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E-cigarettes Associated With Depressed Smoking Cessation: A Cross-sectional Study of 28 European Union Countries

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Abstract

Introduction—Electronic cigarettes (e-cigarettes) are often promoted to assist with cigarette smoking cessation. In 2016–2017, the relationship between e-cigarette use and having stopped smoking among ever (current and former) smokers was assessed in the European Union and Great Britain by itself.

Methods—Cross-sectional logistic regression of the association between being a former smoker and e-cigarette use was applied to the 2014 Eurobarometer survey of 28 European Union countries controlling for demographics.

Results—Among all ever smokers, any regular ever use of nicotine e-cigarettes was associated with lower odds of being a former smoker (unadjusted OR=0.34, 95% CI=0.26, 0.43, AOR=0.43, 95% CI=0.32, 0.58) compared with smokers who had never used e-cigarettes. In unadjusted models, daily use (OR=0.42, 95% CI=0.31, 0.56); occasional use (OR=0.25, 95% CI=0.18, 0.35); and experimentation (OR=0.24, 95% CI=0.19, 0.30) of nicotine e-cigarettes were associated with lower odds of being a former smoker compared with having never used nicotine-containing e-cigarettes. Comparable results were found in adjusted models. Results were similar in Great Britain alone. Among current smokers, daily cigarette consumption was 15.6 cigarettes/day (95% CI=14.5, 16.7) among those who also used e-cigarettes versus 14.4 cigarettes/day (95% CI=13.4, 15.4) for those who did not use them ($p<0.05$).

Conclusions—These results suggest that e-cigarettes are associated with inhibiting rather than assisting in smoking cessation. On the population level, the net effect of the entry of e-cigarettes into the European Union (and Great Britain) is associated with depressed smoking cessation of conventional cigarettes.

Introduction

Electronic cigarettes (e-cigarettes) are promoted to assist with cigarette-smoking cessation, including by the National Health Service in England,¹ by Public Health Wales,² and, more tentatively, by NHS Health Scotland,³ and cessation is one of the major reasons smokers use them.^{4,5} Public health institutions in other European Union (EU) countries do not endorse e-cigarettes as cessation devices. RCTs on efficacy for smoking cessation are limited, and their

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results have been equivocal.^{6,7} Most studies have been based on e-cigarette use in the real world, which, taken together, show that e-cigarettes are associated with significantly less quitting^{8–11}. Some studies, however, suggest that intensive use of e-cigarettes (daily use of tank systems,¹² daily use for at least 1 month,¹³ long-term use,¹⁴ and use among established current smokers and recent quitters¹⁵) is associated with more quitting. E-cigarettes are mass-marketed consumer products, not medicines administered as part of a medically supervised cessation attempt. Thus, rather than asking the clinically relevant question “Are e-cigarettes effective when used as part of an organized cessation attempt?” this paper asks, “What effect is use of e-cigarettes having on smoking cessation in the real world as they are actually used?”

One limitation of the available literature is that the sample sizes are relatively small and often do not have detailed assessment of e-cigarette use patterns. Filippidis et al.¹⁶ used the Eurobarometer, a cross-sectional household survey performed in a representative sample of the population of the EU, to assess increases in e-cigarette use between 2012 and 2014, and Farsalinos and colleagues¹⁷ used the 2014 Eurobarometer¹⁸ to assess cigarette smoking behavior among e-cigarette users. As Farsalinos and colleagues noted, the Eurobarometer survey is useful for evaluating e-cigarette use by the EU population because it is representative of the entire EU region (28 countries), and the 2014 Eurobarometer makes a clear distinction between regular and occasional use and between nicotine-containing and nicotine-free e-cigarettes. Using the Eurobarometer, they found that 35% of current e-cigarette users reported smoking cessation. Although Farsalinos and colleagues¹⁷ specifically examined the relationship between intensity of e-cigarette use and being a former smoker among e-cigarette users, they did not include people who did not use e-cigarettes as the control group, so they did not estimate the effect of e-cigarette use on smoking cessation. This is a major shortcoming as their study did not assess the association of any e-cigarette use with cigarette smoking status. The same dataset is used to assess the relationship between e-cigarette use and having stopped smoking among all ever (current and former) smokers.

