Nicotine Concentration of E-Cigarettes Used by Adolescents

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Abstract

Objective—E-cigarettes are popular among youth, but little is known about the nicotine concentrations of e-liquids used by adolescents.

Materials and Method—In Spring, 2014, we conducted cross-sectional surveys in four Connecticut high schools and two middle schools. Among past-30-day e-cigarette users (n = 513, 45% female, mean age 15.9 [*SD*=1.4]), we examined what nicotine concentration adolescents typically used in their e-cigarettes (range 0-30mg/mL and "I don't know"). We first examined whether age, sex, smoking status, e-cigarette use frequency, and/or e-cigarette acquisition source were associated with using nicotine-free e-liquid, nicotine e-liquid, or not knowing the e-liquid nicotine concentration. Among nicotine users (n = 185), we then examined whether the aforementioned variables were associated with using higher nicotine concentrations.

Results—Adolescents reported using nicotine-free e-liquid (28.5%), nicotine e-liquid (37.4%), or not knowing their e-liquid nicotine concentration (34.1%). Nicotine users comprised more smokers and heavier e-cigarette users compared to nicotine-free e-liquid users and those who did not know their nicotine concentration. Nicotine users also comprised more males and were more likely to purchase e-cigarettes online or from tobacco shops compared to those who did not know their nicotine concentration. Among nicotine users, cigarette smoking, male sex, and purchasing e-cigarettes from tobacco shops predicted using higher nicotine concentrations.

Conclusions—Adolescents reported using e-liquids with variable nicotine concentrations. Smokers, males, and those who purchased their own e-cigarettes reported using the highest nicotine levels. Of concern, many adolescents were unaware of the nicotine concentration in their e-liquid, raising concerns about inadvertent nicotine exposure among youth.

Keywords

adolescent; nicotine; electronic cigarette; e-cigarette; vaping

1. INTRODUCTION

Electronic cigarettes (e-cigarettes) are the most commonly used tobacco product by adolescents, and national survey data indicate 9.5% of 8th graders, 14.0% of 10th graders, and 16.2% of 12 graders reported past-month e-cigarette use (Johnston et al., 2016). Of note, irrespective of the model of e-cigarette one is using (e.g., refillable tank, disposable, cartridge models), e-cigarettes contain liquid (e-liquid) that is available in a variety of nicotine concentrations, ranging from 0mg/mL (nicotine-free) to over 30mg/mL. Despite dramatic increases in research on e-cigarettes, little attention has been paid to the nicotine concentrations of e-liquids used by youth. Understanding what nicotine concentrations youth commonly use is important for several reasons. First, nicotine exposure has detrimental effects on the developing brain (e.g., England et al., 2015; Kandel et al., 2007; Slotkin, 2002). Thus, using nicotine e-liquid exposes nonsmokers to negative health effects they otherwise may not be exposed to and may increase total nicotine exposure among smokers. Second, adolescent smokers are susceptible to nicotine dependence at lower levels of exposure compared to adults (Doubeni et al., 2010; Kandel et al., 2007), suggesting that using e-liquids containing even low levels of nicotine may produce addiction. Third, e-cigarette use confers risk for the uptake of combustible tobacco products including cigarettes (Leventhal et al., 2015). Fourth, e-cigarettes expose users to a range of toxicants, carcinogens, and metal particulates, so even using nicotine-free e-liquid may carry health risks (Walley et al., 2015). Finally, some adolescents may be exposing themselves to nicotine inadvertently because they are unaware of the nicotine content of the e-cigarettes they use. For example, given that nicotine concentrations often are printed on product packaging, youth who use their friends' e-cigarettes may be unaware of the nicotine concentration of the e-liquid which is already inside of the e-cigarette and is no longer in its packaging.

