

# Determinants and prevalence of e-cigarette use throughout the European Union: a secondary analysis of 26 566 youth and adults from 27 Countries

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## ABSTRACT

**Objective** This study assessed the prevalence and determinants of e-cigarette use among persons aged  $\geq 15$  years in 27 European Union (EU) member countries during 2012.

**Methods** The 2012 Eurobarometer 385 (77.1) survey was analysed for  $n=26\ 566$  respondents. Knowledge, perception of harm, and determinants of e-cigarettes use were assessed, while separate regression analyses among current ( $n=7352$ ) and former cigarette smokers ( $n=5782$ ) were performed. National estimates of the number of e-cigarette users were also extrapolated.

**Results** 20.3% of current smokers, 4.7% of ex-smokers, and 1.2% of never cigarette smokers in the EU reported having ever used an e-cigarette (overall approximately 29.3 million adults). Among smokers, ever e-cigarette use was more likely among 15–24-year-olds (aOR 3.13, 95% CI 2.22 to 4.54) and 25–39-year-olds (aOR 2.00, 95% CI 1.47 to 2.78) in comparison to older smokers, and among those who smoked 6–10 cigarettes/day (aOR 1.53, 95% CI 1.10 to 2.13) or 11–20 cigarettes/day (aOR 2.07, 95% CI 1.52 to 2.81) in comparison to very light smokers ( $\leq 5$  cigarettes/day). Moreover, e-cigarette use was more likely among smokers who had made a past year quit attempt (aOR 2.08, 95% CI 1.67 to 2.58). E-cigarette use among ex-smokers was associated only with the respondents' age, with younger ex-smokers being more likely to have ever used an e-cigarette.

**Conclusions** A substantial number of EU adults have ever used e-cigarettes. Ever users were more likely to be younger, current smokers, or past-year quit attempters. These findings underscore the need to evaluate the potential long term impact of e-cigarette use on consumer health, cessation and nicotine addiction and formulate a European framework for e-cigarette regulation within the revised EU Tobacco Product Directive.

## INTRODUCTION

Electronic cigarettes (e-cigarettes) are battery operated electronic nicotine delivery systems (ENDS) designed to provide nicotine and mimic the sensory perception of smoking without combustion. For example, the presence of 'vapour' (propylene glycol), and the hand-to-mouth motions of smoking associated with e-cigarettes have been designed to simulate smoking. Controversy surrounds the promotion of e-cigarettes as a modified risk tobacco product.<sup>1–5</sup> E-cigarettes may have the potential to treat the neurobiologic basis of addiction by delivering nicotine, while simultaneously addressing the habitual addictions which secondarily reinforce

smoking behaviour. Moreover, e-cigarettes by design do not involve the combustion of tobacco, and hence are less likely to pose a direct hazard to the user. Hence, when used exclusively instead of cigarettes, e-cigarettes could possibly lower individuals' risks of tobacco related morbidity and mortality; it could thus be argued that they confer an individual and population benefit through a harm reduction strategy. On the other hand, the impact of continued nicotine addiction and the renormalisation of smoking (or 'vaping') and dual use must also be assessed, while variations in potential toxicants within the e-cigarette fluid or vapour warrant further research and potential regulation.<sup>4 6</sup>

As e-cigarettes represent an emerging market—in which the tobacco industry has significantly invested—it is imperative to set the base for product regulation in regards to their manufacture, marketing, and health risk/benefit (individual and population based) for the protection of public health. This is especially of interest to stakeholders and researchers as e-cigarettes were finally included—after extensive debate—within the new Tobacco Products Directive (TPD) of the European Union (EU) to be implemented from 2014.<sup>7</sup> To date, very limited research exists on the determinants of use and awareness of e-cigarettes by youth and adults within the EU. Research from the UK in 2012 indicated that e-cigarette experimenters were more likely to be younger than non-experimenters, and almost all current e-cigarette users were either current or former cigarette smokers.<sup>8 9</sup> Similarly, research among Polish youth during 2010/2011 indicated that 23.5% had ever used e-cigarettes.<sup>10</sup> Such population based studies in other EU countries are, to the best of our knowledge, scarce; thus, the determinants of use among smokers, ex-smokers and never smokers as well as the extrapolated population within the EU that has ever used an e-cigarette remains relatively unknown.

To aid the regulatory actions of the revised EU TPD and to elucidate the existing knowledge gap we performed a secondary analysis of the Eurobarometer 385 (77.1) survey to assess the determinants of use, awareness, perception, and prevalence of e-cigarette use among European youth and adults in 2012.

