Has the prevalence of asthma increased in children? Evidence from a long term study in Israel

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Abstract

Background—The permit to build and operate the first 1400 megawatt coal fired power plant in Israel was given provided that three monitoring systems—environmental, agricultural, and health monitoring—be set up near the plant. This study was carried out in the framework of a health monitoring system which included a mortality survey, requests for health services, a schoolchildren's health survey, and an adult panel study.

Methods—2nd, 5th, and 8th grade schoolchildren living in three communities with different expected levels of air pollution were followed up every three years. They performed pulmonary function tests (PFT), and their parents filled out American Thoracic Society-National Heart and Lung Institute (ATS-NHLI) health questionnaires. A follow up of the prevalence of respiratory conditions among the studied schoolchildren in four rounds of tests was carried out. This report deals with the changes in the prevalence of asthma, related respiratory conditions, and PFT in the data sets gathered among 5th grade schoolchildren.

Results—A significant ($p=0.0024$) increase in the prevalence of asthma could be observed among 5th grade children in all three communities studied between 1980 and 1989. At the same time a significant ($p=0.0172$) rise in the prevalence of wheezing accompanied by shortness of breath could be observed. A similar trend could not be found for the prevalence of bronchitis and other respiratory conditions among the studied children. PFT (FEV_1 , FEV_1/FVC) of children suffering from asthma or from wheeze accompanied by shortness of breath were lower than those of healthy children. Changes in the prevalence of background variables over time could not explain the significant rise in the prevalence of asthma among the children.

Conclusions—The significant rise in asthma and related respiratory conditions coupled with reduced PFT observed in this study suggest that the increase over time in the prevalence of asthma is a true increase in morbidity and not due to reporting bias. The increased prevalence of asthma could be observed in all the communities studied and does not seem to be connected with the operation of the power plant.

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The first coal fired power plant in Israel is located on the coast in a semi-rural region midway between Tel-Aviv and Haifa. The plant consists of four 350 megawatt units. From 1981 the units were gradually put into operation until the summer of 1984, by which time all were operating. The permit to build and operate this power plant was given provided that three monitoring systems—environmental, agricultural, and long term health monitoring—be set up near the plant. The health monitoring programme¹ included four health surveys as follows: a mortality survey, requests for health services, a schoolchildren's health survey, and an adult panel study. The aim of this monitoring programme was to carry out a spatio-temporal follow up of the health status of the population residing in the vicinity of the power plant in order to be able to detect any deterioration in their health which could be attributed to the operation of the plant.

Reports about an increase in the prevalence of asthma in Israel^{2,3} and elsewhere⁴⁻¹² motivated us to analyse trends in the prevalence of asthma and related symptoms among the cohorts of children studied in the framework of this health monitoring system. The aim of this analysis was to find out whether an increased prevalence of asthma could be observed among all the children followed up, similarly to findings in other studies,²⁻¹² or if such an increase only characterises a specific residential area near the power plant.

Methods

A follow up was regularly conducted in three cohorts of schoolchildren—ie, 2nd, 5th, and 8th grade pupils living in three communities located within 19 km of the power plant (fig 1). According to the environmental impact statement prepared by the Israel Electric Company¹³ differing extents of pollution were expected in these communities as a result of the operation of the power plant.

Baseline data for this study were gathered in 1980, before the first unit was put into operation. The second data set was gathered in 1983 when two units of the plant were operating, and the third and fourth sets were gathered in 1986 and 1989 when all units were operating. The health questionnaire used in this survey was a translated version of the American Thoracic Society-National Heart and Lung Institute (ATS-NHLI) self administered questionnaire,¹⁴

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Figure 1 Map of the power plant area.

Figure 2 Prevalence of asthma and wheezing with shortness of breath (SOB) among 5th grade children in 1980, 1983, 1986 and 1989.

to be completed by the children's parents. The questionnaires included information on respiratory symptoms and diseases in the children studied and their parents, as well as socio-economic information. They were distributed to the children by the school nurses, who also collected them after they were completed. After receiving these questionnaires, the survey technician conducted pulmonary function tests

(PFT) in the participating schools using a portable spirometer (Minato AS-1000).