To date, only three studies have assessed the nicotine content of e-liquids used by youth. First, national data from the Monitoring the Future survey (2016) indicated that the majority of youth in grades 8, 10, and 12 (approximately 60%) reported using e-cigarettes containing "just flavoring" (i.e., nicotine-free) while 22.2% reported using nicotine e-liquid (Miech et al., 2016). Second, although selling e-liquids containing nicotine is illegal in Canada, Hamilton and colleagues (2015) found that 28% of adolescent e-cigarette users reported using nicotine e-liquid. In this study, cigarette smokers were more likely than nonsmokers to use nicotine e-liquid. Third, data from Connecticut indicated that 40.6% of adolescents initiated e-cigarette use by using nicotine-free e-liquid (Krishnan-Sarin et al., 2015). However, nonsmokers were more likely than smokers to report progressing from using

nicotine-free e-liquid to using nicotine e-liquid, raising concerns about nicotine exposure and potential dependence. While these studies indicate that adolescent cigarette smokers and nonsmokers are using e-cigarettes containing nicotine-free and nicotine e-liquid, none of these studies provided information about the specific nicotine concentrations of the e-liquids used by adolescents.

The current study had three specific goals. First, we evaluated the nicotine concentrations of e-liquids typically used by adolescents (0mg to over 30 mg/mL) and assessed whether any adolescents were unaware of the nicotine concentration of their e-liquid. We anticipated that e-liquid nicotine concentrations would vary but that a sizeable portion of adolescents would be unaware of their nicotine concentration. Second, we examined whether sex, age, cigarette smoking status, e-cigarette use frequency, and/or sources of e-cigarette acquisition were associated with adolescents' awareness of the nicotine concentration of the e-liquid (i.e., using nicotine-free, nicotine, or unknown e-liquid nicotine concentrations in e-cigarettes). We anticipated that nicotine users would be older, use e-cigarettes more frequently, and purchase their e-cigarettes from physical or online stores. Finally, within the sample of nicotine users, we examined the aforementioned independent variables as predictors of using higher nicotine concentrations. Based on prior research (Hamilton et al., 2015), we hypothesized that cigarette smokers would use higher nicotine concentrations than nonsmokers. Linked to the addictive nature of nicotine, we anticipated that using e-cigarettes more frequently would be associated with using higher nicotine concentrations. Because males and older adolescents are often heavier smokers (Johnston et al., 2015), we anticipated that older adolescents and males would use higher nicotine concentrations in their e-cigarettes. Given the novelty of the current study, we did not outline any hypotheses for e-cigarette acquisition source.

2. MATERIALS AND METHOD

2.1 Participants

During Spring, 2014, 5,133 participants (78.2% HS; 21.8% MS) completed a survey about tobacco and e-cigarette use. The analytic sample comprised past-month e-cigarette users (N = 513; HS = 92%).

2.2 Procedures

The Institutional Review Board of Yale University, the school boards, and the participating schools approved the survey. Passive parental permission was obtained prior to survey administration. All participants were informed that the anonymous survey was voluntary and that their responses would be kept confidential. Completing the survey indicated participants' consent/assent. Surveys were completed during homeroom/advisory periods.

2.3 Measures

Participants reported their sex and age.

Past-month smoking status was determined using the following question: "During the past 30 days, on how many days did you smoke cigarettes?" Response options included 0, 1, 2,

3–5, 6–10, 11–20, 21–28, and everyday. "Past-month smokers" reported smoking on at least 1 day.

Past-month e-cigarette use status and frequency were determined using the following question: "During the past 30 days, on how many days did you use an e-cigarette?" (open-ended response). "Past-month e-cigarette users" reported using e-cigarettes at least once.

The nicotine concentration of the e-liquid contained in e-cigarettes was assessed via the question: "What concentration of nicotine do you typically use in your e-cigarette?" Response options included: I don't know, 0-, 6-, 12-, 18-, 24-mg, and other (which was recoded to 30mg based on write-in responses). To examine potential differences between individuals who used nicotine, did not use nicotine, and did not know their nicotine concentration, we created a 3-level variable reflecting: no nicotine (0mg), nicotine (6 mg-30 mg), and unknown nicotine concentration (I don't know).