## METHODS

### Data source

The datasets used in this secondary analysis were obtained from the Special Eurobarometer 385 (77.1) conducted by the European Commission,



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Directorate General Press and Communication, Public Opinion, between 25 February and 12 March 2012.<sup>11</sup> In total 26 566 adults aged  $\geq 15$  years from 27 countries in the EU were surveyed. 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. The sampling points were drawn systematically from each of the 'administrative regional units', after stratification by individual unit and type of area and thus represent the whole territory of the countries surveyed. In each region/country a comparison between the national sample and the EU sample was carried out (post weighting). Estimates are representative at a national and EU level. Baseline results provided by the Eurobarometer 385 survey reported 50.6% of respondents as never smokers, 27.9% as current smokers, and 21.3% as ex-smokers, while additional Eurobarometer 385 descriptive results are available through the official report.<sup>11</sup>

### Definitions

Use, awareness and perceptions of harm related to e-cigarette use  
Ever use of an e-cigarette was self-reported and was assessed with the question 'Have you ever tried (electronic cigarettes)?' Responses of 'regularly', 'occasionally', or 'tried it once or twice' were categorised as having ever tried an e-cigarette. A response of 'no' was categorised as never having tried an e-cigarette. The grouping of all responses as a dichotomous variable (yes vs no) was because of the small samples in some categories (eg,  $n=130$ ,  $n=283$ , and  $n=1027$  for responses of 'regularly', 'occasionally' or 'tried it once or twice', respectively, among smokers). Awareness of e-cigarettes was defined as an affirmative response to the question: 'Have you ever heard of electronic cigarettes, also called e-cigarettes?' Perception of the potential harmfulness of e-cigarettes was assessed using the question: 'Do you think that they are harmful or not to the health of those who use them?' Categorical response options included: 'Yes', 'No' and 'Don't know'.

### Smoking status, cessation and factors influencing brand preferences

The population was grouped into exclusive categories as either current smokers, ex-smokers or never smokers based on their self-reported status. Among current smokers, quit attempts in the past 12 months, ever quit attempts, and the number of cigarettes per day (CPD) were also noted. Use of e-cigarettes as a potential smoking cessation aid was assessed with the question: 'Which of the following did you use in order to quit or to try to quit smoking?: e-cigarettes?'

Because e-cigarette use could be associated with perception of reduced harm, smoking sensory experience (eg, flavour and taste), as well as lower pricing, we further assessed factors influencing brand preferences among smokers using the question: 'How important is each of the following factors in your choice of brand of cigarettes?' Categorical responses included 'price', 'packaging', 'taste of tobacco', 'brand', 'specific flavors' or 'tar/nicotine/carbon monoxide levels'.

### Sociodemographic characteristics

All countries surveyed were categorised into four sub-regions using the United Nations' grouping: Western Europe (France, Belgium, Austria, Germany, The Netherlands, and Luxembourg), Southern Europe (Greece, Italy, Malta, Portugal, Slovenia, Spain, and the Republic of Cyprus), Northern Europe (Denmark, Ireland, Northern Ireland, Great Britain, Latvia, Lithuania, Finland, Sweden, and Estonia), and Eastern Europe (Hungary,

Poland, Bulgaria, Romania, Slovakia and Czech Republic). Data were also collected on respondents' age (15–24, 25–39, 40–54 or  $\geq 55$  years); sex (male or female); marital status (married or living with partner, single, or widowed, divorced or other); and type of residence (rural area, small town, or large town). Difficulty in paying monthly bills was used as a proxy for socioeconomic status (SES) and was assessed with the question 'During the last 12 months, would you say you had difficulties to pay your bills at the end of the month...?' Response options included: 'Most of the time', 'From time to time' or 'Almost never/never'.

### Statistical analyses

Nationally representative estimates for awareness, perceptions and use of e-cigarettes were calculated with 95% CI, while the projected number within the EU was extrapolated based on the total sampling population. Logistic regression analyses were performed to assess correlates of ever use of e-cigarettes among all respondents, with sensitivity analyses for current smokers and former smokers. Analysis among never smokers were not performed due to the small sample size that yielded unstable estimates with inflated relative SEs ( $>30\%$ ) and wide CIs. Variables were included in the final multivariate model if they were significant at  $p < 0.05$  on univariate analyses using  $\chi^2$  statistics. Probability weights in the Eurobarometer dataset were used to estimate the number of smokers who reported ever use of e-cigarettes in each EU country. Separate analyses were performed for current and former smoker. All analyses were weighted and performed with STATA V.12.0

### RESULTS

Within the Eurobarometer 385 survey, ever use of an e-cigarette was reported by 20.3% (95% CI 18.9% to 21.8%) of smokers, 4.4% (95% CI 3.6% to 5.3%) of former smokers, and 1.1% (95% CI 0.8% to 1.4%) of never smokers. Extrapolating the percentage of e-cigarette users to the entire EU population, approximately 23.1 million European smokers  $>15$  years of age would have used an e-cigarette. Of these, 69.9% (approximately 16.2 million) reported using them once or twice, 21.1% (approximately 4.9 million) reported occasional use, whereas 9.0% (approximately 2.1 million) reported regular use. It is noteworthy to report that, based on the above percentages, an extrapolated 3.9 million former smokers and 2.3 million never smokers in the EU reported in 2012 that they had ever used e-cigarettes. As seen in [table 1](#), differences in the awareness of e-cigarettes among smokers throughout the EU ranged from 57.1% in Sweden to 97.8% in Greece. The perception of harm among smokers also significantly varied throughout the EU, with overall 40.6% (38.8% to 42.3%) of smokers reporting e-cigarettes as not harmful, 28.5% (26.9% to 30.1%) as harmful, while 30.9% (29.3% to 32.6%) reported that they did not know if they were or were not harmful.

