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Assessing Nicotine Dependence in Adolescent E-cigarette Users: The 4-item Patient-Reported Outcomes Measurement Information System (PROMIS) Nicotine Dependence Item Bank for Electronic Cigarettes

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Abstract

Background.—Adolescent e-cigarette use (i.e., "vaping") likely confers risk for developing nicotine dependence. However, there have been no studies assessing e-cigarette nicotine dependence in youth. We evaluated the psychometric properties of the 4-item Patient-Reported Outcomes Measurement Information System Nicotine Dependence Item Bank for E-cigarettes (PROMIS-E) for assessing youth e-cigarette nicotine dependence and examined risk factors for experiencing stronger dependence symptoms.

Methods.—In 2017, 520 adolescent past-month e-cigarette users completed the PROMIS-E during a school-based survey (50.5% female, 84.8% White, 16.22[1.19] years old). Adolescents also reported on sex, grade, race, age at e-cigarette use onset, vaping frequency, nicotine e-liquid use, and past-month cigarette smoking. Analyses included confirmatory factor analysis and examining the internal consistency of the PROMIS-E. Bivariate correlations and independent-samples t-tests were used to examine unadjusted relationships between e-cigarette nicotine dependence and the proposed risk factors. Regression models were run in which all potential risk factors were entered as simultaneous predictors of PROMIS-E scores.

Results.—The single-factor structure of the PROMIS-E was confirmed and evidenced good internal consistency. Across models, larger PROMIS-E scores were associated with being in a higher grade, initiating e-cigarette use at an earlier age, vaping more frequently, using nicotine e-liquid (and higher nicotine concentrations), and smoking cigarettes.

Conclusions.—Adolescent e-cigarette users reported experiencing nicotine dependence, which was assessed using the psychometrically sound PROMIS-E. Experiencing stronger nicotine dependence symptoms was associated with characteristics that previously have been shown to confer risk for frequent vaping and tobacco cigarette dependence.

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Keywords

E-cigarette; electronic cigarette; adolescent; youth; dependence; addiction; nicotine

1.0 Introduction

Recent research suggests that approximately 16% of American high school students have used an e-cigarette ("vaped") in the past month, eclipsing rates of tobacco cigarette smoking (Johnston et al., 2016). Researchers have identified several risk factors associated with adolescent vaping status (i.e., never user, experimenter, current user) and vaping frequency including male sex, White race, older age, using nicotine e-liquids, and smoking cigarettes (e.g., Anand et al., 2015; Barnett et al., 2015; Kong et al., 2015; Krishnan-Sarin et al., 2015; Morean et al., 2016; Willis et al., 2017). However, there have been no studies of dependence on nicotine, the primary determinant of addiction to tobacco products (Benowitz, 2010), in adolescent vapers.

Research on the development of nicotine dependence in adolescent vapers requires a psychometrically sound measure that is appropriate for administration to youth. While no psychometrically validated measure of youth e-cigarette nicotine dependence currently exists, the Patient-Reported Outcomes Measurement Information System (PROMIS) Nicotine Dependence Item Banks recently were validated for assessing nicotine dependence in adult vapers (i.e., the PROMIS-E; Morean et al., 2018). The PROMIS-E evidenced strong psychometric properties including a confirmable, internally consistent, single-factor latent structure; convergent validity with alternative indices of nicotine dependence; and test-criterion relationships with vaping frequency, e-liquid nicotine concentration, and e-cigarette quit attempts. The 4-item PROMIS-E performed comparably to the 22-item PROMIS-E, suggesting that e-cigarette nicotine dependence is captured adequately using the briefest version.

In the current study, we first aimed to validate the 4-item PROMIS-E for assessing adolescent e-cigarette nicotine dependence. We anticipated being able to replicate the PROMISE's internally-consistent, single-factor latent structure. Further, we expected being able to document the presence of youth e-cigarette nicotine dependence (PROMIS-E scores > 0) based on extant research on the development of nicotine dependence in adolescent cigarette smokers. Nicotine dependence develops quickly in adolescent smokers, often before daily smoking occurs; up to 50% of adolescents experience at least one dependence symptom within two months of initiating monthly smoking (DiFranza et al., 2002) and 25% experience tobacco use disorder within 2 years of initiating smoking (Kandel et al., 2007).

