Exposure to secondhand aerosol of electronic cigarettes in indoor settings in 12 European countries: data from the TackSHS Survey

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ABSTRACT

Introduction: Exposure to secondhand aerosol from e-cigarette (SHA) may pose harmful effects to bystanders. This study aims to investigate the prevalence, duration, and determinants of SHA exposure in various indoor settings in 12 European countries.

Methods: In 2017-2018, we conducted a cross-sectional study, the TackSHS survey, on a representative sample of the population aged ≥15 years in 12 European countries (Bulgaria, England, France, Germany, Greece, Ireland, Italy, Latvia, Poland, Portugal, Romania, and Spain). We described the prevalence and duration of exposure to SHA in several indoor settings among 11,604 e-cigarette non-users. Individual- and country-level characteristics associated with SHA exposure were also explored using multi-level logistic regression analyses.

Results: Overall, 16.0% of e-cigarette non-users were exposed to SHA in any indoor setting at least weekly, ranging from 4.3% in Spain to 29.6% in England. The median duration of SHA exposure among those who were exposed was 43 minutes/day. "Other indoor settings" (e.g. bar, restaurant) was reported as the place where most of e-cigarette non-users were exposed (8.3%), followed by workplace/educational venues (6.4%), home (5.8%), public transportation (3.5%), and private transportation (2.7%). SHA exposure was more likely to occur in certain groups of non-users: men, younger age groups, those with higher level of education, e-cigarette past users, current smokers, those perceiving SHA harmless and living in countries with a higher e-cigarette use prevalence.

Conclusions: We found inequalities of SHA exposure across and within European countries. Governments should consider extending their tobacco smoke-free legislation to e-cigarettes to protect bystanders, particularly vulnerable populations such as young people.

What this paper adds

- The growing use of e-cigarettes has raised concerns as the product is potentially harmful not only to users, but also to bystanders. Yet, e-cigarette use has often been observed in indoor places where smoking is prohibited.
- Little is known about population exposure to secondhand aerosol from e-cigarette (SHA) in indoor settings in European countries.
- Our study found that there was a notable proportion and duration of exposure to SHA among non-users in indoor settings in 12 European countries, with variability of exposure across and within countries.

INTRODUCTION

Electronic cigarette (e-cigarette) use has increased in many parts of the world. In the United States (US), with Juul's extraordinary growth and marketing strategy, e-cigarette use has been declared as an epidemic in youth by the US Surgeon General as it substantially increased by 78% from 2017 to 2018.[1,2] According to the Eurobarometer surveys, the prevalence of adults who had at least tried e-cigarettes in 28 European countries has grown from 12% in 2014 to 15% in 2017.[3]

The growing use of e-cigarettes has raised concerns as the product is potentially harmful not only to users, but also to bystanders.[4,5] Whilst some studies showed that e-cigarettes emit lower levels of some toxic chemicals compared to smoke from conventional cigarettes other studies revealed that e-cigarette aerosol contains comparable or higher levels of other harmful constituents, such as nicotine and metals.[6–9] It has been also shown that bystanders absorb nicotine from e-cigarette's aerosol at levels comparable with secondhand tobacco smoke (SHS).[10] Additionally, e-cigarette's aerosol may expose non-users to toxic chemicals, including particulate matter and carcinogens, such as volatile organic compounds, polycyclic aromatic hydrocarbons, formaldehyde, acetaldehyde and tobacco-specific nitrosamines.[11–14] Secondhand aerosol (SHA) from e-cigarettes has been found to cause acute reduced lung function and associated with higher odds of asthma exacerbations, which might reflect more adverse health effects with longer period of exposure.[15,16] Exposure to SHA from e-cigarette may renormalise tobacco smoking, induce relapse to smoking for those who have quit smoking, and trigger initiation of e-cigarette use among non-smokers, particularly young people.[17–21] The above evidence suggests that appropriate regulations are needed to prevent involuntary exposure to SHA.