### E-cigarette use among all adults in the EU

Multivariate logistic regression analyses performed among all respondents of the 2012 Eurobarometer 385 survey (smokers, ex-smokers, and never smokers,  $n=26\,566$ ), indicated that current smoking of combustible tobacco products was the strongest predictor of ever e-cigarette use (adjusted OR (aOR) 10.63, 95% CI 8.72 to 12.95) ([table 2](#)). Participants' age was a significant determinant of e-cigarette use: younger respondents aged between 15–24 years were 3.3 (95% CI 2.50 to 4.55) times more likely to have used an e-cigarette, those aged 25–39 years were 1.89 times more likely (95% CI 1.43 to 2.50), while those

**Table 1** Awareness, perception of harmfulness, reported use and potential number of electronic cigarette users among smokers within European Union member countries, Euro-barometer 385 (77.1) in 2012

Region/country	Awareness		Perception of harmfulness			Use		Users
	Heard of e-cigarettes % (95% CI)	Heard of e-cigarettes and know what they are % (95% CI)	e-cigarettes are harmful % (95% CI)	e-cigarettes are harmless % (95% CI)	Do not know % (95% CI)	Ever used e-cigarettes % (95% CI)	Ever used e-cigarettes as a smoking cessation aid* % (95% CI)	Have used or experimented with e-cigarettes n
Overall	n/a†	n/a†	28.5 (26.9 to 30.1)	40.6 (38.8 to 42.3)	30.9 (29.3 to 32.6)	20.3 (18.9 to 21.8)	3.7 (3.1 to 4.3)	23 125 617
France (n=1059)	86.5 (82.3 to 90.7)	66.8 (61.1 to 72.6)	25.8 (20.5 to 31.1)	36.3 (30.4 to 42.2)	37.9 (32.0 to 43.8)	22.6 (17.4 to 27.7)	3.9 (2.0 to 5.8)	3 030 872
Belgium (n=1051)	69.3 (63.7 to 74.9)	45.3 (39.3 to 51.4)	36.5 (30.7 to 42.4)	45.4 (39.3 to 51.5)	18.0 (13.5 to 22.6)	11.5 (7.4 to 15.5)	3.2 (1.2 to 5.2)	275 748
Austria (n=1031)	84.9 (80.9 to 88.8)	53.3 (47.7 to 58.9)	25.8 (21.0 to 30.6)	44.2 (38.7 to 49.8)	30.0 (24.8 to 35.2)	13.7 (9.9 to 17.6)	4.2 (2.0 to 6.4)	315 404
Germany (n=1552)	93.5 (90.9 to 96.1)	81.0 (76.8 to 85.3)	47.5 (41.9 to 53.2)	23.6 (18.7 to 28.5)	28.9 (23.6 to 34.1)	20.2 (15.6 to 24.9)	2.8 (1.3 to 4.2)	3 437 044
The Netherlands (n=1014)	93.9 (90.6 to 97.2)	72.6 (66.6 to 78.7)	43.4 (36.6 to 50.3)	34.5 (27.8 to 41.2)	22.1 (16.5 to 27.6)	21.9 (16.0 to 27.9)	2.5 (1.1 to 4.0)	688 703
Luxembourg (n=501)	92.4 (88.2 to 96.7)	77.1 (69.9 to 84.3)	40.8 (32.0 to 49.6)	29.2 (21.0 to 37.4)	30.0 (21.8 to 38.2)	28.0 (19.7 to 36.3)	3.7 (0.8 to 6.7)‡	30 389
Greece (n=999)	97.8 (96.4 to 99.3)	84.4 (80.8 to 88.0)	46.7 (41.8 to 51.6)	37.6 (32.8 to 42.4)	15.7 (12.1 to 19.3)	22.4 (18.3 to 26.6)	8.8 (5.6 to 12.0)	777 226
Italy (n=1036)	86.0 (81.6 to 90.4)	64.8 (58.8 to 70.9)	17.3 (12.5 to 22.1)	53.0 (46.7 to 59.3)	29.7 (24.0 to 35.5)	8.8 (5.1 to 12.4)	2.9 (0.7 to 5.0)	1 092 236
Malta (n=500)	79.6 (71.7 to 87.4)	62.9 (53.1 to 72.8)	22.2 (14.0 to 30.3)	45.9 (35.6 to 56.3)	31.9 (22.5 to 41.3)	16.7 (9.5 to 24.0)	3.6 (0.3 to 6.9)‡	15 369
