

e-Cigarette Awareness, Use, and Harm Perceptions in US Adults

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A heterogeneous collection of battery-driven nicotine inhalers—"e-cigarettes" or electronic nicotine delivery systems (ENDS)—are emerging products receiving considerable advocacy, policy, and media attention.¹ ENDS have been marketed as harm-reducing alternatives to smoking and used as cessation aids, though the US Food and Drug Administration (FDA) has not reviewed these claims or devices.^{2,3} Independent testing of ENDS has demonstrated poor quality control,^{2,4} low-level toxic contaminants,⁵ variable nicotine delivery,^{2,6,7} and insufficient evidence of overall public health benefit.⁸ Packaging and Web sites for ENDS reveal unsubstantiated health claims and erroneous nicotine content labeling.⁴ In addition, their wide combination of flavorings and "high-tech" image are potentially attractive to youths and young adults.^{2,4} In 2010, the World Health Organization recommended that ENDS products be regulated as combination drug and medical devices.¹ Consistent with this recommendation, several countries, such as Australia and Canada, restricted or banned ENDS until reviewed by their regulatory agencies.^{9,10} A 2009 court decision (*Sottera Inc v. Food and Drug Administration*)¹¹ blocked the FDA from regulating ENDS as drug delivery devices in the United States, ruling that products containing nicotine derived from tobacco are "tobacco products" under the 2009 Family Smoking Prevention and Tobacco Control Act unless they are sold as therapeutic aids for cessation.¹² In keeping with this ruling, on April 25, 2011, the FDA announced its intention to regulate ENDS as tobacco products. The nature of the FDA's ENDS regulation procedure has yet to be determined; until that time, ENDS will likely continue to be sold to consumers without regulation, raising serious concerns for public health.

Although variations of ENDS have been on the market since at least 2007,¹³ little is known about the population prevalence of ENDS use

in representative samples. One study examined Google searches and reported a sharp increase from 2008 to 2010 in queries, with ENDS search terms receiving more hits than nicotine patches and snus.¹⁴ Although this suggests relative increased interest, the denominators are unknown. In a European study, Etter et al.¹⁵ posted a survey in French for 34 days on a cessation Web site (<http://www.stop-tabac.ch>), which typically obtains about 120 000 visitors a month. Of 214 respondents, 81 eligible ENDS users reported mainly using ENDS for cessation or to avoid disturbing others; some were concerned about potential ENDS toxicity.¹⁶ Another online survey¹⁷ of first-time ENDS purchasers yielded a response proportion of only 4.5%; considering this low percentage, participants are not likely representative of ENDS purchasers and results are difficult to interpret. In a 2009 Zogby opinion poll, 59% of Americans supported FDA regulation of ENDS, with almost half (47%) saying that ENDS should be made available for people who want to quit smoking.¹⁸

There are several widely cited and as yet unaddressed concerns regarding the effect of ENDS on public health. First is the concern that ENDS could act as a starter product for combustible cigarettes, especially among youths or young adults who may be attracted to their "tech" image or flavorings.^{3,19} Other concerns include that ENDS may lure former smokers to return to nicotine dependence, delay cessation among current smokers,^{2,3} serve as a dual-use-product, or enable individuals to avoid smoking restrictions.¹⁹ Despite these gaps in our knowledge, there are no reliable national estimates of ENDS awareness, utilization, or harm perceptions in the peer-reviewed literature. Furthermore, other than the 2009 Zogby poll, no investigation of ENDS among nonsmokers is evident.¹⁸ This study makes an initial contribution to address some of these pressing knowledge gaps by using cross-sectional data from 2 separate surveys conducted in 2010, 1 nationally representative and 1 from the follow-up of a large cohort of current smokers and recent former smokers, to estimate ENDS

Objectives. We estimated e-cigarette (electronic nicotine delivery system) awareness, use, and harm perceptions among US adults.

Methods. We drew data from 2 surveys conducted in 2010: a national online study (n = 2649) and the Legacy Longitudinal Smoker Cohort (n = 3658). We used multivariable models to examine e-cigarette awareness, use, and harm perceptions.

Results. In the online survey, 40.2% (95% confidence interval [CI] = 37.3, 43.1) had heard of e-cigarettes, with awareness highest among current smokers. Utilization was higher among current smokers (11.4%; 95% CI = 9.3, 14.0) than in the total population (3.4%; 95% CI = 2.6, 4.2), with 2.0% (95% CI = 1.0, 3.8) of former smokers and 0.8% (95% CI = 0.35, 1.7) of never-smokers ever using e-cigarettes. In both surveys, non-Hispanic Whites, current smokers, young adults, and those with at least a high-school diploma were most likely to perceive e-cigarettes as less harmful than regular cigarettes.

Conclusions. Awareness of e-cigarettes is high, and use among current and former smokers is evident. We recommend product regulation and careful surveillance to monitor public health impact and emerging utilization patterns, and to ascertain why, how, and under what conditions e-cigarettes are being used. (*Am J Public Health.* 2012;102:1758–1766. doi:10.2105/AJPH.2011.300526)

awareness, use, and harm perceptions in the adult US population.

METHODS

We drew data for this study from items within 2 cross-sectional surveys: a nationally representative online sample (online survey) and a large cohort of smokers (Legacy Longitudinal Smoker Cohort [LLSC]). Results from these 2 surveys are presented separately because of their different sampling designs. Each survey partially replicates and extends the other, using virtually identical items to assess ENDS awareness, use, and harm perceptions. Utilizing both data sets permits investigation of these subjects in a large cohort of smokers in the LLSC ($n = 3658$ recent quitters and current smokers) while also presenting national estimates from the online survey ($n = 2649$ never, former, and current smokers).

