Brit. J. prev. soc. Med. (1970), **24**, 223–228

PATTERNS OF RESPIRATORY ILLNESS IN SHEFFIELD JUNIOR SCHOOLCHILDREN

A FOLLOW-UP STUDY

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THE study of the influence of atmospheric pollution on respiratory disease in adults is difficult, because of complicating factors such as smoking, changes in occupation, and migration. Studies in young children avoid these difficulties and the child's atmospheric environment can be fairly precisely defined for most of his life by the conditions in the area in which he lives. On the other hand, children may not show so much response as adults to general atmospheric pollution, partly because they have not been exposed for so long and partly because they may not be as sensitive as adults who are subject to the additional insult of tobacco smoke and industrial fumes and dusts. Nevertheless, several reports suggest that atmospheric pollution may be an important factor in the causation of respiratory illness in children. Toyama and Tomono (1961) showed that a group of 10- and 11-year-old schoolchildren living in a highly polluted industrial area had lower peak flow and forced expiratory volume in 0·5 second ($FEV_{0.5}$) measurements than a group living in an unpolluted rural area. Douglas and Waller (1966), studying a British birth cohort, showed a direct relationship between air pollution and lower respiratory tract infection in both boys and girls. Holland and Elliott (1968) and Holland, Halil, Bennett and Elliott (1969a and b), looking at children living in contrasting areas of Kent near the Medway towns, found that smoking habits in the older children and area of residence were of overriding importance as contributors to the development of respiratory diseases. Variation between areas was attributed mainly to different levels of air pollution.

Sheffield has been a particularly good area in which to examine the role of environment on respiratory disease in children. Because of its geography, different areas of the city experience considerable contrasts in pollution levels, and over a considerable period of time reliable pollution data have been recorded from many sampling sites scattered throughout the city. An earlier paper (Lunn, Knowelden and Handyside, 1967) showed how this situation could be exploited by using a population of children attending selected schools serving, in the main, council estates, i.e., serving a child population, homogeneous in many respects, but exposed to a range of pollution levels which were known for the areas immediately surrounding these schools. The earlier report described the method of enquiry and the findings on 5-year-old children, in their first year in the infant school, examined in the summer of 1963, 1964, and 1965.

The present paper gives additional findings on:

1. a group of 11-year-old children attending the same schools as the 5-year-olds and examined at the same time in 1963, 1964, and 1965; and
2. the original group of 5-year-olds re-examined four years later in 1967, 1968, and 1969, i.e., when they were 9 years of age.

These additional data have been analysed to see if the 11-year-old children showed the same pattern as the 5-year-old children in the original sample, and to examine whether the contrasts shown by the original sample of 5-year-old children had persisted in them several years later.

The investigation procedure consisted of a questionnaire to parents, a clinical examination of the children, and the recording of $FEV_{0.75}$ and forced ventilatory capacity (FVC) measurements. These measurements were adjusted to permit direct comparison of children of varying heights; the technique has been fully described in an earlier article (Lunn, 1965). All data were collected during the summer terms with a view to minimizing absences and any effect of acute respiratory illnesses upon the pulmonary ventilatory measurements.

The samples of the children came from eight local authority schools in four contrasting areas:

1. Greenhill—a relatively new housing estate on the south-west boundary of the city, enjoying a clean atmosphere;
2. Longley—a pre-war council housing estate in

TABLE I

ATMOSPHERIC POLLUTION (μg./cu.m.) IN THE STUDY AREAS (1964 AND 1968)

Area		Greenhill		Longley		Park		Attercliffe	
Pollution Station		Newfield School		Southey Green School		St. John's School		Carbrook School	
		1964	1968	1964	1968	1964	1968	1964	1968
Mean daily figures (μg./cu.m.)	Smoke	97	48	230	141	262	118	301	169
	Sulphur dioxide	123	94	181	166	219	186	275	253
No. of days with readings over 500μg./cu.m.	Smoke	4	0	30	4	40	3	45	4
	Sulphur dioxide	1	0	11	5	16	4	32	23

the northern part of the city with a less clean atmosphere;

3. Park—an area of pre- and post-war council flats in the centre of the city just above the main railway station; and
4. Attercliffe—an area of heavy industry in the Don Valley with the highest pollution in the city.

