

# Electronic cigarette use in the European Union: analysis of a representative sample of 27 460 Europeans from 28 countries

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## ABSTRACT

**Aims** To assess prevalence of electronic cigarette (e-cigarette) use, reported changes in smoking status due to e-cigarette use and correlates of e-cigarette use in the European Union (EU) member states in 2014. **Design** Cross-sectional survey of EU citizens representative of the population (Special Eurobarometer 429). **Setting** All 28 Member States of the EU. **Participants** A total of 27 460 EU citizens aged  $\geq 15$  years (after excluding those who responded 'Do not know' to the questions about smoking status and e-cigarette use). **Measurements** Descriptive analysis [%; 95% confidence interval (CI)] of e-cigarette use prevalence (current use, past use and past experimentation) according to smoking status, self-reported changes in smoking status according to patterns of e-cigarette use and logistic regression analysis to examine correlates of e-cigarette use, especially socio-demographic factors and smoking status. **Findings** Ever e-cigarette use was reported by 31.1% (95% CI = 30.0–32.2%) of current smokers, 10.8% (95% CI = 10.0–11.7%) of former smokers and 2.3% (95% CI = 2.1–2.6%) of never smokers. Past experimentation [7.2% (95% CI = 6.9–7.5%)] was more common than current [1.8% (95% CI = 1.6–1.9%)] and past use [2.6% (95% CI = 2.4–2.8%)]. Extrapolated to the whole population, approximately 48.5 million EU citizens were ever e-cigarette users, with 76.8% using nicotine-containing e-cigarettes. An estimated 6.1 and 9.2 million EU citizens had quit and reduced smoking with the help of e-cigarettes, respectively. Initiation with e-cigarettes was reported by 0.8% (95% CI = 0.6–0.9%) of participants who reported ever use of any tobacco-related product. Only 1.3% (95% CI = 1.1–1.5%) of never smokers used nicotine-containing e-cigarettes, with 0.09% (95% CI = 0.04–0.14%) reporting daily nicotine use. Smoking cessation with the help of e-cigarettes was reported by 35.1% (95% CI = 30.7–39.5%) of current e-cigarette users, while a further 32.2% (95% CI = 29.9–36.5%) reported smoking reduction. Being current [odds ratio (OR) = 21.23, 95% CI = 18.32–24.59] or former smokers (OR = 6.49, 95% CI = 5.49–7.67) were the strongest correlates of ever e-cigarette use. **Conclusions** E-cigarette use in the European Union appears to be largely confined to current or former smokers, while current use and nicotine use by people who have never smoked is rare. More than one-third of current e-cigarette users polled reported smoking cessation and reduction.

**Keywords** Electronic cigarettes, European Union, nicotine, smoking, smoking cessation, tobacco.

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## INTRODUCTION

Electronic cigarettes (e-cigarettes) are the most recently developed tobacco harm reduction products. These electronic devices have the potential to substitute smoking, mainly because of both providing nicotine [1,2] and mimicking the act of smoking, thus dealing with the psychobehavioural aspect of smoking dependence. E-cigarettes do not contain tobacco and do not involve

combustion. Chemistry [3–5] and toxicology studies [6,7], as well as a few clinical studies [8,9], have shown that they are by far less harmful compared to tobacco cigarettes. Thus, substitution of smoking with e-cigarette use could have important public health benefits by reducing smoking-related morbidity and mortality.

Awareness and use of e-cigarettes has grown exponentially over the past few years [10–12]. Although surveys and studies of users have shown that many smokers

succeed in quitting smoking with the use of e-cigarettes [13–16], randomized controlled trials have shown modest effects [17–19] and the efficacy of e-cigarettes in smoking cessation and reduction has been questioned. E-cigarettes are basically used as consumer rather than therapeutic products [20,21]. The large variability of devices and flavours, which satisfy the demand of consumers to choose based on self-preference [22], is incompatible with the conventional methods used when performing randomized controlled trials, in which a single product is provided to all participants. Real-world studies of realistic use may be more appropriate in defining the exact effects of e-cigarettes on smoking prevalence. A recent study showed that e-cigarette users were 60% more likely to have quit smoking compared to nicotine replacement therapy (NRT) users and those who tried to quit with no aid [23].

