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Prevalence and Correlates of Adolescents' E-Cigarette Use Frequency and Dependence

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Abstract

Background: Understanding predictors of e-cigarette use among adolescents in the context of wide availability and extreme popularity of these products is important for prevention and treatment. This study identifies correlates of e-cigarette use frequency and dependence among adolescent users. **Methods:** Adolescent e-cigarette users (*N*=173) were recruited from the San Francisco Bay Area. Participants reported demographic and psychosocial characteristics, e-cigarette use behaviors, and cigarette use. Bivariate relationships between potential correlates were examined, with correlates significant at *p* < .10 included in full models predicting frequency and dependence. **Results:** In the full models, frequent use was associated with receiving one's first e-cigarette from a family member rather than a friend (*r*= -.23, *p* < .001) or a store (*r* = -.13, *p* = .037), using nicotine in all e-cigarettes versus some e-cigarettes (*r* = -.17, *p* = .007) or unknown nicotine use (*r* = -.15, *p* = .014), using a customizable device versus Juul (*r* = -.22, *p* < .001), vape pen (*r* = -.20, *p* = .002), or other/unknown device (*r* = -.16, *p* = .009), and friends' e-cigarette use (*r* = .20, *p* = .002). Dependence was associated with younger age of first use (*r* = - .18, *p* = .012), friends' use (*r* = .18, *p* = .01), and recent cigarette use (*r* = .17, *p* = .019). **Conclusions:** When assessing problematic e-cigarette use among adolescents, it is important to consider social factors (e.g., friends' and family members' e-cigarette use) device type, and dual use with cigarettes.

Keywords: electronic cigarette; e-cigarette; electronic nicotine delivery systems; vaping; adolescent; nicotine; dependence

1. **Introduction**

Electronic cigarette (e-cigarette) use has eclipsed cigarette smoking among adolescents in the United States (Johnston et al., 2018). E-cigarette use predicts subsequent smoking initiation (Best et al., 2017; Conner et al.; Hammond et al., 2017; Leventhal et al., 2015; Lozano et al., 2017; Primack et al., 2015; Wills et al., 2017), especially among those who would otherwise be at low risk for smoking (Best et al., 2017; Conner et al.; Wills et al., 2017). E-cigarettes have many features (e.g., flavors, devices, nicotine levels) that differentiate them from cigarettes and that may be associated with problematic use. Moreover, correlates of frequency and dependence may differ from those of experimentation. Frequent e-cigarette use in adolescence is associated with smoking (Lee et al., 2017; Warner, 2016) and other health risk behaviors (i.e., poor nutrition, drug use; Dunbar et al., 2017). To our knowledge, no study has explored features of e-cigarette use and psychosocial factors that may be associated with e-cigarette use frequency. Furthermore, adolescent e-cigarette dependence is rarely studied. This study aims to identify correlates of e-cigarette use frequency and dependence in a sample of adolescent e-cigarette users.

2. Methods

2.1 Participants and Procedures

Participants were 173 adolescents (age 13-18) who reported having used an e-cigarette product at least once in the past 30 days and at least 10 times in their lives (Rubinstein et al., 2018) (see Table 1). Participants were recruited for a longitudinal study on teen vaping using online advertising and fliers posted around the San Francisco Bay Area. Potential participants initiated contact with study personnel via phone, email, text messaging, or social media. Eligibility screening included a review of procedures and requirements via phone. Eligible adolescents were scheduled for an initial in-person session. Informed consent and assent were

obtained. The research design and procedures were approved by the University of California, San Francisco Institutional Review Board.

2.2 Measures

    2.2.1 Frequency. Frequency of use was measured with, "In a typical month (i.e., 30 days), on how many days do you use e-cigarettes?". Responses were approximately normally distributed.

    2.2.2 Dependence. Dependence on e-cigarettes was measured using the Penn State Electronic Cigarette Dependence Index, validated previously with adults (Foulds et al., 2015) and approximately normally distributed.

    2.2.3 Demographics. Demographics included age, sex, race (White/Caucasian, African American/Black, Asian, Native American, Pacific Islander, mixed race/biracial, or other, re-categorized into Non-Hispanic White or Non-White), and mother's education (a validated measure of adolescents' socioeconomic status; Ensminger et al., 2000).

