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E-cigarette- specific symptoms of nicotine dependence among Texas adolescents

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Abstract

Introduction—The potential of e-cigarettes to elicit symptoms of nicotine dependence has not been adequately studied, particularly in adolescent populations. The present study examined the prevalence of e-cigarette-specific symptoms of nicotine dependence (“symptoms of e-cigarette dependence”) and the associations between these symptoms, e-cigarette usage group, and e-cigarette cessation-related items among Texas adolescents.

Methods—This study involved a cross-sectional analysis of adolescents from Wave 4 of the Texas Adolescent Tobacco and Marketing Surveillance System (TATAMS) (n=2,891/N=461,069). Chi-Square analyses examined differences in the prevalence of symptoms of dependence by e-cigarette usage group (exclusive versus dual users of e-cigarettes and combustible tobacco products) and demographic characteristics. Weighted multivariable logistic regression analyses examined the associations between symptoms of e-cigarette dependence, e-cigarette usage group, and e-cigarette cessation items.

Results—Exclusive e-cigarette users experienced symptoms of e-cigarette dependence, although the prevalence of most of the symptoms was higher for dual users. Adolescents who reported more symptoms of dependence were less likely to report both wanting to quit e-cigarettes and a past-year quit attempt for e-cigarettes (adjusted odds ratio “AOR”=0.61 (95% CI=0.41, 0.92) and AOR=0.52 (95% CI=0.30, 0.92), respectively).

Conclusions—This study is the first to demonstrate that adolescent e-cigarette users are experiencing symptoms of dependence specific to e-cigarettes. In addition, symptoms of dependence may be barriers to e-cigarette cessation. Future research is needed to determine if

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Contributors

Dr. Case conducted all statistical analyses and wrote the majority of the manuscript. Mr. Mantey contributed to the background and discussion sections, as well as helped with conceptualization of the manuscript. Dr. Harrell served as Principal Investigator for the TATAMS study and contributed to the conceptualization of the manuscript and provided feedback throughout the writing process. Dr. Creamer provided statistical consultation for the project and helped edit the manuscript. Drs. Kelder and Perry were involved in editing all versions of the manuscript. Dr. Perry also serves as Principal Investigator for the entire Texas Tobacco Center of Regulatory Science. All authors contributed to and have approved the final manuscript.

Conflict of Interest

All authors declare that they have no conflicts of interest.

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characteristics of e-cigarette use (e.g. frequency and intensity) are associated with dependence.

Keywords: E-cigarettes; adolescents; dependence

INTRODUCTION

Electronic cigarettes (e-cigarettes) are now the most commonly used tobacco product among adolescents¹, and research is needed to explore the addictive potential of these products. While the amount of nicotine delivered to e-cigarette users varies considerably depending on various factors (e.g., model type, manufacturer, user vaping behaviors)^{2,3}, recent research suggests that some types of e-cigarettes are capable of delivering nicotine at levels similar to or greater than those produced by conventional cigarettes.^{3,4} This is concerning as nicotine is a highly addictive stimulant whose use can result in dependence even at low levels and prior to the initiation of daily use.⁵⁻⁷ The biological consequences of nicotine dependence may be particularly harmful for adolescents given the rapid changes in brain development that occur during this time period.³ Previous research in animal models found that nicotine alters normal brain development³, which may result in the development of mood disorders and a reduction in cognitive function.^{3,8,9}

Importantly, the majority of nicotine dependence research has occurred in the context of conventional cigarette use; less is known about symptoms of nicotine dependence among non-cigarette tobacco users.^{10,11} In addition, while a handful of studies have demonstrated e-cigarette dependence symptoms among adults¹¹⁻¹³, no studies have yet examined e-cigarette-specific symptoms of nicotine dependence among adolescent e-cigarette users. One potential explanation for the lack of research is the relative novelty of e-cigarettes; e-cigarettes were introduced to the U.S. market about a decade ago.³ Furthermore, to date, measures for nicotine dependence largely focus on conventional cigarette use and thus, measures specific to e-cigarette use are still in development.¹⁴ Ultimately, e-cigarette-specific measures of nicotine dependence are important as characteristics (e.g. nicotine concentration, type of device) differ substantially from other tobacco products.^{14,15}

Furthermore, no study has examined the associations between symptoms of dependence and e-cigarette cessation-related behaviors among adolescents. In research specific to conventional cigarette smoking, nicotine dependence was a significant barrier to smoking cessation; adolescents who demonstrated higher levels of nicotine dependence were less likely to quit smoking successfully.¹⁶ Ultimately, examining potential barriers to e-cigarette cessation is particularly important as the recent Surgeon General's Report on e-cigarette use called for effective strategies to encourage youth to abstain or quit e-cigarette use.³ Thus, to develop effective cessation interventions, it is important to understand factors associated with cessation-related behaviors of past 30-day e-cigarette users.

