapproval						
Not Disapprove					−0.283	<0.001
Don't know					−0.220	<0.001
Curiosity about e-cigarettes						
At least a little curious					−0.121	<0.001
Model R^2	0.006		0.017		0.118	
ΔR^2 (relative to prior model)			0.011		0.101	

Hierarchical regression analyses were conducted to quantify potential changes in the magnitude of associations as additional sets of variables were added to the model. Model coefficients are standardized. Block 1 included only demographic variables, such as race/ethnicity, gender identity, and age. Block 2 incorporated SES and neighborhood conditions and block 3 added potential individual, family, and peer factors related to e-cigarette use. The sample size for the analyses was 8,814.

range that included negative values. The mean adjusted positive expectancies score for the full sample was 0.04 ($SE = 0.01$, range: −1.06 to 3.04), while the mean adjusted negative e-cigarette expectancy score for the full sample was 0.02 ($SE = 0.01$, range: −2.58 to 1.64). Mean positive and negative expectancy scores are reported by race/ethnicity in Table 4.

3.1 Block 1: race/ethnicity, gender, and age

3.1.1 Positive e-cigarette expectancies

In block 1 (Table 2), Black/Latinx race/ethnicity (relative to White race/ethnicity) was associated with significantly lower positive expectancies [coefficient = −0.073 (standardized value), $p = 0.001$]. Latinx race/ethnicity, when compared to Black race/ethnicity, was associated with significantly higher positive expectancies (coefficient = 0.129, $p < 0.001$). There was no significant difference in positive expectancies between youths identifying as girls vs. those identifying as boys. However, individuals identifying as another gender reported significantly higher positive expectancies than those who identified as boys (coefficient = 0.436, $p < 0.001$). The R^2 value for block 1 was 0.019, indicating that the model explained approximately 1.9% of the variance in positive expectancies.

3.1.2 Negative e-cigarette expectancies

In block 1 (Table 3), identifying as Black or Latinx (relative to White) was associated with lower negative e-cigarette expectancies (coefficient = −0.102, $p < 0.001$), while identifying as Latinx (relative to Black) was associated with higher negative expectancies

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TABLE 4 Individual, family, and peer risk factors by race/ethnicity.

Variable	Total		White		Black		Latinx		% missing
N (%)	8,814 (100.00)		5,481 (62.19)		1,325 (15.03)		2,008 (22.78)		0.00
	N or *M*	% or *SE*	*N* or *M*	% or *SE*	*N* or *M*	% or *SE*	*N* or *M*	% or *SE*	%
Lifetime e-cigarette use									0.00
Yes	195	2.21	74	1.35	11	0.83	49	2.44	
No	8,619	97.79	5,407	98.66	1,314	99.17	1,959	97.56	
Use of e-cigarettes in home									5.93
Yes	655	7.43	429	8.08	83	7.23	143	7.79	
No	8,159	92.57	4,879	91.92	1,065	92.77	1,692	92.21	
Perceived risk of regular e-cigarette use									0.05
No risk	231	2.62	59	1.08	108	8.16	64	3.19	
Slight risk	751	8.52	411	7.50	141	10.66	199	9.91	
Moderate risk	2,344	26.61	1,524	27.82	281	21.24	539	26.84	
Great risk	5,004	56.80	3,263	59.55	667	13.33	1,074	53.49	
Don't know	480	5.45	222	4.05	126	9.52	132	6.57	
Perceived peer disapproval									0.05
Not disapprove	297	3.37	158	2.88	58	4.38	81	4.03	
Disapprove	1,963	22.28	1,088	19.86	370	27.97	505	25.15	
Strongly disapprove	6,087	69.09	4,016	65.98	791	59.79	1,280	63.75	
Don't know	463	5.26	217	3.96	104	7.86	142	7.07	
Curiosity about e-cigarettes									5.89
Not at all curious	7,256	87.47	4,566	88.59	1,100	87.09	1,590	84.66	
A little curious	698	8.41	420	8.15	90	7.13	188	10.01	
Somewhat curious	180	2.17	106	2.06	29	2.30	45	2.54	
Very curious	41	0.49	15	0.29	14	1.11	12	0.64	
Don't know	97	1.17	38	0.74	24	1.90	35	1.86	
No response	23	0.28	9	0.17	6	0.48	8	0.43	
Adjusted positive outcome expectancy score									0.00
	0.04	0.01	0.06	0.01	−0.09	0.03	0.05	0.02	
Adjusted negative outcome expectancy score									0.00
	0.02	0.01	0.01	0.01	−0.01	0.03	−0.01	0.02	

M, mean; *SE*, standard error.
e-cigarette positive and negative expectancy scores were adjusted for possible measurement bias by race/ethnicity and sex.

(coefficient = 0.099, $p = 0.005$). There was no significant difference in negative e-cigarette outcome expectancies between youths identifying as girls and boys. However, individuals identifying as another gender reported significantly lower negative expectancies compared to boys (coefficient = −0.278, $p < 0.001$). The R^2 value for block 1 was 0.006, reflecting 0.6% of the variance in negative expectancies.

3.2 Block 2: addition of SES and neighborhood factors

3.2.1 Positive e-cigarette expectancies

In block 2 (Table 2), identifying as Black or Latinx (relative to White race/ethnicity) was associated with lower positive e-cigarette expectancies (coefficient = −0.058, $p = 0.033$). Identifying as Latinx (relative to Black) was associated with higher positive expectancies (coefficient = 0.122, $p = 0.001$). In addition, the second ADI quartile was associated with lower positive e-cigarette expectancies relative to the lowest ADI quartile (i.e., most advantaged; coefficient = −0.056, $p = 0.021$). SES indicators were not significant. The addition of SES and neighborhood variables in block 2 accounted for an additional 0.20% of the explained variance in positive expectancies.

3.2.2 Negative e-cigarette expectancies

In block 2 (Table 3), neither identifying as Black or Latinx (relative to White) nor identifying as Latinx (relative to Black) was significantly associated with negative e-cigarette expectancies. Relative to the lowest ADI quartile, the highest ADI quartile (most disadvantaged) was associated with lower negative e-cigarette expectancies (coefficient = −0.201, $p < 0.001$). Further, primary caregiver education level of high school or lower (relative to some college) was associated with lower negative e-cigarette expectancies ($ps < 0.01$). In addition, household income >$100,000 (vs. medium household income) was associated with high negative e-cigarette expectancies ($p = 0.012$). The addition of the SES and neighborhood variables in block 2 accounted for an additional 1.11% of the explained variance in negative outcome expectancies.

3.3 Block 3: addition of individual, family, and peer risk factors

3.3.1 Positive e-cigarette expectancies

In block 3 (Table 2), which accounted for individual, family, and peer risk factors related to e-cigarette use, neither of the race/ethnicity variables—Black/Latinx (compared to White) and Latinx (compared to Black)—was significantly associated with positive expectancies (coefficient = −0.025, $p = 0.338$; coefficient = 0.069, $p = 0.067$, respectively). SES indicators were non-significant, but ADI was significant; relative to quartile 1 (most advantaged), all three quartiles were associated with lower positive expectancies (second quartile: coefficient = −0.065, $p = 0.005$; third quartile: coefficient = −0.067, $p = 0.032$; fourth quartile: coefficient = −0.081, $p = 0.028$). Among the predictors added in block 3, e-cigarette use in the household, perceived risk of regular e-cigarette use (no/slight to moderate risk), perception that peers do not disapprove of e-cigarette use, and report of being at least a little curious about e-cigarettes were each positively associated with positive e-cigarette expectancies ($ps < 0.001$). The addition of variables in block 3 accounted for an additional 11.4% of the explained variance in positive expectancies.

3.3.2 Negative e-cigarette expectancies

In block 3 (Table 3), after including possible individual, family, and peer factors related to e-cigarette use, neither of the race/ethnicity variables was significantly related to negative expectancies. All SES indicators were non-significant except for the following: having less than a high school education (compared to some college) was associated with lower negative expectancies (coefficient = −0.213, $p < 0.001$), as was completing high school (coefficient = −0.108, $p = 0.022$). In addition, being in the fourth ADI quartile (i.e., most disadvantaged) compared to the first quartile (most advantaged) was associated with lower negative expectancies (coefficient= −0.135, $p = 0.001$). Among the predictors added in block 3, perceived risk of regular e-cigarette use (no/slight to moderate risk, don't know), perception that peers do not disapprove of e-cigarette use (and don't know), and report of being at least a little curious were each uniquely negatively associated with negative e-cigarette expectancies ($ps < 0.001$). The added variables in block 3 accounted for an additional 10.1% of the explained variance in negative e-cigarette expectancies.

4 Discussion

4.1 Race/ethnicity and e-cigarette expectancies: results of hierarchical regression analyses

The present study examined associations of race/ethnicity with positive and negative e-cigarette outcome expectancies in adolescents in the context of SES, neighborhood conditions, and individual, family, and peer risk factors. We found partial support for each of our three hypotheses regarding race/ethnicity differences and the extent to which socioeconomic disadvantage indicators may confound associations and the unique contributions of individual, family, and peer risk factors.

Our hypothesis—that Black and Latinx youth would have higher positive expectancies than White youth before adjusting for socioeconomic and neighborhood factors—was based on racial/ethnic differences in e-cigarette use prevalence from the Monitoring the Future study (5) and prior research showing higher positive expectancies among racial/ethnic minority youth than White youth (15). We expected positive expectancies to follow the same pattern as prior research. However, we found the opposite: Black and Latinx youths reported lower positive expectancies than White youths, with Latinx youths showing higher expectancies than Black youths.

Notably, a key methodological distinction that could help explain the difference in results across studies is that Morean et al. (15) categorized participants into broad racial/ethnic groups, without directly comparing Black and Latinx youth. In contrast, our study separately examined non-Latinx White, non-Latinx Black, and Latinx youth, making it one of the first studies to directly compare e-cigarette expectancies between Black and Latinx adolescents. This distinction is critical, as it allows for a more nuanced understanding of how expectancies differ within minoritized groups rather than solely in contrast to White youth.

In addition, differences in results across this study and that by Morean et al. (15) might also reflect developmental differences in exposure to and experience with e-cigarettes between high school-aged youth (15) and the younger sample (ages 12–14) studied here. The types of e-cigarette expectancies examined by Morean et al. (15), and in this study also differed, although measurement equivalence by race/ethnicity was used in both studies.

Our hypothesis that distinctions by race/ethnicity in positive expectancies would be reduced following the addition of SES and neighborhood factors was not supported. The retention of significant associations between race/ethnicity and positive expectancies suggests that race/ethnicity differences were not simply a marker for the effects of socioeconomic disadvantage on positive expectancies. The reduction of race/ethnicity differences to non-significance after family, peer, and individual risk factors were included suggested that variation by race/ethnicity was attributable, at least in part, to these risk factors.

In contrast to the results for positive expectancies, we found support for our hypothesis that prior to considering socioeconomic and neighborhood factors, negative expectancies would be lower among Black and Latinx youth relative to White youth, and Latinx youth relative to Black youth. In further support of our hypotheses, negative e-cigarette expectancies among Black and Latinx youths were attributable at least in part to social determinants of health (i.e., SES, neighborhood factors). As to why this result was found for negative, but not positive expectancies, we can only speculate. It is possible that negative expectancies are more strongly shaped by structural factors, such as exposure to anti-tobacco messaging, school policies, and community norms that discourage substance use. In contrast, positive expectancies may be more influenced by

direct individual and peer experiences with e-cigarettes. Taken together, these findings suggest that observed racial/ethnic differences in e-cigarette expectancies are attributable in part to SES and neighborhood conditions, in the case of negative expectancies, and to individual, family, and peer risk factors in the case of positive expectancies.

4.2 Co-occurrence of positive and negative e-cigarette expectancies

Our findings indicated that racial/ethnic groups with high positive expectancies also tended to report high negative expectancies, a pattern that may seem counterintuitive. This pattern of endorsement suggests that youth who recognize the potential benefits of e-cigarette use, such as stress relief or social acceptance, are also aware of its potential harms, including addiction or respiratory issues. This phenomenon is consistent with prior research showing that adolescents can simultaneously hold both risk-promoting and risk-deterring beliefs about substance use (41). This finding also raises the possibility that the distinction between anticipated effects characterized as "positive" or "negative" may not be strong among youth at this age, and thus, the measure may be capturing the degree to which effects of e-cigarettes more generally are expected.

4.3 Associations of socioeconomic status and neighborhood conditions with expectancies

The results from our hierarchical regression models reveal complex relationships of SES and neighborhood disadvantage with expectancies, including distinctions between positive and negative expectancies in these relationships. For instance, whereas parental education was unrelated to positive expectancies—either in the presence or absence of individual, family, and peer risk factors—parental education at the high school level or below was associated with lower negative expectancies, even after accounting for individual, family, and peer risk factors. One possibility for the specificity of this association to negative expectancies is that education regarding the harms of e-cigarette use, which may be more accessible to highly educated populations, would impact negative expectancies to a greater degree than positive expectancies. With respect to neighborhood disadvantage, living in any neighborhood conditions below the most advantaged was associated with lower positive expectancies after accounting for individual, family, and peer risk factors, whereas only living in the most disadvantaged neighborhood conditions was associated with lower negative expectancies. The association of neighborhood disadvantage with lower e-cigarette expectancies, in general, might reflect more limited exposure and access to e-cigarettes for youth who reside in more disadvantaged neighborhoods (42). Notably, the relation of neighborhood conditions (e.g., access and availability) and SES with e-cigarette expectancies and e-cigarette use will likely change with age, a dynamic that can be captured in future ABCD data collections (24).

4.4 Individual, family, and peer risk factors in relation to expectancies

At the individual, family, and peer levels, key predictors of both positive and negative e-cigarette expectancies included e-cigarette use in the household, curiosity about e-cigarettes, perceived risk, and perception of peer disapproval of e-cigarette use. These findings are consistent with previous studies that highlight the role of peer influence and parental use as contributors to adolescent attitudes toward e-cigarettes (25, 43, 44). The results underscore the importance of the social environment in shaping e-cigarette expectancies, for example, beliefs that their peers do not disapprove of e-cigarette use leading to higher positive expectancies, and the need to target these social factors in prevention efforts.

4.5 Limitations

Several limitations need to be considered when interpreting study findings. First, there was heterogeneity within racial/ethnic categories of "Black," "Latinx", and "White" that are not addressed here. Second, the analyses were cross-sectional and, therefore, only capture concurrent associations. Longitudinal data would be necessary to examine how e-cigarette expectancies change over time. Third, while these analyses included a wide range of demographic and psychosocial factors, there are other unmeasured risk and protective factors that contribute to e-cigarette expectancies.

4.6 Conclusions

Findings from the present study highlight the importance of considering differences by race/ethnicity in e-cigarette expectancies in the context of social determinants of health from a developmental perspective, and suggest intervention targets at multiple levels of influence. The endorsement of positive expectancies by Black, Latinx, and White middle-school-aged youths in this sample did not track with the patterns by race/ethnicity in the prevalence of e-cigarette use or expectancies in the high school years (5, 15). Together, the results suggest that as expectancies evolve across developmental periods, distinctions across racial/ethnic groups also shift. Critically, our hierarchical regression analysis approach revealed that most associations of race/ethnicity with e-cigarette expectancies were reduced after adjusting for social determinants of health, specifically SES and neighborhood disadvantage. Finally, the consistency across positive and negative expectancies in the relevance of perceived risk, perceived peer disapproval, and curiosity about e-cigarettes suggest multiple potential targets for early prevention efforts.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: Data used in the preparation of this article were obtained from the Adolescent Brain Cognitive Development (ABCD) Study (https://abcdstudy.org), held in the NIMH Data Archive (NDA). A full list of supporters is available at https://abcdstudy.org/federal-partners.html. A listing of participating sites and a complete listing of the study investigators can be found at https://abcdstudy.org/consortium_members/. ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in the analysis or writing of this report. Requests to access these datasets should be directed to https://abcdstudy.org.

Ethics statement

A centralized Institutional Review Board approved the ABCD study protocols. Parents provided written informed consent, and the youths provided assent for ABCD study participation. The use of pre-existing, non-identifiable data for these secondary data analyses was approved by the Rutgers University Human Research Protections Office. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

JT: Conceptualization, Data curation, Methodology, Software, Visualization, Writing – original draft. TC: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing. NK: Data curation, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. SL: Writing – review & editing, Formal analysis, Data curation, Methodology, Supervision, Visualization. MP: Data curation, Formal analysis, Writing – review & editing. CS: Conceptualization, Funding acquisition, Project administration, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

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EDITED BY
Anita Cservenka,
Oregon State University, United States

REVIEWED BY
Catherine Nagawa,
University of Oklahoma Health Sciences Center, United States
Sarah S. Dermody,
Toronto Metropolitan University, Canada
Denise Tran,
University of Southern California, United States

*CORRESPONDENCE
Magdalena Kozela
m.kozela@uj.edu.pl

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Socioeconomic status and its limited influence on perceptions of heated tobacco products and cigarettes: no relation with physical health, but association with mental health benefits and lower sensitivity to peer pressure

Magdalena Kozela[1]*, Janusz Sytnik-Czetwertyński[2], Maciej Polak[1], Barbara Gradowicz-Prajsnar[1] and Maciej Rogala[3]

[1]Department of Epidemiology and Population Studies, Jagiellonian University Medical College, Krakow, Poland, [2]Centre of Postgraduate Medical Education, Warsaw, Poland, [3]Department of Health Policy and Management, Jagiellonian University Medical College, Krakow, Poland

Introduction: Socioeconomic status is related with individuals' attitudes toward health behaviors and perceptions of risk. This study investigated the relationships between socioeconomic status and perceptions of the impact of heated tobacco products (HTPs) and cigarette smoking on the physical, mental, and social well-being of users.

Methods: A cross-sectional study was conducted using a population-based random sample of 2,500 HTP users and former smokers over the age of 25. The computer-assisted web interview (CAWI) method was employed to gather data. Information on gender, age, education, place of residence, income, and detailed perceptions of the impact of HTPs use and cigarette smoking on physical, mental, and social well-being was collected. A socioeconomic status score was derived based on education and income data. Multivariable multinomial regression analysis was used to assess the impact of socioeconomic status on perceptions of HTPs use and cigarette smoking in relation to physical, mental, and social well-being, controlling for age, place of residence, and perceived health status. The reference category was middle socioeconomic status and the middle category of perceived impact.

