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Exposure to second-hand smoke in the home and mental health in children. A population-based study

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ABSTRACT

Objective. To examine the association between exposure to second-hand smoke (SHS) in the home and mental health among children.

Methods. Cross-sectional study of 2357 children representative of the Spanish population aged 4-12 years in 2011-2012. Duration of SHS exposure on children was reported by parents. Probable mental disorder was defined as a score $>90^{\text{th}}$ percentile in the parental version of the Strengths and Difficulties Questionnaire. Statistical analysis was performed with logistic regression and adjusted for sociodemographic variables, lifestyle, neighborhood environment, and family characteristics, including parental mental health.

Results. Among study participants, 6.9% (95% confidence interval [CI] 5.7-8.0%) were exposed to SHS in the home during <1 h/day and 4.5% (95% CI 3.5-5.5%) during ≥ 1 h/day. Compared to children not habitually exposed to SHS, the multivariate odds ratios for probable mental disorder were 1.49 (95% CI 0.85-2.62) for SHS exposure <1 h/day and 2.73 (95% CI 1.38-5.41) for SHS exposure ≥ 1 h/day (p for linear trend=0.002). The corresponding odds ratios for attention-deficit hyperactivity disorder were 2.18 (95% CI 1.30-3.64) for <1 h/day exposure and 3.14 (95% CI 1.63-6.04) for ≥ 1 h/day exposure (p for linear trend <0.001).

Conclusions Among children, SHS exposure in the home during ≥ 1 h/day is associated with a higher frequency of mental disorder. Moreover, even exposure to SHS during <1 h/day is associated with a higher frequency of attention-deficit hyperactivity disorder.

Abbreviations SHS: second-hand smoke; SDQ: Strengths and Difficulties Questionnaire; OR: odds ratio; CI: Confidence interval.

BACKGROUND

Second-hand smoke (SHS) exposure in children increases the risk of respiratory conditions, otitis media and sudden-death syndrome, among other health problems. [1] Nonetheless, over 10% of children between 5 and 14 years of age in Spain are regularly exposed to SHS in the home.[2]

It is estimated that up to 20% of children and adolescents are affected by mental disorders.[3,4] Post-natal SHS has been related to behavioral problems[5,6], but the evidence is inconsistent.[1,7,8] Further, SHS has been linked to mental symptoms in both children and adolescents 8 to 15 years-old who participated in the National Health and Nutrition Examination Survey from 2001 to 2004, but the study failed to identify associations with specific diagnoses.[9] However, a recent investigation among adolescents did find a relationship between duration of exposure to SHS at home and a greater frequency of psychological distress.[10]

In children of different ages, a few studies have examined the relationship between postnatal SHS exposure and a wide range of mental and behavioral disorders based on the Strengths and Difficulties Questionnaire (SDQ). Unfortunately they failed to reach conclusive results.[11-14] Finally, only one study on children took into consideration parental mental health,[5] despite existing evidence showing an association with both SHS exposure and children's mental health.[15-18]

Many countries have adopted smoke-free policies; however, these policies do not usually apply to private areas such as homes or vehicles [19,20] where most of the SHS exposure to children takes place. Thus, in this study we examined the relationship between duration of SHS exposure in the home and children's mental health while accounting for parental mental health.

METHODS

Study design and population

Data were taken from the 2011-2012 National Health Survey, conducted on a sample representative of the child population in Spain. [21]. Study participants were selected through multi-stage sampling, stratified according to the size of the municipality, among children residing in private homes distributed all across Spain. Data were collected using face-to-face interviews from July 2011 through June 2012.

The response rate was 71.1% of surveyed households. The members of a total of 13.7% households were absent from their homes, 14.6% refused to participate, and 0.7% were unable to participate.[22] Data included interviews from 5495 households with at least one child under 14 years of age. Information regarding the participating child was collected from one of the parents, a legal guardian, or another adult if neither were available.

