

Emotional symptoms and sensation seeking: Implications for tobacco interventions for youth and young adults

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ABSTRACT

INTRODUCTION Although emotional symptoms and sensation seeking are recognized as important risk factors for tobacco use among youth and young adults, to date, their joint influence on tobacco use has not been examined.

METHODS Data used in this study are from the Texas Adolescent Tobacco and Marketing Surveillance study, a population-based cohort. At baseline, in 2014, participants were in the 10th grade. Mixed-effects logistic regression models examined associations between emotional symptoms and sensation seeking in 2014 and odds of past 30-day cigarette and e-cigarette use in 2018. Interactions between emotional symptoms and sensation seeking were examined to assess whether one modifies the effect of the other on cigarette and e-cigarette use.

RESULTS After adjusting for age, sex, race/ethnicity, school type, and ever use of cigarettes or e-cigarettes at baseline, adolescents with high emotional symptoms ($AOR_{cig} = 1.97$; 95% CI: 1.07–3.60, and $AOR_{e-cig} = 1.68$; 95% CI: 1.06–2.66) and with high sensation seeking tendencies ($AOR_{cig} = 2.05$; 95% CI: 1.03–4.10, and $AOR_{e-cig} = 1.68$; 95% CI: 1.02–2.76) had significantly higher odds of past 30-day cigarette and e-cigarette use four years later compared to adolescents with low emotional symptoms and low sensation seeking tendencies. The interaction was significant ($p=0.01$) for e-cigarette use only; among low sensation seekers, adolescents who reported high levels of emotional symptoms were at increased risk for past 30-day use ($AOR_{e-cig} = 3.43$; 95% CI: 1.38–8.51), and among adolescents with low emotional symptoms, high sensation seekers were at increased for risk for past 30-day use ($AOR_{e-cig} = 3.50$; 95% CI: 1.54–7.91).

CONCLUSIONS It is important for tobacco use prevention programs to consider both behavioral risk factors – sensation seeking and emotional symptoms – in an integrative way, to target high risk subgroups and thereby increase the efficacy of existing effective intervention strategies in order to curb tobacco use among youth and young adults.

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INTRODUCTION

Tobacco use remains the leading cause of preventable death in the United States¹. Tobacco use typically starts and is established primarily during adolescence, when the developing brain is most susceptible to nicotine

addiction^{1,2}. Nearly 9 in 10 current cigarette smokers tried their first cigarette by the age of 18 years, and 98% first tried smoking cigarettes by 26 years². In 2019, about 6 in 100 high school students (5.8%) reported that they smoked cigarettes in the past 30

days – a decrease from 15.8% in 2011³. However, in 2019 more than 1 in 4 high school students (27.5%) reported using electronic cigarettes (e-cigarettes) in the past 30 days – an increase from 1.5% in 2011³. In 2014, the US Food and Drug Administration (FDA) concluded that e-cigarettes are considered tobacco products because most contain nicotine, which comes from tobacco⁴. Both cigarettes and e-cigarettes have similar negative effects on the body in the short-term, such as excessive coughing, shortness of breath, and fatigue^{5,6}. However, to date, the full breadth of health consequences associated with e-cigarette use is unknown. This includes whether their use over time will result in other long-term health consequences similar in magnitude to the well-established negative effects of long-term cigarette use^{1,5}. Given the negative health consequences of nicotine and tobacco use and these prevalence rates, preventing tobacco product use among youth remains critical to ending the tobacco epidemic in the United States.

Emotional symptoms and tobacco use

Emotional symptoms in youth and young adults can manifest as mental health symptoms of depression, anxiety, inability to focus attention, and suicide ideation⁷. Nicotine has both anxiolytic⁸ and anti-depressive⁹ qualities; in turn one reason smokers report smoking is to reduce emotional symptoms¹⁰. For some, smoking is initiated in response to negative emotions¹⁰ and the perception that smoking is a good way to control negative emotions predicts smoking maintenance and escalation¹¹. Indeed, youth and young adults with emotional symptoms report a higher prevalence of nicotine use than their peers who do not report emotional symptoms¹²⁻¹⁵. Currently and overall, less is known about the relationship between emotional symptoms and e-cigarette use compared to cigarette use.