The World Health Organization (WHO) recommends to Parties of the Framework Convention on Tobacco Control (FCTC) to consider the prohibition of e-cigarette use in indoor settings or

at least those places where smoking is already banned.[22] In Europe, e-cigarette use has been frequently observed in indoor places where smoking is normally banned, such as workplaces, bars, restaurants, and train and metro stations.[23–25] Evading smoke-free regulation has been reported by e-cigarette users as one of the main reasons for the use of e-cigarettes.[26–28] To the best of our knowledge, to date there have been 28 European countries regulating the use of e-cigarettes, but mostly in selected public places only.[29]

While public debate about the risks and benefits of e-cigarette use continues to arise, evidence on the extent of the population's exposure to the SHA has been documented.[30] According to the 2015 National Youth Tobacco Survey data, exposure to SHA in indoor or outdoor public places was reported by one in four middle and high-school students in the US, including 4.4 million who were e-cigarette non-users and one million not exposed to SHS.[31] Recent data from six European countries indicated that 37% of smokers (e-cigarette non-users) were exposed to SHA, ranging from 18% in Spain to 63% in Greece.[23] However, there has been no study on exposure to SHA from e-cigarettes among the general population in Europe.

This paper aims to assess the prevalence and duration of exposure to SHA from e-cigarettes in various indoor settings among e-cigarette non-users aged 15 years or older in 12 European countries. We also explored the socio-demographic factors at the individual and country level that were associated with SHA exposure.

METHODS

Data Source

This is a questionnaire-based cross-sectional study using data from the TackSHS survey, conducted in 12 selected European countries (Bulgaria, England, France, Germany, Greece, Ireland, Italy, Latvia, Poland, Portugal, Romania, and Spain). The detailed methods of the

TackSHS survey, including the questionnaire development, have been explained elsewhere.[32,33] Sampling methods varied across countries, including multistage sampling (in Bulgaria, Greece, Italy, Latvia, Poland and Romania), cluster sampling with quotas (in England and France), and stratified random sampling (in Germany, Ireland, Portugal and Spain). In each country, we sampled around 1,000 people representative of the general population in terms of age, sex, geographic area, and in most of countries, socioeconomic characteristics. In total, the survey included 11,902 subjects aged 15 years or older from 12 European countries, representing 79.2% of the whole EU population. A pilot study was conducted in Italy in November 2016 while the fieldwork in other countries was conducted between June 2017 (in Romania) and October 2018 (in Latvia), using the same questionnaire administered with computer-assisted personal interviewing (CAPI) in all 12 countries. The questionnaire included information on socioeconomic and demographic characteristics, cigarette smoking, e-cigarette use, SHS and SHA exposures in various indoor and outdoor settings, and attitudes and perception towards SHS and SHA exposures.[33]

For the purpose of this study, only e-cigarette non-users were included. Thus, the total sample size in this study was 11,604 subjects.

Ethical issues

We obtained the approval from a local ethics committee in each of the 12 countries. The study protocol has been registered in ClinicalTrials.gov (ID: NCT02928536). All respondents received detailed information about the survey before they provided their consent to participate.

Measures

Respondents who reported that they had never used e-cigarette during their lifetime or had stopped using it at least for 30 days before the time of the survey were considered as e-cigarette non-users (i.e., never and ex-users). From a question “On average, how much time per day do

you think you are exposed to e-cigarette aerosol in each of the following sites?", interviewees indicated one or more of the indoor settings where they experienced SHA exposure. Five indoor settings were considered: home, workplace (or educational venues for students), public transportation (e.g. train, tram, bus, subway), private transportation, and "other indoor places" (e.g., cafeterias, bars, restaurants, leisure facilities). For each indoor setting, e-cigarette non-users reported the average exposure time (in minutes/day) during a working and non-working day. An e-cigarette non-user was defined as exposed to SHA in a certain setting, if (s)he was exposed in that setting at least one minute per day in a working and/or non-working day. The prevalence (%) of exposure (at least weekly) was computed for each setting and overall. Duration of SHA exposure was computed as the weighted daily average minutes of exposure in working and non-working days among subjects exposed to SHA in each setting.

