Preventive Medicine 123 (2019) 34–40

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Burden of respiratory disease attributable to secondhand smoke exposure at home in children in Spain (2015)

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ARTICLE INFO

Keywords:
Tobacco smoke pollution
Child
Respiratory tract diseases
Morbidity
Hospitalization

ABSTRACT

This study aimed to estimate the number of incident cases and hospital admissions attributable to secondhand smoke (SHS) exposure at home for asthma, otitis media (OM), and lower respiratory infections (LRI) in children in Spain. The burden of respiratory disease caused by SHS exposure was estimated in terms of incident cases and hospitalized cases for asthma, OM, and LRI. Estimates were calculated using the population attributable fraction. The age-specific (0-1 year, 0-4 years, 5-11 years, and 0-11 years) prevalence of SHS exposure in children was estimated through a telephone survey performed in a representative sample of Spanish households with children in 2016. The risk estimates for all diseases were selected from international meta-analyses. The number of hospitalized cases was obtained for each disease from the Hospital Minimum Data Set provided by the Ministry of Health of Spain. Incident cases were obtained from the Global Health Data Exchange. In 2015, SHS exposure caused an estimated total of 136,403 incident cases of the following respiratory diseases: 9058 (8.5%) cases of asthma, 120,248 (8.5%) of OM, and 7097 (13.5%) of LRI in children aged 0–14 years old in Spain. Likewise, SHS exposure caused a total of 3028 hospitalized cases, with 379 (8.5%) for asthma and 167 (8.5%) for OM in children 0–11 years old, and 2482 (11.6%) for LRI in children < 2 years old. The high burden of respiratory disease attributed to SHS exposure supports the need to improve protection of children against SHS exposure by extending smoke-free regulations to homes and cars.

Abbreviations: CI, confidence interval; GHDx, Global Health Data Exchange; ICD-9-CM, International Classification of Diseases, ninth revision, Clinical Modification; ICD-10, International Classification of Diseases, tenth revision; LRI, lower respiratory infections; MDS, Hospital Minimum Data Set; OM, otitis media; OR, odds ratio; PAF, population attributable fraction; SHS, secondhand smoke

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https://doi.org/10.1016/j.ypmed.2019.02.028
Received 18 October 2018; Received in revised form 12 February 2019; Accepted 23 February 2019
Available online 25 February 2019

1. Introduction

Secondhand smoke (SHS) exposure has been comprehensively associated with adverse health effects, especially on the cardiovascular and respiratory systems (Öberg et al., 2010). Children are particularly vulnerable to the detrimental health effects of SHS, mainly due to their less developed immune and respiratory systems and their faster breathing rate (Kerem, 1996), among other factors. Additionally, younger children are usually very close to the source of SHS on account of their tendency to be held or to sit on their parents' laps (López and Continente, 2016). In children, SHS exposure has been causally associated with asthma, lower respiratory infections (LRI), otitis media (OM), sudden infant death syndrome, and low birth weight, among other conditions (Office on Smoking and Health (US), 2006).

Smoke-free policies have been progressively introduced worldwide since the application of the World Health Organization Framework Convention on Tobacco Control (2003) to protect people from SHS. In Spain, a partial smoke-free law was implemented in 2006 (Law 28/2005) (López, 2010; BOE, 2005), which was subsequently modified and became more restrictive in 2011 (Law 42/2010) (BOE, 2010). The introduction of smoke-free laws reduced SHS exposure in venues directly affected by the law (enclosed workplaces, public places, and hospitality venues) as well as in unregulated settings, such as homes (Fernández et al., 2017). After Law 42/2010 came into effect, a study found a 2% reduction in the proportion of Spanish households with smokers (García-Villar and López-Nicolás, 2015). However, homes are still one of the main sources of SHS exposure among children (López et al., 2018), who are highly exposed whenever there are smokers in the family (Arechavala et al., 2018a).