Methods

Study Population

Following Farsalinos and colleagues,¹⁷ data from Eurobarometer 82.4 (Special Eurobarometer 429) was used, a survey conducted in all 28 EU states in November and December 2014. Interviews took place in participants' homes in their native language. The multistage probability sample of Europeans aged 15 years was based on the total population of a country and population density. A weighting procedure was applied for all countries by using official population figures provided by Eurostat or national statistic offices. For the analyses using all the countries, generalizability was achieved using the weighting variable for the full EU population.¹⁸ The total sample size for the survey is 27,801; a total of 12,608 current and former smokers were used for the analyses. Because health authorities have endorsed e-cigarettes in England and Wales, and tentatively in Scotland, a separate analysis for the 411 current and former smokers in Great Britain (GB)

was also run. For use with the GB subsample, the weight for the United Kingdom was adjusted to apply to GB only, excluding Northern Ireland.

Measures

The main outcome variable was being a former smoker, defined by the answer to the question, *Regarding smoking cigarettes, cigars, cigarillos or a pipe, which of the following applies to you?* with the following response options: *you used to smoke, but you have stopped* (former smoker, coded 1) or *you currently smoke* (current smoker, coded 0).

The primary independent variable was nicotine-containing e-cigarette use, quantified in two different ways: (1) nicotine e-cigarette use (dichotomous, excluding experimenters who had only used e-cigarettes once or twice), and (2) intensity of nicotine e-cigarette use. Experimenters were excluded on the assumption that they did not use e-cigarettes enough to have an impact on smoking behavior. Nicotine-containing e-cigarette ever use was measured with the question, *How often do you or did you use the following products: Nicotine-containing electronic cigarettes or similar electronic devices?* after participants previously endorsed using e-cigarettes or similar electronic devices (e-shisha, e-pipe), having used e-cigarettes in the past or having tried e-cigarettes in the past. Those who used e-cigarettes every day, weekly, monthly, or less than monthly were coded as 1. The people who endorsed having never used e-cigarettes were coded as 0 (non-users). The 80 people who responded *don't know* were excluded. Intensity of nicotine e-cigarette use was measured using the same question to create a four-level variable: (1) daily use; (2) occasional use (weekly, monthly, less than monthly); (3) experimentation (used once or twice); and (4) never use (the reference group).

Covariates included age (continuous); sex; cigarettes per day (continuous from the item: *On average, how many cigarettes do you or did you or did you [before you stopped smoking] smoke each day?*); marital status (single, divorced/separated/widowed, with married/living with a partner as reference); and age at which respondents completed their education (16–19 years, 20 years, still studying, with no formal education as reference). People who only used non-nicotine e-cigarettes (201/2,430=8% in the EU and 6/118=5% in GB) were coded as never users of nicotine-containing e-cigarettes.

Statistical Analysis

Weighted logistic regression models were run using former smoking as the outcome variable using Mplus, version 8.¹⁹ Predictors included one of two variables: (1) e-cigarette ever use (dichotomous, excluding people who only experimented with e-cigarettes) and (2) intensity of nicotine e-cigarette use. Sensitivity analyses were also run only including current e-cigarette use (not shown), which gave similar results. All models were run using all the countries unadjusted and adjusting for the control variables listed above.

Cigarette consumption was compared among all current smokers who did and did not currently use e-cigarettes using a *t*-test.

Missing data were handled using full-information maximum likelihood, which allows all observations to be used,²⁰ including those with some missing data. The full-information

maximum likelihood method produces more accurate effect size estimates and smaller SEs than listwise deletion by using all the available information, including from incomplete records.^{21–23} Country was entered using the CLUSTER option with TYPE = COMPLEX in Mplus.²⁴ The same analyses were also conducted for GB alone using GB-specific weights.

Sensitivity analyses were run for the EU without GB and excluding 509 smokers (4% of sample) who only used cigars, cigarillos, or a pipe. The results remained essentially the same. Data analysis was done in 2016 and 2017.

