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Chest Deformity, Residual Airways Obstruction and Hyperinflation, and Growth in Children with Asthma

I: Prevalence Findings from an Epidemiological Study

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McNicol, K. N., Williams, H. E., and Gillam, G. L. (1970). *Archives of Disease in Childhood*, **45**, 783. **Chest deformity, residual airways obstruction and hyperinflation, and growth in children with asthma. Part I: Prevalence findings from an epidemiological study.** A random sample of 276 10-year-old asthmatic children, with varying grades of asthma, were examined at a time when they did not have asthma and compared with a control group of normal children.

Of the asthmatic children, 3% showed unequivocal evidence of chest deformity, 7% had airways obstruction by spirometry, and 12% rhonchi on auscultation in an interval phase. Only 3% of asthmatic children had two or three of these abnormal findings, and only 1% all three.

Most of the children who showed one or more of the three findings were in the group of asthmatic children who had a long history with more than 20 attacks and regular recurrence of episodes at 10 years of age.

There was no significant growth impairment in this group of children with a prolonged history of asthma. However, in the small subset of 3% of asthmatic children who had, in addition to a prolonged history, two or three of the above abnormal findings (11 children), a trend towards some reduction of weight was shown.

For a long time clinicians have observed that a few children with asthma were stunted in growth and had deformed chests. The deformity was commonly a barrel chest, but pigeon chest and Harrison's sulci also occurred. Growth impairment and chest deformity were considered to be associated with severe and persistent asthma.

No reports on the prevalence of the various types of chest deformity in asthma have been published, and the nature of the various types of deformity has been only partially understood. It is known that acute pulmonary hyperinflation occurs with a severe attack of acute asthma, and that the chest may become barrel-shaped only to return to normal as the attack resolves. It is likely that barrel chest deformity in a patient with chronic asthma is due to persistent pulmonary hyperinflation resulting from continued airways obstruction. Horowitz (1969) showed that marked barrel chest deformity was closely correlated with radiological evidence of pulmonary hyperinflation, raised lung volumes, and airways obstruction. The way in which pigeon chest deformity and Harrison's sulcus develops is not understood, and experimental work on the mechanics of respiration and the structure and elasticity of the chest wall will be needed to elucidate the problem.

Growth impairment in asthmatic children was reported infrequently until corticosteroid drugs were used in treatment. After their use clinicians often observed growth failure in their patients. Subsequent workers who studied growth in asthmatic children had difficulty in assessing whether asthma alone played any part in growth impairment, as there was no information on growth in a random sample of the asthmatic population. Falliers *et al.* (1961, 1963) and Schook (1966) showed that some children with severe asthma were retarded in growth, especially in weight, even when they had not been given corticosteroid therapy. However, both workers as well as Blodgett *et al.* (1956), van Metre and

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Pinkerton (1959), van Metre, Niermann, and Rosen (1960), Spock (1965), and Kerrebijn *et al.* (1968) considered that corticosteroid therapy was the major factor responsible for growth retardation in asthma.

Dawson *et al.* (1969), in an epidemiological study of children with asthma in Aberdeen, reported data relating to growth. They showed that both heights and weights tended to be below the mean for age and sex, and that this trend was most evident in the clinically severely affected patient.

The object of these two papers is to determine the prevalence of chest deformity, airways obstruction, and growth impairment in children with asthma, and to attempt to relate these changes to the chronicity and severity of asthma as assessed by airways obstruction and pulmonary hyperinflation, using clinical, physiological, and radiological methods

The purpose of the present paper is to examine the prevalence of (a) chest deformity, (b) residual airways obstruction, and (c) growth impairment in a randomly selected population of asthmatic children. The distribution of these findings is compared in 3 groups of asthmatic children graded on specific clinical criteria of asthma.

Material and Methods

The children examined were the subjects of a longitudinal epidemiological study of asthmatic children in Melbourne (Williams and McNicol, 1969).

The children studied comprised a control group and 3 grades of asthmatic children, grading being based on a combination of two factors, the total frequency of asthma episodes and the persistence of asthma at 10 years of age. The grades were defined as follows.

Grade I: children who have had no more than 5 episodes of asthma by 10 years of age.

Grade II: children who have had no more than 20 episodes, *or* who have had no asthma within 12 months of examination at 10 years of age.

Grade III: children who have had more than 20 episodes *and* were still having asthma within 12 months of examination at 10 years of age.