A total of 1522 children under the age of 4 were excluded since the SDQ is not appropriate for this specific subgroup. We also excluded 807 children over the age of 12 because experimentation with tobacco products is not unusual at that stage [23] and any tobacco consumption may confound the SHS-mental health relationship. Lastly, we additionally excluded 701 children whose information was collected from other than parents or legal guardians, and 108 with missing data on the variables of interest. Thus, the analytical sample included 2357 children.

Study variables

Mental health of the child

The child's mental health was evaluated with the parental version of the SDQ which has shown good validity and reliability in its original version [24] as well as in Spanish.[25-26] The SDQ consists of 25 questions grouped into 5 subscales: emotional symptoms, conduct problems, hyperactivity-inattention, peer problems, and prosocial behavior. Each question is scored from

0 to 2 based on the following answers: not true, somewhat true, certainly true. The global SDQ score is calculated as the sum of the four first subscales, ranging from 0 to 40.

Individuals with global or subscale scores above the 90th percentile have a substantially raised probability of independently diagnosed mental disorders.[24] As the SDQ scoring system is discrete, cut-off points in either the global or the subscale scores may not match their corresponding 90th percentile and, thus, an approximation is used.[27,28] Thus, we used the cut-off point of the immediately next percentile, as in previous studies.[27-29]

Second-hand smoke (SHS)

SHS exposure was assessed by asking the parent or legal guardian how long was the child exposed to tobacco smoke in the home (not habitually exposed (never or only sporadically), <1h/day, and \geq 1h/day).

Potential confounders

Information was collected on the child's sex, age, country of birth (Spain or other), physical activity (playing sports or doing physical activity several times per week), and exposure to SHS outside the home. Adults were also asked their perception of the child's weight (underweight, normal weight, somewhat overweight, very overweight). Information regarding household structure (two-parent household or not) and parental characteristics [sex, employment status (working or unemployed at time of the interview), educational level (university, vocational training, secondary, primary, or no formal studies)] were also collected. Finally, to assess the social class of the family member who contributed the most to the household expenses on a regular basis, we used the Spanish Society of Epidemiology classification (I to VI for the highest through the lowest class).[30]

The mental health of the parents interviewed was assessed with the General Health Questionnaire (GHQ-12), validated for the Spanish population.[31] The GHQ-12 consists of 12

questions with four possible answers each. Responses were classified using a binary scoring method, in which the options ‘much less than usual’ and ‘same as usual’ received 0 points, and ‘more than usual’ and ‘much more than usual’ received 1 point. The total score ranges from 0 to 12 points, and individuals scoring ≥ 3 were classified as having psychological distress.[31]

Household crowding was defined as residing in a house or flat having $<20 \text{ m}^2/\text{person}$ or <1 room/person [12] Lastly, five neighborhood environmental risk factors were evaluated by the adult interviewed: nuisance noise, dirty streets, air pollution from a nearby factory, air pollution due to other causes, and delinquency, violence, or vandalism in the house or neighborhood. Each question had 3 possible answers (none, a little or a lot) ranging in value from 0 to 2 for an aggregate score from 0 to 10.

Statistical analysis

Data were analyzed using logistic regression models. The dependent variable was a score above the 90th percentile for the global SDQ or its subscales and the main independent variable was SHS exposure in the home. Duration of exposure was categorized into three levels using dummy terms: not habitually exposed, $<1\text{h}/\text{day}$, or $\geq 1\text{h}/\text{day}$. Three logistic models were built with progressive adjustment for potential confounders. Model A was the crude model. Model B included all potential confounders described above except for parental mental health. Model C further adjusted for parental mental health. The dose-response relationship between SHS and child’s mental health problems was tested with the p for linear trend.

We also examined whether the study association varied by the sex of the child or of the parent interviewed by using likelihood ratio tests which compared models with and without interaction terms. Finally, a sensitivity analyses was performed by including mother’s tobacco consumption as an additional adjustment in Model C.

Analyses were performed with Stata V.11.0 for Windows (StataCorp, Texas, USA).