The Eurobarometer is a cross-sectional survey performed in a representative sample of the population of European Union (EU) Member States which addresses, among other issues, tobacco use. The Special Eurobarometer 385, conducted in 2012 evaluated e-cigarette use among Europeans for the first time [24,25]. Recently, the results from the 2014 survey, Special Eurobarometer 429 [26], were announced by the EU. This study is a secondary analysis of the Special Eurobarometer 429. The main aims were to assess the: (1) prevalence of ever, current and past e-cigarette use, including past experimentation; (2) prevalence of nicotine-containing e-cigarette use; (3) self-reported changes in smoking status due to e-cigarette use; and (4) correlates of ever and current e-cigarette use.

## METHODS

### Design, setting and participants

The data set used in this analysis was acquired from the Special Eurobarometer 429 (82.4) conducted by TNS Opinion and Social at the request of the Directorate-General for Health and Food Safety. The survey was coordinated by the Directorate-General for Communication (DG COMM 'Strategy, Corporate Communication Actions and Eurobarometer' Unit). It is a cross-sectional survey performed in 28 EU Member States between 29 November and 8 December 2014. Europeans aged  $\geq 15$  years from different social and demographic groups were interviewed face to face at home in their native language. In each country, a number of sampling points was drawn with probability proportional to population size (for a total coverage of the country) and to population density. For each country, a comparison between the sample and the EU sample was carried out. The EU sample was derived from Eurostat population data or from national statistics offices. For all countries surveyed, a national weighting

procedure, using marginal and intercellular weighting, was carried out. In all countries, gender, age, region and size of locality were introduced in the iteration procedure. For international weighting (i.e. EU averages), TNS Opinion and Social applied the official population figures as provided by Eurostat or national statistic offices. Extrapolation to the whole EU population was performed by using a weighting variable present in the Eurobarometer data set. The population size weighting factor corrects for the fact that most samples are of almost identical size, no matter how large or small the populations are from which they were drawn. These weights ensure that each country is represented in proportion to its population size. More information about the weighting methodology is available through GESIS-Leibniz Institute for Social Sciences (<http://www.gesis.org>). A total of 27 801 Europeans participated to the survey. To facilitate the present analysis, participants responding 'Do not know' in the questions about their smoking status and e-cigarette use were excluded from the analysis. Thus, a total of 27 460 participants were included in the analysis.

## DEFINITIONS AND MEASUREMENTS

### Socio-demographic factors

The exact age of the participants was recorded, but the data set provided a recoding into five categories (15–24, 25–39, 40–54 and 55 years and older). The latter was used in this analysis. Participants' residence was coded as 'rural', 'small/middle town' and 'large town'. Education was assessed by asking the age of the participants when they stopped their full-time education. Responses were coded as 'no full-time education', ' $\leq 15$  years', '16–19 years', ' $\geq 20$  years' and 'still studying'. Due to the low number of participants with no full-time education, the variable was re-coded by merging the responses 'no full-time education' and ' $\leq 15$  years' into one category. Social class of the participants was recorded as 'working class', 'lower middle class', 'middle class', 'upper middle class' and 'higher class'. Marital status was recorded and categorized as 'married/single living with a partner', 'single' and 'widowed, divorced or other'. The financial status of the participants was assessed by asking: 'During the last twelve months, would you say you had difficulties to pay your bills at the end of the month?'. Responses were coded as 'most of the time', 'from time to time', and 'almost never/never'.

### E-cigarette use

E-cigarette use was assessed with the question: 'Regarding the use of electronic cigarettes or any similar electronic devices (e-shisha, e-pipe), which of the following statements applies to you?'. The responses 'you currently use electronic cigarettes or similar electronic devices

(e.g. e-shisha, e-pipe)' (current use), 'you used them in the past, but no longer use them' (past use) and 'you tried them in the past but no longer use them' (past experimentation) were categorized as ever e-cigarette use, while the response 'you have never used them' was categorized as never use. A separate question assessed the use of nicotine-containing e-cigarettes. Frequency of ever e-cigarette use was defined specifically for nicotine-containing e-cigarettes. The responses 'every day' was classified as regular use, while the responses 'weekly', 'monthly' and 'less than monthly' were classified as occasional use. The response 'You have tried it once or twice' was classified as experimentation while the response 'never' was classified as never use. The question was asked to all participants reporting ever e-cigarette use.

