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Exclusive E-Cigarette Use Predicts Cigarette Initiation among College Students

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Abstract

Introduction—An increasing body of research indicates that use of electronic nicotine delivery systems (ENDS) predicts cigarette initiation. However, no studies examine if risk for cigarette initiation varies for exclusive ENDS users versus users of ENDS and other tobacco products. This study examined if: a) cigarette-naïve young adults (i.e., never cigarette users) who ever used ENDS had a greater odds of initiating cigarettes than non-ENDS users over a 1.5 year period and b) the odds of cigarette initiation was consistent across exclusive ENDS users and users of ENDS and at least one tobacco product.

Methods—Participants were 2,558 cigarette-naïve 18–25 year old (*M*=19.71; *SD*=1.61) students from 24 Texas colleges who participated in a four-wave study, with six months between each wave.

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Contributors

A Loukas conceptualized the study and wrote the first draft of the paper. CN Marti conducted the analyses, and contributed to writing the methods and results. M Cooper contributed to writing the method and editing the paper. KE Pasch and CL Perry edited the paper and all authors have approved the final manuscript.

Conflict of Interest

All authors declare that they have no conflicts of interest.

Results—Overall, 11% of students reported cigarette initiation by wave 4. Of those, 20.1% were wave 1 ENDS users and 8.4% were non-ENDS users. Multivariable, multilevel discrete-time hazard models indicated that wave 1 ENDS use predicted subsequent cigarette initiation, over and above the significant effects of cigarette use susceptibility, family-of-origin tobacco use, friend cigarette use, and other tobacco use. Additional findings indicated that exclusive ENDS users had a greater odds than non-users of subsequent cigarette initiation. Among users of alternative tobacco products, ENDS users did not have a greater odds of initiation than non-ENDS users.

Conclusion—Findings extend existing research by showing that ENDS use by young adults is a specific risk factor for later cigarette initiation and not an extension of a constellation of existing tobacco use behaviors.

Keywords

e-cigarettes; longitudinal study; poly-tobacco use; survival analysis; young adults

1.0 Introduction

Use of electronic nicotine delivery systems (ENDS) has increased substantially over the past few years. Estimates from a United States (U.S.) nationally-representative survey indicate that current, or past 30-day, ENDS use among adults 18 years of age and older increased significantly from .3% in 2010 to 6.8% in 2013 (McMillen, Gottlieb, Shaefer, Winickoff, & Klein, 2015). The same nationally-representative survey (McMillen et al., 2015) and results from the 2014 U.S. National Health Interview Survey (Schoenborn & Gindi, 2016) indicate that among adults, 18–24 year old young adults report the highest prevalence of ENDS use. Heightened prevalence of use is concerning because the U.S. Food and Drug Administration (FDA) only recently announced ENDS regulations, many of which are not fully implemented, and the long-term health consequences of ENDS use are not known (Hess et al., 2017). There is also concern that ENDS use may lead to the use of combustible cigarettes (Barrington-Trimis et al., 2016), which have been shown to be more harmful to health than ENDS (Hecht et al., 2015).

The role of ENDS in cigarette use is a hotly debated topic. Some researchers argue that ENDS may have a public health benefit if they are used by current cigarette smokers to quit or cut down on smoking (Levy et al., 2017). Others note that the public health benefit may be diminished if ENDS use contributes to the initiation of combustible cigarettes and an increased number of new cigarette smokers (Levy et al., 2017). A growing number of prospective studies indicate that ENDS use among never cigarette smokers/cigarette-naïve participants is associated with subsequent cigarette initiation up to 16 months later, even after controlling for various socio-demographic, intrapersonal, and contextual factors (Barrington-Trimis et al., 2016; Leventhal et al., 2015; Primack, Soneji, Stoolmiller, Fine, & Sargent, 2015; Wills, Knight, et al., 2016; Wills, Sargent, Gibbons, Pagano, & Schweitzer, 2016). However, most studies are limited to examination of cigarette initiation among adolescent or combined adolescent and young adult samples.

