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Trends in children's exposure to second-hand smoke in the INMA-Granada cohort: An evaluation of the Spanish anti-smoking law

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ABSTRACT

The smoke-free legislation implemented in Spain in 2006 imposed a partial ban on smoking in public and work places, but the result did not meet expectations. Therefore, a more restrictive anti-smoking law was passed five years later in 2011 prohibiting smoking in all public places, on public transport, and the workplace. With the objective of assessing the impact of the latter anti-smoking legislation on children's exposure to second-hand smoke (SHS), we assessed parent's smoking habits and children's urine cotinine (UC) concentrations in 118 boys before (2005–2006) and after (2011–2012) the introduction of this law. Repeated cross-sectional follow-ups of the "Environment and Childhood Research Network" (INMA-Granada), a Spanish population-based birth cohort study, at 4–5 years old (2005–2006) and 10–11 years old (2011–2012), were designed. Data were gathered by ad-hoc questionnaire, and median UC levels recorded as an objective indicator of overall SHS exposure. Multivariable logistic regression was used to examine the association between parent's smoking habits at home and SHS exposure, among other potential predictors. An increase was observed in the prevalence of families with at least one smoker (39.0% vs. 50.8%) and in the prevalence of smoking mothers (20.3% vs. 29.7%) and fathers (33.9% vs. 39.0%). Median UC concentration was 8.0 ng/mL (interquartile range [IQR]: 2.0–21.8) before legislation onset and 8.7 ng/mL (IQR: 2.0–24.3) afterwards. In the multivariable analysis, the smoking status of parents and smoking habits at home were statistically associated with the risk of SHS exposure and with UC concentrations in children. These findings indicate that the recent prohibition of smoking in enclosed public and workplaces in Spain has not been accompanied by a decline in the exposure to SHS among children, who continue to be adversely affected. There is a need to target smoking at home in order to avoid future adverse health effects in a population that has no choice in the acceptance or not of SHS exposure-derived risk.

1. Introduction

Over recent decades, a vast array of findings has associated both active and passive smoking with multiple adverse health effects. Young children are not smokers; however, their exposure to second-hand smoke (SHS) is considered a major global public health issue, given the vulnerability of this age group to the health effects of passive smoking. This has been attributed to their higher respiratory rates and less mature immune, nervous, and respiratory systems (Polanska et al., 2006) and it has been reported that SHS is among the leading causes of respiratory morbidity and mortality among infants (Puig et al., 2008). SHS has also been associated with recurrent wheezing, respiratory illnesses, decreased lung function, and asthma (Akinbami et al., 2013), as well as obesity (Lisboa et al., 2012), behavioral disorders (Desrosiers

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et al., 2013), and kidney and endocrine dysfunction (García-Esquinas et al., 2013) in young children. Indeed, it has been reported that the annual excess mortality in children aged 5 years or younger due to SHS exposure may be higher than that due to all other causes (Florescu et al., 2009). According to the EPA, children's exposure to SHS in the USA is responsible for: (i) increases in the number of asthma attacks and severity of symptoms in 200,000–1 million children with asthma; (ii) between 150,000 and 300,000 lower respiratory tract infections in children under 18 months of age; and (iii) respiratory tract infections that result in 7500–15,000 hospitalizations each year (EPA, 2011).

Public health authorities have taken various steps to reduce smoke-related diseases. In 2006, Spanish government approved an initial law to prevent smoking in all enclosed workplaces (Law 28/2005), although the degree of restriction depended on the decision of each business owner. This legislation, aimed to protect the health of non-smokers, did not meet expectations. Some studies showed major reductions in the exposure to SHS at the workplace, but no significant changes were observed at home or in leisure spaces (Galán et al., 2007; Jiménez-Ruiz et al., 2008). As a result, the law was amended five years later on January 2 2011, establishing a more severe anti-smoking regime (Law 42/2010, of December 30) and imposing a complete ban on smoking in enclosed public places, on public transport, and in the workplace. The aims of this law were: (i) to protect non-smokers from SHS exposure, (ii) to prevent smoking initiation among young people, and (iii) to promote smoking cessation.

According to the National Health Survey carried out in Spain in 2012, a quarter of the population smoked daily; the prevalence of exposure to SHS in the workplace (2.6%) and in enclosed places and on public transport (2.4%) had markedly decreased; and the household was the most frequent place for exposure to tobacco smoke (17.8%) (National Health Survey, 2011–2012). This is especially relevant to children, given the amount of time they spend in the home.