Portugal (n=1009)	91.2 (87.4 to 94.9)	73.6 (67.7 to 79.5)	40.4 (33.8 to 46.9)	24.7 (18.9 to 30.5)	34.9 (28.5 to 41.3)	17.0 (11.8 to 22.1)	0.4 (0.1 to 1.2)‡	309 847
Slovenia (n=1017)	76.7 (71.7 to 81.8)	48.2 (42.1 to 54.4)	34.0 (28.2 to 39.8)	30.7 (25.0 to 36.5)	35.2 (29.4 to 41.1)	20.3 (15.3 to 25.3)	2.3 (0.6 to 4.0)	97 947
Spain (n=1004)	87.2 (83.5 to 90.8)	70.7 (65.6 to 75.7)	16.3 (12.2 to 20.4)	48.9 (43.4 to 54.4)	34.8 (29.5 to 40.0)	10.9 (7.5 to 14.4)	2.3 (0.8 to 3.8)	1 395 241
Cyprus (Republic) (n=506)	88.2 (83.1 to 93.3)	72.4 (65.3 to 79.5)	29.5 (22.2 to 36.7)	40.2 (32.4 to 48.0)	30.3 (23.0 to 37.6)	23.6 (16.8 to 30.3)	5.4 (1.7 to 9.0)	46 936
Denmark (n=1019)	92.1 (89.0 to 95.3)	77.3 (72.4 to 82.3)	29.5 (23.6 to 35.4)	50.6 (44.3 to 56.9)	19.9 (15.1 to 24.7)	36.3 (30.1 to 42.5)	5.3 (3.4 to 7.3)	424 522
Slovakia (n=1000)	74.4 (68.6 to 80.3)	46.2 (39.4 to 53.0)	26.7 (20.7 to 32.8)	51.4 (44.5 to 58.2)	21.9 (16.3 to 27.6)	7.9 (4.3 to 11.4)	1.3 (0.2 to 2.4)‡	82 063
Czech Republic (n=1003)	96.7 (94.6 to 98.9)	82.6 (78.1 to 87.2)	29.0 (23.5 to 34.5)	56.8 (50.8 to 62.7)	14.2 (10.1 to 18.4)	34.3 (28.6 to 40.0)	6.6 (3.6 to 9.5)	903 055
Ireland (n=1008)	66.6 (60.9 to 72.2)	50.5 (44.5 to 56.6)	15.8 (11.4 to 20.3)	37.3 (31.5 to 43.2)	46.8 (40.8 to 52.8)	12.1 (8.1 to 16.1)	2.7 (1.0 to 4.4)	122 451
UK (n=1331)	82.8 (78.2 to 87.4)	69.4 (63.7 to 75.2)	14.6 (10.3 to 19.0)	48.6 (42.3 to 54.8)	36.8 (30.8 to 42.8)	26.9 (21.3 to 32.5)	4.8 (2.7 to 6.8)	3 716 491
Latvia (n=1024)	94.3 (91.9 to 96.6)	64.4 (59.5 to 69.2)	43.6 (38.5 to 48.7)	29.7 (25.0 to 34.4)	26.6 (22.1 to 31.1)	23.9 (19.5 to 28.4)	1.7 (0.4 to 2.9)	125 861
Lithuania (n=1021)	65.8 (60.4 to 71.1)	43.8 (38.1 to 49.5)	24.9 (20.0 to 29.9)	29.3 (24.1 to 34.6)	45.8 (40.1 to 51.4)	11.8 (8.0 to 15.5)	0.6 (0.1 to 1.5)‡	101 088
Finland (n=1003)	97.7 (95.9 to 99.6)	80.4 (73.9 to 86.8)	42.0 (33.5 to 50.5)	41.3 (32.8 to 49.8)	16.7 (10.6 to 22.7)	20.5 (13.2 to 27.8)	3.2 (0.6 to 5.7)‡	226 234
Sweden (n=1016)	57.1 (47.5 to 66.7)	38.0 (28.0 to 48.0)	20.3 (11.8 to 28.8)	34.4 (24.7 to 44.0)	45.3 (35.7 to 55.0)	12.4 (5.6 to 19.3)	2.5 (0.9 to 4.2)	122 286
Estonia (n=1000)	83.9 (79.4 to 88.4)	58.5 (52.2 to 64.8)	32.5 (26.4 to 38.6)	38.8 (32.4 to 45.1)	28.7 (23.0 to 34.3)	22.3 (16.8 to 27.9)	2.8 (1.1 to 4.6)	55 707
Hungary (n=1021)	91.6 (88.6 to 94.5)	74.9 (70.2 to 79.7)	34.9 (29.6 to 40.2)	42.0 (36.6 to 47.5)	23.0 (18.5 to 27.6)	22.3 (17.6 to 27.0)	4.7 (2.5 to 6.9)	597 970
Poland (n=1000)	85.7 (81.8 to 89.6)	75.3 (70.4 to 80.2)	28.9 (23.6 to 34.2)	41.8 (36.0 to 47.6)	29.3 (24.0 to 34.6)	31.0 (25.5 to 36.6)	5.2 (3.0 to 7.5)	3 187 636
Bulgaria (n=1006)	91.5 (88.6 to 94.3)	68.1 (63.1 to 73.1)	20.2 (16.0 to 24.4)	43.2 (37.9 to 48.4)	36.6 (31.5 to 41.7)	31.1 (26.1 to 36.0)	4.6 (2.3 to 6.9)	736 318
Romania (n=1020)	93.6 (90.8 to 96.4)	68.8 (63.6 to 74.0)	37.2 (31.7 to 42.6)	32.3 (27.0 to 37.6)	30.5 (25.3 to 35.7)	22.2 (17.4 to 27.0)	5.1 (2.6 to 7.5)	1 210 973

All data were weighted to yield nationally representative estimates.

