

Available online at www.sciencedirect.com

Public Health

journal homepage: www.elsevier.com/puhe

Original Research

Truck traffic related air pollution associated with asthma symptoms in young boys: a cross-sectional study

F.J. Gonzalez-Barcala^{a,*}, S. Pertega^b, L. Garnelo^c, T.P. Castro^d, M. Sampedro^c, J.S. Lastres^c, M.A. San Jose Gonzalez^c, L. Bamonde^c, L. Valdes^a, J.-M. Carreira^e, A.L. Silvarrey^f

^a Department of Respiratory Diseases, Hospital de Pontevedra, Spain

^b Clinical Epidemiology and Biostatistics Unit, University Hospital Complex, A Coruña, Spain

^c Department of Paediatrics, Servicio Galego de Saude, Spain

^d University College of Health Sciences, A Coruña, Spain

^e Department of Radiology, University of Santiago de Compostela, Spain

^f Maria Jose Jove Foundation, A Coruña, Spain

ARTICLE INFO

Article history:

Received 23 February 2012

Received in revised form

5 November 2012

Accepted 21 December 2012

Available online xxx

Keywords:

Asthma

Children

Traffic pollutants

ISAAC

SUMMARY

Objectives: The aim of this study was to evaluate the influence of intensity of truck traffic on asthma symptomatology, and its relationship with age and gender.

Study design: A cross-sectional study was conducted on children and adolescents from Galicia (North-West Spain).

Methods: Following the methodology of the International Study of Asthma and Allergies in Childhood (ISAAC): children from schools randomly selected, answered a self-administered questionnaire included questions on asthma symptoms and some risk factors.

The association between self-reported truck traffic on the street of residence and symptoms of asthma were investigated by logistic regression adjusted for body mass index, maternal education and parental smoking.

Results: Almost 40% of children in Galicia are exposed to the frequent and constant passing of heavy goods vehicles.

The odds of 6–7 year-old boys having severe or exercise induced asthma is tripled when they live in streets with the constant passing of heavy goods vehicles, compared with those living in streets where these vehicles never pass. In adolescents and 6–7 year-old girls, no relationship was observed between truck traffic and asthma symptoms.

Conclusions: The results of this study appear to support a distinct effect of truck traffic on asthma symptoms depending on the age and sex of the exposed population, being more harmful for young males.

© 2013 The Royal Society for Public Health. Published by Elsevier Ltd. All rights reserved.

* Corresponding author. C/Choupana SN, 15706 Santiago de Compostela, Spain. Tel.: +34 607819141; fax: +34 981583312.

E-mail addresses: fjgbarcala@telefonica.net, francisco.javier.gonzalez.barcala@sergas.es (F.J. Gonzalez-Barcala).

0033-3506/\$ – see front matter © 2013 The Royal Society for Public Health. Published by Elsevier Ltd. All rights reserved.

<http://dx.doi.org/10.1016/j.puhe.2012.12.028>

Introduction

Traffic pollution consists of a complex mixture of motor engine gases and dust from the roads, tyres and brakes.¹ The effect of these contaminants on health is of great concern to society.

Although there are solid experimental data on the effects of road traffic contamination on respiratory health,^{1–4} epidemiological data are less consistent.^{5,6} In some studies there appears to be a relationship observed between contamination from traffic and asthma in children,^{7,8} while in others no relationship is observed.^{9–11} In a recent meta-analysis, including 19 studies, the results appear to support some relationship between the exposure to high density traffic and childhood asthma.¹²

In a recent publication with data from the phase III ISAAC study, it showed that higher exposure to heavy goods vehicle traffic is associated with more asthma symptoms; but the results are not homogeneous between countries or between the age groups studied.¹³ Thus, in 6–7 year-old children in North America or Western Europe there is a relationship between the high intensity of truck traffic and asthma symptoms, which is not seen in the 13–14 year-old group. On the other hand, in a Northern and Eastern Europe population, an increase in asthma symptoms was observed with more exposure to traffic in the adolescent population, but not in the younger children.¹³

The aim of this study was to evaluate the influence of the intensity of truck traffic on asthma symptomatology, and its relationship with age and gender.

