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Environmental and social factors as determinants of respiratory dysfunction in junior schoolchildren in Moscow

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Abstract

Background The process of industrialization of the USSR has left a legacy of widespread and often poorly controlled pollution which is widely believed to have adverse implications for health, in particular for respiratory disease among children.

Objectives To assess the relationship between area of residence and respiratory function in junior schoolchildren in different districts of Moscow.

Methods A survey was conducted of 539 children aged 6–12 years who attend school and live in one of three districts of Moscow with varying ambient pollution levels. Spirometry [forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV_1)] was assessed at school by trained school health staff. Parents of the children completed a questionnaire asking about respiratory function and factors potentially associated with it, as well as about social and other factors that could influence respiratory development and the health status of their children.

Results There was appreciable difference in the character istics of the children from the three districts. Children from the lower pollutant districts were generally younger, had higher parental income, and were less frequently exposed to cigarette smoke at home. They were also less likely to report heavy lorry traffic in the streets outside their homes. After adjustment for age, gender and height the FVC was 7.6 per cent (3.6–11.5 per cent) lower in children from the medium pollution district and 9.9 per cent [95 per cent confidence interval (CI) 5.6–14.0 per cent] lower in children from the high pollution district compared with those in the least polluted district ($p < 0.001$ for trend). These differences were little affected by further adjustment for household income or exposure to household smoking. In contrast, FEV_1 showed comparatively little variation across districts. The odds of a forced expiratory ratio (FER) <75 per cent were substantially lower in the high pollution compared with the low pollution district (odds ratio 0.10, 95per cent CI 0.03–0.32 after adjustment for age, gender and height), and there was clear evidence of a trend across pollution categories ($p < 0.001$). The frequency of reported allergy was also lower in the high pollution district. FVC increased, and the probability of a low FER decreased, with household income.

Conclusion Children from areas of high environmental pollution had lower lung capacity but also smaller risk of a low FER compared with those from cleaner areas. The extent to which these differences can be attributed to environmental pollution is unclear without more detailed study. However, socio-economic deprivation, which was associated with pollution, appears to be an important determinant of respiratory function although it was associated with a lower risk of an obstructive pattern of lung function tests.

Keywords: respiratory function, environment, Russia

Introduction

Within Russia it is widely believed, among both the public and many health policy makers, that poor environmental conditions have been among the leading causes of the country's high and, in the early 1990s, rising level of mortality and morbidity.[1–4] In part, this reflects the very extensive, and easily visible, scale of the damage inflicted in many places, the low investment in technologies that might ameliorate this pollution and, especially, some well known environmental disasters in other former Soviet republics such as Chernobyl and the evaporation of much of the Aral Sea. Indeed, some commentators have used the term 'ecocide' when arguing that environmental damage has been a major factor in the country's mortality crisis in the 1980s and 1990s.[5]

One manifestation of the considerable public concern about environmental pollution in Russia is that raions (districts) are now classified on the basis of ambient air pollution data collected by the Sanitary-Epidemiological (Public Health) Service. Housing in the low pollution ('clean') areas is more desirable and up to twice as expensive as that in the high pollution ('dirty') areas. Indeed, the status of the raion is a major element in sales advertisements by estate agents. Yet there is still very little

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empirical evidence about whether this difference translates into observable differences in health.

While the health effects of pollution are potentially numerous, depending on the agents involved,[6,7] there have been particular concerns about the impact on respiratory disease, especially among children.[8,9] There are many ecological studies from different parts of Russia showing high rates of asthma in more polluted areas.[10–12] For example, one author has stated, on the basis of mapping of pollution and morbidity data, that 'The level of air pollution varies from one neighbourhood of the city to another. This accounts for the variability of child health levels'.[13]

