




Use of electronic nicotine delivery systems and recent initiation of smoking among US youth

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Received: 12 May 2015 / Revised: 8 December 2015 / Accepted: 28 December 2015 / Published online: 1 February 2016
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Abstract

Objectives We assessed whether the prevalence of recent (within a year) initiation of cigarette smoking was associated with reports of ever using electronic delivery systems (ENDS) in the National Youth Tobacco Survey (NYTS) and whether the association varied by age.

Methods Weighted cross-sectional analysis of use of ENDS, cigarette smoking, age at interview and age at initiation of smoking collected systematically through the 2011–2013 NYTS cycles.

Results In multivariate analyses those who ever used ENDS were twice as likely as nonusers of ENDS to have tried cigarette smoking in the last year (multivariate PR: 2.3; 95 % CI 1.9, 2.7). This average hid significant variations by age: a 4.1-fold increase (95 %; 2.6, 6.4) among those 11–13 years of age, compared to a smaller increase among those 16–18 years: 1.4-fold (95 % CI 1.1, 1.8).

Conclusions Use of ENDS by adolescents was associated with initiation of cigarette smoking in the last year. This association was stronger in younger adolescents.

Keywords Electronic cigarettes · Cross-sectional studies · United States · Adolescent · Nicotine · Dependence · Age · Epidemiology

Introduction

Nicotine dependence is usually established in adolescence when the brain is still maturing and exposure to electronic nicotine delivery systems (ENDS) could result in continued ENDS use or uptake of smoking. Exposure of the developing brain to nicotine alters critical functions mediated through synapses both in adrenergic and cholinergic pathways that increase nicotine dependence (Slotkin 2002; Leslie et al. 2004). Based on the biology of nicotine dependence, one could hypothesize that the effect of ENDS usage on the uptake of smoking is modified by age. Indeed, ENDS use was inversely related to age in most studies among college students (Pokhrel et al. 2014; Sutfin et al. 2013; Saddleon et al. 2015). The increased marketing of ENDS observed since 2010 is specifically targeted to youth: television ENDS advertisements increased threefold from 2011 to 2013 (Kim et al. 2014; Kornfield et al. 2014), and websites target youth using celebrity endorsement as well as candy flavors among other marketing techniques (Grana and Ling 2014; Duke et al. 2014). An observational study at points of sale reported that ENDS were placed in close proximity to youth-related products (Eadie et al. 2015).

With few exceptions (Leventhal et al. 2015; Sutfin et al. 2015), most studies to date on the association between ENDS use and the risk of escalation to cigarette smoking have been cross-sectional using data collected in national or state youth tobacco use surveys. A previous cohort study conducted in high school students (age 14 years) found an almost threefold increased risk of cigarette smoking initiation among high school non-smokers who used ENDS at baseline (Leventhal et al. 2015). The second cohort study conducted among 217 college students (age 19+ years) who smoked 3 cigarettes in their lifetime, reported an association between ENDS use an increased odds of

This article is part of the special issue “Electronic Cigarettes and Public Health”.

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current smoking (Sutfin et al. 2015) In this current analysis, we assessed the cross-sectional relation between recent initiation of cigarette smoking and ENDS ever use utilizing data on 11- to 18-year-olds from the 2011–13 US National Youth Tobacco Survey (NYTS) and we assessed if this association was modified by age.

Methods

We examined age at initiation of cigarette smoking in three consecutive cycles of the NYTS (i.e., 2011, 2012, 2013), which also collected data on ENDS use. The NYTS, which is used for public health surveillance of tobacco use among US youth, is a nationally representative sample of US middle (grade 6–8) and high school students (grade 9–12) from all 50 states and the District of Columbia, carried out by the US Centers for Disease Control and Prevention. Detailed information on the design of the NYTS is presented elsewhere (CDC 2015). A total of 61,930 young persons participated in the 2011–2013 NYTS. Participants were excluded from the current analysis if they had missing data on ENDS use ($n = 2519$), race/ethnicity ($n = 2067$), age started smoking ($n = 1098$), cigarette smoking during the past 30 days ($n = 1500$), ever smoked cigarettes ($n = 1319$), grade ($n = 463$), age ($n = 386$), sex ($n = 294$) and/or age ($n = 63$). In addition, 140 participants under 11 years of age and 536 participants 19 years old or older were excluded. Thus, the analytic dataset was limited to records of participants age 11–18 years with complete data on cigarette smoking, ENDS use and covariates ($n = 54,677$).