Although a total ban on smoking at home could be expected to significantly reduce the children's SHS exposure, there appears to be no short-term prospect of this type of legislation in Europe. Most EU member states, including Spain, have implemented complementary strategies to protect children and adolescents, following the Tobacco Products Directive of the EU Commission (2001/37/EC 2001) and the Framework Convention on Tobacco Control (FCTC), which has been ratified by 177 countries. One key aspect of these strategies is to raise the consciousness of citizens about the need for a smoke-free environment in the home (Borland et al., 2006).

Research carried out in countries with an established anti-smoking law has warned that national anti-smoking legislation for workplaces and public places is inadequate to protect children and adolescents from SHS (Akhtar et al., 2007; Protano et al., 2012). Thus, it was reported that the 2006 anti-smoking law in Scotland had no significant effect on the prevalence of smoke-free homes (64.5% vs. 64.3% just before and after smoke-free legislation, respectively) or on the exposure of school students to environmental tobacco smoke (Akhtar et al., 2007).

There has been some research into the effects of the 2010 Spanish anti-smoking law on SHS exposure in adults (Villaverde Royo et al., 2012; Perez-Rios et al., 2014; Sureda et al., 2014; Sánchez-Rodríguez et al., 2015). However, it is also important to establish whether the stricter smoking ban has had an impact on the reduction of exposure in children, by evaluating, for example, the cotinine load in this population. The objectives of the present study were: to assess the impact of the Spanish anti-tobacco legislation (Law 42/2010) on children's exposure to passive smoking exposure by comparing urine cotinine (UC) excretion before and after implementation of the law; and to review how the smoking status of parents and smoking habits at home were related to SHS exposure among boys from the Spanish INMA-Granada cohort evaluated at follow-ups in 2005–2006 and 2011–2012.

2. Methods

2.1. Study population and design

The study sample was drawn from the "Environment and Childhood Research Network" (INMA network), a population-based cohort study in different regions of Spain that focuses on prenatal environmental exposures in relation to growth, development, and health from early fetal life until childhood. The INMA study protocol includes medical follow-ups of the children during childhood as well as epidemiological questionnaires and biological sample collections (Guxens et al., 2012).

From October 2000 to July 2002, 668 eligible mother–son pairs registered at the San Cecilio University Hospital of Granada (a province in Southern Spain) were recruited at delivery, establishing the INMA-Granada cohort, with the initial aim of assessing the prevalence of urogenital male malformations (cryptorchidism and hypospadias) (Fernandez et al., 2007). The inclusion and exclusion criteria were published elsewhere (Freire et al., 2009). Between April 2005 and June 2006, 1 out of 3 mothers of control boys was randomly contacted to arrange a follow-up appointment, which included completion of an ad hoc questionnaire on their home environment. Two hundred-twenty families agreed to participate; urine samples were collected for 196 of the 220 children, but self-report questionnaire and urine was only available for 166 of these (Freire et al., 2009). Six years later (between February 2011 and December 2012), all families in the cohort ($n=668$) were contacted and invited to participate in this follow-up. A total of 300 boys were finally enrolled and their families again completed an ad hoc questionnaire on their home environment. Twenty-four of these were excluded for an inadequate urine sample or incomplete questionnaire; therefore, urine was available for 276 of these boys. The present study only included the 118 boys who attended both follow-ups in order to compare SHS exposure levels before and after the anti-smoking law entered into force (Fig. 1). Written informed consent was obtained from the parents (mother or father) on behalf of children enrolled in our study. The families registered in the follow-ups signed the informed consent form, which included completion of ad hoc questionnaires. The study followed the guidelines laid down in the Declaration of Helsinki and was approved by the Ethics Committee of San Cecilio University Hospital, Granada, Spain.

2.2. Covariates and SHS exposure data gathered by questionnaire

The structured questionnaire completed by parents in both follow ups included information on the smoking habits of parents; maternal smoking habits during pregnancy, the number of cigarettes per day smoked by family members, and the presence or absence of cohabitant smokers (global SHS exposure).

Children were considered to be exposed to SHS when at least one family member declared a smoking habit, based on responses to the questionnaire item: "are there smokers living with the child?", defining smokers as those consuming any amount of tobacco (>2 times per week). The degree of exposure was assessed according to: the smoking habit of the mother during the pregnancy; current smoking habits of the parents (yes/no) and of all cohabitants (cigarettes/day, and cigarettes/day smoked in the house).