Worldwide, 603,000 deaths were attributed to SHS exposure in 2004, including 166,221 deaths among children younger than 15 years old (Öberg et al., 2011). The number of deaths caused by LRI attributable to SHS exposure among children younger than 5 years old was the second largest (165,000) after ischemic heart disease deaths in adults (379,000). In Europe, 6245 deaths caused by LRI were attributable to SHS (Öberg et al., 2011). In children, estimates of the burden of disease in terms of mortality and disability-adjusted life years lost attributable to SHS have been published in countries such as the United Kingdom (The Royal College of Physicians, 2010), Poland (Jarosińska et al., 2014), Canada (Simons et al., 2011), and New Zealand (Mason, 2016). These studies have mostly focused on asthma, LRI, and OM.

In Spain, mortality in adults due to SHS-related causes was estimated before (López et al., 2007) and after (López et al., 2016) the introduction of the smoke-free law. However, to the best of our knowledge, studies assessing the burden of SHS-related diseases attributable to SHS exposure in children in Spain are scarce, and none has focused on incident cases and hospital admissions. The objective of this study was to estimate the number of incident cases and hospital admissions attributable to SHS exposure at home for asthma, OM, and LRI in children in Spain.

2. Methods

2.1. Exposure to secondhand smoke

Data on the prevalence of SHS exposure in children were obtained from a telephone survey administered in 2016 to a representative sample of 2411 Spanish households with children younger than 12 years old (López et al., 2018). Households were randomly selected considering different strata according to geographical region, size of municipality of residence and quota of sex and age of the youngest child living at home. The questionnaire gathered specific and extensive information related to SHS exposure in different settings and was administered to parents or legal tutors through landlines and mobile phones. Exposure to SHS at home was defined by the existence of at least one smoker among household members at the time of the interview, which has been widely used in studies analyzing the association between SHS exposure and health outcomes (The Royal College of Physicians, 2010; Jones et al., 2012, 2011; Burke et al., 2012). The prevalence of exposure was calculated for boys and girls separately and for different age groups: 0 to 1 years old, 0 to 4 years old, 5 to 11 years old, and 0 to 11 years old.

2.2. Health outcomes and risk estimates

The health outcomes selected where those with sufficient and strong evidence to be causally linked to SHS exposure and with information about incidence and hospitalizations available for Spain in 2015. The health outcomes analyzed were asthma, OM and LRI, which includes bronchitis, bronchiolitis, and other LRI diseases. All measures were estimated for the year 2015. Risk estimates of disease from SHS exposure were selected from previous meta-analyses (Jones et al., 2012; Jones et al., 2011; Tinuoye et al., 2013), which showed consistent evidence of causality between SHS exposure and the health outcomes studied (Table 1).

Incident cases were estimated through complex mathematical models using different information sources according to data availability in each country by the Global Health Data Exchange (GHDx) (Global Burden of Disease Study 2015, 2016) and were defined as the number of new cases of a given disease during the year of the study. We selected figures referring to incident cases of asthma, OM, and LRI in 2015 among children aged 0 to 14 years old in Spain, stratifying by sex and age groups (0–4 years old for all diseases and 5–14 years old for asthma and OM). The codes used to define each health outcome were those used by the GHDx for the incidence of nonfatal diseases (Global Burden of Disease Study 2015, 2015): 1) asthma included diseases with tenth Revision of International Classification of Diseases (ICD-10) codes J45-J45.5 and J45.8-J45.9; 2) OM included diseases with ICD-10 codes H65-H65.4 and H66-H66.2; and 3) LRI included diseases with ICD-10 codes A48.1, J10-J10.2, J10.8-J10.9, J11-J11.2, J11.8, J12-J12.3, J12.8-J12.9, J15-J15.9, J16.0, J16.8, J17-J17.3, J17.8, J18-J18.2, J18.8-J18.9, J20-J20.9, J21-J21.1, J21.8-J21.9, J85.1, P23-P23.6, and P23.8-P23.9.

Hospitalizations were obtained from the Hospital Minimum Data Set (MDS) provided by the Ministry of Health, Social Services and Equality of Spain. The database gathers individual information on the main and secondary diagnosis by physicians in all Spanish hospitals. We subsequently selected the number of cases hospitalized, which was defined as those children aged 0 to 11 years old who had been admitted at least once to a hospital with the selected health outcomes (asthma, OM, bronchitis, bronchiolitis, and LRI) as the main admission diagnosis in 2015 in Spain. The number of cases with any hospitalization was calculated according to sex and age groups depending on the health outcome (0–4 years and 5–11 years old for asthma and OM; 0–1 year old for bronchitis, bronchiolitis and LRI). The codes used to define each health outcome were selected according to those employed in studies included in the meta-analysis used in the present study for risk estimates. The ICD-9-CM codes included for each health outcome were as follows: 1) asthma: code 493; 2) OM: codes 381.0–381.4 and 382; 3) bronchitis: codes 466.0, 490, and 491.22; 4) bronchiolitis: codes 466.11 and 466.19; and 5) LRI: 073.0, 079.8, 466, 480–488, 490, 491.22, 513.0, and 770.0.