The atmospheric pollution measurements for these areas in 1964 and 1968 are shown in Table I.

The first paper described the findings in 819 children of average age 5 years 4 months seen in 1963, 1964, and 1965. Four years later, when they were 9 years of age, 558 of this group were still attending the same school, living in the same area and nearly always in the same house. In this paper the data for 5-year-old children seen in 1963-5 and 9-year-old children seen in 1967-9 refer to the 558 who were seen on both occasions. A comparison was made of the data for the 5-year-old children between the whole group of 819 and the 558 seen later, and there was no evidence that those examined in 1967-9 were a biased sample of the original cohort. This paper also presents the data for 1,049 children aged 11 examined in 1963-5.

RESULTS

COMPARISON BETWEEN 5-YEAR-OLD AND 11-YEAR-OLD CHILDREN EXAMINED in 1963-5

The older children gave a less frequent history of three or more colds, persistent cough, or colds going to the chest than the 5-year-olds but a rather similar picture for nasal discharge (Table II).

This pattern of a decreasing prevalence of respiratory symptoms as children grow older and pass from infant to junior school is well known to teachers and nursing staff. It can be seen in Colley and Reid's (1970) data for 'chronic cough' between the ages of 6 and 10 years and is also reflected in sickness absence rates which fall as infants and junior school-children grow older. Presumably the pattern is due to the acquisition, as time goes on, of an ever wider range of antibodies against organisms present in the school environment.

A history of lower respiratory tract illnesses, pneumonia and bronchitis, at some time in the past was given less frequently by the 11-year-old than the 5-year-old children (Table II). As the 11-year-old children would have had twice as long as the 5-year-olds in which to suffer these illnesses, it is surprising that the histories were given less commonly. This

TABLE II

HISTORY AND CLINICAL EVIDENCE OF RESPIRATORY DISEASES (ALL AREAS)

558 Children seen at age 5 and followed up at age 9 years (1963–5 and 1967–9)
1,049 Children seen at age 11 years (1963–5)

Children Examined		Prevalence of: Muco-purulent Nasal Discharge %	3 + Colds/Year %	Persistent or Frequent Cough %	Colds going to Chest %	Past History of Lower Respiratory Tract Illness %
558	Age 5 years (1963–5)	7·6	38·4	28·6	35·5	28·1
	Age 9 years (1967–9)	6·3	21·7	11·9	30·5	29·8
1,049	Age 11 years (1963–5)	9·6	26·2	15·3	21·2	23·3

feature of the data, and the general question of the reliability of histories, will be discussed shortly.

Comparison between Children examined in 1963-5 aged 5 Years and re-examined in 1967-9 aged 9 Years

The children at 9 years of age gave a less frequent history of three or more colds, persistent cough or colds going to the chest than at 5 years and once more gave a rather similar picture for nasal discharge (Table II). There was some correlation between the prevalence of these complaints on the two occasions. Table III shows that those who complained of symptoms when 5 years old were about twice as likely to complain of the same symptoms when they were 9 as children without symptoms at the age of 5 years.

Table III

RELATIONSHIP BETWEEN PREVALENCE OF RESPIRATORY DISEASE AT 5 AND 9 YEARS OF AGE

History at 5 Years	Prevalence at 9 Years for			
	Muco-purulent Nasal Discharge %	3 + Colds/Year %	Persistent or Frequent Cough %	Colds going to Chest %
Yes	16·7[1]	26·6[1]	18·2[2]	45·5[3]
No	5·6	18·6	9·3	22·2