Study Aims

First, this study examines the prevalence of e-cigarette-specific symptoms of nicotine dependence ("symptoms of e-cigarette dependence") and cessation-related items by e-cigarette usage group (exclusive e-cigarette users versus dual product users of e-cigarettes and combustible tobacco products), and demographic characteristics (age, gender, race/ethnicity). Second, this study examines the association between symptoms of e-cigarette

dependence, e-cigarette usage group, and e-cigarette cessation-related items (wanting to quit e-cigarettes and past-year quit attempt) among adolescents. No specific hypotheses were tested as this is the first study to examine these associations in e-cigarette. In addition, previous research has found that the associations between symptoms of nicotine dependence and cigarette smoking cessation behaviors differ based on the measurement and conceptualization of each construct.^{16–19}

METHODS

Study Design & Participants

This study examines cross-sectional data from Wave 4 of the Texas Adolescent Tobacco and Marketing Surveillance System (TATAMS). TATAMS is a multi-component, rapid response surveillance system focused on the four largest metropolitan areas in Texas (i.e., Austin, Dallas/Fort Worth, Houston, and San Antonio). TATAMS assesses tobacco product use, and exposure to marketing of tobacco products in Texas adolescents every six months over a period of three years. Participants for Wave 4 of TATAMS include a representative sample of 7th, 9th and 11th grade students; data collection for Wave 4 was conducted from April 2016 to June 2016. A total of 79 schools and 2,891 adolescents, representative of 461,069 students, participated in Wave 4. All analyses applied sampling weights to generalize the findings back to the population from which it was drawn, to adjust for school-level clustering, and to account for non-response bias. More details about study recruitment and sampling design have been reported elsewhere.²⁰

Measures

Past 30-Day E-cigarette Usage Groups—Participants were classified as past 30-day users if they reported using a product (e-cigarettes, cigarettes, hookah, large cigars/cigarillos, and little filtered cigars) on at least one day in the past 30 days. Two categories of use were created: 1) exclusive e-cigarette users, and 2) e-cigarette and combustible tobacco product users (“dual users”).

E-cigarette- Specific Symptoms of Nicotine Dependence—Symptoms of e-cigarette dependence were assessed by six measures; response options were coded as 0 (“No”) and 1 (“Yes”). Five items were adapted from the Hooked on Nicotine Checklist⁷: 1) “Have you ever felt like you really needed an electronic cigarette, vape pen, or e-hookah?;” 2) “Do you ever have a strong urge to use an e-cigarette, vape pen or e-hookah?;” “When you have not use an e-cigarette, vape pen, or e-hookah...” 3) “Do you find it hard to concentrate?;” 4) “Do you feel more irritable?;” and 5) “Do you feel nervous, restless or anxious?” The 10-item HONC has demonstrated acceptable reliability (interclass correlation coefficient=0.88) and convergent construct validity in adolescent samples.^{5,21} One additional item based on the Fagerstrom Tolerance Questionnaire²² was also assessed: “Do you typically use an e-cigarette, vape pen, or e-hookah within 30 minutes of waking up in the morning?.” In addition to each item, a summary score was developed corresponding the total number of symptoms experienced, ranging from 0 to 6. The alpha for the six items was 0.79.

E-cigarette Cessation-Related Variables—Wanting to quit e-cigarettes was assessed by the question: “Do you want to completely stop using electronic cigarettes, vape pens, or e-hookah right now?” Past-year e-cigarette quit attempts was assessed by the question “Have you tried to completely stop using electronic cigarettes, vape pens, or e-hookah within the past 12 months?” These measures were adapted from the Population Assessment of Tobacco and Health (PATH) survey.²³ Response options were “yes” and “no.”