All participants were asked to report whether they had seen advertisements or promotions for electronic cigarettes in the past 12 months and if they considered e-cigarettes harmful or not to the health of those who use them. The latter question assessed the absolute harmfulness of e-cigarettes.

### Smoking status and its change among e-cigarette users

Participants were categorized according to their smoking status as current smokers, past smokers and never smokers. Current smokers were asked whether they had tried to quit, with responses being 'Yes, in the last 12 months', 'Yes, more than a year ago' and 'No, never'. Both current smokers who had tried to quit in the past as well as former smokers were subsequently asked which smoking cessation methods they had used in order to quit or to try to quit smoking. Available responses were: 'Nicotine replacement therapies', 'Support from the doctor or other health professional or special stop-smoking services such as clinics or specialists', 'Telephone quit line services', 'Internet quit line services', 'Alternative therapies such as acupuncture or hypnosis', 'Oral tobacco (snus) chewing or nasal tobacco (snuff)', 'Electronic cigarettes or any similar device', 'Smokeless cigarettes (other than electronic)', 'You quit or you tried to quit without assistance' and 'Other'.

Participants who were current or former smokers, or were never smokers but reported use of smokeless tobacco and e-cigarettes were asked to report which product they used first. To facilitate the analysis, the responses were re-coded as 'combustible tobacco products' (boxed cigarettes, hand-rolled cigarettes, cigars, cigarillos, pipe and water-pipe), smokeless tobacco products (oral tobacco, chewing tobacco and nasal tobacco) and e-cigarettes (with nicotine and without nicotine).

The effect of e-cigarettes on smoking status was assessed among participants who reported ever e-cigarette use using the question: 'You said that you smoke or used to

smoke tobacco but also use or used electronic cigarettes or any similar device. Did the use of electronic cigarettes or any similar device help you to stop or reduce your tobacco consumption?'. The response options were: 'Yes, you stopped smoking tobacco completely', 'Yes, you stopped smoking tobacco for a while but started again', 'Yes, you reduced your tobacco smoking but did not stop', 'No, you did not reduce your tobacco smoking at all' and 'No, and actually you increased your tobacco smoking'.

### Statistical analysis

Nationally representative estimates for use of e-cigarettes and effects on smoking status were calculated with 95% confidence intervals (CI), while the projected number within the EU was extrapolated based on the total sampling population using the appropriate weighing variable available in the Eurobarometer survey data set. Differences in prevalence of e-cigarette current use, past use and past experimentation were assessed using the  $\chi^2$  test. Similar comparisons were made between the prevalence of nicotine-containing e-cigarette use frequencies (daily use, occasional use and experimentation). Logistic regression analysis was performed to assess the association between smoking cessation and e-cigarette use pattern (current use, past use, past experimentation). This was performed by recoding the variable assessing change in smoking status as smoking cessation versus all other effects (cessation but subsequent relapse, smoking reduction, no change in consumption and increased smoking consumption); this was used as the dependent variable. The analysis was performed among ever e-cigarette users only and was adjusted for age and gender. Multivariate logistic regression analysis was performed to determine correlates of ever and current e-cigarette use among the participants, with smoking status, socio-demographic factors, perceived harmfulness of e-cigarettes and seeing e-cigarette advertising as independent variables. The possibility for collinearity between social class and difficult paying bills was assessed but was not found; thus, both variables were included to the logistic regression analysis. All analyses were weighted (besides logistic regression analyses) and were performed with commercially available software (SPSS version 22.0; SPSS, Inc., Chicago, IL, USA).