\*Among all current smokers that had made a past quit attempt or former smokers that had quit (n=10 219).

†Data presented in the original Eurobarometer report.

‡Estimates with relative standard errors  $\geq 40\%$ .

**Table 2** Predictors of electronic cigarette use among all respondents of the Eurobarometer 385 (77.1), February–March 2012 (n=26 566)

Determinant	Unadjusted OR (95% CI)	Adjusted ORs (95% CI)
Current smoking status*		
Non-smoker (referent)		
Smoker	11.88 (9.84 to 14.34)	10.63 (8.72 to 12.95)†
Perceived harmfulness of e-cigarettes		
Harmful (referent)		
Harmless	1.19 (1.01 to 1.41)	1.10 (0.92 to 1.31)
Don't know	0.27 (0.21 to 0.34)	0.33 (0.26 to 0.42)†
Residence		
Rural (referent)		
Small town	1.11 (0.92 to 1.34)	1.11 (0.91 to 1.36)
Large town	1.53 (1.26 to 1.84)	1.27 (1.03 to 1.56)†
EU region		
Western Europe (referent)		
Southern Europe	0.71 (0.57 to 0.89)	0.63 (0.50 to 0.81)†
Northern Europe	1.26 (1.02 to 1.55)	1.29 (1.03 to 1.62)†
Eastern Europe	1.71 (1.40 to 2.08)	1.56 (1.25 to 1.94)†
Gender		
Male (referent)		
Female	0.70 (0.60 to 0.81)	0.90 (0.77 to 1.06)
Age		
55+ (referent)		
40–54	1.14 (0.92 to 1.39)	1.26 (1.00 to 1.61)†
25–39	1.82 (1.44 to 2.27)	1.89 (1.43 to 2.50)†
15–24	5.26 (4.17 to 6.66)	3.30 (2.50 to 4.55)†
Self-reported difficulty in paying bills‡		
Most of the time (referent)		
Occasionally	0.83 (0.66 to 1.05)	0.99 (0.77 to 1.28)
Never	0.65 (0.53 to 0.81)	1.07 (0.84 to 1.36)
Refused to answer	0.69 (0.42 to 1.15)	1.14 (0.65 to 2.02)

Multivariate logistic regression model adjusted for all factors listed in table.

\*Defined as a report by a respondent that they currently smoked cigarettes, cigars or pipes.

†Statistically significant ( $p < 0.05$ ).

‡Proxy for socioeconomic status.

EU, European Union.

aged 40–54 years were 1.26 times more likely to have ever used an e-cigarette in comparison to respondents  $\geq 55$  years old. Other factors that were associated with e-cigarette use included: residing in a large town rather than a rural area (aOR 1.27, 95% CI 1.03 to 1.56), as well as living in Northern (aOR 1.29, 95% CI 1.03 to 1.62), or Eastern (aOR 1.56, 95% CI 1.25 to 1.94) Europe compared to Western Europe. No significant differences in ever use of e-cigarettes were observed by gender, status, or marital status. With regards to the perception of relative harm of e-cigarettes, respondents who reported that they 'do not know' if e-cigarettes are more or less harmful than cigarettes were less likely to have ever used an e-cigarette (aOR 0.33, 95% CI 0.26 to 0.42).

### E-cigarette use among current smokers in the EU

Factors associated with having ever used an e-cigarette among EU smokers are shown in table 3. Our adjusted regression analysis indicated that younger smokers, especially those 15–24 (aOR 3.13, 95% CI 2.22 to 4.54) and 25–39 (aOR 2.00, 95% CI 1.47 to 2.78) were more likely to have used an e-cigarette than those aged  $\geq 55$  years of age. Relative to smokers who

**Table 3** Predictors of electronic cigarette use among current Smokers\*, Eurobarometer 385 (77.1), February–March 2012 (n=7352)