Only two prospective studies examine the role of ENDS use in cigarette initiation among young adults, the population at highest risk for ENDS use. Unger, Soto, and Leventhal

(2016) reported that among 23-year-old Hispanic young adults, current use of ENDS by those who did not use cigarettes in the past month, predicted past month cigarette use one year later, even after socio-demographic, and alcohol and other tobacco use were taken into account. Similarly, Spindle and colleagues (2017) reported that among approximately 18.5 year old college students, current and ever use of e-cigarettes predicted cigarette initiation one year later, even after controlling for socio-demographics, other tobacco and drug use, and various intrapersonal factors. Findings from these studies extend our understanding of the potential consequences of ENDS use during young adulthood, but additional data are needed to assess the role of concurrent use of ENDS with other tobacco products (e.g., cigars and hookah) in subsequent cigarette initiation. Although existing studies control for the use of other tobacco products, none have determined if risk for cigarette initiation is consistent across exclusive ENDS users and users of ENDS and other tobacco products or multiple tobacco product users.

Multiple tobacco product use is more prevalent among young adults in the contemporary tobacco landscape than exclusive use of one product (Richardson, Williams, Rath, Villanti, & Vallone, 2014). Limited studies indicate that multiple tobacco product use is associated with elevated risk for sustaining tobacco use and for subsequently trying other products (Huh & Leventhal, 2016; Kaufman, Land, Parascandola, Augustson, & Backinger, 2015). It is possible, therefore, that cigarette-naïve young adults who use ENDS and other tobacco products, such as cigars and hookah, may be more likely than exclusive ENDS users to subsequently also try cigarettes because cigarette use is part of a constellation of tobacco use behaviors. To date, however, no studies have examined if users of ENDS and at least one tobacco product (but not cigarettes) are more likely than their exclusive ENDS user peers to subsequently initiate cigarettes. Thus, it is not clear if ENDS use is a specific risk factor for subsequent cigarette initiation or if cigarette initiation is an extension of a constellation of existing tobacco use behaviors.

The present study extended existing research by examining the role of ENDS use, both exclusive and not exclusive, in the subsequent initiation of cigarettes over a 1.5 year period among a sample of initially 18–25 year old year cigarette-naïve college students. Understanding consequences of ENDS use among college students is important because this population comprises more than 40% of 18–24 year old young adults in the U.S. (U.S. Department of Education. National Center for Education Statistics) and the college years are characterized by transitions in tobacco use (Wetter et al., 2004). We used discrete-time hazard models to determine if cigarette-naïve college students who used ENDS had a greater odds of initiating cigarettes than did non-ENDS users over three subsequent waves, or 1.5 years. Similar to other studies, we controlled for other tobacco use, and various socio-demographic, intrapersonal, and interpersonal factors that have been associated with ENDS use. Consistent with existing research, we hypothesized that ENDS use among cigarette-naïve college students would be associated with increased odds of subsequent cigarette initiation, over and above the covariates. Extending existing research, we assessed if the odds of cigarette initiation was consistent across exclusive ENDS users and users of ENDS and at least one of the following tobacco products: cigars/cigarillos, little cigars, hookah, and smokeless tobacco.

2.0 Materials and Method

2.1 Participants

Participants were 2,558 students involved in the first four waves of the Marketing and Promotions across Colleges in Texas project (Project M-PACT). Project M-PACT is a rapid response surveillance study, collecting data every six months from a cohort of 5,482 students attending one of 24 colleges in Texas. Wave 1 data were collected in November 2014–February 2015 and the three subsequent waves were collected approximately every six months thereafter with retention rates ranging from 79% (waves 2 and 3) to 81% (wave 4) of the original participants. Because the goal of the present study was to examine cigarette initiation, only data from participants who indicated having never used cigarettes at baseline, had complete data on the wave 1 predictor variables, and responded to the cigarette use question on at least one follow-up wave (n= 2,558) were included in the current analyses. Data from an additional 216 students were excluded due to attrition at the three follow-up waves (n=213) or missing data on a wave 1 predictor variable (n=3). At baseline, the 2,558 students included in the present study were 18–25 years old (*Mean* age=19.71; *SD*=1.61), 67.7% were female, and 93.9% attended a four-year institution versus a two-year institution. Regarding race/ethnicity, 31.8% were non-Hispanic white, 27.4% were Hispanic/Latino, 23.4% were Asian, 9.8% were African-American/Black, and 7.5% were another race/ethnicity or reported two or more races/ethnicities. Retention rates of the 2,558 cigarette-naïve students were 90.2% at wave 2 (n=2,307), 89.1% at wave 3 (n=2,279), and 91.8% at wave 4 (n=2349).