Results: A total of 2,254 participants were included in the analysis. Socioeconomic status was not related with perceptions of the impact of HTPs use or cigarette smoking on physical well-being. Compared to those with middle socioeconomic status, individuals with low socioeconomic status were more likely to perceive a positive impact of HTPs use on mental well-being (OR = 1.71, 95% CI: 1.12–2.60). Women with low socioeconomic status showed a stronger perception of being unaffected by peer pressure, both against smoking cigarettes and using HTPs (OR = 1.69, 95% CI: 1.11–2.57; OR = 1.53, 95% CI: 1.10–2.12, respectively).

Conclusion: While socioeconomic status did not differentiate perceptions of the impact of HTPs use or smoking on physical health, more tailored public health strategies that consider socioeconomic factors may be needed when addressing mental health perceptions and the influence of peer pressure.

KEYWORDS

socioeconomic status, heated tobacco products, tobacco, smoking, physical wellbeing, mental wellbeing, peer pressure

1 Introduction

Tobacco use is the leading preventable cause of death both in Europe and globally. Although the harmful effects of tobacco smoking have been well-established through reliable research for at least 70 years, population-based efforts to reduce smoking remain insufficient (1–3). The World Health Organization encourages the goal of becoming tobacco-free populations, where smoking prevalence does not exceed 5%. While a decline in cigarette smoking prevalence has been observed in Europe, the rate of decline is far too slow to achieve the target by 2030 (4). In Poland, it is estimated that over 20% of adults are regular smokers (5, 6). In Western European countries, the rate is slightly lower, but the most favorable rates are found in the Nordic countries. For example, in Sweden, the prevalence of tobacco smoking has fallen below 10% (6). As in other countries, cigarette smoking is strongly inversely related to socioeconomic status.

Heated tobacco products (HTPs), introduced in recent years, are designed to heat tobacco to a temperature high enough to release vapor without burning it and producing smoke. HTPs likely expose users to fewer toxins than cigarettes, but possibly more than not using any tobacco at all (7). A systematic review of the adverse effects of HTP use indicated that HTPs may be considered products with a reduced risk of chronic diseases for smokers, but they may increase the risk of these diseases in non-smokers (8). In July 2020, the U.S. Food and Drug Administration (FDA) granted limited authorization to market IQOS (an HTP produced by Philip Morris International) as a modified-risk tobacco product, allowing claims that IQOS reduces exposure to harmful chemicals, but not allowing claims that it reduces harm (9). Following the launch of HTPs in Japan, cigarette sales declined more rapidly, although it is uncertain whether this can be attributed to a switch from cigarettes to heated tobacco. Comparisons across countries suggest that nations with higher adoption rates of alternative nicotine products have achieved lower smoking rates. These findings suggest that the introduction of alternative nicotine products may help reduce smoking prevalence more quickly than focusing solely on prevention and smoking cessation (10). However, the results of the Cochrane review on the use of HTPs for smoking cessation and reducing smoking prevalence highlighted the limited reliability of analyses based on trend comparisons only (7).

In some countries, the use of HTPs has become very popular, reaching 11% of the total tobacco market in South Korea in 2020, and also in Japan (11, 12). Studies conducted in these populations revealed that the most common reasons for initiating HTPs use among all consumers were: curiosity (58.9%), family and friends using HTPs (45.5%), and an interest in the technology behind HTPs (35.9%). Regular use of HTPs was most often driven by the fact that they were less smelly than cigarettes (71.3%), beliefs that HTPs are less harmful to health than cigarettes (48.6%), and the perceived stress-reducing effects of HTPs (47.4%). Overall, about one-third of HTPs consumers reported using these devices to quit smoking, 14.7% used them to reduce smoking but not to quit, while half of all consumers (49.7%) used HTPs for other reasons, suggesting that the majority of HTPs users in South Korea had no intention of using them as an aid to quit smoking. In a Japanese study, the most common reasons for regular HTPs use were beliefs that HTPs are less harmful than cigarettes (90.6%), enjoyment (76.5%), and social acceptability (74.4%). Over half of smokers reported using HTPs as an aid to quit smoking. However, the other half used HTPs to replace some cigarettes, meaning they did not intend to quit smoking entirely. With this approach, the risk-reduction potential of HTPs, as suggested by toxicity studies, may be substantially diminished. Data from Europe show that, in 2017–2018, HTPs use remained limited in the general population. However, the dual use of these products alongside cigarettes, their high use among younger generations, and the interest in these products from non-smokers are concerning, as they may indicate a growing public health issue (13).

Data from HTPs users in Canada, England, the United States, and Australia indicated that cigarette smokers who used HTPs appeared more interested in quitting. Both the intention to quit smoking within 6 months and a history of failed quit attempts were positively associated with current HTPs use. It was reported that, compared to non-users, current HTP users were younger and had higher socioeconomic status (14). A Chinese study also confirmed a positive association between socioeconomic status and HTPs use, as well as the intention to use HTPs (15). Similarly, in South Korea, a positive association was found between socioeconomic status and subsequent HTPs use among ever-smokers (16). HTPs users were more likely than non-users to perceive HTPs as less harmful than cigarettes, and the stronger this perception, the more frequently HTPs were used. Smokers who had been exposed to HTPs advertising were more likely to perceive HTPs as less harmful than cigarettes (17). Socioeconomic status is not only associated with smoking behaviors but may also shape perceptions toward the health impacts of tobacco products. In Japanese study tobacco users were more likely to perceive HTPs as less harmful compared to non-users, but younger age and low education both among users and non-users were related to perception of lower harmfulness of HTPs compared to traditional cigarettes. The mechanisms linking socioeconomic status to perceptions of the health effects of HTPs use may involve several mechanisms, including variations in risk perception, health literacy, as well as differences in chronic stress or coping strategies across different social strata (18–21).

The primary aim of this study was to examine the relationship between socioeconomic status and perceptions of the impact of HTPs use and cigarette smoking on users' physical, mental, and social well-being.

2 Materials and methods

A cross-sectional study was conducted using a random population sample. Collaboration was established with the Public Opinion Research Center (Centrum Badania Opinii Społecznej - CBOS) as the

leading partner. CBOS is a publicly funded, independent research center, one of the largest and most renowned public opinion research institutes in Poland. Through CBOS, direct research contractors were engaged: the IQS Think Forward Research Institute and Pollster. Each contractor recruited study participants from their respective representative panels. Participants who met the following inclusion criteria were included: Polish citizenship, over 18 years of age, smoking cigarettes for at least 1 year in the past, and then - after quitting smoking use HTP only, for at least 6 months. These conditions were designed to ensure that the study sample represented individuals who currently use HTP but have ceased cigarette smoking. The study utilized the computer-assisted web interview (CAWI) method, with groups independently recruited by each contractor. The research was conducted simultaneously by both contractors, who adhered strictly to the same standardized research protocol, with the aim of examining at least 1,250 individuals.

The final study group consisted of 2,500 participants. The interview collected data on gender, age, education, place of residence, and income. Detailed self-reported information was gathered on the perceived impact of cigarette smoking or HTP use on fitness (endurance), mental health and perceived peer pressure against smoking cigarettes or using HTPs. Since the participant structure across the two research contractors was consistent, the data were combined, and the analysis was conducted on the entire sample.

Socioeconomic status was defined using the method developed by Kozakiewicz et al. in the WOBASZ Study, based on the experience from the ATTICA Study (22, 23). The socioeconomic status score was calculated by multiplying ordinal numerical values assigned to consecutive categories of education and income level. Education categories were as follows: primary = 1, vocational = 2, secondary = 3, bachelor's degree = 4, and master's degree or PhD = 5. Income in PLN was categorized as: <3,000 = 1, 3,000–4,999 = 2, 5,000–9,999 = 3, and ≥10,000 = 4. Responses indicating "I am supported by others," which accounted for approximately 4% of all responses, were excluded. The socioeconomic status score ranged from 1 to 20. For further analysis, participants were divided into three subgroups based on tertile distribution: low (0–5), medium (6–9), and high (7, 10–19) socioeconomic status. Given that the socioeconomic status index score was determined based on income and education, participants under the age of 25 could not achieve the highest possible score solely due to their age, as the completion of a Master's degree in Poland typically occurs at age 24. Inclusion of younger participants would result in a systematic decrease in the SES index, which would be attributable solely to age. To mitigate this possible bias, we decided to include only participants who were able to have reached their highest level of education by the age of 25.

Continuous variables were presented as medians with first and third quartiles (Q1-Q3). Categorical variables were reported as counts and percentages. Multivariable multinomial regression analysis was conducted, adjusting for age, place of residence, and perceived health status. The reference category was middle socioeconomic status (SES) and the middle category of perceived impact. The results were expressed as odds ratios (OR) with 95% confidence intervals (CI) and *p*-values. Given that men and women differ in the distributions of basic characteristics and that cultural gender differences may also play a role and the presence of significant interaction terms between the gender and socioeconomic status for some outcomes, gender-specific analyses were conducted. Results of combined analysis are also available in Supplementary Table 1. The analysis was done using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, 2021) or R version 4.0.5 (R Core Team, 2021, R Foundation for Statistical Computing, Vienna, Austria). p-values < 0.05 were considered statistically significant.

3 Results

A total of 2,254 participants (62% women) were included in the analysis (Figure 1). The median age in women was 35.5 years (Q1 = 30, Q3 = 44) and in men 40 years (Q1 = 33, Q3 = 49). In total sample 65% of participants had a university education (bachelor's degree or higher), but compared to men, higher proportion of women had university education (68% vs. 60%, respectively). Approximately half of the participants reported a monthly income between 3,000 and 4,999 PLN, but on average men had higher income and higher SES. About 15% of women and 12% of men declared living in rural areas, while the majority of respondents resided in small and medium-sized towns. Women assessed their health condition worse than men (24.3% vs. 33.6% of participants with very good or good perceived health, respectively). The most frequent experiences related to replacing cigarettes with HTPs were: feeling of increased comfort of life (27%) and motivation for major lifestyle changes (25%) in women while in men motivation for major lifestyle changes (28%) was followed by mobilization to decide to quit the addiction (23%). Regardless of gender, almost half of the participants stated they were well-informed about the harmful effects of cigarettes and HTPs. However, 15% of women and 14% of men admitted they were not informed about the harmfulness of smoking or using HTPs, but did not consider it necessary to be informed. Nearly three-quarters of participants indicated that state-provided information on the harmfulness of cigarettes is easily accessible, but only 36.2% found it sufficient (Table 1).

Table 2 presents the adjusted associations between socioeconomic status and the perceived impact of HTPs use or cigarette smoking on physical, mental, and social well-being. The perceived impact of HTPs use or cigarette smoking on fitness (endurance) was independent of the users' socioeconomic status. Socioeconomic status also did not differentiate the perception of the impact of cigarette smoking on mental health in women. However, compared to men with middle socioeconomic status, men with low socioeconomic status were 71% more likely to report a positive impact of HTPs use on mental health (OR = 1.71, 95% CI = 1.12–2.6). Women with low socioeconomic status were more likely to disregard peer pressure against smoking (OR = 1.95, 95% CI = 1.26–3.04) or HTPs use (OR = 1.54, 95% CI = 1.11–2.15) than women with medium socioeconomic status. Additionally, low socioeconomic status in women was associated with the perception of being unaffected by peer pressure against both smoking cigarettes and using HTPs (OR = 1.69, 95% CI = 1.11–2.57; OR = 1.53, 95% CI = 1.10–2.12, respectively).

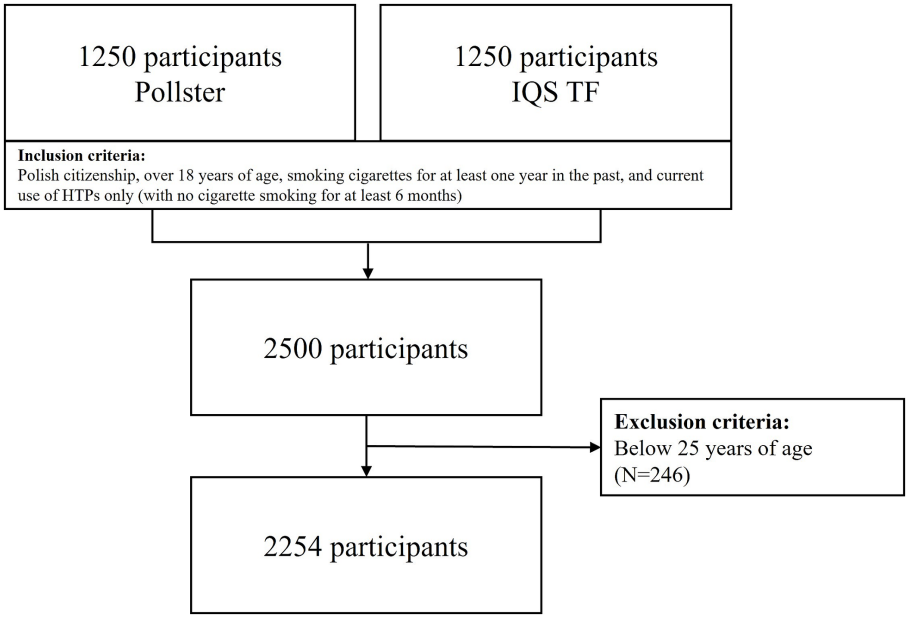

FIGURE 1
Study participants.

4 Discussion

Our results suggest that socioeconomic status does not differentiate the perception of the impact of cigarette smoking or HTPs use on physical well-being. This may be due to the widespread knowledge of the harmful effects of these substances, which appears to be similarly distributed across the population. As a result, no differences were observed based on socioeconomic status. However, low socioeconomic status was associated with the perception of a beneficial impact of HTPs use on mental well-being in men. This finding may reflect some cultural gender-specific factors that play a role in shaping men's perceptions of tobacco use, including newer tobacco alternatives. In women with low socioeconomic status, a strong independence from peer pressure against both cigarette smoking and HTP use was observed. This may reflect an internalized awareness of the harmful effects of tobacco use on their health and well-being.

In Korean studies among cigarette smokers, approximately half of the participants perceived both HTPs and nicotine vaping products as equally harmful as cigarettes. Over 25% of respondents considered HTPs less harmful than cigarettes, while nearly 8% viewed HTPs as more harmful than cigarettes (24). HTPs users tended to assess HTPs more favorably in terms of smoke, smell, harm, aid in quitting, design, and price compared to users of other products (25). American data indicated that about 50% of both ever and current HTPs users considered HTPs less harmful than cigarettes, and over 50% stated that HTPs are socially acceptable (26). Explanatory studies suggest that the perception of HTPs may largely depend on cultural factors. Positive evaluations of HTPs may be stronger in cultures that value purity, exclusivity, and technologically advanced aesthetics. In communities where cigarette smoking is seen as an expression of freedom and individualism, the value of HTPs may be perceived as lower (27). Additionally, this perception may vary within a single community, influenced by differences in socioeconomic status.

However, the majority of quantitative evidence on the perceived impact of cigarette smoking or HTPs use comes from high-income countries and does not explore further socioeconomic differences. Data from the United Kingdom provide deeper insight into the socioeconomic disparities associated with the use of alternative smoking products. A qualitative study of current and former HTPs users in London identified six key factors influencing the initiation and use of HTPs. In addition to health-related factors and the expected harm reduction or long-term financial benefits, sensory experiences such as discretion, cleanliness, reduced odor, and the practical benefits of accessibility in smoke-free environments were noted. Psychological factors, such as the similarity to smoking rituals and routines, as well as enhanced social interactions from using HTPs, were also identified (28). A cross-sectional study on e-cigarette use among former smokers in England found an overall increase in e-cigarette use among individuals who had not smoked for at least 1 year. However, the highest increase was observed among participants with low socioeconomic status (29). Additionally, the UK Household Longitudinal Study demonstrated that socioeconomic disadvantage was associated with e-cigarette use among ex-smokers (OR: 1.17; 95% CI: 1.09–1.26) (30). Moreover, Four Country Survey (ITC-4) showed that lower levels of education were associated with higher nicotine dependence across countries. Respondents with lower education had lower self-efficacy and were more likely to have no intention of quitting compared to those with higher income (31).

Our result of a positive impact of HTP use on mental well-being among male participants with low socioeconomic status is intriguing. Although the possibility that this finding may be attributable to random variation cannot be entirely ruled out, a review of the existing literature suggests notable gender differences in this regard. Cultural and gender-specific factors play a critical role in shaping men's perceptions of tobacco use, influencing both their attitudes toward traditional tobacco products and newer alternatives. Research has

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TABLE 1 Descriptive statistics of studied group.