Ever smokers were defined as respondents who reported smoking at least 100 cigarettes (including hand-rolled cigarettes) during their lifetime. Among ever smokers, current smokers were participants who reported current smoking at the time they participated in this survey, while ex-smokers were those who had stopped smoking by the time they participated in this survey.[34]

Information on harm perception from SHA exposure was obtained by asking respondents "Do you agree or disagree with the following sentence? Exposure to e-cigarette vapour is harmful to my health, with five possible answer options: 1) Strongly agree; 2) Moderately agree; 3) Moderately disagree; 4) Strongly disagree; 5) Does not know OR does not answer". Options 1 and 2 were categorised as "harmful", whereas options 3 and 4 were categorised as "harmless".

Level of education was constructed by taking country-specific tertiles of schooling years as low, intermediate, and high. The 12 countries were classified by their geographic area into Northern Europe, Western Europe, Southern Europe, and Eastern Europe according to United

Nations M49 Standard [35], by the World Bank gross domestic product (GDP) per capita [36], by their score in the 2016 Tobacco Control Scale [37], by country's smoking prevalence, and by country's e-cigarette use prevalence. The latter two were estimated from the TackSHS survey data.

Statistical analysis

We reported proportion, and median estimates of the SHA exposure among e-cigarette non-users across countries and socio-demographic sub-populations. We used the median of the minutes exposed as point of estimates for duration of SHA due to extremely right-skewed distribution of the data.

A multilevel logistic regression model, allowing for clustering of observations at the country level was fitted to examine the relationship between SHA exposure status (as a binary dependent variable) and socio-demographic characteristics at individual and country level (independent variables). Adjusted odds ratios (aOR), and their corresponding 95% confidence intervals (CI), were estimated after adjusting for sex, age, level of education, e-cigarette use status, and smoking status.

Statistical weights were used to generate representative estimates of the general population of each country (individual weight). To calculate results for the entire sample, we applied "country weights", which combined individual weights with an additional weighting factor, with each country contributing in proportion to its population aged 15 years or over, obtained by Eurostat.[38] Analyses were performed with STATA 14.0.

RESULTS

The sample sociodemographic characteristics are presented in **Supplementary Table 1**. Among 11,604 e-cigarette non-users, 16.0% (95% CI: 15.3-16.7%) were exposed at least

weekly to SHA from e-cigarettes in any indoor setting, and ranged from 4.3% (95% CI: 3.2-5.7) in Spain to 29.6% (95% CI: 26.7-32.6) in England, with significant differences among men and women (17.2% vs. 15.0%, p<0.001) for the 12 countries combined (**Table 1**). The highest prevalence of at least weekly SHA exposure was observed in England for both men and women (31.8% and 27.8%, respectively). Overall, the median duration of SHA exposure for e-cigarette non-users who had been exposed to SHA was 43 minutes/day (Q1-Q3: 14-130). The duration of SHA exposure ranged from 2 minutes/day (Q1-Q3: 1-7) in Spain to 103 minutes/day (Q1-Q3: 21-240) in Italy (**Figure 1)**.

Table 1. Country-specific prevalence (%) of e-cigarette secondhand aerosol (SHA) exposure (at least weekly), overall and by sex in e-cigarette non-users of the European population aged ≥15 years.* TackSHS survey, 2017-2018.

Country	N†	% exposure to SHA from e-cigarettes (95% CI)		
		Total	Men	Women
Bulgaria	1035	14.9 (12.8-17.2)	14.3 (11.4-17.6)	15.4 (12.6-18.7)
England	940	29.6 (26.7-32.6)	31.8 (27.5-36.3)	27.8 (24.1-31.8)
France	974	26.3 (23.6-29.1)	27.5 (23.6-31.7)	25.2 (21.6-29.2)
Germany	1000	11.1 (9.2-13.2)	12.6 (10.0-15.9)	9.5 (7.3-12.4)
Greece	959	28.9 (26.1-31.8)	30.3 (26.4-34.6)	27.4 (23.6-31.6)
Ireland	916	22.1 (19.6-24.9)	24.6 (20.8-28.8)	19.8 (16.4-23.7)
Italy	1045	12.8 (10.9-15.0)	15.7 (12.8-19.2)	10.1 (7.9-13.0)
Latvia	1009	5.6 (4.4-7.2)	6.7 (4.8-9.3)	4.7 (3.2-6.8)
Poland	718	12.3 (10.1-14.9)	13.9 (10.5-18.1)	11.0 (8.2-14.5)
Portugal	991	11.4 (9.6-13.5)	12.5 (9.8-15.8)	10.5 (8.1-13.4)
Romania	999	10.0 (8.3-12.0)	10.9 (8.5-14.0)	9.2 (6.9-12.0)
Spain	1018	4.3 (3.2-5.7)	2.2 (1.2-3.9)	6.3 (4.5-8.7)
Total	11,604	16.0 (15.3-16.7)	17.2 (16.2-18.2)	15.0 (14.1-15.9)