2.3. Estimation of burden of disease

The burden of respiratory disease (for asthma, OM, bronchitis, bronchiolitis, and LRI) attributable to SHS exposure was estimated by multiplying the population attributable fraction (PAF) to SHS by the total burden of these diseases in terms of incident cases and hospitalized cases.

The PAF, which is the proportion of a health outcome attributable to a specific risk factor, was calculated by applying the classic

Table 1
Effect estimates for the health outcomes related to SHS in children.

Health outcome	Odds ratio (95%CI)	SHS exposure	Age (y)	Design of included studies	Reference
Asthma	1.32 (1.23–1.42)	Self-reported SHS or biomarkers (cotinine)	< 18 y	14 cross-sectional; 2 case-control; 4 cohort	Tinuoye et al., 2013
Otitis media	1.32 (1.20–1.45)	Self-reported SHS at home (any household member smokes)	< 16 y	Cross-sectional; case-control; cohort (38)	Jones et al., 2012
Bronchitis	1.58 (1.27–1.98)	Self-reported SHS at home and/or biochemical validation (any household member smokes)	< 2 y	3 cross-sectional; 4 cohort	Jones et al., 2011
Bronchiolitis	2.51 (1.96–3.21)	Self-reported SHS at home and/or biochemical validation (any household member smokes)	< 2 y	2 cross-sectional; 5 case-control	Jones et al., 2011
Lower respiratory infection	1.54 (1.40–1.69)	Self-reported SHS at home and/or biochemical validation (any household member smokes)	< 2 y	17 cross-sectional; 11 case-control; 9 cohort	Jones et al., 2011

CI: confidence interval; SHS: secondhand smoke.

epidemiological formula (Szklo and Nieto, 2014):

$$PAF_{SHS} = (P_{SHS} \times (OR-1))/(P_{SHS} \times (OR-1) + 1)$$

where P_{SHS} is the prevalence of children exposed to SHS and OR refers to the odds ratio of morbidity related to SHS exposure. The PAF and the total burden of disease attributable to SHS was calculated by sex and age groups for each health outcome.

2.4. Sensitivity analysis

We conducted a sensitivity analysis including alternative assumptions to assess different scenarios. Incident cases attributable to SHS were assessed according to the following alternative assumptions: 1) defining SHS exposure at home as any household member usually smoking inside the home (excluding outside areas such as balconies or terraces); 2) defining SHS exposure at home as any household member usually smoking either inside or outside (i.e., balcony, terrace) the home; 3) defining SHS exposure as overall exposure in both private and public settings; 4) using the lower 95% confidence interval (CI) of OR estimates and prevalence of SHS exposure; and 5) using the upper 95%CI of OR estimates and prevalence of SHS exposure. For hospitalizations, we also tested the following assumptions: 6) for asthma, using the risk rate of hospital admissions due to asthma exacerbation on the basis of another recent meta-analysis (Wang et al., 2015); and 7) considering the main diagnosis and subsequent diagnosis as the cause of the hospitalizations for each disease.

All sensitivity analyses were conducted for asthma, OM, and LRI without considering sex and age groups. The effect of changing assumptions is presented in terms of both absolute and percentage changes in the number of incident cases and hospitalized cases attributable to SHS with respect to the baseline assumption.

3. Results

In 2015, SHS exposure caused an estimated total of 136,403 incident cases (65,860 cases in boys and 70,552 in girls) of the following respiratory conditions: 9058 of asthma, 120,248 of OM, and 7097 of LRI in children aged 0 to 14 years old in Spain. The largest number of cases attributed to SHS exposure was caused by OM (120,248). In children 0 to 4 years old, 73,194 incident cases of OM, 7097 of LRI, and 3560 of asthma were attributed to SHS exposure. In children 5 to 14 years old, this number was lower for OM (46647) and was higher for asthma (5498). SHS exposure caused 57,326 incident cases of OM, 4159 of LRI and 4375 of asthma in boys. In girls, these numbers were 62,922, 2948 and 4682, respectively (Table 2).