	Women 1,380 (61.2)	Men 874 (38.8)	*p*-value
	Me	Q1-Q3	
Age [years]	35.5 (30–44)	40 (33–49)	**<0.001**
	n	%	
Education			
Primary	9 (0.6)	14 (1.6)	**0.001**
Vocational	121 (8.8)	93 (10.6)	
Secondary school	316 (22.9)	245 (28.0)	
Bachelor degree	378 (27.4)	206 (23.6)	
Master or PhD	556 (40.3)	316 (36.2)	
Monthly income			
0–2,999 PLN	402 (29.1)	126 (14.4)	**<0.001**
3,000–4,999 PLN	684 (49.6)	423 (48.4)	
5,000–9,999 PLN	241 (17.5)	255 (29.2)	
≥10,000 PLN	53 (3.8)	70 (8.0)	
Socioeconomic status			
Low	449 (32.6)	175 (20.0)	**<0.001**
Middle	391 (28.3)	329 (37.7)	
High	540 (39.1)	370 (42.3)	
Place of residence			
Countryside	213 (15.4)	105 (12.0)	**<0.01**
City less than 50,000 inhabitants	421 (30.5)	316 (36.2)	
City 50.000–1 00.0000 inhabitants	447 (32.4)	260 (29.7)	
City 500.000 inhabitants or more	299 (21.7)	193 (22.1)	
Perceived health			
Very good or good	335 (24.3)	294 (33.6)	**<0.001**
Moderate or bad	1,045 (75.7)	580 (66.4)	
Experiences related to replacing cigarettes with HTP			
Mobilization to decide to quit the addiction	266 (19.3)	199 (22.8)	**0.001**
Motivation for major lifestyle changes	351 (25.4)	244 (27.9)	
Last resort to quit smoking	188 (13.6)	141 (16.1)	
Feeling of increased comfort of life	375 (27.2)	178 (20.4)	
No change	200 (14.5)	112 (12.8)	
Being well informed about the harmfulness of cigarettes and HTP			
No. not considered necessary	210 (15.2)	122 (13.9)	0.44
No. do not know where to get information from	265 (19.2)	150 (17.2)	
Yes. Knows everything considered necessary	649 (47.0)	429 (49.1)	
Yes. But there is a need for additional support	256 (18.6)	173 (19.8)	
State information on the of harmfulness of cigarettes			
Easily accessible and sufficient	500 (36.2)	315 (36.0)	0.62
Easily accessible but insufficient	516 (37.4)	325 (37.2)	
Hardly accessible. But sufficient	165 (12.0)	119 (13.6)	
Hardly accessible and insufficient	199 (14.4)	115 (13.2)	
Perceived impact of smoking cigarettes on fitness (endurance)			
Good	146 (10.6)	109 (12.5)	**0.03**
No	380 (27.5)	199 (22.8)	
Bad	854 (61.9)	566 (64.7)	

(Continued)

TABLE 1 (Continued)

	Women 1,380 (61.2)	Men 874 (38.8)	*p*-value
Perceived impact of HTP use on fitness (endurance)			
Good	326 (23.6)	191 (21.9)	0.42
No	655 (47.5)	410 (46.9)	
Bad	399 (28.9)	273 (31.2)	
Perceived impact of HTP use on mental condition			
Good	397 (28.8)	245 (28.0)	0.36
No	829 (60.1)	514 (58.8)	
Bad	154 (11.1)	115 (13.2)	
Thoughts about returning to smoking cigarettes			
No	883 (64.0)	532 (60.9)	**0.03**
Do not know	320 (23.2)	245 (28.0)	
Yes	177 (12.8)	97 (11.1)	
Perceived peer pressure against smoking cigarettes			
Often	777 (56.3)	484 (55.4)	0.47
Rarely	398 (28.8)	271 (31.0)	
Never	205 (14.9)	119 (13.6)	
Perceived peer pressure against using HTP			
Often	297 (21.5)	180 (20.6)	0.35
Rarely	730 (52.9)	489 (55.9)	
Never	353 (25.6)	205 (23.5)	
Influence of peer pressure against smoking cigarettes			
Great	810 (58.7)	532 (60.9)	0.20
Little	298 (21.6)	196 (22.4)	
No	272 (19.7)	146 (16.7)	
Influence of peer pressure against using HTP			
Great	438 (31.7)	319 (36.5)	**0.007**
Little	477 (34.6)	312 (35.7)	
No	465 (33.7)	243 (27.8)	

HTP, heated tobacco products; PLN, Polish zloty; Significant results in bold.

shown that gender norms can affect how men engage with tobacco use and it is associated with masculinity in many cultures. Scoping review by Kodriati et al. revealed that men often associated their smoking behavior with perceptions of being powerful, being emotionally stable, being in control, and having self-reliance. This cultural context and the fact that HTPs are often presented as a "healthier" alternative to traditional cigarettes may influence men's attitudes toward tobacco use, shaping their perception of its potential mental health benefits (32). Also, men are more likely to use substances like tobacco to cope with stress and negative emotions (33). As a result, tobacco use, including HTPs, may be perceived by men as a means of stress relief or improvement of mental well-being, particularly for those in lower socioeconomic status groups who may face greater stressors.

Public health communications that emphasize the potential negative psychological effects of both cigarette smoking and HTPs use, including mental health distress and the risk of addiction, could play a crucial role in reshaping these perceptions. It is particularly important to highlight the risks associated with HTPs use not only for physical health but also for mental well-being, especially within lower socioeconomic groups, as these individuals appear to underestimate or overlook such threats.

Population studies have identified peer pressure as a key factor influencing smoking behavior patterns. It has been found that individuals with a partner who objects to smoking, those who experience peer pressure to quit, or people living in smoke-free homes are more likely to attempt to quit smoking (34–38). Conversely, higher social acceptance has been observed regarding HTPs use, and interestingly, a substantial proportion of users acquired their devices as gifts from relatives or friends (39). It is also known that gender plays a role in susceptibility to peer pressure, with slightly more boys than girls being vulnerable to peer pressure (40). Our finding of women's independence from peer pressure against smoking or HTPs use aligns with the results of a study by Tsai et al., which suggested that social peer pressure is more influential on smoking behaviors in men, whereas women are more likely to use smoking as a coping mechanism for psychological distress (41). While available evidence does not fully explain the relationship, it raises questions about the causes of differences in perceptions of peer pressure against smoking or HTPs use, especially by socioeconomic status. In the case of HTPs use in Polish society, it seems plausible that individuals higher in the social hierarchy may be more susceptible to peer pressure.

TABLE 2 The associations between socioeconomic status and perceived impact of smoking or HTP use on physical, mental well-being and perceived peer pressure in men and women.

Socioeconomic status	Women					Men				
	OR[a] (95%CI)	*p*-value		OR[a] (95%CI)	*p*-value	OR[a] (95%CI)	*p*-value		OR[a] (95%CI)	*p*-value
	Perceived impact of smoking cigarettes on fitness (endurance)					Perceived impact of smoking cigarettes on fitness (endurance)				
	Good		No	Bad		Good		No	Bad	
Low	1.33 (0.8–2.21)	0.279	Ref.	0.93 (0.68–1.27)	0.631	1.81 (0.95–3.45)	0.072	Ref.	0.7 (0.44–1.12)	0.138
Mod	Ref.		Ref.	Ref.		Ref.		Ref.	Ref.	
High	1.57 (0.96–2.59)	0.075	Ref.	1.08 (0.8–1.46)	0.624	1.21 (0.69–2.13)	0.511	ref.	0.73 (0.5–1.06)	0.097
	Perceived impact of HTP use on fitness (endurance)					Perceived impact of HTP use on fitness (endurance)				
	Perceived impact of smoking cigarettes on mental condition					Perceived impact of smoking cigarettes on mental condition				
	Good		No	Bad		Good		No	Bad	
Low	0.91 (0.61–1.34)	0.616	ref.	1.06 (0.76–1.46)	0.744	1.24 (0.74–2.06)	0.416	Ref.	0.89 (0.58–1.36)	0.591
Mod	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	
High	1.1 (0.76–1.58)	0.607	ref.	0.79 (0.58–1.08)	0.146	1.31 (0.85–2.02)	0.224	Ref.	1.25 (0.87–1.77)	0.224
	Perceived impact of HTP use on mental condition					Perceived impact of HTP use on mental condition				
	Good		No	Bad		Good		No	Bad	
Low	0.84 (0.62–1.15)	0.289	Ref.	1.27 (0.8–2.01)	0.311	**1.71 (1.12–2.6)**	**0.012**	Ref.	1.22 (0.69–2.17)	0.492
Mod	Ref.		Ref.	Ref.		Ref.		Ref.	Ref.	
High	1.01 (0.76–1.36)	0.924	Ref.	1.26 (0.8–1.98)	0.324	1.01 (0.71–1.45)	0.939	Ref.	1.14 (0.72–1.83)	0.577
	Thoughts about returning to smoking cigarettes					Thoughts about returning to smoking cigarettes				
	No		Do not know	Yes		No		Do not know	Yes	
Low	0.92 (0.66–1.29)	0.624	Ref.	1.14 (0.72–1.81)	0.589	1.08 (0.7–1.66)	0.723	Ref.	0.54 (0.26–1.12)	0.098
Mod	Ref.		Ref.	Ref.		Ref.		Ref.	Ref.	
High	0.98 (0.71–1.36)	0.916	Ref.	0.74 (0.46–1.19)	0.211	0.95 (0.67–1.35)	0.78	Ref.	0.84 (0.5–1.42)	0.506
	Perceived peer pressure against smoking cigarettes					Perceived peer pressure against smoking cigarettes				
	Often		Rarely	Never		Often		Rarely	Never	
Low	0.92 (0.67–1.27)	0.622	Ref.	**1.95 (1.26–3.04)**	**0.003**	0.73 (0.48–1.12)	0.154	Ref.	1.07 (0.59–1.93)	0.83
Mod	Ref.		Ref.	Ref.		Ref.		Ref.	Ref.	
High	1.01 (0.75–1.37)	0.932	Ref.	0.98 (0.62–1.55)	0.943	**0.62 (0.44–0.87)**	**0.007**	Ref.	0.67 (0.4–1.11)	0.118
	Perceived peer pressure against using HTP					Perceived peer pressure against using HTP				
	Often		Rarely	Never		Often		Rarely	Never	
Low	1.16 (0.81–1.66)	0.409	Ref.	**1.54 (1.11–2.15)**	**0.01**	0.8 (0.48–1.33)	0.386	Ref.	1.13 (0.72–1.78)	0.583
Mod	Ref.		Ref.	Ref.		Ref.		Ref.	Ref.	
High	1.24 (0.89–1.74)	0.205	Ref.	1.03 (0.75–1.43)	0.845	1.02 (0.69–1.51)	0.915	Ref.	0.94 (0.64–1.37)	0.736

(Continued)

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TABLE 2 (Continued)

Socioeconomic status	Women ORᵃ (95%CI)	p-value		Women ORᵃ (95%CI)	p-value	Men ORᵃ (95%CI)	p-value		Men ORᵃ (95%CI)	p-value
	Influence of peer pressure against smoking cigarettes					Influence of peer pressure against smoking cigarettes				
	Great		Little	No		Great		Little	No	
Low	0.97 (0.69–1.37)	0.87	Ref.	**1.69 (1.11–2.57)**	**0.015**	1.39 (0.86–2.24)	0.178	Ref.	1.19 (0.63–2.23)	0.589
Mod	Ref.		Ref.	Ref.		Ref.		Ref.	Ref.	
High	1.28 (0.92–1.77)	0.142	Ref.	1.04 (0.68–1.6)	0.86	0.87 (0.6–1.26)	0.449	Ref.	1.05 (0.65–1.71)	0.835
	Influence of peer pressure against using HTP					Influence of peer pressure against using HTP				
	Great		Little	No		Great		Little	No	
Low	1.29 (0.91–1.83)	0.159	Ref.	**1.53 (1.1–2.12)**	**0.011**	1.03 (0.66–1.61)	0.889	Ref.	1.15 (0.72–1.82)	0.568
Mod	Ref.		Ref.	Ref.		Ref.		Ref.	Ref.	
High	**1.48 (1.07–2.05)**	**0.017**	Ref.	0.86 (0.62–1.18)	0.347	1.38 (0.96–1.99)	0.081	ref.	1.44 (0.98–2.13)	0.065

[a]Adjusted for age, place of residence, and perceived health status; Significant results in bold.

There are several limitations in interpreting the results that should be considered. First, the study assessed respondents' perceptions of their feelings, rather than objective measures of their physical and mental health or social functioning. Second, the study group likely consisted of healthier individuals with a higher-than-average socioeconomic status, which may have led to an underestimation of the relationships examined. However, this profile is representative of HTPs users in the Polish population, so the findings can be generalized to this group. To facilitate a comparison between HTPs use and cigarette smoking, former smokers who were current HTP users were included in the study. This may have influenced their perception of cigarettes, potentially leading them to assess cigarettes more negatively and HTP use more favorably, although this effect likely applies uniformly across the entire study group.

Despite the limitations, there are several notable strengths that should be highlighted. This is the first large-scale survey on HTP use conducted in Central and Eastern Europe, a region still facing a slow decline in the prevalence of cigarette smoking. The study uniquely addressed socioeconomic differences in the perception of HTPs and cigarette smoking, offering new insights into this area of research. A large, representative sample of people who use HTP but do not smoke cigarettes was drawn from two independent polling stations, ensuring a similar distribution of sociodemographic characteristics among respondents. Standard research methods were employed, and a well-defined protocol was followed to minimize systematic errors. Associations were assessed after adjusting for potential confounders.

5 Conclusion

Low socioeconomic status is related with perceived positive impact of HTP use on the mental well-being of male users, independent of age, place of residence, and self-rated health. Women from lower socioeconomic backgrounds may exhibit greater resistance to peer pressure regarding tobacco use. The unique findings related to psychological well-being in men and resilience to peer pressure in women provide a foundation for more targeted research and interventions. The observed differences in mental health perceptions and sensitivity to peer pressure suggest that tailored messages are needed to address the diverse ways individuals perceive the impact of smoking alternatives like HTPs, as well as to promote healthier coping strategies. Overall, the study findings emphasize the importance of tailoring public health strategies to address the nuanced needs of different socioeconomic groups. While socioeconomic status did not significantly differentiate perceptions of the physical health effects of tobacco, it clearly influences mental health perceptions and the ability to resist peer pressure. Therefore, planned interventions probably should go beyond generic health messaging and include targeted approaches that address both mental health and peer dynamics, particularly for low SES individuals who may be more vulnerable to misperceptions or external social pressures.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans because the participants in this study are respondents of contractors with whom they cooperate on the basis of separate agreements. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MK: Conceptualization, Methodology, Writing – original draft. JS-C: Conceptualization, Funding acquisition, Investigation, Methodology, Writing – review & editing, Supervision. MP: Conceptualization, Formal analysis, Methodology, Writing – review & editing. BG-P: Conceptualization, Data curation, Methodology, Writing – review & editing. MR: Conceptualization, Methodology, Writing – review & editing.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2025.1586447/full#supplementary-material

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EDITED BY
Alessandra Maria Passarotti,
University of Illinois Chicago, United States

REVIEWED BY
Tim Durazzo,
Stanford University, United States
Frances Leslie,
University of California, Irvine, United States

*CORRESPONDENCE
Joanna Jacobus
✉ jjacobus@health.ucsd.edu

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Age of onset of nicotine use and severity of nicotine addiction symptoms are associated with hippocampal volume in late adolescents and emerging adults

Joseph P. Happer[1], Kelly E. Courtney[1], Rachel E. Baca[1], Gianna Andrade[1], Qian Shen[2], Thomas T. Liu[3,4] and Joanna Jacobus[1]*

[1]Department of Psychiatry, University of California San Diego, San Diego, CA, United States, [2]Department of Neurosciences, University of California San Diego, San Diego, CA, United States, [3]Center for Functional MRI, University of California San Diego, San Diego, CA, United States, [4]Department of Radiology, University of California San Diego, San Diego, CA, United States

Background: Despite declining use of traditional combustible cigarettes, the use of nicotine and tobacco-related products (NTPs) remains high among adolescents and emerging adults largely due to the use of e-cigarettes. Adolescents and emerging adults who initiate e-cigarette use reach comparable indices of nicotine dependence as traditional cigarette smokers and can report symptoms of dependence even before developing a pattern of daily use. Symptoms such as craving, positive and negative reinforcement, and biological markers of toxicity are closely linked to the development and persistence of substance use problems. Adolescents/emerging adults may transition to dependence more quickly than adults, and the age of onset of regular NTP use is a highly predictive risk factor for future use and problems. Within the brain, the hippocampus is particularly sensitive to the effects of nicotine and may play a role in the transition from NTP initiation to more habitual and even problematic use.

Methods: A cross-sectional sample of healthy, NTP-using late adolescents/emerging adults ($N = 86$) ages 16–22 completed a structural MRI to examine whether subjective nicotine craving, stronger positive and negative reinforcement, elevated cotinine levels, and earlier age of onset of regular nicotine use would be associated with hippocampal volumes.

Results: Across measures of nicotine addiction, linear regression models revealed an interaction between symptoms and age of onset of regular use. A general pattern emerged such that greater symptom severity and younger age of onset of regular use was associated with larger hippocampal volumes.

Conclusions: These findings provide potential insight into the relationship between late adolescent/emerging adult brain health and a risk factor for NTP initiation and symptoms of nicotine addiction. Greater understanding of these interactions is essential for informing prevention, intervention, and public health policy.

KEYWORDS

hippocampus, age of onset, nicotine, vaping, adolescent, emerging adult

Introduction

While the use of combustible cigarettes has declined among late adolescents and emerging adults [AEAs, (1, 2)], the prevalence of nicotine and tobacco-related products (NTPs) remains high (1, 3, 4), largely due to the increased use of e-cigarettes (2, 5). Although e-cigarettes were initially marketed as tools for cigarette cessation (6, 7), AEAs have frequently been targeted with digital advertising by tobacco companies (8, 9), which may contribute to reductions in perceived risk and more favorable attitudes towards e-cigarette use (10–12). E-cigarettes provide similar or possibly greater nicotine delivery per puff as compared to combustible cigarettes (13), and vaping further allows for easy consumption across the day leading to increased use, intensity, and nicotine exposure (14, 15). AEAs who initiate use of e-cigarettes reach comparable indices of nicotine dependence as cigarette users (16–18) highlighting the highly addictive nature of nicotine for AEAs (19–21). Notably, use of e-cigarettes among AEAs has been associated with problematic substance use including alcohol and cannabis misuse (22–25). Therefore, understanding the associations between known risk factors for the initiation of e-cigarettes and other nicotine use, the progression to nicotine dependence, and their impact for brain health is crucial for informing prevention, intervention, and public health policy.

Craving, positive and negative reinforcement (e.g., pleasurable effects, escaping unpleasant states), and biological markers of toxicity (i.e., the accumulation of harmful metabolites in the body) are closely linked to the development and persistence of substance use problems. Substance dependence can generally be defined as intense cravings for the substance of choice, development of tolerance, and loss of autonomy over use despite potential negative consequences (26). Consistent with this definition, reports of initial symptoms of nicotine dependence among AEAs have included intense craving or desire to use, feelings of loss of control, withdrawal, and tolerance (19, 27–29). These symptoms have been associated with increased risk for continued and even escalated NTP use (19, 27–30). Initial pleasurable experiences with NTPs can similarly predict future use as well as severity of dependence symptoms among AEAs (28). This pattern maps on to models of addiction in which substances such as nicotine are often initiated for their hedonic effects and continued due to positive reinforcement of those experiences (26). Repeated use of nicotine can then lead to tolerance and the need for greater consumption (26). Consistent with more intense NTP use, higher levels of cotinine, the primary metabolite of nicotine, have been associated with greater symptoms of dependence in AEAs, potentially reflecting greater physiological dependence and thus neurobiological changes (31–33). This is particularly concerning as AEAs may report dependence symptoms even before developing a pattern of daily use (20, 34), suggesting heightened sensitivity to the effects of nicotine (35).