Sensation seeking and tobacco use

Sensation seeking is a personality trait defined by ‘the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take risks for the sake of such experience’¹⁶. Both cross-sectional and longitudinal studies have found that as sensation seeking increases, the risk of negative behaviors such as nicotine and tobacco use, including both cigarettes and e-cigarettes, also

increases^{17,18}. High sensation seeking youth may try tobacco because it is illegal and may enjoy the arousal and sensations associated with contravening social norms and breaking the law. In addition, the novelty of smoking may be attractive to youth with higher levels of sensation seeking¹⁹. Thus, e-cigarettes, which entered the market in 2007 and have become increasingly popular among youth, may be particularly appealing to sensation seekers, for their novelty.

Emotional symptoms and sensation seeking

When examining the influence of family dynamics on substance use, Trujillo et al.²⁰ report that it is through an increase in negative emotional symptoms, which in turn augments sensation seeking behaviors, that family conflict serves to increase both intentions to use and substance use itself. In this study, both emotional symptoms and sensation seeking mediated the relationship between family dynamics and both alcohol and marijuana use. However, to date, although emotional symptoms and sensation seeking are recognized as important risk factors for tobacco use, how their joint exposure impacts nicotine and tobacco use risk is unclear. We seek to fill this gap.

Study purpose and aims

Given that emotional symptoms and sensation seeking independently increase risk for nicotine and tobacco use^{12-15,17-19}, we hypothesize that youth who experience many emotional symptoms and contemporaneously report as high sensation seekers will be at higher risk for nicotine and tobacco use relative to youth who experience few emotional symptoms and contemporaneously report as low sensation seekers. Of importance, sensation seeking is a modifiable trait²¹, and some adolescents with high sensation seeking tendencies choose safe positive behaviors to meet arousal needs²². A better understanding of the sensation seeking trait among youth with emotional symptoms may serve to identify youth at risk of future nicotine and tobacco use and may help to hone prevention strategies. Therefore, this study aimed to examine whether: 1) emotional symptoms at baseline are associated with cigarette and e-cigarette use four years later, after adjusting for sociodemographic characteristics; 2) sensation seeking tendencies at baseline are associated with cigarette and e-cigarette use four years later after

adjusting for sociodemographic characteristics; 3) sensation seeking is a potential effect modifier of the association between emotional symptoms and product use; and 4) emotional symptoms are a potential effect modifier of the association between sensation seeking and product use.

METHODS

Study design and participants

The data used in this study were derived from the Texas Adolescent Tobacco and Marketing Surveillance System (TATAMS), a longitudinal surveillance study of e-cigarette and other tobacco use behaviors among a population-based cohort of adolescents living in major metropolitan areas of Texas (Austin, Dallas-Ft. Worth, Houston, San Antonio). Baseline data were collected in the classroom during the 2014–2015 academic year from 3907 students in the 6th, 8th, and 10th grades using computerized surveys administered via tablets. After wave 2, all surveys were administered remotely, every six months for four years thereafter with the same web-based forms used at baseline, through Spring 2018 (wave 8). TATAMS human subject's methods were approved by the University of Texas Health Science Center at Houston Institutional Review Board (HSC-SPH-13-0377). Active consent from parents/guardians and assent from students were obtained for all surveys. The retention rates for waves 1–8 ranged 64–85%. Further description about TATAMS sampling methodology and study design are provided elsewhere²³. The present study prospectively examined data at baseline (wave 1) and the follow-up at 4 years (wave 8). The analysis sample for this study was limited to adolescents who were in the 10th grade at baseline ($n=1463$; average age=15.0 years, $SD=0.79$) with complete data on sociodemographic and risk variables at follow-up ($n=948$; average age=18.3 years, $SD=0.77$). We focused on these older adolescents because they are in a critical period of development; their behavioral decisions during the transition into young adulthood strongly affects their trajectories and have long-term consequences for their health and wellbeing²⁴.