Nationally Representative Online Survey

We obtained data on never, former, and current smokers from a cross-sectional survey (June 2010) drawn from Knowledge Networks' KnowledgePanel, a nationally representative online panel of adults aged 18 years and older. KnowledgePanel is a commercial online research panel that covers both the online and offline populations in the United States. Panel members were randomly recruited primarily via address-based sampling, although some panel members who were recruited during earlier efforts with random-digit-dial sampling remained in the panel. To address the bias associated with online samples, members who did not have access to the Internet were given a computer with Internet access to facilitate data collection. All new members completed a separate profile survey that collected demographic information used for determining eligibility for studies and statistical weighting. This information is updated annually, with members typically active for 3 years. Panel members are rewarded for completing surveys with points that are redeemable for cash, or with free access to the Internet if not already available in the household. Unsampled volunteers are not eligible to join the panel.

For this survey, we randomly sampled panel members from the KnowledgePanel participant list, with oversampling for African Americans

and Hispanics. Overall, we contacted 10 537 panel members for participation, of which 6792 (64.5%) completed the screening and 2649 never, former, and current smokers were eligible and completed the survey. This study was exempted by Independent IRB, an external institutional review board (IRB) used by the sponsor of this survey.

Legacy Longitudinal Smoker Cohort

The LLSC collected data over the phone from a cohort of 5616 smokers aged 18 to 49 years living in 8 metro areas, selected to ensure variation with respect to racial/ethnic composition, strength of tobacco control efforts (clean indoor air legislation, state tobacco control expenditures, and cigarette price), smoking prevalence, and geographic location.²⁰ After purposeful selection of metro areas, the sample was stratified by race/ethnicity to capture sufficient samples of African Americans and Hispanics. Within each metro area, households were selected via list-assisted random-digit-dial methodology, generating a list of approximately 874 000 numbers. Of these numbers, 24% were residential telephone numbers and 6663 were for households containing at least 1 person who met age and tobacco-use eligibility criteria. Allowing up to 2 smokers per household to participate, a total of 8489 eligible participants were identified and 5616 (66%) completed the baseline interview. Participants were interviewed using computer-assisted telephone interviews in either English or Spanish.

Of the original 5616 respondents who completed the baseline interview between February and April 2008, 73% completed the first follow-up ($n = 4067$) from August through October 2008 and 64.8% ($n = 3658$) completed the second follow-up from January through April 2010, which included items for this analysis. This study was approved by the institutional review board (IRB) of Westat, the company that conducted the data collection, and Copernicus Group IRB, an external IRB used by the sponsor of this survey. For more information about the LLSC, see Vallone et al.^{20,21}

Measures

The online survey and the LLSC contained identical items except where otherwise noted.

Smoking status in both samples was self-reported, with never-smokers classified as having never smoked up to 100 cigarettes in their lives, former smokers having smoked 100 cigarettes or more in their lives but currently smoking "not at all," and current smokers having smoked in excess of 100 cigarettes in their lives and currently smoking "every day" or "some days." Both surveys asked respondents about ENDS awareness, use, and harm perceptions. Items included

1. "Have you ever heard of a product called an electronic cigarette or e-cigarette, or brands such as Smoking Everywhere, NJOY, Gamucci, or others?";
2. "Please indicate whether you have ever tried or used the following product: electronic cigarettes, or e-cigarettes"; and
3. "Now, based on your smoking experience, we'd like your opinion about several tobacco products. Compared to regular-strength cigarettes, do you think that electronic or e-cigarettes are a lot less harmful to a person's health, a little less harmful, about the same, a little more harmful, or a lot more harmful to health?"

These items were identical in both surveys, but the online survey included a picture of an e-cigarette with the awareness item, whereas the LLSC survey was administered over the phone and thus did not include a visual cue. In addition, the online survey included a question about ENDS use in the past 30 days that was not included in the LLSC. Respondents also provided information on demographic variables, intention to quit, and perceived health.

Data Analysis

In the LLSC, response rates for all items were greater than 98.9%. Despite this very low level of nonresponse, we imputed missing values by using nearest neighbor hotdeck imputation by matching respondents who had missing data to respondents who had answered the item. In the online survey, the only variable with missing data was perceived health, with 21 of 2649 or 0.8% of observations missing. The missing data pattern was correlated with other variables in the model at less than 5% and, thus, we treated the missing values as missing completely at

random, which assumes that the probability of the value being missing is not related to the value that would have been reported for that variable or the value of any other independent variable.²² In the online survey, we also conducted a sensitivity analysis to ascertain any bias associated with participants quickly clicking through the survey and neglecting to read the questions carefully. Removing participants who took 7 minutes or less (median = 15 minutes) to complete the survey did not alter our conclusions and, thus, we retained these participants' answers for statistical analysis.

Using Stata version 11.2 (StataCorp LP, College Station, TX), we conducted both a weighted and unweighted analysis to obtain demographic and point estimates for awareness, use, and harm perceptions associated with ENDS. We analyzed both samples by using design-based population weights that adjusted for the probability of selection into the sample. We further constructed weights to reflect the 2009 US national population demographic characteristics (online survey) or the 2007 population demographic characteristics for each of the 8 sampled cities (LLSC) according to the appropriate wave of the Current Population Survey.^{23,24} For the harm perception analysis, we collapsed responses from a 5-point Likert scale into "less harmful," "about the same," and "more harmful." We estimated bivariate statistical significance with the Rao-Scott test. We used multivariable logistic regression to estimate odds ratios (ORs) of outcome variables adjusted for demographic and smoking-related cognitions and behaviors.

RESULTS

The online survey and LLSC sample baseline characteristics are presented in Table 1. Both samples included comparable percentages of African Americans (11.4% and 10.6%, respectively), Hispanics (12.9% and 12.1%), and non-Hispanic Whites (69.0% and 71.7%). Because the LLSC is a younger (aged 18–49 years) smoker-only sample, the mean age, particularly the mean age of smokers, is lower in the LLSC than the online survey sample. A higher proportion of participants in the LLSC sample did not have a high-school diploma, consistent with the profile of smokers in the United States.²⁵ When we compared the online

survey weighted demographic characteristics to the Current Population Survey 2010 estimates, we saw that it is reasonable to conclude that the online survey is nationally representative of both the total population and smoker-only population.

