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Secondhand smoke exposure in outdoor children's playgrounds in 11 European countries

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ABSTRACT

Introduction: Tobacco presence in outdoor children's playgrounds is concerning not only because it leads to secondhand smoke (SHS) exposure, but also cigarette butt pollution and tobacco normalization.
Objectives: This study aimed to assess SHS exposure in children's playgrounds, according to area-level socioeconomic status (SES), smoke-free regulations, national smoking prevalence, and SHS exposure prevalence in playgrounds (2017–2018).
Methods: We monitored vapor-phase nicotine concentration and tobacco-related variables in 20 different playgrounds in 11 European countries (n = 220 measurements) from March 2017 to April 2018. Playgrounds were selected according to area-level SES. Data on the number of people smoking, and cigarette butts inside the playground and on playground surroundings (<1 m away) were recorded. Playground smoking bans, the Tobacco Control Scale (TCS) score, national smoking prevalence and SHS exposure prevalence in playgrounds were

Abbreviations: SHS, Secondhand smoke; SES, Socioeconomic status; TCS, Tobacco Control Scale; LOQ, Limit of Quantification; IQR, Interquartile Range.

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used to group countries. To determine nicotine presence, we dichotomized concentrations using the limit of quantification as a cut-off point (0.06 μg/m^3). Nicotine median concentrations were compared using non-parametric tests, and nicotine presence and tobacco-related observational variables using the Chi-squared test.
Results: Airborne nicotine presence was found in 40.6% of the playgrounds. Median nicotine concentration was <0.06 μg/m^3 (Interquartile range: <0.06–0.125) and higher median concentrations were found in more deprived neighborhoods, non-regulated playgrounds, in countries with lower overall TCS scores, higher national smoking prevalence and higher SHS exposure prevalence in playgrounds. Overall, people were smoking in 19.6% of the playgrounds. More than half of playgrounds had cigarette butts visible inside (56.6%) and in the immediate vicinity (74.4%). Presence of butts inside playgrounds was higher in sites from a low area-level SES, in countries with low TCS scores, and greater smoking prevalence and SHS exposure prevalence ($p<0.05$).
Conclusions: There is evidence of SHS exposure in children's playgrounds across Europe. These findings confirm the need for smoking bans in playgrounds and better enforcement in those countries with smoking bans in playgrounds.

1. Introduction

Secondhand smoke (SHS) is a widespread health hazard for which there is no safe level of exposure. The harmful effects derived from long-term exposure to SHS are well-documented. SHS has been causally associated with increased risk of lung cancer and myocardial infarction in adults (U.S. Department of Health and Human Services, 2006; Oberg et al., 2011). Transient exposures, those that typically occur in outdoor settings, might also trigger different biological mechanisms that could negatively impact non-smokers' health (Flouris et al., 2010).

Children are more vulnerable to the harmful effects of SHS than adults, as they have higher breathing rates and they inhale a greater mass of toxic material per body volume. A less mature immune system, a still-developing respiratory tract, and their dependence on the caregiver's choice regarding smoke-free environments all further contribute to their susceptibility to tobacco smoke pollutants (Öberg et al., 2010). There is evidence that SHS exposure in early life increases the risk for sudden infant death syndrome, middle ear infections, respiratory disorders, and asthma exacerbations (U.S. Department of Health and Human Services, 2006; Öberg et al., 2010).

There are marked social inequities in children's exposure to SHS. Studies in high-income countries reveal socioeconomic factors to be closely related to children's exposure at home; and confirm that social disparities in SHS exposure in early life persist over time among households of different socioeconomic status (SES) (Moore et al., 2012; Pisinger et al., 2012; Gartner and Hall, 2013; Orton et al., 2014; Kuntz and Lampert, 2016). Smoking restrictions in private spaces (mainly homes) are less common in more disadvantaged families (Moore et al., 2012) and lower educated parents are more likely to smoke in the vicinity of their child (Kovess et al., 2013). Social disparities in children's SHS exposure go beyond the dwelling environment. Children in cars from deprived neighborhoods are more likely to be exposed to SHS while traveling (Montreuil et al., 2017). Additionally, a study assessing SHS in different private and public settings found children's SHS exposure to be higher in some outdoor settings such as schools and nursery gates, with lower parental education and occupational social class (López et al., 2018).