Determinant	Unadjusted OR (95% CI)	Adjusted ORs (95% CI)
Past year quit attempt		
No (referent)		
Yes	2.21 (1.81 to 2.71)	2.08 (1.67 to 2.58)†
Cigarettes smoked per day		
$\leq 5$ (referent)		
6–10	1.36 (0.99 to 1.87)	1.53 (1.10 to 2.13)†
11–20	1.66 (1.24 to 2.23)	2.07 (1.52 to 2.81)†
$\geq 21$	1.00 (0.68 to 1.47)	1.48 (0.97 to 2.27)
Don't know	1.21 (0.31 to 4.78)	2.11 (0.42 to 10.52)
Factors important to choice of cigarette		
The price	0.93 (0.76 to 1.15)	0.95 (0.75 to 1.15)
The specific tastes (menthol, spicy, fruity or sweet)	1.34 (1.01 to 1.79)	1.34 (0.97 to 1.85)
The levels of tar, nicotine and carbon monoxide	1.05 (0.88 to 1.26)	1.06 (0.87 to 1.30)
Perceived harmfulness of e-cigarettes		
Harmful (referent)		
Harmless	0.97 (0.79 to 1.18)	1.00 (0.81 to 1.23)
Don't know	0.26 (0.19 to 0.34)	0.28 (0.21 to 0.38)†
Marital status		
Married or living with partner (referent)		
Single	1.49 (1.21 to 1.84)	1.22 (0.97 to 1.54)
Widowed, divorced or other	0.95 (0.74 to 1.22)	1.15 (0.87 to 1.52)
Residence		
Rural (referent)		
Small town	1.09 (0.87 to 1.37)	1.05 (0.83 to 1.33)
Large town	1.48 (1.18 to 1.86)	1.27 (1.00 to 1.60)
EU region		
Western Europe (referent)		
Southern Europe	0.53 (0.41 to 0.69)	0.49 (0.37 to 0.65)†
Northern Europe	1.32 (1.03 to 1.70)	1.17 (0.89 to 1.53)
Eastern Europe	1.50 (1.19 to 1.89)	1.37 (1.06 to 1.78)†
Gender		
Male (referent)		
Female	0.96 (0.80 to 1.15)	1.01 (0.83 to 1.22)
Age, years		
55+ (referent)		
40–54	1.49 (1.15 to 1.92)	1.32 (0.99 to 1.75)
25–39	2.38 (1.78 to 3.12)	2.00 (1.47 to 2.78)
15–24	3.70 (2.70 to 5.00)	3.12 (2.22 to 4.55)
Self-reported difficulty in paying bills‡		
Most of the time (referent)		
Occasionally	1.07 (0.82 to 1.40)	0.98 (0.74 to 1.31)
Never	1.18 (0.92 to 1.51)	1.10 (0.84 to 1.45)
Refused to answer	1.23 (0.66 to 2.30)	1.20 (0.60 to 2.37)

Multivariate logistic regression model adjusted for all factors listed in table.

\*Defined as a report by a respondent that they currently smoked cigarettes, cigars or pipes.

†Statistically significant ( $p < 0.05$ ).

‡Proxy for socioeconomic status.

EU, European Union.

smoked  $\leq 5$  CPD, the likelihood of using e-cigarettes was higher among those who smoked 6–10 CPD (aOR 1.53, 95% CI 1.10 to 2.13) or 11–20 CPD (aOR 2.07, 95% CI 1.52 to 2.81). Our regression analysis indicated that factors related to the smoker's current cigarette brand preferences, such as price, taste,



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nicotine, tar and carbon monoxide content were not significant determinants of ever e-cigarette use, with smokers responding homogeneously regardless of their current cigarette brand descriptors. However, it is noteworthy that smokers who responded that they did not know whether or not e-cigarettes are harmful to consumer health were less likely to have used an e-cigarette (aOR 0.28, 95% CI 0.21 to 0.38) in comparison to smokers who perceived e-cigarettes to be harmful.

Within the regression analysis, after adjusting for sociodemographic characteristics, geographical region and cigarette preferences, current smokers who had made a quit attempt during the past year were more likely to have experimented with e-cigarettes (aOR 2.08, 95% CI 1.67 to 2.58). With respect to the percentage of smokers who had ever made an attempt to quit, 7.1% had used e-cigarettes as a cessation aid (which corresponds to 4.2% of all current smokers). In comparison, 65.7% reported to have had attempted to quit cold turkey, 22.5% reported use of nicotine replacement therapy, and 7.3% reported they had received counselling from a healthcare professional.

### E-cigarette use among ex-smokers in the EU

Ex-smokers were significantly more likely to have ever used e-cigarettes compared to never smokers (aOR 6.58, 95% CI 4.60 to 9.42). As shown in [table 4](#), after adjusting for all other

factors, ex-smokers in Eastern Europe were more likely to have ever used e-cigarettes compared to those in Western Europe (aOR 1.67, 95% CI 1.08 to 2.59). Furthermore, when compared with respondents aged  $\geq 55$  years, the odds of ever using an e-cigarette were significantly higher among respondents aged 40–54 (aOR 2.42, 95% CI 1.56 to 3.73), or 25–39 years (aOR 3.83, 95% CI 2.54 to 5.79), or 15–24 years (aOR 6.75, 95% CI 3.85 to 11.84). No significant differences in the ever use of e-cigarettes were observed by gender, place of residence, marital status or SES.