E-cigarette acquisition sources were assessed using the question, "Where do you usually get e-cigarettes?" Response options included: "My friend/girlfriend/boyfriend gave it to me," "My parents/adult family members gave it to me," "My brother/sister/cousin gave it to me," "I bought it at a gas station," "I bought it online," "I bought it from a tobacco shop," "I bought it from a mall kiosk," and "other". Participants selected as many sources as were applicable.

2.4 Statistical Analysis

We conducted statistical analyses using SPSS 21.0 (IBM Corp., 2013). Demographics, nicotine concentration, and sources of e-cigarette acquisition were analyzed using frequencies. Chi-squares and ANOVAS were calculated to explore unadjusted differences in nicotine use status based on demographics and sources of e-cigarette acquisition. We then used multinomial logistic regression to evaluate the adjusted effects of sex, age, e-cigarette use frequency, smoking status, and/or e-cigarette acquisition sources on nicotine use status when all independent variables were entered simultaneously. We also controlled for school to account for clustering. Finally, among adolescents who used nicotine, we used univariate general linear modeling (GLM) to examine whether the aforementioned independent variables were associated with the level of nicotine concentration used (range 6–30mg/mL).

3. RESULTS

Past-month e-cigarette users (n=513; 45% female; 39.9% cigarette smokers; mean age 15.9 [SD = 1.4]) reported using e-cigarettes on 9.5 days/month [SD = 10.4 days]. Adolescents reported using nicotine-free e-liquid (28.5%), nicotine e-liquid (i.e., 6mg [10.1%], 12mg [12.3%], 18mg [8.1%], 24mg [5.7%], and 30mg [1.2%]), or did not know the nicotine concentration of the e-liquid contained in their e-cigarettes (34.1%). Adolescents reported obtaining e-cigarettes from a number of sources including: friends (45.0%), tobacco shops (20.7%), gas stations (12.7%), online retailers (9.9%), siblings (6.6%), parents (4.9%), mall kiosks (1.9%), and other sources (5.1%).

In the unadjusted chi-square models, using nicotine e-liquid uniquely was associated with cigarette smoking; purchasing e-cigarettes from tobacco shops, gas stations, and online retailers; and not obtaining e-cigarettes from friends, all p-values < .01. ANOVA indicated nicotine users also were heavier e-cigarette users, p < .01 (See Table 1, column titled "Prevalence Rates by Nicotine Use Group").

The multinomial logistic regression model accounted for 40.9% of the variance in nicotine use status when all independent variables were entered simultaneously. The adjusted findings indicated that nicotine users were more likely to be smokers and to use e-cigarettes more frequently compared to those who used nicotine-free e-liquid or unknown nicotine concentrations. Nicotine users also were more likely to be male and to purchase e-cigarettes online or from tobacco shops compared to those who did not know their nicotine concentration (see Table 1 for adjusted odds ratios and 95% confidence intervals).

The univariate GLM model accounted for 13.3% of the variance in nicotine concentration. Males ($\eta_p^2 = 0.04$), smokers ($\eta_p^2 = 0.03$), and those who purchased their e-cigarettes from tobacco shops ($\eta_p^2 = 0.03$) were more likely than their counterparts to use higher nicotine concentrations (p-values < 0.05; Table 2).

4. DISCUSSION

Adolescent smokers and nonsmokers reported using e-cigarettes that contained e-liquids with varying amounts of nicotine (0mg/mL-30mg/mL) and obtained their e-cigarettes from a variety of social and commercial sources; friends were the most common social source of acquisition (45.0%) and tobacco shops (20.7%) were the most common retail source.

Of obvious concern, 37.4% of adolescents reported using nicotine e-liquid. Both the unadjusted and adjusted results indicated that nicotine users were more likely than their counterparts to be smokers and to use e-cigarettes frequently. Unadjusted results indicated that nicotine users also were more likely to purchase their own e-cigarettes from tobacco shops, gas stations, and online retailers but less likely to obtaining e-cigarettes from friends. Additionally, adjusted findings indicated that nicotine users were more likely to be male and to purchase e-cigarettes online or from tobacco shops compared to those who did not know their nicotine concentration.