The questionnaire yielded additional information on the children's age, area of residence, and parent's education. Parental

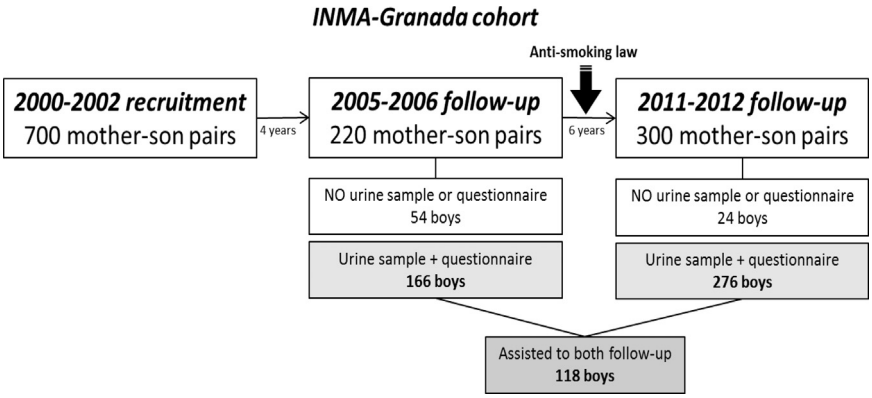

Fig. 1. The flow chart details the boy's flux from birth recruitment to final subpupulation included in the study.

educational level was considered in two categories (university and others). Area of residence was classified into four categories: urban (city of Granada), metropolitan (towns of $>20{,}000$ inhabitants in city residential belt), sub-urban (towns of 10,000–20,000 inhabitants), rural ($<10{,}000$ inhabitants).

2.3. Urine cotinine levels

Urine samples (≈ 30 ml) were collected in the afternoon during the follow up visits at the hospital and stored immediately in three 10-ml aliquots at -80 °C until analysis. One aliquot of each sample was sent to the Public Health Laboratory of the Basque Country (Spain) for analysis. Cotinine levels were determined by competitive enzyme immunoassay (EIA) using commercial EIA microplate test kits (Ora Sure Technologies, Inc, Bio-Rad) for saliva adapted for urine samples (Bio-Rad). The method was validated by using a certified reference material (EPA/NIST Reference Material 8444); the quantification limit (LOQ) was 4.0 ng/mL and the coefficients of repeatability 7% and reproducibility were 7% and 10%, respectively. Laboratory method for UC quantification was already described (Aurrekoetxea et al., 2013, 2014). Samples with cotinine levels above 50 ng/mL were diluted. For urine samples with cotinine levels $\leq$ LOQ, a value of half the LOQ was taken. UC levels were expressed as median and interquartile range (IQR) in ng/mL. The results were also expressed as creatinine-corrected cotinine to minimize the effect of renal clearance. Considering the standard cut-offs of UC levels (5.0 and 10 ng/mL) (Florescu et al., 2009), children were classified as exposed (above or equal cut-off) or unexposed (below cut-off) to SHS at home. The researcher responsible for the urine analyses (A.M.C.) was blinded to the questionnaire results.

2.4. Statistical analysis

Descriptive analysis was performed to calculate the mean, median, IQR, and percentage of each continuous variable. UC concentrations were not normally distributed (Shapiro–Wilk test); therefore, non-parametric tests were applied. The Mann–Whitney *U*-test was used to assess differences in the concentrations of UC levels according to SHS exposure of children at home, maternal smoking habits during pregnancy, current parental tobacco habit, and educational levels of parents. The Kruskal–Wallis test was employed to explore differences in UC levels according to cohabitation with smoker(s), daily cigarette consumption of cohabitants, and area of residence. McNemar's test was used to investigate changes in the proportion of exposed children between the two time points analyzed (pre- and post-legislation). The Wilcoxon test was applied to assess changes in UC levels in relation to modifications in smoking habits at home, which were considered as follows: (i) "never smoked"=host families reporting smoking-free homes at both follow-ups; (ii) "finished smoking"=families reporting smoking-free homes in 2011–2012 but not in 2005–2006; (iii) "started smoking"=families reporting smoking-free homes in 2005–2006 but not in 2011–2012; and (iv) "continued smoking"=families reporting smoking at home at both follow-ups.