CI: confidence interval; Q1: First quartile; Q3: Third quartile

* Individual-level weight factors in proportion to country's population aged 15 years or over are applied to all estimates. For Total estimates of the entire sample, country-level weight factors are applied with each country contributing in proportion to its population aged 15 years or over.[38]
† Sample size (N) is the unweighted country-specific number of e-cigarette non-user.

Table 2 shows the country-specific prevalence and duration of SHA exposure in various indoor settings. SHA exposure among e-cigarette non-users mostly occurred in "other indoor settings" (8.3%), followed by workplace/educational venues (6.4%), home (5.8%), public transportation (3.5%), and private transportation (2.7%). France had the highest prevalence of SHA exposure at home (12.0%), workplace/educational venues (13.2%), and private vehicles (5.9%) compared to other countries, while the highest prevalence of SHA exposure in public transportation was in England (7.9%) and in "other indoor settings" in Greece (19.0%). The longest median duration of SHA exposure was 43 minutes/day which was taken place at home and workplace, while the shortest one was in public transportation with a median of 14 minutes/day of exposure. Despite the low prevalence of SHA exposure (1.8%) among Latvian e-cigarette non-users in "other indoor places", they reported a 2-hour-per-day of SHA exposure in these venues.

Table 2. Country-specific at least weekly prevalence (%) and duration (minutes/day) of e-cigarette secondhand aerosol (SHA) exposure in selected indoor settings among e-cigarette non-users of the European population aged ≥15 years.* TackSHS survey, 2017-2018.

Country	N†	Home		Workplace / Educational venues		Public Transportation		Private Transportation		Other Indoor Places	
		%	Median‡ minutes/day	%	Median‡ minutes/day	%	Median‡ minutes/day	%	Median‡ minutes/day	%	Median‡ minutes/day
Bulgaria	1035	4.6	64	4.6	43	2.8	17	1.3	43	10.8	43
England	940	7.6	30	10.9	14	7.9	7	5.1	12	14.2	17
France	974	12.0	34	13.2	48	5.1	24	5.9	17	14.2	48
Germany	1000	2.3	34	2.8	43	2.6	30	1.4	27	8.0	26
Greece	959	8.1	60	10.8	46	3.4	43	1.6	60	19.0	60.0
Ireland	916	8.8	31	9.4	14	3.8	7	2.3	10	11.6	10
Italy	1045	5.6	60	6.3	43	3.3	60	3.0	60	5.1	60
Latvia	1009	2.1	60	2.4	43	0.3	21	0.3	14	1.8	120
Poland	718	6.6	69	4.8	21	2.9	14	0.9	19	3.7	33
Portugal	991	4.4	60	4.2	21	0.3	6	2.3	17	6.8	18
Romania	999	4.1	60	4.4	43	1.4	15	2.5	21	3.4	24
Spain	1018	1.5	10	0.5	4	0.9	1	0.0	0	1.9	2
Total	11,604	5.8	43	6.4	43	3.5	14	2.7	21	8.3	33

* Individual-level weight factors in proportion to country's population aged 15 years or over are applied to all estimates in each country. For total estimates of the entire sample, country-level weight factors are applied with each country contributing in proportion to its population aged 15 years or over.[38]

† Sample size (N) is the unweighted, country-specific number of e-cigarette non-users

‡ Median estimates were calculated among e-cigarette non-users who had been exposed to SHA at the corresponding indoor setting.