There is a widely held belief that outdoor SHS exposure does not pose such a high risk to health as in indoor spaces. In confined areas, SHS concentrations linger for hours after smoking has ceased, whereas outdoor SHS concentrations diffuse much faster into the environment and exposure periods are generally brief. Even so, field (CARB (California Air ResourcesBoard), 2005; Klepeis et al., 2007; Repace, 2007; Sureda et al., 2013) and experimental (Klepeis et al., 2007; Repace, 2007) evidence has shown that outdoor SHS levels might be comparable to indoor SHS levels while tobacco sources are active and dependent on certain conditions of wind, source-receptor proximity, and the number of smokers present. Tobacco presence in outdoor child-related venues like playgrounds raises concerns not only because children might be exposed to SHS but also because smoking might be perceived as a normal behavior by children, shaping their perceptions. In addition, cigarette butts are non-biodegradable waste left within their reach. These tobacco leftovers contain toxins and carcinogenic substances, posing a potential hazard for children, who might play with or even swallow cigarette butts (Moriwaki et al., 2009; Novotny et al., 2011).

Although progress on adopting smoke-free legislation in most European countries has been made after the World Health Organization (WHO) Framework Convention on Tobacco Control, outdoor smoke-free regulations continue to be limited, at least in the WHO European region (Martinez et al., 2014). Besides, even when national or local measures exist, legislation can be complex or not communicated sufficiently, via signposting or other means, making enforcement and compliance a challenge.

Data on SHS exposure in children's outdoor play areas are scarce and, to the best of our knowledge, SHS concentrations in such settings have not been yet measured using objective markers. In the present study, we aimed to describe SHS levels in children's playgrounds in 11 European countries by measuring airborne nicotine concentrations taking into account area-level SES, smoke-free regulations, the country's smoking prevalence and self-reported SHS exposure prevalence in playgrounds.

2. Methods

The study was conducted within the framework of the TackSHS Project (Fernández et al., 2020). This is a cross-sectional study based on SHS objective environmental measurements. We measured SHS levels in children's playgrounds from major cities in 11 European countries: Bulgaria, France, Germany, Greece, Ireland, Italy, Poland, Portugal, Romania, Spain, and the United Kingdom. For each of the countries, we assessed SHS exposure in a convenience sample of 20 playgrounds. A total of 220 observations were carried out between March 2017 and April 2018, excluding winter and summer months. Children's playgrounds were selected according to the neighborhood's SES. Half of the measurements were done at sites belonging to the most deprived neighborhoods (below the 20th percentile of the SES distribution) and half to the most affluent neighborhoods (above the 80th percentile of the SES distribution). Neighborhood SES was established on the basis of local synthetic deprivation indexes or other economic indicators, such as residential rental prices, income of the neighborhood residents or rate of poverty by district depending on the country. Only playgrounds located outdoors and with slides, swings or other playing facilities were eligible. Measurements took place when there were at least five people, adults and/or children, in the playground area. To congregate the maximum number of people, fieldwork was mostly performed during weekdays and at the end of school hours.

We monitored vapor-phase nicotine. Researchers taking part in the environmental measurements received training on the use of monitoring equipment and collecting additional tobacco-related observational data through specific forms. Guidance was provided in a written protocol for environmental sampling. We took outdoor nicotine measurements following a previously validated method (Hammond et al., 1987).

Samplers were 37-mm diameter plastic cassettes that contained a filter treated with sodium bisulfate. All nicotine samplers were coded and attached to air pumps (Sidekick, SKC Ltd., Dorset, UK) with a constant flow rate of 3 l/min. Air pumps were calibrated before and after monitoring using a calibrator Defender 510 M (Mesa Labs, Lakewood, CO, USA). We assessed nicotine concentrations for 30 min through active sampling. During nicotine measurements, observers were either still or walking around the setting. Nicotine measurements were taken inside the playground area and/or in the immediate playground surroundings, at a maximum distance of 1 m. The Agència de Salut Pública de Barcelona Laboratory determined nicotine concentrations by gas chromatography-mass spectrometry method. For every 20 nicotine samples, one blank filter that had not been exposed was analyzed. We quantified the time-weighted average nicotine concentration (in $\mu g/m^3$) by dividing the amount of nicotine extracted from the filter by the volume of air sampled (estimated flow rate times the minutes the filter had been exposed). This procedure has a limit of quantification (LOQ) of 5 ng per filter, which is equivalent to 0.06 $\mu g/m^3$ of nicotine per 30 min of exposure. To account for nicotine presence in playgrounds, concentration values were dichotomized using the LOQ as a cut-off point.

Smell of smoke, the number of children and adults, and people smoking inside and just around the playground area were collected at three time points: at the beginning (0 min), after 15 min of sampling and at the end (30 min). We considered there was smell of smoke, people smoking inside and people smoking in immediate vicinity to the playground when present at least in one of the three time points assessed. The number of cigarette butts inside and just outside the playground were also recorded. There was presence of cigarette butts in playgrounds when one or more cigarette butts were found inside or in the immediate vicinity to the playground.