2.2 Procedure

The 24 colleges were located in the five counties surrounding Austin, Dallas/Fort Worth, Houston, and San Antonio. Students were recruited to participate in the online survey regarding tobacco use via email invitation. There were two eligibility criteria for participating students [details reported elsewhere (Loukas et al., 2016)]: Participants were required to be 18–29 years old and full- or part-time degree- or certificate-seeking undergraduate students attending a four-year college or a vocational/technical program at a two-year college. Only students who were 18–25 years old at wave 1 were included in the present study because almost all [but 15 (5.7%)] students 26 years of age and older reported ever using cigarettes. Eligible students who wished to participate in the study provided informed consent and then completed the online survey. More than 13,000 students (n=13,714) were eligible to participate in the study and of these, 5,482 students (40%) provided consent and completed the survey, a response rate similar to other online surveys such as this (Berg, Haardoerfer, Escoffery, Zheng, & Kegler, 2015; Velazquez et al., 2011).

2.3 Measures

2.3.1 Outcome Variable

Ever Cigarette Use: Ever cigarette use at wave 1 was assessed by asking students “How old were you the first time you smoked part or all of a cigarette?” and “How many cigarettes have you smoked in your entire life?” The latter question was also asked at each of the three follow-up waves. If students indicated cigarette use for either question at any of the four

waves, they were coded as cigarette users/initiators. Given the study purpose, wave 1 ever cigarette users were excluded from analyses.

2.3.2. Wave 1 Predictor Variables

Socio-demographics: Four socio-demographic variables, all assessed at wave 1, were included in study models; sex (0=female/1=male), race/ethnicity (coded as White, Hispanic/Latino, African American, Asian, and other), the z-score for age in years, and type of college attended (0=two-year/1=four-year).

Cigarette Use Susceptibility: Two items were used to assess the intrapersonal factor of cigarette susceptibility at wave 1. Consistent with Pierce et al. (1996), never cigarette users were classified as susceptible to cigarette use (coded as '1') if they responded "probably not," "probably yes," or "definitely yes" to the item, "If one of your friends were to offer you these products, would you smoke/use it?" or to the item, "Do you think you will use any of the following in the next 12 months?" Participants were classified as not susceptible to cigarette use (coded as '0') if they responded "definitely not" to both items.

Interpersonal Factors: Two interpersonal factors, family-of-origin tobacco use and friend cigarette use, were assessed at wave 1. Family-of-origin tobacco use was assessed for father/male guardian, mother/female guardian, grandparent(s), and others with the question, "When you were growing up, did any of the following people in your household use tobacco products?" Responses were coded '1' if the participant endorsed at least one member in their household who smoked while they were growing up. Friend's cigarette use was also assessed with one item, "How many of your close friends smoke/use cigarettes." Responses were coded as '1' if the participant had at least one friend who smoked cigarettes.

Ever Other Tobacco Use: Wave 1 ever use of three tobacco products (large cigars/cigarillos/little cigars, hookah, and smokeless tobacco/snus) were assessed with items adapted from the Youth Tobacco Survey (YTS; Starr et al., 2005) and the Population Assessment of Tobacco and Health (PATH) Survey (National Institutes of Health, 2015). Ever use of large/cigarillos/little cigars were assessed with the question, "Have you ever used/tried these cigar products as intended, even one or two puffs?" Ever use of hookah and smokeless tobacco were assessed with the question, "How old were you the first time you tried (smoking a hookah or using smokeless tobacco), even one or two times/puffs?" Respondents were considered ever-users of other tobacco products if they replied yes or provided an age of first use for at least one of the aforementioned tobacco products (coded as '1').

Ever ENDS Use: Ever use of ENDS was assessed at wave 1 with an item adapted from the PATH study, "Have you ever used an ENDS product, (i.e. e-cigarette, vape pen, or e-hookah) as intended (i.e. with nicotine cartridges and/or e-liquid/e-juice), even one or two puffs?" Respondents were considered ever ENDS users if they responded "yes" to this question (coded as '1').