Although any nicotine exposure may confer risk for negative health outcomes and nicotine dependence, exposure to higher concentrations of nicotine presumably increases risk further (Slotkin, 2002). Within the current study, three characteristics were associated with using higher nicotine concentrations of e-liquid: 1) smoking, which is consistent with research showing that smokers are more likely to use nicotine e-cigarettes than non-smokers (Hamilton et al., 2015); 2) being male, which is consistent with research indicating that males are heavier smokers than females (Baumert et al., 2010; CDC, 2014); and 3) purchasing e-cigarettes from tobacco shops, which likely is due to the fact that adolescents who purchased e-cigarettes from tobacco shops were more likely to be smokers.

Using nicotine-free e-liquid also was prevalent (28.5%) especially among non-smokers and adolescents who used e-cigarettes infrequently. While exclusively using nicotine-free e-

liquid prevents nicotine exposure, it still may confer risk for negative health effects since little is known about the potential risks of non-nicotine e-liquid constituents (e.g., propylene glycol). Also of concern, research suggests that some adolescents who use nicotine-free e-liquid ultimately transition to using nicotine e-liquid (Krishnan-Sarin et al., 2015), putting them at risk for nicotine dependence and other tobacco product use. Longitudinal research is needed to examine risks of using nicotine-free e-liquids and trajectories of nicotine exposure in adolescents.

Finally, many adolescents (34.1%) did not know the nicotine concentration of the e-liquid contained in their e-cigarettes, which raises concerns about inadvertent exposure to any nicotine in nonsmokers or inadvertent exposure to higher nicotine levels in smokers. These adolescents were more likely to be female, nonsmokers, and to use e-cigarettes infrequently compared to nicotine users. They also were less likely to purchase their e-cigarettes online or from tobacco shops. These results suggest that nonsmokers and infrequent users may be naïve about nicotine concentrations relative to experienced tobacco users. Additionally, individuals who do not purchase their own e-cigarettes may be less likely to know the nicotine concentration of their e-liquid because nicotine concentration often is printed on product packaging. As mentioned earlier, if an adolescent uses an e-cigarette that is not in its original packaging, the nicotine concentration would not be obvious. It also is possible that adolescents ignore or are confused by e-cigarette packaging, which is continually changing (Goniewicz et al., 2012). Future research using nationally representative data should evaluate why adolescents are unaware of e-liquid nicotine concentrations, how adolescents come to learn about nicotine concentrations, and whether the nicotine concentrations they use change over time.

Several study limitations should be considered. Data were collected from students in Connecticut, which may limit the generalizability of our findings. Data also were not available for race. Further, our study relied on adolescent self-report, which is limited by their willingness and ability to report honestly. Related, we neither visually inspected adolescents' e-cigarettes nor obtained biochemical verification of nicotine exposure, making it impossible to confirm whether self-reported nicotine concentrations were accurate. Finally, we did not assess whether e-cigarette users were using cig-a-likes, tank models, or cartridges, and therefore could not assess relationships between e-cigarette model type and nicotine concentration.

Despite these limitations, our findings highlight that both youth who are smokers and nonsmokers are obtaining e-cigarettes from a wide range of social and commercial sources and are using e-cigarettes containing e-liquids with varying nicotine concentrations. In our sample, males, smokers, and those who were purchasing their own e-cigarettes generally were using higher nicotine concentrations. Of concern, many adolescents did not know the nicotine concentration of the e-liquids contained in the e-cigarettes they use. Considering the variability of the products offered in the market, regulatory authorities should consider standardizing e-cigarette product labeling or developing other strategies to prevent adolescents from being exposed to nicotine inadvertently.

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Highlights

- Little is known about the nicotine concentration of e-cigarettes used by adolescents.

- Smokers and non-smokers reported using nicotine-free and nicotine e-cigarettes.