The PFT parameters obtained were forced vital capacity (FVC), the forced expiratory volume in the 1st second (FEV_1), and FEV_1/FVC . The pupils performed the test standing and repeated the manoeuvre at least three times until two similar tests (within 10%) were obtained. The best test (highest FVC + FEV_1) was chosen. In each round the same technician carried out the PFT in all the participating schools. The school nurses weighed the children and measured their height. All tests were done between April and June during the morning.

Statistical analysis was carried out using *SPSS* and *BMDP* programs.¹⁵¹⁶ Prevalences of respiratory symptoms and diseases among children from the different cohorts, were analysed by means of χ^2 test for trend. The χ^2 trend analysis was also carried out for background variables. In order to examine the combined effect of background variables and year of study on respiratory conditions, logistic regressions were fitted for the prevalence of asthma and related respiratory symptoms. The independent variables included in the regressions were as follows: year of study, respiratory diseases among parents, mothers' education, mothers' smoking, and the crowding index. Pulmonary function tests were analysed using one way analysis of variance.

This report deals with the changes in the prevalence of asthma, related respiratory conditions, and PFT in the data sets gathered among 5th grade schoolchildren.

The environmental monitoring network (fig 1) consists of 12 monitoring stations, of which 10 are stationary and 2 are mobile. The stations are fully automatic and measure the following data: SO_2 , NO_x , O_3 , CO, total hydrocarbons, and meteorological parameters. Not all monitoring stations perform all measurements. The instruments are automatically calibrated and continuously measure the levels of ambient air pollution. The data are sent by radio to the Association of Towns and fed into a computer that stores and analyses them.

Results

The study population in the four rounds of examinations included 834 children in 1980, 957 children in 1983, 1074 children in 1986, and 802 children in 1989. A somewhat higher percentage of girls could be observed during the study years, with no significant change in their representation in the different cohorts.

The prevalences of asthma (ever) and of wheeze accompanied by shortness of breath (ever) among all 5th grade schoolchildren from the four cohorts are presented in figure 2. A significant gradual increase in the prevalences of both asthma and wheeze accompanied by shortness of breath characterised 5th graders from the 1980 through the 1989 cohorts. As can be seen in figure 3, bronchitis and cough accompanied by sputum did not show similar trends. A non-significant decrease in the prevalence of bronchitis (ever) and a stable pre-

Table 1 Prevalence (%) of background variables for 5th grade healthy and asthmatic children in four cohorts in Hadera, Israel

Background variable	Affected or unaffected	1980 % (no)	1983 % (no)	1986 % (no)	1989 % (no)	p value for trend
Crowded homes	Unaffected	55.6 (552)	48.2 (629)	40.3 (662)	37.3 (502)	<0.0001*
	Affected	52.5 (101)	40.5 (126)	38.3 (162)	27.3 (143)	0.0001*
Heating (kerosene or gas)	Unaffected	53.9 (564)	48.5 (646)	41.9 (673)	36.1 (513)	<0.0001*
	Affected	52.4 (105)	57.0 (128)	41.5 (164)	30.5 (144)	<0.0001*
High education, father (13+ years)	Unaffected	24.0 (567)	23.2 (646)	26.8 (672)	28.0 (511)	0.0567
	Affected	16.2 (105)	25.0 (128)	23.2 (164)	26.6 (143)	0.1032
High education, mother (13+ years)	Unaffected	24.7 (567)	27.1 (646)	28.2 (673)	32.0 (512)	0.0077*
	Affected	21.0 (105)	30.5 (128)	28.6 (164)	37.8 (143)	0.0098*
Smoking mother	Unaffected	20.7 (551)	26.0 (634)	30.5 (656)	28.3 (508)	0.0008*
	Affected	30.4 (102)	25.0 (120)	28.1 (160)	41.0 (144)	0.0409*
One parent with respiratory disease	Unaffected	11.7 (497)	12.4 (590)	11.0 (609)	9.5 (472)	0.2179
	Affected	20.4 (86)	23.2 (99)	18.2 (132)	21.3 (127)	0.4440

*p value <0.05.