    2.2.4 E-cigarette Use History. Measures included age of first use ("How old were you when you first used an e-cigarette?"), source of first e-cigarette ("Where did you get your first e-cigarette from?": "friend", "my brother/sister", "I ordered it on the Internet", "from another family member", "I bought it in a store", "other", recoded into friend, family, purchased, or other), nicotine content of first e-cigarette, ("Did your first e-cigarette contain nicotine?": "yes", "no", "I don't know"), first flavor ("What flavor was your very first e-cigarette?": "tobacco", "fruit", "candy", "menthol", "other", "I don't remember"), and source of first e-cigarette knowledge ("Where did you first hear about e-cigarettes?": "an e-cigarette website", "social media [i.e., Facebook]", "advertisement on the web", "TV show", "a friend", "a family

member", "other website [i.e., Amazon]", "magazine", "other", recoded into family, peer, or media).

      2.2.5 Current E-cigarette and Cigarette Use. Measures included current nicotine use ("Do the e-cigarettes you use now contain nicotine?": "all", "some", "none", "I don't know if they contain nicotine"), current flavor use ("What flavor e-cigarette do you usually use?": "tobacco", "fruit", "candy", "menthol", "other"; select all that apply), device type ("What kind of e-cigarette do you use most often?": "brand name [i.e., Blu or Njoy]", "hookah pen/e-hookah", "vape pen", "I build/make my own", "e-pipe", "e-cigar", "Juul", "other", "I don't know", recoded into customizable [e.g., modifications/"mods"], Juul, vape pen, or other/unknown), friends' e-cigarette use ("On a scale of 0-100%, how many of your friends use e-cigarettes?"), and recent smoking ("Have you smoked a cigarette in the past 30 days?": "yes", "no").

2.3 Analyses

      Bivariate associations between potential correlates and outcome variables (frequency and dependence) were assessed using linear regression. Categorical correlates with more than two levels were dummy-coded. For bivariate screening, a more liberal p-value ($p < .10$) was used, so as not to exclude potentially important correlates (e.g., Prochaska et al., 2014). Statistically significant correlates ($p < .10$) were entered into two multiple linear regression models: one predicting frequency and another predicting dependence ($p < .05$).

      Missing data were handled using listwise deletion. Among potential correlates, all cases were complete except for 1 missing response to nicotine content of first e-cigarette (0.6%) and 1 missing response to source of first hearing about e-cigarettes (0.6%). Four cases (2.3%) were

missing data on the dependence measure and were excluded from dependence analyses. Thirty

regression models were conducted using IBM SPSS 25.

3. Results

Participant characteristics are presented in Table 1.

3.1 Use frequency

Significant bivariate correlates of higher frequency of use ($p< .10$) were older age ($r=.23$,

$p=.003$), higher SES ($r=.20$, $p=.019$), receiving one's first e-cigarette from a family member

(model $R^2=.10$, $p=.001$), using nicotine in one's first e-cigarette (model $R^2=.04$, $p=.039$),

presently using nicotine in all e-cigarettes (model $R^2=.17$, $p<.001$), currently using menthol

flavoring ($r=.13$, $p=.099$), using a customizable device (model $R^2 = .17$, $p<.001$), having a higher

percentage of friends who use e-cigarettes ($r=.30$, $p<.001$), and recent cigarette use ($r=.30$,

$p<.001$). The final adjusted model is presented in Table 2.

3.2 Dependence

Significant bivariate correlates of dependence ($p< .10$) were younger age of first use

($r=.20$, $p=.013$), receiving one's first e-cigarette from a family member (model $R^2=.09$, *p=.002),*

using nicotine in one's first e-cigarette (model $R^2=.03$, p=.089), presently using nicotine in all e-

cigarettes (model $R^2=.10$, p < .001), first hearing about e-cigarettes from a family member

(model $R^2=.08$, p=.004), using a customizable device (model $R^2=.07$, $p=.008$), having a higher

percentage of friends who use e-cigarettes ($r=.25$, $p=.001$), and recent cigarette use ($r=.26$,

$p=.001$). The final adjusted model is presented in Table 2.

4. Discussion

We examined the prevalence and correlates of e-cigarette use frequency and dependence in a sample of adolescent e-cigarette users. Frequent use was associated with receiving one's first e-cigarette from a family member, using nicotine in all e-cigarettes, using a customizable device, and having a higher percentage of friends who use e-cigarettes. Receiving one's initial e-cigarette from a family member suggests possible household exposure to e-cigarette use, which has been associated with e-cigarette use (Barrington-Trimis et al., 2015; Joung et al., 2016). Permissive norms and rules in the household may enable adolescents to use e-cigarettes more frequently without fear of repercussions. Only 18% of the adolescents who received their first e-cigarette from a family member also reported recent smoking (compared to 28% in the full sample), suggesting that household rules and norms may differ for e-cigarettes versus combustible cigarettes.