Smoking characteristics were similar between the samples. The majority in the online sample (76.4%; 95% confidence interval [CI] = 73.2, 79.6) and the LLSC (85.1%; 95% CI = 83.1, 87.2) were daily smokers who consumed a median of 15 to 20 cigarettes a day. Nearly identical proportions of participants smoked within the first 30 minutes of waking in both the online survey (59%; 95% CI = 55.3, 62.7) and the LLSC (60.7%; 95% CI = 58.7, 62.9). Two thirds of all respondents in the online survey (64.1%; 95% CI = 60.5, 67.6) and the LLSC (66.6%; 95% CI = 64.4, 68.7) samples were seriously considering a quit attempt within the next 6 months. In the online survey, 31.8% of smokers (95% CI = 28.3, 35.2) had made at least 1 quit attempt within the past 3 months; in the LLSC, 69.7% of smokers (95% CI = 67.7, 71.7) had tried to quit in the past 6 months.

Electronic Nicotine Delivery System Awareness

Overall, 40.2% (95% CI = 37.3, 43.1) of Americans aged 18 years and older had heard of ENDS as assessed by the nationally representative online survey. Awareness increased from never smokers (32.5%; 95% CI = 20.1, 37.2), to former smokers (41.5%; 95% CI = 36.5, 46.8), to current smokers (57.1%; 95% CI = 53.3, 60.7; Table 2). When we compared these results to findings in the LLSC, awareness among current smokers in the LLSC was virtually identical to the online survey sample (58.2% vs 57.1%, respectively). However, there was no difference in awareness between current and recent former smokers in the LLSC (58.0% vs 58.2%; $P = .96$).

In multivariable analysis of the online survey, the odds that current (3.18; 95% CI = 2.40, 4.18) and former (1.6; 95% CI = 1.26, 1.96) smokers were aware of ENDS were higher than the odds that never-smokers were aware of ENDS; this comparison was not statistically significant in the online survey ($P = .99$). Age was inversely related to awareness in the online survey (adjusted OR = 0.99; 95% CI = 0.98, 0.99), but not the LLSC ($P = .54$).

However, both surveys agreed that the odds of awareness decreased for African Americans (online survey: 0.56; 95% CI = 0.37, 0.84; LLSC: 2.31; 95% CI = 1.72, 3.08) compared with Whites, and increased for men (online survey: 1.57; 95% CI = 1.26, 1.96; LLSC: 1.64; 95% CI = 1.35, 2.00) compared with women.

Electronic Nicotine Delivery System Utilization

In the online survey sample, 3.4% (95% CI = 2.6, 4.2) of the general population had ever used an ENDS product. Of those who had ever used ENDS, 35.9% (95% CI = 26.1, 44.8) had used one in the past 30 days. Use was most common among current smokers (11.4%; 95% CI = 9.3, 14.0; Table 2). However, 2.0% (95% CI = 1.0, 3.8) of former smokers had also ever used an ENDS product, 2.5 times higher than use among never smokers. Nationally, past-30-day use was also higher among current smokers (4.1%; 95% CI = 3.0, 5.6) compared with former (0.5%; 95% CI = 0.1, 1.8) or never smokers (0.3%; 95% CI = 0.1, 0.8). Similar to data on awareness, ENDS use was also inversely related to age in both samples (Table 3).

When we compared the LLSC and online survey samples, there were several consistent trends among current smokers (Table 3). In both samples, non-Hispanic Whites were most likely to use ENDS (online survey: 7.1%; 95% CI = 5.9, 8.6; LLSC: 6.3%; 95% CI = 5.1, 7.7); the odds of use were statistically significantly different in the LLSC compared with African Americans (adjusted OR = 0.10; 95% CI = 0.03, 0.29). These racial/ethnic groups were not statistically significantly different from each other in the online survey sample, but the pattern of differences was the same. Age was inversely related to ENDS use in both samples, with the adjusted OR of use decreasing by 2% to 3% in both samples with every year of increased age. Better self-reported health status was found to be associated with ENDS use in both samples, with statistically significant results in the online survey.

There were also some discrepant findings between the 2 samples. In the online survey, the odds of ENDS use was higher in respondents with an intention to quit within the next 6 months (adjusted OR = 1.74; 95% CI = 1.02, 2.98) compared with smokers with no plans

TABLE 1—Unweighted and Weighted Demographic Characteristics in the National Online Survey and Legacy Longitudinal Smoker Cohort Studies, United States, 2010