Affected = children suffering from asthma or wheezing with shortness of breath.

valence of cough accompanied by sputum could be observed in the four cohorts studied. Similar trends for the prevalence of asthma, bronchitis, and related symptoms could be observed among the subgroups of children living in the three communities studied. In table 1 the prevalence of background variables among healthy (non-asthmatic) and among asthmatic children (suffering from asthma or wheezing with shortness of breath) in the different cohorts is presented.

A significant decrease in the prevalence of crowded homes (>1.5 persons/room), characterised both healthy and asthmatic children. Similarly, a significant decrease in the number of homes heated by kerosene or gas could

be observed, both among healthy and among asthmatics, during the study years. Asthmatic children did not grow up in more crowded homes or in homes heated more often with kerosene or gas when compared with healthy children. A significant rise in the prevalence of high education (13+ years) of mothers could be observed during the years of this study with no major differences between healthy and asthmatic children.

A trend of increased prevalence of (ever) smoking mothers among both healthy and asthmatic children could be observed during the study. No significant change in the prevalence of ever diagnosed asthma or bronchitis among the parents of both asthmatic and healthy children could be observed. The rate of respiratory diseases among the parents of asthmatics was roughly double their rate among the parents of healthy children.

Logistic regressions enabled us to study the combined effect of background variables and the effect of the year on the prevalence of the symptoms and diseases.

In table 2 the odds ratio values for asthma and wheezing (accompanied by shortness of breath) are presented. The criteria for inclusion of a variable in the model were p value to remove >0.15, p value to enter <0.10. The model describing the prevalence of asthma includes the year of study as a significant factor indicating a gradual increased risk of suffering from asthma. The same holds for the model built for wheezing accompanied by shortness of breath. The models also include as a significant explanatory factor, a history of respiratory diseases among the children's parents.

The model for wheezing accompanied by shortness of breath does not fit ($p < 0.1$) the data very well—eg there is a substantial discrepancy between the observed and the predicted values. Pulmonary function tests (FEV_1 , FEV_1/FVC) for healthy and for asthmatic children in the four cohorts are presented in table 3. Most pulmonary function tests in the four cohorts studied were significantly lower among children suffering from asthma than in healthy children. For children reporting wheezing accompanied by shortness of breath, a trend of reduced pulmonary function tests could be observed, part of the differences were statistically significant. A similar trend could not be observed among children in whom bronchitis or related

Figure 3 Prevalence of bronchitis and cough with sputum among 5th grade children in 1980, 1983, 1986 and 1989.**Table 2** Odds Ratio (95% confidence interval) for respiratory conditions among 5th grade schoolchildren as related to background variables and year of study (calculated from logistic models)

Respiratory condition	Factors included in model	Odds ratio	(95% CI)	Goodness of fit
Asthma	Year of study	1980	1.00	
		1983	1.01 (0.64,1.60)	
		1986	1.54 (1.00,2.35)	
		1989	1.79 (1.16,2.74)	
	Respiratory diseases of parents	1.96	(1.35,2.83)	p=0.368
Wheezing with shortness of breath	Year of study	1980	1.00	
		1983	1.07 (0.74,1.55)	
		1986	1.30 (0.91,1.84)	
		1989	1.59 (1.11,2.28)	
	Respiratory diseases of parents	2.22	(1.62,3.03)	p=0.033

Figure 4 Summary of sulphur dioxide and nitrogen oxide "events" measured at 10 permanently sited monitoring stations during the period 1981-92.

symptoms (such as cough accompanied by sputum) were reported.

During the period of the study, the ambient air pollution levels did not exceed the Israeli air quality standards or the more stringent local standards (half of the Israeli standard), based on measurements of SO_2 and NO_x at the 12 monitoring stations (fig 1). In fact, the annual average SO_2 and NO_x values were very low. For instance, the 1989 annual SO_2 averages did not exceed 20 mg/m^3 , less than a quarter of the US standard, at any monitoring station.