Unlike prior research (Lee et al., 2017; Warner, 2016), we did not find a significant association between frequency of e-cigarette use and likelihood of smoking cigarettes. However, more frequent e-cigarette users were more likely to use nicotine in all of their e-cigarettes than were less frequent users. Thus, even adolescents who do not smoke may have substantial nicotine exposure from more frequent e-cigarette use.

Use of a customizable device was associated with frequent use. It is possible that participants' e-cigarette use escalated in frequency before they began using customizable devices. However, customizable devices allow for greater nicotine delivery, and may be more reinforcing (Farsalinos et al., 2014). Moreover, use of a customizable device was strongly correlated with nicotine use in this sample ($\chi^2(9) = 31.05$, $p < .001$). Although use of a customizable device was not associated with dependence on e-cigarettes, the average dependence

score in this sample was low, and it is plausible that teens who use customizable devices

frequently may be more likely to develop nicotine dependence over time.

The relationship between friends' e-cigarette use and frequency of e-cigarette use is

consistent with the extant literature. Adolescents whose friends use e-cigarettes may perceive

greater social approval and greater prevalence of e-cigarette use, both of which increase

adolescents' likelihood of use (Barrington-Trimis et al., 2015; Barrington-Trimis et al., 2016;

Gorukanti et al., 2017). Relatedly, using e-cigarettes socially (i.e., while spending time with

friends) may lead to more frequent use if friends are also using.

Dependence was associated with younger age of first use, recent cigarette use, and having

a higher percentage of friends who use e-cigarettes. Smoking at an early age is known to be

associated with greater likelihood of regular smoking and future nicotine dependence (Azagba et

al., 2017; Dierker et al., 2008; Guo et al., 2010; Van De Ven et al., 2010; Walker and Loprinzi,

2014). Early substance use is often predictive of substance use disorders and other forms of

externalizing psychopathology later in life (Iacono et al., 2008). Our findings suggest that early

e-cigarette use may carry similar risks.

Recent cigarette use was also associated with dependence on e-cigarettes. Nicotine

addiction may be a common underlying factor. Indeed, nicotine use in e-cigarettes was

associated with cigarette smoking, such that dual users were more likely to use nicotine in their

e-cigarettes than those who only used e-cigarettes ($\chi^2(3) = 19.62$, $p < .001$). Although e-cigarette

use alone carries a risk of nicotine dependence, dual users of e-cigarettes and combustible

cigarettes may be a particularly high-risk group.

Friends' use was correlated with both frequency and dependence. Perceived social approval, perceiving e-cigarette use as normative, and using e-cigarettes while spending time with friends may lead to more frequent use and dependence. Acceptance of e-cigarette use among adolescents is likely an important target for intervention, as social norms regarding novel products, such as customizable devices, are likely to be less entrenched and more malleable than those regarding older tobacco products.

Taken together, these correlates suggest a common risk profile for frequent use and dependence in a subset of adolescent e-cigarette users, particularly those who are exposed to nicotine and have family members and friends who are accepting of e-cigarette use. Along with our recent findings of toxicants in the bodies of adolescent e-cigarette users (Rubinstein et al., 2018), these findings suggest that more effort is needed to counter the promotion of these products to teens.

4.1 Limitations and Future Directions

This study had a few notable limitations. First, the cross-sectional design does not allow for identification of predictors of future e-cigarette use. These participants are enrolled in a longitudinal study that will allow us to investigate future use, as well as potential associations between frequent use and the development of nicotine dependence over time. Second, there are currently no validated measures of e-cigarette dependence in adolescents. We chose a measure that is relatively comprehensive and has good psychometric properties among adults. However, further research on measuring e-cigarette dependence among adolescents is needed. Third, generalizability of the data may be limited due to the relatively small, non-representative sample in this pilot study. Many of the analyses conducted may have been underpowered. For instance, few participants reported first hearing about e-cigarettes from the media (1.3%). A larger,

representative sample is needed to draw firmer conclusions. Moreover, the sample drawn from urban location in the United States, and e-cigarette use characteristics may differ across regions and countries (Noland et al., 2017; Pesko and Robarts, 2017). Future research could include adolescents from various social and regulatory environments.