However, many of these studies rely on routine morbidity data; they do not provide data on individual levels of exposure, nor do they take account of potential confounders. An exception was a small study from Mytichi, near Moscow, that compared the difference in respiratory function of children residing in 'dirty' and 'clean' areas, finding a significant difference in rates of respiratory dysfunction (14 per cent in the 'clean' area and 25 per cent in the 'dirty' area), but again it was not possible to examine the effects of other factors.[14]

In contrast, studies using more rigorous approaches have painted a rather different picture. Thus, the ISAAC study, which used validated and consistent methods to measure the prevalence of asthma in 56 countries worldwide, found some of the lowest rates in countries of the former Soviet Union.[15] A study looking at childhood asthma prevalence in areas of Kaunas, Lithuania with differing levels of pollution found no significant differences,[16] and a detailed survey of children living in Nikel, a highly polluted city in northern Russia, found a prevalence of childhood asthma that was substantially lower than in a comparable area in Norway, where pollution levels were lower,[17] and within Nikel asthma and other atopic symptoms were associated with indoor dampness but not with external environmental pollutants.[18]

So far, however, there have been no rigorously conducted studies that have looked at the specific question of the relationship between respiratory symptoms in children and the official pollution status of their district of residence. In this paper we report the results of such a study, conducted in Moscow in 2002.

Methods

A cross-sectional study was conducted in three districts of Moscow, selected using an ecological map of the city (Fig. 1). One, Krylatskoe, is in the west of the city and is designated as 'clean' and the others, Vyhino and Kapotny, are in the south-east. Vyhino is designated as a 'medium' district and Kapotny is designated as 'dirty'. The latter two are close to a large oil

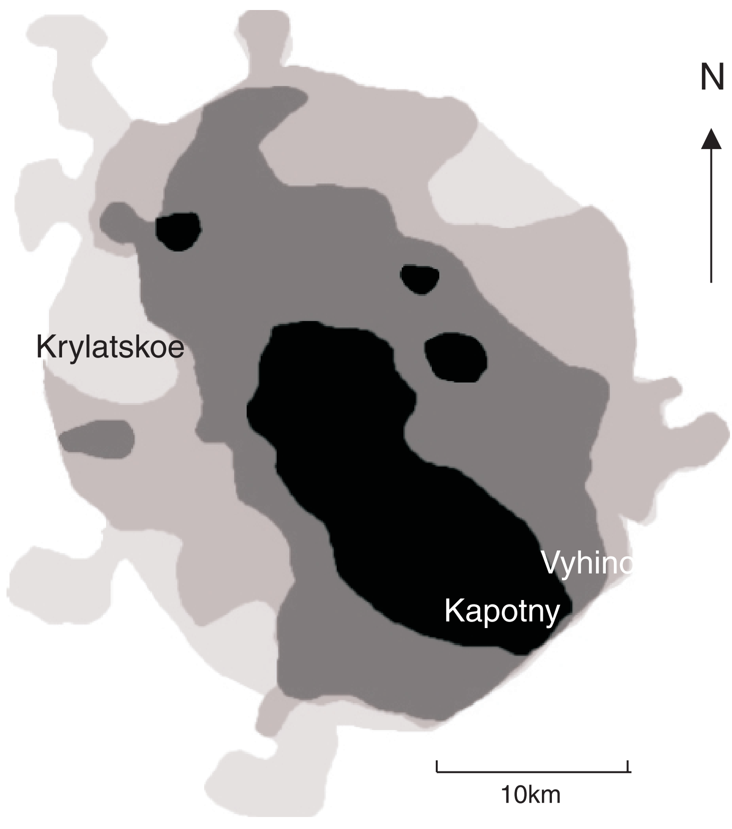

Fig 1 Ecological map of Moscow (increasing shading indicates greater level of overall pollution).