Covariates—Current age, gender, and race/ethnicity were included as covariates in the regression analyses. Race/ethnicity was dichotomized due to small sample sizes (n=74 for White/Other, n=58 for non-White/Other).

Statistical Analysis

First, Chi-Square tests were conducted to examine differences in the prevalence of symptoms of e-cigarette dependence and e-cigarette cessation-related variables by e-cigarette usage group and demographic characteristics (Table 1). Further, mean age was compared for those who reported each symptom/cessation-related item versus those who did not using weighted means. Next, multivariable logistic regression analyses were conducted to examine the associations between e-cigarette usage groups, symptoms of e-cigarette dependence, and e-cigarette cessation-related items, after controlling for covariates (Table 2). Separate models were conducted for each of the outcome variables (wanting to quit and past-year quit attempt). The summary score for symptoms of e-cigarette dependence served as the independent variable for the regression analyses. Analyses were conducted using Stata 14.0 (College Station, TX).

RESULTS

Overall, 132 adolescents reported using an e-cigarette in the past 30 days, of which 91 were exclusive e-cigarette users and 41 were dual users of e-cigarettes and a combustible tobacco product. Of the past 30-day e-cigarette users, 34.3% were White/Other and 48.5% were female; participants included in the analyses had a mean age of 15.1 years. The mean number of symptoms of e-cigarette dependence was 0.89 (standard deviation “sd”=1.49), results not shown. As seen in Table 1, the most frequently reported symptoms of e-cigarette dependence included strong urge to use an e-cigarette (13.5%) and really need an e-cigarette (12.3%). There were significant differences in the proportion of symptoms of dependence, with dual users reporting a higher prevalence for each of the following items compared to exclusive users: really need an e-cigarette, strong urge to use, find it hard to concentrate, feel irritable, and feel anxious. Conversely, a significantly higher proportion of exclusive users reported wanting to quit e-cigarettes as compared to dual users (53.3% versus 24.2%, $p=.04$).

The results of the analyses for the association between symptoms of e-cigarette dependence, e-cigarette usage group and 1) wanting to quit e-cigarettes, and 2) past-year e-cigarette quit attempt controlling for demographic characteristics are presented in Table 2. The odds of wanting to quit e-cigarettes were significantly lower for dual users as compared to exclusive users after controlling for covariates (Adjusted Odds Ratio “AOR”=0.22, 95% CI=0.07, 0.70). In addition, experiencing more symptoms of e-cigarette dependence was associated

with lower odds of wanting to quit e-cigarettes (AOR=0.61, 95% CI=0.41, 0.92). For past year e-cigarette quit attempt, dual users reported significantly lower odds as compared to exclusive users (AOR=0.25, 95% CI=0.07, 0.91). Similarly to wanting to quit e-cigarettes, experiencing more symptoms of e-cigarette dependence was associated with lower odds of a past-year quit attempt (AOR=0.52, 95% CI=0.30, 0.92).

DISCUSSION

The present study is the first to report the prevalence of e-cigarette-specific symptoms of nicotine dependence and to investigate the associations between symptoms of dependence and e-cigarette cessation-related items among adolescents. Dual users of e-cigarettes and a combustible tobacco product reported a significantly higher prevalence of experiencing five out of the six symptoms of e-cigarette dependence as compared to exclusive e-cigarette users. Dual users were significantly less likely to report wanting to quit e-cigarettes and at least one e-cigarette quit attempt in the past year. Finally, experiencing more e-cigarette-specific symptoms of dependence was associated with lower odds of both wanting to quit e-cigarettes and a past-year e-cigarette quit attempt. These results have important implications for understanding the addictive potential of e-cigarettes among adolescents.

Notably, a significant proportion of e-cigarette users reported experiencing symptoms of dependence, providing preliminary indication that e-cigarettes may lead to nicotine dependence among adolescents. These findings are important as those in the scientific community are still examining the nicotine-delivery capabilities of e-cigarettes. Research on early models of e-cigarettes suggest that they are less effective in delivering nicotine than conventional cigarettes; however, research on new generations of e-cigarettes indicate that they may administer nicotine at comparable rates.³ Ultimately, in light of our findings, future research is warranted to investigate the levels of nicotine concentration that are sufficient to elicit symptoms of nicotine dependence among adolescents.