Measures

Dependent variables

The main outcomes in this analysis were assessed at follow-up in 2018. Past 30-day cigarette use was

assessed using the question: 'During the past 30 days, did you smoke a cigarette?'. Response options were 'yes' and 'no.' Participants who responded 'no' at follow-up were classified as non past 30-day cigarette users, participants who responded 'yes' were classified as past 30-day cigarette users. Past 30-day e-cigarette use was assessed using the question: 'During the past 30 days, did you use an electronic cigarette, vape pen or e-hookah?'. Response options were 'yes' and 'no.' Participants who responded 'no' at follow-up were classified as non past 30-day e-cigarette users, participants who responded 'yes' were classified as past 30-day e-cigarette users.

Independent variables

The main exposure variables were assessed at baseline in 2014. The Strengths and Difficulties Questionnaire (SDQ) is a five-scale mental health screening tool used in children and adolescents²¹. The scales measure emotional symptoms, conduct-problems, hyperactivity-inattention, peer relationship problems, and prosocial behaviors²⁵. In the current analysis, we used the emotional symptoms subscale from the SDQ. The emotional symptoms subscale consists of five items that probe somatic symptoms (i.e. 'I get a lot of headaches, stomach aches or sickness' and 'I have many fears, I am easily scared') as well as mental health symptoms (i.e. 'I worry a lot', 'I am unhappy, depressed or fearful', and 'I am nervous in new situations'). Response options include: 'Not true', 'Somewhat true', and 'Certainly true'. Participants who completed at least three of the five items were included in the analyses; a mean composite score was created corresponding to the sum of the items divided by the total number of items completed. Emotional symptoms scores ranged 1–10, with a mean of 2.67 ($SD=2.73$), with higher scores reflecting higher levels of emotional symptoms. Emotional symptoms were divided into three groups based on the distribution: low (≤ 1); medium (2–3); and high (8–14). Based on data from participants in the current analysis, the SDQ demonstrated excellent internal reliability (Cronbach's $\alpha=0.96$).

We used the Brief Sensation Seeking Scale (BSSS-4; 22) to assess sensation seeking²⁶. The BSSS-4 consists of four items that use a five-point response option, ranging from 'strongly disagree' to 'strongly agree': 1) 'I would like to explore strange places';

2) 'I like to do frightening things'; 3) 'I like new and exciting experiences, even if I have to break the rules'; and 4) 'I prefer friends who are exciting and unpredictable'. Participants who completed at least two of the four items were included in the analyses; a mean sensation seeking score was created by summing responses across all completed items and dividing by the number of completed items. Sensation seeking scores ranged from 1 to 5, with a mean of 3.09 (SD=1.04), with higher scores reflecting higher levels of sensation seeking. Sensation seeking symptoms were divided into tertiles based on their distribution: low (≤ 2.75); medium (>2.75 to 3.5); and high (>3.5). Based on data from participants in the current report, the BSSS-4 demonstrated excellent internal reliability (Cronbach's $\alpha=0.95$).

Covariates

Several covariates were included in the analysis to adjust for confounding influences¹⁸. These covariates included sociodemographic variables: sex (female, male), race/ethnicity (non-Hispanic White, Hispanic, non-Hispanic Black or African American, and non-Hispanic other), age in years, and type of school attended (charter, private, or public). Ever use of either product at baseline also was included in the analysis to control for previous behavior. Ever cigarette use was assessed using the question: 'Have you EVER tried cigarette smoking, even one or two puffs?'. Response options were 'yes' and 'no.' Participants who responded 'no' at baseline were classified as never users; participants who responded 'yes' were classified as ever users. Ever e-cigarette use was assessed using the question: 'Have you EVER used an electronic cigarette, vape pen, or e-hookah, even one or two puffs?'. Response options were 'yes' and 'no'. Participants who responded 'no' at baseline were classified as never users; participants who responded 'yes' were classified as ever users.