	Online Survey, Total Population			Online Survey, Smokers Only			Legacy Longitudinal Smoker Cohort, Total Population			Legacy Longitudinal Smoker Cohort, Smokers Only		
	No.	% Sample Unweighted (CPS 2010) ^a	% Sample Weighted (95% CI)	No.	% Sample Unweighted (CPS 2010) ^a	% Sample Weighted (95% CI)	No.	% Sample Unweighted (CPS 2010) ^b	% Sample Weighted (95% CI)	No.	% Sample Unweighted (CPS 2010) ^b	% Sample Weighted (95% CI)
Gender												
Male	1323	49.9 (48.3)	48.4 (45.4, 51.4)	614	46.9 (47.7)	47.2 (43.5, 51.0)	1653	45.2 (48.3)	55.5 (55.4, 55.6)	1443	44.6 (47.7)	55.3 (54.6, 56.0)
Female	1326	50.1 (51.7)	51.6 (48.6, 54.6)	694	53.1 (52.3)	52.8 (49.0, 56.5)	2005	54.8 (51.7)	44.5 (44.4, 44.6)	1796	55.5 (52.3)	44.7 (44.0, 45.5)
Smoking status												
Never	680	25.7 (52.5)	52.5 (49.5, 55.4)	...	...	...	...	...	...	...	...	...
Former	661	25.0 (25.5)	25.4 (23.0, 27.8)	...	...	...	419	11.5 (25.5)	11.2 (9.5, 12.8)	...	...	...
Current	1308	49.3 (21.8)	22.2 (20.3, 24.0)	1308	100	100	3239	88.5 (21.8)	88.8 (87.2, 90.5)	3239	100	100
Race/ethnicity												
White	1902	71.8 (69.0)	69.0 (66.1, 72.0)	910	69.6 (61.7)	62.6 (58.6, 66.4)	2721	74.4 (69.0)	71.7 (71.2, 72.1)	2422	74.8 (61.7)	72.7 (71.7, 73.7)
African American	298	11.3 (11.1)	11.4 (9.2, 13.5)	160	12.2 (13.4)	13.6 (11.1, 16.7)	432	11.8 (11.1)	10.6 (9.8, 11.3)	393	12.1 (13.4)	10.7 (9.9, 11.7)
Hispanic	288	10.9 (13.4)	12.9 (10.7, 15.2)	157	12.0 (19.2)	18.0 (14.8, 21.8)	256	7.0 (13.4)	12.1 (11.7, 12.5)	211	6.5 (19.2)	11.0 (10.2, 11.9)
Other	161	6.1 (5.4)	6.7 (5.0, 8.4)	81	6.2 (4.6)	5.8 (4.2, 7.9)	249	6.8 (5.4)	5.6 (4.9, 6.4)	213	6.6 (4.6)	5.5 (4.7, 6.5)
Age, y												
18-29	403	15.2 (22.0)	22.1 (19.4, 24.8)	209	16.0 (20.4)	20.2 (17.2, 23.5)	938	25.6 (22.0)	38.7 (36.8, 40.6)	829	25.6 (20.4)	39.3 (37.3, 41.3)
30-44	627	23.7 (26.2)	26.1 (23.3, 28.8)	324	24.8 (26.5)	26.5 (23.3, 30.0)	1677	45.8 (26.2)	41.6 (39.5, 43.6)	1489	46.0 (26.5)	41.2 (39.1, 41.4)
45-59	890	33.6 (27.8)	27.8 (25.1, 20.3)	522	39.9 (36.2)	36.4 (33.0, 40.0)	1043	28.5 (27.8)	19.8 (18.5, 21.2)	921	28.4 (36.2)	19.5 (18.1, 21.0)
≥ 60	729	27.5 (24.0)	24.1 (21.7, 26.5)	253	19.3 (16.9)	16.9 (14.4, 19.9)	...	...	...	...	...	...
Education												
College degree	661	25.0 (27.2)	27.6 (24.9, 30.3)	200	15.3 (11.7)	11.9 (10.0, 14.1)	404	11.0 (27.2)	11.0 (10.9, 11.0)	333	10.3 (11.7)	10.2 (9.7, 10.7)
Some college	789	29.8 (27.8)	28.3 (25.7, 31.0)	425	32.5 (30.2)	30.6 (27.5, 34.0)	1122	30.7 (27.8)	27.1 (26.5, 27.7)	979	30.2 (30.2)	26.5 (25.4, 27.6)
High school diploma or GED	861	32.5 (31.0)	31.0 (28.2, 33.8)	461	35.2 (33.9)	34.4 (30.9, 37.8)	1444	39.5 (31.0)	36.9 (35.4, 38.3)	1301	40.2 (33.9)	37.8 (36.1, 39.6)
< high school diploma	338	12.8 (24.0)	13.1 (11.0, 15.1)	222	17.0 (24.2)	23.2 (19.7, 27.0)	688	18.8 (24.0)	25.1 (23.8, 26.4)	626	19.3 (24.2)	25.5 (24.0, 27.0)
Perceived health												
Good	1967	74.9 (NA)	77.7 (75.3, 80.2)	865	66.7 (NA)	64.0 (60.2, 67.6)	2674	73.1 (NA)	75.1 (73.1, 77.1)	2345	72.4 (NA)	73.8 (71.7, 75.8)
Fair	540	20.6 (NA)	18.7 (16.4, 21.0)	340	23.2 (NA)	28.2 (24.8, 31.8)	729	19.9 (NA)	19.1 (17.2, 21.0)	655	20.2 (NA)	19.9 (18.0, 22.0)
Poor	121	4.6 (NA)	3.6 (2.6, 4.6)	91	7.0 (NA)	7.9 (5.9, 10.3)	255	7.0 (NA)	5.8 (4.8, 6.8)	239	7.4 (NA)	6.3 (5.3, 7.4)

Note. CI = confidence interval; CPS = Current Population Survey; GED = general equivalency diploma; NA = not applicable. The sample size was n = 2649 for the online survey and n = 3658 for the Legacy Longitudinal Smoker Cohort.

^aProportions were drawn from the April 2010 Current Population Survey²⁴ and used to compute the final weighted proportions in the online survey.

^bThe Legacy Longitudinal Smoker Cohort sample is not nationally representative. April 2010 Current Population Survey²⁴ data are included to facilitate comparison of the online survey and Legacy Longitudinal Smoker Cohort samples.

TABLE 2—Point Estimates for Electronic Nicotine Delivery System Awareness, Use, and Harm Perceptions in the National Online Survey and Legacy Longitudinal Smoker Cohort Studies, United States, 2010

	Online Survey (n = 2649), % (95% CI)			Legacy Longitudinal Smoker Cohort (n = 3658), % (95% CI)		
	Never Smoker	Former Smoker	Current Smoker	Never Smoker	Former Smoker	Current Smoker
ENDS aware	32.5 (20.1, 37.2)	41.5 (36.5, 46.8)	57.1 (53.3, 60.7)	...	58.0 (50.4, 65.2)	58.2 (55.7, 60.5)
ENDS use						
Ever	0.77 (0.35, 1.7)	2.0 (1.0, 3.8)	11.4 (9.3, 14.0)	...	3.1 (1.3, 7.1)	6.4 (5.3, 7.7)
Past 30 d	0.29 (0.1, 0.8)	0.49 (0.13, 1.8)	4.1 (3.0, 5.6)	...	...	...
ENDS harm perception						
Less harmful	...	46.0 (40.9, 51.3)	43.2 (39.6, 46.9)	...	44.9 (37.5, 52.6)	46.0 (43.5, 48.5)
About the same	...	43.1 (37.9, 48.4)	18.0 (15.5, 20.9)	...	13.8 (9.5, 19.5)	11.3 (9.6, 13.0)
More harmful	...	9.1 (6.8, 12.0)	5.9 (4.2, 8.2)	...	3.2 (1.5, 6.6)	2.6 (2.0, 3.5)