RESULTS

Among study participants, 7.7% (95% confidence interval [CI] 6.5-8.9%) had a probable mental disorder, with a higher prevalence found in households headed by one parent and in children of unemployed parents, with lower education or social class (Table 1). Also, 6.9% (95% CI: 5.7-8.0%) of children were exposed to SHS in the home during <1h/day and 4.5% (95% CI 3.5-5.5%) during \geq 1h/day. Again, SHS exposure was more frequent in children not living in a two-parent household, with unemployed parents or having parents with lower education or lower social class (Table 1).

The proportion of children at a higher risk for probable mental disorders was greater among those whose parents were under psychological distress and had a perception of the child's weight being either below or above normal. The frequency of probable mental disorders also increased as the neighborhood environmental conditions worsened (Table 2). As regards SHS in the home, the frequency was greater in children exposed to SHS outside the home (Table 2).

Compared to children with none/sporadic SHS exposure in the home, the odds ratio (OR) of a probable mental disorder after adjusting for the main confounders (Model B) was 1.61 (95% CI 0.92-2.81) in children exposed to SHS during <1h/day and 3.16 (95% CI 1.63-6.12) in those exposed during \geq 1 h/day (p linear-trend <0.001). When adjustment was further made for parental mental health (Model C), the corresponding ORs decreased to 1.49 (95% CI 0.85-2.62) and 2.73 (95% CI 1.38-5.41), p linear-trend=0.002 (Table 3). Results did not vary with the sex of the child (p=0.871) or of the participating parent (p=0.700). Further adjustment for mother's tobacco use reduced the OR but not substantially; the corresponding OR were 1.37 (95% CI 0.76-2.46) for <1h/day exposure and 2.58 (95% CI 1.29-5.18) for \geq 1h/day exposure.

Table 4 shows the results for the specific SDQ subscales. Children with any SHS exposure in the home had a higher risk of ADHD than their counterparts with none/sporadic exposure; the OR for <1h/day exposure was 2.18 (95% CI 1.30-3.64) and for \geq 1h/day exposure was 3.14

(95% CI 1.63-6.04). Results were similar after adjustment for mother's tobacco consumption, with an OR 1.98 (95% CI 1.16-3.39) for <1h/day exposure and 2.95 (95% CI 1.53-5.70) for \geq 1h/day exposure. None of the other SDQ subscales showed a statistically significant association with SHS exposure in the home.

DISCUSSION

Children between 4 and 12 years of age who are exposed to SHS in the home are at a greater risk for mental disorders, especially ADHD, than those who are not exposed or have sporadic exposure only.

The high prevalence of SHS exposure in the home among Spanish children is of public health concern because SHS contains higher concentrations of certain toxic substances than the smoke inhaled by the active smoker.[1,32] In addition, some of these substances remain during months after tobacco consumption in the home environment (on surfaces and as dust particles), and may be re-suspended in the air or react with other substances creating new pollutants, an exposure come to be known as “third-hand smoke”. [33] Children are especially vulnerable to “third-hand smoke” exposure [33], furthermore, the neurological effects of nicotine are greater and longer-lasting in children than in adults.[34,35]

Four previous studies have examined the association between SHS in the home and SDQ-based mental health in children, with inconclusive results [11-14]. Only Hamer et al. found a positive dose-response relationship between SHS in the home and worse mental health.[11] However, three studies using the SDQ concluded that SHS in the home was associated with a greater risk for ADHD,[11-13] with two of them finding a robust dose-response relationship in addition to an association between SHS and behavioral problems.[11,12] In contrast, Rückinger *et al.* [14] found that the association between SHS exposure in the home and a greater risk for mental disorders was mostly explained away by prenatal exposures.

Several studies have explored the effect of postnatal SHS on behavioral problems using instruments other than the SDQ, and although some have observed a direct relationship,[5,6] existing evidence of a possible association remains inconclusive.[1,7,8]

In our analyses, the association between SHS exposure in the home and mental disorders in children remained robust after controlling for many potential confounders such as social class,[12,36] parental education,[12,36] family structure,[12,36] and parental mental health.[15,16,18] The latter is a potential confounder since it is associated with parental tobacco consumption [17] and, thus, a greater SHS exposure in the home, and because it is also associated with the child's mental health.[15,16,18] Additionally, parents with poorer mental health may have a more negative interpretation of their children's mental health.[7] Only Williams *et al.*[5] accounted for this potential confounder in the analysis. In our study, the associations between SHS and mental health in general, and ADHD in particular, were reduced only slightly after adjusting for parental mental health.