Methods

A cross-sectional study was conducted between October 2006 and February 2007 on children (6–7 years) and adolescents (13–14 years) from Galicia (North-West Spain), following the methodology of the International Study of Asthma and Allergies in Childhood (ISAAC) (<http://isaac.auckland.ac.nz>), using the questionnaires designed for this study, previously translated and validated in Spanish.^{14,15}

Six of the largest Health Areas in Galicia were included in the study, with a total population of 1.9 million inhabitants, which is 69% of the total population in this Autonomous Region. The number of schools required to achieve a sample of 1500 children in each group were randomly selected from each of the six Health Areas. The schools that refuse to take part in the study were replaced in random selection order. All the children in the previously defined age groups, of each school selected, were asked to take part in the study.

Written permission to participate in the study was requested from the parents and guardians of the children.

In accordance with the methodology of the ISAAC study, the responses to the questions were made by the parents and guardians of the children in the 6–7 years group, while the 13–14 year-old made their own responses in school.¹³

The questionnaire data was introduced manually into a data base, using double entry with subsequent validation, in accordance with the ISAAC protocols.

The environmental questionnaire included questions about truck traffic exposure, asthma symptoms, self-reported height and weight, smoking habits of parents and mother's education level.¹³

Parental smoking was classified, based on the responses in the questionnaire, into four mutually exclusive categories: (1) no parent smokes; (2) only the mother smokes; (3) only the father smokes; and (4) both parents smoke.

The educational level of the mother was classified into three categories: (1) No education or only primary school education; (2) Secondary school education; and (3) University education.

The exposure to heavy vehicle traffic was evaluated from the response to the question: 'How often do trucks pass through the street where you live, on weekdays?' The four answers to choose from were never, seldom, frequently through the day, and almost the whole day.¹³

For the purpose of this study, **Asthma ever** was defined as a positive answer to the question 'Has your child ever had asthma?'.

Current asthma was defined as a positive answer to the question 'Has your child had wheezing or whistling in the chest during the last 12 months?'.

Severe asthma was defined as a combination of the three questions assessing the severity of asthma: 'How many attacks of wheezing has your child had during the last 12 months? (none, 1–3, 4–12, >12)', 'In the last 12 months, how often on average has your child's sleep been disturbed due to wheezing? (never, <1 night/week, ≥1 nights/week)', and 'In the last 12 months, has wheezing been severe enough to limit your child's speech to only one or two words at a time between breaths?'. Children were considered to have current severe asthma when there were ≥4 asthma attacks or when sleep was disturbed ≥1 nights/week or when there had been an episode of speech limitation.¹³

Exercise induced asthma was defined as a positive answer to the question, 'In the last 12 months, has your child's chest sounded wheezy during or after exercise?'.^{14,16}

Obesity and overweight were defined in accordance with the Body Mass Index (BMI) cut-off points mentioned by Cole et al. for each age group and sex.¹⁷

Data analysis

Logistic regression was used to calculate the prevalence Odds Ratio (OR) of the asthma symptoms, in accordance with the four exposure to truck traffic categories, adjusted for body mass index, maternal education and parental smoking.

The children with incomplete data were excluded from the study.

The statistical analysis was performed using SPSS 17.0 software (SPSS Inc, Chicago, Illinois).

The study was approved by the Clinical Research Ethics Committee of Galicia.

Results

A total of 7250 children were included in the 6–7 years group, with a response rate of 75%. In the 13–14 years group, the

response rate was 85%, with 7295 children being included (Table 1).

Almost 40% of our children are exposed to the frequent and constant passing of heavy goods vehicles (Table 1).

The prevalence of asthma symptoms was higher in 6–7 year-old boys and in 13–14 year-old girls (Tables 1.A and 1.B).

As regards the covariables in this study, it can be seen that almost half the children and adolescents are exposed to passive smoking in the home and that one third of the mothers have a university education. As for obesity, almost one third of the children were obese or overweight, with no differences between sexes. The rates are reduced in the adolescents, the prevalence of overweight and obesity being 23.4% in the females, significantly higher than the 13.5% of males (Tables 1.A and 1.B).

In adolescents, no relationship was observed between truck traffic and asthma symptoms (Tables 2 and 3). A statistically significant relationship was observed in the children, with more asthma symptoms in those exposed to more intense truck traffic. It is noted that in the multivariate analysis, this relationship is only significant in the males, and not in the females (Tables 3.A and 3.B). The odds of the boys having severe or exercise induced asthma is tripled when they live in streets with the constant passing of heavy good vehicle, compared with those living in streets where these vehicles never pass.