Note. CI = confidence interval; ENDS = electronic nicotine delivery system.

to quit. In the same survey, the odds of ENDS use were also higher among those who had made a quit attempt in the past 3 months (adjusted OR = 1.78; 95% CI = 0.90, 3.53) compared with those who had not made a quit attempt, though this finding was only marginally statistically significant (Table 3); however, quit intentions and attempts were not significantly associated with ENDS use in the LLSC. In addition, there was a strong positive association between ENDS use and education in the LLSC, but no such association was evident in the online survey.

Electronic Nicotine Delivery System Harm Perception

Among smokers aware of ENDS, 70.6% (95% CI = 65.0, 75.7) in the online survey and 84.7% (95% CI = 81.5, 87.4) in the LLSC believed that ENDS were less harmful than regular cigarettes (Table 4). In the online survey, African Americans were more skeptical of ENDS than were non-Hispanic Whites (adjusted OR = 0.37; 95% CI = 0.16, 0.82). Although the perception that ENDS were less harmful than regular cigarettes decreased with decreased perceived health status in the online survey (adjusted OR of poor vs good perceived health = 0.40; 95% CI = 0.17, 0.93); this pattern was not observed in the LLSC.

DISCUSSION

This is the first large-scale report that examined ENDS awareness, use, and harm

perceptions in a nationally representative sample of the US adult population and in a large cohort of smokers and recent quitters. National estimates of ENDS ever-use prevalence of 11.4% for smokers, 2.0% for former smokers, and 0.8% for never smokers suggest that, in absolute numbers, roughly 5 million smokers and more than 1 million former and never smokers have ever used ENDS. (Estimates based on number of current [46 million], former [48.1 million], and never smoking [136 million] adults aged 18 years and older in 2008.⁵) Ever use is most heavily concentrated among smokers, young adults, and non-Hispanic Whites, with some suggestion that use is also popular among those with a college degree; past-30-day use, a proxy for current use, was most common among current smokers (4.1%) and former smokers (0.5%). Although the prevalence of past-30-day ENDS use at the time of the surveys was moderate to low, the fact that the absolute number of ever-users among never, former, and current smokers was more than 5 million is cause for concern, given that ENDS have not been adequately evaluated by the FDA and continue to be sold in the United States despite the World Health Organization's recommendation to regulate these products as drug (nicotine) delivery devices.^{9,10}

Our finding that 40.2% of Americans were aware of ENDS products is similar to the 2009 Zogby poll estimate, which found that 48% of Americans had heard of ENDS.¹⁸ Considering the lack of traditional mass media advertising

for ENDS products, high awareness via word of mouth, mall kiosk sales, retail outlets, and Internet advertising is noteworthy.¹⁹ Proprietary data yield an estimate that a third of the 3 major mall chains (Westfield, Simon, and General Growth) host ENDS product kiosks (D. Schlottmann; media strategist, PHD Media; written communication; March 2011). At least 1 ENDS company has begun selling e-cigarette starter kits at convenience stores nationwide for less than \$20.^{26a} Most recently, Lorillard Inc., maker of Newport cigarettes, acquired Blu Ecigs and became the first major US tobacco company to move into the ENDS market.^{26b} With these developments, it seems likely that ENDS awareness and use will increase in the near future.

One concern that has been raised about ENDS is their use as a starter product by youths, young adults, and never-smokers. Among never-smokers aged 18 years and older, we found that 0.8% had ever tried ENDS. This estimate has a wide confidence interval because of the small sample size of this subgroup. Although age was inversely related to awareness and use in both of our samples, echoing the Zogby conclusion that young adults aged 18 to 29 years were most open to trying ENDS, it cannot be ascertained whether ENDS, cigarettes, or other noncombustible tobacco products came first among those aged 18 to 24 years in our study. Additional surveillance of young adults and youths aged 12 to 17 years is necessary to monitor ENDS as a starter product. This is especially important,

TABLE 3—Point Estimates and Adjusted Odds Ratios of Electronic Nicotine Delivery System Use for Current Smokers in the National Online Survey and Legacy Longitudinal Smoker Cohort Studies, United States, 2010