- Smokers, males, and teens who bought e-cigarettes from tobacco shops used higher nicotine levels.

- Many youth (34.1%) were unaware of the nicotine concentration of their e-cigarettes.

- These findings raise concerns about inadvertent nicotine exposure among youth.

Table 1

Adolescents' awareness of using e-cigarettes with nicotine, without nicotine, or not knowing the nicotine concentration of the e-liquid contained in their e-cigarette differs based on demographic characteristics and sources of e-cigarette acquisition

Independent Variables	Prevalence Rates by Nicotine Use Group			Nicotine vs. Nicotine-Free[r]		Nicotine vs. Unknown Nicotine[r]	
	Nicotine-Free	Nicotine	Unknown	OR	95% CI	OR	95% CI
Males	63.8[a]	61.1[a]	39.6[b]	0.98	0.56 1.72	2.47***	1.49 4.11
Age	15.70 (1.47)[a]	16.06 (1.42)[a]	15.87 (1.28)[a]	0.96	0.76 1.22	0.99	0.80 1.22
E-Cigarette Frequency	6.98 (9.06)[a]	13.59 (11.33)[b]	6.92 (8.71)[a]	1.04*	1.01 1.07	1.04**	1.01 1.07
Cigarette Smokers	9.9[a]	62.7[b]	39.1[c]	10.80***	5.51 21.17	1.71*	1.03 2.84
Sources of Acquisition							
Friends	48.9[a]	35.1[b]	55.0[a]	0.86	0.48 1.56	0.75	0.44 1.28
Parent/Family	2.8[a]	7.6[a]	3.6[a]	3.03	0.76 12.14	3.06	0.92 10.13
Sibling	7.1[a]	4.3[a]	8.9[a]	0.36	0.10 1.26	0.36	0.11 1.14
Gas Station	7.8[a]	19.5[b]	10.1[a]	2.17	0.91 5.19	2.00	0.98 4.08
Online	9.9[a]	15.7[b]	4.7[a]	1.71	0.70 4.15	3.62**	1.39 9.39
Mall	1.4[a]	3.8[a]	0.6[a]	3.56	0.43 20.56	5.83	0.55 61.39
Tobacco Shop	12.1[a]	34.6[b]	13.6[a]	1.96	0.92 4.06	2.12*	1.11 4.08
Other	2.8[a]	6.5[a]	5.3[a]	3.18	0.74 13.63	0.88	0.28 2.71

Note.

*
p < .05

**
p < .01

Prevalence rates for continuous variables are presented as mean (standard deviation) and as percentages for dichotomous variables.

Within rows, superscript letters reflect the results of Bonferroni-corrected comparisons among the nicotine status groups used (Chi-square for dichotomous variables; ANOVA for continuous variables). Cell values with different superscript letters assigned to them differ significantly from one another at $p < .01$. Regarding the multinomial logistic regression analyses, superscript "r" denotes the reference group. All independent variables were entered into the multinomial logistic regression model simultaneously.

Table 2

Demographic characteristics and sources of e-cigarette acquisition are associated with the nicotine concentration of e-liquid used by adolescents

	B	η_p^2	95% Confidence Interval	
Males	0.46**	0.04	0.12	0.81
Age	−0.07	0.01	−0.21	0.06
E-Cigarette Frequency	−0.01	0.01	−0.01	0.03
Nonsmokers	−0.42*	0.03	−0.77	−0.07
Source of Acquisition				
Friends	−0.04	0.00	−0.42	0.34
Family	0.43	0.01	−0.24	1.09
Sibling	0.29	0.01	−0.57	1.15
Gas Station	−0.05	0.00	−0.46	0.37
Online	0.47	0.02	−0.01	0.94
Mall	−0.01	0.00	−0.86	0.83
Tobacco Shop	0.43*	0.03	0.05	0.81
Other	−0.05	0.00	−0.78	0.69

Note.

*
$p < .05$

**
$p < .01$

η_p^2 = Partial Eta Squared

All independent variables were entered into the model simultaneously.