Discussion

The main findings from the study is that in our population, asthma symptomatology was strongly associated with traffic intensity in 6–7 year-old boys, but not in girls of this age or in adolescents.

The inclusion of a large population sample, selected randomly, and studied following extensively validated methodology both in Spain and other countries, appears to reinforce the validity of our results.^{18,19}

As regards asthma symptoms, the validity of the questionnaires appears to have been reasonably demonstrated with studies where they are compared objective measurements. In a Finnish study, the sensitivity and specificity of the diagnosis of asthma by questionnaire was compared with the same diagnosis with hyper-reactivity tests, but without demonstrating the diagnostic superiority of epidemiological studies with the use of complementary tests.²⁰

This study may have some limitations. On the one hand, the fact that it is a cross-sectional study means that causality relationships cannot be established. Also, the data was obtained by using a questionnaire, with no objective measurements of exposure or the disease. Although this should not change the results significantly, given that several authors

Table 1.A – Main characteristics of the children aged 6–7 years, according to gender.

	Girls			Boys			P
	Mean	SD	Median (Interquartile range)	Mean	SD	Median (Interquartile range)	
Age	6.5	0.5	6 (6–7)	6.5	0.5	6 (6–7)	0.634
Height (cm)	122.9	6.9	123 (118–128)	123.7	7.2	124 (119–129)	<0.001
Weight (kg)	25.6	4.7	25 (22–29)	26.0	4.7	25 (22–29)	<0.001
Body mass index (kg/m ²)	16.9	2.39	16.6 (15.3–18.3)	16.99	2.29	16.6 (15.4–18.1)	0.165
	Girls		Boys		P		
	n	%	n	%			
Body mass index (kg/m ²)					0.050		
Normal weight	1877	66.1%	2088	68.9%			
Overweight	663	23.4%	665	22.0%			
Obesity	299	10.5%	276	9.1%			
Paternal or maternal smoking					0.849		
Father	641	18.4%	688	19.2%			
Mother	434	12.4%	441	12.3%			
Mother and father	628	18.0%	634	17.7%			
Maternal education					0.528		
No education	30	0.8%	27	.7%			
Elementary	1076	30.2%	1105	30.1%			
High school	1346	37.7%	1338	36.4%			
University	1116	31.3%	1201	32.7%			
Frequency of truck traffic on the street of residence					0.009		
Never	554	15.5%	470	12.7%			
Seldom	1649	46.2%	1740	47.2%			
Frequent	1202	33.7%	1302	35.3%			
Constant	167	4.7%	175	4.7%			
Asthma ever	320	8.8%	550	14.7%	<0.001		
Current asthma	407	11.2%	605	16.2%	<0.001		
Severe asthma	128	3.5%	215	5.8%	<0.001		
Exercise-induced asthma	193	5.3%	283	7.6%	<0.001		

Table 1.B – Main characteristics of the children aged 13–14 years, according to gender.

	Girls			Boys			P
	Mean	SD	Median (Interquartile range)	Mean	SD	Median (Interquartile range)	
Age	13.5	0.5	13 (13–14)	13.5	0.5	13 (13–14)	0.957
Height (cm)	52.20	8.73	51 (47–57)	56.0	11.0	55 (48–63)	<0.001
Weight (kg)	161.56	6.65	162 (157–166)	165.4	9.2	165 (160–172)	<0.001
Body mass index (kg/m ²)	20.03	2.93	19.6 (18.1–21.5)	20.4	3.2	20.0 (18.2–22.1)	<0.001
	Girls			Boys			P
	n	%		n	%		
Body mass index (kg/m ²)							<0.001
Normal weight	2797	86.5%		2459	76.3%		
Overweight	392	12.1%		653	20.3%		
Obesity	44	1.4%		110	3.4%		
Paternal or maternal smoking							0.023
Father	469	12.6%		492	14.1%		
Mother	704	18.9%		603	17.3%		
Mother and father	697	18.8%		599	17.1%		
Maternal education							0.007
No education	48	1.3%		61	1.8%		
Elementary	839	23.0%		707	20.5%		
High school	1504	41.1%		1530	44.3%		
University	1264	34.6%		1155	33.4%		
Truck traffic on the street of residence							<0.001
Never	372	9.9%		490	13.8%		
Seldom	1836	49.0%		1771	50.0%		
Frequent	1284	34.2%		1081	30.5%		
Constant	258	6.9%		203	5.7%		
Asthma ever	591	15.6%		675	18.8%		<0.001
Current asthma	505	13.3%		413	11.5%		0.017
Severe asthma	219	5.8%		164	4.6%		0.019
Exercise-induced asthma	856	22.6%		586	16.3%		<0.001