## RESULTS

### E-cigarette use in the EU

E-cigarette use according to smoking status is shown in Table 1. Based on the extrapolation to the whole population, almost 48.5 million Europeans (of a total of 419.3 million above age 15 years extrapolated from the 27,460 participants analyzed) reported ever e-cigarette use while 7.5 million Europeans were current e-cigarette users at

**Table 1** Patterns of e-cigarette use and frequency of nicotine-containing e-cigarette use according to smoking status in the European Union.

	<i>Smoking status</i>			
	<i>Current smokers, n = 7243 % (95% CI)</i>	<i>Former smokers, n = 5352 % (95% CI)</i>	<i>Never smokers, n = 14 865 % (95% CI)</i>	<i>Total N = 27 460 % (95% CI)</i>
<b>E-cigarette use n = 3176</b>				
Current use	4.2 (3.8–4.7)	2.7 (2.3–3.1)	0.2 (0.1–0.3)	1.8 (1.6–1.9)
Past use	7.4 (6.8–8.0)	2.6 (2.2–3.1)	0.3 (0.2–0.4)	2.6 (2.4–2.8)
Past experimentation	19.4 (18.5–20.4)	5.5 (4.9–6.1)	1.8 (1.6–2.0)	7.2 (6.9–7.5)
Total	31.1 (30.0–32.2)	10.8 (10.0–11.7)	2.3 (2.1–2.6)	11.6 (11.2–11.9)
<b>Nicotine-containing e-cigarette use n = 2440</b>				
Daily	6.8 (6.2–7.4)	3.6 (3.1–4.1)	0.09 (0.04–0.14)	2.5 (2.4–2.7)
Occasional	4.6 (4.1–5.0)	1.0 (0.8–1.3)	0.18 (0.11–0.24)	1.5 (1.4–1.6)
Experimentation	13.4 (12.6–14.1)	4.0 (3.4–4.5)	1.0 (0.9–1.2)	4.8 (4.6–5.1)
Total	24.7 (23.7–25.7)	8.6 (7.9–9.4)	1.3 (1.1–1.5)	8.9 (8.6–9.2)

CI = confidence interval.

the time of the survey. From the total population of ever e-cigarette users, 70.9% were current smokers, 18.3% were former smokers and 10.8% were never smokers. From the total population of current e-cigarette users, 63.0% were current smokers, 29.7% were former smokers and 7.3% were never smokers.

Past experimentation was the most prevalent pattern of e-cigarette use for the whole population of ever e-cigarette users ( $\chi^2 = 1100.2$ ,  $P < 0.001$ ) and separately for current ( $\chi^2 = 819.8$ ,  $P < 0.001$ ), former ( $\chi^2 = 69.4$ ,  $P < 0.001$ ) and never smokers ( $\chi^2 = 295.3$ ,  $P < 0.001$ ). Characteristically, the vast majority of the never smokers who have used e-cigarettes (77.2%) reported past experimentation only.

Among former smokers and current smokers who had ever tried to quit in the past, e-cigarettes were the fourth most popular smoking cessation method (10.2%, 95% CI = 9.6–10.8%), while the most popular method was trying to quit without any aid (65.3%, 95% CI = 64.4–66.3%). Nicotine replacement therapy was the second (12.1%, 95% CI = 11.5–12.8%) and other methods was the third most popular method (11.1%, 95% CI = 10.5–11.7%). However, among current smokers who tried to quit in the past 12 months, e-cigarettes were the second most popular method of quitting (25.2%, 95% CI = 22.9–27.4%), after trying without any aid (46.7%, 95% CI = 44.1–49.4%).

The vast majority of participants who were ever smokers or e-cigarette users reported that the first product used was combustible tobacco (95.1%, 95% CI = 94.7–95.4%), while oral tobacco was first used by 1.0% (95% CI = 0.8–1.2%) and e-cigarettes by 0.8% (95% CI = 0.6–0.9%).

#### Use of nicotine-containing e-cigarettes

The prevalence and frequency of nicotine-containing e-cigarette use among ever e-cigarette users is shown in

Table 1. An estimated 37.3 million Europeans have ever used nicotine-containing e-cigarettes (76.8% of ever e-cigarette users). From the total number of ever users of nicotine-containing e-cigarettes, 73.3% were current smokers, 18.9% were former smokers and 7.8% were never smokers. From the total population of daily users of nicotine-containing e-cigarettes, 70.4% were current smokers, 27.7% were former smokers and 1.9% were never smokers. Daily use was reported by 54.6% of current e-cigarette users and 36.7% of past e-cigarette users, while 11.7% of current e-cigarette users and 23.9% of past e-cigarette users had never used nicotine-containing e-cigarettes.