Age of onset of regular substance use is also a highly predictive risk factor for future use and dependence (36–40). Individuals who regularly engage in NTP use at younger ages are at increased risk of developing nicotine dependence (36, 39, 40) and may transition to dependence more quickly than adults and even older AEAs (37, 39). Indeed, AEAs may develop nicotine dependence even after minimal exposure (19–21, 27, 28, 34), and nicotine exposure during adolescence/emerging adulthood may uniquely impact brain health compared to older adults (35, 41–43), underscoring the heightened sensitivity of this developmental period to substance use (44). This may be related to nicotine's binding to nicotinic acetylcholine receptors (nAChRs), which can alter nACHRs expression and function (42). These receptors are distributed throughout the brain (42) and may play a role in the gray and white matter morphometric changes observed in association with AEA NTP use (45–51). In particular, the hippocampus is dense with nAChRs (42) and is involved with reinforcement learning and episodic memory of rewarding stimuli (52), which may be particularly heightened in AEAs (41). Nicotine may also enhance dopaminergic transmission within the nucleus accumbens and dorsal striatum, regions heavily implicated in reward processing and the development of substance dependence (41, 52).

We recently reported greater cumulative 6-month NTP use was associated with larger bilateral hippocampal volumes in a sample of AEAs (49). Given greater cumulative use is associated with more severe dependence (19, 27–30) as well as younger age of onset of use (36, 37, 39, 40), in this report we sought to examine these relationships with hippocampal volumes within the sample of AEAs who had initiated regular NTP use. More specifically, we hypothesized that indicators of problematic NTP use, including greater subjective nicotine craving, stronger positive and negative reinforcement, elevated cotinine levels, and earlier age of onset of regular NTP use would be associated with larger hippocampal volumes.

Methods

Participants and procedures

Eighty-six participants were selected for this analysis from a larger study on the effects of nicotine and cannabis co-use on brain structure and function during late adolescence/emerging adulthood. As previously reported (48, 53), participants were recruited via flyers posted physically and electronically at schools, community colleges, four-year universities, and social media sites targeting San Diego County. Recruitment was stratified based on use of NTPs, cannabis products, or both during the previous 6-month period to ensure variability in NTP and cannabis use.

Exclusion criteria included >10 lifetime episodes of illicit substance use; lifetime DSM-5 psychiatric diagnoses other than tobacco and/or cannabis use disorder; acute influence of cannabis or alcohol use at study visit; use of any psychoactive medications; major medical problems; MRI contraindications; or history of prenatal substance exposure or developmental disability.

Participants completed a single 4-hour session consisting of a battery of interviews, self-report assessments covering demographic information, mental health, substance use, and neurocognitive

functioning, which was followed by an MRI session. Before beginning the study session, all participants gave written informed consent (≥18 years old) or parental consent and participant assent (<18 years old). Participants were asked to refrain from using cannabis and alcohol 12 h prior to the appointment, which was confirmed with oral fluid, urine, and breathalyzer. Urine samples were used to confirm abstinence from illicit substances. Participants abstained from caffeine for at least 30 minutes prior to MRI scanning. They were not required to abstain from NTP use to avoid nicotine withdrawal effects during testing. Time of last NTP use was documented. All procedures were approved by the University of California, San Diego Human Research Protections Program.

Measures

Demographic data (e.g., age, sex at birth, race/ethnicity, education) were obtained from a psychosocial interview. To assess quantity and frequency of NTP and cannabis use, the Customary Drinking and Drug Use Record structured interview (54) was used, including a modification to include additional nicotine and cannabis questions (55–57). Lifetime use of nicotine, cannabis and alcohol were estimated in terms of independent episodes, allowing for multiple uses to be reported within a single day (e.g., first thing in the morning, again before bed). Participants were asked to provide additional details related to each substance reported including age at first use and onset of regular (at least weekly) use.

As part of the assessment, participants completed a range of self-report questionnaires related to their NTP use experiences. Severity of nicotine dependence was assessed using the Hooked on Nicotine Checklist [HONC, (58)]. They completed an adapted Smoking Consequences Questionnaire [SCQ, (59)] with questions specific to e-cigarette use. Four subscales can be calculated from the SCQ: negative consequences, positive reinforcement, negative reinforcement, and weight control. For the purposes of this study, only the positive and negative reinforcement subscales were included in analyses. To examine nicotine craving, participants completed the 10-item version of the Questionnaire on Smoking Urges, which was modified to reflect both cigarette and vaping urges, and a total score was computed [QSU, (60, 61)]. Acute nicotine exposure was examined through quantification of urine cotinine levels, which is nicotine's major metabolite (quantification conducted by Redwood Toxicology). Cotinine values were capped at 500 ng/ml per Redwood Toxicology's standard procedures. See Table 1 for a complete description of the sample demographics and substance use characteristics.

TABLE 1 Sample demographics and characteristics.

Characteristic	$N = 86$[a]
Age	19.9 [16.0–22.0]
% Male	63% (54)
Race/Ethnicity	
% White	57% (49)
% Hispanic	34% (29)
Education (years completed)	13.5 [10.0–16.0]
NIH toolbox crystalized composite (age-corrected)	106 [83–146]
Estimated lifetime alcohol episodes	209 [5–978]
Estimated lifetime cannabis use episodes	1,149 [0–14,566]
Days since last cannabis use	40 [0–1,070]
Estimated lifetime NTP use episodes	7,738 [14–87,010]
Age of onset of regular NTP use	18.09 [13.00–22.00] IQR [17, 19]
Years of regular NTP use	1.85 [0.00–7.00]
Days since last NTP use	10 [0–284]
Number of cigarettes previous 6 months	57 [1–1,000]
Urine cotinine (ng/ml)	260 [0–500]
HONC total score	5.1 [0.0–10.0]
SCQ: positive reinforcement total score	13 [0–45]
SCQ: negative reinforcement total score	20 [0–63]
QSU total score	18 [10–63]

[a]Mean [Range]; % (*n*); IQR, interquartile range; NTP, nicotine and tobacco-related product; HONC, hooked on nicotine checklist; SCQ, smoking consequences questionnaire; QSU, questionnaire of smoking urges.

Imaging acquisition and processing

Participants were scanned on a 3.0 Tesla GE Discovery MR750 scanner with a 32-channel receive head coil at the UCSD Center for Functional MRI. A high-resolution T1-weighted anatomical fast spoiled gradient echo (FSPGR) scan was acquired with TI/TE/TR = 1,060/2/2,500 ms, 256 × 256 matrix, flip angle = 8°, FOV = 256 mm, 1.0 mm^3 voxels. Brain images for each participant were spatially normalized, field-bias corrected, and segmented using the Freesurfer pipeline [version 6.0, (62, 63)]. To identify errors made during the Freesurfer reconstruction process, one rater (QS), blind to participant characteristics, followed the reconstruction procedures to correct any errors made during the cortical and subcortical reconstruction process. This involved verification of the automated skull stripping and a slice-by-slice inspection of the gray/white and gray/cerebral spinal fluid surfaces. Modifications to the surfaces were made as necessary to correct for tissue misclassifications (e.g., residual dura mater classified as cortex). Right and left hippocampal volumes and an estimate of total brain volume ("BrainSegVolNotVent") were extracted for analyses.

Data analyses

Data analyses were conducted using R (v4.3.2). Estimates of bilateral hippocampal volumes were examined using individual linear regressions that modeled the interaction between age of onset of regular NTP use and four indices of nicotine addiction severity including: (1) severity of acute nicotine exposure quantified in urine cotinine values; (2) the self-reported positive and negative reinforcing effects of nicotine (SCQ subscales); (3) the craving and urge to use NTPs (QSU total); and (4) nicotine dependence symptoms (HONC total). Total brain volume, current age, sex assigned at birth, and lifetime alcohol, cannabis, and NTP use episodes were included in the models as covariates.

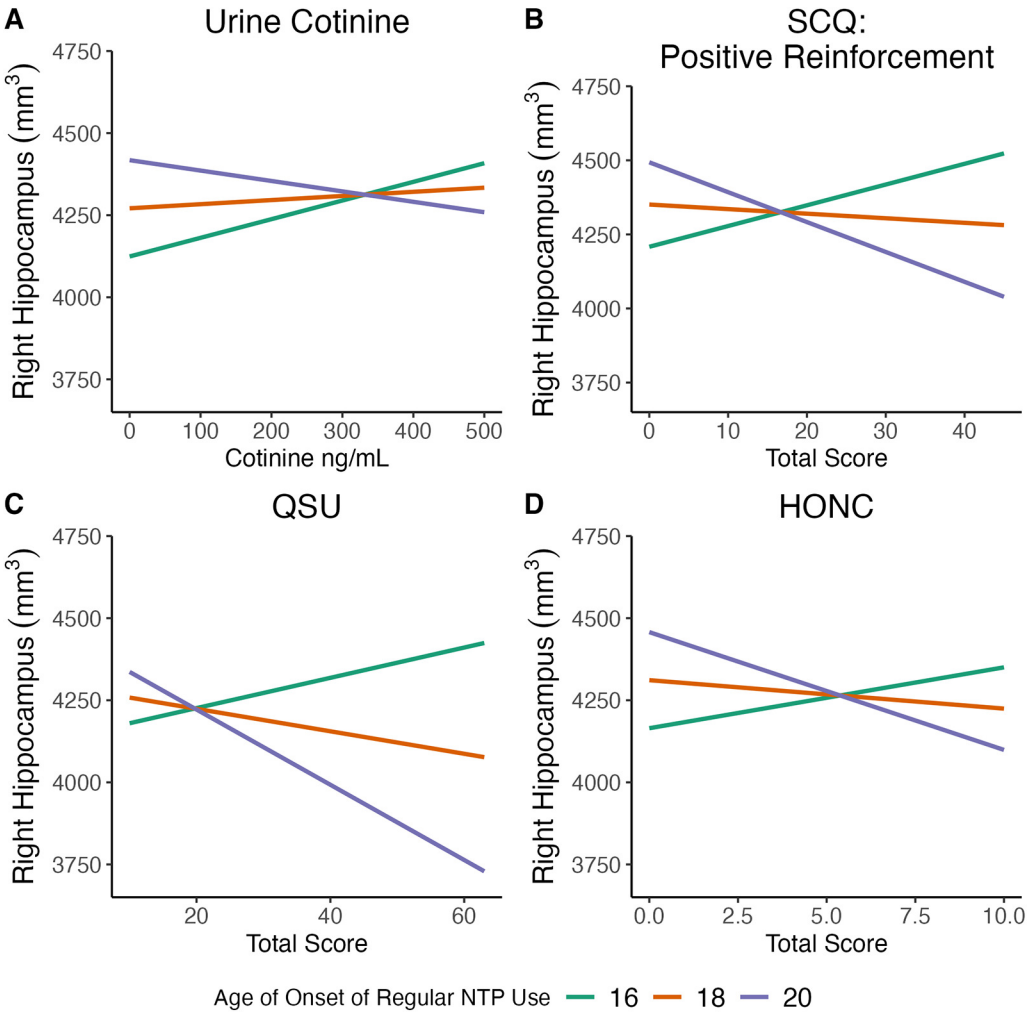

FIGURE 1
Significant relationships were observed between age of onset of regular use of nicotine and tobacco-related products (NTPs) and measures of nicotine addiction severity on (right) hippocampal volume. Measures of nicotine addiction severity included **(A)** urine cotinine; **(B)** Smoking Consequences Questionnaire (SCQ): positive reinforcement; **(C)** Questionnaire on Smoking Urges (QSU); and **(D)** Hooked on Nicotine Checklist (HONC). Data presented are for visualization purposes only and represent trend lines for age of onset of regular NTP use mean age (18 years old) ± 1 SD (20 and 16 years old, respectively).

Results

Cotinine

Regression models were used to examine the relationship between urine cotinine and age of onset of regular NTP use with bilateral hippocampal volumes, controlling for current age, sex, lifetime alcohol, cannabis, and NTP use, and estimated brain volume. Results indicated a significant age of regular use x cotinine interaction for both the left and right hippocampal volumes (Left: $B = -0.17$, $t = -2.4$, $p = 0.021$; Right: $B = -0.22$, $t = -2.7$, $p = 0.010$) (Figure 1A, left not shown). This inverse relationship suggests that as age of regular use of NTPs became younger, hippocampal volumes were larger as a function of increasing cotinine values. Current age, sex, and lifetime alcohol, cannabis, and NTP use were not significant covariates ($ps > 0.1$), though estimated brain volume was a significant covariate for both left and right volumes ($ps < 0.0001$).

Smoking consequences questionnaire: positive reinforcement

Regression models were used to examine the relationship between the self-reported positive reinforcing effects of nicotine as measured by the SCQ and age of onset of regular NTP use with bilateral hippocampal volumes, controlling for current age, sex, lifetime alcohol, cannabis, and NTP use, and estimated brain volume. Results indicated a significant age of regular use x positive reinforcement interaction for both the left and right hippocampal volumes (Left: $B = -2.4$, $t = -2.2$, $p = 0.03$; Right: B: -4.3, $t = -3.4$, $p = 0.001$) (Figure 1B, left not shown). The inverse relationship indicates that hippocampal volumes increased as a function of younger regular use of NTPs and higher positive reinforcement from NTP use. Current age, sex, and lifetime alcohol, cannabis, and NTP use were not significant covariates ($ps > 0.2$), though

estimated brain volume was a significant covariate for both volumes ($ps < 0.0001$).

Smoking consequences questionnaire: negative reinforcement

Regression models were used to examine the relationship between the self-reported negative reinforcing effects of nicotine as measure by the SCQ and age of onset of regular NTP use with bilateral hippocampal volumes, controlling for current age, sex, lifetime alcohol, cannabis, and NTP use, and estimated brain volume. A trend was observed between age of first regular use and negative reinforcement for the right hippocampal volume ($B = -2.3$, $t = -1.9$, $p = 0.06$), though not for the left ($p > 0.6$). The inverse relationship, though not significant, indicates that hippocampal volumes increased as a function younger age of onset of regular use and higher negative reinforcement from NTP use. Current age, sex, and lifetime alcohol, cannabis, and NTP use were not significant covariates ($ps > 0.4$), though estimated brain volume was significant ($p < 0.0001$).

Questionnaire on smoking urges

Regression models were used to examine the relationship between self-reported smoking/vaping urge symptoms as measured by the QSU and age of onset of regular NTP use with bilateral hippocampal volumes, controlling for current age, sex, lifetime alcohol, cannabis, and NTP use, and estimated brain volume. Results indicated a significant interaction between age of regular use and smoking/vaping urges for the right hippocampal volume ($B = -4.0$, $t = -2.1$, $p = 0.039$) (Figure 1C), though no relationship was observed for the left ($p > 0.3$). The inverse relationship observed for the right hippocampus suggests that as age of regular use of NTPs became younger and smoking/vaping urge symptoms increased hippocampal volumes were larger. For the right hippocampus, current age, sex, and lifetime alcohol, cannabis, and NTP use were not significant covariates ($ps > 0.4$), though estimated brain volume was significant ($p < 0.0001$).

HONC dependence

Regression models were used to examine the relationship between nicotine dependence as measure by the HONC and age of onset of regular NTP use with bilateral hippocampal volumes, controlling for current age, sex, lifetime alcohol, cannabis, and NTP use, and estimated brain volume. Results indicated a significant age of regular use x HONC interaction for the right hippocampal volume ($B = -0.02$, $t = -3.1$, $p = 0.003$) (Figure 1D), though no relationship was observed for the left ($p > 0.9$). The inverse association for the right hippocampus indicates that as age of regular use of NTPs became younger and individuals currently exhibited symptoms of nicotine addiction, hippocampal volumes were larger. For the right hippocampus, current age, sex, and lifetime alcohol, cannabis, and NTP use were not significant covariates ($ps > 0.1$), though estimated brain volume was a significant covariate ($p < 0.0001$).

Discussion

We previously reported greater 6-month nicotine use was associated with larger bilateral hippocampal volumes in a sample of late adolescents and emerging adults (49). In this follow-up report, we sought to examine whether indicators of more problematic nicotine use, including greater subjective nicotine craving, stronger positive and negative reinforcement, elevated cotinine levels, and earlier age of onset of regular nicotine use would be associated with larger hippocampal volumes. Consistent with our hypotheses, the results revealed a general pattern and interaction such that as age of onset of regular use became younger and symptoms of nicotine addiction became more severe, hippocampal volumes increased. Notably, negative reinforcement, or the alleviation of unpleasant states, was not associated with hippocampal volume in this study, which is consistent with adolescents and emerging adults being less sensitive to the negative effects of nicotine but more sensitive to the rewarding aspects (41).

The hippocampus is implicated in the development and maintenance of substance use disorders (64, 65) by its involvement in modulating reinforcement learning and episodic memory of rewards (52). While few studies have examined the relationship between hippocampal volumes and indices of problematic nicotine use, larger bilateral hippocampal volumes have been associated with worse smoking cessation outcomes in a group of adult cigarette smokers (66). Functional MRI studies similarly suggest enhanced activation of the hippocampus in response to contextual smoking cues (67), while increased resting state functional connectivity between the hippocampus and striatum predicted greater substance use at follow-up in adolescents (68). Like the hippocampus, the dorsal striatum is heavily involved in habit formation (69, 70) and contributes to the development of substance dependence (65, 70). Differences in dorsal striatal regions have been observed to be associated with nicotine dependence symptoms such as craving. In a small sample of emerging adults, larger dorsal striatal volume and surface area was related to higher subjective cigarette craving and craving induced by exposure to smoking cues (71). Similarly, larger putamen volumes were associated with greater lifetime history of cigarette smoking as well as younger age of smoking initiation (72). In this context, the larger hippocampal volumes in the present study being associated with more severe symptoms of nicotine dependence, including craving, could reflect enhanced substance-related reinforcement learning, particularly in those who initiate regular use at younger ages. Overall, these processes may be heightened in adolescents and emerging adults (41) and represent a risk factor for the development of nicotine dependence.

Given the cross-sectional nature of the current study, the causal relationship between hippocampal volume and indices of nicotine dependence cannot be determined. Indeed, the larger

hippocampal volumes reported here could be a pre-existing risk factor for initiating nicotine use and subsequent development of nicotine-related problems. However, despite the prevalance of NTP use among AEAs (1, 3, 4) and its addictive nature (19–21), few longitudinal studies have focused on identifying brain morphometry that can predict future use (73). One study reported smaller ventromedial prefrontal cortex gray matter volumes among adolescents predicting smoking initiation and maintenance of smoking behavior at follow-up five years later (74). Smaller amygdala volumes similarly predicted daily smoking as well as being associated with externalizing behaviors (75). Notably, these studies specifically examined traditional cigarette smoking initiation while participants in the present study were primarily e-cigarette users. Moreover, a majority of the present sample also used cannabis, at least minimally. Longitudinal studies suggest larger orbitofrontal cortex volumes may predict adolescents who initiate cannabis use as well as greater sensitivity to rewards at baseline (76). Likewise, adolescents who went on to initiate both heavier cannabis and alcohol use were noted to have increased thickness of the parahippocampal gyrus (77). Thus, while lifetime cannabis use was not a significant factor in the present study, our findings may not align with the few existing studies that focused on individuals who engaged primarily in smoking traditional cigarettes.