In order to identify potential explanatory variables associated with SHS exposure, multivariable logistic regression models were built considering dichotomized UC levels as dependant variable using two exposure cut-off points (5 and 10 ng/mL). In the multivariable models, we entered all variables associated with the outcome in the bivariate analysis (p-value ≤ 0.20), with the exception of father's educational level, because of its strong collinearity with that of the mothers. Three different models were built: Model 1, adjusted for children's age, mother's education, maternal smoking during pregnancy, and cohabitation with a smoker (yes/no); Model 2, adjusted for children's age, mother's education, maternal smoking during pregnancy, and parent's smoking habit (smoker/non-smoker); and Model 3, adjusted for children's age, mother's education, maternal smoking during pregnancy, and number of cigarettes/day smoked by any family member at home in the presence of the child. The three models were additionally adjusted for creatinine.

The level of statistical significance was set at 0.05, and all tests were two-tailed. Statistical analyses were performed using R statistical computing environment v3.0 (http://www.r-project.org/) and SPSS 18.0 (IBM, Chicago, IL).

3. Results

Table 1 summarizes the characteristics of the study population. Out of the 668 families in the prospective birth cohort, 220 (32.9%) and 300 (44.9%) families agreed to participate in the first (2005–2006) and second (2011–2012) follow-ups, respectively. Only families taking part in both follow-ups ($n=118$) were included in the present study.

According to the questionnaire data, the percentage of children exposed to SHS (considering the presence of at least one cohabitant declaring a smoking habit at home) was 39.0% in 2005–2006 and 50.8% in 2011–2012 (Table 1). Self-reported information also showed that the prevalence of families with at least one of its members smoking at home increased between before and after implementation of the law; specifically, the prevalence of smoking mothers rose from 20.3% to 29.7% and the prevalence of smoking fathers from 33.9% to 39.0%. The prevalence of families in which one parent smoked rose from 23.7% in 2005–2006 to 29.7% in 2011–2012 and the prevalence in which both parents smoked

Table 1
Urinary cotinine levels (ng/mL) by characteristics of study population. INMA-Granada cohort.[a]

	2005–2006 Follow-up			2011–2012 Follow-up		
	N (%)	Median (IQR)	*p*-Value[b]	*N* (%)	Median (IQR)	*p*-Value[b]
Child						
Urinary cotinine levels (ng/mL)	118 (100.0)	8.0 (2.0–21.8)		118 (100.0)	8.7 (2.0–24.3)	
Age (years)[c]	118 (100.0)	4.3 (4.2–4.4)	0.187	118 (100.0)	9.8 (9.7–9.8)	0.854
Area of residence at evaluation			0.795			0.538
Rural	15 (12.7)	2.0 (2.0–14.3)		15 (12.7)	12.5 (2.0–30.7)	
Sub-urban	22 (18.6)	8.6 (2.0–25.8)		22 (18.6)	2.0 (2.0–23.4)	
Metropolitan	54 (45.8)	8.4 (2.0–19.7)		54 (45.8)	12.4 (2.0–22.7)	
Urban	27 (22.9)	9.3 (2.0–20.0)		27 (22.9)	8.5 (2.0–23.8)	
Exposure to SHS at home			< 0.001			< 0.001
No	72 (61.0)	2.0 (2.0–10.5)		58 (49.2)	2.0 (2.0–13.6)	
Yes	46 (39.0)	21.2 (4.8–27.7)		60 (50.8)	18.1 (2.0–37.3)	
Smokers living in the same household as the child			< 0.001			< 0.001
None	72 (61.0)	2.0 (2.0–40.5)		61 (51.7)	2.0 (2.0–13.8)	
Mother or father	28 (23.7)	10.8 (2.0–24.2)		35 (29.7)	14.1 (2.0–26.1)	
Both father and mother	18 (15.3)	29.6 (16.6–43.3)		22 (18.6)	31.3 (13.9–46.5)	
No of cigarettes per day smoked by parents in the presence of the child[d]	46 (39.0)	6.0 (3.0–14.3)	< 0.001	60 (50.8)	4.0 (0.0–10.0)	< 0.001
Mother						
Age at delivery (years)[c]	118 (100.0)	31.0 (28.0–34.0)	0.244	118 (100.0)	31.0 (28.0–34.0)	0.183
Educational level			0.020			0.325
University	28 (23.7)	2.0 (2.0–12.2)		28 (23.7)	6.65 (2.0–17.3)	
Up to secondary school	90 (76.3)	9.1 (2.0–22.4)		90 (76.3)	12.14 (2.0–25.4)	
Smoking during pregnancy			< 0.001			< 0.001
No	101 (85.6)	5.0 (2.0–16.7)		101 (85.6)	5.7 (2.0–20.5)	
Yes	17 (14.4)	21.8 (12.7–31.3)		17 (14.4)	23.1 (14.8–44.0)	
Smoking habit			< 0.001			0.002
No	94 (79.7)	4.4 (2.0–15.1)		83 (70.3)	5.2 (2.0–17.3)	
Yes	24 (20.3)	23.2 (12.4–38.8)		35 (29.7)	22.7 (3.8–39.3)	
Father						
Educational level			0.032			0.160
University	34 (28.8)	2.0 (2.0–13.2)		34 (28.8)	5.1 (2.0–16.3)	
Up to secondary school	84 (71.2)	9.5 (2.0–22.5)		84 (71.2)	12.7 (2.0–27.5)	
Smoking habit			< 0.001			< 0.001
No	78 (66.1)	2.0 (2.0–11.9)		72 (61.0)	2.0 (2.0–13.9)	
Yes	40 (33.9)	21.2 (5.8–28.0)		46 (39.0)	23.4 (8.6–38.6)	