refinery, at which petrochemical waste is continually burnt. These two districts had been the subjects of numerous complaints to local authorities by residents who expressed concern about the effect of the pollution on the health of their children, and in particular about children attending a school in Kapotny, close to the refinery. The State Report on Environmental Conditions in Moscow, in 1999,[19] reported that, in the South-East district of Moscow, where Vyhino and Kapotny are located, 31 per cent of samples exceeded maximum allowable concentration of NO_2, compared with 12 per cent of samples in the West district of Moscow where Krylatskoe is located. A similar difference was apparent for benzene levels: in the West district all samples were within normal limits but in the South-East district 6 per cent of the samples exceeded the maximum allowable concentration. Russian maximum levels for NO_2 are 40 (daily mean) and 85 $\mu g/m^3$ (single measurement) and for benzene are 100 (daily mean) and 1500 $\mu g/m^3$ (single measurement). The selection of districts was determined, in the first instance, by the concern expressed in Kapotny and, to a lesser extent, Vyhino. In contrast, while Kapotny and Vyhino have been designated by the Sanitary-Epidemiological (Public Health) Service as polluted ('dirty' and 'medium', respectively, according to Russian norms based on measures of ambient air pollution), Krylatskoe has been designated as the cleanest one in Moscow. The school in Kapotny, where there was most concern, was closest (within 500 m) to the refinery. The comparison schools were selected at random in the other districts, one in Vyhino and two in Krylatskoe. Two schools were selected in Krylatskoe as it was thought that as there were no significant public concerns about pollution the response rate may have been lower.

The study population comprised all children in the first three classes of each school (ages 6–11) who lived in the same district as the school.

Informed consent to participate was sought from parents of children, who were also asked to complete a questionnaire asking about respiratory function and factors potentially associated with it. These included age, height and weight of the child; whether breast-fed; parental smoking; ownership of pets; maternal education, occupational and socio-economic status; fuel used for cooking (gas or electricity); and proximity to industrial plants and to traffic. The standard Russian classification of education into five levels, with higher education being highest and incomplete secondary school education the lowest, was used. Parents were also asked if their children had experienced any of a list of respiratory and related symptoms including self-report of different degrees of cough, breathing problems or allergy, as well as diseases that had been medically diagnosed. The questions used to screen for symptoms of airway obstruction comprised a combination of questions from the instrument used in the ISAAC study,[15] with questions of health and experience of illness taken from an instrument used in previous research in Russia and which are believed to be both culturally and linguistically appropriate.[3]

Spirometry [forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV_1)] was assessed at schools by trained school health staff. In each case the best of three attempts was recorded. Forced expiratory ratio (FER) was calculated as FEV_1 / FVC and a FER <75 per cent was used as an indicator of the presence of obstructive airways disease.

The relationship between lung function tests (FVC, FEV_1) and explanatory factors was examined by tabulation and multiple linear regression. We used a regression model of the form:

$$E[\log(\text{lung function test})] = \mu + X\beta$$

where μ is the overall mean, and X is the vector of covariates. This model, which is additive on the log scale, was chosen to achieve constant variance across values of the explanatory factors. Modelling of the proportion of children with a FER <75 per cent was performed using logistic regression. In all models, the effect of age and height were modelled using quadratic terms to allow for non-linear relationships. Robust standard errors and confidence intervals (CIs) were calculated using the Huber-White 'sandwich' estimator.[20]

Results

The survey included 539 (77 per cent) of the potential 700 children aged 6–12 years in the participating schools. Valid spirometry and questionnaire data were available for 479 of these (Table 1). The lower participation in the 'clean' area was largely due to the refusal of the parents association representing one of the classes to participate; otherwise the participation rates were similar. Non-participation was almost entirely due to lack of parental consent, although it is not now possible to distinguish failure to obtain consent from refusal to participate.

Children from the lower pollution districts were on average younger than those from the highest pollution district, and this was reflected in height distributions (Table 2). One of the notable findings was the greater social disadvantage of children from the high pollution district, as indicated by household incomes and also the fact that only 20.9 per cent of mothers in the high pollution district had higher education, compared with 71.4 per cent in the lowest pollution district.