In terms of hospitalizations in 2015, SHS exposure caused 3028 cases with at least 1 hospitalization due to asthma, OM, or any LRI. In children 0 to 11 years old, a total of 379 cases hospitalized due to asthma and 167 due to OM were attributable to SHS exposure. For both health outcomes, the number of cases hospitalized was slightly higher in children aged 0 to 4 years old (206 in asthma and 103 in OM) and among boys (235 and 97, respectively). An estimated 2482 cases of hospitalization due to LRI (1493 in boys and 998 in girls) were attributed to SHS exposure in infants 0 to 1 years old. When bronchiolitis was analyzed separately from other LRI, SHS exposure was responsible for an estimated 4036 of hospitalized cases, this number being 2415 in boys and 1634 in girls (Table 3).

Estimates obtained from sensitivity analyses are shown in Table 4. When we used a more restrictive definition of SHS exposure (based on reporting smoking inside the home), incident cases attributable to SHS exposure decreased to 38,117 (a 72% decrease). On the other hand, when we assumed an overall SHS exposure including different private and public settings, the total number of incident cases increased to 299,239. When we used the lower and upper limits of the 95%CI of OR and prevalence of SHS exposure, the total number of incident cases ranged from 89,272 to 184,512. For hospitalizations, cases of asthma ranged from 105 to 831, cases of OM from 46 to 367, and cases of LRI from 660 to 5463 when we assumed different definitions of SHS exposure and 95%CI of OR and prevalence of SHS exposure. When we assumed an estimate risk of hospital admissions due to asthma exacerbations instead of the incidence of disease, incident asthma cases increased to 882 (an increase of 133%). Finally, when we considered not only the main diagnosis but also secondary diagnosis, SHS exposure was responsible for 505 cases hospitalized with asthma (an increase of 33.2%), 610 with OM (an increase of 265.3%), and 2782 with LRI (an increase of 12.1%).

4. Discussion

SHS exposure caused almost 140,000 incident cases of asthma, OM and LRI in Spanish children in the year 2015. By far the highest number of incident cases was caused by OM (120,248). Hospitalizations attributable to SHS exposure occurred mostly in infants aged 0–1 years old and were due to LRI, especially to bronchiolitis (4036).

Smoke-free laws introduced in Spain (Law 28/2005 and Law 42/2010) have been found to be successful in reducing SHS exposure (Fernández et al., 2017; López et al., 2013). These laws reduced SHS exposure not only in the public places covered by their content, but also in private transport and homes (Fernández et al., 2017; García-Villar and López-Nicolás, 2015; Sureda et al., 2014). In some regions of Spain, there are also specific strategies implemented in primary health care level focused on reducing SHS exposure in children (i.e. smoke-free childhood in Catalonia). Nevertheless, SHS exposure in homes remains unacceptably high. In 2016 one out of every 3 children younger than 12 years of age was exposed to SHS at home (López et al., 2018). Moreover, previous studies have found high nicotine concentrations in

Table 2
Number of incident cases attributable to secondhand smoke exposure in children by sex. Spain, 2015.