[a] $N = 118$.
[b] *p*-Value for Spearman correlation or non-parametric tests; IQR: interquartile range.
[c] Median age and IQR.
[d] Median (IQR) of UC levels from children whose parents are smokers.

Table 2
Urinary cotinine levels (ng/mL) according to changes in parents smoking habits at home in families ($n = 118$) bellowing to INMA-Granada cohort, before (2005–2006) and after (2011–2012) Spanish smoke-free legislation (Law 42/2010).

	N (%)	2005–2006			2011–2012			*p*-Value[a]
			Percentiles			Percentiles		
		Median	25th	75th	Median	25th	75th	
Never smoked	62 (52.5)	2.0	2.0	9.47	3.3	2.0	14.11	0.189
Finished smoking	16 (13.6)	10.8	5.3	23.5	4.8	2.0	23.75	0.969
Started smoking	10 (8.5)	9.3	2.0	16.8	14.2	3.4	29.0	0.343
Continues smoking	30 (25.4)	23.1	6.2	33.0	28.2	12.0	43.8	0.096

"Never smoked": hosts families who self-reported smoking-free homes at both follow-ups.
"Finished smoking": families reported smoking-free homes in 2011–2012 but no in 2005–2006.
"Started smoking": comprise those families who declared smoking-free homes in 2005–2006 but not in 2011–2012.
"Continues smoking": as families reporting smoking habits at home at both follow-ups.

[a] *p*-Value for paired non-parametric tests; IQR: interquartile range.

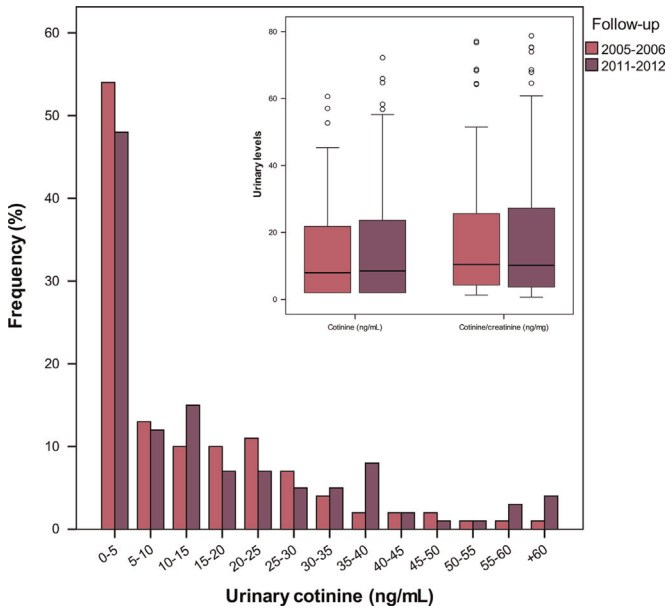

Fig. 2. Urinary continue levels in boys from IMMA Granada cohort before (2005–2006) and after law entrance into force (2011–2012).

increased from 15.3% to 18.6%, respectively.