The association between SHS in the home and worse mental health outcomes may be explained in part by prenatal exposure to tobacco. Unfortunately, the two exposures are difficult to differentiate since prenatal and postnatal maternal tobacco use are highly correlated.[8,37] In this study, adjusting for postnatal tobacco consumption did not modify the results substantially. There is previous evidence of associations of postnatal exposure with different aspects of mental and behavioral problems independently from prenatal exposure.[5-12] Additionally, some authors have concluded that the association between prenatal tobacco exposure and behavioral problems is influenced by other risk factors in behavioral development such as growing up in disadvantaged conditions,[38,39] parental mental health,[38-39] and country of birth.[39] Low maternal educational achievement has also been suggested as a potential confounding factor between child's mental health and prenatal tobacco exposure.[36] We were able to adjust our analyses for all these variables, thus, although there could be some residual confounding from

variables not included, we believe the direct association observed between childhood SHS exposure and risk for mental disorders to be robust.

Limitations

Our results should be interpreted in the context of the study's limitations. First, due to the cross-sectional nature of the data, we were unable to establish causality between SHS exposure in the home and mental health. Second, data were reported by parents, which may provide somewhat biased information. However, there is evidence that the data on tobacco consumption in the home provided by parents are valid estimates of children's SHS exposure when compared to data from biomarkers.[40] Third, the SDQ for parents is a screening instrument and it does not provide a clinical diagnosis. Still, it has proven a reliable and valid instrument. In addition, values over the 90th percentile in both the general SDQ as well as SDQ subscales have proven to be good predictors of risk for mental health disorders.[24]

Strengths

Major strengths of this study include a large population-based sample representative of the child population in Spain and analyses adjusted for a wide array of potential confounders. In fact, this is the first examination of the link between SHS in the home and children's mental health using the SDQ that also adjusts for parental mental health.

Conclusions

SHS exposure in the home for one hour or more per day was associated with a higher frequency of mental disorders in children; further, even lower exposures of under one hour per day were linked to ADHD. Longitudinal research confirming these results is needed. Given that legislation in Spain has not reduced SHS exposure in the home, additional actions may be required to reduce children's exposure to SHS.

What this paper adds

- ▶ Previous research on the association between second hand smoke (SHS) exposure and children's mental health is inconclusive. Further, past studies using the Strengths and Difficulties Questionnaire (SDQ) have not accounted for the role of parental mental health in this association.
- ▶ Based on a population-based sample of 4 to 12 year-olds residing in Spain, we showed a significant and substantial association between SHS exposure in the home (of at least one hour per day) and a higher frequency for mental disorders measured with SDQ. We also observed a significant dose-response relationship. Unlike most previous findings, our results are adjusted for parental mental health.
- ▶ Further, in this same sample, SHS exposure in the home during even less than one hour per day had a dose-response relationship with attention-deficit and hyperactivity disorder.

Competing Interests

None

Funding

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Contributors

All authors have contributed substantially to the research, have reviewed the manuscript for important intellectual content, and agree with its contents and with the decision to submit it for publication.

Table 1. Frequency of mental disorders* and levels of exposure to second-hand smoke (SHS) in the home among 4 to12 year-old children in Spain, by sociodemographic variables.