Williams and McNicol (1969) showed that the persistence of asthma at 10 years of age significantly correlated with early onset of symptoms, before 3 years, and high frequency of attacks in the year they started. Thus the Grade I children selected on the criteria of less than 5 episodes were usually found to have started wheezing later, at 4 to 5 years on average, and to have stopped by 8 years of age. Many of these children had not attended a doctor. By contrast, most of the Grade III children had their first episode before 3 years, with frequent recurrence from the outset and were still having symptoms within 3 months of the 10 years examination. Most of them had many more than 20 episodes. The Grade II children occupied an intermediate position, the attacks often starting before 3 years of age but occurring less frequently. The common pattern in this grade consisted of a few attacks each year over about 4 to 6 years, with cessation or amelioration of symptoms between 8 and 10 years.

Table I shows the number of subjects studied in each group and the calculated prevalence of children with each of these types of asthma history in the Melbourne population. The calculations take account of the different sampling ratios used in the original sampling for children with different patterns of asthma (Williams and McNicol, 1969).

TABLE I

	No. of Subjects in Group (at 10 years of age)	Prevalence in Melbourne Population (%)
Control group	94	—
Grade I asthmatics ..	86	7·7%
Grade II asthmatics ..	117	7·7%
Grade III asthmatics ..	73	3·7%

The following observations and measurements were made on all children in the four groups at 7 years and 10 years of age at a time when there was no overt or subjective evidence of asthma.

Clinical findings. Height, weight, the degree of barrel chest, pigeon chest, and Harrison's sulcus deformity and the presence of rhonchi on auscultation during relaxed normal breathing and during deep breathing after coughing.

Radiological findings (at 7 years' examination only). Hyperinflation and vascular markings.

Spirometry. Vital capacity, half-second, and one-second forced expiratory volumes, measured on a Vitalor dry spirometer.

Definitions

Barrel chest deformity was assessed in the frontal view by a rectangular appearance of the chest, elevation of the shoulders, and horizontal placement of the ribs; in the lateral view by increase in the antero-posterior diameter of the chest, elevation of the sternum, the degree of thoracic kyphosis, and the relatively large size of the chest in comparison with the abdomen.

Pigeon chest deformity was recorded when pronounced 'keeling' of the sternum and adjacent costal cartilages and rib ends was present.

Harrison's sulcus was recorded as a depression of the antero-lateral part of the chest wall in the region of the costal insertion of the diaphragm.

Each of these types of deformity was graded as nil, mild, moderate, severe. The observer attempted to maintain standardized concepts of mild, moderate, and severe deformity, after a 'pilot' examination of subjects comparing observations with several experienced physicians.

Hyperinflation in chest radiographs was assessed, in

TABLE II

Mean Age, Height, and Weight at 7 Years' Examination

	Age (mth.)		Height (cm.)		Weight (kg.)	
	Mean	SD	Mean	SD	Mean	SD
Control	90·0	6·4	123·9	5·6	25·0	3·8
Grade I	90·0	6·1	123·3	4·9	25·3	3·8
Grade II	89·0	7·1	122·9	5·8	24·8	4·0
Grade III	90·9	6·0	123·9	5·8	24·5	3·3

TABLE III

Mean Age, Height, and Weight at 10 Years' Examination

	Age (mth.)		Height (cm.)		Weight (kg.)	
	Mean	SD	Mean	SD	Mean	SD
Control	123·4	7·0	138·9	6·5	33·7	6·4
Grade I	123·8	8·4	138·4	6·8	33·4	7·6
Grade II	123·2	7·5	137·3	7·5	32·7	6·8
Grade III	124·8	7·3	138·6	6·6	32·5	6 5

the antero-posterior view, by the appearance of voluminous lungs, a rectangular appearance of the thoracic cage, horizontally placed ribs, a large chest cage in relation to the size of the abdomen, small cardiac size in relation to the transverse diameter of the chest, elevation of the heart from the diaphragm, and depression of the diaphragm. In the lateral view, assessment was made by increase in antero-posterior diameter of the thoracic cage, thoracic kyphosis, an air shadow anterior to the heart, and a low flat diaphragm. Hyperinflation was graded as nil, present, or severe.

Results

The findings are shown in Tables II–XII. The three asthma groups and the control group were found to be satisfactorily matched for age. The mean height, weight, vital capacity, and FEV/VC ratios for each group of asthmatic children, shown in the following tables, was compared with the corresponding control mean, using 't' tests for evidence of significant difference in the populations.