2.4 Attrition Analyses

Chi-square and t-test analyses were conducted to examine differences in wave 1 study variables between college students included in the present study (n=2,558) and those excluded due to attrition at follow-up waves (n=213). Compared with excluded students, those included in the study were more likely to be Asian than all other races/ethnicities [$X^2(4)=11.39$, p=.022], enrolled in a four-year versus two-year institution [$X^2(1)= 4.77$, p=.029], less likely to use at least one other tobacco product [$X^2(1)=6.17$ p=.013], and less likely to be susceptible to other tobacco use [$X^2(1)=5.19$, p=.023]. There were no differences between the two groups on the other five study variables.

2.5 Data Analysis

Multivariable, multilevel discrete-time hazard models (Singer & Willett, 2003) were fit using the R glmer function to evaluate if ENDS use predicted cigarette initiation over the 1.5 year period. Discrete-time hazard models are applied when the exact time of the event cannot be identified. In the present study, cigarette initiation occurred within a six-month interval between two of the study waves; thus, there were three discrete time periods between the four waves. The model was fit to a person-period data set that contained a dummy variable for each of the three six-month periods (e.g., between wave 1 and wave 2) and did not contain an intercept. Respondents were nested within the college they attended at wave 1 and the time parameters were treated as random effects. Prior to testing study questions, we evaluated multicollinearity among the study variables following recommendations from Allison (2010). The maximum variance inflation factor (VIF) observed was 1.39, indicating that multicollinearity was not a concern.

Study questions were assessed in two models. In the first main effects model, all wave 1 variables were entered simultaneously to determine if ENDS use uniquely predicted subsequent cigarette initiation, over and above the socio-demographic, other tobacco use, intrapersonal, and interpersonal variables. In the second model, a two-way interaction between wave 1 ENDS use and wave 1 ever other tobacco use was added to the main effects model to determine if risk for cigarette initiation was consistent across exclusive ENDS users and users of ENDS and at least one tobacco product.

3.0 Results

Overall, 11% (n=282) of wave 1 cigarette-naïve participants reported cigarette initiation by wave 4. A significantly higher proportion of wave 1 ENDS users reported initiating cigarette use by wave 4 (20.1%; n=114) compared with wave 1 non-ENDS users (8.4%; n=168) ($X^2[1]=61.25$, $p<.001$). The distribution of cigarette initiation by study period is presented in a life table (see Table 1), which also shows cumulative survival estimates (i.e., the probability that a participant did not use cigarettes).

Table 2 presents descriptive data, and results from univariate X^2 and t-test analyses examining differences on all study variables between participants who initiated cigarette use by wave 4 and those who did not. There were no differences between the two groups on any socio-demographic factor. However, participants who initiated cigarette use by wave 4 were

more likely than those who did not to be susceptible to cigarette use at wave 1, have at least one family member who used tobacco while they were growing up, have at least one friend who used cigarettes at wave 1, use at least one other type of tobacco product at wave 1, and report ever using ENDS at wave 1.

Findings from the first multivariable, multilevel discrete-time hazard model were consistent with the univariate findings (see Table 3). Even after accounting for all other study variables, wave 1 ever ENDS use was associated with 1.36 greater odds of cigarette initiation. The wave 1 variables of cigarette susceptibility, family tobacco use, friends' cigarette use, and other tobacco use were also positively associated with cigarette initiation. Note that cigarette susceptibility and other tobacco use were stronger predictors of cigarette initiation than wave 1 ENDS use. However, findings from the second model indicated that the main effect of wave 1 ENDS use was qualified by a significant two-way interaction with other tobacco use (exp(β)=0.50, CI= 0.27–0.92). Probing the two-way interaction using the methods outlined by Aiken and West (1991) indicated that among students who used no other tobacco products at wave 1, ENDS use (OR=2.26; CI=1.35–3.76) predicted greater odds of cigarette initiation, but among users of other tobacco products, ENDS use (OR=1.13; CI=.81–1.58) did not predict greater odds of cigarette initiation. Thus, students reporting exclusive ENDS use, and no other products, had increased risk of cigarette initiation up to 1.5 years later compared with non-tobacco users.