### DISCUSSION

Our secondary analysis of the Eurobarometer data results indicated that e-cigarette users were more likely to be younger (15–24 years), smokers of up to 20 CPD, and to be past-year quit attempters. Significant geographical variations in the prevalence of e-cigarette use were also noted. Among current non-smokers, ex-smokers were also more likely to have ever used e-cigarettes in comparison to never smokers, with again a higher likelihood of use among younger population groups. Extrapolating our findings to the EU population in 2012, approximately 29.3 million adults have tried e-cigarettes. These findings are cross sectional and hence cannot identify causality. However, they provide a substantial insight into the correlates and extent of e-cigarette use throughout Europe and provide substantial evidence of the need to regulate and further investigate the impact of e-cigarette use on health, addiction, cessation, and existing regulatory standards.

Previous surveys or focus group discussions have noted that e-cigarettes may be more appealing to youth, a factor which we identified as the strongest predictor of ever use of e-cigarettes among both current and former smokers.<sup>9 12–15</sup> Curiosity, health consciousness, and marketing, have been suspected as potential determinants of e-cigarette use in this age group and may have contributed to this finding.<sup>10 14 16–18</sup> Indeed, one prospective study among US youths identified that individuals with perceptions of e-cigarette safety relative to cigarettes and their effectiveness as a smoking cessation aid were more likely to report experimenting with e-cigarettes at follow-up.<sup>19</sup> On the other hand marketing may also play an important role, as the e-cigarette industry has a significant online presence, through which e-cigarettes have been promoted as both a safer alternative to cigarette smoking and a dual use product in places where smoking is not allowed. Stressing the fact that age was the strongest determinant of e-cigarette use throughout the EU, our study's implications are strategically important for European policymakers. On the one hand, quitting tobacco use at an earlier age would substantially benefit individuals and public health. However, the renormalisation of smoking (or 'vaping' in this context) or maintained nicotine addiction may significantly hinder efforts to stop tobacco use.<sup>2 20 21</sup>

Within our analysis we did not identify an association between e-cigarette ever use and current cigarette brand preferences. We assessed the hypothesis that e-cigarettes may be appealing as a harm reduction strategy to a specific audience (ie, low TNCO (tar/nicotine/carbon monoxide) cigarette smokers); however, responses between groups of smokers were homogenous. Moreover, using 'taste preference' for their current type of cigarette smoked as a proxy for hedonistic reward also showed no significant association. Nonetheless, it is intriguing to note that smokers who reported that they were unaware of the relative harmfulness of e-cigarettes were less likely to have used an e-cigarette, indicating consumer uncertainty with regards to the safety of e-cigarettes as a consumer device or potential harm reduction strategy. Nonetheless, the e-

**Table 4** Factors associated with e-cigarette among ex-smokers\* EU adults, Eurobarometer 385 (77.1), February–March 2012 (n=5782)

Determinant	Unadjusted OR (95% CI)	Adjusted ORs (95% CI)
Marital status		
Married or living with partner (referent)		
Single	1.44 (1.03 to 2.02)	1.03 (0.66 to 1.62)
Widowed, divorced or other	0.47 (0.29 to 0.74)	0.73 (0.45 to 1.17)
Residence		
Urban (referent)		
Rural	0.81 (0.59 to 1.11)	0.86 (0.62 to 1.19)
EU Region		
Western Europe (referent)		
Southern Europe	1.25 (0.82 to 1.91)	1.52 (0.99 to 2.34)
Northern Europe	1.49 (0.99 to 2.25)	1.40 (0.92 to 2.13)
Eastern Europe	1.60 (1.06 to 2.43)	1.67 (1.08 to 2.59)†
Self-reported difficulty in paying bills‡		
Most of the time (referent)		
Occasionally	1.17 (0.68 to 2.03)	1.14 (0.64 to 2.03)
Never	1.07 (0.64 to 1.78)	1.17 (0.68 to 1.98)
Refused to answer	1.63 (0.63 to 4.21)	1.44 (0.55 to 3.79)
Age, years		
55+ (referent)		
40–54	2.36 (1.54 to 3.61)	2.42 (1.56 to 3.73)†
25–39	3.33 (2.26 to 4.89)	3.83 (2.54 to 5.79)†
15–24	3.99 (2.57 to 6.20)	6.75 (3.85 to 11.84)†
Sex		
Male (referent)		
Female	0.65 (0.49 to 0.87)	0.83 (0.61 to 1.12)

Multivariate logistic regression model adjusted for all factors listed in table.

\*Defined as a report by a respondent that they did not currently smoked cigarettes, cigars or pipes.

†Statistically significant ( $p < 0.05$ ).

‡Proxy for socioeconomic status.