Children in the higher pollution districts were exposed to greater environmental hazards, with a greater probability of proximity to heavy traffic (as measured by having trucks in the street frequently or almost the whole day – odds ratio 3.14

Table 1 Numbers of children at each school and response rates

School	School roll	Responses (%)	Responses with valid data (%)
Viyhino	175	154 (88.0)	136 (77.7)
Kapotny	146	118 (81.0)	111 (76.0)
Krylatskoe A and B	379	267 (70.4)	232 (61.2)
Total	700	539 (77)	479 (68.4)

(95 per cent CI 2.18–4.55) and to indoor air pollution, as assessed by exposure to tobacco smoke in the home – odds ratio 2.13 (95 per cent CI 1.41–3.21) (Table 2). However, children in the high pollution district spent, on average, 3.2 hours playing outside their homes each school day compared with 1.4 hours in the lowest pollution district. Cooking was with gas, rather than electricity, in 83.8 per cent of houses in the highest pollution district compared with 12.1 per cent in the lowest pollution district. Traditionally, cooking in Russian apartments was with gas, whereas electricity tends to be found in newer houses.

In summary, higher pollution areas were characterized by greater social disadvantage, greater exposure to outdoor air pollution, both as assessed from the map of pollution in Moscow and self-reported exposure to heavy traffic, and indoor

Table 2 Characteristics of surveyed children by area

	Area classification No. (%) or median (5th to 95th centile range)		
	Low pollution ('clean') (*n* = 232)	**Medium pollution (*n* = 136)**	**High pollution ('dirty') (*n* = 111)**
Age (years)			
<7	71 (30.6)	33 (24.3)	13 (11.7)
8	64 (27.6)	40 (29.4)	31 (27.9)
9	64 (27.6)	41 (30.2)	31 (27.9)
10	32 (13.8)	21 (15.4)	22 (19.8)
11+	1 (0.4)	1 (0.7)	14 (12.6)
Gender			
Male	125 (53.9)	71 (52.2)	58 (52.3)
Female	107 (46.1)	65 (47.8)	53 (47.8)
Height			
<130	70 (30.2)	37 (27.2)	24 (21.6)
130–	66 (28.5)	28 (20.6)	30 (27.0)
135–	39 (16.8)	42 (30.9)	26 (23.4)
140+	57 (24.6)	29 (21.3)	31 (27.9)
Income			
US$20–50	33 (14.2)	51 (37.5)	34 (30.6)
US$51–70	31 (13.4)	32 (23.5)	24 (21.6)
US$71–100	32 (13.8)	21 (15.4)	15 (13.5)
US$101–150	35 (15.1)	17 (12.5)	21 (18.9)
US$151–200	33(14.2)	6 (4.4)	8 (7.2)
US$201+	35 (15.1)	6 (4.4)	5 (4.5)
Unrecorded	33 (14.2)	3 (2.2)	4 (3.6)
Whether smoker in family			
1 – no	98 (42.2)	46 (33.8)	24 (21.6)
2 – 1 smoker	16 (6.9)	11 (8.1)	4 (3.6)
3 – 2 smokers	89 (38.4)	49 (36.0)	46 (41.4)
4 – >2 smokers	23 (9.9)	29 (21.3)	26 (23.4)
Unrecorded	6 (2.6)	1 (0.7)	11 (9.9)
Trucks in street			
Never	20 (8.6)	10 (7.4)	5 (4.5)
Seldom	157 (67.7)	57 (41.9)	52 (46.9)
Frequently	42 (18.1)	40 (29.4)	37 (33.3)
Almost whole day	13 (5.6)	28 (20.6)	17 (15.3)
Unrecorded	0	1 (0.7)	0
Reported allergy			
No	140 (60.3)	92 (67.7)	82 (73.9)
Yes	92 (39.7)	43 (31.6)	27 (24.3)
Unrecorded	0	1 (0.74)	2 (1.8)
FVC (l)	1.69 (1.14–3.30)	1.71 (1.21–3.20)	1.65 (1.24–2.31)
FEV_1 (l)	1.55 (1.08–2.07)	1.63 (1.00–2.14)	1.60 (1.23–2.14)
%FER <75%	47 (20.3)	7 (5.2)	3 (2.7)

FVC, forced expiratory volume; FEV_1, forced expiratory volume in 1 second; FER, forced expiratory ratio = FEV_1 / FVC.

air pollution, as assessed by exposure to smokers and cooking with gas.