[1]$P < 0.05$ [2]$P < 0.01$ [3]$P < 0.001$

It has already been noted that the 11-year-old children examined in 1963-5 gave a history of respiratory tract illness at any time in the past less commonly than the 5-year-olds. Similar findings have been described by Holland *et al.* (1969b), who attributed them to differences in recall and stated that events occurring in the first four years of life are more often remembered by parents of young children. This had been considered a likely reason for the lower pneumonia and bronchitis figures recorded in the Sheffield juniors during the analysis of the 5- and 11-year-old data. Consequently it was decided for the 1967-9 follow-up of 9-year-olds that parents who gave a negative history should be asked if they were quite certain that their children had never suffered from pneumonia or bronchitis. This procedure may well be responsible for the higher proportion of children with a positive history at 9 years than at 5 years (Table II); nevertheless, it is clear that many episodes of pneumonia and bronchitis have remained forgotten, because, of the 157 infants with a positive history in the original study, no less than 76 (48·4%) were alleged four years later to have had neither pneumonia nor bronchitis (Table IV). It is obvious that retrospective histories of lower respiratory tract illnesses have serious limitations.

Table IV

PAST HISTORY OF LOWER RESPIRATORY TRACT ILLNESS RECORDED AT 5 AND 9 YEARS OF AGE

History at 5 Years	History at 9 Years		Total No. of Children
	Yes	No	
Yes	81	76	157
No	85	316	401
Total no. of children	166	392	558

Comparison between Areas

Atmospheric Pollution (Table I). The daily mean pollution levels have fallen in all areas between 1964 and 1968, more for smoke than for sulphur dioxide.

In 1964 only Greenhill Area, a smokeless zone, had lower smoke than sulphur dioxide readings, but by 1968 this was true for all four areas. This underlines the progress made by Sheffield in smoke control over the past few years and demonstrates how all areas have benefited from the policy of concentrating first of all on the windward side of the city. Whereas the Park area ranked third cleanest for smoke in 1964, it ranked second cleanest in 1968 despite a considerable improvement in the Longley area which it displaced. This large change was due partly to the general clean up of the city, partly due to the application of a Smoke Control Order to the area in July 1968, and partly to the withdrawal of steam locomotives from the nearby Midland Station in 1965 and 1966 (Batey, 1970). Before these dates the area had been subject to smoke from standing locomotives raising steam and from shunting operations.

Because of the reduction in pollution levels and the change in ranking order for smoke, and because of the smaller number of children in the follow-up study, it was decided to amalgamate the Longley, Park, and Attercliffe areas for the purpose of comparison with the Greenhill area. Of the 558 children seen both at 5 years of age and at 9 years in the follow-up study 288 came from Greenhill and 270 from the 'other areas'. For purposes of comparison a similar procedure has been adopted for the 1,049 children seen at age 11 years in 1963-5. Of these children 595 came from Greenhill and 454 from the 'other areas'.

History and Clinical Evidence of Respiratory Diseases by Area (Table V). The prevalence of three or more colds, persistent or frequent cough,

TABLE V

AREA DIFFERENCES IN PREVALENCE OF RESPIRATORY DISEASE

	Age 5 Years (1963–5)		Age 11 years (1963–5)		Age 9 years (1967–9)	
	Greenhill %	Other Areas %	Greenhill %	Other Areas %	Greenhill %	Other Areas %
Muco-purulent nasal discharge	6·7	8·6	9·9	9·1	6·0	6·7
3 + colds/year	34·0	43·0[1]	23·5	29·7[1]	19·8	23·7
Persistent or frequent cough	22·4	35·2[3]	11·4	20·3[3]	12·3	11·5
Colds going to chest	30·7	40·7[1]	19·8	22·9	27·9	33·3

[1]$P < 0·05$ [2]$P < 0·01$ [3]$P < 0·001$

and colds going to the chest among the 5-year-olds examined in 1963-5 was significantly higher in the 'other areas' than in Greenhill. Similar but less marked differences occurred among the 11-year-olds examined at the same time but the difference in prevalence of colds going to the chest was no longer significant.

The area differences found when the 5-year-olds were re-examined at the age of 9 years in 1967-9 were narrowed and insignificant in all cases; indeed the area difference for persistent cough was reversed.