The present study also provides important new insight into e-cigarette-specific cessation-related behaviors including wanting to quit and past-year quit attempts. Dual users had significantly lower odds of wanting to quit e-cigarettes and a past-year e-cigarette quit attempt compared to exclusive users. Potential explanations for these findings include the role of harm perceptions and the use of e-cigarettes as smoking cessation tools. It is well documented that adolescents view e-cigarettes as less harmful than other tobacco products, and health concerns are positively related to smoking cessation behaviors.^{24–26} Therefore, adolescents who use other tobacco products in conjunction with e-cigarettes may view e-cigarettes as the less harmful product and thus may be less motivated to quit e-cigarette use. Future research is needed to more fully understand motivations for dual use; specifically, whether adolescents are using e-cigarettes in order to quit conventional cigarette use.

Other important findings from the current study include adolescents who reported more symptoms of dependence had lower odds of e-cigarette cessation behaviors, including both wanting to quit e-cigarettes and past-year e-cigarette quit attempts. One potential explanation for these findings is the relationship between frequency and intensity of use and nicotine dependence. For example, research suggests that more frequent tobacco users

exhibit more symptoms of nicotine dependence, which are then negatively associated with ability to quit.^{27,28} Sargent et al.²⁸ found that occasional users were more likely to report wanting to quit smoking and more likely to actually quit smoking as compared to daily smokers. Importantly, that study did not assess symptoms of nicotine dependence but used frequency of smoking as a proxy for the measure. Future research should assess if frequency of e-cigarette use (daily, weekly, monthly) is differentially associated with cessation behaviors.

Strengths and Limitations

There are several limitations of the current study that should be noted. First, our sample size of past 30-day e-cigarette users was small (n=132), thus we may not have been able to detect meaningful differences due to small sample sizes. Furthermore, while the dependence items had high internal consistency, e-cigarette measurement development is still in its infancy and future research is needed to further validate these measures in adolescents. In addition, 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. In spite of these limitations, the current study has several strengths including the use of product-specific symptoms of nicotine dependence, which provide important information on e-cigarette dependence. The current study is the first study to our knowledge to examine e-cigarette-specific nicotine dependence among adolescents.

Conclusions

This study provides preliminary support that adolescent e-cigarette users experience symptoms of nicotine dependence specific to e-cigarettes. Importantly, our results show that both exclusive users and dual users of e-cigarettes and combustible tobacco products experience e-cigarette-specific symptoms of dependence suggesting that e-cigarettes may have unique characteristics that influence dependence. Furthermore, as experiencing more symptoms of dependence was inversely associated with wanting to quit e-cigarettes and past-year e-cigarette quit attempts, dependence may be an important barrier to e-cigarette cessation and interventions aimed at reducing dependence may be warranted. Future research should explore the role of frequency and intensity of e-cigarette use on the associations between dependence and cessation-related outcomes.

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Highlights

- Adolescents report symptoms of nicotine dependence specific to e-cigarettes.
- Dependence symptoms associated with lower odds of e-cigarette cessation behaviors.
- Research is needed to identify e-cigarette use behaviors that affect dependence.

E-cigarette-specific symptoms of nicotine dependence in Texas adolescents by past 30-day e-cigarette usage group and demographic characteristics