Table 3. Proportion (%) and Adjusted Odds Ratios (aOR) for at least weekly exposure to e-cigarette secondhand aerosol (SHA) and corresponding 95% confidence intervals (CI) according to selected individual-level characteristics among e-cigarette non-users of European population aged ≥15 years.* TackSHS survey, 2017-2018.

Individual-level characteristics	N†	At least weekly exposed to SHA from e-cigarettes	
		%	aOR (95% CI) ‡
Sex			
Women	6122	15.0	1§
Men	5482	17.2	**1.13 (1.01-1.25)**
Age group (years)			
<25	1401	20.9	**3.15 (2.52-3.94)**
25-44	3955	19.3	**2.69 (2.20-3.30)**
45-64	4218	16.4	**2.23 (1.83-2.73)**
≥65	2030	6.2	1§
P for trend			***<0.001***
Level of education¶			
Low	4381	13.4	1§
Intermediate	4064	17.5	**1.19 (1.05-1.35)**
High	3156	17.8	**1.26 (1.10-1.44)**
P for trend			***0.001***
E-cigarette use status			
Never user	11299	15.6	1§
Past user	305	32.9	**1.49 (1.14-1.95)**
Smoking status			
Never smoker	6478	14.2	1§
Former smoker	1943	15.2	1.12 (0.96-1.31)
Current smoker	3183	20.9	**1.54 (1.36-1.74)**
Perception of SHA exposure harm¶			
Harmless	2104	22.8	1§
Harmful	7662	14.6	**0.69 (0.61-0.78)**

*Country-level weight factors are applied with each country contributing in proportion to its population aged 15 years or over.[38]

†Sample size (N) is the unweighted number of e-cigarette non-users for each corresponding individual-level characteristic.

‡aORs for individual-level characteristics were estimated using multiple logistic regression models, adjusting for sex, age, level of education, e-cigarette use status, and smoking status. A multilevel model was used to include variation among countries. Estimates in bold are statistically significant at 0.05 level.

§ Reference category.

¶The sum does not add to the total because of missing values.

Table 3 shows the proportion of SHA exposure and the corresponding aOR according to selected individual-level characteristics. At least weekly SHA exposure was more frequent in men (aOR: 1.13; 95% CI: 1.01-1.25) than in women and in the young (aOR for <25 vs. ≥65 years: 3.13; 95% CI: 2.52-3.94; p for trend <0.001). The higher the level of education, the more likely the e-cigarette non-users were exposed to SHA (aORs for intermediate level of education: 1.19; 95% CI: 1.05-1.35, and for high-level of education: 1.26; 95% CI: 1.10-1.44; p for trend <0.001). Higher odds of SHA exposure was related with being an e-cigarette past user (compared with never users aOR: 1.49; 95% CI: 1.14-1.95) and being a current smoker (compared with never smokers, aOR: 1.54; 95% CI: 1.36-1.74). Those who perceived SHA exposure as harmful were less likely to be exposed to SHA (vs. harmless; aOR: 0.69; 95% CI: 0.61-0.78).

Compared to Northern Europe, the SHA exposure was lower among e-cigarette non-users living in Southern (aOR: 0.27; 95% CI: 0.11-0.68) and Eastern Europe (aOR: 0.35; 95% CI: 0.13-0.94) (**Table 4**). E-cigarette non-users living in countries with higher prevalence of e-cigarette use were more likely to be exposed to SHA (vs. <1% e-cigarette use prevalence; aOR for 1%-4% group: 1.64, 95% CI :1.05-2.56; aOR for >4% group: 4.35, 95% CI: 2.72-6.96; p for trend <0.001).

Table 4. Proportion (%) and Adjusted Odds Ratios (aOR) for at least weekly exposure to e-cigarette secondhand aerosol (SHA) and corresponding 95% confidence intervals (CI) according to selected country-level characteristics among e-cigarette non-users of European population aged ≥15 years.* TackSHS survey, 2017-2018.