The other findings relating to normal and abnormal radiographic findings, the presence or

TABLE IV

Barrel Chest Deformity at 10 Years' Examination

	No Deformity	Mild	Moderate	Severe
Control	99·0%	1·0%	—	—
Grade I	93·2%	5·7%	1·1%	—
Grade II	90·2%	8·1%	1·7%	—
Grade III	83·6%	10·9%	4·1%	1·4%

TABLE V

Pigeon Chest Deformity at 10 Years' Examination

	No Deformity	Mild	Moderate	Severe
Control	100·0%	—	—	—
Grade I	97·7%	2·3%	—	—
Grade II	98·3%	1·7%	—	—
Grade III	97·2%	—	2·8%	—

TABLE VI

Harrison's Sulcus Deformity at 10 Years' Examination

	No Deformity	Mild	Moderate	Severe
Control	96·8%	3·2%	—	—
Grade I	96·5%	3·5%	—	—
Grade II	96·5%	3·6%	—	—
Grade III	87·6%	6·9%	4·1%	1·4%

TABLE VII

Radiographic Findings at 7 Years' Examination

	Vascular Markings		Hyperinflation	
	Increased	Much Increased	Present	Gross
Control	9·6%	—	6·7%	—
Grade I	10·0%	—	9·8%	—
Grade II	16·4%	—	11·7%	—
Grade III	22·5% ($p<0·05$)	—	22·9% ($p<0·01$)	—

TABLE VIII

Presence of Rhonchi in Interval Phase at 10 Years' Examination

	Detected on Normal Resp.	Detected on Maximal Resp. After Coughing
Control	Nil	1·0%
Grade I	1·0%	3·5%
Grade II	2·6%	7·7%
Grade III	19·1% ($p<0·01$)	34·3% ($p<0·001$)

absence of rhonchi, and each type of chest deformity were tested in 2×2 tables, comparing the distribution in each grade of asthma with the control group. χ^2tests were applied.

Table XI summarizes the prevalence in asthmatic children, at 10 years of age, of chest deformity, spirometric evidence of airways obstruction and rhonchi. The criteria accepted as evidence of abnormality for the three parameters compared are respectively, (i) moderate or severe chest deformity of either barrel chest and/or Harrison's sulcus type, and any degree of pigeon chest deformity, (ii) an $FEV_{1·0}/VC$ finding of 74·9% or less (i.e. more than 2 SD from the control mean), and (iii) rhonchi on deep breathing, after coughing.

Percentages are shown for the 3 findings singly and in combinations, for all asthmatic children and for each grade of asthma. Radiological findings were not included as only those children with chest deformity or severe persisting asthma were re-

TABLE IX

Spirometry Findings in Interval Phase at 7 Years' Examination

	Vital Capacity		FEV 0·5%/VC		FEV 1·0%/VC	
	Mean	SD	Mean	SD	Mean	SD
Control	1·80	0·24	72·6	9·1	93·3	5·7
Grade I	1·79	0·26	71·5	8·6	92·5	6·0
Grade II	1·75	0·27	69·4	9·0 ($p<0·05$)	90·8	8·3 ($p<0·05$)
Grade III	1·76	0·33	64·8	9·8 ($p<0·01$)	86·0	8·8 ($p<0·01$)

TABLE X

Spirometry Findings in Interval Phase at 10 Years' Examination

	Vital Capacity		FEV 0·5%/VC		FEV 1·0%/VC	
	Mean	SD	Mean	SD	Mean	SD
Control	2·14	0·36	65·3	9·1	89·1	7·1
Grade I	2·14	0·38	64·6	9·8	88·3	6·4
Grade II	2·13	0·43	64·3	9·4	87·3	7·2
Grade III	2·13	0·35	58·2	9·8 ($p<0·01$)	81·3	9·4 ($p<0·01$)

TABLE XI

Prevalence of Chest Deformity, Airways Obstruction, and Rhonchi, all as assessed in Interval Phase at 10 years Examination*

	Each Parameter Considered Separately			Two Parameters Present	All Three Parameters present
	Chest Deformity	Airways Obstruction	Rhonchi		
Grade I	1·2%	4·7%	3·5%	Nil	Nil
Grade II	1·7%	3·4%	7·7%	1·7%	Nil
Grade III	11·0%	19·2%	34·3%	6·8%	5·5%
All children with asthma ..	3·3%	6·9%	11·9%	2·0%	1·1%

* The criteria for inclusion as an abnormal finding is presented in the text above for each of these parameters; see also discussion.

examined radiologically at 10 years. The percentage of children who showed each of the combinations of abnormal findings is also shown for all asthmatic children and for each grade.

Only 3% of the whole range of children with asthma had two or three of these objective findings in an interval phase. The mean age, height, and weight of this 3% subset of asthmatic children is shown in Table XII.