A history of lower respiratory tract illness at some time in the past was reported more frequently in the 'other areas' than in Greenhill for all the age groups examined (Table VI). Comment has already been made that these data are of limited value for the purpose of comparing one age group with another.

TABLE VI

AREA DIFFERENCES IN PAST HISTORY OF LOWER RESPIRATORY TRACT ILLNESS

Age	Greenhill %	Other Areas %
5 years (1963–5)	22·2	34·4[2]
11 years (1963–5)	21·7	24·9
9 years (1967–9)	24·7	35·2[2]

[2]$P < 0·01$

PULMONARY VENTILATORY MEASUREMENTS

All pulmonary ventilatory measurements were adjusted to permit direct comparison of children of varying height. This adjustment was achieved by expressing each child's measurements as ratios of the expected measurements for the child's standing height. The ratio has been recorded as a percentage; therefore the average child has an $FEV_{0.75}$ ratio or an FVC ratio of 100.

COMPARISON BETWEEN 5-YEAR-OLDS EXAMINED IN 1963-5 AND RE-EXAMINED IN 1967-9 AGED 9 YEARS. A fairly strong correlation between measurements at 5 and 9 years of age occurred for height ($r = +0·84$) and to a lesser extent for weight ($r = +0·63$). There was much less association between the ventilatory function measurements at the two ages ($FEV_{0.75}$ $r = +0·36$; FVC $r = +0·40$; and (FEV/FVC) % $r = +0·31$). Table VII shows the distributions for FEV at the two ages. It is based on only 500 of the 558 children seen on both occasions because respiratory measurements were not available for 58 of the children at the age of 5 years.

TABLE VII

DISTRIBUTION OF $FEV_{0.75}$ RATIOS AT 5 YEARS AND 9 YEARS

(Correlation coefficient + 0·36)

5 Years	9 Years: <80	80 –	90 –	100 –	110 –	120+	Total
<80	5	7	19	7	1	2	41
80 –	6	16	30	25	5	2	84
90 –	8	25	59	32	8	1	133
100 –	6	19	31	50	13	1	120
110 –	1	5	19	28	18	10	81
120+	—	1	5	13	14	8	41
Total	26	73	163	155	59	24	500

COMPARISON BETWEEN AREAS. The differences shown by the $FEV_{0.75}$ and FVC measurements between Greenhill and the 'other areas' were not consistent and were so small as to be insignificant (Tables VIII and IX).

TABLE VIII

AREA DIFFERENCES IN $FEV_{0.75}$ RATIO

Age	Greenhill	Other Areas
5 years (1963–5)	100·2	99·8
11 years (1963–5)	100·6	100·9
9 years (1967–9)	98·5	100·1

TABLE IX
AREA DIFFERENCES IN FVC RATIO

Age	Greenhill	Other Areas
5 years (1963–5)	99·5	99·4
11 years (1963–5)	100·9	100·1
9 years (1967–9)	105·1	104·1

TABLE X
MEAN $FEV_{0.75}$ RATIO AND RESPIRATORY ILLNESS

History at Ages Shown	$FEV_{0.75}$ Ratio		
	5 years (1963–5)	11 years (1963–5)	9 years (1967–9)
Persistent or frequent cough			
No	100·6[1]	101·0	99·2
Yes	97·6	99·3	99·5
Colds going to chest			
No	101·1[2]	101·1	98·9
Yes	97·5	99·5	100·2
Past lower respiratory tract illness			
No	100·8[1]	101·3	99·1
Yes	97·1	99·2	99·6

[1]$P < 0.05$ [2]$P < 0.01$

COMPARISON BY HISTORY AND CLINICAL EVIDENCE OF RESPIRATORY DISEASE (Table X). In the 5-year-olds examined in 1963-5, a history of persistent or frequent cough, colds going to the chest, or lower respiratory tract illness was associated with a significantly reduced $FEV_{0.75}$ measurement. The 11-year-old children seen at the same time showed a similar picture but the differences were small and insignificant. Re-examination of the 5-year-olds in 1967-9 at the age of 9 years showed a change of picture. A positive history was then associated with an increase in the $FEV_{0.75}$ measurement but the differences again were small and insignificant.