Second, we aimed to identify characteristics of adolescent vapers that confer risk for experiencing e-cigarette nicotine dependence. Characteristics were selected for inclusion based on research linking them to vaping frequency and/or the development of tobacco cigarette dependence. We anticipated that stronger e-cigarette nicotine dependence would be associated with male sex, older age, White race, initiating vaping at an earlier age, vaping more frequently, using nicotine e-liquids, and smoking cigarettes (Apelberg et al., 2014; Doubeni et al., 2010; Hu et al., 2006; Kandel et al., 2007; Krishnan-Sarin et al., 2015; Kong

et al., 2017; Morean et al., 2018). Given that e-liquids are available in many different nicotine concentrations (e.g., 0–60mg/ml), we also examined the relationship between nicotine concentration and e-cigarette nicotine dependence, with the expectation that using higher nicotine concentrations would be associated with experiencing more dependence symptoms.

2.0 Methods

2.1 Participants and Procedures.

The Yale School of Medicine Institutional Review Board approved all study procedures. In 2017, 2,945 high school students completed a 20-minute, school-based, paper-and-pencil survey assessing tobacco product use. The survey was administered in a fixed order, with questions about vaping presented before questions about other tobacco products. The PROMIS-E appeared approximately one third of the way through the survey. In total, 629 students reported past-month vaping. The analytic sample (n = 520) comprised past-month vapers with non-missing e-cigarette dependence data, a requirement for examining the PROMIS-E latent structure. Compared to past-month vapers who did not complete the PROMIS-E (n = 109), those included in the analytic sample reported vaping more frequently (13.0[11.0] vs. 10.2[11.2] days,p=0.18) and were more likely to smoke cigarettes (57.0% vs. 30.0%, p=0.02).

2.2 Measures.

Participants reported on sex, current grade in school, and race.

Age at vaping onset was assessed using the question “How old were you when you first tried an e-cigarette, even just 1 or two puffs?”

Past-month tobacco cigarette smoking and vaping frequency were assessed using the questions “Approximately how many days out of the past 30 days did you vape an e-cigarette/smoke a cigarette?” (responses: 0–30). For our analyses, we treated vaping frequency as a continuous variable and created a dichotomous variable reflecting any past-month smoking, consistent with previous research (Morean et al., 2018).

Nicotine e-liquid use was assessed using the question “Did you vape e-cigarettes with nicotine in the past 30 days?” (no, yes, I don’t know). Nicotine concentration was assessed using the question “What concentration of nicotine do you typically use in your e-cigarettes?” (0, 3, 6, 12, 18, 24 mg, other [write-in], I don’t know). In reviewing the write-in data, nearly 20% of students reported using nicotine concentrations >24mg/ml. The most common write-in responses ranged from 50–60mg/ml, a range that corresponds to the nicotine concentration of the popular Juul e-cigarette (Juul, 2018). As such, we created an additional category for concentrations >24mg.

E-cigarette nicotine dependence was assessed using the 4-item PROMIS-E (Morean et al., 2018). Items included: “I find myself reaching for my e-cigarette without thinking about it,” “I vape more before going into a situation where vaping is not allowed,” “When I haven’t been able to vape for a few hours, the craving gets intolerable,” and “I drop everything to go

out and get e-cigarettes or e-juice." For the final item, we substituted the words "go out and get e-cigarettes or e-juice" for the original wording of "go out and buy e-cigarettes or e-juice" because adolescents often do not purchase their own e-cigarettes/e-liquid. Response options included: 0 (never), 1 (rarely), 2 (sometimes), 3 (often), and 4 (almost always).

2.3 Data Analytic Plan.

Descriptive statistics were run on all study variables using SPSS 24. MPlus 7.0 was used to run a confirmatory factor analysis evaluating whether the 4-item PROMIS-E fit the adolescent data. Adequate model fit was defined as Bentler's Comparative Fit Index (CFI) > .95, Root Mean Square Error of Approximation (RMSEA) < .06, and Standardized Root Mean Square Residual (SRMR) < .08 (Hu and Bentler, 1999). Internal consistency was evaluated using Cronbach's alpha.