	Online Survey (n = 1308)		Legacy Longitudinal Smoker Cohort (n = 3239)	
	Use ENDS, % (95% CI) or Mean ±SE	Use ENDS, AOR (95% CI)	Use ENDS, % (95% CI) or Mean ±SE	Use ENDS, AOR (95% CI)
Overall	11.4 (9.2, 14.0)	...	6.4 (5.3, 7.7)	...
Gender				
Male	12.6 (9.2, 16.9)	1.31 (0.81, 2.10)	7.3 (5.6, 9.5)	1.32 (0.93, 1.88)
Female (Ref)	10.3 (7.7, 13.7)	1.00	5.3 (4.2, 6.7)	1.00
Race/ethnicity				
White (Ref)	11.8 (9.4, 14.7)	1.00	7.4 (6.1, 9.1)	1.00
African American	8.2 (3.6, 17.7)	0.53 (0.23, 1.25)	0.8 (0.03, 2.0)	0.10* (0.03, 0.29)
Hispanic	10.2 (5.1, 19.6)	0.55 (0.26, 1.17)	5.5 (3.2, 9.5)	0.69 (0.38, 1.27)
Other	18.1 (8.4, 34.6)	1.62 (0.63, 4.16)	6.0 (2.5, 13.6)	0.76 (0.30, 1.88)
Age, y	40.2 ±1.59	0.98* (0.96, 0.99)	31.3 ±0.64	0.97* (0.96, 0.99)
Education				
< high school diploma (Ref)	11.6 (6.5, 19.8)	1.00	3.4 (2.0, 7.7)	1.00
High school diploma or GED	8.5 (6.0, 11.9)	1.00 (0.41, 2.41)	7.0 (5.3, 9.1)	1.96* (1.00, 3.85)
Some college	13.6 (9.8, 18.5)	1.09 (0.50, 2.35)	7.4 (5.2, 10.4)	2.14* (1.05, 4.38)
College degree	13.7 (8.4, 21.6)	0.70 (0.33, 1.46)	9.4 (5.6, 15.5)	2.72* (1.33, 5.59)
Perceived health				
Good (Ref)	6.2 (5.0, 7.8)	1.00	7.2 (5.8, 8.8)	1.00
Fair	7.1 (4.4, 11.1)	1.02 (0.56, 1.86)	4.6 (2.8, 7.6)	1.16 (0.35, 3.89)
Poor	3.1 (1.5, 6.4)	0.32* (0.12, 0.83)	3.4 (1.4, 8.0)	1.47 (0.82, 2.65)
Intention to quit				
Not interested in quitting (Ref)	8.4 (5.8, 12.0)	1.00	5.6 (4.0, 7.7)	1.00
Next 6 mo	14.1 (10.4, 18.8)	1.74* (1.02, 2.98)	6.6 (4.9, 8.7)	1.16 (0.70, 1.92)
Next 30 d	10.7 (7.0, 16.1)	1.00 (0.48, 2.08)	7.7 (5.1, 11.5)	1.47 (0.82, 2.65)
Quit attempts ^a				
None (Ref)	7.5 (5.4, 10.4)	1.00	6.2 (5.0, 7.6)	1.00
≥ 1	17.3 (12.5, 23.5)	1.78 (0.90, 3.53)	7.1 (5.2, 9.6)	1.13 (0.74, 1.73)

Note. AOR = adjusted odds ratio; CI = confidence interval; ENDS = electronic nicotine delivery system; GED = general equivalency diploma. Adjusted for all other covariates in the model.

^aThe Legacy Longitudinal Smoker Cohort item asked about quit attempts in the past 6 months, whereas the online survey item asked about quit attempts in the past 3 months.

**P* < .05.

as ENDS are promoted via youth-dominated channels such as social media and online advertising.¹⁴ Moreover, ENDS are offered in a variety of flavors that may appeal to youths, particularly because all flavors excluding menthol have been eliminated from the cigarette market under the 2009 Family Smoking Prevention and Tobacco Control Act.

In the online survey, smokers who were considering quitting in the next 6 months were more likely to have used ENDS than smokers who were not interested in quitting. The national online survey data suggested that some smokers who were interested in quitting were using ENDS as cessation devices, possibly

discouraging the use of proven smoking cessation treatments, delaying cessation, and thus prolonging exposure to harmful agents in combusted tobacco as an unintended consequence. However, this finding in the online survey sample was not echoed in the LLSC sample. Without longitudinal data and survey items that specifically address ENDS as cessation aids, we cannot directly ascertain the popularity of ENDS for smoking cessation or the unintended, long-term harmful consequences of failure to quit when using ENDS. More rigorous randomized trials with appropriate control conditions to evaluate ENDS as a cessation therapy are needed, using representative samples

of smokers and with adequate follow-up as is recommended under FDA approval of any claim for a new cessation therapy.

In our 2 surveys, dual use of ENDS and combustible tobacco among current smokers who were considering quitting in the next 6 months was the most common pattern of use in both ever users and past-30-day users. Our research confirms the popularity of dual use, perhaps because ENDS are convenient, advertised as less expensive than cigarettes, have the look and feel of a real cigarette, and are perceived as not emitting second-hand smoke. Another related concern is that ENDS may serve as a means for smokers to avoid smoke-free air

TABLE 4—Point Estimates and Adjusted Odds Ratios for Belief That Electronic Nicotine Delivery Systems Are Less Harmful Than Regular Cigarettes Among Current Smokers Aware of Electronic Nicotine Delivery Systems in the National Online Survey and Legacy Longitudinal Smoker Cohort Studies, United States, 2010