Results

The overall sample of ever smokers in the EU had a mean age of 49.9 years (SD=16.8); 55.6% were male; >65% were married or living with a partner; and >36% had finished education at age 20 years or were currently studying. Overall, 45.6% were former smokers. They smoked on average 14.8 cigarettes per day as smokers, and 19.4% had used or currently used any e-cigarettes, whereas 15.5% had used nicotine-containing e-cigarettes. The GB sample of ever smokers was slightly older ($p=0.009$); less likely to be married ($p<0.001$); less educated ($p<0.001$); and more likely to use ($p<0.001$) e-cigarettes and use them more frequently ($p<0.001$); and tended to smoke fewer cigarettes/day ($p=0.055$) than the entire EU sample (including GB) by t -test or chi-square. Gender ($p=0.696$) and being a former smoker ($p=0.429$) were similar (Table 1).

Among ever smokers any regular use of nicotine e-cigarettes was associated with lower odds of being a former smoker (unadjusted OR=0.34, 95% CI=0.26, 0.43; AOR=0.43, 95% CI=0.32, 0.58). In unadjusted models, daily use (OR=0.42, 95% CI=0.31, 0.56); occasional use (OR=0.25, 95% CI=0.18, 0.35); and experimentation (OR=0.24, 95% CI=0.19, 0.30) of nicotine e-cigarettes were all associated with lower odds of being a former smoker compared with having never used nicotine-containing e-cigarettes. Similar results were found in the adjusted models (daily use: OR=0.52, 95% CI=0.36, 0.73; occasional use: OR=0.33, 95% CI=0.23, 0.47; and experimentation: OR=0.32, 95% CI=0.25, 0.41; Table 2).

Data from GB revealed similar results (unadjusted OR=0.33, 95% CI=0.18, 0.64; AOR=0.42, 95% CI=0.20, 0.87) for any regular nicotine-containing e-cigarette use. Likewise, daily use (OR=0.42, 95% CI=0.20, 0.84); occasional use (OR=0.15, 95% CI=0.03, 0.68); and experimentation (OR=0.28, 95% CI=0.12, 0.66) were all related to lower odds of being a former smoker compared with having never used nicotine-containing e-cigarettes. Similar results were found in the adjusted models, though the result for daily use was not statistically significant (daily use: OR=0.55, 95% CI=0.25, 1.21, occasional use: OR=0.19, 95% CI=0.04, 0.84; and experimentation: OR=0.32, 95% CI=0.11, 0.93). The AORs from GB did not differ significantly from the EU excluding GB ($p=0.93$).

EU current smokers consumed 14.5 cigarettes a day (95% CI=13.6, 15.5), whereas former smokers smoked 15.2 cigarettes/day (95% CI=14.0, 16.4, $p=0.05$). Among all EU current smokers, daily cigarette consumption was 15.6 cigarettes/day (95% CI=14.5, 16.7) among those who also used e-cigarettes versus 14.4 cigarettes/day (95% CI=13.4, 15.4) for those who did not use them ($p<0.05$).

Discussion

These results, based on a large cross-sectional study of EU countries conducted in 2014, found that nicotine e-cigarette use was associated with lower odds of being a former smoker. The finding that on the EU level even daily use of e-cigarettes is associated with lower odds of being a former smoker differs from three earlier smaller longitudinal studies,^{12–14} which found increased quitting for intensive users, a national cross-sectional sample from the U.S.¹⁵ and an ecological analysis of time series behavior in England.²⁵ The International Tobacco Control Four-Country Surveys, based on data collected from 2010 to 2014 and hence relatively early in the e-cigarette era, showed that there appear to be differences in the effectiveness of e-cigarettes as cessation devices, depending on the degree to which e-cigarettes are regulated. E-cigarettes seem to facilitate quitting (abstinence for at least 30 days) in less restrictive environments (United Kingdom, U.S.), while inhibiting sustained abstinence in more restrictive ones (Australia, Canada).²⁶ The findings in this paper are, however, consistent with most other real-world studies of e-cigarette use.^{8,27,28}

England, Scotland, and Wales, unlike other EU countries, have embraced e-cigarettes as a smoking cessation aid.^{1–3} As of May 2017, the National Health Service website advised patients, “Research has found that e-cigarettes can help you give up smoking, so you may want to try them rather than [NRT and other] medications.... There are no e-cigarettes currently available on prescription. But once medicinally licensed e-cigarette products become available, GPs and stop smoking services will be able to prescribe them.”¹ This recommendation is consistent with recommendations from the Royal College of Physicians²⁹ and Public Health England.³⁰ In January 2017, Public Health Wales updated their position to state that e-cigarettes “may prove helpful in achieving a successful quit from tobacco although they are not currently licensed as a medicine for this purpose.”² In September 2017, NHS Scotland said, “e-cigarettes are useful for public health and health service purposes only as a potential route towards stopping smoking.”³ In contrast to these recommendations, Eurobarometer data from GB indicated that regular e-cigarette use was associated with lower odds of being a former smoker.