	N	Mental Disorder % (95% CI)	Not habitually exposed % (95% CI)	SHS <1h/day % (95% CI)	SHS ≥1h/day % (95% CI)
Total	2357	7.7(6.5-8.9)	88.7(87.2-90.1)	6.9(5.7-8.0)	4.5(3.5-5.5)
Age (years)					
4-10	1842	7.8(6.4-9.1)	89.3(87.7-90.9)	6.7(5.4-8.0)	4.0(3.0-5.0)
11-12	515	7.6(4.9-10.3)	86.1(82.5-89.7)	7.5(4.9-10.1)	6.4(3.7-9.0)
Sex					
Male	1222	8.6(6.8-10.4)	89.8(87.8-91.8)	6.3(4.7-7.8)	3.9(2.6-5.2)
Female	1135	6.8(5.2-8.4)	87.5(85.3-89.7)	7.5(5.7-9.2)	5.1(3.6-6.5)
Country of birth					
Spain	2216	7.7(6.4-9.0)	88.6(87.1-90.2)	6.9(5.7-8.1)	4.5(3.5-5.5)
Other country	141	8.1(3.0-13.2)	88.8(83.1-94.4)	6.4(2.4-10.4)	4.9(0.6-9.1)
Family structure					
Two-parent	1995	7.0(5.7-8.2)	89.6(88.0-91.1)	6.5(5.3-7.8)	3.9(2.9-4.9)
Not two-parent	362	12.1(8.1-16.1)	83.3(78.8-87.9)	8.8(5.5-12.1)	7.9(4.5-11.4)
Parental working status					
Employed	1557	6.1(4.7-7.4)	89.7(87.9-91.5)	6.9(5.4-8.3)	3.4(2.3-4.5)
Unemployed	800	11.0(8.5-13.5)	86.6(83.9-89.3)	6.8(4.8-8.8)	6.6(4.6-8.5)
Parental education level					
University	483	4.3(2.2-6.5)	93.4(90.6-96.1)	5.2(2.7-7.6)	1.5(0.2-2.8)
Vocational training	554	6.9(4.4-9.3)	90.3(87.5-93.2)	6.9(4.4-9.3)	2.8(1.3-4.3)
Secondary	345	6.7(3.6-9.8)	92.5(89.4-95.7)	4.9(2.6-7.2)	2.6(0.3-4.8)
Primary	814	9.7(7.4-11.9)	83.3(80.3-86.3)	8.9(6.6-11.1)	7.8(5.6-10.0)
No formal schooling	161	15.2(8.9-21.6)	85.5(79.5-91.4)	6.6(2.5-10.7)	7.9(3.4-12.4)
Social Class					
Class I (highest)	309	5.9(2.7-9.0)	93.4(90.0-96.8)	4.8(1.9-7.6)	1.8(0.0-3.8)
Class II	201	6.0(2.0-10.0)	92.3(88.5-96.1)	7.1(3.3-10.8)	0.6(0.0-1.6)
Class III	505	5.9(3.5-8.2)	91.2(88.3-94.1)	6.9(4.2-9.5)	1.9(0.6-3.2)
Class IV	347	8.6(5.4-11.8)	87.9(83.8-91.9)	7.5(4.4-10.5)	4.7(1.9-7.5)

Class V	709	9.7(7.2-12.2)	86.4(83.4-89.3)	6.6(4.5-8.7)	7.1(4.8-9.3)
Class VI (lowest)	254	9.0(5.2-12.8)	82.0(76.5-87.5)	10.1(5.9-14.3)	7.9(4.0-11.8)
Don't Know/No answer	32	7.1(0.0-16.3)	80.5(64.6-96.4)	4.5(0.0-13.5)	15.0(1.2-28.8)

*According to the Strengths and Difficulties Questionnaire (SDQ)

CI: Confidence interval.

Table 2. Frequency of mental disorders* and level of exposure to second-hand smoke (SHS) in the home among 4 to12 year-old children in Spain, by risk factors and environmental variables