Figure 2 shows the clear relationship between lung function and income after adjustment for age, gender, height and district. FVC was significantly higher in children from better-off families (p-value for trend = 0.001). FEV_1, however, varied little across income groups, but there was evidence that higher income families were more likely to have a FER <75 per cent ($p = 0.04$ for trend).

Table 3 shows the effect of progressively adjusting first for age and gender, then additionally for height, then also for income and, finally, also for exposure to smoking in the home. After adjustment for age, gender and height, FVC was 7.6 and 9.9 per cent lower in the medium and high pollution districts, respectively, compared with the low pollution district. Progressive adjustment changes the figures slightly but, after the addition of both income and exposure to smoking, children in the medium and high pollution districts have FVCs that are 6.0 and 9.7 per cent, respectively, lower than children in clean areas.

The odds of having a FER <75 per cent, as an indicator of obstructive airways disease, shows the opposite effect. In the fully adjusted model, children in the medium area are 72 per cent less likely to have a reduced FER, while children in the dirty area are 92 per cent less likely.

Finally, mothers were asked about a range of common respiratory symptoms. A diagnosis of asthma was reported in 1.5 per cent of mothers in the 'clean' area and 1.9 per cent in the 'dirty' area but this difference was not significant. However, 39.8 per cent of mothers in the 'clean' area reported a history of allergy, compared with only 27.6 per cent in the 'dirty' area ($p = 0.003$). Reported rates of bronchitis were almost identical at 36.7 and 36.2 per cent in the 'clean' and 'dirty' areas, respectively, as were throat infections in the last year (39.7 and 35.4 per cent, respectively).

Discussion

Before looking at the implications of these findings the limitations of the study must be considered. First, the children were classified for environmental 'exposure' using an indirect, group-level (i.e. area) marker of ambient pollution. Given just three areas and the relative crudeness of such markers,[21] it is difficult to draw firm inferences about the role of pollution in explaining observed differences in lung function, especially as we know that residence in the more polluted districts was associated with relative socio-economic disadvantage. The size of the study population was also fairly small (so limiting precision of risk estimates), and information on asthma symptoms was not collected using a validated questionnaire. In addition, given the episodic nature of asthma, a more detailed assessment of symptoms over time, as was done in the ISAAC study, would have been preferable to a single point measurement of airways function, which anyway is not diagnostic of asthma.

However, the study does have certain strengths. Assessment of lung function was undertaken by trained medical personnel using standardized methods. Response rates were reasonably high, although data are not available on non-responders. As already noted, the slightly lower rate in the 'clean' district was largely because one entire class declined to participate, so that it is unlikely that this could have introduced any bias in relation to health. In passing, our experience in other Russian surveys and that of the recent Russian census is that, contrary to the situation in western Europe, non-response is more common in higher socio-economic groups. A particular strength is that it also combines objective measurement of lung function with information on a wide range of socio-economic and other information from the survey.