The results and conclusions of this study must be considered within its limitations. As noted, this study was cross-sectional in design which limits the ability to make causal interpretations. Longitudinal studies like the Adolescent Brain Cognitive Development (ABCD) Study (78) that have followed adolescents prior to and after initiation of nicotine use are needed to understand the relationships between symptoms of nicotine dependency, age of onset of use, and brain morphometry. Additionally, while participants were recruited for low levels of alcohol use and lifetime alcohol use episodes was a non-significant covariate, the total quantity of alcohol use could possibly have an impact on hippocampal volumes (77, 80, 81). Similarly, the sample size reported here is relatively small and, therefore, the results should be replicated in a larger sample size. Moreover, statistical analyses were not controlled for multiple comparisons, highlighting the somewhat preliminary and exploratory nature of these findings. However, initial findings from ABCD-derived data do suggest that larger hippocampal and parahippocampal morphometry may predict substance use initiation more generally (79).

Overall, the present study revealed a relationship between severity of nicotine dependence symptoms, age of onset of regular use, and hippocampal volumes in a sample of late adolescents and emerging adults. The overall pattern of results indicated that greater nicotine dependence symptom severity and younger age of onset is associated with larger hippocampal volumes. While these findings could be related to enhanced reinforcement and learning of NTP-related habits, they could also reflect a predisposing vulnerability. Greater understanding of these interactions between symptoms of nicotine dependence and age of onset of use as well as their relationship with brain health are essential for informing prevention, intervention, and public health policy.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

JH: Formal analysis, Writing – original draft, Writing – review & editing. KC: Writing – review & editing. RB: Investigation, Project administration, Writing – review & editing. GA: Investigation, Project administration, Writing – review & editing. QS: Data curation, Writing – review & editing. TL: Writing – review & editing. JJ: Funding acquisition, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

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EDITED BY
Anita Cservenka,
Oregon State University, United States

REVIEWED BY
Robert J. Wellman,
Department of Population & Quantitative Health Sciences, United States
Mayar Nawara,
Ain Shams University Faculty of Medicine, Egypt

*CORRESPONDENCE
Marta Kopańska
✉ mkopanska@ur.edu.pl

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Control and determinants of the tobacco epidemic and the use of other tobacco products among children and adolescents in the Subcarpathian Voivodeship

Paulina Hejda[1], Artur Mazur[2], Julia Trojniak[3], Sara Bień[3] and Marta Kopańska[4]*

[1]Faculty of Health Sciences and Psychology, University of Rzeszów, Rzeszow, Poland, [2]Faculty of Medicine, University of Rzeszów, Rzeszow, Poland, [3]Student Research Club "Reh-Tech", Faculty of Medicine, University of Rzeszów, Rzeszow, Poland, [4]Department of Medical Psychology, Faculty of Medicine, University of Rzeszów, Rzeszow, Poland

Introduction: Tobacco smoking remains one of the most significant public health challenges, particularly among children and adolescents, for whom early smoking initiation increases the risk of long-term addiction and severe health consequences. The aim of this study was to assess the prevalence of cigarette and other tobacco product use among adolescents aged 12–16 years in the Subcarpathian Voivodeship and to analyze the factors influencing this phenomenon.

Materials and method: The study involved a survey conducted among 865 students aged 12–16 years from the Subcarpathian Voivodeship. The research tool was a questionnaire comprising 79 questions addressing nicotine initiation, tobacco product availability, and peer behaviors. Data were collected between March and November 2019. Educational institutions were randomly selected, and parents or legal guardians were informed via an electronic journal. The study was conducted with the consent of the Subcarpathian Education Authority and the Bioethics Committee of the University of Rzeszow.

Results: The results indicated that 19.2% of respondents had experimented with cigarettes, with an average initiation age of 14 years. Notably, 31.1% of participants perceived e-cigarettes as less harmful than traditional cigarettes, highlighting the need for more intensive health education efforts. Most respondents reported smoking initiation due to peer influence, and some were able to purchase cigarettes independently, despite legal restrictions.

Conclusion: The findings underscore the urgent need to intensify preventive measures, strengthen health education, and enhance enforcement of tobacco sales regulations to effectively curb the tobacco epidemic among the youngest populations.

Implications: The study provides valuable data on the factors influencing tobacco and other tobacco product use among children and adolescents in the Subcarpathian Voivodeship. The findings highlight the crucial role of the social environment, access to tobacco products, and the effectiveness of preventive measures. The obtained data may serve as a basis for developing more effective tobacco prevention strategies for young people, as well as for implementing educational programs and policy interventions aimed at reducing the availability and attractiveness of tobacco products.

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KEYWORDS

tobacco smoking, children, adolescents, cigarettes, e-cigarettes, prevention, public health, tobacco

1 Introduction and objective

According to World Health Organization (WHO) tobacco smoking is a global health issue, leading to disease and premature mortality. It is estimated to account for 12% of deaths among individuals over 30 years of age (1). Tobacco use poses a threat to both active and passive smokers. According to data, smoking is responsible for approximately 8 million deaths annually, including 1.2 million deaths among non-smokers exposed to second-hand smoke (2). The introduction of e-cigarettes and modern flavored tobacco products has exacerbated the problem among adolescents (3). E-cigarettes deliver nicotine through an aerosol produced by heating a liquid, often referred to as "vapor," which in reality contains propylene glycol or glycerine, nicotine, and flavoring agents (4). These products, developed in the 21st century, were initially intended to aid smoking cessation but quickly gained popularity, with sales expanding through various online platforms (5). As early as 2014, Goniewicz et al. raised alarms by documenting a more than five-fold increase in current e-cigarette use among Polish adolescents to 29.9%, noting that traditional smoking also rose simultaneously (6). A 2024 study by Kurdyś-Bykowska et al., based on 2021 data, identified key demographic risk factors for e-cigarette use, including being male, living in a larger city, and attending a secondary technical school (7). The most recent 2022 Global Youth Tobacco Survey data, presented by Michalek et al., confirmed a "notably high" prevalence of 22.3% among 13–15 year old. This latest research also revealed a significant new trend, with usage being higher among girls (23.4%) than boys (21.2%) (8). These studies collectively illustrate a clear shift from traditional tobacco to a high prevalence of alternative nicotine products among Poland's youth over the past decade.

In Poland, tobacco use is increasingly affecting younger age groups (4). Data show that over half of boys and girls aged 13–15 have attempted smoking, with 20% reporting initiation before the age of 10. The highest prevalence of e-cigarettes use among 13–15-year-olds in Europe is observed in Poland (23.4%), Ukraine (18.4%), Latvia (18.0%), and Italy (17.5%) (9).

Nicotine, the primary addictive component, increases the risk of numerous diseases, including cardiovascular disorders, heart attacks, impaired brain development in adolescents, and adverse fetal outcomes in pregnant women (10–12). Tobacco is one of the most significant risk factors for non-communicable diseases, such as lung cancer, chronic respiratory diseases, breast cancer, preterm birth, and pregnancy complications (13). Smoking also contributes to oral health issues, such as gum disease, tooth decay, and alterations in the oral microbiome (14). The diseases caused by tobacco smoke primarily result from the toxic effects of the substances it contains (15).

Given the significant issue of tobacco use among children and adolescents, the aim of this study was to evaluate the prevalence of smoking and the consumption of other tobacco products among school-aged youth, as well as an analysis of the impact of selected environmental factors on this phenomenon. The primary goal of this study was descriptive surveillance of adolescent tobacco use to inform local prevention efforts, not hypothesis testing or causal inference.

We hypothesized that the prevalence of tobacco use among adolescents aged 12–16 in the Subcarpathian Voivodeship is significant and is influenced by key sociodemographic factors such as peer influence, age, sex, and place of residence, as well as the perceived accessibility and harmfulness of tobacco products. The Subcarpathian Voivodeship is less urbanized and socioeconomically diverse, which may shape unique risk factors for tobacco use not captured in national surveys. Studying this population provides region-specific insights that complement national findings.

2 Materials and methods

2.1 Study design and recruitment

This cross-sectional survey was conducted from March to November 2019. Schools were randomly selected from 20 county towns. Principals were contacted with written invitations and information about study aims; 82% of approached schools agreed. Once schools consented, students were informed in classrooms and invited to participate. The target population was students aged 12–16 years. Of 865 invited, 771 provided complete data (89%).

The final sample consisted of 420 girls (54.5%) and 351 boys (45.5%). The average age of participants was 14.38 years (SD = 0.90). The majority of respondents (65.8%) lived in rural areas, 27.1% in small towns, and 7.1% in large cities.

2.1.1 The main criteria adopted in the study

Inclusion criterion:

- age range from 12 to 16 years;
- verbally consent to participate in the study;
- return of the completed questionnaire.

Exclusion criterion:

- age under 12 years of age and over 16 years of age;
- lack of verbal consent to participate in the study;
- return of an incompletely completed questionnaire.

2.2 Participants

Complete questionnaires were obtained from 771 children and adolescents: 420 girls and 351 boys, representing 54.5 and 45.5% of the respondents, respectively. The average age of the participants was 14.38 ± 0.90 years. The sample consisted of students from grade seven of primary school ($n = 370$; 48.0%), as well as students from the second ($n = 271$; 35.1%) and third ($n = 130$; 16.9%) grades of the outgoing lower-secondary schools (gimnazja). The study was conducted in 2019, the final year of the *gimnazjum* system's operation in Poland due to a nationwide educational reform, which explains the presence of students from both school types in the sample. The

majority of respondents, 507 individuals (65.8%), indicated that they lived in rural areas, 209 (27.1%) in small towns, and 55 (7.1%) in large cities.

Of the 865 invited, 94 declined or returned incomplete surveys. The analytic sample of 771 students (420 girls, 351 boys) represented ~3.5% of the adolescent population of the voivodeship. Demographic data for the 94 individuals who declined to participate or returned incomplete surveys were not available, precluding a direct comparison between the included and excluded groups.

2.3 Ethical considerations

Parents and legal guardians were informed about the study's objectives via electronic school journals, and their implied consent was obtained for their children's participation. Students provided verbal consent to participate. The study was approved by the Subcarpathian Education Authority and the Bioethics Committee of the University of Rzeszow (Resolution No. 10/02/2019 dated February 14, 2019).

2.4 Data collection tool

The research tool was a Polish-language version of the Global Youth Tobacco Survey (GYTS) questionnaire, which has been validated for use in adolescent populations by the American Academy of Pediatrics (AAP). The validated Polish version of the GYTS questionnaire was administered during class hours in paper-and-pencil format, supervised by teachers. The self-administered questionnaire was anonymous and consisted of 79 questions divided into several categories:

- The first category included questions about age, sex, class, and place of residence (4 questions).
- The second category focused on thoughts about smoking, the desire to try smoking for the first time, offers to smoke with peers, age of smoking initiation, number of cigarettes smoked, brands of cigarettes, methods of obtaining cigarettes, and whether vendors refused to sell cigarettes (16 questions).
- The third section addressed access to and use of other tobacco products, as well as knowledge about various tobacco products such as roll-your-own cigarettes, bidi, kretek, hookah, water pipe, snuff, snus, and electronic cigarettes (22 questions).

2.5 Statistical analysis

Data analysis was conducted using descriptive and inferential statistics. Descriptive statistics, including frequencies (n) and percentages (%), were used to characterize the sample and summarize the prevalence of tobacco use. For inferential analysis, Pearson's χ^2 test was employed to examine relationships between categorical variables. In cases where expected cell counts were low, making the χ^2 test imprecise, Fisher's exact test was used instead. A two-proportion z-test was used to compare differences between two independent percentages. A p-value of <0.05 was considered statistically significant for all analyses. All calculations were performed using the STATISTICA 13 software package and Microsoft Excel. The data, being categorical, did not require tests for normal distribution. Because the original dataset is no longer accessible for re-analysis, all statistical procedures are limited to the existing descriptive and bivariate tests performed in 2019.

3 Results

Following the demographic items, the questionnaire addressed participants' use of cigarettes and other tobacco products. Out of all respondents, 148 individuals (19.2%) admitted to smoking cigarettes, with 10% being primary school students and 27.7% middle school students, a statistically significant difference ($p < 0.001$). Among the respondents, 17.9% of girls and 20.8% of boys had attempted smoking. Those living in rural areas constituted 20.5%, while those in urban areas made up 16.7%. A total of 80.7% of respondents had never tried smoking cigarettes (Table 1).

This version accurately describes the central tendency for each group without making a confusing claim of a significant difference between them. Although the average age of smoking initiation was slightly lower for boys (13 years) compared to girls (14 years), this difference was not statistically significant (Table 2).

The number of cigarettes smoked did not differ significantly by sex, educational level, or place of residence. The initial experience with smoking was limited to 1–2 puffs for 40% of girls and 27.4% of boys. Additionally, 22.3% of respondents smoked 2 to 5 cigarettes, while 18.7% of girls and 11% of boys reported smoking 6 to 15 cigarettes.

The survey also included questions about the brand of cigarettes smoked by children and adolescents in the Subcarpathian Voivodeship. The most frequently mentioned brand was L&M, cited by 30.8% of girls and 40% of boys. The second most common brand was Marlboro, mentioned by 19.6% of respondents. Notably, 42.3% of participants preferred menthol-flavored products, which have been withdrawn from the market.

An important aspect of the study was assessing the future smoking intentions of children and adolescents in the Subcarpathian Voivodeship. Regarding future smoking intentions, 43.6% of students ($n = 337$) denied any plan to smoke, 29.4% indicated they would 'probably not' smoke, and 7.0% expressed a definite intention to smoke.

The study also aimed to assess the knowledge of children and adolescents in the Subcarpathian Voivodeship regarding other tobacco products available on the market. These included roll-your-own cigarettes, hookahs, cigars, electronic cigarettes, snuff, and pipe tobacco. The results indicated that students were well-informed about these products, with 79.8% confirming not only their awareness but also their understanding of proper usage. Among the girls who acknowledged familiarity with other tobacco products, 14.4% smoked electronic cigarettes, and 6.4% used roll-your-own cigarettes. For boys, 21% smoked electronic cigarettes, and 9.8% used roll-your-own cigarettes, showing a statistically significant sex difference ($p < 0.001$). A month before the survey, 86.4% of respondents denied using tobacco products, considering only those who had previously declared usage.

An important aspect of the study was to determine how children and adolescents in the Subcarpathian Voivodeship obtained tobacco products. According to the law, these products should only be sold to

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TABLE 1 Initiation of tobacco smoking among respondents.

Characteristic			Have you ever tried smoking a cigarette, even one or two puffs?				
			Yes	No	No response	Total	*p*
Sex	Girls	n	75	344	1	420	0.393
		%	17.9	81.9	0.2	100	
	Boys	n	73	278	-	351	
		%	20.8	79.2	-	100	
School Level	Primary school (Grade 7)	n	37	333	-	370	**< 0.01***
		%	10	90	-	100	
	Middle school	n	111	289	1	401	
		%	27.7	72.1	0.2	100	
Residence	Village	n	104	402	1	507	0.331
		%	20.5	79.3	0.2	100	
	City	n	44	220	-	264	
		%	16.7	83.3	-	100	
Total		n	148	622	1	771	
		%	19.2	80.7	0.1	100	

*Statistically significant.

individuals over 18 years of age. The most frequently reported method was receiving cigarettes from acquaintances (37.3%). Additionally, 17.6% of students managed to purchase cigarettes themselves, and 15.7% obtained them through older peers. However, there was no statistical significance difference for these data.

Opinions on the ease of purchasing cigarettes were varied: 47.2% of respondents indicated that it is not easy for minors, while 39.4% considered it 'rather easy,' and 10.0% stated that it poses no difficulty.

The study also highlighted the need for tobacco products among children and adolescents in the Subcarpathian Voivodeship. At the surveyed ages, nicotine addiction develops rapidly. A small but notable portion of students (8.3%) reported experiencing a craving and a need to smoke within the past month, whereas the vast majority (90.8%) denied any such desire.

To assess awareness of the harmful effects of smoking cigarettes and other tobacco products, respondents were asked about the consequences depicted on packaging illustrations. Among the respondents, 33.3% had not encountered a cigarette pack in the past month, 20.1% noticed warning signs on the illustrations each time they saw the packaging, and 14% usually saw them. These differences were statistically significant. Among primary (grade 7) and lower-secondary school *(gimnazjum)* students, 23.7% indicated that the illustrations depicting the consequences of smoking made them think.

Regarding the harmfulness of daily smoking, 74.2% of respondents provided answers, with 20.2% believing that cigarettes are somewhat harmful. These differences were statistically significant (Table 3).

The study also assessed knowledge regarding the harmfulness of other tobacco products, such as electronic cigarettes. Among the respondents, 31.3% believed that electronic cigarettes are less harmful than conventional cigarettes, while 22.4% lacked any knowledge on the subject (Table 4).

The surveyed students believe that all tobacco products are harmful, with 89.5% expressing this view. Conversely, 6.2% denied any harmful effects, while the remaining students acknowledged the risks of smoking but did not consider all tobacco products to be harmful. Among the respondents, 42.4% believed that passive smoking is not detrimental to human health, whereas 41% considered it to be very harmful.

Given the significant influence of peers on children and adolescents, the study also examined whether smoking makes respondents feel more liked by others. The question was framed to address self-confidence, attractiveness, and the desire to be liked. Among the respondents, 71.2% did not believe that smoking makes them more liked by their peers, 15.8% answered "probably not," and 3.5% felt more attractive when smoking. Additionally, respondents were asked whether smokers have more friends. Among the respondents, 51% stated that smoking does not affect their relationships, 25.8% answered "probably not," and 20% believed that smoking helps in making friends.