	Online Survey (n = 1308)		Legacy Longitudinal Smoker Cohort (n = 1882)	
	Believe ENDS Less Harmful, % (95% CI) or Mean ±SE	Believe ENDS Less Harmful, AOR (95% CI)	Believe ENDS Less Harmful, % (95% CI) or Mean ±SE	Believe ENDS Less Harmful, AOR (95% CI)
Overall	70.6 (65.0, 75.7)	...	84.7 (81.5, 87.4)	...
Gender				
Male (Ref)	70.6 (62.1, 78.0)	1.00	83.7 (78.5, 87.9)	1.00
Female	70.7 (63.2, 77.1)	1.08 (0.64, 1.84)	86.0 (82.2, 89.1)	1.06 (0.63, 1.77)
Race/ethnicity				
White (Ref)	74.6 (68.9, 79.6)	1.00	86.8 (83.5, 89.5)	1.00
African American	50.8 (32.1, 69.3)	0.37* (0.16, 0.82)	67.8 (54.1, 79.0)	0.31 (0.16, 0.58)
Hispanic	58.9 (37.1, 77.8)	0.59 (0.24, 1.46)	75.2 (52.4, 89.3)	0.48 (0.18, 1.31)
Other	74.5 (45.01, 91.2)	1.04 (0.26, 4.10)	89.6 (77.3, 95.6)	1.21 (0.43, 3.43)
Age, y	47.2 ±0.80	1.01 (0.99, 1.03)	32.8 ±0.28	1.02 (0.99, 1.04)
Education				
< high-school diploma	46.3 (31.7, 61.5)	0.61 (0.26, 1.42)	81.6 (70.2, 89.3)	1.31 (0.57, 3.20)
High-school diploma or GED	75.3 (66.1, 82.6)	1.15 (0.53, 2.50)	86.6 (82.4, 89.9)	1.91 (0.95, 3.83)
Some college	76.5 (68.5, 85.0)	1.58 (0.75, 3.32)	86.7 (82.7, 89.8)	1.76* (1.02, 3.05)
College degree (Ref)	71.6 (58.5, 81.8)	1.00	78.6 (67.2, 86.8)	1.00
Perceived health				
Good (Ref)	74.0 (67.8, 79.4)	1.00	85.3 (81.3, 88.6)	1.00
Fair	69.8 (58.1, 79.4)	0.81 (0.46, 1.43)	80.3 (73.3, 85.8)	0.68 (0.39, 1.20)
Poor	48.8 (27.4, 70.7)	0.40* (0.17, 0.93)	90.5 (79.3, 99.0)	1.50 (0.55, 4.08)
Intention to quit				
Not interested in quitting (Ref)	74.9 (65.8, 82.2)	1.00	83.3 (75.9, 88.8)	1.00
Next 6 mo	72.3 (64.2, 79.1)	0.94 (0.51, 1.74)	86.5 (83.2, 89.2)	1.47 (0.93, 2.30)
Next 30 d	59.2 (44.0, 72.9)	0.71 (0.34, 1.48)	81.5 (75.1, 86.5)	1.19 (0.71, 1.99)
Quit attempts ^a				
None (Ref)	77.7 (69.8, 84.1)	1.00	86.1 (82.1, 89.3)	1.00
≥ 1	64.5 (54.7, 73.3)	0.96 (0.64, 1.43)	81.1 (74.5, 86.4)	0.83 (0.49, 1.40)

Note. AOR = adjusted odds ratio; CI = confidence interval; ENDS = electronic nicotine delivery system; GED = general equivalency diploma. Adjusted for all other covariates in the model.

^aThe Legacy Longitudinal Smoker Cohort item asked about quit attempts in the past 6 months, whereas the online survey item asked about quit attempts in the past 3 months.

**P* < .05.

restrictions (a “bridge” product) and, thus, attenuate these policies’ effect on cessation or delay a smoker’s desire to quit.² Dual use may or may not have long-term reduced-harm benefits to consumers and the population as a whole. Such benefits depend on the specific pattern of dual use and the duration of exposure to the harmful ingredients in both ENDS and conventional tobacco products over time. These concerns point out the importance of conducting additional in-depth postmarket surveillance of dual-use patterns, as well as the need for

laboratory studies in humans to evaluate exposure levels and biomarkers of harm of typical dual-use patterns.^{2,6,7,8,27} Such studies are beyond the scope of this research, and additional survey items that directly address the specific patterns of use over time in any greater depth were not included.

Consistent with and extending previous work,¹ these results show that ENDS are perceived as less harmful than combustible cigarettes. However, ENDS have not been adequately tested under FDA standards. Although ENDS

may well prove to be less harmful than combustible cigarettes, an unregulated product may still pose a risk to the public’s health.^{2,3} Thus far, ENDS have avoided regulation because of their ambiguous status as neither a drug delivery device nor a traditional tobacco product.^{2,3} Trtchounian and Talbot examined 6 major ENDS brands and found that cartridge labeling, such as nicotine concentration, flavor, and expiration date, were missing across all brands.⁴ Four of the 6 brands listed ingredients, but the lists were not exhaustive. In

addition, ENDS product quality varied greatly within and between brands, orders were often incorrectly filled, and actual nicotine content in cartridges was much lower than claimed.²⁻⁴ Given the widespread availability, awareness, and use of ENDS by millions of consumers, ENDS should not be marketed until adequately tested and regulated by the FDA. In addition, ENDS and aftermarket refill bottles of nicotine in solution should not be sold to minors or sold in flavors outlawed in combustible cigarettes, and should require childproof packaging to avoid accidental ingestion by children.^{3,8}

Strengths and Limitations

Although the results were consistent overall between the 2 samples, there were some notable differences that are likely associated with the distinct target populations, sample frames, selection criteria, and methods used in the 2 studies. For example, although the surveys' estimates of ENDS awareness were virtually identical among current smokers (online survey: 57.1%; 95% CI = 53.3, 60.7; LLSC: 58.2%; 95% CI = 55.7, 60.5), awareness prevalence for former smokers in the LLSC (58.0%; 95% CI = 54.0, 65.2) was closer to that of current smokers in the LLSC than former smokers in the online survey (41.5%; 95% CI = 36.5, 46.8). This is likely attributable to the fact that former smokers in the LLSC were recent quitters (in past 18 months) and, thus, may resemble current smokers more than the longer-term former smokers in the online survey sample.

In addition, ENDS use was more popular among current smokers in the online survey sample. This may be attributable to differences in socioeconomic status, marketing, or availability of ENDS products across the nation, or other differences between the 2 samples. Other differences may stem from the presence of a visual cue of the products within the online survey sample that was not presented in the LLSC sample. Despite these limitations, this analysis presents largely consistent estimates of ENDS use between the 2 samples and compared with other reports available to date.

Conclusions

This study begins to address some of the many concerns and knowledge gaps related to the introduction of ENDS to the US market

and raises issues of more general concern for any emerging products with similar characteristics. Awareness of ENDS is widespread and experimentation and use by millions of smokers, especially young adults, is of concern. Further research is needed to determine the prevalence of consistent ENDS use, the role of ENDS as a starter product, and the impact of dual use on cessation. We also need FDA premarket testing of ENDS products for safety and efficacy to protect public health and validate claims of safety and efficacy. Related concerns involve the need for more in-depth postmarket surveillance of patterns of ENDS use with other tobacco products, and for more human laboratory studies to measure harm exposure and risk reduction biomarkers in dual users. Inclusion of ENDS-related items in national surveillance for both adults and youths is required to assess the potential public health impact of ENDS on the US population, quantify degree of reduced harm if any, and to determine any unintended consequences on overall population prevalence of smoking and on morbidity and mortality. ■

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Contributors

J. L. Pearson was primarily responsible for data analysis and wrote the first complete draft of this article. R. S. Niaura and A. Richardson made significant contributions to the data analysis approach and refinement of the "Methods" and "Results" sections. D. M. Vallone and D. B. Abrams made significant contributions to the refinement of the introduction and "Discussion" sections. The entire team took part in the creation of the survey items that are the basis of this analysis.