4.0 Discussion

Findings from the present study on young adults contribute to a growing body of research, primarily on adolescents, indicating that ENDS use is associated with increased risk for subsequent cigarette initiation. Overall, 11% of our 18–25 year old cigarette-naïve college student sample reported initiating cigarettes over the 1.5 year study period. Moreover, more than twice as many ENDS using students initiated cigarettes during the study period compared with their non-ENDS using peers (20.1% versus 8.4%). Similar to existing research, our initial findings indicated that ENDS use elevated risk for subsequent cigarette initiation, even after controlling for various other tobacco use, socio-demographic, intrapersonal, and interpersonal factors, some of which were notably stronger predictors of cigarette initiation than ever ENDS use. However, further examination indicated that exclusive ENDS use increased risk for subsequent cigarette use. These findings are unique and extend existing research by showing that exclusive ENDS use is a specific predictor of cigarette initiation among young adults and not merely an extension of a constellation of existing tobacco use behaviors.

Although multiple tobacco product use is now more prevalent than single product use among young adults (Richardson et al., 2014) and cigarette users are at elevated risk for multiple tobacco product use (Lee, Hebert, Nonnemaker, & Kim, 2014), findings showed that among cigarette-naïve young adults who were users of other tobacco products, ENDS use did not increase risk for cigarette initiation. Rather, young adults who used ENDS exclusively had an increased risk for later cigarette use relative to non-users. Findings corroborate research by Leventhal and his colleagues (2015) showing that 9th graders who used ENDS, but no combustible tobacco products, were more likely than those who did not use ENDS to use

cigarettes up to one year later. Taken together, findings from our study and Leventhal's suggest that use of ENDS may introduce tobacco-naïve individuals to subsequent combustible tobacco products, which are likely more harmful to health than ENDS (Hecht et al., 2015).

How or why exclusive ENDS use contributes to cigarette use is not well-understood. Perhaps college students who use ENDS, and no other tobacco products, initially do so because they believe ENDS are less harmful and addictive, and more socially acceptable than other tobacco products (Cooper, Loukas, Harrell, & Perry, 2016; Trumbo & Harper, 2013). ENDS users may then become accustomed to the sensory effects of nicotine and subsequently use cigarettes, not only because cigarettes can more efficiently deliver nicotine than many ENDS products, but also because of the behavioral similarity between ENDS and cigarettes (Primack et al., 2015). Similarly, ENDS users may develop positive expectancies for cigarette use because of the sensory similarity between the two products, which might also explain later cigarette initiation (Wills, Gibbons, Sargent, & Schweitzer, 2016). Given our lack of clear understanding of the factors explaining the role of ENDS use in cigarette initiation, additional research is needed.

The present study extends existing research by disentangling the role of ENDS from that of other tobacco products on later cigarette initiation by young adults. However, the study has several limitations. First, we examined the role of ENDS use in cigarette initiation/onset, but not all young adults who initiate will become established smokers. Consequently, we cannot determine the long-term consequences of ENDS use on smoking. Because the transition from initiation to established smoking may take several years (USDHHS, 1994), additional research with a longer follow-up period is warranted to determine the long-term consequences of ENDS use. Second, we did not assess if type of ENDS device, concentration of nicotine, or other characteristics of ENDS products contributed to cigarette initiation. Establishing a specific link between ENDS use and cigarette initiation among young adults is the first step in understanding how product characteristics may influence this link, which should be undertaken in future research. Finally, the study was limited to college students from Texas and therefore, results may not generalize to the general population of young adults. However, our sample was drawn from 24 colleges in the four largest cities in Texas and is racially/ethnically diverse.

4.1 Conclusions

Despite the aforementioned limitations, the present study has implications for prevention programs and policy development. Although most tobacco prevention programs target adolescents, initiation of tobacco products, including ENDS and cigarettes, continues to occur during young adulthood. For this reason, it is important that colleges, where more than 40% of 18–24 year olds will spend some portion of their lives (United States Census Bureau, 2012), provide programs that prevent the use of all types of tobacco and nicotine products. At the same time, findings underscore the importance of recently introduced FDA regulations over the distribution, manufacture, and marketing of ENDS. Use of ENDS by cigarette- and tobacco-naïve adolescents may be due to a variety of factors, including marketing messages promoting ENDS as healthier substitutes for cigarettes (Grana & Ling,

2014) and to the availability of ENDS in over 7,500 unique flavors (Zhu et al., 2014) that are appealing to young adults. Existing regulations should continue to limit the marketing of these products and new regulations are needed to limit the availability of an unlimited number of flavors, particularly to young adults who are continuing to show changes in their tobacco use.