Different contextual variables were included as well. We checked for national and local smoking bans in children's outdoor playgrounds and their implementation dates. For those playgrounds with smoking bans, we looked at the years elapsed since the smoking ban was applied until the year samples were taken. We classified playgrounds into not regulated, five or less years under a smoking ban and more than five years under a smoking ban. We grouped countries according to the Tobacco Control Scale (TCS) overall score published in 2016 that quantifies the implementation of tobacco control policies in European countries. The cut-off point for the TCS was set at the midpoint of the index score (50/100), following the country classification done at the TCS 2016 report (Joossens and Raw, 2016). We also grouped countries based on their current smoking prevalence (respondents were considered smokers when reported smoking at the time and had smoked at least 100 cigarettes during their lifetime); and on their playground self-reported SHS exposure prevalence (considering exposure when non-smokers reported someone smoking at the place), both estimated through national surveys carried out within the TackSHS project on a representative sample of approximately 1000 people aged 15 years or older in each country (Fernández et al., 2020, Gallus et al., 2020). In the case of current smoking prevalence and self-reported SHS exposure prevalence in playgrounds, we used median values to generate categories (above or equal/below).

We excluded from the analyses one outlying nicotine measurement as the calculated nicotine concentration was considered to be extremely high (>100 $\mu g/m^3$) in outdoor settings. Given the skewed distribution of nicotine, we used median and interquartile ranges (IQR) to describe airborne nicotine concentrations. Samples with concentrations below the LOQ of 0.06 $\mu g/m^3$ were assigned half of this value. We provided raw frequencies and percentages to describe nicotine presence and tobacco-related observational data. Nicotine levels were described according to SES, contextual variables and tobacco-related observational variables. Tobacco-related observational data were also described according to SES and contextual variables. Nicotine concentrations were compared using non-parametric U-Mann Whitney or Kruskal Wallis tests as appropriate, and nicotine presence and tobacco-related observational variables by Chi-squared test. All analyses were performed with the statistical package Stata 15.

The TackSHS project was approved by the Clinical Research Ethics Committee of the Bellvitge University Hospital (PR341/15) and this study was specifically approved by the country's local Ethics Committees (Supplementary Table 1).

3. Results

Table 1 shows information about smoke-free regulations in countries included in the study. In 2017, nearly all European countries had some form of national or local smoking bans for children's playgrounds. TCS overall scores ranged from 81 out of 100 in the UK to 37 out of 100 in Germany.

Overall, the median nicotine concentration in playgrounds was below the LOQ of 0.06 $\mu g/m^3$ (IQR: <0.06–0.125 $\mu g/m^3$). Four countries had median nicotine levels above the LOQ, with the highest levels found in Romania (0.604 $\mu g/m^3$ IQR: 0.063–2.354). There were detectable levels of nicotine in 40.6% of the playgrounds. Among countries, there was high variability in the proportion of playgrounds with nicotine presence. Most of the sites assessed in Greece (95.0%), France (90.0%), Romania (75.0%), and Bulgaria (73.7%) had detectable levels of nicotine (Table 2).

We found people smoking inside 19.6% of the playgrounds, and in the immediate vicinity of the playground, in one out of four playgrounds. More than half of the playgrounds had cigarette butts visible inside (56.6%) and outside the playground area (74.4%) (Table 3).

As shown in Table 4, we found higher nicotine concentrations in playgrounds located in the most deprived neighborhoods (<0.06 $\mu g/m^3$ IQR: <0.06–0.153 $\mu g/m^3$); in countries that scored below 50 in the TCS (0.090 $\mu g/m^3$ IQR: <0.06–0.202 $\mu g/m^3$); in countries with higher smoking prevalence (0.096 $\mu g/m^3$ IQR: <0.06–0.270 $\mu g/m^3$); and higher self-reported SHS exposure prevalence in playgrounds (0.067 $\mu g/m^3$ IQR: <0.06–0.176 $\mu g/m^3$) ($p < 0.05$). Moreover, the proportion of playgrounds with airborne nicotine present was greater when countries scored below 50 points in the TCS (69.5%), had higher current smoking prevalence (62.2%) and higher self-reported SHS exposure prevalence in playgrounds (53.8%). In those playgrounds with no smoking bans, we observed higher median nicotine levels (0.073 $\mu g/m^3$ IQR: <0.06–0.155 $\mu g/m^3$) than in playgrounds with recent smoking bans (<0.06 $\mu g/m^3$ IQR: <0.06–0.221 $\mu g/m^3$) and playgrounds with smoking bans for more than 5 years (<0.06 $\mu g/m^3$ IQR: <0.06–<0.06 $\mu g/m^3$). The proportion of playgrounds with airborne nicotine present in the case of a smoking ban for more than five years (18.3%) was much lower than when playgrounds had recent smoking bans (47.1%) or no smoking bans at all (52.7%).