No significant difference in children's UC levels was found between the two follow-ups (Table 2 and Fig. 2). In the first follow up (2005–2006), the median UC concentration was 8.0 ng/mL (IQR 2.0–21.8) both for the whole sample ($n=166$) and for the subsample attending both follow ups ($n=118$). In the second 2011–2012 follow-up, the median UC concentration was 7.8 ng/mL (IQR 2.0–23.4) for the whole sample ($n=276$) and 8.7 ng/mL (IQR 2.0–24.3) for the subsample ($n=118$) (Supplementary Table 1). The median UC concentration for children not living with smoker (s) was 2.0 ng/mL at both the first and second follow-up, whereas the median concentration for children living with any smoker (s) was 21.2 ng/mL at the first follow-up (2005–2006) and 18.1 ng/mL at the second (2011–2012). The median UC concentration for children of smoking mothers or fathers was 10.8 ng/mL at the first follow-up, and 14.1 ng/mL at the second. The median UC concentration for children whose parents both smoked was 29.6 ng/mL at the first follow-up and 31.3 ng/mL at the second (Table 1). Changes in smoking habits at home were also explored. For example, an increase in UC levels was found in children from families which "continued smoking", with median values of 23.1 ng/mL before and 28.2 ng/mL after legislation, although without reaching statistical significance (p-value 0.096) (Table 2).

The exposure or non-exposure of children to SHS was also considered by using two standard cut-offs (5 and 10 ng/mL).

Table 3
Percentages of exposed and unexposed children between the two time points analyzed (pre- and post-legislation).

	Follow-ups		*p*-Value
	2005-2006	**2011–2012**	
Cut-off: 5 ng/mL[a]			
Non exposed	54 (45.76%)	48 (40.68%)	0.366
Exposed	64 (54.24%)	70 (59.32%)	
Cut-off: 10 ng/mL[a]			
Non exposed	67 (56.78%)	60 (50.85%)	0.297
Exposed	51 (43.22%)	58 (49.15%)	

[a] Urinary cotinine levels (ng/mL).

McNemar's test showed that the proportion of exposed children did not significantly change between the two follow-ups (Table 3). Finally, the percentage of children with UC levels ≤ 4 ng/mL (LOQ) was 41.5% at the first follow-up and 39.0% at the second (data not shown).

Table 4 reports the three multivariable logistic regression models of the predictors of SHS exposure with different levels of adjustment. Models did not show any important change in the associations found, with or without adjustment for creatinine. As expected, all variables related to home smoking habits (smoking at home, smoking status of both parents, no. cigarettes smoked daily in the presence of child, and maternal smoking during pregnancy) were positively associated with the risk of SHS exposure at home. The aforementioned associations were consistently observed at both follow-ups.

4. Discussion

This prospective study, based on self-reports and an objective biomarker of exposure to second-hand smoke, reveals that the ban on smoking in public places introduced in Spain at the beginning of 2011 (Law 42/2010), was not accompanied by a decrease on SHS exposure in children; i.e. no significant difference in children's UC levels was observed (8.0 vs. 8.7 ng/mL); furthermore the percentage of children exposed to SHS at home increased from 39.0% in the period 2005–2006 to 50.8% in 2011–2012, mostly due to a rise in the prevalence of parental smoking habits. Research into predictors of childhood SHS exposure is of interest to identify possible modifiable factors as a basis for preventive actions. Our study shows that the main contributors of increased UC levels is having a family member who smokes at home, especially the mother and/or the father, while the number of cigarettes smoked daily by family members in the presence of the child had a lesser influence. Evidence from elsewhere suggests that smoke-free legislation produces an increase in smoke-free homes and a tendency to smoke less (Edwards et al., 2008; Borland et al., 2006; Fong et al., 2006; Jarvis et al., 2012; Sureda et al., 2014); however, the prevalence of Europeans who allow smoking everywhere or in certain rooms inside the house remains very high (39%) (European Commission, 2010). In the present study, no reduction was observed in the proportion of smoking homes.

Consistent with previous research reporting that the magnitude of SHS exposure in children is highly correlated with parental smoking habits and home-smoking patterns (Akhtar et al., 2007; Puig et al., 2008; Protano et al., 2012; Martínez-Sánchez et al., 2014), our own results suggest that SHS exposure in the home makes an important contribution to cotinine concentrations in children. Thus, the highest concentrations were found in children whose parents both smoked and the lowest in children whose parents did not. In addition, the levels in children living with smokers increased in direct proportion to the intensity of the parents' smoking habits. Furthermore, in our series, median UC levels in urine increased by 10% in children from families who "continued smoking" after legislation, although this increase was not statistically significant (p-value 0.096).