Study variables

Participants were asked in each cycle: “*Have you ever tried cigarette smoking, even one or two puffs?*” and “*How old were you when you first tried cigarette smoking, even one or two puffs?*” Based on current age and age first tried cigarette smoking, participants were categorized as: “tried cigarette smoking for the first time in the past year”, “tried cigarette smoking for the first time more than a year ago” or “never tried smoking cigarettes”. Participants were also asked: “*During the past 30 days, on how many days did you smoke cigarettes?*” and current smokers were defined as participants who answered one or more days.

Data on ENDS ever use were collected by: “*Which of the following tobacco products have you ever tried, even just one time?*” One of the eight response choices included “*electronic cigarettes or e-cigarettes such as Ruyan or NJOY?*”

Covariates included age, sex, school grade (6–8; 9–12) and ethnic/racial group (Non-Hispanic White; Other than Non-Hispanic White). Data on cigarette smoking at home

were collected by: “*Does anyone who lives with you now...?*”; with “*Smoke cigarettes*” as one response choice. Data on the number of close friends who smoke were drawn from the 2013 survey data.

Data analysis

We used SAS callable SUDAAN v.11 [Research Triangle Institute (2012). SUDAAN Language Manual, Volumes 1 and 2, Release 11. Research Triangle Park, NC] to obtain weighted estimates of prevalence, totals and prevalence ratios. The ADJRR option on the PREDMARG statement was used to estimate the prevalence ratio in multinomial logistic regression analyses, avoiding the use of odds ratios which often over-estimate the prevalence ratio when the outcome of interest is common ($>5\%$) (Bieler et al. 2010; Kelsey et al. 1996). Although the effective sample size was 54,677, we retained the entire data set ($n = 61,930$) to compute the estimates using the SUBPOPN statement available in SUDAAN. Multivariate multinomial logistic regression was used to estimate prevalence and confidence intervals in three levels of the ‘smoking initiation’ (in the past year, more than a year ago, and never).

To study effect modification in the prevalence ratio of recent (i.e., in the past year) cigarette smoking by age, we obtained estimates of ENDS ever use on the three-level ‘tried cigarette smoking’ nominal variable in each of three age groups (11–13, 14–15, 16–18 years).

Results

Overall, in the three NYTS cycles (2011–2013), 3.2 % of young persons age 11–18 years reported that they had tried cigarette smoking for the first time in the past year. This represents approximately 690,000 young persons in the USA in 2013; 234,000 (33.9 %) were current smokers. Among young persons in grades 6–12 who reported ever smoking cigarettes, 55.0 % (i.e., 25.5 % of all 6–12th graders) had first tried in the last 3 years (i.e., 3.1, 6.3 and 4.6 % in the last 1, 2 and 3 years) (Fig. 1). Figure 2 shows the distribution of young persons who reported smoking initiation in the last year and the proportion who had ever tried smoking, by age started smoking. The proportion of young persons who tried smoking in the last year remained stable across age (3–4 %). The proportion that had ever smoked increased monotonically with age to 42.4 % by age 18. Mean age at initiation was 12.8 years [median (interquartile range) = 12.6 (10.6–14.3)] years.

In 2011–2013, 5.9 % (SE = 0.3 %) and 2.0 % (SE = 0.1 %) of young persons in the NYTS reported ever and currently (i.e., 1 or more days in the past 30 days) using ENDS, respectively.

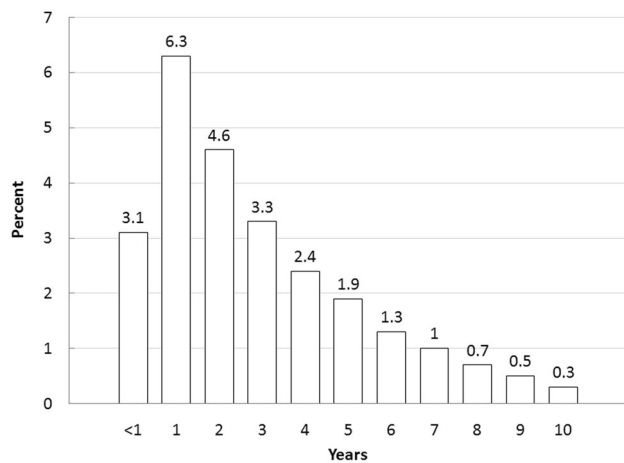


Fig. 1 Years since first tried smoking, 6–12th graders who ever smoked among participating of the National Youth Tobacco Survey 2011–2013. Ever smokers were 25.5 % of the participants across the three cycles. *Source:* National Youth Tobacco Survey