Health outcome	BOYS				GIRLS				TOTAL[a]			
	Total number of incident cases	Prevalence of SHS exposure[b]	PAF_{SHS}	Cases attribut.[c]	Total number of incident cases	Prevalence of SHS exposure[b]	PAF_{SHS}	Cases attribut.[c]	Total number of incident cases	Prevalence of SHS exposure[b]	PAF_{SHS}	Cases attribut.[c]
	N	% (95%CI)	%	n	N	% (95%CI)	%	n	N	% (95%CI)	%	n
Asthma												
0–4 y	21,594	29.4 (25.5–33.6)	8.6	1856	20,598	28.1 (24.2–32.5)	8.3	1699	42,192	28.8 (26.0–31.8)	8.4	3560
5–14 y	29,772	28.9 (25.7–32.3)	8.5	2520	34,370	29.8 (26.5–33.2)	8.7	2992	64,142	29.3 (27.0–31.7)	8.6	5498
All ages	51,366	29.1 (26.6–31.7)	8.5	4375	54,968	29.1 (26.6–31.8)	8.5	4682	106,334	29.1 (27,3–31.0)	8.5	9058
Otitis media												
0–4 y	415,246	29.4 (25.5–33.6)	8.6	35,707	452,162	28.1 (24.2–32.5)	8.3	37,304	867,408	28.8 (26.0–31.8)	8.4	73,194
5–14 y	257,703	28.9 (25.7–32.3)	8.5	21,814	286,470	29.8 (26.5–33.2)	8.7	24,939	544,173	29.3 (27.0–31.7)	8.6	46,647
All ages	672,949	29.1 (26.6–31.7)	8.5	57,326	738,632	29.1 (26.6–31.8)	8.5	62,922	1,411,581	29.1 (27.3–31.0)	8.5	120,248
LRI												
0–4 y	30,356	29.4 (25.5–33.6)	13.7	4159	22,381	28.1 (24.2–32.5)	13.2	2948	52,737	28.8 (26.0–31.8)	13.5	7097
Total[d]	44,458	–	–	65,860	1,609,581	–	–	70,552	77,566	–	–	136,403

CI: confidence interval; LRI: lower respiratory infection; PAF: population attributable fraction; SHS: secondhand smoke.
[a] Totals were calculated directly using specific prevalences of SHS exposure for both girls and boys together. Totals do not exactly sum results for girls and boys.
[b] Any household member is a smoker. SHS exposure was calculated according to the age groups 0–4 y, 5–11 y and 0–11 y.
[c] Incident cases attributable to SHS have been calculated using all decimal digits obtained from the PAF classic formula.
[d] Includes the sum of incident cases of asthma, OM, and LRI attributable to SHS exposure.

homes with smokers. A study performed in homes with children showed a median nicotine concentration of 1.04 μg/m^3 in the living room and 0.48 μg/m^3 in the children's bedroom in homes with smokers who reported smoking inside the home, these values being relevant to child health (Arechavala et al., 2018a).

There is strong evidence to infer a causal association between SHS exposure and the occurrence and severity of respiratory diseases in children (Office on Smoking and Health (US), 2006). Our results showed that the PAF_{SHS} estimated for OM and asthma ranged from 8.3% to 8.7%, depending on sex and age group. The PAF_{SHS} for LRI were higher, ranging from 11.1% to 27.6%. The markedly highest PAF_{SHS} were found for bronchiolitis in infants 0 to 1 years old, which doubled those obtained for bronchitis and LRI in general. This difference was mainly due to the stronger causal relationship between SHS exposure and bronchiolitis (Jones et al., 2011). The risk estimate for LRI was lower than for bronchiolitis, because the estimate was obtained from a meta-analysis that included some other LRI (i.e., pneumonia, acute respiratory infection) along with bronchiolitis, which have been found to be more weakly associated with SHS exposure.

In our study, SHS exposure was defined as living with at least one smoker. The use of a more stringent definition of SHS exposure, such as children living in homes where smoking inside was reported, would have led to more intensive SHS exposure and therefore more conservative criteria to calculate estimates of PAF_{SHS} (a decrease of approximately 70% according to results found in the sensitivity analysis). However, most studies analyzing the relationship between SHS exposure and health problems define exposure as reported in the present study (The Royal College of Physicians, 2010; Jones et al., 2012; Jones et al., 2011; Burke et al., 2012). On the other hand, we could consider this assumption as conservative, as we did not analyze global SHS exposure, taking into account exposure in other settings such as private cars, relatives' households or outdoor settings where children have been found to be exposed to SHS (López et al., 2018), which could harm their health. As per our sensitivity analysis, use of global SHS exposure (71.8%) to calculate the PAF_{SHS} would increase the figures obtained by 120% (around 300,000 incident cases and almost 7000 cases of hospitalized cases).