have analysed data using similar methodologies to the ones used in this study, which seems to defend their reliability. Thus, the evaluation of self-reported exposure to traffic by the children themselves or their parents, seems to be a reliable measurement; given the good correlation between the objective measurement of environmental contaminants of traffic and the intensity of that which is self-reported.^{21–23} Furthermore, this form of measurement enables a complex mixture of contaminants produced by road traffic to be

analysed, nearer to the epidemiological reality than only determining the levels of an individual contaminant.²⁴

Compared to previous studies, these results are in agreement with other authors who observed a greater effect in males²⁵ or in younger children,¹³ although the majority of published studies report a greater effect in females.^{10,26,27}

The greater effect in the younger boys could be associated with the lower calibre of the airway that boys of this age have compared to girls.²⁸

Table 2.A – Risk of asthma symptoms and self-reported frequency of truck traffic on the street of residence in children aged 6–7 years old according to gender. Univariate logistic regression analysis.

	Asthma ever OR (95% CI)	Current asthma OR (95% CI)	Severe asthma OR (95% CI)	Exercise-induced asthma OR (95% CI)
Boys				
<i>Frequency of truck traffic on the street of residence</i>				
Never	1.0	1.0	1.0	1.0
Seldom	0.9 (0.8–1.1)	1.0 (0.7–1.3)	1.3 (0.8–2.1)	1.2 (0.8–1.9)
Frequent	1.0 (0.8–1.2)	1.1 (0.8–1.4)	1.4 (0.9–2.4)	1.3 (0.8–1.9)
Constant	1.2 (0.9–1.7)	1.7 (1.1–2.6)	2.6 (1.3–5.0)	1.8 (1.0–3.4)
Girls				
<i>Frequency of truck traffic on the street of residence</i>				
Never	1.0	1.0	1.0	1.0
Seldom	1.0 (0.8–1.2)	1.0 (0.7–1.3)	0.9 (0.5–1.6)	0.8 (0.5–1.2)
Frequent	1.3 (1.0–1.6)	1.2 (0.9–1.6)	1.2 (0.7–2.0)	1.1 (0.7–1.6)
Constant	1.5 (1.0–2.1)	1.5 (0.9–1.6)	1.4 (0.6–3.3)	1.3 (0.6–2.5)

Table 2.B – Risk of asthma symptoms and self-reported frequency of truck traffic on the street of residence in children aged 13–14 years old according to gender. Univariate logistic regression analysis.

	Asthma ever OR (95% CI)	Current asthma OR (95% CI)	Severe asthma OR (95% CI)	Exercise-induced asthma OR (95% CI)
Boys				
<i>Frequency of truck traffic on the street of residence</i>				
Never	1.0	1.0	1.0	1.0
Seldom	1.17 (0.90–1.53)	0.98 (0.72–1.34)	0.99 (0.61–1.61)	1.27 (0.95–1.68)
Frequent	1.19 (0.90–1.53)	1.01 (0.72–1.42)	1.05 (0.63–1.76)	1.21 (0.89–1.63)
Constant	1.15 (0.75–1.75)	1.04 (0.62–1.73)	0.99 (0.45–2.18)	1.34 (0.86–2.08)
Girls				
<i>Frequency of truck traffic on the street of residence</i>				
Never	1.0	1.0	1.0	1.0
Seldom	1.17 (0.85–1.61)	1.01 (0.72–1.42)	1.06 (0.65–1.73)	1.01 (0.77–1.33)
Frequent	1.03 (0.74–1.43)	1.16 (0.82–1.64)	1.03 (0.62–1.72)	1.20 (0.91–1.59)
Constant	1.24 (0.80–1.91)	1.34 (0.85–2.11)	1.48 (0.78–2.81)	1.40 (0.97–2.03)

Table 3.A – Multivariate logistic regression analysis for factors relating to asthma symptoms in children aged 6–7.