Because of the difficulty of following multi-year trends of such low levels of annual average concentrations, we decided to focus on half hourly concentrations, for which there is also an Israeli ambient standard. We counted the number of air pollution "events" in which the half hourly averages for SO_2 or NO_x were above an arbitrary threshold. The threshold values chosen were 183 mg/m^3 (70 ppb) for SO_2 and 235 mg/m^3 (125 ppb) for NO_x , which are about one quarter of the local air quality standards and about one eighth of the Israeli air quality standards.

In figure 4 the summary of "events" for SO_2 and for NO_x during 1981-92 is presented. From this summary, an increase in the total number of "events" measured by the monitoring stations can be observed. Part of the increase in the number of "events" originated from the operation of the power plant, but the main increase was connected with other sources, such as industry and especially traffic. The sources responsible for the "events" were identified according to the wind direction measured at the time of the event. The highest number of SO_2 "events" from the power plant was measured at the monitoring station located in the area expected to be most polluted (fig 5); a markedly lower number of "events" was registered in the area expected to be moderately polluted. No "events" were registered in the monitoring station located in the expected low pollution area.

Discussion

Similar to other studies,²⁻¹² we showed a significant increase in the prevalence of asthma and of wheezing accompanied by shortness of breath over the years of study. Fleming and Crombie⁴ compared the prevalence of asthma in general practices in England and Wales in 1981-82 with that in 1970-71. They found a statistically significant increase in asthma morbidity from 11.6 to 20.5 per 1000 among men and from 8.8 to 15.9 among women. Burney and his group⁵ estimated changes in the prevalence of reported respiratory symptoms and reported diagnoses of asthma and bronchitis in primary school children in England between 1973 and 1986. They found significant trends of an increasing prevalence of asthma and of wheeze for each annual birth cohort studied. Burr and his group^{6,9} conducted two surveys, 15 years apart, among children aged 12 years in South Wales. An increase in the prevalence of wheeze from 17% to 22% and an increase of a history of asthma from 6% to 12% were observed. Exercise provocation tests suggested that both mild and severe asthma had become

Table 3 Pulmonary function tests (as % of predicted values) among 5th grade healthy and asthmatic children in four cohorts in Hadera, Israel

Year	PFT	Symptom/ disease	Wheezing with shortness of breath			Asthma		
			Mean (no. of children)	SD	p value	Mean (no. of children)	SD	p value
1980	FEV ₁	Unaffected	89.02 (690)	14.25	0.4412	89.35 (619)	14.30	0.1020
		Affected	87.78 (84)	14.71		86.05 (56)	16.03	
	FEV ₁ /FVC	Unaffected	85.14 (692)	9.93	0.3461	85.23 (621)	9.75	0.0087*
		Affected	84.07 (86)	9.94		81.59 (57)	12.46	
1983	FEV ₁	Unaffected	87.69 (788)	14.06	0.2860	88.14 (706)	14.27	0.0328*
		Affected	86.14 (106)	13.93		84.17 (63)	12.42	
	FEV ₁ /FVC	Unaffected	91.55 (788)	8.70	0.0071*	91.60 (706)	8.66	<0.0001*
		Affected	89.10 (106)	9.28		86.58 (63)	9.26	
1986	FEV ₁	Unaffected	85.62 (784)	11.09	0.1481	85.80 (695)	11.28	0.0079*
		Affected	84.13 (131)	9.81		82.51 (90)	9.04	
	FEV ₁ /FVC	Unaffected	92.63 (784)	6.10	0.0003*	92.76 (695)	6.05	<0.0001*
		Affected	90.55 (131)	6.29		89.53 (90)	6.78	
1989	FEV ₁	Unaffected	93.25 (584)	13.09	0.0013*	93.24 (536)	13.10	0.0203*
		Affected	89.01 (114)	11.09		89.67 (82)	11.78	
	FEV ₁ /FVC	Unaffected	91.06 (584)	7.69	<0.0001*	90.82 (536)	6.99	0.1311
		Affected	87.76 (114)	7.31		89.41 (82)	12.16	

*p value <0.05.