4.2 Conclusions

This study was among the first to examine the prevalence and correlates of both frequency and dependence in a sample of adolescent e-cigarette users. Overall, results suggest that among adolescent e-cigarette users, those who have greater exposure to nicotine and greater acceptance of e-cigarette use in their social circles are at higher risk for more problematic e-cigarette use. In addition to screening for risk factors such as cigarette smoking and age of first use, clinicians should assess use of customizable e-cigarette devices and friends' use. E-cigarette use risk profiles may differ from those of combustible cigarettes, and attention should be paid to specific features of e-cigarette use such as device type.

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539.

	M (SD) / %
Demographics	
Age	16.6 (1.2)
Sex, % male	75.1
Race, % Non-Hispanic White	54.9
Mother's Education	
Graduated college	54.3
Did not graduate college	39.9
Unknown	5.8
E-Cigarette Use History	
Age of first use	14.8 (1.3)
Source of first e-cigarette	
Friend	68.5
Family member	6.5
Purchased	25.0
Nicotine content of first e-cigarette	
Contained nicotine	48.3
Did not contain nicotine	39.5
Nicotine content unknown	12.1
First flavor	
Tobacco	6.4
Fruit	49.1
Candy	14.5
Menthol	8.7
Other	9.2
Unknown	12.1
Current E-Cigarette Use	
Frequency (days of use in a typical month)	15.4 (9.8)
Dependence (score)	3.5 (4.1)
Current nicotine use	
All e-cigarettes contain nicotine	41.6
Some contain nicotine	38.7
None contain nicotine	7.5
Unknown nicotine content	12.1
Current flavor use	
Tobacco flavor	11.0
Fruit flavor	61.3
Candy flavor	16.8
Menthol flavor	15.0
Other flavor	12.7
First heard of e-cigarettes	
Family member	7.6
Peer (friend or social media)	79.1
Media (TV, magazine, or Internet site)	9.3
Other	4.1
Type of e-cigarette used	
Customizable	32.4
Juul	22.0
Vape pen	34.1
Other or unknown	11.6
% of friends who use	42.4 (27.7)
Past-month cigarette use (% yes)	26.6

Table 1. Demographic and e-cigarette use characteristics of participants (N = 173)

Table 2. Correlates of e-cigarette use frequency and dependence (adjusted models)

	Frequency (N=173)			Dependence (N=169)		
	β	r	p	β	r	p
Current age	.04	.04	.572	-	-	-
Mother's education (Ref: did not graduate college)						
Graduated college	.12	.11	.075	-	-	-
Unknown	.02	.02	.780	-	-	-
Age of first use				-.19	-.18	.013*
Source of first e-cig (Ref: family member)						
Friend	-.47	-.23	<.001***	-.28	-.09	.190
Purchased	-.26	-.13	.037*	-.19	-.07	.306
Other	-.11	-.09	.140	-.01	-.004	.957
First e-cigarette nicotine (Ref: contained nicotine)						
Did not contain nicotine	.01	.01	.916	-.06	-.05	.486

Unknown	-.01	-.01	.895	.03	.02	.747
Current nicotine use (Ref: all contain nicotine)						
Some e-cigarettes contain nicotine	-.21	-.17	.007**	-.12	-.10	.157
No e-cigarettes contain nicotine	-.13	-.10	.096	-.13	-.10	.139
Unknown	-.20	-.15	.014*	-.13	-.10	.144
First heard of e-cigarettes (Ref: family)						
Peer (friend or social media)	-	-	-	-.13	-.05	.474
Media (Internet, TV, or magazine)	-	-	-	-.02	-.008	.913
Other	-	-	-	.04	.02	.728
Current menthol flavor use (Ref: yes)	.08	.07	.268	-	-	-
Device type used most often (Ref: customizable)						
Juul	-.28	-.22	<.001***	.03	.02	.748
Vape pen	-.24	-.20	.002**	-.14	-.11	.114
Other or unknown	-.19	-.16	.009**	-.01	-.01	.869
Percentage of friends who use e-cigarettes	.21	.20	.002**	.19	.18	.013*
Past-month cigarette use	.13	.12	.058	.19	.17	.014*

Note: Correlations reported here are adjusted for all other variables in the model (i.e., semipartial correlations).

*$p < .05$, **$p < .01$, ***$p < .001$