Mortality due to asthma, OM, and LRI attributable to SHS exposure among children from countries with similar mortality rates to Spain is lower than those found in African or Asian countries (Öberg et al., 2011; Mason, 2016). However, morbidity caused by SHS exposure is not negligible and calls for further public health awareness. A study conducted in the United Kingdom estimated PAF_{SHS} and the disease events caused by SHS exposure at home in children for 2008 and reported PAF_{SHS} (11% of LRI, 7% of middle ear disease and 4–10% of asthma depending on age) similar to those shown in our study. In terms of morbidity, that study showed that 20,500 cases of LRI (children < 3 years), 121,400 cases of OM (children 0–16 years), and 15,400 cases of asthma (children 3–14 years) were attributable to SHS exposure. After analyzing differences in population size (2-fold higher in the United Kingdom (The Royal College of Physicians, 2010) than in Spain (National Statistics Institute, 2016)) and similarities in PAF_{SHS}, these estimates seem to differ from our results (120,248 for OM and 9058 for asthma in children 0–14 years and 7097 for LRI in children 0–4 years), being higher in our study for OM. However, comparisons between the two studies should be interpreted with caution, due to methodological differences such as the year when the study was conducted, the age groups analyzed, sources of data, differences in SHS exposure prevalences, disease incidences and differences in the ICD codes used to classify cases for the studied health outcomes.

Our results show a large number of hospital admissions due to LRI. Around 2500 hospital admissions could have been prevented by introducing smoke-free rules at home. When we estimated hospitalizations specifically due to bronchiolitis, this figure increased to > 4000. An explanation for this huge difference could be that bronchiolitis by itself is a disease with one of the strongest causal associations with SHS exposure. As previously stated, when we included other diseases of the lower respiratory tract in the analysis, the risk estimate of morbidity

Table 3
Number of hospitalized cases attributable to secondhand smoke exposure in children by sex. Spain, 2015.

Health outcome	Boys				Girls				Total[a]			
	Total number of hospitalized cases	Prevalence of SHS exposure[b]	PAF_{SHS}	Hospitalized cases attribut.[c]	Total number of hospitalized cases	Prevalence of SHS exposure[b]	PAF_{SHS}	Hospitalized cases attribut.[c]	Total number of hospitalized cases	Prevalence of SHS exposure[b]	PAF_{SHS}	Hospital admission attribut.[c]
	N	% (95%CI)	%	n	N	% (95%CI)	%	n	N	% (95%CI)	%	n
Asthma												
0–4 y	1563	29.4 (25.5–33.6)	8.6	134	888	28.1 (24.2–32.5)	8.3	73	2451	28.8 (26.0–31.8)	8.4	206
5–11 y	1202	28.9 (25.7–32.3)	8.5	101	798	29.8 (26.5–33.2)	8.7	69	2000	29.3 (27.0–31.7)	8.7	171
All ages	2765	29.1 (26.6–31.7)	8.5	235	1686	29.1 (26.6–31.8)	8.5	143	4451	29.1 (27,3–31.0)	8.5	379
Otitis media												
0–4 y	731	29.4 (25.5–33.6)	8.6	62	495	28.1 (24.2–32.5)	8.3	40	1226	28.8 (26.0–31.8)	8.4	103
5–11 y	418	28.9 (25.7–32.3)	8.5	35	325	29.8 (26.5–33.2)	8.7	28	743	29.3 (27.0–31.7)	8.6	63
All ages	1149	29.1 (26.6–31.7)	8.5	97	820	29.1 (26.6–31.8)	8.5	69	1969	29.1 (27,3–31.0)	8.5	167
Bronchitis												
0–1 y	1884	25.3 (19.3–32.4)	12.8	241	1169	23.2 (17.1–30.6)	11.9	138	3053	24.3 (19.9–29.3)	12.4	377
Bronchiolitis												
0–1 y	8738	25.3 (19.3–32.4)	27.6	2415	6301	23.2 (17.1–30.6)	25.9	1634	15,039	24.3 (19.9–29.3)	26.8	4036
LRI												
0–1 y	12,427	25.3 (19.3–32.4)	12.0	1493	8970	23.2 (17.1–30.6)	11.1	998	21,397	24.3 (19.9–29.3)	11.6	2482
Total[d]	30,877	–	–	1825	21,452	–	–	1210	52,329	–	–	3028

CI: confidence interval; LRI: lower respiratory infection; PAF: population attributable fraction; SHS: secondhand smoke.
[a] Totals were calculated directly using specific prevalences of SHS exposure for both girls and boys together. Totals do not exactly sum results for girls and boys.
[b] Any household member is a smoker. SHS exposure was calculated according to the age range analyzed.
[c] Hospitalized cases attributable to SHS have been calculated using all decimal digits obtained from the PAF classic formula.
[d] Includes the sum of hospitalized cases for asthma, OM, and LRI.

due to SHS exposure for LRI decreased, since the relationship between SHS and other LRI are weaker. Thus, estimates may change depending on the diseases classified as LRI in the analysis.