	N†	At least weekly exposure to SHA from e-cigarettes	
Country-level characteristics		%	aOR (95% CI) ‡
Geographic area			
Northern Europe	2865	28.2	1§
Western Europe	1974	17.6	0.52 (0.22-1.27)
Southern Europe	4013	10.9	**0.27 (0.11-0.68)**
Eastern Europe	2752	11.9	**0.35 (0.13-0.94)**
Gross Domestic Product per Capita			
≤25.000€	5711	13.7	1§
>25.000€	5893	16.7	1.22 (0.51-2.89)
Tobacco Control Scale score			
≤50	5712	12.8	1§
>50	5892	18.0	1.31 (0.62-2.79)
Total population smoking prevalence (%)			
<20	2901	20.4	1§
20-30	2727	11.4	0.52 (0.22-1.25)
>30	5976	16.4	0.58 (0.25-1.37)
P for trend			<0.266
Total population e-cigarette use prevalence (%)			
<1	2727	8.3	1§
1-4	6004	11.9	**1.64 (1.05-2.56)**
>4	2873	27.8	**4.35 (2.72-6.96)**
P for trend			**<0.001**

* Country-level weight factors are applied with each country contributing in proportion to its population aged 15 years or over.[38]

† Sample size (N) is the unweighted number of e-cigarette non-users for each corresponding country-level characteristic.

‡ aOR were estimated using multiple logistic regression models, adjusting for sex, age, level of education, e-cigarette use status, and smoking status. A multilevel model was used to include variation among countries. Estimates in bold are statistically significant at 0.05 level.

§ Reference category.

Geographic area was categorised into Northern Europe (Ireland, Latvia, England), Western Europe (France, Germany), Southern Europe (Italy, Greece, Portugal, Spain), and Eastern Europe (Bulgaria, Poland, Romania) according to United Nations M49 Standard [35], by the World Bank gross domestic product (GDP) per capita into GDP per capita [36] ≤25.000€ (Bulgaria, Latvia, Romania, Poland, Portugal, Greece) and GDP per capita >25.000€ (England, France, Germany, Ireland, Italy, Spain), by score of Tobacco Control Scale 2016 [37] into Tobacco Control Scale ≤50 (Bulgaria, Poland, Portugal, Latvia, Greece, Germany) and Tobacco Control Scale >50 (England, Ireland, France, Romania, Italy, Spain), by country's total smoking prevalence into <20% (Ireland, Italy, England), 20%-30% (Germany, Latvia, Poland), and >30% (Bulgaria, France, Greece, Portugal, Romania, Spain) [33] and by country's total population e-cigarette use prevalence into <1% (Poland, Portugal, Spain), 1%-4% (Bulgaria, Germany, Ireland, Italy, Latvia, Romania), and >4% (France, Greece, England). The latter two were estimated from the TackSHS survey data.

Discussion

Sixteen percent of e-cigarette non-users in 12 European countries were exposed to SHA at least weekly in any indoor setting, with this group reporting a median of 43 minutes/day of exposure. Most of their exposure took in "other indoor settings" that includes restaurants and bars, but, importantly, the exposure of longest duration occurred at home and workplace (43 minutes/day). It is also evident that variability in SHA exposure exists across countries and among different socio-demographic groups -- men, the youngest, highly educated, past e-cigarette users, current smokers, those perceiving SHA as harmless, and living in a country with high e-cigarette use prevalence were among individuals who were more likely to be exposed to SHA.

The highest prevalence of SHA exposure (more than 1 in 4 non-users, England) does not correspond to the longest duration of SHA exposure (103 minutes/day, Italy). The discrepancy might be partly due to lower time-sensitisation towards duration of SHA exposure among bystanders in countries where SHA exposure was more common; they perceived shorter duration of SHA exposure because they had already accustomed to it. However, the discrepancy highlights the importance of monitoring both measures, prevalence and duration of SHA exposure, in a population. There has been no evidence on the safety levels of SHA exposure, while for SHS, there has been established evidence showing that there is no risk-free level of SHS.[39–41] However, it has been shown that 2 hours/day of exposure to exhaled aerosol of e-cigarettes for a week may significantly increase urinary and salivary cotinine among bystanders living in homes with e-cigarette users.[10] Another study also found that after a SHA exposure of one hour, the serum cotinine concentrations increased at similar levels as in subjects exposed to SHS.[42] That indicates bystanders may systematically absorb the nicotine from acute exposure to SHA.