TATAMS Wave 4-Weighted (Youth) (n=132/N=21,874) ^a									
	Cessation-Related Items		Symptoms of E-cigarette Dependence						
	Want to Quit % (95% CI)	Quit Attempt % (95% CI)	Really need % (95% CI)	30 minutes % (95% CI)	Strong urge % (95% CI)	Find it difficult to concentrate % (95% CI)	Feel irritable % (95% CI)	Feel anxious % (95% CI)	When you have not used an e-cigarette, vape pen, or e-hookah for a while, do you....
Overall	44.5 (31.9, 57.9)	38.7 (26.6, 52.4)	12.3 (6.7, 21.6)	8.5 (4.7, 15.0)	13.5 (7.5, 23.0)	6.1 (3.2, 11.2)	10.6 (5.3, 20.3)	6.2 (3.1, 11.9)	
E-cigarette Usage group									
Dual User ^b	24.2 (10.0, 48.0)	22.9 (9.1, 46.9)	32.7 (16.9, 53.9)	16.4 (7.3, 32.7)	35.7 (18.3, 57.8)	19.2 (9.1, 36.0)	29.0 (12.8, 53.1)	15.4 (6.9, 30.9)	
Exclusive E-cig User ^c	53.3 (37.6, 68.4)	45.7 (30.2, 62.1)	5.0 (2.2, 10.9)	5.7 (2.5, 12.5)	5.6 (2.5, 11.9)	1.6 (0.4, 5.7)	4.7 (2.1, 10.3)	2.8 (1.1, 7.4)	
p-value	.04	.11	<.001	.06	<.001	<.001	<.001	<.001	.001
Gender									
Male	37.3 (21.1, 56.9)	28.6 (15.6, 46.5)	5.7 (2.1, 14.3)	11.8 (6.1, 21.8)	12.8 (6.2, 24.4)	4.2 (1.6, 10.4)	8.5 (3.1, 21.1)	5.0 (2.1, 11.2)	
Female	52.3 (35.2, 68.9)	49.5 (32.6, 66.5)	18.8 (8.9, 35.5)	6.2 (2.4, 15.6)	14.6 (6.3, 30.2)	8.1 (3.4, 17.8)	12.2 (4.8, 27.8)	7.1 (2.9, 16.4)	
p-value	.26	.10	.03	.23	.79	.29	.57	.49	
Age (m. sd) ^d	15.4 (0.33)	15.7 (0.25)	15.5 (0.29)	16.0 (0.22)	15.6 (0.24)	15.5 (0.29)	15.7 (0.23)	15.9 (0.22)	
p-value ^e	.94	.26	.80	.08	.47	.76	.28	.13	
Race/ethnicity									
White/Other	36.8 (16.8, 62.7)	44.0 (23.8, 66.4)	8.6 (3.6, 19.5)	15.4 (7.3, 29.6)	13.3 (7.1, 23.5)	4.0 (1.6, 9.4)	7.2 (2.5, 18.9)	5.3 (2.4, 11.3)	
Non-White	48.9 (31.1, 67.0)	35.8 (19.9, 55.4)	13.9 (6.5, 27.4)	5.6 (2.0, 14.7)	13.8 (6.3, 27.9)	7.2 (3.4, 14.9)	12.0 (5.2, 25.3)	6.4 (2.6, 15.1)	
p-value	.49	.60	.39	.10	.93	.27	.40	.74	

^aSample is presented as unweighted ("n") and weighted ("N")^bUsed both e-cigarettes and a combustible tobacco product in the past 30 days

p-value for difference in age for those who experienced the symptom compared to those who did not

Mean age of those reporting the symptom

Used only e-cigarettes in the past 30-days

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Table 2

The association between e-cigarette-specific symptoms of nicotine dependence, past 30-day e-cigarette usage group, demographic characteristics, and cessation-related items

Want to Quit (n=131/N=20,780)^a	
	AOR (95% CI)
E-cigarette Usage group	
Exclusive E-cig User ^b	1
Dual User ^c	0.22 (0.07, 0.70)*
Dependence Symptoms ^d	0.61 (0.41, 0.92)*
Gender	
Female	1
Male	0.42 (0.14, 1.27)
Age	1.05 (0.62, 1.78)
Race/ethnicity	
Non-Hispanic White/Other	1
Other Races/Ethnicities	1.89 (0.31, 11.38)
Past-Year Quit Attempt (n=131/N=20,780)^a	
E-cigarette Usage group	
Exclusive E-cig User ^b	1
Dual E-cig User ^c	0.25 (0.07, 0.91)*
Dependence Symptoms ^d	0.52 (0.30, 0.92)*
Gender	
Female	1
Male	0.28 (0.09, 0.90)*
Age	1.27 (0.83, 1.92)
Race/ethnicity	
Non-Hispanic White/Other	1
Other Races/Ethnicities	0.69 (0.15, 3.17)

^aSample is presented as unweighted ("n") and weighted ("N")

^bUsed only e-cigarettes in the past 30-days

^cUsed both e-cigarettes and a combustible tobacco product in the past 30 days

^dResponses ranged from 0 to 6 symptoms