Statistical analysis

Descriptive statistics were calculated as percentages for categorical variables and means and standard deviations for continuous variables. We used a mixed-effects logistic regression to model the association between the exposure variables at baseline (i.e. emotional symptoms, sensation seeking) and the odds of past 30-day cigarette and e-cigarette use at follow-

up at 4 years, after adjusting for sociodemographic factors and ever tobacco use at baseline. The random effect was included in the mixed-effects logistic regression to account for the correlation of subjects in the same school. To meet the linearity assumption between the log odds of the outcome and each predictor and to improve the accuracy of our models, we categorized emotional symptoms and sensation seeking variables into tertiles (low, medium, high). A potential interaction between emotional symptoms and sensation seeking was examined to assess whether one modifies the effect of the other on cigarette and e-cigarette use. We included the product term of sensation seeking with emotional symptoms and compared the model with and without the product terms, in terms of model fit using the likelihood ratio test. Stratified analyses were conducted as the interaction was significant. Participants with missing values for any covariates were excluded in the model (35% of the sample). An attrition analysis was conducted to identify differences between participants who provided data at both time points compared to those who provided data at baseline only. Data were expressed as odds ratios (ORs) with 95% confidence intervals (95% CIs). Alpha was set at 0.05 and all analyses were conducted using STATA statistical software (version 16.0; 23)²⁷.

RESULTS

Sample characteristics

The sociodemographic characteristics of the 1463 adolescents in 10th grade included in the current analysis are presented in Table 1. The majority were females (55%). Approximately 40% identified as Hispanic, 27% as non-Hispanic White, 20% as non-Hispanic Black or African American, and the remaining 14% identified as non-Hispanic other. Most (82%) attended public schools. Most (44%) of the adolescents reported low emotional symptoms, 24% reported medium emotional symptoms, and 32% reported high emotional symptoms. Roughly a third (34%) of the adolescents reported low level of sensation seeking, 31% reported medium level of sensation seeking, and 32% reported high level of sensation seeking. In 2014, at baseline, almost 16% of the 10th graders reported that they had tried cigarettes and 32% reported they had tried e-cigarettes. By the follow-up at four years in 2018, 23% reported they

Table 1. Descriptive statistics of the study sample at baseline, TATAMS 2014 (N=1463)

Characteristics	n	%
Sex		
Female	807	55.16
Male	656	44.84
Age (years), mean, SD	15.03	0.79
Race/ethnicity		
Non-Hispanic White	401	27.41
Non-Hispanic Black	291	19.89
Hispanic	569	38.89
Non-Hispanic Other ^a	202	13.81
School type		
Charter	91	6.22
Private	166	11.35
Public	1206	82.43
Ever cigarette use*		
No	1228	83.94
Yes	233	15.93
Ever e-cigarette use*		
No	995	68.01
Yes	466	31.85
Emotional symptoms**b		
Low	619	43.84
Medium	336	23.80
High	457	32.37
Scale, mean, SD	2.67	2.70
Sensation seeking***c		
Low	503	34.38
Medium	460	31.44
High	464	31.72
Scale, mean, SD	3.09	1.04

a Other: Asian, American Indian/Alaska Native, Native Hawaiian and other Pacific Islanders. b Score: low (≤1); medium (2–3); high (4–10). c Score: low (≤2.75); medium (>2.75 to 3.5); high (>3.5). *Missing = 2 (0.14%). **Missing = 51 (3.49%). *** Missing = 36 (2.46%).

Table 2. Longitudinal association between emotional symptoms at baseline, sensation seeking at baseline, and cigarette and e-cigarette use at follow-up at four years, among Texas adolescents, TATAMS 2014–2018

	Cigarettes ^a		E-cigarettes ^b	
	OR (95% CI) (n=949)	AOR ^c (95% CI) (n=948)	OR (95% CI) (n=949)	AOR ^c (95% CI) (n=948)
Emotional symptoms^c				
Low	Ref.	Ref.	Ref.	Ref.
Medium	0.58 (0.27–1.26)	0.64 (0.28–1.43)	0.83 (0.49–1.39)	0.95 (0.55–1.65)
High	1.57 (0.91–2.70)	1.97 (1.07– 3.60)	1.46 (0.96–2.22)	1.68 (1.06–2.66)
Sensation seeking^d				
Low	Ref.	Ref.	Ref.	Ref.
Medium	1.77 (0.88–3.58)	1.47 (0.71–3.04)	1.43 (0.88–2.35)	1.28 (0.77–2.13)
High	2.58 (1.32–5.02)	2.05 (1.03– 4.10)	1.92 (1.20–3.09)	1.68 (1.02–2.76)