	Asthma ever OR (95% CI)	Current asthma OR (95% CI)	Severe asthma OR (95% CI)	Exercise-induced asthma OR (95% CI)
Boys				
<i>Frequency of truck traffic on the street of residence</i>				
Never	1	1	1	1
Seldom	0.87 (0.63–1.21)	0.95 (0.69–1.31)	1.34 (0.74–2.41)	1.31 (0.79–2.15)
Frequent	0.93 (0.66–1.30)	1.01 (0.72–1.40)	1.50 (0.82–2.73)	1.35 (0.81–2.26)
Constant	1.63 (0.99–2.67)	1.66 (1.02–2.70)	3.11 (1.45–6.65)	2.46 (1.24–4.86)
Girls				
<i>Frequency of truck traffic on the street of residence</i>				
Never	1	1	1	1
Seldom	1.03 (0.68–1.54)	1.04 (0.72–1.50)	1.02 (0.54–1.93)	0.94 (0.56–1.60)
Frequent	0.99 (0.65–1.52)	1.22 (0.84–1.78)	0.98 (0.50–1.92)	1.16 (0.68–1.98)
Constant	1.45 (0.76–2.78)	1.44 (0.80–2.62)	1.16 (0.40–3.35)	1.03 (0.42–2.52)

Adjusted by body mass index, parental smoking and maternal education.

The analysis of published studies shows inconsistencies in the effect of road traffic contamination on asthma. Some authors report an increase in asthma symptoms with higher exposure to traffic^{9,11,27,29–33}; but others did not observe any

effect.^{34,35} In one study, it even observed a protector effect in 7–15 year-old children.³⁶ These authors presented the hypothesis that the protector effect for wheezing on living next to a main road could be related to the fact that those most

Table 3.B – Multivariate logistic regression analysis for factors relating to asthma symptoms in children aged 13–14.

	Asthma ever OR (95% CI)	Current asthma OR (95% CI)	Severe asthma OR (95% CI)	Exercise-induced asthma OR (95% CI)
Boys				
<i>Frequency of truck traffic on the street of residence</i>				
Never	1	1	1	1
Seldom	1.09 (0.82–1.44)	0.89 (0.64–1.25)	0.90 (0.53–1.53)	1.15 (0.85–1.57)
Frequent	1.13 (0.83–1.52)	1.01 (0.71–1.45)	1.09 (0.63–1.88)	1.16 (0.84–1.61)
Constant	1.01 (0.64–1.60)	0.98 (0.57–1.69)	0.84 (0.35–2.04)	1.19 (0.73–1.92)
Girls				
<i>Frequency of truck traffic on the street of residence</i>				
Never	1	1	1	1
Seldom	1.30 (0.91–1.87)	1.02 (0.70–1.48)	1.14 (0.66–1.98)	0.93 (0.69–1.26)
Frequent	1.09 (0.75–1.59)	1.12 (0.76–1.65)	1.03 (0.58–1.83)	1.10 (0.81–1.50)
Constant	1.18 (0.71–1.97)	1.17 (0.69–1.99)	1.40 (0.67–2.95)	1.14 (0.75–1.75)

Adjusted by body mass index, parental smoking and maternal education.

susceptible to asthma avoid these environments, or that another more frequent exposure in the rural environment could be associated with asthma; but both justifications have not been analysed.³⁶

Other hypotheses have also been implicated as causes of these inconsistencies. On the one hand, the possibility of biases are suggested for estimating the exposure, as was observed in a UK study, where the parents of the children with more severe respiratory symptoms over-estimated the exposure to traffic.³⁷ But contradicting this, in an Italian study, a good correlation was observed between the traffic indicators by questionnaire and objective measurements of these.²⁷

Another possible cause of the differences in the results could be the different ways of evaluating exposure. Some authors do this as self-reported traffic intensity, amount of heavy traffic, geographical information system (GIS) indices, direct measurement of some contaminants associated with traffic, or the distance to the nearest major road.^{7,21,36,38,39}

There could also be differences in the overall contaminants from sources other than traffic, such as biomass combustion or some industries; and even sociodemographic aspects such as, altitude, winds or population density can be determining factors of the levels of exposure to contaminants.⁶

Another factor could be the type of traffic, since a higher incidence of allergic sensitization was observed with higher exposure to truck traffic but not to cars.⁴⁰

Furthermore, the time of the exposure could have an influence, with a critical window of susceptibility, particularly in early life.⁶ This is in agreement with the results of a study in France, where exposure to traffic throughout life is not associated with more asthma, but if the exposure takes place in the first three years of life, it is associated with more asthma symptoms.⁴¹

Even differences in the characteristics of the exposed population, since it is known that there are differences between populations in the prevalence of allergic sensitization, which could be a factor for determining susceptibility to environmental contaminants.^{18,42}

In conclusion, the results of this study appear to support a distinct effect of truck traffic on asthma symptoms depending on the age and sex of the exposed population, being more harmful for young males.