There is an increasing body of large-scale international research on the epidemiology of lung function in children. This study, in contrast, had a more limited objective, but one that is of considerable interest to those living in the former Soviet Union where the legacy of often poorly planned and weakly

Table 3 Variation in lung function by area type

Adjusting for	Pollution level of area	% Difference in FVC compared with clean area	% Difference in FEV_1 compared with clean area	Odds ratio for FER <75%
Age and gender	Low	0	0	1
	Medium	−7.8 (−12.0 to −3.5)	2.3 (−1.8 to 6.6)	0.20 (0.09 to 0.45)
	High	−11.3 (−15.6 to −6.8)	0.9 (−2.7 to 4.6)	0.10 (0.03 to 0.32)
Age, gender and height	Low	0	0	1
	Medium	−7.6 (−11.5 to −3.6)	2.6 (−1.2 to 6.4)	0.20 (0.09 to 0.45)
	High	−9.9 (−14.0 to −5.6)	2.5 (−0.6 to 5.8)	0.10 (0.03 to 0.32)
Age, gender, height, income	Low	0	0	1
	Medium	−5.2 (−9.5 to −0.8)	2.8 (−1.3 to 7.0)	0.29 (0.12 to 0.69)
	High	−8.7 (−13.1 to −4.2)	3.1 (−0.4 to 6.7)	0.08 (0.02 to 0.34)
Age, gender, height, income, whether smoker in family	Low	0	0	0
	Medium	−6.0 (−10.3 to −1.6)	2.2 (−1.9 to 6.5)	0.28 (0.12 to 0.68)
	High	−9.7 (−14.2 to −5.0)	3.0 (−0.7 to 6.9)	0.08 (0.02 to 0.33)

