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Short communication

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 0–30 mg/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.

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 0 mg/mL (nicotine-free) to over 30 mg/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

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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 and Jenssen, 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 2015 Monitoring the Future survey 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 et al. (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 (0 mg 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, 5133 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 ≥30 mg 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 (0 mg), 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 6–30 mg/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-