Some authors have addressed the direct effects of smoke-free legislation on childhood SHS exposure with disparate results. A study in Scotland after implementation of legislation in 2006 (Akhtar et al., 2007) found no significant changes in the proportion of children whose parents both smoked or in those with a mother who smoked. Sims et al. (2012) also found that the legislation in England (1 July 2007) had no significant impact on the proportion of children exposed to SHS, reporting a large proportion of children living in homes where smoking inside was allowed (Sims et al., 2012). However, the percentage of children with smoking

Table 4
Logistic multivariable association of exposure to second-hand smoke and child's urinary cotinine levels (ng/mL). INMA-Granada cohort.

	4 yr follow-up (2005–2006)												9 yr follow-up (2011–2012)										
	Model I				Model 2				Model 3				Model 1				Model 2				Model 3			
	OR	95% CI		p-Value	OR	95% CI		p-Value	OR	95% CI		p-Value	OR	95% CI		p-Value	OR	95% CI		p-Value	OR	95% CI		p-Value
Cut-off 5 ng/mL																								
Child's age (years)	5.02	0.45	60.66		4.82	0.44	57.37		4.89	0.49	54.33		2.70	0.49	16.99		2.91	0.51	18.65		2.52	0.48	14.86	
Maternal education[a]																								
Up to secondary school	1.94	0.66	6.19		1.98	0.67	6.28		2.35	0.82	7.33		0.90	0.34	2.37		0.88	0.33	2.33		1.02	0.39	2.62	
Maternal smoking during pregnancy	7.17	1.61	42.83	*	6.07	1.23	38.27	*	5.82	1.36	32.91	*	14.82	2.69	277.94	*	8.60	1.32	169.92	·	13.42	2.44	251.34	*
Exposure to SHS at home=yes	3.67	1.44	9.92	**	–	–	–		–	–	–		3.99	1.58	10.96	**	–	–	–		–	–	–	
Smokers living with the child[b]																								
Mother or Father	–	–	–		2.83	1.01	8.45	*	–	–	–		–	–	–		2.60	1.04	6.81	*	–	–	–	
Both mother and father	–	–	–		7.49	1.56	56.70	*	–	–	–		–	–	–		7.82	1.70	56.98	*	–	–	–	·
Number of cigarettes/day smoked by smokers	–	–	–		–	–	–		1.05	0.98	1.15		–	–	–		–	–	–		1.05	1.00	1.13	
Cut-off 10 ng/mL																								
Child's age (years)	3.91	0.34	47.56		3.81	0.33	45.88		3.55	0.36	36.24		2.36	0.42	13.78		2.85	0.48	17.47		2.23	0.42	12.30	
Maternal education[a]																								
Up to secondary school	1.57	0.51	5.26		1.60	0.52	5.32		2.02	0.70	6.52		1.49	0.56	4.10		1.48	0.55	4.10		1.65	0.64	4.45	
Maternal smoking during pregnancy	13.05	2.85	80.65	**	10.87	2.12	71.59	**	9.18	2.20	50.75	**	5.80	1.63	27.61	*	3.62	0.82	19.40		5.12	1.44	24.24	*
Exposure to SHS at home	5.51	2.15	15.18	***	–	–	–		–	–	–		4.27	1.80	10.70	**	–	–	–		–	–	–	
Smokers living with the child[b]																								
Mother or Father	–	–	–		3,79	1,34	11.40	*	–	–	–		–	–	–		3.66	1.45	9.71	**	–	–	–	
Both mother and father	–	–	–		15.34	3.19	116.55	**	–	–	–		–	–	–		6.86	1.84	30.48	**	–	–	–	
Number of cigarettes/day smoked by smokers	–	–	–		–	–	–		1.07	1.00	1.17	·	–	–	–		–	–	–		1.06	1.01	1.13	*

Model 1 (exposure to SHS at home); Model 2 (smokers living with the child); Model 3 (no. of cigarettes/day smoked by parents). The three models were additionally adjusted for creatinine
OR: Odds Ratio; CI: confidence interval; SHS: environmental tobacco smoke; · < 0.1;
* < 0.05; ** < 0.01; *** < 0.001.

[a] Reference category: University.
[b] Reference category: None.

parents in England significantly declined between 2006 and 2008 after the introduction in July 2007 of legislation prohibiting smoking in most public places, according to Jarvis et al. (2012). Various other studies have revealed a decrease in the proportion of children exposed to SHS over recent years (Fong et al., 2006; Holliday et al., 2009; Leatherdale and Ahmed, 2009). A recent systematic review from the Cochrane database concluded that there was no change in either the prevalence or duration of reported exposure to SHS in the home as a result of anti-tobacco legislation (Callinan et al., 2014).