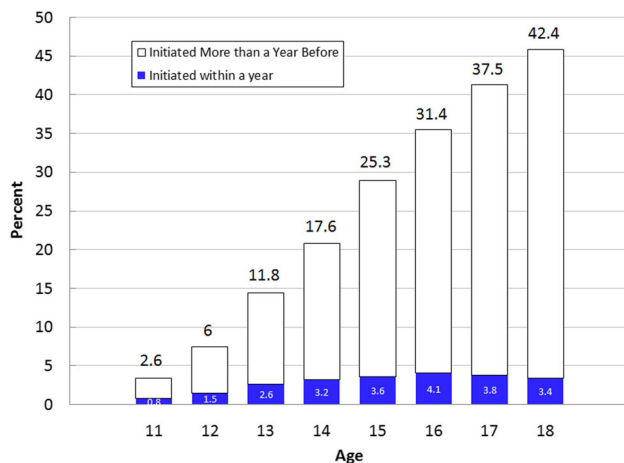


Fig. 2 Proportion of 6–12th graders that initiated cigarette smoking in the last year and more than a year among ever smokers by age, National Youth Tobacco Survey 2011–2013. *Source:* National Youth Tobacco Survey

Table 1 shows the proportion of young persons who initiated cigarette smoking in the past year or more than a year ago, according to ever use of ENDS. Only 2.9 % of young persons who had never used ENDS had tried smoking in the past year, compared to 6.6 % of those who had ever used ENDS. Similarly 18.7 % of those who had never used ENDS had tried smoking more than a year ago compared to 82.1 % of those who had. These observations were statistically significant multivariately, with prevalence ratios of 2.3 (95 % CI 1.9, 2.7) and 4.0 (95 % CI 3.8, 4.2), respectively.

Only the 2013 cycle of the NYTS had data on numbers of friends that smoked. Analysis restricted to the 2013 NYTS for adjustment on the effect of ENDS use on the

prevalence of recent initiation of cigarette smoking found that after controlling for having close friends who smoke cigarettes, and all the other covariates mentioned, the effect of ever using ENDS on the prevalence of recent initiation of cigarette smoking was similar (multivariate PR: 2.0; 95 % CI 1.4, 2.9). As expected having friends that smoke cigarettes increased the prevalence of recent smoking initiation (multivariate PR = 4.3; 95 % CI 3.0, 6.2), as well as initiating smoking more than a year before (multivariate PR = 2.2; 95 % CI 2.0, 2.4).

Subgroup analysis indicated that the association between ENDS use and the prevalence of recent initiation of cigarette smoking was modified significantly by age (Table 2). The multivariate prevalence ratios among those age 11–13, 14–15, and 16–18 years were 4.1 (95 % CI 2.6, 6.4), 3.0 (95 % CI 2.2, 3.9) and 1.4 (95 % CI 1.1, 1.8), respectively. Thus, the prevalence ratios measuring the effect of ENDS use decreased significantly with age.

Discussion

In this large cross-sectional study of US youth, we found that ENDS use was associated with recent initiation of cigarette smoking. In previous studies, when cigarette was the main form of tobacco use, initiation at a younger age predicted nicotine dependence in adolescence (Karp et al. 2006). Concordant with animal models wherein younger brains are more susceptible to nicotine addiction (Slotkin 2002; Leslie et al. 2004), we also found that the association between ENDS use and recent initiation was stronger in younger children.

While adult smokers may use ENDS as an aid to quit or decrease smoking, this is unlikely among youth who have just recently started smoking. A recent report on non-smoking youth in the 2011–2013 NYTS found that ENDS users were more likely to report that they were considering starting smoking (Bunnell et al. 2015). Our findings support recently published cohort data suggesting that ENDS might be a “gateway” for cigarette smoking initiation, (Leventhal et al. 2015) escalation into or continuation of cigarette smoking. Our study adds to existing knowledge that this relation could possibly be at play for younger children.

Our finding that ENDS users initiate smoking at a higher proportion than nonusers cannot exclude the possibility that ENDS users are a separate population more likely to initiate cigarette smoking. Another consideration is that they have behavior phenotypes unmeasured in NYTS questionnaires placing them at higher risk of initiating cigarette smoking.

ENDS may lead children to smoke simply by virtue of nicotine addiction. The actual nicotine yield per puff in ENDS is lower than the yield in regular (i.e., combustible)

Table 1 Prevalence of recent and distant cigarette smoking initiation by selected factors including electronic nicotine delivery (ENDS) use, National Youth Tobacco Survey 2011–2013