To address the second aim, bivariate correlations and independent-samples t-tests were run in SPSS to examine unadjusted relationships between the potential risk factors and e-cigarette nicotine dependence. A Bonferroni-corrected alpha value (0.006) indicated statistical significance. Multivariable linear regressions were then run within MPlus to evaluate cross-sectional predictors of adolescent e-cigarette nicotine dependence. Missing data were handled using full information maximum likelihood (FIML), which produces reliable parameter estimates when <20% of the data are missing (Dong and Peng, 2013). The first model contained the following independent variables: sex (%missing: 1.7%), grade (to account for age and potential cohort effects; 1.5%), race (2.3%), age of e-cigarette use onset (0.4%), nicotine e-liquid use (7.9%), vaping frequency (0%), and past-month cigarette smoking status (13.7%). For the second model, nicotine concentration (34.2%) was included in place of nicotine content (no/yes). Given the large amount of missing data, the analysis was run for adolescents who had non-missing nicotine concentration data (n = 342). For both models, all independent variables were entered simultaneously as predictors of e-cigarette nicotine dependence.

3.0 Results

Descriptive statistics are presented in Table 1. E-cigarette nicotine dependence was transformed to better approximate normality for use in all statistical models, but raw data are presented in Table 1 to facilitate interpretation. The 4-item, single factor PROMIS-E model fit the adolescent data well (RMSEA = 0.02, CFI = 0.99, SRMR = 0.01), and internal consistency was excellent (alpha = 0.91). Stronger nicotine dependence was associated with being in a higher grade ($r = 0.13$), vaping at an earlier age ($r = -0.31$), vaping more frequently ($r = 0.47$), and using higher nicotine concentrations ($r = 0.46$), p-values < .01. E-cigarette nicotine dependence also was significantly associated with using nicotine e-liquid (nicotine 0.36[0.40], nicotine-free 0.07[0.19], $t = 9.90$) and past-month cigarette smoking (smokers 0.51[0.41], nonsmokers 0.24[0.36], $t = 6.00$), p-values < .001. E-cigarette nicotine dependence did not different significantly based on sex or race.

The first regression model accounted for 31.7% of the variance in e-cigarette nicotine dependence. Stronger dependence was associated with being in a higher grade, initiating e-cigarette use at an earlier age, vaping more frequently, using nicotine e-liquids, and past-

month smoking (Table 2, “Model 1”; *p*-values < .001). The model including nicotine concentration accounted for 35.4% of the variance in e-cigarette nicotine dependence (Table 2, “Model 2”). The pattern of significant findings mirrored that observed for the first model.

4.0 Discussion

This study is the first to demonstrate that adolescent e-cigarette users experience nicotine dependence. In general, adolescent past-month e-cigarette users reported low levels of dependence, due, in part, to the fact that our sample included all past-month e-cigarette users, some of whom used e-cigarettes as infrequently as once in the past month (10.8% of the sample). However, important information was gleaned about risk factors for youth e-cigarette nicotine dependence. Across unadjusted and adjusted models, nicotine dependence scores were higher among adolescents who were older, had an earlier age of e-cigarette onset (and thus a longer duration of use), vaped more frequently, used nicotine e-liquid (and higher nicotine concentrations), and currently smoked cigarettes. These findings are consistent with previous research that has identified these user characteristics as risk factors for youth e-cigarette use and/or developing nicotine dependence via cigarette smoking (Apelberg et al., 2014; Doubeni et al., 2010; Hu et al., 2006; Kandel et al., 2007; Krishnan-Sarin et al., 2015; Kong et al., 2017; Morean et al., 2018). Inconsistent with prior research on risk factors for youth e-cigarette use (Krishnan-Sarin et al., 2014; Kong et al., 2017), neither males nor White adolescents reported stronger nicotine dependence. Future research is needed to better understand the relationships between sex, race, e-cigarette use frequency, and e-cigarette nicotine dependence.