The presence of people smoking inside play areas was more common in playgrounds where smoking was either not banned (29.1%) or recently banned (22.1%) than in countries with playground smoking bans for more than 5 years (6.7%) ($p = 0.007$). Smoking inside playgrounds was also more common when playgrounds were located in countries with a higher current smoking prevalence (26.1%) and higher self-reported SHS exposure prevalence in playgrounds (25.2%) compared to those with lower smoking prevalence (12.0%) and lower self-reported SHS exposure prevalence in playgrounds (13.0%) ($p < 0.05$). The presence of cigarette butts within the playground was higher in deprived neighborhoods (64.2%), in countries with no smoking bans in playgrounds (83.6%), lower overall scores in the TCS (76.3%), with greater smoking prevalence (63.0%), and greater self-reported SHS exposure prevalence in playgrounds (65.6%) ($p < 0.05$) (Table 5).

Median nicotine concentrations and the percentage of presence of airborne nicotine according to observational data related to tobacco consumption are provided in Table 6. Median nicotine levels were 0.093 $\mu g/m^3$ (IQR: <0.06–0.297 $\mu g/m^3$) when smell of smoke was noticeable, 0.115 $\mu g/m^3$ IQR: <0.06–0.313 $\mu g/m^3$) when there were

Table 1
Information on smoking regulations in children's outdoor playgrounds and Tobacco Control Scale ranking in 11 European countries (2017–2018).

Country	City	National smoking regulation up to 2017 (implementation year)	Local[a,b] smoking regulation (implementation year)	Tobacco Control Scale 2016 ranking (overall score)
Bulgaria	Sofia	Banned (2012)	N/A	20 (47/100)
France	Paris	Banned (2015)	N/A	4 (64/100)
Germany	Heidelberg	Not regulated	Banned (2005)	33 (37/100)
	Mannheim	Not regulated	Banned (2011)	
Greece	Athens	Not regulated	Not regulated	31 (40/100)
Ireland	Dublin	Not regulated	Banned (2013)	2 (70/100)
Italy	Milano	Not regulated	Banned (2012)	
	Varese	Not regulated	Banned (2017)	13 (51/100)
	Others[c]	Not regulated	Not regulated	
Poland	Warsaw	Banned (2010)	N/A	15 (50/100)
	Ciechanów	Banned (2010)	N/A	
Portugal	Braga	Not regulated	Not regulated	15 (50/100)
Romania	Bucharest	Banned (2016)	N/A	7 (56/100)
Spain	Barcelona	Banned (2011)	N/A	8 (55/100)
United Kingdom	Edinburgh	Not regulated	Banned (2016)	1 (81/100)

[a] City's smoke-free regulation.
[b] N/A: Not assessed as national regulation is in place.
[c] Induno Olona, Arcisate, Bisuschio, Porto Cersio, Ponte Tresa, Buccinasco, Corsico, Cormano and Cesano Boscone.

Table 2
Airborne nicotine concentration (μg/m^3) in children's outdoor playgrounds by country (2017–2018). TackSHS Project.

Country	N	Median (μg/m^3) (IQR)	Min (μg/m^3)	Max (μg/m^3)	% nicotine presence (n)
All	219	<0.06 (<0.06–0.125)	<0.06	6.038	40.6 (89)
Bulgaria	19	0.090 (<0.06–0.125)	<0.06	0.708	73.7 (14)
France	20	0.190 (0.113–0.305)	<0.06	2.700	90.0 (18)
Germany	20	<0.06 (<0.06–0.085)	<0.06	0.422	40.0 (8)
Greece	20	0.196 (0.099–0.289)	<0.06	0.688	95.0 (19)
Ireland	20	<0.06 (<0.06–<0.06)	<0.06	0.081	5.0 (1)
Italy	20	<0.06 (<0.06–<0.06)	<0.06	0.206	25.0 (5)
Poland	20	<0.06 (<0.06–<0.06)	<0.06	<0.06	0.0 (0)
Portugal	20	<0.06 (<0.06–0.065)	<0.06	0.616	25.0 (5)
Romania	20	0.604 (0.063–2.354)	<0.06	6.038	75.0 (15)
Spain	20	<0.06 (<0.06–<0.06)	<0.06	0.194	15.0 (3)
UK	20	<0.06 (<0.06–<0.06)	<0.06	0.150	5.0 (1)
p-Value		0.0001[a]			<0.0001[b]

Note: IQR, Interquartile Range. Limit of Quantification (LOQ): 0.06 μg/m^3.
[a] Kruskal-Wallis test.
[b] Chi-squared test.