Previous studies (Rayens et al., 2008; Rando-Matos et al., 2017) have shown a decrease in hospital admissions due to asthma in adults after the introduction of smoke-free legislation. However, in children, reductions have been less intense (Rando-Matos et al., 2017). These discrepancies among adults and children might be due to differences in SHS exposure settings. Adults might be exposed in settings covered by smoke-free legislations such as hospitality venues and the workplace while the main venues of SHS exposure in children are homes and private cars (Office on Smoking and Health (US), 2006), neither of which are covered by legislation in most countries, except for some, such as the United Kingdom, France, Australia, the US, Canada (López and Continente, 2016), or recently Italy in cars. Our results show figures for OM (167) and asthma (379) markedly lower than for LRI. However, when considering the risk of hospital admissions for asthma exacerbations in the sensitivity analysis, morbidity attributable to hospitalizations due to asthma (Wang et al., 2015), which are probably due to more severe asthma exacerbations, increased by 133% to a total of 882 cases. Therefore, these figures should not be disregarded since they are not trivial and might represent high health costs for children and economic costs for healthcare services (Batscheider et al., 2012).

This study has intrinsic limitations. First, we estimated the number of incident cases and hospitalized cases caused by past SHS exposure by using the most recent year (2016) exposure figures. However, since most children involved in this study were born after the introduction of smoke-free laws, the prevalence of SHS exposure would not have differed much from then onward. Children born before the law came into effect may have been exposed to higher levels of SHS, and consequently we may have underestimated the number of incident cases and hospitalizations attributable to SHS exposure. Additionally, SHS exposure was defined on the basis of self-reported information, which may generate information bias. However, self-reported SHS exposure has been proven to have good validity (Arechavala et al., 2018b). Moreover, the indicator used was the number of smokers at home, which should not be that sensitive to this type of bias. Second, our estimates are not based on relative risks for SHS exposure from the Spanish population, due to a lack of local and national evidence. Moreover, risk estimates used in this study did not take into consideration some potential confounding factors such as indoor or outdoor pollution. Nevertheless, we obtained risks estimates from meta-analyses, pooling data from different countries, used in previous studies to determine the burden of respiratory disease attributable to SHS exposure in other countries (Jarosińska et al., 2014), which also made our results comparable with those of other published studies. Third, the number of incident cases for all diseases was not obtained from microdata, but from estimates published in the GHDx website, which hampers the acquisition of further information about what this measure takes into account. However, incidence data for the diseases studied are not available in Spain. Finally, we analyzed heterogeneous age groups, depending on the health outcome, the measure studied, and the information source used. Thus, the prevalence of SHS exposure was calculated for children 0 to 11 years old, while data on incident cases were for children 0 to 14, since incident cases were obtained from aggregated data published in specific age groups instead of microdata;

Table 4
Sensitivity analysis of incident cases and hospitalized cases attributable to SHS based on different alternative assumptions.[a]