AOR: adjusted odds ratio. CI: confidence interval. Ref.: reference. Bold indicates statistical significance, p<0.05. a Current cigarette use indicates self-reported as smoking cigarette(s) in the past 30 days. b Current e-cigarette use indicates self-reported use of electronic cigarette, vape pen or e-hookah in the past 30 days. c Score: low (≤1); medium (2–3); high (4–10). d Score: low (≤2.75); medium (>2.75 to 3.5); high (>3.5). e Adjusted for sex, age, ethnicity, school type and ever product use at wave 1.

had tried cigarettes and 4.5% reported past 30-day use, while 36% reported they had tried e-cigarettes and 9% reported past 30-day use (data not shown).

Direct effects: Emotional symptoms

In Table 2 we present the unadjusted and adjusted associations between emotional symptoms assessed at baseline and past 30-day cigarette and e-cigarette use at follow-up. After adjusting for age, sex, ethnicity, school type, and ever use of cigarettes or e-cigarettes, adolescents with high emotional symptoms had significantly higher odds of reporting past 30-day cigarette and e-cigarette use compared to adolescents with low emotional symptoms (AOR=1.97; 95% CI: 1.07–3.60, and AOR=1.68; 95% CI: 1.06–2.66), respectively.

Direct effects: Sensation seeking

In Table 2 we present unadjusted and adjusted associations between sensation seeking assessed at baseline and past 30-day cigarette and e-cigarette use assessed at follow-up. After adjusting for age, sex, ethnicity, school type, and ever use of cigarettes or e-cigarettes, the odds of past 30-day cigarette and e-cigarette use were significantly higher among adolescents with high sensation seeking tendencies compared to adolescents with low sensation seeking tendencies (AOR=2.05; 95% CI: 1.03–4.10, and AOR=1.68; 95% CI: 1.02–2.76, respectively).

Effect modification: Emotional symptoms interaction with sensation seeking

The interaction between emotional symptoms and

sensation seeking in regard to their relationship with past 30-day e-cigarette use was statistically significant ($p=0.01$), but it was not with past 30-day cigarette smoking ($p>0.05$). Results of the analysis stratified by sensation seeking level for past 30-day e-cigarette use are reported in Table 3. Among low sensation seekers, adolescents who reported high levels of emotional symptoms were at increased risk for e-cigarette use at follow-up (AOR=3.43; 95% CI: 1.38–8.51). However, among adolescents with medium or high levels of sensation seeking, this association was not statistically significant. Results of the analysis stratified by emotional symptom level for past 30-day e-cigarette use are reported in Table 4. Among adolescents with low emotional symptoms, those who reported high levels of sensation seeking were at increased risk for e-cigarette use at follow-up (AOR=3.50; 95% CI: 1.54–7.91). However, among adolescents with medium or high levels of emotional symptoms this association was not statistically significant.

DISCUSSION

In the current study, we examined whether emotional symptoms result in additional risk for tobacco use among a sample of adolescent Texans with varying levels of sensation seeking – and whether sensation seeking results in additional risk for tobacco use among adolescents with varying levels of emotional symptoms. Using a prospective study design, we found the association between emotional symptoms and e-cigarette use differed depending on the level of sensation seeking: among low sensation seeking youth, those with high levels of emotional problems were at increased risk for e-cigarette use, however, this relationship was not present among adolescents with medium or high levels of sensation seeking. We further found that among youth with few emotional symptoms, those with high levels of sensation seeking were at increased risk for e-cigarette use. This is the first study that has specifically investigated the joint effect of emotional symptoms and sensation seeking

Table 3. Longitudinal association between emotional symptoms assessed at baseline and e-cigarette use, stratified by level of sensation seeking at follow-up at four years, among Texas adolescents, TATAMS 2014–2018 (N=948)

	Sensation seeking ^b		
	Low (n=321) AOR ^c (95% CI)	Medium (n=315) AOR ^c (95% CI)	High (n=312) AOR ^c (95% CI)
Emotional symptoms^a			
Low	Ref.	Ref.	Ref.
Medium	1.27 (0.43–3.74)	1.62 (0.63–4.16)	0.44 (0.17–1.15)
High	3.43 (1.38–8.51)	2.29 (0.97–5.42)	0.80 (0.38–1.67)

AOR: adjusted odds ratio. CI: confidence interval. Ref.: reference. Bold indicates statistical significance, $p<0.05$. a Score: low (≤ 1); medium (2–3); high (4–10). b Score: low (≤ 2.75); medium (>2.75 to 3.5); high (>3.5). c Adjusted for age, sex, ethnicity, school type and ever e-cigarette use. For sensation seeking interaction $p=0.01$.