Author statements

Ethical approval

The study was approved by the Clinical Research Ethics Committee of Galicia.

Funding

This work was funded by the Maria Jose Jove Foundation.

Competing interests

None declared.

REFERENCES

1. Sandström T, Kelly FJ. Traffic-related air pollution, genetics and asthma development in children. *Thorax* 2009;**64**(2):98–9.
2. Calderón-Garcidueñas L, Mora-Tiscareño A, Fordham LA, Chung CJ, Valencia-Salazar G, Flores-Gómez S, Solt AC, Gomez-del Campo A, Jardón-Torres R, Henríquez-Roldán C, Hazucha MJ, Reed W. Lung radiology and pulmonary function of children chronically exposed to air pollution. *Environ Health Perspect* 2006;**114**(9):1432–7.
3. Churg A, Brauer M, del Carmen Avila-Casado M, Fortoul TI, Wright JL. Chronic exposure to high levels of particulate air pollution and small airway remodeling. *Environ Health Perspect* 2003;**111**(5):714–8.
4. McCreanor J, Cullinan P, Nieuwenhuijsen MJ, Stewart-Evans J, Malliarou E, Jarup L, Harrington R, Svartengren M, Han IK, Ohman-Strickland P, Chung KF, Zhang J. Respiratory effects of exposure to diesel traffic in persons with asthma. *N Engl J Med* 2007;**357**(23):2348–58.
5. Holguin F. Traffic, outdoor air pollution, and asthma. *Immunol Allergy Clin North Am* 2008;**28**(3):577–88.
6. Salam MT, Islam T, Gilliland FD. Recent evidence for adverse effects of residential proximity to traffic sources on asthma. *Curr Opin Pulm Med* 2008;**14**(1):3–8.
7. Gehring U, Wijga AH, Brauer M, Fischer P, de Jongste JC, Kerkhof M, Oldenwening M, Smit HA, Brunekreef B. Traffic-related air pollution and the development of asthma and allergies during the first 8 years of life. *Am J Respir Crit Care Med* 2010;**181**(6):596–603.
8. Pénard-Morand C, Raherison C, Charpin D, Kopferschmitt C, Lavaud F, Caillaud D, Annesi-Maesano I. Long-term exposure to close-proximity air pollution and asthma and allergies in urban children. *Eur Respir J* 2010;**36**(1):33–40.
9. Brauer M, Hoek G, Smit HA, de Jongste JC, Gerritsen J, Postma DS, Kerkhof M, Brunekreef B. Air pollution and development of asthma, allergy and infections in a birth cohort. *Eur Respir J* 2007;**29**(5):879–88.
10. Kim JJ, Smorodinsky S, Lipsett M, Singer BC, Hodgson AT, Ostro B. Traffic-related air pollution near busy roads: the East Bay Children's Respiratory Health Study. *Am J Respir Crit Care Med* 2004;**170**(5):520–6.
11. McConnell R, Islam T, Shankardass K, Jerrett M, Lurmann F, Gilliland F, Gauderman J, Avol E, Künzli N, Yao L, Peters J, Berhane K. Childhood incident asthma and traffic-related air pollution at home and school. *Environ Health Perspect* 2010;**118**(7):1021–6.
12. asana J, Dillikar D, Mendy A, Forno E, Ramos Vieira E. Motor vehicle air pollution and asthma in children: a meta-analysis. *Environ Res* 2012;**117**:36–45.
13. Brunekreef B, Stewart AW, Anderson HR, Lai CK, Strachan DP, Pearce NISAAC Phase 3 Study Group. Self-reported truck traffic on the street of residence and symptoms of asthma and allergic disease: a global relationship in ISAAC phase 3. *Environ Health Perspect* 2009;**117**(11):1791–8.
14. Garcia-Marcos L, Canflanca IM, Garrido JB, Varela AL, Garcia-Hernandez G, Guillen Grima F, Gonzalez-Diaz C, Carvajal-Urueña I, Arnedo-Pena A, Busquets-Monge RM, Morales Suarez-Varela M, Blanco-Quiros A. Relationship of asthma and rhinoconjunctivitis with obesity, exercise and Mediterranean diet in Spanish schoolchildren. *Thorax* 2007;**62**(6):503–8.
15. López-Silvarrey Varela A, González Barcala FJ, Paz Esquete JJ, Pérez Castro TR, Valdés Cuadrado L, Castro Iglesias A. Prevalence of asthma and rhinitis symptoms in A Coruña (Spain). *An Pediatr (Barc)* 2007;**66**(2):146–53.
16. The International Study of Asthma and Allergies in Childhood (ISAAC) Steering Committee. Worldwide variations in the