Alternative assumption	Asthma[b]		Otitis media[b]		LRI[c]		TOTAL	
	n	% of change[d]	n	% of change[d]	n	% of change[d]	n	% of change[d]
Incident cases								
SHS exposure based on household members smoking inside (7.6% in 0-11y)	2524	−72.1%	33,514	−72.1%	2079	−70.7%	38,117	−72.1%
SHS exposure based on household members smoking inside or outside (25.8% in 0-11y)	8109	−10.5%	107,652	−10.5%	6448	−9.1%	122,209	−10.4%
Overall SHS exposure (71.8% in 0-11y)[e]	19,866	119.3%	263,730	119.3%	15,643	120.4%	299,239	119.4%
SHS exposure and odds ratio obtained from lower 95%CI	6670	−26.4%	77,635	−35.4%	4967	−30.0%	89,272	−34.6%
SHS exposure and odds ratio obtained from upper 95%CI	11,580	27.8%	163,443	35.9%	9489	33.7%	184,512	35.3%
Hospitalizations								
SHS exposure based on household members smoking inside (7.6% in 0-11y and 5.9% in 0-1y)	105	−72.3%	46	−72.5%	660	−73.4%	811	−73.2%
SHS exposure based on household members smoking inside or outside (25.8% in 0-11y and 22.5% in 0-1y)	339	−10.6%	150	−10.2%	2318	−6.6%	2807	−7.3%
Overall SHS exposure (71.8% in 0-11y and 63.5% in 0-1y)[d]	831	119,3%	367	119,8%	5463	120,1%	6661	120.0%
SHS exposure and odds ratio obtained from lower 95%CI	279	−26.4%	108	−35.3%	1895	−23.7%	2282	−24.6%
SHS exposure and odds ratio obtained from upper 95%CI	484	27.7%	227	35.9%	3072	23.8%	3783	24.9%
Hospital admissions according to the main or subsequent diagnosis	505	33.2%	610	265.3%	2782	12.1%	3897	28.7%
Risk rate for hospital admissions due to asthma exacerbation (OR = 1.85 [95%CI:1.20–2.86]) (Wang et al., 2015)	882	132.7%	–	–	–	–	–	–

CI: confidence interval; LRI: lower respiratory infections; OR: odds ratio; SHS: secondhand smoke.
[a] Risk estimates used are the ones showed in Table 1 except for the assumption "risk rate for hospital admissions due to asthma exacerbation".
[b] Children aged 0–14 years old for incident cases and children aged 0–11 years old for hospitalizations.
[c] Children aged 0–4 years old for incident cases and children aged 0–1 years old for hospitalizations.
[d] Percentage of change compared with the main assumption.
[e] It includes homes, cars, public transport stations, school and nursery gates, hospitality venues, leisure centers, family or friends' houses and other places related to leisure time (Lopez et al., 2018).

consequently, we were not able to disaggregate data for different age groups. The inclusion of children aged 12–14 years old for some diseases might result in an overestimation of attributable incident cases among this group of age since some of them might already have ever smoked, and be thus misclassified as passive smokers. Nonetheless, the mean age of starting tobacco consumption in Spain in 2016 was 14.1 years old (Plan Nacional sobre Drogas, 2018), minimizing thus this limitation.

To our knowledge, there are no published studies estimating the burden of respiratory disease attributable to SHS exposure in children in a southern European country. In addition, we used primary data from a representative sample of Spanish children to determine the prevalence of SHS exposure, which provided specific prevalences of SHS exposure according to sex and age groups to calculate more reliable estimates. We also used objective data of hospital admissions from the MDS to determine cases hospitalized due to the diseases studied, which allowed us to analyze data aggregated by using suitable age groups.

5. Conclusions

Exposure to SHS at home in 2015 caused about 140,000 incident cases and 3000 cases hospitalized for preventable respiratory diseases such as asthma, OM, and LRI in children 0 to 14 years old. This relevant burden of respiratory disease due to SHS exposure calls for improvements in the protection of children against SHS exposure through the further implementation of existing legislation and the extension of smoke-free regulations. Regarding SHS exposure at home, educational campaigns and counseling about smoking cessation among household members of families with children or alternatively interventions focused on promoting smoke-free homes would be needed.

Acknowledgments

The authors would like to thank all participants of the survey to assess SHS exposure. We also thank the Health Information Institute of the Ministry of Health, Social Services and Equality of Spain for providing us with the Hospital Minimum Data Set.

Funding

This work was supported by the Instituto de Salud Carlos III (PN I +D+I 2013–2016) and co-funded by the European Regional Development Fund (FEDER) (grant number PI13/02734). The Evaluation and Intervention Methods Service of the Public Health Agency of Barcelona and the Tobacco Control Unit of the Catalan Institute of Oncology were also partially supported by the Ministry of Universities and Research of Catalonia (AGAUR) (grant numbers 2014SGR1373 and 2014SGR319). This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 681040.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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