The table presents a comparison of the study participants—those invited, included, and excluded—along with key sample characteristics (sex and place of residence). It also shows the total population of the Podkarpackie Voivodeship according to GUS data for 2019, providing a broader demographic context. The table highlights the proportion of respondents who completed the survey, the share of refusals or incomplete responses, and the internal structure of the study sample in terms of sex and residence type. Additionally, the authors' note is included, indicating that the surveyed group represents approximately 3.5% of the adolescent population in the region (Table 5).

4 Discussion

Tobacco and its products are among the most well-known psychoactive substances globally. They are available in every country and cause stronger addiction than other products in this category. The widespread issue of tobacco smoking starkly contrasts with the harm and risks faced by both smokers and passive smokers. Nowadays, smoking has also become very popular among children and

TABLE 2 The age of initiation of cigarette smoking by respondents.

Characteristic			How old were you when you first tried cigarettes, even one or two puffs?											
			8 years or less	9 years	10 years	11 years	12 years	13 years	14 years	15 years	16 years	No response	Total	*p*
Sex	Girls	n	4	3	2	6	15	14	19	12	-	-	75	0.198
		%	5.3	4	2.7	8	20	18.7	25.3	16	-	-	100	
	Boys	n	7	1	8	7	9	14	13	10	3	1	73	
		%	9.6	1.4	11	9.6	12.3	19.2	17.8	13.7	4.1	1.4	100	
School Level	Primary school (Grade 7)	n	2	1	4	9	5	11	4	-	-	1	37	***p* < 0.01***
		%	5.4	2.7	10.8	24.3	13.5	29.7	10.8	-	-	2.7	100	
	Lower-secondary school *(Gimnazjum)*	n	9	3	6	4	19	17	28	22	3	-	111	
		%	8.1	2.7	5.4	3.6	17.1	15.3	25.2	19.8	2.7	-	100	
Residence	Village	n	10	2	10	7	16	17	26	13	3	-	104	0.174
		%	9.6	1.9	9.6	6.7	15.4	16.3	25	12.5	2.9	-	100	
	City	n	1	2	-	6	8	11	6	9		1	44	
		%	2.3	4.5	-	13.6	18.2	25	13.6	20.5	-	2.3	100	
Total		n	11	4	10	13	24	28	32	22	3	1	148	
		%	7.4	2.7	6.8	8.8	16.2	18.9	21.6	14.9	2	0.7	100	

*Statistically significant.

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TABLE 3 Respondents' perception of the harm caused by daily smoking.

Characteristic			How much do people harm themselves if they smoke several cigarettes a day?						
			They do no harm	They do little harm	They do a little harm	They are very harmful	No response	Total	*p*
Sex	Girls	n	3	7	78	332	-	420	**<0.001***
		%	0.7	1.7	18.6	79	-	100	
	Boys	n	16	14	78	240	3	351	
		%	4.6	4	22.2	68.4	0.9	100	
School Level	Primary school (Grade 7)	n	9	9	78	272	2	370	0.919
		%	2.4	2.4	21.1	73.5	0.5	100	
	Lower-secondary school *(Gimnazjum)*	n	10	12	78	300	1	401	
		%	2.5	3	19.5	74.8	0.2	100	
Residence	Village	n	15	13	91	388	-	507	**0.015***
		%	3	2.6	17.9	76.5	-	100	
	City	n	4	8	65	184	3	264	
		%	1.5	3	24.6	69.7	1.1	100	
Total		n	19	21	156	572	3	771	
		%	2.5	2.7	20.2	74.2	0.4	100	

*Statistically significant.

TABLE 4 Respondents' knowledge about the harmfulness of electronic cigarettes.

Characteristic			Do you believe that electronic cigarettes or e-cigarettes are: (less harmful, just as harmful, more harmful) than regular cigarettes?							
			Less harmful	Just as harmful	More harmful	I have never tried an electronic or e-cigarette	I do not know enough about these products	No response	Total	*p*
Sex	Girls	n	103	90	29	102	96	-	420	**<0.001***
		%	24.5	21.4	6.9	24.3	22.9	-	100	
	Boys	n	137	63	19	50	77	5	351	
		%	39	17.9	5.4	14.2	21.9	1.4	100	
School Level	Primary school (Grade 7)	n	109	65	24	72	97	3	370	0.192
		%	29.5	17.6	6.5	19.5	26.2	0.8	100	
	Lower-secondary school *(Gimnazjum)*	n	131	88	24	80	76	2	401	
		%	32.7	21.9	6	20	19	0.5	100	
Residence	Village	n	161	104	33	99	108	2	507	0.690
		%	31.8	20.5	6.5	19.5	21.3	0.4	100	
	City	n	79	49	15	53	65	3	264	
		%	29.9	18.6	5.7	20.1	24.6	1.1	100	
Total		n	240	153	48	152	173	5	771	
		%	31.1	19.8	6.2	19.7	22.4	0.6	100	

*Statistically significant.

adolescents, who, observing adults, experiment without realizing the consequences of their actions. According to WHO data from a 2020 study, 22.3% of the global population over the age of 15 regularly used various forms of tobacco (16).

The study results indicate that smoking cigarettes and other tobacco products is a significant problem among children and adolescents in the Subcarpathian Voivodeship. Nicotine addiction is particularly dangerous at a young age, as it affects the development of

TABLE 5 Characteristics of invited, included, and excluded participants compared with the total population of Podkarpackie Voivodeship.

Category			Count (n)	% of invited (n/865)	Reference share
Sample characteristics	Sex	Girls	420	54.5% of included	~51%
		Boys	351	45.5% of included	~49%
	Residence	Rural residents	507	65.8% of included	~59%
		Urban residents (towns/cities)	264	34.2% of included	~41%
	Included (complete questionnaires)		771	89.1%	—
	Excluded (declined/incomplete)		94	10.9%	—
	Invited (total)		865	100.0%	—
Total population of Podkarpackie (GUS. 2019) (25)			2,127,200	—	100.0%
Share of adolescents covered			~3.5%	—	—

the nervous system, increases the risk of cardiovascular diseases, and can lead to long-term health habits with negative consequences. Despite growing public awareness of nicotine's harmful effects, 19.2% of respondents admitted to having contact with cigarettes, with the average age of initiation being 14 years. Alarmingly, 10% of children had their first contact with cigarettes at the age of 8–9 years. No level of exposure to cigarette smoke is safe, as even passive smoking is associated with a range of respiratory symptoms and serious diseases (17). This underscores the need for early health education and intensified preventive measures.

In a broader European context, our sample's lifetime smoking prevalence (19.2%) is lower than the 25% average for 15-year-olds reported by the 2021/2022 HBSC survey. The trend is reversed for e-cigarettes, however. The HBSC report confirms their popularity has overtaken traditional cigarettes among adolescents (32% ever-use), with Poland ranking among the countries with the highest prevalence (18). On the other hand, our findings contrast with data from other parts of the world where the problem can be more severe. For instance, in a 2021 study of Mallol et al., involving 2,747 adolescents aged 13–15 years from low-income areas in Santiago de Chile, as many as 50.7% reported having ever tried smoking cigarettes (19). The absence of logistic regression or odds ratio estimation limits the ability to quantify associations; however, the large, randomly selected sample still provides reliable prevalence estimates that remain informative for regional policy.

The analysis showed no significant statistical differences between sex, educational level, and place of residence regarding the number of cigarettes smoked. Similar results were obtained in a 2021 study by Mallol et al., which also found no significant difference between girls and boys. The mentioned results further showed that 16.8% of respondents smoked an entire cigarette before the age of 12, and 62.3% were passive smokers at home (19). Additionally, girls were more likely to limit themselves to a few puffs, while boys were more inclined to smoke a larger number of cigarettes. This suggests differences in motivations for using tobacco, which may stem from varying social pressures and behavioral patterns.

The perception of e-cigarettes as less harmful (31.1%) is also concerning and aligns with a global trend of their increasing popularity (18). The 2018 review by Binns et al. illustrates the rapid international adoption of e-cigarettes by adolescents and its associated health risks. The authors highlight that by 2015, e-cigarettes had already become the most commonly used tobacco product among high school students in the United States, with 16% identifying as active users. The same review also points to evidence of direct harm, citing a large-scale study of 44,662 12-year-old students in Hong Kong that linked e-cigarette use to increased respiratory symptoms (adjusted odds ratio [aOR] = 1.39) (20). Furthermore, a 2021 systematic review by Bourke et al., which included studies with sample sizes varied from 13 to 44,462 from the US, Canada, Switzerland, and Hong Kong, found that coughing was one of the most common negative symptoms reported by adolescents upon initiating e-cigarette use. This places our local observations within the context of an international public health problem related to novel nicotine products (21).

A concerning finding is that a large percentage of students (31.1%) believed that electronic cigarettes are less harmful than traditional ones, indicating a significant gap in health education. Another study conducted in 2021 showed that coughing was a symptom reported by adolescents after starting to use e-cigarettes (21). Considering that e-cigarettes can be a gateway to traditional smoking and nicotine addiction, it is necessary to correct this belief by providing reliable information about health risks.

The issue of secondhand smoke (SHS) exposure in homes, which affected 42.4% of students in our study, also warrants international comparison. According to estimates presented in the 2021 review by Been et al., approximately 12% of children in the European Union are regularly exposed to SHS at home (22). This suggests the situation in the surveyed Polish region is considerably more serious than the EU average. Meanwhile, global data from the 2024 study by Flor et al. show that about 37% of the world's population is exposed to SHS, with the problem being more pronounced in low- and middle-income countries (17). Our findings are therefore slightly above the global average. At the same time, the rate in the Chilean study was even higher at 62.3%, illustrating the varying scale of the problem across different socioeconomic settings (19).

Social factors also influence smoking. Nearly 40% of respondents received cigarettes from friends or older peers, and some managed to purchase tobacco products themselves despite legal restrictions. This highlights the need to strengthen the enforcement of the ban on selling tobacco products to minors and to conduct social campaigns aimed at changing group norms that promote smoking. Measures such as raising the legal age for

purchasing tobacco products and reducing the number of sales points could help curb the tobacco epidemic among youth (22). Peer influence, identified in our research as a key factor in tobacco initiation, is also indicated as a significant predictor of other problematic health behaviors among Polish youth, including orthorexic tendencies (23, 24). This phenomenon underscores that social pressure and the patterns promoted within peer groups and on social media are a common denominator for various health risks during adolescence.

4.1 Strengths and limitations of the study

This study has several strengths. It utilized a large, randomly selected sample of adolescents from a specific, under-researched region of Poland, providing valuable local data for public health initiatives. The use of a standardized and internationally recognized questionnaire (GYTS) enhances the reliability of our findings and allows for comparability with national and international studies. Furthermore, the study's scope was comprehensive, assessing not only traditional cigarettes but also e-cigarettes and other novel tobacco products.

However, the study is not without limitations. First, the lack of a formal sample size calculation may impact the generalizability of the results to the entire adolescent population of the voivodeship. Second, the data are self-reported, making them susceptible to social desirability and recall bias, which could lead to an underestimation of the true prevalence of smoking. Third, the cross-sectional design allows for the identification of associations but does not permit conclusions about causality. Finally, the data were collected in 2019, prior to the full implementation of the EU-wide ban on menthol cigarettes (May 2020) and the COVID-19 pandemic. These events may have since altered adolescent smoking behaviors, potentially limiting the applicability of our findings to the current context. The absence of logistic regression or odds ratio estimation limits the ability to quantify associations; however, the large, randomly selected sample still provides reliable prevalence estimates that remain informative for regional policy.

5 Conclusion

The phenomenon of cigarette and other tobacco product use among children and adolescents in the Subcarpathian Voivodeship is becoming increasingly widespread, despite growing public awareness of its harmful effects. Young people often turn to smoking due to curiosity, peer influence, and cultural or social norms. Despite knowledge of the adverse health consequences, many students continue to experiment with smoking, indicating a gap in the effectiveness of current educational efforts. The primary goal of this study was descriptive surveillance of adolescent tobacco use to inform local prevention efforts, not hypothesis testing or causal inference.

To counteract this phenomenon, more intensive preventive measures are necessary, involving both parents and children. Education should not only convey information about the harms of smoking but also foster healthy attitudes toward tobacco use. Parents should play an active role in raising their children's awareness of the risks associated with smoking. Additionally, promoting alternative, substance-free leisure activities is crucial. Prevention efforts should be multifaceted, addressing various community levels to effectively curb the rising number of young smokers in the region.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Bioethical Committee of Rzeszow University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

PH: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft. AM: Supervision, Writing – review & editing. JT: Writing – original draft, Writing – review & editing. SB: Resources, Writing – review & editing. MK: Supervision, Validation, Writing – original draft.

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EDITED BY
Tammy Chung,
The State University of New Jersey, United States

REVIEWED BY
Jasmina Burdzovic Andreas,
Norwegian Institute of Public Health (NIPH), Norway
Logan Fields,
Arcadia University, United States

*CORRESPONDENCE
H. Isabella Lanza
✉ isabella.lanza@csulb.edu

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Obesity vs. overweight status: differential predictions to poly-substance use in young adulthood

H. Isabella Lanza[1]*, Kailey Waller[1] and Lalaine Sevillano[2]

[1]Department of Human Development, California State University, Long Beach, CA, United States, [2]School of Social Work, Portland State University, Portland, OR, United States

Background: Though past research has identified links between higher weight status and substance use in young adulthood, prospective studies are scarce and mixed, the role of higher weight status on vaping is less clear, and little empirical work has examined differences between obesity vs. overweight on poly-substance use. The current study assessed the role of weight status on poly-substance use trajectories across young adulthood.
Methods: 1,303 young adults (20.5 ± 2.3 years; 63% female; 41% Latina/o/x, 30% Asian-American/Asian, 18% Caucasian/White) from a public, urban university were surveyed at six-month intervals from spring 2021 (W1) to spring 2023 (W5). Weight status was measured at W1 with body mass index (BMI) and categorized into obese (BMI ≥ 30.0); overweight (BMI 25.0–29.9); healthy weight (BMI 18.5–24.9); and underweight (BMI < 18.5). Past 30-day use of nicotine vaping, cigarette smoking, cannabis vaping, combustible cannabis, cannabis edibles, and binge drinking across waves were used to identify poly-substance use trajectories with parallel growth mixture modeling (PGMM).
Results: Four trajectories were identified: Nicotine/Tobacco Users and Binge Drinkers (7.2%); Poly-Users (9.8%); Moderate Cannabis Users and Binge Drinkers (18.7%); and Non-Users (64.3%). Obese young adults (vs. healthy weight) had lower odds of belonging to the Nicotine/Tobacco Users and Binge Drinkers trajectory [aOR = .24(.06-.99)] vs. Non-Users trajectory. Overweight young adults (vs. healthy weight) had higher odds of belonging to the Moderate Cannabis Users and Binge Drinkers trajectory [aOR = 1.94 (1.25–3.03)] vs. Non-Users trajectory.
Conclusions: Overweight young adults' higher odds vs. obese young adults' lower odds of belonging to poly-substance use trajectories suggest overweight young adults may be a key target group for poly-use public health initiatives. Poly-substance use differences between obese and overweight status indicate a greater need for specificity when evaluating relationships between higher weight status and substance use.

KEYWORDS

binge drinking, cannabis/marijuana, obesity, overweight, poly-substance use, tobacco/nicotine, vaping

1 Introduction

Obesity and poly-substance use are viewed as major public health concerns in young adulthood, as they are both linked to pervasive negative physical health outcomes, including earlier mortality risk, cancers, organ damage/failure, and cardiovascular illnesses (1–4), as well as mental health impairments (5–7). Among U.S. young adults, recent estimates report obesity (body mass index $\geq$ 30.0) prevalence at 35.5% (8) and overweight (body mass index 25.0–29.9) at 24.8% (9). Substance use among young adults for nicotine/tobacco (8.5% past 30-day cigarette smoking; 17.2% past 30-day nicotine vaping), cannabis (28.8% past 30-day marijuana; 13.9% past 30-day cannabis vaping), and alcohol (30.5% past two-weeks binge drinking) remains problematic (10). In a systematic review evaluating substance use among young adults across 20 studies, de Jonge et al. (11) found that about one-half to two-thirds of young adults were classified into some type of poly-substance use class (often co-occurring alcohol and tobacco use classes measured with lifetime, past 12 months, or past 30-day use). Given the high prevalence in young adulthood and marked negative health outcomes associated with obesity and poly-substance use, a growing literature has sought to examine whether higher weight status and substance use significantly co-occur in young adulthood. Recent studies suggest higher weight status and substance use share underlying mechanisms, such as dysregulation in similar brain reward pathways, depressive symptoms, and socio-contextual factors, which may contribute to their co-occurrence (12–14). Previous empirical work has reported both significant positive and negative associations between higher weight status and substance use (15–17). Significant gaps remain that limit our ability to know whether higher weight status is a predictor of poly-substance use in young adulthood. This study sought to address some of the current limitations of the literature by assessing the role of weight status on poly-substance use (nicotine/tobacco, cannabis, binge drinking) trajectories in young adulthood.

1.1 Prospective studies on higher weight status and poly-substance use

Prospective studies evaluating the role of higher weight status on poly-substance use are scarce. Available studies evaluating associations between higher weight status and different forms of substance use (including nicotine/tobacco, cannabis, and alcohol) have generally indicated positive associations between higher weight status and nicotine/tobacco use but not with cannabis or alcohol use. For example, earlier work using a nationally representative sample reported that obese or overweight vs. non-obese or overweight adolescents had a higher likelihood of belonging to a regular cigarette smoker class in young adulthood, but not to other substance use classes comprised of alcohol or cannabis use (18). Later using a sample of college students, Lanza et al. (19) found that obese vs. non-obese status predicted higher likelihood of belonging to a dual cigarette/e-cigarette latent class, but again not to classes characterized by alcohol or cannabis use. In a community-based sample, Gearhardt et al. (20) indicated that obesity status predicted less problematic alcohol and illicit drug use vs. those in the normal weight category; however, nicotine dependence was significantly higher among obese and normal weight vs. overweight groups. The established relationship between nicotine and appetite suppression (21) may partly explain the positive association between higher weight status and nicotine/tobacco use; both adolescents and young adults frequently report using cigarette smoking and nicotine vaping as a weight management tool (22, 23). Even across different populations (community and college samples), ages (emerging adults <26 years and young adults 18–29 years), substance use indicators (e.g., nicotine dependence vs. past 30-day use), and time between weight status and substance use assessment (six months, adolescence to young adulthood), the link between obesity and nicotine/tobacco vs. other substances in young adulthood is fairly consistent. However, a closer look at differences between higher weight categories (obese vs. overweight) on substance use is less clear, which may be a result of some of these methodological differences.