Table 4. Longitudinal association between sensation seeking assessed at baseline and e-cigarette use at follow-up at four years, stratified by level of emotional symptoms among Texas adolescents, TATAMS 2014–2018 (N=948)

	Emotional Symptoms ^a		
	Low (n=321) AOR ^c (95% CI)	Medium (n=315) AOR ^c (95% CI)	High (n=312) AOR ^c (95% CI)
Sensation seeking^b			
Low	Ref.	Ref.	Ref.
Medium	1.27 (0.50–3.20)	1.50 (0.50–4.47)	0.94 (0.43–2.08)
High	3.50 (1.54–7.91)	1.04 (0.30–3.58)	0.87 (0.40–1.89)

AOR: adjusted odds ratio. CI: confidence interval. Ref.: reference. Bold indicates statistical significance, $p<0.05$. a Score: low (≤ 1); medium (2–3); high (4–10). b Score: low (≤ 2.75); medium (>2.75 to 3.5); high (>3.5). c Adjusted for age, sex, ethnicity, school type and ever e-cigarette use. For emotional symptoms interaction $p=0.01$.

among adolescents; accordingly, the interactions cannot be directly compared with any existing literature. Although these results do not support our hypothesis, lending support to our novel finding, and consistent with previous literature, we also found that among 10th graders, experiencing emotional symptoms and higher levels of sensation seeking¹⁷⁻¹⁹ were directly and independently associated with past 30-day cigarette and e-cigarette use¹²⁻¹⁵, four years after baseline.

As expected and consistent with prior research²⁸, adolescents reporting high emotional symptoms in 10th grade were at increased risk of past 30-day cigarette and e-cigarette use four years later; this effect remained after controlling for covariates, including sex, race/ethnicity, age, school type, and ever tobacco use. For example, a Greek study among 1030 participants found that emotional symptoms were positively associated with adolescents' past 30-day cigarette smoking²⁸. Research suggests that emotional symptoms and tobacco use are linked in a bidirectional manner: on the one hand, emotional symptoms, such as depression and anxiety, may precede and promote tobacco use but on the other hand, chronic tobacco users may either develop emotional symptoms or worsen their condition²⁹⁻³². Several hypotheses have been proposed regarding the nature of this relationship. The self-medication hypothesis suggests that depressed or anxious people smoke because it is the easiest, most accessible way to control their emotional symptoms, and that leads to smoking initiation and subsequent regular use³³. Tobacco companies funded research in support of this hypothesis³⁴. Alternatively smoking and exposure to nicotine may lead to emotional symptoms by affecting an individual's neurocircuitry, which increases susceptibility to environmental stressors^{35,36}. Of note, individuals with emotional symptoms tend to start using tobacco at an earlier age, use it more heavily, and may be less likely to quit³⁷ than peers with fewer emotional symptoms. Together these results suggest that developing interventions to address emotional symptoms, as an important risk factor among high school adolescents, may serve to reduce the onset and amount of cigarette and e-cigarette use in the future.

Some adolescents with high sensation seeking tendencies meet their sensation seeking needs

through engaging in arousal behaviors that enhance health, rather than behaviors that compromise their health²². Consistent with previous research¹⁷⁻¹⁹, we found that self-reported sensation seeking tendencies reported in 10th grade were associated with product use at follow-up. Our result extends previous research, as the follow-up period in this study was four years. During follow-up many of the participants transitioned to young adulthood, passing the age where they could both legally use tobacco and serve as targets of tobacco marketing³⁸, and when tobacco use is often consolidated^{11,39}. As such, developing interventions that target adolescents with high sensation seeking tendencies may be a useful strategy. Changing attitudes and beliefs about how to meet arousal needs may lead to the adoption of healthy behaviors rather than health compromising behaviors or the adoption of both healthy behaviors and health compromising behaviors.