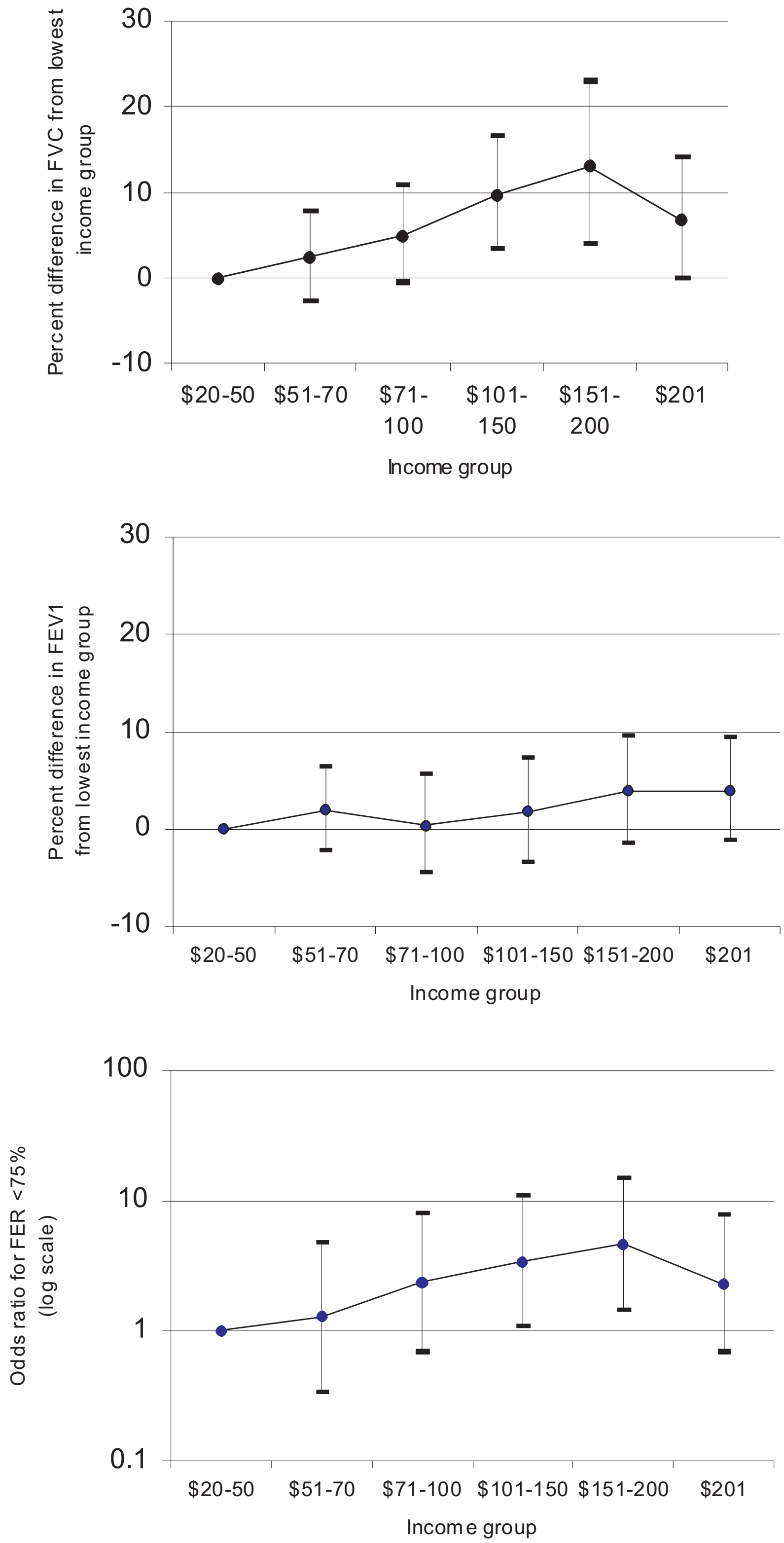

Fig 2 Variation in FVC, FEV_1 and percentage of children with FER <75 per cent across income groups. (Estimates adjusted for age, gender, height and area.)

regulated industrial development has given rise to widespread pollution, often in close proximity to residential areas. There is a widespread view that such polluted areas are associated with symptoms of respiratory disease in children.

The first observation of the study is that it shows that those living in the 'dirtier' areas of Moscow suffer greater social disadvantage, as indicated by lower family income and lower participation of the mother in higher education, while also being exposed to higher volumes of heavy traffic and greater indoor air pollution.

However, the findings with regard to lung function are mixed. FVC was lower in children from the more polluted areas, but the odds of having an objective measure of obstructive airways disease was also substantially lower. In would be too simplistic to attribute the lower FVCs to the presence of pollution, as many factors are involved in lung development. It is interesting and perhaps relevant that a clear gradient of increasing FVC and decreasing FER was seen with household income. The increasing FVC in children of more affluent families may reflect a number of factors, including early life development and better nutrition (though there was no clear difference in, for example, the frequency of fruit consumption with income). The greater risk of a low FER at high income, indicating propensity to airflow limitation, appears counter-intuitive. One possibility is that it might in part be an artefact arising from a better spirometer technique in children from more affluent families, who achieved generally higher FVCs, although we believe this to be unlikely given the attention to standardization of the methods and the level of training of the staff involved. But it could also be consistent with the somewhat controversial 'hygiene' hypothesis concerning the aetiology of asthma.[22,23] While again noting the absence of a validated instrument to compare symptoms, and recognizing the scope for systematic reporting bias, it is noteworthy that mothers in the more affluent, low pollution area reported a much higher prevalence of allergy – though there was no clear association with income.

Given the high, and often very obvious levels of environmental pollution affecting residential areas in many areas of Russia, there is clearly a need for much more research on possible effects on health. The results of this study do not support the widely held view that there are substantially higher levels of respiratory symptoms among children living in polluted areas, though the difference in FVC is potentially a cause for concern, especially giving that, in areas where smoking in the family is more common, these children can also be expected to have higher rates of smoking in adulthood. Thus, they face a double burden starting from a lower level of lung function that will then be subject to greater insults, and so decline more rapidly, at older ages.

In conclusion, this study provides insights on a topic that has been the subject of a great deal of rhetoric but relatively little empirical research. It suggests that the influence of outdoor pollution on respiratory health of children in Russia is often over-estimated. But it also shows that socio-economic factors, which are associated with pollution, are important determinants of respiratory function in children, and the mechanisms of influence merit further investigation.

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