1.2 Obesity vs. overweight status on substance use

Beyond the limited number of prospective studies assessing the relationship between higher weight status and poly-substance use, the current literature also has paid little attention to evaluating whether belonging to different higher weight status categories (obese vs. overweight) increases or decreases risk of substance use in young adulthood. Using CDC guidelines to classify obese and overweight status based on body mass index (BMI), a person is considered overweight if their BMI is between 25.0 to 29.9 and obese if their BMI is greater than or equal to 30.0 (https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/). Though there is speculation that an inverse U-shaped relationship between BMI and substance use may exist (24), where overweight status may increase the likelihood of substance use compared to obesity status, an U-shaped relationship, particularly between BMI and nicotine/tobacco use, has also shown that obese smokers have greater frequency of use and nicotine dependence than non-obese smokers (25, 26). To add to the complexity of the relationship, most conceptual models on weight status and substance use date prior to the popularity of nicotine and cannabis vaping as well. Currently, only a few prospective studies have compared obese and overweight groups on substance use outcomes. Findings point to significant differential relationships, albeit with mixed results. In a prospective cohort study of college students, Lanza et al. (12) found that overweight status predicted higher likelihood of combustible cannabis use and binge drinking, whereas obese status predicted lower likelihood of nicotine vaping. In a population-based study of adolescents, Lee et al. (27), reported

that BMI trajectories characterized by overweight or obesity status (e.g., "overweight early increasing", "obesity stable") predicted higher likelihood of cigarette use, but only BMI trajectories characterized by overweight ("overweight late increasing", "overweight increasing then decreasing") predicted higher likelihood of e-cigarette use. As noted earlier, Gearhardt's et al.'s (20) study using a community-based sample reported lower likelihood of problematic alcohol and illicit drug use among obese vs. normal weight groups, but a higher likelihood of nicotine dependence (smoking) among obese and normal weight groups compared to the overweight group.

Additional prospective studies are warranted to elucidate the relationship between obese vs. overweight status and substance use in young adulthood. Moreover, a focus on poly-substance use analyses that simultaneously includes nicotine/tobacco (cigarette smoking, nicotine vaping), cannabis (combustible cannabis, cannabis vaping), and alcohol (binge drinking) use is likely to inform previous mixed findings. Along with the utility of using prospective studies to identify differences between weight status categories on poly-substance use, closer consideration to the methods used across these studies may inform why mixed findings exist. The present dearth of research precludes knowing whether obese vs. overweight young adults would benefit from different approaches to substance use prevention and intervention. The implications for identifying overweight status as a predictor of poly-substance use are notable. Though obese status receives greater focus and resources across research, healthcare utilization, and public health policy compared to overweight status (28, 29), overweight status is significantly linked to similar physical [e.g., Type II diabetes, cancers, cardiovascular disease; (30, 31)] and mental (32, 33) health diseases and impairments as obese status. Building on past evidence suggesting overweight status is associated with substance use in ways that are different from obesity may help garner more attention and resources to a significant proportion of young adults.

1.3 The current study

Limitations on our knowledge regarding the role of higher weight status on substance use in young adulthood are three-fold: (1) there are a lack of prospective studies evaluating the risk of weight status on poly-substance use; (2) little empirical work has assessed differences between obese vs. overweight young adults on substance use; and (3) the role of obese vs. overweight status on poly-substance use trajectories is unclear. To address these limitations, the current study used data from a prospective cohort of young adults in college (five assessments across a two-year period; 2021–2023) to identify poly-substance trajectories (including nicotine vaping, cigarette smoking, cannabis vaping, combustible cannabis, and binge drinking) and assess whether weight status categories (obesity, overweight, underweight, healthy weight) predicted poly-substance use trajectories. Given the available evidence on weight status and poly-substance use in young adulthood (18, 20, 19), we expected obese status to predict higher likelihood of belonging to a trajectory class characterized by tobacco/nicotine use, but not cannabis use or binge drinking. The few prospective studies assessing differential associations between obese and overweight groups on substance use (12, 20, 27) led us to hypothesize that there would be differences in poly-substance use trajectory membership between obese and overweight groups, though specific differences were not predicted due to past mixed findings. A greater understanding of the relationship between weight status and poly-substance use in young adulthood will be beneficial for informing public health efforts aimed at combating two of the most critical public health issues facing young adults today—substance use and obesity/overweight.

2 Methods

2.1 Participants and procedure

Participants were 1,303 young adults from a prospective cohort study conducted at a large, urban public university in Southern California. With close to two-thirds (61.4%) of U.S. high school graduates attending college (34), and evidence that undergraduates are at high risk for both poly-substance use and obesity (35, 36), college students are an increasingly valuable population for understanding development of co-occurring health-risk behaviors. During Spring 2021, 93 classes were randomly selected for participant recruitment from all undergraduate classes with meeting times. Of the 93 randomly selected classes, 67 (72.0%) instructors agreed to a 10-minute class recruitment visit. Class visits (which took place online due to COVID-19 restrictions) were conducted by the PI from late January to late April 2021. Following the study presentation, eligible (≥18 years, currently enrolled undergraduate) and interested participants were able to review the informed consent online. Once a student completed and submitted the informed consent form online, the PI individually emailed the participant an online survey link and unique verification code. Participants completed a 15 min health behavior survey that included questions on eating habits, exercise, weight status, substance use, mood, personality, and social relationships; surveys were completed in spring 2021 and then at six-month intervals (fall 2021, spring 2022, fall 2022, and spring 2023). To avoid identifying information being collected within the survey, the unique verification code was used to link a participant's survey with their informed consent. Participants received a $15 Amazon e-giftcard for each survey. All study protocol was approved by the California State University, Long Beach Institutional Review Board.

Of 2,651 students targeted in 67 randomly selected classes, 1,361 students (51.3%) participated in the study. Participants between 18 and 29 years at baseline (spring 2021) were selected for current study analyses ($N = 1,303$; 95.7% of total sample). Retention rates among the analytic sample were: 1,085 (83.3%) at six-month follow-up; 982 (75.4%) at one-year follow-up; 890 (68.3%) at 18-month follow-up; and 888 (68.2%) at two-year

follow-up. The average age of participants was $M = 20.52$ ($SD = 2.29$) years. The sample closely aligned with the gender and race/ethnicity composition of the institution's undergraduate population. Participants in the sample included (university 2020–2021 academic year statistics in parentheses): 62.5% (59.4%) female, 34.8% (40.6%) male; 2.5% transgender or gender variant/non-binary/non-conforming; 41.2% (47.9%) Hispanic/Latino/a/x, 30.3% (25.3%) Asian-American/Asian, 18.0% (16.1%) Caucasian/White, 1.8% (3.7%) African-American/Black, 7.5% (4.6%) Multiracial; 0.8% (0.2%) Pacific Islander/Native Hawaiian, and 0.1% (0.1%) Native American/Alaskan Native. About two-thirds (63.8%) reported their parents attended some college or a higher level of education.

3 Measures

3.1 Weight status

Participants self-reported height and weight at baseline (Wave 1), which was used to calculate body mass index (BMI; weight(lbs)/[height(in)$^2 \times 703$). Based on U.S. Centers for Disease Control (CDC) recommendations (https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/), participants were categorized into one of four weight status categories: obese (BMI ≥ 30.0); overweight (BMI 25.0–29.9); healthy weight (BMI 18.5–24.9); and underweight (BMI < 18.5). Dummy coding for the multinomial weight status variable was created with healthy weight as the reference category (*obese vs. healthy weight*, *overweight vs. healthy weight*, *underweight vs. healthy weight*).

3.2 Substance use

Past 30-day use of nicotine vaping, cigarette smoking, cannabis vaping, combustible cannabis, cannabis edibles, and binge drinking were assessed with participant self-report at each wave, from spring 2021 (W1) to spring 2023 (W5). The exception was cannabis edibles, which was not measured until fall 2021 (W2). Questions were derived from the National Institute of Drug Abuse (NIDA) Clinical Trials Network Tobacco, Alcohol, Prescription Medications, and Substance Use/Misuse (TAPS) assessment, which validated substance use questions on an adult population-based sample (37), as well as the Health & Happiness Study, a population-based prospective cohort study of adolescents and young adults in Southern California that has published vast studies on youth tobacco/nicotine and cannabis use (38, 39). For each type of substance, participants were first asked about lifetime use: "Have you ever used a vaporizer to vape nicotine (e.g., Puff Bar, JUUL, Box mod)?"; "Have you ever smoked a cigarette?"; "Have you ever used a vaporizer to vape cannabis (e.g., Pax Era, Heavy Hitters, Dosist, Kandypens)?"; "Have you ever smoked cannabis (marijuana, weed, pot)?"; "Have you ever consumed a cannabis (marijuana) edible?"; "Have you ever consumed more than 5 alcoholic drinks in one sitting (if you are a man) or 4 alcoholic drinks in one sitting (if you are a woman)?". If participants reported lifetime use for a specific substance, they were asked a corresponding question on past 30-day use: (e.g., "In the past 30 days have you vaped nicotine?"; "In the past 30 days have you consumed a cannabis edible?"). Dichotomous variables for past 30-day use (*past 30-day use* vs. *no past 30-day use*) were created for each substance use product at each wave.

3.3 Sociodemographic covariates

Age, gender, race/ethnicity, and parent highest education were self-reported at baseline. Participants reported their age (in years), gender (female, male, transgender female, transgender male, gender variant/non-binary/non-conforming), race/ethnicity (African-American/Black, Asian-American/Asian, Caucasian/White, Hispanic/Latino/a/x, Native American/Alaskan Native, Pacific Islander/Native Hawaiian, Multi-racial, and other), and highest parent education (less than some high school, some high school, graduated from high school, some college, graduated from college, earned graduate degree). Gender was recoded as *male* vs. *non-male* (instead of male vs. female) to include all participants, including transgender and non-binary, in analyses. Race/ethnicity was recoded into dummy variables (*Asian American/Asian* vs. *non-Asian American/Asian*) for racial/ethnic groups representing $\geq$10% of the sample (89.2% of the total sample was comprised of Hispanic/Latino/a/x: 41.4%, Asian American/Asian: 29.6%; and Caucasian/White: 18.2%). Highest parent education was recoded into a dichotomous variable ($\geq$*some college* vs. <*some college*).

3.4 Analysis plan

We used parallel process growth mixture modeling (PGMM) to estimate poly-substance use trajectories. Each substance use product was simultaneously modeled as a unique growth process producing 3 growth factors (i.e., intercept, linear and quadratic slopes [rate of change across the five time points, (40, 41)]. The model estimated trajectory groups based on covariation across the six distinct sets of growth factors (i.e., one set of growth factors—intercept, linear, quadratic—per product, 18 total factors). GMM uses a data-driven approach to estimate trajectory classes; classes are not identified *a priori* but rather derived from the unobserved heterogeneity in the population. An increasing number of trajectory classes were estimated until an optimal model was identified using statistical fit indices, including the Bayesian Information Criterion [BIC; (42)] and Lo-Mendell Rubin Likelihood Ratio Test [LMR LRT; (43)], as well as class interpretation and parsimony. Full information maximum likelihood was used to account for missing data. Covariates of identified trajectories were evaluated within the PGMM framework using a validated 3-step approach to account for classification error (44). After the best fitting class model was chosen, a most likely latent class variable was created using the latent class posterior probabilities. Logits reflecting the classification uncertainty rate were applied to account for measurement error in the most likely class variable. The most

likely class variable was then used to assess covariates of trajectory membership. Analyses were conducted with Mplus 8.11 (45).

4 Results

4.1 Descriptive statistics

Table 1 presents demographic characteristics and weight status at Wave 1, as well as past 30-day substance use prevalence at each wave. Just over a half of participants were classified as healthy weight (57.6%). A third of the sample were obese (13.3%) or overweight (20.4%); 6.0% were underweight. Across all waves, binge drinking had the highest past 30-day prevalence (13.0%-16.8%) while cigarette smoking had the lowest past 30-day prevalence (2.1%–2.8%).

4.2 Substance use trajectories

4.2.1 Model selection

Model fit was evaluated across an increasing number of trajectory classes. Based on statistical indices (Table 2), class interpretability, and parsimony, the four-class model was identified as best-fitting the data. The LMR LRT indicated that the four-class model was ideal; the LMR LRT was not significant past the five-class solution. Although the four-class model did not have the lowest BIC or adjusted-BIC values, the BIC values leveled off between the three- and four-class models. This leveling-off, along with consideration of class interpretation (distinct and homogenous classes) and parsimony, resulted in identifying the four-class model as optimal. Figure 1 presents the probability of past 30-day use of each substance use product for each identified trajectory.

4.2.2 Identified trajectories

The Nicotine/Tobacco Users and Binge Drinkers trajectory (7.2%) was characterized by relatively high probability of nicotine/tobacco use and binge drinking, but low probability of cannabis use (Figure 1A). Nicotine vaping probabilities across waves (60.0%–82.5%), as well as binge drinking (48.7%–59.4%) were prominent. Comparatively, cigarette smoking probabilities were low across waves (19.3%–21.8%), but still higher within this trajectory than any other trajectory class.

TABLE 1 Demographic characteristics, weight status, and substance use ($N = 1,303$).

	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
Demographics	N(%) or *Mean* ± *SD*				
Age (years)	20.52 ± 2.29				
Gender					
Female	815 (62.5%)				
Male	454 (34.8%)				
Non-Binary	26 (2.0%)				
Transgender	6 (0.6%)				
Ethnicity/Race					
African-American/Black	24 (1.8%)				
Asian-American/Asian	395 (30.3%)				
Caucasian/White	235 (18.0%)				
Hispanic/Latino/a/x	537 (41.2%)				
Native American/Alaska Native	1 (0.1%)				
Pacific Islander/Native American	11 (0.8%)				
Multiracial	98 (7.5%)				
Parent Highest Education Level					
≥Some college	831 (63.8%)				
<Some college	469 (36.0%)				
Weight Status[a]					
Obese	173 (13.3%)				
Overweight	266 (20.4%)				
Healthy Weight	751 (57.6%)				
Underweight	78 (6.0%)				
Nicotine Vaping[b]	113 (8.7%)	109 (8.4%)	100 (7.7%)	94 (7.2%)	85 (6.7%)
Cigarette Smoking[b]	35 (2.7%)	37 (2.8%)	29 (2.2%)	31 (2.4%)	28 (2.1%)
Cannabis Vaping[b]	163 (12.5%)	138 (10.6%)	123 (9.4%)	116 (8.9%)	105 (8.1%)
Combustible Cannabis[b]	180 (13.8%)	151 (11.6%)	137 (10.5%)	113 (8.7%)	104 (8.0%)
Cannabis Edibles[b,c]		103 (7.9%)	100 (7.7%)	87 (6.7%)	78 (6.0%)
Binge Drinking[b]	177 (13.6%)	219 (16.8%)	179 (13.7%)	175 (13.4%)	169 (13.0%)

[a]Weight status was estimated using the U.S. Centers for Disease Control (CDC) recommendations: obese (BMI ≥ 30.0); overweight (BMI 25.0–29.9); healthy weight (BMI 18.5–24.9), and underweight (BMI < 18.5).
[b]Past 30-day use (yes/no) was used to measure substance use across each wave.
[c]Cannabis edibles was not reported until Wave 2.

TABLE 2 Model fit indices for substance use trajectories.

Trajectory#	AIC[a]	BIC[b]	Adjusted BIC[c]	LMR LRT *p*-value for *k*-1[d]	Entropy
1	19,871.67	19,964.76	19,907.58	N/A	N/A
2	15,616.05	15,807.40	15,689.87	<.0001	.92
3	14,972.48	15,262.09	15,084.20	<.01	.91
4	14,564.04	14,951.91	14,713.67	<.05	.88
5	14,347.64	14,833.77	14,535.18	.3216	.82
6	14,255.12	14,839.52	14,480.57	.2398	.82

[a]AIC, akaike information criterion.
[b]BIC, bayesian information criterion.
[c]Sample-size adjusted Bayesian information criterion.
[d]LMR LRT, Lo-Mendell-Rubin likelihood ratio test, *p*-value for *k*-1 refers to significant improvement in model fit between the class (*k*) and the class preceding it (*k*-1).

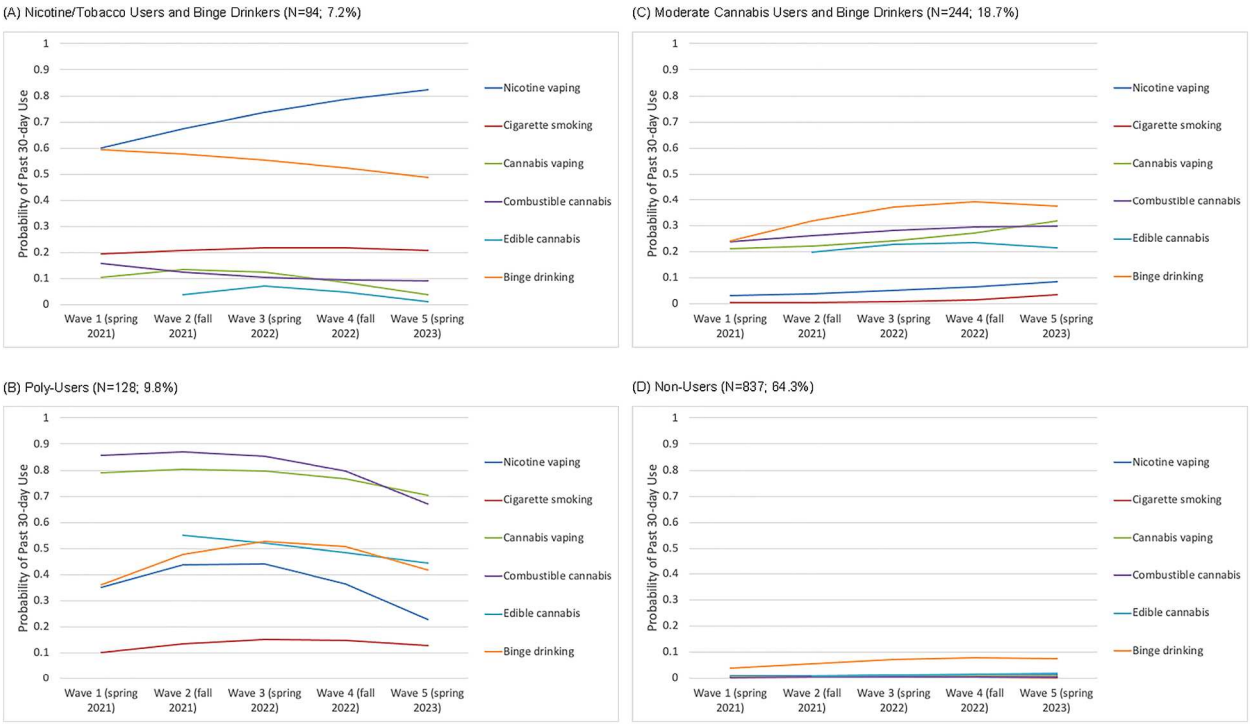

FIGURE 1
Substance use trajectories.