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Highlights

- 11% of college students initiated cigarette use over the 1.5 year study period.
- More ENDS users than non-users initiated cigarette use during the study period.
- Exclusive ENDS use predicted subsequent cigarette initiation.

Table 1

Life table showing number of college students who initiated cigarettes during the study period and the cumulative survival estimates, i.e., the probability that a participant did not use cigarettes.

Period	Number of Cigarette Initiators in Period	Number of Students at Risk for Initiation[1]	Hazard	Hazard Standard Error	Survival	Survival Standard Error
1 (Wave 1–2)	119	2,558	.05	0.004	.95	0.004
2 (Wave 2–3)	85	2,347	.04	0.004	.92	0.005
3 (Wave 3–4)	78	2,151	.04	0.004	.89	0.006

[1]The number of students at risk after period 1is the number from the prior period minus those who initiated cigarettes in the prior period *and* those missing data at each period (n=92 and 111 in period 2 and 3, respectively).

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Table 2

Descriptive statistics for the entire sample, and differences in wave 1 predictor variables between college students who initiated cigarette use over the 1.5 year study period and those who did not.

Wave 1 Predictor Variables	Overall Sample (*N*=2,558)	Initiated Cigarette Use (*n*=282)	Did Not Initiate Cigarette Use (*n*=2,276)	X^2/*t*
Male	32.3%	35.8%	31.8%	$X^2[1]=1.84$, $p=.175$
Age in Years	19.71 (*SD*=1.61)	19.68 (*sd*=1.64)	19.71 (*sd*=1.60)	$t(2556)=0.31$, $p=.757$
Race/Ethnicity				$X^2[4]=5.55$, $p=.236$
% White (REF)	31.8%	29.4%	32.1%	
%				
Hispanics/Latinos	27.4%	32.6%	26.8%	
% African American	9.8%	8.2%	10.0%	
% Asian	23.4%	21.3%	23.7%	
% Other	7.5%	8.5%	7.4%	
Four-year institution	93.9%	95.0%	93.8%	$X^2[1]=0.67$, $p=.414$
Cigarette susceptibility	6.3%	16.7%	5.0%	$X^2[1]=57.82$, $p<.001$
Family of origin tobacco use	52.5%	61.0%	51.5%	$X^2[1]=9.08$, $p=.003$
Friend's cigarette use	52.7%	64.5%	51.2%	$X^2[1]=17.95$, $p<.001$
Ever Other tobacco use	31.6%	58.2%	28.3%	$X^2[1]=103.16$, $p< .001$
Ever e-cigarette use	22.2%	40.4%	19.9%	$X^2[1]=61.25$, $p<.001$

Table 3

Results from multivariable, multilevel discrete-time hazard model predicting cigarette initiation over a 1.5 year period from wave 1 ever ENDS use, over and above other wave 1 predictor variables (*N*=2,558).

Wave 1 Predictors Variables	Adjusted Odds Ratio	95% Confidence Interval
Sex (Ref=Male)	1.24	0.96, 1.60
Age in years z-score	0.89	0.73, 1.08
Race/Ethnicity		
% White	Ref	—
% Hispanic/Latino	1.25	0.91, 1.71
% African American	0.92	0.57, 1.50
% Asian	0.96	0.68, 1.36
% other race/ethnicity	1.13	0.70, 1.82
School Type (Ref=four-year institution)	1.19	0.67, 2.11
Cigarette Use Susceptibility	3.02	2.14, 4.27
Family-of-Origin Tobacco Use	1.35	1.05, 1.73
Friend Cigarette Use	1.44	1.11, 1.86
Other Tobacco Use	2.85	2.13, 3.82
Ever E-Cigarette Use	1.36	1.01, 1.83