Smoke-free legislation in Wales in 2007 did not change geometric mean salivary cotinine concentrations in 10- to 11-yr-old children recruited immediately before and one year after the ban (Holliday et al., 2009). Likewise, researchers in the USA compared serum cotinine levels over a period of 14 years (1988–2002) from the National Health and Nutrition Examination Survey, i.e., before and after legislations banning smoking in public spaces, and found that serum cotinine levels were an order of magnitude higher among children with reported SHS exposure at home compared with those with no exposure in the home (Marano et al., 2009).

Anti-tobacco legislation appears to have been much more effective in reducing the SHS exposure of adults. In Spain, cross-sectional studies in Galicia (a Northern Spanish region) and several primary care centers in Zaragoza city (Villaverde Royo et al., 2012; Perez-Rios et al., 2014) found a marked decrease in the SHS exposure of adults after the 2010 legislation. Nevertheless, more than 25% of the adults (16–74 yr) reported SHS exposure, predominantly at home. In the Galician study, there was only a small reduction in the proportion of smoke-free homes after the law (Perez-Rios et al., 2014). Recent studies in Madrid and Barcelona (Spain) showed that UC levels also significantly decreased among adult passive smokers between before and after this legislation came into force (Sánchez-Rodríguez et al., 2015; Sureda et al., 2015).

Our study has several limitations. First, the relatively small size of our sample, which derives from a single province and does not fully represent Spanish children. However, we attempted to maximize the internal validity by evaluating the intra-individual changes in cotinine concentrations, characterizing the exposure to SHS at home, and comparing exposure between children who lived with smokers and those who lived in smoke-free homes. In addition, the performance of two repeated cross-sectional studies within a longitudinal birth cohort reduces this disadvantage. A further weakness is that the second follow-up was conducted a very short time after the introduction of the anti-smoking legislation; studies after a longer period may reveal a greater impact on childhood exposure, as emerging social norms become more firmly entrenched. The imprecision of the ad hoc questionnaire, based on parental responses, is another shortcoming of our study. It should be taken into account that differences in SHS exposure may also be related to characteristics not captured by the questionnaire, such as the duration of exposure, home size, ventilation, or other sources of exposure. Thus, it would also have been of interest to explore the SHS exposure of children in vehicles, among other exposures, to supplement data reported in a previous study in our country (Curto et al., 2011). A strength of our study is that it contributes baseline data for the analysis of trends in SHS exposure over time within a prospective birth cohort. To our knowledge, this is the first study to address the impact of anti-smoking legislation on childhood SHS exposure in Spain.

The present findings revealed that recent national legislation to ban smoking in public and workplaces appears to have had little effect to date on childhood SHS exposure. More effective strategies are needed to reduce SHS exposure of children, including mass-media campaigns and school-based programs to raise awareness of the risks to children of smoking at home and in the car. A considerable proportion of the SHS exposure in our children could be attributed to smoking in the home, with urinary cotinine levels being significantly higher in children with a smoker in the house and even higher with two cohabitating smokers in comparison to those living in a smoke-free home. These data emphasize the need to target smoking at home in order to avoid future adverse health effects in a population that has no choice in the acceptance or not of SHS exposure-derived risk.

While awaiting implementation of a stricter regulation of exposure to SHS, health professionals (i.e. general practitioners and pediatricians) should be fully aware of this issue and warn parents about the health risks. Mothers and fathers should be advised about the potential risk to their children and the important role that the family can play in minimizing SHS exposure. Better informed smokers are more likely to have smoke-free homes and to abstain from smoking close to children (Evans et al., 2012).

Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

Contributor statement

All authors meet the criteria for authorship, had read and approved the final manuscript. MFF conceived of the idea and obtained financial support. MFF and FAC wrote the manuscript. CF, RR, RPL, IC, OO and CD were in charge of field activities (recruitment of children in follow-ups, questionnaire and database). AMC performed the urine analyses. FAC and JPA carried out the statistical analysis. NO contributed to writing and revised the final manuscript.

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Ethical statement

We obtained written informed consent from the parents (mother or father) on behalf of children enrolled in your study. The families registered in the follow-ups signed the informed consent form, which included completion of ad hoc questionnaires. The study followed the guidelines laid down in the Declaration of Helsinki and was approved by the Ethics Committee of San Cecilio University Hospital, Granada, Spain.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.envres.2015.03.002.

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