The Poly-Users trajectory (9.8%) reflected high probability of use for various tobacco/nicotine and cannabis products, as well as binge drinking across waves (Figure 1B). Probability of use was highest for combustible cannabis (67.1%–86.9%) and cannabis vaping (70.2%–80.5%) across waves. Edible cannabis remained at about 45%–55% across the study period. A significant quadratic decrease was identified for both binge drinking (quadratic = −.14, $p < .01$) and nicotine vaping (quadratic = −.17, $p < .01$). Binge drinking increased from Wave 1 (36.2%) to Waves 2 (47.6%) and 3 (52.6%), but then decreased at Waves 4 (50.6%) and 5 (41.8%). Similarly, nicotine vaping increased from Wave 1 (35.0%) to Waves 2 (43.7%) and 3 (44.2%), but then decreased at Waves 4 (36.4%) and 5 (22.6%). Cigarette smoking probability was lower than other substance use products and held stable across waves (10.1%–15.1%).

The Moderate Cannabis Users and Binge Drinkers trajectory (18.7%) was characterized by moderate probability of cannabis use and binge drinking and low probability of tobacco/nicotine use (Figure 1C). Probability of all cannabis products (vaping, combustible, edible) ranged between 20%-32% across waves. Binge drinking probability was slightly higher; a significant rate of change (slope = .46, $p < .05$) was found for binge drinking across waves (24.0%–39.0%). Probability of nicotine vaping and cigarette smoking was relatively low (<10%) across waves.

Non-Users (64.3%) comprised the largest trajectory class. This trajectory was comprised of no or very low substance use across waves (Figure 1D). Probability of tobacco/nicotine use and cannabis use was negligible across waves (<2%). Binge drinking probability was also low (<8%) across waves; a significant rate of

change (slope = .49, $p < .05$) was found for binge drinking across waves (3.7%–7.6%).

4.3 Correlates of substance use trajectories

Sociodemographic and weight status covariates were added to the parallel process GMM to determine the odds of trajectory membership in each of the three substance-using trajectories vs. the Non-Users trajectory (Table 3). Obese young adults (vs. healthy weight) had lower odds of belonging to the Nicotine/Tobacco Users and Binge Drinkers trajectory [aOR = .24(.06–.99)] vs. Non-Users trajectory. Overweight young adults (vs. healthy weight) had higher odds of belonging to the Moderate Cannabis Users and Binge Drinkers trajectory [aOR = 1.94(1.25–3.03)] vs. Non-Users trajectory. Underweight status was not a significant covariate of any poly-substance use trajectory.

Older participants had higher odds of belonging to the Nicotine/Tobacco Users and Binge Drinkers [aOR = 1.27(1.11–1.35)] and Poly-Users [aOR = 1.11(1.02–1.20)] trajectories vs. the Non-Users trajectory. Males had lower odds of belonging to the Moderate Cannabis Users and Binge Drinkers trajectory [aOR = .62(.42–.92)] vs. the Non-Users trajectory. Asian/Asian-American young adults had lower odds of belonging to the Poly-Users [aOR = .44(.21–.92)] and Moderate Cannabis Users and Binge Drinkers [aOR = .42(.22–.79)] trajectories compared to the Non-Users trajectory. Latina/o/x young adults had lower odds of belonging to the Nicotine/Tobacco Users and Binge Drinkers trajectory [aOR = .24(.11–.56)] vs. the Non-Users trajectory.

5 Discussion

The current study advanced understanding of the relationship between weight status and poly-substance use during young adulthood by identifying trajectories of tobacco/nicotine, cannabis, and alcohol poly-use and assessing the role of weight status on trajectory membership. All three identified substance-using trajectories (Nicotine/Tobacco Users and Binge Drinkers, Poly-users, Moderate Cannabis Users and Binge Drinkers) were characterized by some form of poly-use, highlighting the importance of integrative substance use approaches for prevention and intervention during this critical developmental period for substance use. Compared to healthy weight status, obesity status predicted lower, not higher, odds of belonging to a substance-using trajectory (Nicotine/Tobacco Users and Binge Drinkers). On the other hand, overweight status (vs. healthy weight) predicted higher odds of belonging to a substance-using trajectory (Moderate Cannabis Users and Binge Drinkers). The marked difference between obese and overweight young adults' risk of poly-substance use suggests greater specificity is needed when evaluating the relationship of higher weight status on substance use.

Using a parallel approach to GMM, this study identified four distinct underlying subpopulations of tobacco/nicotine, cannabis, and alcohol use: (1) Non-Users (64.3%); (2) Moderate Cannabis Users and Binge Drinkers (18.7%); (3) Poly-Users (9.8%); and (4) Tobacco/Nicotine Users and Binge Drinkers (7.2%). These developmental patterns indicate a significant proportion of young adults in this study—close to 40%—engaged in some form of poly-substance use. This proportion of poly-substance use is in line with de Jonge et al.'s (11) systematic review that reported one-half to two-thirds of young adults were engaged in poly-use. It is notable that all three poly-substance use trajectories were characterized by a high probability of binge drinking. Though current binge drinking prevalence remains high among young adults [30.5%; (10)], the rise of novelty tobacco/nicotine and cannabis products (nicotine vaping, cannabis vaping, cannabis edibles, etc.) and significant attention paid to ever-evolving tobacco/nicotine and cannabis legislative

TABLE 3 Estimated adjusted odds ratios (aOR) of substance use trajectory membership.

	Nicotine/Tobacco Users and Binge Drinkers	Poly-Users	Moderate Cannabis Users and Binge Drinkers
Reference Trajectory: Non-Users			
Covariates	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Age (years) at baseline	1.27 (1.11–1.35)***	1.11 (1.02–1.20)*	1.05 (.97–1.14)
Male vs. non-male[a]	1.01 (.60–1.69)	.90 (.58–1.39)	.62 (.42–.92)*
Race/Ethnicity[c]			
Asian/Asian-American vs. non-Asian/Asian-American	.47 (.22–.1.01)	.44 (.21–.92)*	.42 (.22–.79)**
Latina/o/x vs. non-Latina/o/x	.24 (.11–.56)**	.67 (.33–1.37)	.64 (.35–1.17)
White/Caucasian vs. non-White/Caucasian	.92 (.42–1.99)	1.22 (.59–2.52)	.85 (.44–1.65)
Highest parental education level[b]	.79 (.46–1.37)	1.42 (.86–2.33)	1.34 (.87–2.06)
Weight Status[c]			
Obese vs. healthy weight	.24 (.06–.99)*	.92 (.49–1.74)	1.15 (.66–2.01)
Overweight vs. healthy weight	1.49 (.82–2.68)	1.35 (.79–2.31)	1.94 (1.25–3.03)**
Underweight vs. healthy weight	.42 (.09–1.84)	.80 (.31–2.04)	.66(.26–1.67)

[a]Males compared to females and other gender identities (non-binary, transgender).
[b]Highest parent education coded as ≥ some college vs. < some college.
[c]Race/ethnicity and weight status modeled as dummy-coded variables.
* $p < .05$; ** $p < .01$; *** $p < .001$.

policies (e.g., e-cigarette flavor bans, cannabis legalization) has potentially undermined public health concerns related to young adult binge drinking. This is concerning as recent studies, including systematic reviews and meta-analyses, show young adult binge drinking is linked to structural and functional abnormalities in brain regions involved in self-regulation and reward processing, which increases the likelihood of risky sexual behavior, poly-substance use, and interpersonal violence (46–49). Overall, the current study finds that focus on poly-substance use vs. single-substance use is warranted to prevent problematic substance use patterns in young adults.

In addition to addressing gaps in the young adult substance use literature related to longitudinal measurement of poly-use involving tobacco/nicotine, cannabis, and binge drinking, a key aim of the study was to add to the small but burgeoning knowledge base on the role weight status plays on substance use in young adulthood. Though our hypothesis that obese vs. healthy weight young adults would have a higher likelihood of belonging to tobacco/nicotine-using trajectories was based on past studies indicating obesity status predicted tobacco/nicotine use in young adulthood (18–20), the lack of prospective studies, especially on nicotine vaping, makes the unexpected finding that obese status (vs. healthy weight) predicted lower likelihood of belonging to the Nicotine/Tobacco Users and Binge Drinkers vs. Non-Users trajectory less surprising. Moreover, the finding that overweight vs. healthy weight young adults had a higher likelihood of belonging to the Moderate Cannabis Users and Binge Drinkers vs. Non-Users trajectory suggests overweight young adults may be a key target group for anti-cannabis and binge drinking public health initiatives. There is already some evidence indicating overweight young adults are vulnerable to combustible cannabis and binge drinking (12). Though this study lends some evidence for the inverse U-shaped relationship between weight status and substance use posited by Amiri and Behnezhad (24), it is important to note underweight vs. healthy weight was not associated with higher or lower risk of poly-substance use. The notable differences between obese and overweight young adults suggest greater specificity is needed when evaluating relationships between weight status and substance use.

Obese and overweight young adults' differential poly-substance use risk suggest obese vs. overweight categories have distinct shared underlying mechanisms with poly-substance use. For example, different socio-environmental contexts between obese and overweight young adults may explain why overweight young adults were at higher risk of poly-substance use vs. healthy weight young adults, but obese young adults were not. Overweight young adults may have an easier time than obese young adults socializing with peers, but their vulnerability to being socially excluded may influence greater risk of poly-substance use to appear cool and engaged in what they believe is the normative peer social context (50). It is also possible that a significant proportion of overweight young adults in this study recently shifted from healthy to unhealthy weight status, as increased weight is a common experience among college students (51). Potentially these overweight young adults may be engaging in poly-substance use as a coping mechanism in response to recent body weight increases (52–54). Conversely, obese young adults' opportunities to engage in poly-substance use, which often take place at social events with peers during the college years (55, 56) may be more limited because obese young adults face greater challenges (e.g., social stigma, marginalization) participating in social and recreational activities compared to overweight young adults (57, 58). Moreover, it is possible that the food-drug competition hypothesis (20, 59, 60) played a role in obese young adults' lower risk of poly-substance use compared to healthy weight peers. Obese individuals' greater vulnerability towards over-eating compared to other weight categories (61) may protect against poly-substance use as the neural reward pathways shared by food and drugs are saturated with over-eating behaviors.

The current study also used a sample that was largely racial/ethnic minority (82.0%) and female (62.5%), which may explain differences with previous studies evaluating race/ethnicity and gender across poly-substance use trajectories. Unlike two recent studies indicating White vs. non-White participants had higher odds of belonging to a poly-substance use vs. a non-users trajectory (62, 78), this study did not find Caucasian/White (vs. non-Caucasian/White) young adults at higher risk of membership in a poly-substance use vs. non-users trajectory. A lower likelihood of Asian/Asian-American vs. non-Asian/Asian-American young adults belonging to the Poly-Users and Moderate Cannabis Users and Binge Drinkers vs. Non-Users trajectory corroborates Cho et al.'s (63) study that showed Asian (vs. Hispanic) adolescents had lower odds of belonging to an early initiation poly-use trajectory (vs. non-users). We also found that Latina/o/x vs. non-Latina/o/x young adults had lower odds of belonging to the Nicotine/Tobacco and Binge Drinkers vs. Non-Users trajectory. Males vs. non-males lower odds of belonging to the Moderate Cannabis Users and Binge Drinkers vs. Non-Users trajectory aligns with a past finding indicating males vs. females had lower odds of belonging to a Young Adult-Onset Poly-Substance/Poly-Product Users vs. non-users trajectory (64), though another poly-substance trajectory study reported males (vs. females) had a higher likelihood of belonging to a poly-substance use trajectory vs. non-users trajectory, as well as earlier vs. later poly-use (65). Potentially the higher risk of overweight and obesity status among Latina/o/xs and females, and lower risk among Asian/Asian-Americans (36, 66, 67) may have contributed to the racial/ethnic and gender differences observed in this sample, which was predominately Asian/Asian-American, Latina/o/x and female.

Of course, limitations of this study need to be considered when drawing conclusions. The use of a sample specific to Southern California limits generalizability of findings to other regions; however, a regionally-specific sample increases the likelihood that participants were exposed to similar tobacco/nicotine, cannabis, and alcohol regulatory policies and trends during assessment. The sample attrition rate grew across timepoints and was close to one-third at the conclusion of the study; however, full information maximum likelihood enabled participants with at least one wave of data to be analyzed. Though the study relied on self-report of past 30-day substance use, self-report remains the most common method of measuring substance use behaviors. In addition, we recognize that measuring substance use with a binary (yes/no) indicator

compared to frequency of use did not allow us to determine whether poly-substance use trajectory classes reflect problematic use. The study also relied on self-reported vs. directly measured BMI. Although directly measured vs. self-reported height and weight is ideal, past research has indicated that self-reported BMI has high concordance with directly measured BMI among adolescents and young adults (68–70). That said, we recognize that BMI, whether directly measured or self-reported, is not as accurate an indicator as anthropometric measures (e.g., visceral adiposity, waist circumference, skinfold thickness) for evaluating healthy vs. unhealthy status (70, 79, 80), and additional research on this topic using anthropometric measures is needed. Moreover, only weight status at baseline was included in the analysis; thus, we do not know the impact between acute vs. chronic higher weight status. Additionally, though most prospective studies among adolescent and young adult populations have focused on the pathway from higher weight status to substance use, there is evidence that substance use, specifically cigarette smoking and binge drinking, predict higher BMI, overweight, and obese status in adolescents and young adults (71–74). Future research assessing bidirectional associations between poly-substance use and weight status is warranted to further inform the underlying pathways to co-occurring substance use and weight status health-risks among young adults. We also note that our proxy for SES, parent education, did not allow for more meaningful interpretations of the role SES has on poly-substance use trajectories. Additionally, we did not consider hypothesized underlying mechanisms of both weight status and substance use, such as depressive symptoms, social context, and biobehavioral markers of shared reward pathways (12–14). Though our primary aim in the current study was addressing gaps in the literature related to the use of prospective studies, poly-substance use measures, and comparison of weight status categories, moving forward with the current findings can inform which underlying processes may best explain the significant associations identified.

Despite these limitations, this study advances knowledge on the relationship between weight status and substance use by identifying distinct differences between higher weight status categories' risk of poly-substance use trajectories in young adulthood. Obese and overweight young adults, often viewed as more similar than different in relation to physical and psychosocial consequences, reported unique associations with substance use. Overweight (vs. healthy weight) young adults had a higher likelihood of belonging to a Moderate Cannabis Users and Binge Drinkers vs. Non-users trajectory, whereas obese (vs. healthy weight) young adults unexpectedly had a lower likelihood of belonging to a Tobacco/Nicotine Users and Binge Drinkers vs. Non-users trajectory. The findings highlight a need to better understand the epidemiological distinctions between obese and overweight young adults' poly-substance use. A more nuanced view of the role weight status plays on substance use in young adulthood is likely to improve current efforts to reduce co-occurring health-risks earlier in the lifespan. Though obese status earns significantly more research and clinical attention than overweight status, overweight young adults' greater risk of poly-substance use compared to healthy weight peers suggests they may be a key target group for anti-poly-substance use public health initiatives. Moving forward, identifying underlying risk processes and pathways linking overweight to poly-substance use in young adulthood, which may involve an interaction between peer context and internalizing symptoms different from obese young adults, is warranted. Additionally, the significant proportion of poly-substance use vs. single-substance use observed in this study indicates poly-substance use may be the normative pattern of tobacco/nicotine, cannabis, and binge drinking among young adults. Greater attention to developing comprehensive, integrative approaches to substance use health services that reflect the high prevalence of poly-substance use is critical moving forward, especially as young adults engaged in poly-substance use are at greater risk of deleterious health outcomes compared to single-substance users, including cognitive deficits, mental health impairments, and greater substance dependence (75–77). Further research on the determinants and health consequences of poly-substance use is warranted to not only understand key targets for intervention, but also policy priorities for reducing poly-substance use in young adulthood.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institutional Review Board, California State University, Long Beach. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

HL: Visualization, Resources, Formal analysis, Funding acquisition, Project administration, Writing – original draft, Validation, Data curation, Investigation, Supervision, Conceptualization, Methodology, Writing – review & editing. KW: Writing – review & editing, Writing – original draft. LS: Writing – review & editing, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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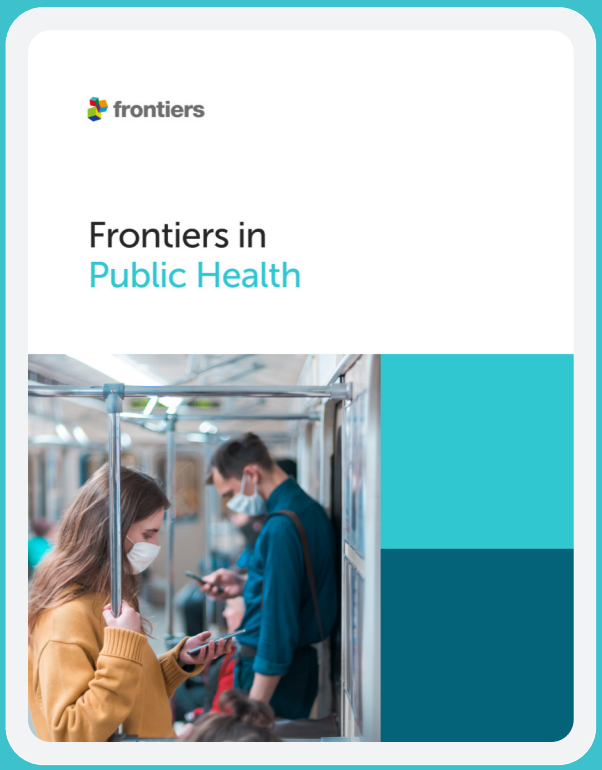

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