Experimentation was the most prevalent pattern of nicotine-containing e-cigarette use for current ( $\chi^2 = 333.5$ ,  $P < 0.001$ ), former ( $\chi^2 = 100.6$ ,  $P < 0.001$ ) and never smokers ( $\chi^2 = 174.8$ ,  $P < 0.001$ ). In current smokers the prevalence of experimentation was twice that of daily use, while the vast majority of the never smokers who had ever used nicotine-containing e-cigarettes (79.3%) reported experimentation only.

#### E-cigarette use and change in smoking patterns

Smoking cessation was reported by 14.0% (95% CI = 12.7–15.3%) of ever e-cigarette users, while smoking reduction was reported by an extra 21.2% (95% CI = 19.7–22.7%). Extrapolating to the whole EU population, an estimated 6.1 million Europeans have quit smoking with the use of e-cigarettes, while a further 9.2 million have reduced their smoking consumption. The results of the analysis according to e-cigarette use patterns and frequency of use of nicotine-containing e-cigarettes are shown in Table 2. Current e-cigarette users reported high rates of smoking cessation (35.1%, 95% CI = 30.7–39.5%) and reduction



**Table 2** Change in smoking status among current and former smokers who reported ever e-cigarette use in the European Union. Data are presented according to patterns of e-cigarette use and frequency of nicotine-containing e-cigarette use.

	<i>Change in smoking status<sup>a</sup></i>				
	Quit smoking, n = 396 % (95% CI)	Quit but relapsed, n = 361 % (95% CI)	Reduced smoking, n = 600 % (95% CI)	Did not reduce smoking, n = 1288 % (95% CI)	Increased smoking, n = 107 % (95% CI)
E-cigarette use n = 2832					
Current use	35.1 (30.7–39.5)	11.6 (8.7–14.6)	32.2 (27.9–36.5)	19.2 (15.5–22.8)	0.5 (0.0–1.1)
Past use	14.3 (11.6–16.9)	22.0 (18.9–25.2)	26.3 (22.9–29.6)	30.4 (26.9–33.9)	6.0 (4.2–7.8)
Past experimentation	8.3 (7.0–9.6)	9.3 (8.0–10.7)	16.3 (14.5–18.0)	58.5 (56.1–60.8)	3.8 (2.9–4.7)
Total	14.0 (12.7–15.3)	12.7 (11.5–14.0)	21.2 (19.7–22.7)	45.5 (43.7–47.3)	3.8 (3.1–4.5)
Nicotine-containing e-cigarette use n = 2249					
Daily	30.6 (27.1–34.0)	18.4 (15.5–21.3)	28.5 (25.1–31.9)	18.9 (15.9–21.8)	3.6 (2.2–5.0)
Occasional	8.9 (6.0–11.7)	17.8 (13.9–21.6)	33.3 (28.6–38.1)	35.9 (31.1–40.7)	2.4 (0.9–3.9)
Experimentation	6.4 (5.0–7.8)	8.8 (7.2–10.4)	13.8 (11.8–15.8)	62.7 (60.0–65.5)	3.7 (2.6–4.8)
Total	14.2 (12.8–15.7)	13.2 (11.8–14.7)	21.6 (19.9–23.3)	44.7 (42.7–46.8)	3.4 (2.7–4.2)

<sup>a</sup>79 participants responded 'Do not know' in the question about the change in smoking status and are not presented in this table. CI = confidence interval.

(32.2%, 95% CI = 27.9–36.5%). Overall, more than two out of three current users reported either smoking cessation or reduction. Past e-cigarette use had a combined smoking cessation and reduction rate of more than 40%. Past e-cigarette experimentation was associated with low smoking cessation and reduction rates, while the majority reported no change in consumption. An increase in smoking consumption was reported by a small minority of e-cigarette users.