TABLE XII

Mean Age, Height, and Weight of Subset of 11 children with Two or Three of Following; Chest Deformity, Airways Obstruction, and Rhonchi

Age (mth.)		Height (cm.)		Weight (kg.)	
Mean	SD	Mean	SD	Mean	SD
125·1	5·7	139·6	4·9	31·5	4·8

Discussion

Discrimination between mild degrees of barrel chest and Harrison's sulcus and normal variations of chest shape in asthmatics and controls proved difficult. (See Discussion in Part II of this paper (Gillam, McNicol, and Williams, 1970).) If the children rated as having only a mild degree of barrel chest or Harrison's sulcus were excluded, the number of children found to have unequivocal signs of chest deformity was very small (Tables IV, V, VI). The number was too small to demonstrate a statistically significant difference from the control population. Most subjects with unequivocal chest deformity were found in Grade III.

There was a significantly greater incidence of both pulmonary hyperinflation and increased bronchovascular markings in the chest x-rays of Grade III asthmatic children compared with the control group (Table VII).

The physical sign that showed the greatest contrast in incidence from the control population was the presence of rhonchi in the chest in an interval phase (Table VIII), this difference being significant in the Grade III group. The difference in incidence between controls and Grade III asthmatics was found to be much greater when subjects were examined while breathing deeply after coughing.

The mean vital capacity in each grade of asthmatic children showed no appreciable difference from the control group (Table IX and X). The half-second and one-second forced expiratory volume, and the ratio of each to the vital capacity in Grades I and II showed only slightly lower mean values than in the controls at the 7 years' examination. Only in Grade III did the mean values (of both FEV/VC ratios) show a significant difference from the controls, at the 10 years of age examination. This difference in means was associated with a greater standard deviation in the Grade III population. The Fig. shows that this difference in

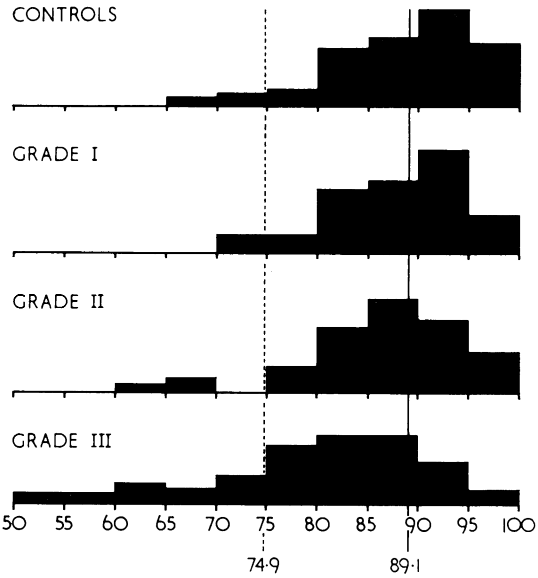

FIG.—*Distribution of $FEV_{1\cdot0}$/vital capacity ratio in controls and in three grades of asthmatic children. Ordinates show proportion of children in each group whose $FEV_{1\cdot0}$/VC ratios fall in each 5% increment. The continuous line shows the mean value in the control group. The interrupted line shows the mean value for controls minus 2SD.*

the mean and standard deviation is mainly due to the more substantial left tail in the Grade III distribution. In the Grade III group, 19·2% of the children are found in this tail of more than 2 SD from the control mean, compared with 3·2% of the control, 4·7% of Grade I, and 3·4% of Grade II children.

A small number of control children were assessed as having spirometric evidence of airways obstruction, radiological evidence of mild hyperinflation, or mild degree of chest deformity. Clearly any one of these criteria alone may be unreliable as evidence of asthma.

Most of the children who showed these abnormalities were in Grade III, the group consisting of asthmatic children with a persistent history over several years and regular recurrence of asthma at 10 years of age. However, the mean height and mean weight in Grade III (as in the other two grades of asthmatic children) did not differ significantly from the corresponding means in the control population (Tables II and III), though the mean weight was less than in the control group.

Only 1% of all asthmatic children had the combination of chest deformity, spirometric evidence of airways obstruction, and the presence of rhonchi when examined in an interval phase at 10 years. Only 3% (represented by 11 children in this study) showed at least two of these abnormalities. These 11 children were slightly older, slightly taller, and their mean weight was 2·2 kg. less than the control mean. This indicated a trend towards reduction of weight, only, in the more severely affected asthmatic children, but this population was too small to show a statistically significant difference from the control group.

It is clear that children with severe chest deformity, persistent airways obstruction, and substantial stunting of growth comprise only a very small proportion of the whole population of asthmatic children.

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