Table 3
Tobacco-related variables in children's outdoor playgrounds by country (2017–2018). TackSHS Project.

Country	N	Smell of smoke[a] % (n)	Smoking inside % (n)	Smoking outside[a,b] % (n)	Butts inside % (n)	Butts outside[b] % (n)
All	219	18.1 (36)	19.6 (43)	24.6 (49)	56.6 (124)	74.4 (163)
Bulgaria	19	36.8 (7)	15.8 (3)	42.1 (8)	68.4 (13)	94.7 (18)
France	20	–	55.0 (11)	–	0.0 (0)	40.0 (8)
Germany	20	25.0 (5)	20.0 (4)	20.0 (4)	80.0 (16)	80.0 (16)
Greece	20	35.0 (7)	45.0 (9)	40.0 (8)	80.0 (16)	90.0 (18)
Ireland	20	5.0 (1)	15.0 (3)	30.0 (6)	55.0 (11)	95.0 (19)
Italy	20	25.0 (5)	25.0 (5)	35.0 (7)	65.0 (13)	75.0 (15)
Poland	20	5.0 (1)	0.0 (0)	5.0 (1)	25.0 (5)	70.0 (14)
Portugal	20	15.0 (3)	10.0 (2)	15.0 (3)	95.0 (19)	100 (20)
Romania	20	25.0 (5)	30.0 (6)	30.0 (6)	50.0 (10)	45.0 (9)
Spain	20	10.0 (2)	0.0 (0)	20.0 (4)	85.0 (17)	95.0 (19)
UK	20	0.0 (0)	0.0 (0)	10.0 (2)	20.0 (4)	35.0 (7)
p-Value[c]		0.009	<0.0001	0.070	<0.0001	<0.0001

[a] Total numbers do not add 219 because of missing values.
[b] Just around the playground at a maximum distance of 1 m.
[c] Chi-squared test.

people smoking inside, and < 0.06 μg/m^3 (IQR: <0.06–0.222 μg/m^3) when there were people smoking outside ($p < 0.05$). In such cases, the percentage of playgrounds with detectable nicotine levels were 66.7%, 74.4% and 49.0%, respectively ($p < 0.05$). Median nicotine concentrations and nicotine presence were lower when there were no cigarette butts outside the playing area ($p < 0.05$).

4. Discussion

This study is the first to report on SHS levels in outdoor children's playgrounds in 11 European countries. Our data reveal that SHS exposure is present in outdoor playgrounds, with considerable differences in exposure by area-level socioeconomic status, presence of smoking bans in playgrounds, the country's level of implementation of tobacco control policies, national smoking prevalence and self-reported SHS exposure prevalence in playgrounds.

Child-related settings have been widely recognized as a priority in tobacco control by health and political authorities, especially after The WHO Framework Convention on Tobacco Control entered into force in 2005, and the following MPOWER measures (2008), and the European Council Recommendation on smoke-free environments were released (2009). However, very few objective data exist on the exposure at these outdoor public settings.

The present results show there was airborne nicotine in roughly one-third of the playgrounds studied. Our data also indicate there were discarded cigarette butts in nearly three out of five playgrounds and people smoking in one out of five playgrounds across Europe. These findings are important for several reasons. First, there is no risk-free

Table 4
Airborne nicotine concentration (μg/m^3) in children's outdoor playgrounds by area-level socioeconomic status, smoke-free regulation in playgrounds, Tobacco Control Scale overall score, national smoking prevalence, and national self-reported secondhand smoke exposure prevalence in playgrounds (2017–2018). TackSHS Project.