	N	Mental Disorder* % (95% CI)	Not habitually exposed % (95% CI)	SHS <1h/day % (95% CI)	SHS ≥1h/day % (95% CI)
Physical Activity					
No	1937	7.5(6.2-8.8)	88.5(86.8-90.1)	6.9(5.6-8.2)	4.7(3.5-5.8)
Yes	420	8.5(5.3-1.8)	89.5(86.2-92.9)	6.8(3.9-9.7)	3.7(1.8-5.6)
Weight perception					
Normal	1876	6.7(5.4-8.0)	89.6(88.0-91.1)	6.6(5.3-7.8)	3.9(2.9-4.9)
Underweight	235	14.1(9.0-19.1)	86.5(81.2-91.7)	6.8(3.2-10.5)	6.7(2.6-10.8)
Somewhat / very overweight	246	9.0(5.0-13.1)	83.6(78.0-89.1)	9.3(4.8-13.8)	7.2(3.4-10.9)
SHS exposure outside home					
Yes	12	4.0(0.0-13.3)	27.9(0.0-59.0)	29.4(0.0-60.1)	42.7(5.7-79.7)
No	2345	7.7(6.5-9.0)	88.9(87.5-90.4)	6.8(5.6-7.9)	4.3(3.3-5.3)
Parental psychological distress					
Yes	456	16.2(12.1-20.3)	80.7(76.4-85.1)	10.5(7.1-13.9)	8.8(5.6-11.9)
No	1901	5.8(4.6-6.9)	90.5(89.0-92.0)	6.0(4.8-7.2)	3.5(2.5-4.4)
Household crowding					
Yes	1283	7.7(6.1-9.4)	89.0(87.0-90.9)	5.9(4.5-7.4)	5.1(3.7-6.5)
No	798	6.9(5.0-8.9)	89.2(86.8-91.6)	8.0(5.8-10.1)	2.8(1.6-4.0)
Don't know / No answer	276	9.3(5.5-13.1)	86.0(81.2-90.8)	8.9(4.9-12.9)	5.1(2.1-8.1)
Neighborhood environment					
0 (best)	1028	6.0(4.4-7.6)	88.9(86.6-91.1)	6.8(5.0-8.5)	4.4(2.9-5.8)
1-2	865	8.0(5.9-10.1)	89.3(86.9-91.6)	6.7(4.8-8.5)	4.1(2.6-5.5)
≥3 (lowest)	464	10.8(7.7-14.0)	87.2(83.6-90.8)	7.3(4.5-10.2)	5.5(3.1-7.9)

*According to the Strengths and Difficulties Questionnaire (SDQ)

CI: Confidence interval.

Table 3. Association between exposure to second-hand smoke in the home and mental disorders* in 4 to 12 year-old children in Spain

Duration of exposure to second-hand smoke in the home				
	Not habitually exposed Reference	<1hour/day Odds ratio (95% CI)	≥1hour/day Odds ratio (95% CI)	<i>P for linear trend</i>
Model A	1	1.68 (0.94-3.01)	3.94 (2.19- 7.09)	<0.001
Model B	1	1.61 (0.92-2.81)	3.16 (1.63-6.12)	<0.001
Model C	1	1.49 (0.85-2.62)	2.73 (1.38-5.41)	0.002

*According to the Strengths and Difficulties Questionnaire (SDQ)

CI: Confidence Interval

Model A: Crude logistic regression model.

Model B: Adjusted for sex of participating parent, child's sex, child's age, child's country of birth, family structure, parental employment, parental educational level, social class, physical activity, parental perception of child's weight, exposure to second-hand smoke outside the home, household crowding, and neighborhood environmental factors.

Model C: As model B with additional adjustment for parental mental health.

Table 4. Association between exposure to second-hand smoke and specific mental disorders* in 4 to 12 year-old children in Spain

Duration of exposure to second-hand smoke in the home				
	Not habitually exposed	<1h/day	≥1h/day	
	Reference	Odds ratio (95% CI)†	Odds ratio (95% CI)†	<i>P for linear trend</i>
Emotional symptoms	1	1.18 (0.63-2.22)	1.27 (0.65-	0.404
Conduct problems	1	1.56 (0.86-2.83)	1.28 (0.56-2.94)	0.292
Hyperactivity-Inattention	1	2.18 (1.30-3.64)	3.14 (1.63-6.04)	<0.001
Peer problems	1	0.74 (0.35-1.58)	0.82 (0.36-1.91)	0.465
Prosocial behavior	1	0.71 (0.35-1.48)	0.69 (0.23-2.04)	0.337

*According to the subscales of the Strengths and Difficulties Questionnaire (SDQ)

CI: Confidence Interval

† Logistic regression model adjusted as model c in table 2.

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