The interaction between emotional symptoms and sensation seeking was only observed for e-cigarettes. The odds ratios for the interactions are both statistically significant, both are in the same direction, and both are roughly double those for the direct effects. Thus, in terms of implications for interventions, among youth with low emotional symptoms, the subset of individuals with high sensation seeking tendencies are at increased risk for product use due to their sensation seeking tendencies, while among youth with low sensation seeking tendencies, the subset with high emotional symptoms are at increased risk for product use due to emotional symptoms. As noted, the interaction reveals that the risk for e-cigarette use is almost double among the two subsets of youth. Therefore, identifying these high-risk youth and addressing the reasons for their e-cigarette use may serve as a useful intervention. For example, some youth believe that using tobacco and nicotine will relieve stress^{8,40} and improve their social standing with their peers⁴¹. Identifying similar beliefs in youth with emotional symptoms and sensation seeking tendencies and providing options and resources to address such beliefs may serve to improve the efficacy of interventions to prevent and reduce product use.

Strengths and limitations

The current findings should be interpreted within

the context of study limitations. First, the overall drop-out rate was 35% and the analysis is restricted to individuals with complete data only; results of such analyses can be biased. We observed some attrition bias over the four years – more males and youth with high sensation seeking tendencies, than females and low sensation seekers, dropped out of the study, which may have underestimated the strength of the associations between sensation seeking and product use, especially as males in general tend to be higher sensation seekers than females¹⁷. Of note, the overall drop-out rate is similar to that reported from other adolescent Texas-based cohort studies⁴². Second, all items were measured via self-report, therefore, social desirability bias could affect youth responses and cause underreporting of their tobacco use, emotional symptoms and sensation seeking tendencies. Studies should attempt to replicate these results using, for instance, biological measures of tobacco use such as urine or hair screening analysis. Third, risk factors were assessed only at baseline, so it is possible for some risk factors to change across study waves. Fourth, our sample is limited to adolescents residing in the four largest cities in Texas and thus our findings may not be generalizable to other populations. Finally, it is possible that factors other than the variables included in the statistical analyses are related to the associations between emotional symptoms and tobacco use. For example, genetic factors, parents' smoking, and personality type could mediate or modify the abovementioned relationship.

In spite of these limitations, the current study has several strengths including its complex, longitudinal design. Accordingly, we avoid temporal ambiguity in our assessment of adolescent's transition from non-tobacco users to tobacco users. Also, the study utilized well-validated measures of emotional symptoms and sensation seeking that have been used in previous studies including adolescents. Moreover, the current study utilizes an ethnically diverse population-based sample, which is about 40% Hispanic.

CONCLUSIONS

The study results confirm previous research and expand our understanding of the role of emotional symptoms and sensation seeking factors on adolescent tobacco risk, with implications for the development

of prevention programs among adolescents. It is important for prevention programs to consider both types of predictors in an integrative way and to address both factors since they interact to increase risk of product use more than the sum of emotional symptoms or sensation seeking alone. Therefore, addressing behavioral risk factors, such as sensation seeking, along with emotional symptoms, may serve to increase the efficacy of existing effective intervention strategies in the school environment⁴³ in order to curb nicotine and tobacco use among youth.

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ETHICAL APPROVAL AND INFORMED CONSENT

The TATAMS human subject's methods were approved by the University of Texas Health Science Center at Houston Institutional Review Board (HSC-SPH-13-0377). Active consent from parents/guardians and assent from students were obtained for all surveys.

AUTHORS' CONTRIBUTIONS

BB conducted all statistical analyses and wrote the manuscript. MBH served as Principal Investigator for the TATAMS study and contributed to the conceptualization of the manuscript and provided feedback throughout the writing process. KRC, SLC, AS and AVW contributed to the conceptualization of the manuscript and provided critical feedback throughout the writing process. BC provided statistical consultation for the project and serves as statistician for the TATAMS study. All authors contributed to and have approved the final manuscript.

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