- prevalence of asthma symptoms: the International Study of Asthma and Allergies in Childhood (ISAAC). *Eur Respir J* 1998;12:315–35.
17. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000;320:1240–3.
 18. Weinmayr G, Genuneit J, Nagel G, Björkstén B, van Hage M, Priftanji A, Cooper P, Rijkjær MA, von Mutius E, Tsanakas J, Forastiere F, Doekes G, Garrido JB, Suarez-Varela MM, Bråbäck L, Strachan DP, ISAAC Phase Two Study Group. International variations in associations of allergic markers and diseases in children: ISAAC Phase Two. *Allergy* 2010;65(6):766–75.
 19. Garcia-Marcos L, Arnedo Pena A, Busquets-Monge R, Morales Suárez-Varela M, García de Andoin N, Batlles-Garrido J, Blanco-Quirós A, López-Silvarrey Varela A, García-Hernández G, Aguinaga-Ontoso I, González-Díaz C, Garcia-Merino A. How the presence of rhinoconjunctivitis and the severity of asthma modify the relationship between obesity and asthma in children 6–7 years old. *Clin Exp Allergy* 2008;38(7):1174–8.
 20. Remes ST, Pekkanen J, Remes K, Salonen RO, Korppi M. In search of childhood asthma: questionnaire, tests of bronchial hyperresponsiveness, and clinical evaluation. *Thorax* 2002;57:120–6.
 21. Cesaroni G, Badaloni C, Porta D, Forastiere F, Perucci CA. Comparison between various indices of exposure to traffic-related air pollution and their impact on respiratory health in adults. *Occup Environ Med* 2008;65(10):683–90.
 22. Janssen NAH, van Vliet PHN, Aarts F, Harssema H, Brunekreef B. Assessment of exposure to traffic related air pollution of children attending schools near motorways. *Atmos Environ* 2001;35(22):3875–84.
 23. van Roosbroeck S, Wichmann J, Janssen NA, Hoek G, van Wijnen JH, Lebret E, Brunekreef B. Long-term personal exposure to traffic-related air pollution among school children, a validation study. *Sci Total Environ* 2006;368(2–3):565–73.
 24. Balmes JR. Can traffic-related air pollution cause asthma? *Thorax* 2009;64(8):646–7.
 25. Gehring U, Cyrus J, Sedlmeir G, Brunekreef B, Bellander T, Fischer P, Bauer CP, Reinhardt D, Wichmann HE, Heinrich J. Traffic-related air pollution and respiratory health during the first 2 yrs of life. *Eur Respir J* 2002;19(4):690–8.
 26. Venn AJ, Lewis SA, Cooper M, Hubbard R, Britton J. Living near a main road and the risk of wheezing illness in children. *Am J Respir Crit Care Med* 2001;164(12):2177–80.
 27. Migliore E, Berti G, Galassi C, Pearce N, Forastiere F, Calabrese R, Armenio L, Biggeri A, Bisanti L, Bugiani M, Cadum E, Chellini E, Dell'orco V, Giannella G, Sestini P, Corbo G, Pistelli R, Viegi G, Ciccone GSIDRIA-2 Collaborative Group. Respiratory symptoms in children living near busy roads and their relationship to vehicular traffic: results of an Italian multicenter study (SIDRIA 2). *Environ Health* 2009;8:27.
 28. Carey MA, Card JW, Voltz JW, Arbes Jr SJ, Germolec DR, Korach KS, Zeldin DC. It's all about sex: gender, lung development and lung disease. *Trends Endocrinol Metab* 2007;18(8):308–13.
 29. Morgenstern V, Zutavern A, Cyrus J, Brockow I, Koletzko S, Krämer U, Behrendt H, Herbarth O, von Berg A, Bauer CP, Wichmann HE, Heinrich JGINI Study GroupLISA Study Group. Atopic diseases, allergic sensitization, and exposure to traffic-related air pollution in children. *Am J Respir Crit Care Med* 2008;177(12):1331–7.