Frequency of nicotine use was evaluated collectively for current and past e-cigarette users. Daily users of nicotine-containing e-cigarettes reported a smoking cessation rate of 30.6% (95% CI = 27.1–34.0%), while an additional significant proportion reported reduction in smoking consumption (28.5%, 95% CI = 25.1–31.9%). Experimentation with nicotine-containing e-cigarettes was associated with low rates of smoking cessation and reduction, while the majority reported no change in consumption. An increase in smoking consumption was reported by a small minority of users of nicotine-containing e-cigarettes.

After adjusting for age and gender, participants reporting current and past e-cigarette use were more likely to have quit smoking [odds ratio (OR) = 5.10, 95% CI = 3.77–6.89 and OR = 1.72, 95% CI = 1.27–2.3, respectively] compared to those reporting past e-cigarette experimentation.

### Correlates of e-cigarette use

Table 3 displays the correlates of ever and current e-cigarette use from multivariate analysis. Being current and former smokers were the strongest correlates of both ever and current e-cigarette use. Living in a large town, marital status, seeing e-cigarette advertising in the past

12 months and lower perception of harmfulness of e-cigarettes were also correlates of both ever and current e-cigarette use. Male gender, higher education and lower middle class were correlates of ever but not current e-cigarette use, while middle class was a correlate for current e-cigarette use only. All younger age groups were correlates of ever e-cigarette use, but only age group 40–54 years was a correlate of current e-cigarette use.

### DISCUSSION

This Eurobarometer survey is of great importance in evaluating e-cigarette use by the EU population for two reasons; first it is representative of the entire EU region (28 countries) and secondly, it made a clear distinction between current use, past use and past experimentation, between regular and occasional use and between nicotine-containing and nicotine-free e-cigarette use. In many surveys, experimentation in the past 30 days (taking a puff on one or two occasions) has been considered as current use [27]. Amato *et al.* showed recently that use in the past 30 days is an inappropriate definition of current use because it included many infrequent users, including 89.5% of never-smoking e-cigarette users who were in reality occasional users only [28]. Other studies have shown that daily e-cigarette use is a strong predictor of smoking cessation or reduction [15,29]. The precise definitions of the different patterns of e-cigarette use in this survey allowed a more appropriate and detailed analysis of the prevalence of e-cigarette use and its impact on the smoking behaviour.

The first important result of this Eurobarometer survey is that an estimated 48.5 million people have use e-cigarettes in all member states of the EU. Vardavas *et al.*

**Table 3** Correlates of ever and current e-cigarette use in the European Union, derived from multivariate logistic regression analysis.