The fact that the ORs in the unadjusted and adjusted models are similar suggests that confounding by other factors is unlikely to be an important effect on the results. Although the authors do not have an explicit measure of dependence, cigarettes per day are used as an approximation.

As shown above, current cigarette smokers who also use e-cigarettes smoke significantly more cigarettes per day than smokers who do not use e-cigarettes. This finding, combined with e-cigarette use being associated with less quitting, is inconsistent with the hypothesis that e-cigarettes have a positive net public health effect.

Limitations

The major limitation of this study is that the Eurobarometer is a cross-sectional survey that cannot determine causation. An important concern with this analysis is that the survey does not contain information on when smokers quit smoking and hence the sample includes people who quit before e-cigarettes were available. However, if quitting patterns are stable

over time beyond any effects of e-cigarettes, this effect will bias the estimate of the effect of e-cigarette use on quitting smoking toward the null,³¹ which would make the fact that a significant depression was found in the odds of being a former smoker even more reliable. EU quit ratios (former smokers/ever smokers) have increased over time, from 0.32 in 2002³² to 0.43 in 2009³³ before the advent of e-cigarettes, then remained at 0.43 through 2014, the year this study analyzes. Thus, for the 5 years prior to the survey the quit ratio remained stable, which is consistent with the conclusion that the results are biased toward the null. To the extent that some people in the cross-sectional sample quit before 2009, the odds of quitting associated with e-cigarette use will be biased upward (in absolute terms) because some of the quitting as a result of long-term secular trends will be inappropriately associated with e-cigarettes, which biases the results against the conclusion that e-cigarettes are associated with less quitting. In addition, other cross-sectional population-level studies that examined the same association in which data were only collected after e-cigarettes were available show results similar to those presented here.^{34–36}

The Eurobarometer survey also used self-reported e-cigarette and cigarette use without any biomarker verification use status or duration of smoking cessation. An earlier meta-analysis,⁸ however, showed similar results for the relationship between e-cigarette use and smoking cessation between cross-sectional and longitudinal studies and independent of biomarker validation of smoking status. Changes in cigarette consumption between people who did and did not use e-cigarettes could not be compared because the question on changes in consumption was only asked to e-cigarette users. Self-selection to use e-cigarettes might be likely skewed toward those with higher dependence and lower self-efficacy for quitting without a cessation aid. However, the meta-analysis by Kalkhoran and Glantz⁸ included a sensitivity analysis that examined sociodemographic factors associated with such a self-selection and found that they were not significantly associated with the results.

Conclusions

These results, based on a large data set from the EU, suggest that e-cigarettes are associated with inhibiting rather than assisting in smoking cessation. The net effect of the entry of e-cigarettes into the EU (and GB) is associated with depressed smoking cessation of conventional cigarettes.

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MCK and NEL conducted statistical analyses. MCK drafted the methods and results sections, consulted on the data set and revised all original manuscript sections. SAG advised on the statistical analysis and drafted original versions of the introduction and discussion sections. All authors edited subsequent manuscript versions.

No patients were involved in the design or conduct of this study. Because this research is based on a de-identified public use data set, there is no way to notify participants of the results of this paper beyond publication of the paper itself.

All Eurobarometer data and questionnaires are publically available and can be obtained through the Leibniz Institute for the Social Sciences: <http://zacat.gesis.org/webview/>.

All authors state that they do not have any financial relationships with any organizations that might have an interest in the submitted work or any other relationships or activities that could appear to have influenced the submitted work.