A previous study, conducted among smokers in 6 European countries (Germany, Greece, Hungary, Poland, Romania, Spain) from June to September 2016, also identified differences in SHA exposure prevalence across countries, with Spain having the lowest exposure (18%) and Greece having the highest one (63%).[23] The variation of SHA exposure across countries may reflect a diverse country's e-cigarette use prevalence in the region. Spain, for instance, was within the lowest e-cigarette use prevalence group (<1%) and had the lowest SHA exposure among others (4.3%). Indeed, the higher odds of SHA exposure in countries with higher e-cigarette use prevalence was evident from our regression analysis as we would expect, especially, if the use of the device is unregulated. The regression analysis revealed that country's e-cigarette use prevalence was an independent factor of SHA exposure among e-cigarette non-users, suggesting the need for countries to restrict the place of e-cigarette use. The policy for e-cigarette use restriction can be included in the country's current tobacco control strategy as, our study has shown, the current score of Tobacco Control Scale was still irrelevant to SHA exposure status. Moreover, a strong association found between SHA exposure and geographic area of the 12 countries might be attributable to the widespread "vape-free" policy from one country to the neighbouring countries, as has been shown in the policy diffusion theory for local and national smoking ban regulations.[43,44]

Similar to what has been described with SHS exposure, each country's regulatory environment may also affect the differences in SHA exposure among countries.[45–48] Among the 12 countries included in this study, only Greece had introduced a "vape-free" policy in all indoor settings by the time this study was conducted.[29] Despite the extensive coverage of "vape-free" policy in Greece, non-users in the country were still markedly more exposed to SHA in indoor settings compared to other countries without any national "vape-free" policy, like Bulgaria, Germany, Latvia, and Romania.[29] In workplaces, including school and university, France, a country which already banned e-cigarette use in such settings, had the highest

prevalence of SHA exposure.[29] This finding underscores the importance of implementing and enforcing existing policies on e-cigarette use in indoor places. Most of the SHA exposure occurred in "other indoor settings", which include bars and restaurants where smoking, but not e-cigarette use is prohibited in all the 12 countries examined.[49] A previous European study indicated a 20% prevalence of e-cigarette use in indoor places where smoking was banned.[23] The greater opportunity of using e-cigarette compared to smoking conventional cigarettes in enclosed spaces, including pubs, bars, and restaurants, has been mentioned as one of the motivations of using e-cigarettes in such settings.[27,50] That opportunity may encourage e-cigarette users, most of whom are dual users, to use e-cigarettes as an alternative to smoking in places where smoking is banned, as it is the case in "other indoor settings" .[3,27,50] Moreover, the already prevalent social norm of smoking in certain recreational facilities, including bars and restaurants, could also drive e-cigarette use in these settings.[51] Thus, they are important factors to be considered in future public policies.

E-cigarette use in homes and private vehicles is a source of involuntary exposure to SHA for vulnerable populations, especially children. Despite the low prevalence of SHA exposure in homes shown in this study, an intense SHA exposure (43 minutes/day) occurred in such setting. In the UK, less than 10% of e-cigarette users forbid e-cigarette use in their homes, while a study in the US indicates that about one in five e-cigarette users reported banning e-cigarette use inside their homes and cars.[52]We also identified socio-demographic discrepancies in SHA exposure. Men, young, highly educated, current smokers and e-cigarette past users were more likely to be exposed to SHA in indoor settings. These determinants of SHA exposure were also true for smokers as has been shown in a study among 6 European countries.[23] Being in the younger age groups or the higher educational level were also positive determinants for e-cigarette use and awareness about e-cigarettes.[53–55] This peculiarity might be explained by the diffusion of innovation theory which states that early adopters of new

behaviours tend to be males and those from higher socioeconomic status.[56] Accordingly, our data also found that SHA exposure was associated with highly educated non-users, as it is likely that users and bystanders are peers and they socialise together.