<i>Correlates</i>	<i>Ever e-cigarette use</i>		<i>Current e-cigarette use</i>	
	<i>OR (95% CI)</i>	<i>P</i>	<i>OR (95% CI)</i>	<i>P</i>
Smoking status				
Never smokers (referent)				
Current smokers	21.23 (18.32–24.59)	< 0.001	15.71 (10.21–24.18)	< 0.001
Ex-smokers	6.49 (5.49–7.67)	< 0.001	8.38 (5.25–13.37)	< 0.001
Age (years)				
55 and older (referent)				
15–24	5.16 (4.21–6.34)	< 0.001	1.40 (0.83–2.36)	0.213
25–39	2.90 (2.53–3.33)	< 0.001	1.34 (0.95–1.88)	0.093
40–54	1.89 (1.66–2.16)	< 0.001	1.46 (1.07–1.98)	0.017
Gender				
Female (referent)				
Male	1.13 (1.03–1.25)	0.009	1.07 (0.85–1.35)	0.572
Residence				
Rural (referent)				
Small/middle town	1.10 (0.98–1.24)	0.099	1.02 (0.76–1.36)	0.904
Large town	1.20 (1.06–1.36)	0.005	1.40 (1.04–1.89)	0.028
Age when finished education (years)				
No full-time education or ≤ 15 (referent)				
16–19	1.37 (1.16–1.62)	< 0.001	1.00 (0.69–1.45)	0.991
≥ 20	1.54 (1.28–1.84)	< 0.001	0.94 (0.62–1.42)	0.780
Still studying	1.62 (1.24–2.12)	< 0.001	1.37 (0.72–2.62)	0.335
Social class				
Working class (referent)				
Lower middle class	1.16 (1.01–1.33)	0.037	1.15 (0.84–1.57)	0.384
Middle class	1.01 (0.90–1.14)	0.825	0.70 (0.52–0.93)	0.015
Upper middle class	0.91 (0.73–1.14)	0.413	0.77 (0.44–1.34)	0.355
Higher class	1.00 (0.58–1.72)	0.992	1.50 (0.57–3.93)	0.411
Marital status				
Married or living with partner (referent)				
Single	1.01 (0.89–1.15)	0.872	1.25 (0.91–1.69)	0.157
Divorced, widowed or other	1.23 (1.08–1.41)	0.003	1.42 (1.05–1.94)	0.025
Difficulty paying bills				
Most of the time (referent)				
From time to time	0.94 (0.81–1.10)	0.453	0.92 (0.64–1.32)	0.642
Almost never/never	0.90 (0.78–1.05)	0.172	0.99 (0.70–1.40)	0.961
Seeing e-cigarette advertising in past 12 months				
Never (referent)				
Often	2.93 (2.48–3.46)	< 0.001	6.43 (4.66–8.86)	< 0.001
Occasionally	2.23 (1.98–2.51)	< 0.001	2.73 (2.05–3.62)	< 0.001
Rarely	1.74 (1.52–1.99)	< 0.001	1.55 (1.07–2.26)	0.020
Perceived harmfulness of e-cigarettes				
Yes or don't know (referent)				
No	1.28 (1.15–1.41)	< 0.001	2.80 (2.22–3.53)	< 0.001

CI = confidence interval; OR = odds ratio.

analysed data from the 2012 Eurobarometer (performed in 27 member states) and found that approximately 29.3 million Europeans had used e-cigarettes at that time [25]. Thus, there is a substantial increase in use prevalence over less than 2 years in the EU. Similarly to the 2012 Eurobarometer and to surveys recently performed in the United Kingdom [30,31], being current and former smokers were by far the strongest independent correlates

of ever and current e-cigarette use, while adoption of e-cigarette use by never-smokers was very low. The Eurobarometer survey is also innovative by including a question about the use of nicotine-containing e-cigarettes. Surveys have shown that nicotine use with e-cigarettes is important in order to substitute smoking successfully [13,32]. However, nicotine use by never smokers could be a potential problem due to the possibility of causing

dependence, especially if used daily. The present results showed that almost 80% of ever e-cigarette users reported use of nicotine-containing e-cigarettes, most of whom were current and former smokers, while only 0.09% of never smokers reported daily use of nicotine-containing e-cigarettes. A large number of smokers reported quitting smoking with the use of e-cigarettes. The EU announced a smoking cessation rate of 14.0% among ever e-cigarette users [33]; however, this included smokers who only tried e-cigarettes or used them occasionally. It is not reasonable to expect experimentation or occasional use to be substantially effective in smoking cessation. Among current e-cigarette users, the combined smoking cessation and reduction rate was 67.3%. As expected, occasional use was associated with lower rates of smoking cessation. These findings highlight that e-cigarettes are likely to be more successful in substituting smoking when used regularly, as verified in recent longitudinal studies [29,34,35]. Other surveys fail to differentiate between regular and occasional use or experimentation [27,36], which results in overestimation of the prevalence of use and underestimation of their efficacy in smoking substitution.