Contextual factors	N	Median (μg/m^3) (IQR)	p-Value[a]	Min (μg/m^3)	Max (μg/m^3)	% nicotine presence (n)	p-Value[b]
All	219	<0.06 (<0.06–0.125)		<0.06	6.038	40.6 (89)	
SES							
High	110	<0.06 (<0.06–0.087)	0.036	<0.06	4.367	34.6 (38)	0.065
Low	109	<0.06 (<0.06–0.153)		<0.06	6.038	46.8 (51)	
Year since implementation of ban							
>5	60	<0.06 (<0.06–<0.06)		<0.06	0.422	18.3 (11)	
≤5	104	<0.06 (<0.06–0.221)	0.0001	<0.06	6.038	47.1 (49)	<0.0001
Not regulated	55	0.073 (<0.06–0.155)		<0.06	0.688	52.7 (29)	
TCS overall score							
≥50	160	<0.06 (<0.06–0.091)	<0.0001	<0.06	6.038	30.0 (48)	<0.0001
<50	59	0.090 (<0.06–0.202)		<0.06	0.708	69.5 (41)	
Smoking prevalence (2017–18)[c]							
<31%	100	<0.06 (<0.06–<0.06)	<0.0001	<0.06	0.422	15.0 (15)	<0.0001
≥31%	119	0.096 (<0.06–0.270)		<0.06	6.038	62.2 (74)	
SHS exposure prevalence in playgrounds (2017–18)[d]							
<42.4%	100	<0.06 (<0.06–<0.06)	0.001	<0.06	6.038	25.0 (25)	<0.0001
≥42.4%	119	0.067 (<0.06–0.176)		<0.06	2.700	53.8 (64)	

Note: SES, socioeconomic status; TCS, Tobacco Control Scale; SHS, secondhand smoke. Limit of Quantification (LOQ): 0.06 μg/m^3.
[a] Mann-Whitney *U* test or Kruskal-Wallis test.
[b] Chi-squared test.
[c] National smoking prevalence (median): <31 (Germany, Ireland, Italy, Poland, UK) ≥ 31 (Bulgaria, France, Greece, Portugal, Romania, Spain)
[d] National SHS exposure prevalence in playgrounds (median): <42.4 (Germany, Ireland, Poland, Romania, UK) ≥ 42.4 (Bulgaria, France, Greece, Italy, Portugal, Spain)

threshold of SHS exposure, a well-known human carcinogen (IARC, 2004). In consequence, a safe level of exposure for children to be protected cannot be established. Second, even short exposure periods could be harmful to health (Flouris et al., 2010). Third, outdoor playgrounds are spaces designed for children, who are particularly vulnerable to the health effects of SHS (Öberg et al., 2010). Fourth, cigarette butts are a commonly littered item leaving children exposed to the risk of swallowing toxic substances, as well as increasing the costs of playground maintenance. Finally, children could normalize smoking behaviors when smoking in their surroundings is perceived as a socially accepted norm, which therefore might encourage smoking initiation later in life (Bayer and Bachynski, 2013).

We have found socioeconomic inequalities in the exposure to SHS at playgrounds. Our results suggest there is higher exposure to SHS in more deprived areas, indicating exposure is not only to be seen as an individual responsibility but it is also related to contextual factors. These results are in line with other findings from private settings, such as homes. Children's exposure to SHS at home has been linked to composite measures of SES as well as individual-level socioeconomic indicators like parental income, education, and occupational social class (Orton et al., 2014; López et al., 2018). While not required by any of the laws promoting smoke-free environments, evidence points to an increased willingness to adopt smoke-free private spaces when smoke-free policies are implemented (Mons et al., 2013). However, unequal reactions to population-based strategies can also exacerbate health inequalities, as has been shown after the introduction of smoking bans in enclosed public places and workplaces and SHS exposure at households with children in three UK countries (Moore et al., 2012). Therefore, policies tackling SHS exposure at outdoor settings should come along with other public health actions that target deprived areas and disadvantaged groups, as could be rigorous monitoring of the implementation stages of new policies; outreach efforts to raise the awareness of the harms of tobacco presence in child-related settings; and improving the access to smoking cessation services. In any case, all measures seeking to reduce SHS exposure should be framed within structural policies aiming to decrease social inequalities.

Our findings show an association between places frequented by children with smoking bans and lower exposure to SHS. Airborne nicotine concentrations and presence were lowest when playgrounds had been covered by smoking bans for more than 5 years. Moreover, the percentage of people smoking in these playgrounds was half the corresponding percentage in playgrounds not covered by smoking bans. Despite these findings, this study reveals presence of airborne nicotine, people smoking, and other signs related to tobacco consumption inside some playgrounds where smoking is already forbidden. This lack of law enforcement is especially noticeable in countries with more recent restrictions, proving the importance of adopting measures that strengthen law adherence the first years a smoking ban is implemented. Even so, our results might also suggest that smoking bans over time help raise awareness of the health impacts of SHS exposure and reduce social acceptability of smoking. To our knowledge, no previous work has described airborne nicotine levels in playgrounds according to smoking bans. Nevertheless, the impact of smoke-free rules has been reported in outdoor park areas where young adults, regardless of their smoking status, perceived greater difficulty to smoke when smoking bans were in place (Klein et al., 2012). We also found that playgrounds without smoking regulations had a greater presence of cigarette leftovers, indicating a likely higher tobacco consumption level in those sites. However, the presence of cigarette butts is probably also affected by playground maintenance