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Table 1
Sample Characteristics

Characteristic	European Union	Great Britain
Total sample (ever smokers), ^a <i>n</i>	12,608	411
Demographics		
Age	49.9 (16.8)	52.1 (18.6)
Male	7,010 (55.6)	224 (54.5)
Marital status		
Married/living with partner	8,278 (65.8)	218 (53.4)
Single	2,072 (16.5)	99 (24.3)
Divorced/separated/widowed/other	2,241 (17.8)	91 (22.3)
Education		
No full-time education / 15 years at completion	1,931 (15.5)	99 (24.2)
16–19 years	6,012 (48.3)	211 (51.6)
20 years	3,986 (32.0)	89 (21.8)
Still studying	514 (4.1)	10 (2.4)
Smoking variables		
Former smoker	5,743 (45.6)	196 (47.7)
Cigarettes per day, M (SD)	14.8 (5.0)	13.7 (1.2)
Any ever e-cigarette users	2,430 (19.4)	118 (28.9)
Frequency of nicotine containing e-cigarette use		
Daily use	430 (3.4)	46 (11.3)
Occasional use (weekly, monthly, less than monthly)	383 (3.1)	17 (4.2)
Experimentation (used once or twice)	1,132 (9.0)	38 (9.3)
Never	10,571 (84.5)	307 (75.3)

Note: Values are *n* (%) unless otherwise noted.

^a96% of the entire European Union sample are cigarette smokers (including 30% who are dual users with cigars, cigarillos, or pipes); and 4% are cigar, cigarillo, or pipe users only.

Table 2
Odds (95% CI) of Being a Former Smoker (Logistic Regression)

Predictor	European Union		Great Britain	
	Unadjusted	Adjusted	Unadjusted	Adjusted
Ever nicotine-containing e-cigarette use (excluding experimenters), <i>n</i>	11,384	11,384	370	370
Used e-cigarette (ref=never)	0.34 (0.26, 0.43)	0.43 (0.32, 0.58)	0.33 (0.18, 0.64)	0.42 (0.20, 0.87)
Female (ref=male)		1.13 (0.98, 1.31)		1.39 (0.83, 2.33)
Cigarettes per day (per 10 cigs)		1.04 (0.96, 1.12)		1.13 (0.89, 1.44)
Age (per 10 years)		1.51 (1.43, 1.59)		1.68 (1.42, 2.00)
Education				
No formal education		1.00 (ref)		1.00 (ref)
16–19 years at completion		1.23 (1.08, 1.40)		2.35 (1.27, 4.35)
20 years at completion		2.27 (1.82, 2.82)		4.58 (2.15, 9.77)
Still studying		2.71 (2.00, 3.69)		4.22 (0.85, 20.98)
Marital status				
Married/living with partner		1.00 (ref)		1.00 (ref)
Single		0.80 (0.69, 0.93)		0.47 (0.25, 0.89)
Divorced/separated/widowed/other		0.63 (0.54, 0.72)		0.39 (0.19, 0.79)
Intensity of nicotine-containing e-cigarette use, <i>n</i>	12,528	12,528	408	408
Intensity of e-cigarette use				
Never	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Daily use	0.42 (0.31, 0.56)	0.52 (0.36, 0.73)	0.42 (0.20, 0.84)	0.55 (0.25, 1.21)
Occasional use	0.25 (0.18, 0.35)	0.33 (0.23, 0.47)	0.15 (0.03, 0.68)	0.19 (0.04, 0.84)
Experimentation	0.24 (0.19, 0.30)	0.32 (0.25, 0.41)	0.28 (0.12, 0.66)	0.32 (0.11, 0.93)
Female (ref=male)		1.08 (0.94, 1.24)		1.20 (0.72, 1.98)
Cigarettes per day (per 10 cigs)		1.02 (0.94, 1.10)		1.04 (0.85, 1.27)
Age (per 10 years)		1.48 (1.41, 1.56)		1.57 (1.33, 1.85)
Education				
No formal education		1.00 (ref)		1.00 (ref)
16–19 years at completion		1.23 (1.08, 1.40)		2.02 (1.12, 3.62)
20 years at completion		2.25 (1.82, 2.78)		3.56 (1.71, 7.40)
Still studying		2.87 (2.08, 3.96)		2.64 (0.59, 11.80)
Marital status				
Married/living with partner		1.00 (ref)		1.00 (ref)
Single		0.80 (0.69, 0.93)		0.52 (0.28, 0.96)
Divorced/separated/widowed/other		0.64 (0.55, 0.74)		0.43 (0.23, 0.83)