The FVC measurements showed little association with the respiratory history in each age group.

DISCUSSION

The most remarkable occurrence during this study has been the drop in air pollution. During the planning stages, advantage was taken of the vastly differing pollution levels throughout the city to choose areas with large contrasts. The contrasts we were able to utilize in 1964 (Table I) exceeded those available to Holland *et al.* (1969a) and were comparable with the contrasts of the predicted values reported in Douglas and Waller's study (1966).

For the purpose of the study it was desirable that the pollution contrasts should persist during the follow-up, and with this in mind we were careful to select two areas (Longley and Attercliffe) which were not planned for inclusion within smoke control areas during the study period, and one area (Park) which became smokeless only during 1968. Nevertheless our pollution levels fell considerably because the 'dirty' areas benefited from their situation downwind of a number of smoke control areas established after 1964. The pollution has diminished, in particular, in respect of peak pollution readings. Smoke pollution figures exceeded 500μg./cu.m. on 30 to 40 occasions in the three dirtier areas in 1964 (Table I) but only three or four times in 1968. This is largely true for sulphur dioxide also, except in the case of Attercliffe where such episodes have dropped in number only from 32 in 1964 to 23 in 1968. These changes are of particular interest in relation to Lawther's (1963) finding that the degree of illness of groups of patients increased when smoke exceeded 300μg./cu.m. and sulphur dioxide exceeded 600μg./cu.m.

If atmospheric pollution was a major factor in the area contrasts in respiratory disease morbidity, it might be supposed that older children would demonstrate these more than younger children because of their longer exposure. Among those examined in 1963-5, however, the 11-year-old children showed smaller differences between areas than the 5-year-olds; at the same time, the older children had less respiratory morbidity. It seems that part of the area contrast has been lost because the older children had grown past the early school years in which respiratory disease was most common.

Seen four years later, the original group of 5-year-old children, now 9 years of age, had less respiratory disease than the 11-year-old group seen previously and showed no differences of significance between areas. These changes in morbidity go hand in hand with the overall improvement in pollution levels in the city and the narrowing of contrasts between areas, suggesting that the Sheffield Clean Air Programme has already shown effect. If this is so, and some method can be found of changing cigarette smoking habits as well, the prospects of controlling respiratory disease in industrial communities in Britain seem particularly hopeful.

SUMMARY

Follow-up data are presented on 558 9-year-old schoolchildren who were first seen and reported on at the age of 5 years. Data are also presented on 1,049 11-year-old children seen at the same time as the 5-year-olds. The children were selected from areas with widely ranging air pollution levels and came mostly from council housing estates.

The 11-year-olds had a lower prevalence of respiratory illness than the 5-year-olds seen at the same time. An excess of respiratory illness found among 5-year-olds living in 'dirty areas' was also found in the 11-year-olds but to a lesser degree.

Seen four years later, the original group of 5-year-old children, then 9 years old, had less respiratory illness than the 11-year-old group seen previously and showed no differences of significance between areas.

These changes go hand in hand with the overall improvement in pollution levels in the city and the narrowing contrasts between areas, suggesting that the Sheffield Clean Air Programme has already shown effect.

We wish to thank Dr. C. H. Shaw, Principal School Medical Officer, and Dr. J. C. McInnes, Senior School Medical Officer, for their support of this project, and also the headteachers who received us into their schools and gave us every assistance.

For the collection of data we wish to thank Dr. M. T. Lunn, Miss A. E. Salvin, Chief School Nursing Sister, and the nursing sisters and assistants of the Sheffield School Health Service who took part. We also wish to thank Miss M. Beddard, Miss J. Rhodes, and Mrs. M. Tinsley for data processing, and Miss J. Pickering, Mrs. C. Sammans, and Miss J. Thompson for secretarial assistance. Finally, we wish to thank the parents and the children themselves for their enthusiastic cooperation.

This work has been aided by a Sheffield University Tuberculosis Research Fund Grant.

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