Playgrounds located in countries with greater current smoking prevalence rates had higher levels of airborne nicotine, and a greater presence of smokers and cigarette butts. Differences in exposure were also seen and measured according to the scope and degree of implementation of tobacco control policies in Europe. Countries with less developed tobacco control efforts, as indicated by lower TCS overall scores, had higher levels and greater presence of SHS exposure at playgrounds. These results are in agreement with what has been found in indoor settings where exposure to SHS was less likely with increased scores for the smoke-free tobacco component of the TCS in bars, restaurants, and workplaces; and more likely with greater smoking prevalence in bars and restaurants across Europe (Filippidis et al., 2016).

Median nicotine levels and nicotine presence were higher when cigarette butts were not found outside the playground area. This discrepancy might be explained by the fact that the presence of cigarette butts, in contrast to the presence of smell of tobacco smoke or people

Table 5
Tobacco-related variables in children's outdoor playgrounds by area-level socioeconomic status, smoke-free regulation in playgrounds, Tobacco Control Scale overall score, national smoking prevalence, and national self-reported secondhand smoke exposure prevalence in playgrounds (2017–2018). TackSHS Project.

Contextual factors	N	Smell of smoke[a] % (n)	Smoking inside % (n)	Smoking outside[a,b] % (n)	Butts inside % (n)	Butts outside[b] % (n)
All	219	18.1 (36)	19.6 (43)	24.6 (49)	56.6 (124)	74.4 (163)
SES						
High	110	13.0 (13)	15.5 (17)	22.0 (22)	49.1 (54)	71.8 (79)
Low	109	23.2 (23)	23.9 (26)	27.3 (27)	64.2 (70)	77.1 (84)
p-Value[c]		0.061	0.118	0.388	0.024	0.374
Years since implementation						
>5	60	13.3 (8)	6.7 (4)	15.0 (9)	63.3 (38)	81.7 (49)
≤5	104	16.7 (14)	22.1 (23)	28.6 (24)	38.5 (40)	61.5 (64)
Not regulated	55	25.5 (14)	29.1 (16)	29.1 (16)	83.6 (46)	90.9 (50)
p-Value[c]		0.218	0.007	0.117	<0.0001	<0.0001
TCS overall score (2016)						
≥50	160	12.1 (17)	16.9 (27)	20.7 (29)	49.4 (79)	69.4 (111)
<50	59	32.2 (19)	27.1 (16)	33.9 (20)	76.3 (45)	88.1 (52)
p-Value[c]		0.001	0.090	0.049	<0.0001	0.005
Smoking prevalence (2017–18)[d]						
<31%	100	12.0 (12)	12.0 (12)	20.0 (20)	49.0 (49)	71.0 (71)
≥31%	119	24.2 (24)	26.1 (31)	29.3 (29)	63.0 (75)	77.3 (92)
p-Value[c]		0.025	0.009	0.128	0.037	0.286
SHS exposure prevalence in playgrounds (2017–18)[e]						
<42.4%	100	12.0 (12)	13.0 (13)	19.0 (19)	46.0 (46)	65.0 (65)
≥42.4%	119	24.2 (24)	25.2 (30)	30.3 (30)	65.6 (78)	82.4 (98)
p-Value[c]		0.025	0.023	0.064	0.004	0.003

Note: SES, socioeconomic status; TCS, Tobacco Control Scale; SHS, secondhand smoke.

[a] Total numbers do not add 219 because of missing values.

[b] Just around the playground at a maximum distance of 1 m.

[c] Chi-squared test.

[d] National smoking prevalence (median): <31 (Germany, Ireland, Italy, Poland, UK) ≥ 31 (Bulgaria, France, Greece, Portugal, Romania, Spain)

[e] National SHS exposure prevalence in playgrounds (median): <42.4 (Germany, Ireland, Poland, Romania, UK) ≥ 42.4 (Bulgaria, France, Greece, Italy, Portugal, Spain)

smoking, might not strictly relate to the moment airborne nicotine levels were being monitored but capture tobacco consumption beyond the monitoring period.

