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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

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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.

Publisher's note

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