	<i>n</i>	Initiated in the past year			Initiated more than a year ago		
		%*	Crude prevalence ratio (95 % CI)	Adjusted prevalence ratio** (95 % CI)	%*	Crude prevalence ratio (95 % CI)	Adjusted prevalence ratio** (95 % CI)
Ever used ENDS							
No	51,505	2.9	Ref	Ref	18.7	Ref	Ref
Yes	3172	6.6	2.3 (1.9, 2.8)	2.3 (1.9, 2.7)	82.1	4.4 (4.1, 4.7)	4.0 (3.8, 4.2)
Year							
2011	16,466	3.2	Ref	Ref	24.7	Ref	Ref
2012	22,215	3.1	1.0 (0.8, 1.1)	0.9 (0.8, 1.1)	21.7	0.9 (0.8, 1.0)	0.8 (0.7, 0.9)
2013	15,996	2.9	0.9 (0.7, 1.1)	0.9 (0.7, 1.0)	20.9	0.8 (0.7, 1.0)	0.8 (0.7, 0.8)
Age							
11–13	19,276	1.9	Ref	–	8.1	Ref	–
14–15	15,795	3.4	1.8 (1.5, 2.3)	–	21.5	2.7 (2.4, 2.9)	–
16–18	19,606	3.9	2.1 (1.7, 2.5)	–	36.1	4.5 (4.0, 4.9)	–
Sex							
Girls	27,203	3.1	Ref	Ref	23.3	Ref	Ref
Boys	27,474	3.1	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	21.6	0.9 (0.9, 1.0)	0.9 (0.9, 1.0)
School grade							
Middle (6–8)	25,141	1.9	Ref	Ref	10.8	Ref	Ref
High (9–12)	29,536	4.0	2.1 (1.8, 2.5)	1.9 (1.6, 2.2)	31.2	2.9 (2.6, 3.2)	2.3 (2.1, 2.4)
Race/ethnicity							
NH-Whites	28,002	3.0	Ref	Ref	21.6	Ref	Ref
Other than NH-Whites	26,675	3.2	1.1 (0.9, 1.2)	1.1 (1.0, 1.3)	23.6	1.1 (1.0, 1.2)	1.2 (1.2, 1.3)
Household cigarette smoking							
No	37,271	2.5	Ref	Ref	16.6	Ref	Ref
Yes	17,406	4.3	1.7 (1.5, 2.0)	1.6 (1.4, 1.8)	35.1	2.1 (2.0, 2.2)	1.8 (1.2, 1.9)

* Weighted prevalence among all young persons (including those who never tried cigarette smoking)

** Multivariate prevalence ratio, with all variables except age included in the model

Table 2 Prevalence and prevalence ratio of recent initiation (<1 year) of cigarette smoking according to electronic nicotine delivery system (ENDS) ever use, National Youth Tobacco Survey 2011–2013

Ever used ENDS	Predicted prevalence (95 % CI) and multivariate* prevalence ratio (95 % CI)		
	11–13 years	14–15 years	16–18 years
No	Ref	Ref	Ref
Yes	4.1 (2.6, 6.4)	3.0 (2.2, 3.9)	1.4 (1.1, 1.8)

* Adjusted for sex, race/ethnicity, year, and household cigarette smoking

cigarettes, but a review found that current ENDS users achieve similar or even higher levels of nicotine than combustible cigarettes (Schroeder and Hoffman 2014; St Helen et al. 2015).

The apparent effect modification of the effect of ENDS use on smoking initiation by age could be an artifact or be due to underlying differences in the maturing brain. One may think that older children in the NYTS could belong to an earlier birth cohort that missed the targeting of marketing and/or fad of ENDS. However, as described in other reports of the NYTS, older children have reported more ever and current use of ENDS than younger counterparts (Arrazola et al. 2015). Alternatively, younger children could be more susceptible to nicotine exposure: nicotine dependence and nicotine dependence symptoms have been observed following first exposure to smoking, (DiFranza et al. 2002; O'Loughlin et al. 2003). ENDS use in younger children can result in nicotine exposure to levels equivalent to cigarette smoking, and as shown in animal models, a younger age of exposure to nicotine has a stronger effect due to increased susceptibility to nicotine addiction and

other addictions (Slotkin 2002; Leslie et al. 2004). The effect of younger age at uptake of smoking is well known to increase the risk of heavy smoking (CDC 2012). Nicotine exposure stimulates dendritic growth and synaptic connectivity differentially by age as reviewed elsewhere (Smith et al. 2015).

Limitations of this analysis include the cross-sectional design which limits causal inference and that questionnaire items were not framed to identify the sequence of use of different tobacco products. The prevalence of ENDS ever use is not necessarily indicative of established or current ENDS use, since patterns of use are not yet established in youth. Strengths of the analysis include the large sample size, that the data are representative of US children, and that the questionnaire items were extensively validated by CDC.

The US Food and Drug Administration has proposed that ENDS be subject to similar regulations as other tobacco products, and several states have enacted regulations to protect children from the potential hazards of ENDS. This current study indicates that the association between ENDS use and recent cigarette smoking initiation may be stronger among younger than older children.

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