When interpreting our findings, several limitations should be considered. First, the self-report data were limited by participants’ ability and willingness to provide accurate answers. Second, biochemical confirmation of e-cigarette and cigarette use was not possible given the study design. Third, as mentioned previously, overall e-cigarette dependence levels were low in the current sample. Although there is no established cutoff on the PROMIS-E for what constitutes being dependent, more than half of the sample (55.6%) endorsed experiencing some level of e-cigarette nicotine dependence. This finding is consistent with prior research which indicates that half of adolescent smokers experience at least one dependence symptoms within two months of starting to smoke monthly (DiFranza et al., 2002). Fourth, approximately 35% of the sample was missing data on nicotine concentration, suggesting that additional research is needed to determine how to assess nicotine concentration reliably among youth. However, the fact that the results mirrored one another when the binary nicotine e-liquid use variable and the nicotine concentration variable were included in the regression models suggests that using the binary variable may be acceptable in an adolescent population that comprises individuals who are uncertain about the specific nicotine concentration of the e-liquid used. That said, each of the models was just identified within MPlus (df = 0), so model fit could not be compared directly across the models including the binary nicotine use variable and nicotine concentration. Firth, we did not assess tobacco cigarette nicotine dependence, which may influence e-cigarette nicotine dependence. Sixth, because no alternative psychometrically sound measure of youth e-cigarette nicotine dependence exists, we could not examine the convergent or incremental validity of the

PROMIS-E. Finally, data were collected from Connecticut high schools, which may limit generalizability.

Despite its limitations, the current study suggests that adolescent e-cigarette users experience nicotine dependence, which can be assessed reliably using the PROMIS-E. Future research should evaluate the correspondence of self-reported e-cigarette nicotine dependence with biochemical indicators of use (e.g., cotinine level), explore relationships with other indices of addiction (e.g., withdrawal), and replicate the findings in a nationally representative sample. In the interim, our findings suggest that adolescent e-cigarette use can induce nicotine dependence, which could promote escalating e-cigarette use and/or the use of other tobacco products, and highlight the need for adolescent-focused e-cigarette prevention and regulatory efforts.

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References

Anand V, McGinty KL, O'Brien K, Guenthner G, Hahn E, Martin CA, 2015 E-cigarette use and beliefs among urban public high school students in North Carolina. J. Adolesc. Health. 57, 46–51. [PubMed: 26095408]

Apelberg BJ, Corey CG, Hoffman AC, Schroeder MJ, Husten CG, Caraballo RS, Backinger CL, 2014 Symptoms of tobacco dependence among middle and high school tobacco users: results from the 20l2 National Youth Tobacco Survey. Am. J. Prev. Med. 47, S4–S14. [PubMed: 25044195]

Barnett TE, Soule EK, Forrest JR, Porter L, Tomar SL, 2015 Adolescent electronic cigarette use: associations with conventional cigarette and hookah smoking. Am. J. Prev. Med. 49, 199–206. [PubMed: 25840880]

Benowitz NL, 2010 Nicotine addiction. N. Engl. J. Med., 362, 2295–2303. [PubMed: 20554984]

DiFranza JR, Savageau JA, Rigotti NA, Fletcher K, Ockene JK, McNeill AD, Coleman M, Wood C, 2002 Development of symptoms of tobacco dependence in youths: 30 month follow up data from the DANDY study. Tob. Control. 11, 228–235. [PubMed: 12198274]

Dong Y, Peng CYJ, 2013 Principled missing data methods for researchers. Springerplus. 2, 222–239. [PubMed: 23853744]

Doubeni CA, Reed G, DiFranza JR, 2010 Early course of nicotine dependence in adolescent smokers. Pediatrics. 125, 1127–1133. [PubMed: 20439592]

Hu L, Bentler PM, 1999 Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct. Equ. Model. 6, 1–55.

Hu MC, Davies M, Kandel DB, 2006 Epidemiology and correlates of daily smoking and nicotine dependence among young adults in the United States. Am. J. Public Health. 96, 299–308. [PubMed: 16380569]

Johnston LD, O'Malley PM, Miech RA, Bachman JG, Schulenberg JE, 2016 Monitoring the Future national survey results on drug use, 1975–2015: Overview, key findings on adolescent drug use. Ann Arbor: Institute for Social Research, The University of Michigan.