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Human Participant Protection

This study was approved by the institutional review board (IRB) of Westat, the company that conducted the data collection, and Copernicus Group IRB, an external IRB used by the sponsor of this survey.

References

1. World Health Organization Study Group on Tobacco Product Regulation. *Report on the Scientific Basis of Tobacco Product Regulation: Third Report of a WHO Study Group*. Geneva, Switzerland: World Health Organization; 2010.
2. Cobb NK, Byron MJ, Abrams DB, Shields PG. Novel nicotine delivery systems and public health: the rise of the "e-cigarette." *Am J Public Health*. 2010;100(12):2340-2342.
3. Henningfield JE, Zaatari GS. Electronic nicotine delivery systems: emerging science foundation for policy. *Tob Control*. 2010;19(2):89-90.
4. Trtchounian A, Talbot P. Electronic nicotine delivery systems: is there a need for regulation? *Tob Control*. 2011;20(1):47-52.
5. Westenberg B. *Evaluation of e-Cigarettes*. St Louis, MO: US Department of Health and Human Services, Food and Drug Administration Division of Pharmaceutical Analysis; 2009.
6. Eissenberg T. Electronic nicotine delivery devices: ineffective nicotine delivery and craving suppression after acute administration. *Tob Control*. 2010;19(1):87-88.
7. Vansickel AR, Cobb CO, Weaver MF, Eissenberg TE. A clinical laboratory model for evaluating the acute effects of electronic cigarettes: nicotine delivery profile and cardiovascular and subjective effects. *Cancer Epidemiol Biomarkers Prev*. 2010;19(8):1945-1953.
8. Cobb NK, Abrams DB. E-cigarette or drug-delivery device? Regulating novel nicotine products. *N Engl J Med*. 2011;365(3):193-195.
9. Health Canada. Notice—To all persons interested in importing, advertising or selling electronic smoking products in Canada. 2009. Available at: http://www.hc-sc.gc.ca/dhp-mps/prodpharma/applic-demande/pol/noticeavis_e-cig-eng.php. Accessed August 8, 2011.
10. Therapeutic Goods Administration, Australian Government Department of Health and Ageing. Electronic cigarettes. 2011. Available at: <http://www.tga.gov.au/consumers/ecigarettes.htm>. Accessed August 8, 2011.
11. *Sottera Inc v. Food and Drug Administration*, 627 F.3d 891 (DC Cir 2010).
12. Deyton LR, Woodcock J. Regulation of e-cigarettes and other tobacco products. 2011. Available at: <http://www.fda.gov/NewsEvents/PublicHealthFocus/ucm252360.htm>. Accessed May 27, 2011.
13. Pauly J, Li Q, Barry MB. Tobacco-free electronic cigarettes and cigars deliver nicotine and generate concern. *Tob Control*. 2007;16(5):357.
14. Ayers JW, Ribisl KM, Brownstein JS. Tracking the rise in popularity of electronic nicotine delivery systems (electronic cigarettes) using search query surveillance. *Am J Prev Med*. 2011;40(4):448-453.

15. Etter JF, Bullen C, Flouris AD, Laugesen M, Eissenberg T. Electronic nicotine delivery systems: a research agenda. *Tob Control*. 2011;20(3):243–248.
16. Kuehn BM. FDA: electronic cigarettes may be risky. *JAMA*. 2009;302(9):937.
17. Siegel MB, Tanwar KL, Wood KS. Electronic cigarettes as a smoking-cessation tool: results from an online survey. *Am J Prev Med*. 2011;40(4):472–475.
18. Zogby. Electronic cigarettes find fans, but most want regulation. 2009. Available at: <http://www.zogby.com/news/2009/09/24/electronic-cigarettes-find-fans-but-most-want-regulation>. Accessed March 21, 2011.
19. Yamin CK, Bitton A, Bates DW. E-cigarettes: a rapidly growing Internet phenomenon. *Ann Intern Med*. 2010;153(9):607–609.
20. Vallone DM, Duke JC, Mowery PD, et al. The impact of EX: results from a pilot smoking-cessation media campaign. *Am J Prev Med*. 2010;38(Suppl):S312–S318.
21. Vallone DM, Duke JC, Cullen J, McCausland KL, Allen JA. Evaluation of EX: a national mass media smoking cessation campaign. *Am J Public Health*. 2011;101(2):302–309.
22. Heeringa SG, West BT, Berglund PA. *Applied Survey Data Analysis*. Boca Raton, FL: Chapman and Hall; 2010.
23. *Current Population Survey*. Washington, DC: US Census Bureau; 2007.
24. *Current Population Survey*. Washington, DC: US Census Bureau; 2010.
25. King B, Dube S, Kaufmann R, Shaw L, Pechacek T. Vital signs: current cigarette smoking among adults aged ≤ 18 years—United States, 2005–2010. *WMMR Morb Mortal Wkly Rep*. 2011;60(35):1207–1211.
- 26a. NJOY. Find a retail store. 2011. Available at: http://shop.njoy.com/index.php?p=page&page_id=Store_Locator. Accessed April 4, 2011.
- 26b. Esterl M. Got a light-er charger? Big Tobacco's latest buzz. 2012. *The Wall Street Journal*. Available at: <http://online.wsj.com/article/SB10001424052702304723304577365723851497152.html>. Accessed July 3, 2012.
27. Hatsukami DK, Perkins KA, LeSage MG, et al. Nicotine reduction revisited: science and future directions. *Tob Control*. 2010;19(5):e1–e10.