EU, European Union.

cigarette's potential for use as a modified risk tobacco product is demonstrated in our study from the fact that heavier smokers (of 6–10 CPD and 11–20 CPD) were more likely to have used/experimented with e-cigarettes in comparison to very light smokers ( $\leq 5$  CPD). A similar trend was identified for smokers of more than 20 CPD; however, the association lacked statistical significance. These results are in general agreement with those identified through a pooled analysis of adults from the USA, UK, Canada, and Australia in 2012 which indicated that smokers of  $>20$  CPD were more likely to be e-cigarette users than smokers of 1–20 CPD.<sup>8</sup>

Smokers who made a quit attempt in the past year were twice more likely to have used e-cigarettes than smokers who had not. Coupled with the fact that 7.1% of smokers who had ever made any quit attempt had used an e-cigarette as a cessation aid, this suggests that consumers may be experimenting with e-cigarettes as smoking cessation devices. Given that e-cigarettes have only been on the market for a few years, while respondents provided feedback on lifetime quit attempts, it is possible that the prevalence of the use of e-cigarettes as a harm reduction strategy may even be higher, especially among smokers who may not be considered inveterate. We must stress, however, that since we do not have information on the success of smoking cessation, or the length of the quit attempt, a direct comparison between pharmacotherapy, counselling or e-cigarette use cannot be made through this study. Furthermore, we identified that more than 4% of ex-smokers in the EU had ever used an e-cigarette, an ambiguous finding as we are unable to determine if this percentage had (1) tried e-cigarettes when they were smokers and subsequently quit (with or without the use of e-cigarettes), or (2) whether this population of ex-smokers may be using e-cigarettes as a bridge or gateway back to nicotine addiction. The above findings and unanswered questions indicate that further research into the comparative effectiveness of smoking cessation modules, and the e-cigarette's efficacy as a smoking cessation device, is needed to support policy decisions. To date, very limited research on e-cigarettes effectiveness as a smoking cessation device has been performed despite potentially promising results.<sup>22–26</sup>

While the current secondary analysis of the Eurobarometer 385 data provides, to our knowledge, the largest European population based evaluation of e-cigarette use and provides an in-depth look into the awareness, perceptions and determinants of e-cigarette use among smokers in the EU, the current study is not without limitations. First, as all questions were self-reported, the quality of the data depended on the respondents' ability to recall and report information accurately. Research has, however, shown that self-reported tobacco use status has high agreement with biochemically validated assessments.<sup>27</sup> Also, we were not able to perform a stratified analysis between 'occasional' or 'regular' e-cigarette users, between countries or among never smokers, due to small sample sizes that produced wide and invalid CIs. Secondly, previous research has identified that the Eurobarometer results may over- or underestimate national smoking prevalence—hence actual e-cigarette use throughout the EU might differ from the numbers reported.<sup>28</sup> However, regardless of the range estimates, the correlations remain valid and of major scientific and policy importance. Finally, as the Eurobarometer 385 survey is cross-sectional, it lacks the ability to identify causality—only associations can be identified—hence the above results should be corroborated by prospective cohort study research, which should be pursued. Nevertheless, the current analyses provide an intriguing and timely insight into the extent and potential correlates of e-cigarette use throughout the EU.

In summary, in 2012 e-cigarettes were used by approximately 29.3 million European adults, to which the scientific community has not yet provided comprehensive information regarding the harm or efficacy of these products. Moreover, as e-cigarette ever users were more likely to be 15–24 years old, smokers of 5–20 CPD, and smokers who had attempted to quit in the past year, it is important to assess the potential harm versus benefits. In light of the new European TPD—which now includes e-cigarettes and will provide the regulatory framework for their use within the EU—further research is needed to assess the long term impact of e-cigarette use on consumer health, smoking cessation, and nicotine addiction.

### What this study adds

- ▶ Despite the controversy that surrounds the promotion of e-cigarettes as a modified risk tobacco product, very limited research spanning the European Union (EU) exists that could provide a base for regulatory actions, especially in light of the revised EU Tobacco Products Directive.
- ▶ E-cigarette ever use among smokers was more likely among 15–24 years olds in comparison to older smokers, and among those who smoked 6–10+ cigarettes/day in comparison to very light smokers ( $\leq 5$  cigarettes/day). Similar age trends were noted among ex-smokers.
- ▶ Being unaware of the harmfulness of e-cigarettes was associated with a smaller likelihood of having used an e-cigarette, indicating that the lack of scientific knowledge may be a hindrance in e-cigarette use.
- ▶ On the other hand, having attempted to quit smoking in the past was significantly associated with increased odds of having reported ever e-cigarette use/experimentation, identifying the fact that the public may perceive e-cigarettes to have a role in smoking cessation.

**Correction notice** This article has been corrected since it was published Online First. The labels of two categories ("Yes" and "No" responses) of the variable *Perception of the potential harmfulness of e-cigarettes* have been corrected. On page 2, the 11th line under Results now reads "...with overall 40.6% (38.8% to 42.3%) of smokers reporting e-cigarettes as **not harmful**, 28.5% (26.9% to 30.1%) as **harmful**..." In table 1, the headings of the 4th and 5th columns (under *perception of harmfulness*), have been amended to "e-cigarettes are **harmful**" and "e-cigarettes are **harmless**", respectively. In tables 2 and 3, the referent category for the variable *perceived harmfulness of e-cigarettes* has been amended to **harmful**. Finally, the 8th line on page 5 now reads "... in comparison to smokers who perceived e-cigarettes to be **harmful**".

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# Determinants and prevalence of e-cigarette use throughout the European Union: a secondary analysis of 26 566 youth and adults from 27 Countries

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