 30. O'Connor GT, Neas L, Vaughn B, Kattan M, Mitchell H, Crain EF, Evans 3rd R, Gruchalla R, Morgan W, Stout J, Adams GK, Lippmann M. Acute respiratory health effects of air pollution on children with asthma in US inner cities. *J Allergy Clin Immunol* 2008;121(5):1133–9.
 31. Gent JF, Koutrakis P, Belanger K, Triche E, Holford TR, Bracken MB, Leaderer BP. Symptoms and medication use in children with asthma and traffic-related sources of fine particle pollution. *Environ Health Perspect* 2009;117(7):1168–74.
 32. Middleton N, Yiallourous P, Nicolaou N, Kleanthous S, Pipis S, Zeniou M, Demokritou P, Koutrakis P. Residential exposure to motor vehicle emissions and the risk of wheezing among 7–8 year-old schoolchildren: a city-wide cross-sectional study in Nicosia, Cyprus. *Environ Health* 2010;9:28.
 33. Dales R, Wheeler AJ, Mahmud M, Frescura AM, Liu L. The influence of neighborhood roadways on respiratory symptoms among elementary schoolchildren. *J Occup Environ Med* 2009;51(6):654–60.
 34. Lewis SA, Antoniak M, Venn AJ, Davies L, Goodwin A, Salfeld N, Britton J, Fogarty AW. Secondhand smoke, dietary fruit intake, road traffic exposures, and the prevalence of asthma: a cross-sectional study in young children. *Am J Epidemiol* 2005;161(5):406–11.
 35. Wilkinson P, Elliott P, Grundy C, Shaddick G, Thakrar B, Walls P, Oner S. Case-control study of hospital admission with asthma in children aged 5–14 years: relation with road traffic in north west London. *Thorax* 1999;54(12):1070–4.
 36. Pujades-Rodríguez M, Lewis S, McKeever T, Britton J, Venn A. Effect of living close to a main road on asthma, allergy, lung function and chronic obstructive pulmonary disease. *Occup Environ Med* 2009;66(10):679–84.
 37. Kuehni CE, Strippoli MP, Zwahlen M, Silverman M. Association between reported exposure to road traffic and respiratory symptoms in children: evidence of bias. *Int J Epidemiol* 2006;35(3):779–86.
 38. Escamilla-Núñez MC, Barraza-Villarreal A, Hernandez-Cadena L, Moreno-Macias H, Ramirez-Aguilar M, Sienna-Monge JJ, Cortez-Lugo M, Texcalac JL, del Rio-Navarro B, Romieu I. Traffic-related air pollution and respiratory symptoms among asthmatic children, resident in Mexico City: the EVA cohort study. *Respir Res* 2008;9:74.
 39. Rosenlund M, Forastiere F, Porta D, De Sario M, Badaloni C, Perucci CA. Traffic-related air pollution in relation to respiratory symptoms, allergic sensitization and lung function in schoolchildren. *Thorax* 2009;64(7):573–80.
 40. Janssen NA, Brunekreef B, van Vliet P, Aarts F, Meliefste K, Harssema H, Fischer P. The relationship between air pollution from heavy traffic and allergic sensitization, bronchial hyperresponsiveness, and respiratory symptoms in Dutch schoolchildren. *Environ Health Perspect* 2003;111(12):1512–8.
 41. Zmirou D, Gauvin S, Pin I, Momas I, Sahraoui F, Just J, Le Moulec Y, Brémont F, Cassadou S, Reungoat P, Albertini M, Lauvergne N, Chiron M, Labbé AVesta Investigators. Traffic related air pollution and incidence of childhood asthma: results of the Vesta case-control study. *J Epidemiol Community Health* 2004;58(1):18–23.
 42. Wang TN, Lin MC, Wu CC, Leung SY, Huang MS, Chuang HY, Lee CH, Wu DC, Ho PS, Ko AM, Chang PY, Ko YC. Risks of exposure to occupational asthmogens in atopic and nonatopic asthma: a case-control study in Taiwan. *Am J Respir Crit Care Med* 2010;182(11):1369–76.