Affected = children suffering from either asthma or shortness of breath.

FEV₁ = forced expiratory volume in 1 second; FVC = forced vital capacity.

Figure 5 Sulphur dioxide "events" associated with the power plant in expected low pollution (station 11), medium pollution (station 2), and high pollution (station 7) areas and for the 10 permanently sited monitoring stations during 1987-92.

more common. Ninan and Russell⁷ studied the prevalence of asthma related symptoms as well as atopy in Aberdeen schoolchildren. The prevalence of wheeze rose from 10.4% in 1964 to 19.8% in 1989, the prevalence of episodes of shortness of breath increased from 5.4% to 10.0%, and the reported diagnosis of asthma rose from 4.1% to 10.2%. Reported asthma among 6 to 11 year old children in the United States⁸ showed a significant increase from 4.8% in 1971-74 to 7.6% in 1976-80.

Peat and her group¹⁰ reported an increased prevalence of wheeze (in the previous 12 months) among Australian schoolchildren between 1982 (10.4%) and 1992 (27.6%). Robertson and his group¹¹ reported an increase of 141% in the prevalence of a history of asthma among Melbourne 7 year olds between 1964 (19.1%) and 1990 (46%). Shaw and his group¹² who studied adolescent schoolchildren in a rural area in New Zealand, found that the prevalence of reported asthma or wheeze significantly increased from 26.2% in 1975 to 34% in 1989. Two Israeli groups²³ who studied young Israeli adults at the age of 17-18 years, undergoing medical examinations one year before military service, found a significant increase in the prevalence of asthma during the last decade between 1980 and 1990.

The increase in the prevalence of asthma in these studies suggests that there has been a true increase in morbidity that is not simply due to changes in diagnostic fashion. In our study among 5th grade pupils we found a significant increase in the prevalence of asthma from 8.4% in 1980 to 13.0% in 1989, as well as a rise in the prevalence of wheezing accompanied by shortness of breath (from 11.3% to 16.0%).

We tried to find out whether elevated exposure to various risk factors among the studied

children could explain this significant rise in the prevalence of asthma and related symptoms. These increased rates cannot be explained by unfavourable changes over time in socio-economic factors among asthmatic children, such as changes in family size, which could lead to a decrease in respiratory infections in early life. Nor did trends over time in the prevalences of crowding, parents' education, and house heating (by kerosene or gas) differ between asthmatic and healthy children. Although asthmatic children have more often been exposed to smoking mothers and their parents had significantly more histories of respiratory diseases compared with healthy children, no significant changes over time in the prevalences of smoking and of respiratory diseases among their parents did occur between 1980 and 1989. Hence, higher exposure to smoking mothers (though known to predispose respiratory illness¹⁷⁻²⁰) and more frequent history of respiratory diseases among parents of asthmatic children (which could be connected with over reporting^{17,21}) do not seem to be responsible for the rise in the prevalence of asthma between 1980 and 1989. Moreover, logistic regression analysis, which included risk factors such as socioeconomic factors, exposure to passive smoking, and history of parental respiratory diseases, showed only a significant effect of the year of study with a gradual increase in the risk for asthma from 1980 through 1989 and a constant elevated risk related to respiratory diseases among parents. No further explanatory risk factor for increased asthma was included in the logistic regressions.

The lower pulmonary function tests, which characterise the children reporting asthma or wheezing suggest that the increased prevalence of asthma over time is a real rise in prevalence rather than due to reporting bias or changes in diagnostic procedures.

The fact that this trend of an increase in the prevalence of asthma was similar in all three communities, the fact that air pollution levels measured in the environmental monitoring network were very low, and the fact that in no other health study carried out around the power plant could any deleterious health effect be observed, strengthen the hypothesis that this rise in reported asthma is apparently not connected with the operation of the power plant but rather corresponds to a general trend similar to other findings in Israel²³ and elsewhere.⁴⁻¹²

The reason for this increase in asthma and related symptoms is not clear from this study; it could be due to changes in life style, to dietary changes, and to increased allergen exposure—subjects which were not covered in our study.

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