In interpreting these results, several limitations should be acknowledged. We have used a convenience sample of playgrounds, which might lead to a potential selection bias or could undermine the study's external validity. Despite this, the nature of our sample did not interfere with the main objective of the study, which was to assess potential differences in SHS exposure at children's outdoor playgrounds according to contextual variables. Data have been analyzed grouping the selection of playgrounds taking into account the neighborhood's SES, the country's implementation of tobacco control policies, smoking prevalence and self-reported SHS exposure prevalence in playgrounds. Second, to establish the neighborhood's SES, each country used local independent indexes. This approach could result in differences in SES classification between countries. However, by using country specific indexes we more accurately determined SES in each neighborhood and synthetic deprivation indicators were applied when available. Moreover, to overcome this limitation, we selected neighborhoods below the 20th percentile of the SES distribution and above the 80th percentile of the SES distribution. Another limitation is that fieldwork was conducted in one or more cities per country and might not necessarily be representative of the whole country. Finally, many researchers were involved in the fieldwork. Thus, we attempted to minimize the potential variability in data collection by training and by providing a detailed protocol for environmental sampling to all researchers.

This is a multi-country study that includes diverse cities, representing geographical, legislative and cultural variations across Europe. It is also the first study that objectively measures SHS exposure in playgrounds by monitoring airborne nicotine, a tobacco-specific constituent (Apelberg et al., 2013). The procedure for nicotine sampling has been previously validated (Hammond et al., 1987) and several studies have used this tracer previously to estimate SHS exposure in outdoor settings (López et al., 2012; Fu et al., 2016). Furthermore, we examined SHS exposure as a function of a wide range of contextual variables, providing new information about factors influencing SHS exposure in outdoor playgrounds at a local and national level.

In conclusion, this study shows evidence of SHS exposure in children's outdoor playgrounds in Europe. Our findings provide a clear message to policy makers as legislation and tobacco control policies banning smoking in playgrounds are needed. In addition, in those countries where these bans already exist, better enforcement is required. Furthermore, other public health interventions that target a reduction in SHS exposure, especially targeting deprived and vulnerable groups, should be conducted from an equity perspective in order to decrease inequalities.

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6. Disclaimer

This manuscript was developed by the TackSHS Project Consortium and does not necessarily reflect the views of the European Commission. The European Commission is not responsible for any use that may be made of the information that contains in this document.

CRediT authorship contribution statement

Elisabet Henderson: Formal analysis, Writing - original draft, Visualization. **Xavier Continente:** Conceptualization, Investigation, Validation, Writing - review & editing. **Esteve Fernández:** Investigation, Writing - review & editing, Conceptualization, Project administration. **Olena Tigova:** Investigation, Writing - review & editing, Project administration. **Nuria Cortés-Francisco:** Investigation, Writing - review & editing. **Silvano Gallus:** Investigation, Writing - review &

Table 6
Airborne nicotine concentrations (μg/m^3) and tobacco-related variables in children's outdoor playgrounds in 11 European countries (2017–2018). TackSHS Project.

Tobacco-related variables	N	Median (μg/m^3) (IQR)	p-Value[a]	Min (μg/m^3)	Max (μg/m^3)	% nicotine presence (n)	p-Value[b]
Smell of smoke[c]							
Yes	36	0.093 (<0.06–0.297)	<0.0001	<0.06	4.161	66.7 (24)	<0.0001
No	163	<0.06 (<0.06–0.079)		<0.06	6.038	28.8 (47)	
People smoking inside the playground							
Yes	43	0.115 (<0.06–0.313)	<0.0001	<0.06	4.161	74.4 (32)	<0.0001
No	176	<0.06 (<0.06–0.094)		<0.06	6.038	32.4 (57)	
People smoking outside the playground[c,d]							
Yes	49	<0.06 (<0.06–0.222)	0.031	<0.06	1.868	49.0 (24)	0.025
No	150	<0.06 (<0.06–0.087)		<0.06	6.038	31.3 (47)	
Presence of butts inside the playground							
Yes	124	<0.06 (<0.06–0.122)	0.433	<0.06	4.367	38.7 (48)	0.507
No	95	<0.06 (<0.06–0.158)		<0.06	6.038	43.2 (41)	
Presence of butts outside the playground[d]							
Yes	163	<0.06 (<0.06–0.104)	0.009	<0.06	2.700	36.8 (60)	0.049
No	56	0.063 (<0.06–0.308)		<0.06	6.038	51.8 (29)	

Note: Limit of Quantification (LOQ): 0.06 μg/m^3.
[a] Mann-Whitney *U* test.
[b] Chi-squared test.
[c] Total numbers do not add 219 because of missing values.
[d] Just around the playground at a maximum distance of 1 m.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

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