Kandel DB, Hu MC, Griesler PC, Schaffran C, 2007 On the development of nicotine dependence in adolescence. Drug. Alcohol. Depend. 91, 26–39. [PubMed: 17553635]

Kong G, Kuguru KE, Krishnan-Sarin S, 2017 Gender differences in US adolescent e-cigarette use. Curr. Addict. Rep. 4, 422–430. [PubMed: 29545987]

Kong G, Morean ME, Cavallo DA, Camenga DR, Simon P, Connell C, Bulmer SM, Krishnan-Sarin S, 2015 Reasons for e-cigarette initiation and discontinuation among adolescents and young adults. Nicotine. Tob. Res. 17, 847–854. [PubMed: 25481917]

Krishnan-Sarin S, Morean ME, Camenga D, Cavallo D, Kong G, 2015 E-cigarette use among high school and middle school adolescents in Connecticut. Nicotine. Tob. Res. 17, 810–818. [PubMed: 25385873]

Morean ME, Butler E, Bold K, Kong G, Camenga D, Cavallo D, Simon P, O'Malley S, Krishan-Sarin S, 2018 E-cigarette flavor preferences are associated with vaping frequency among adolescents but not among adults. PLoS One. 10.1371/journal.pone.0189015

Morean ME, Kong G, Cavallo DA, Camenga DR, Krishnan-Sarin S, 2016 Nicotine concentrations of e-cigarettes used by adolescents. Drug. Alcohol. Depend. 167, 224–227. [PubMed: 27592270]

Morean ME, Krishnan-Sarin S, Sussman S, Foulds J, Fishbein H, Grana R. O'Malley SS, 2018 Psychometric evaluation of the Patient-Reported Outcomes Measurement Information System (PROMIS) Nicotine Dependence Item Bank for use with electronic cigarettes. Nicotine. Tob. Res. doi: 10.1093/ntr/ntx271

Wills TA, Knight R, Sargent JD, Gibbons FX, Pagano I, Williams RJ, 2017 Longitudinal study of e-cigarette use and onset of cigarette smoking among high school students in Hawaii. Tob. Control. 26, 34–39. [PubMed: 26811353]

Table 1.

Descriptive statistics on all study variables

	% or Mean (Std. Dev.)
Sex (% female)	50.5%
Race (% White)	84.8%
Age	16.22 (1.19)
Grade	10.58 (1.03)
9	18.60%
10	27.00%
11	32.80%
12	21.70%
Age of E-cigarette Use Onset	14.52 (1.77)
E-cigarette Use Frequency (# days/past 30)	12.97 (10.97)
Nicotine E-liquid Use (% yes)	76.5%
Nicotine Concentration (mg/ml)	11.53 (11.65)
0 mg	22.5%
3 mg	21.3%
6 mg	14.9%
12 mg	7.0%
12 mg	3.8%
24 mg	10.8%
>24 mg	19.6%
Past-Month Cigarette Smoking	21.8%
E-cigarette Dependence Total	2.27 (3.84)
1. *When I haven't been able to vape for a few hours, the craving gets intolerable.*	0.50 (1.00)
2. *I drop everything to go out and get e-cigarettes or e-juice.*	0.30 (0.93)
3. *I vape more before going into a situation where vaping is not allowed.*	0.74 (1.22)
4. *I find myself reaching for ecigarettes without thinking about it.*	0.73 (1.22)

Note. The values for nicotine concentration reflect percentages from the subsample of 342 adolescents who provided valid data.

Table 2.

Cross-sectional predictors of e-cigarette nicotine dependence in adolescents

	Model 1		Model 2	
	β	Std. Error	β	Std. Error
Sex (ref: male)	−0.02	0.04	0.02	0.04
Grade (ref: 9)	0.11**	0.04	0.15**	0.05
Race (ref: not White)	−0.04	0.04	−0.07	0.05
Age of E-cigarette Use Onset	−0.18***	0.05	−0.17**	0.05
E-cigarette Use Frequency	0 34***	0.05	0.33***	0.05
Nicotine E-liquid (ref: no)	0.12***	0.04	--	--
Nicotine E-liquid Concentration)	--	--	0.19***	0.05
Cigarette Smoking (ref: no)	0.17***	0.05	0.12*	0.05

Note. Model 1 represents the model in which the binary variable reflecting any nicotine e-liquid use versus nicotine-free e-liquid use was included (N = 520). Model 2 represents the model in which the continuous variable reflecting nicotine concentration was included. Model 2 was run within the subsample of adolescents who reported on nicotine concentration (n = 342). *B* = standardized regression coefficient; “ref” indicates reference group; -- denotes a variable that was not included in the model.

* *p* < .05

** p < .01

*** p < .001