Lower perception of harmfulness about e-cigarettes was a statistically significant correlate of ever and current e-cigarette use. Studies have shown that dual users of tobacco cigarettes and e-cigarettes have higher perception of e-cigarette harmfulness compared to former smoking e-cigarette users [13], and this is a strong independent correlate of dual use [37]. A recent analysis of the International Tobacco Control Netherlands survey found that considering e-cigarettes to be less harmful than tobacco cigarettes was one of the main motivations for current e-cigarette use among smokers [38]. Other studies reported a substantial and growing number of smokers who believe, falsely, that e-cigarettes are equally or more harmful than smoking [39–41]. It is reasonable to expect that if smokers do not believe that e-cigarettes are less harmful they would not be motivated to use them as smoking substitutes. It should be mentioned, however, that the Eurobarometer 429 questionnaire assessed whether e-cigarettes are considered harmful or not in absolute terms. It would be more appropriate for this question to be rephrased in order to assess the perception of relative harmfulness of e-cigarettes compared to tobacco cigarettes (more than, equal to or less harmful than tobacco cigarettes), as it is possible that some participants would believe that e-cigarettes may be harmful but to a lower extent compared to smoking. By including 'absolutely harmless' as a response option, the question would assess both the absolute and relative harmfulness of e-cigarettes. E-cigarette advertising is probably a way of increasing awareness about e-cigarettes among the population, and it was associated significantly with e-cigarette use (especially current use). This can be beneficial for smokers but could result in increased use by

unintended (from a public health perspective) population (i.e. never smokers). Considering that current e-cigarette use is rare among never smokers, it would seem acceptable to allow advertising of e-cigarettes in a controlled manner so that they are marketed solely as smoking substitutes for established smokers rather than as a new 'trendy' habit for anyone to adopt. Younger age (especially 15–24 years) was also associated with ever e-cigarette use. A similar finding was observed in an analysis of the Eurobarometer 2012 survey [42]. This age group is generally more familiar with technology products such as e-cigarettes and such appeal may have significant beneficial effects because, although smoking cessation at young age can reduce significantly the risk for future smoking-related disease [43–45], few young smokers try or seek assistance to quit and many relapse [46]. However, only age 40–54 years was associated with current e-cigarette use, which implies that younger age groups may be simply experimenting with e-cigarettes. This association needs to be examined further.

The Eurobarometer 429 survey results do not suggest that e-cigarettes are creating a new generation of nicotine users. This is supported by findings that regular use by never smokers was rare, while a very small proportion reported that e-cigarettes were the first tobacco-related product they used. This replicates the observations so far with the enhanced accessibility of NRTs, when their availability changed from prescription-only to over-the-counter [47,48]. This survey also showed that e-cigarettes have a substantial success rate in smoking cessation and reduction. This could be attributed to the fact that e-cigarettes satisfy the needs and preferences of smokers more effectively, and that until now they have been easily accessible. The current situation may change when the EU Member States will finalize the adoption of the European Tobacco Product Directive (TPD) [49]. It remains to be seen how this policy will affect product availability, accessibility and acceptance of use, particularly when e-cigarette use was associated with seeing e-cigarette advertisements and with lower perception of harmfulness. The former will be regulated strictly through the implementation of the TPD, while the latter has been highlighted as a barrier to the use e-cigarettes in a recent report by Public Health England [30]. Other effects of the regulation will be an increase in the price and a reduction in product variability due to the costs of compliance. Conversely, the TPD regulation will introduce some quality criteria, which might boost confidence in the products by consumers.

A major limitation of the study is that it is a cross-sectional survey which cannot determine causation. Moreover, the survey examined the self-reported smoking cessation rate; there was no objective verification of the smoking status and no assessment of the duration of smoking cessation. However, it is important to note

that the survey question assessed specifically whether e-cigarette use helped to reduce or quit smoking. Another limitation is that the survey did not assess the magnitude of smoking reduction. Finally, there is no direct evidence on whether e-cigarettes may act as gateway to smoking. However, the minimal use of e-cigarettes (especially nicotine-containing e-cigarettes) by never smokers and the fact that a very small minority reported that e-cigarettes were the first product used make the gateway-to-smoking effect highly unlikely.

## CONCLUSION

E-cigarette use in the EU is observed predominantly among current and former smokers. In never smokers, e-cigarette use is minimal and confined largely to past experimentation, while regular use of nicotine-containing e-cigarettes is extremely rare. A substantial proportion of current e-cigarette users reported quitting smoking and reducing consumption. Considering that, based on currently available evidence, e-cigarettes are less harmful than smoking, the findings herein suggest a positive public health impact for smokers accompanied by minimal potential harm due to use by never smokers.

## Declaration of interests

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