Exposure to SHA has its impact on social norm and using e-cigarette. Constant SHA exposure among youths may increase their susceptibility to using e-cigarettes and tobacco products, as well as decreased their harm perception of e-cigarettes.[19,57] A higher likelihood of SHA exposure among e-cigarette past users (compared to never users) found in this study may pose a risk of relapse for those who have quit using e-cigarette. An experimental study reported that passive exposure to e-cigarette significantly increased desire to use e-cigarette.[21] Additionally, exposure to SHA may put current smokers at a risk of being dual users, as they might start using e-cigarettes.[58,59] Thus, more preventive campaigns are needed to avoid initiation, relapse and dual use in such vulnerable populations.

In line with a study among youth in the US, [57] our study found that those who perceived SHA as harmful were less likely to report SHA exposure. Generally, people viewed SHA as less harmful than SHS.[60] A parental interview data in the US has shown that, while compared to smoke-free policy at homes and cars, there were fewer parents who enforced "vape-free" homes and cars, suggesting that parents perceived e-cigarette aerosol was safe for their children.[61] Therefore, increasing awareness of the potential harmful effects might decrease SHA exposure.

This study was limited by the inherent nature of the cross-sectional study design and the use of self-reported data by respondents. The accuracy of responses, indeed, relies on participants' perception to sense the passive exposure itself. Moreover, our question did not define the specific sign of SHA exposure (e.g, smell, visibility of the cloud, etc) as it may freely capture all possible indicators of SHA exposure. A similar question has also been used by the ITC 6

European Country survey.[23] Another strength associated to using self-reported exposure is that the respondents assign it to specific setting, which cannot be ascertained when using personal biomarkers of exposure. As the design of our questionnaire does not have a separate question for educational venues, we were unable to estimate specific exposure at such setting. However, we believe this would not undermine our results given the low proportion of student participants (less than 10%) in this study. The questionnaire gathered information on SHA in working and non-working days in separate, thus preventing potential information bias derived from using longer times of recall but it cannot ascertain daily prevalence. We have computed prevalence of "at least weekly" exposure that in addition to be reliable is useful, given the relatively low exposure to SHA.

There was relatively small sample size in each country (approximately 1,000 subjects), but the total sample size is large enough to draw an overall inference. Lastly, this study had some differences in sampling methods across countries.[33] However, we ensured the representativeness of the sample in proportion to each country's population aged ≥15 years by applying the weight factors into the analyses.

To our knowledge, this is the first study that investigates self-reported exposure to SHA at the population level in European countries using a standardised questionnaire that allows comparison among countries. The duration of SHA exposure described in this study may offer an alternative measure of SHA exposure burden apart from the prevalence. Additionally, countries selected in this study enable us to understand the variation of SHA exposure in different regions and tobacco products, including e-cigarette regulatory environment.

In conclusion, we found that there was a substantial proportion and duration of exposure to SHA among non-users of e-cigarettes in indoor settings in European countries, with

heterogeneity of exposure across countries and among socio-demographic groups. Thus, governments are strongly recommended to include e-cigarettes in smoke-free laws and tailor such legislation to be specifically targeted to vulnerable groups, particularly young people and former users, to protect them from the harms of SHA exposure and the temptation to (re)fall into nicotine addiction. Enforcement to increase compliance with existing e-cigarette use legislation is needed. Lastly, future work should include repeated cross-sectional and/or longitudinal studies on SHA exposure to monitor the change of burden of such exposure in a population.

Authors contribution BA, EF, and SG had the original idea for the study; SG, XL, and AL contributed to the finalization of the survey questionnaire; BA and XL carried out the statistical analysis with the supervision of AL; BA wrote the first draft of the article in collaboration with XL, AL, MF, EF, and SG; AO, SS, LC, JBS, and PvdB made substantial contributions to conception, design, and interpretation of data; all the authors contributed to manuscript preparation and approved its final version prior to submission. SG and EF are the guarantors.

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