VENTILATORY FUNCTION OF ASTHMATIC CHILDREN IN STABLE STATE SEEN AT KENYATTA NATIONAL HOSPITAL

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B Y:

DR. L.N. GACHARE M.B Ch.B (NAIROBI).

DECLARATION

This dissertation is a result of my original work and has not been presented for a degree in any other University.

Signed: ______________________

DR. L.N. GACHARE

M.B.Ch.B. (NAIROBI)

This dissertation has been presented with my approval as supervisor:-

Signed: ______________________

DR. E.M. WAFULA M.B.Ch.B. (NBI) M.MED (NBI)

Senior Lecturer, Department of Paediatrics

University of Nairobi.

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LIST OF ABBREVIATIONS

1. FVC = Forced vital capacity. Measured in litres.
2. FEV_1 = Forced expiratory volume in the first second. Measured in Litres.
3. $FEV_1\%$ = The ratio FEV_1 : FVC expressed as a percentage.
4. PEFR = Peak expiratory flow rate. Measured in litres per minute.
5. K.N.H. = Kenyatta National Hospital.
6. $>$ = Greater than.
7. $<$ = Less than.
8. $\geqslant$ = Greater than or equal to.
9. $\leqslant$ = Less than or equal to.
10. P = Probability.
11. HT = Height.
12. HT^2 (ht^2, $height^2$) = Height to the second power.
13. HT^1 (ht^1, $height^1$) = Height to the first power.
14. cm, m = Centimetres, Metres. The measure of height used.
15. °C = Degrees Centigrade.
16. SD = Standard deviation from the mean.
17. N = Number of subjects

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SUMMARY

Ninety-one asthamatic children aged 5-13 years and 92 controls matched for age and sex were systematically selected to perform ventilatory function tests.

There was a highly significant difference between patients and controls before and after exercise using PEFR and FEV_1% parameters. FEV_1 and FVC showed no marked difference between patients and controls but a statistically significant difference within the patients after exercise.

Males turned out to have better ventilatory function than females.

PEFR is recommended as the most reliable parameter. Spirometric parameters FVC and FEV_1 are recommended as useful for follow up of asthmatic patients on treatment.

INTRODUCTION

Asthma is a Greek word meaning "breath hard". Kuzemko(1) defines bronchial asthma as a condition of altered dynamic state of respiratory passages due to the action of diverse stimuli resulting in airway obstruction of varying degree and duration and reversible partially or completely, spontaneously or under treatment.

Asthma is a leading cause of chronic illness in childhood responsible for a significant number of lost school days (2). In developed countries it has been found that it forces the affected children to lose nine million school days annually (3).

The diagnosis of bronchial asthma has mainly been clinical especially in developing countries where the pulmonary function tests are not freely available (4). Traditionally the paediatricians have depended upon the history and physical examination in the office to assess the patient, the course of his illness and his response to treatment. These subjective parameters are not completely adequate as was shown by Rejent and Konig (5). McNicol and Williams (6) have also shown that there can be a lot of discrepancy between the history and ventilatory function tests.

A number of factors have been found to have a high correlation with bronchial asthma in children and should be borne in mind in history taking:-

(i) Chronic cough may be a manifestation of airway hypersensitivity and in the absence of wheezing may be responsive to bronchodilators (7). This may be the only sign of bronchial asthma in a child (4).

(ii) Recurring diagnosis of pneumonia in a child should suggest possibility of bronchial asthma. In these two conditions ventilatory function testing is very useful in aiding the diagnosis. This was also supported by Aderele (8) who carried out a study in Nigeria and concluded that the clinical diagnosis of bronchial asthma is not infrequently difficult. He therefore recommended respiratory function tests for confirmation.

One of the most important tasks of ventilatory function testing in children is determining airway obstruction. The lungs of asthmatic children not only reflect pathophysiologic changes but also morphologic and ultrastructural changes which contribute to a relatively more marked airway obstruction. For example younger children with narrow airways obstruct more easily than older children with bigger airways, when both are subjected to the same stimuli (9). Various studies have shown that most ventilatory function tests correlate in a linear fashion with height, weight and surface area (10) which in children are in constant change. However in analysing the data, height alone has been found adequate in children.

Flow dependent parameters form the simplest and most established way of detecting airway obstruction in bronchial asthma. The most frequently used ones are:-

i) Forced vital capacity (FVC). This is the volume of air maximally expired after maximal inspiration. The manourve is performed as fast as possible.

ii) Forced expiratory volume at 1st second (FEV_1). It is the volume of gas expired during the first second in performance of FVC.

Both FVC and FEV_1 are limited in their use. It has been found that they are abnormal only in severely affected children. They cannot detect minimal persistent airway obstruction during symptom free periods in those children with episodic asthma (11).

(iii) $FEV_1\%$ - this is the ratio FEV_1: FVC expressed as a percentage. Extreme caution in the interpretation of this parameter is required. For example both FEV_1 and FVC may decrease simultaneously in the severely affected child hence giving normal $FEV_1\%$. Also FVC may fall greater than FEV_1, such as from air trapping or decreased effort as in a sick child so that $FEV_1\%$ is much higher. This would give a false idea of improvement.

(iv) Peak expiratory flow rate (PEFR). This is the highest flow rate reached during performance of FVC. It has been found to be the most reliable of the four parameters. Burr et al (12) found it to correlate well with clinical findings.

Because of the fact that some children with bronchial asthma develop attacks on exercise and also because some of these children may not have a clear history or clinical features of asthma, it is recommended that ventilatory function tests be done before and after exercise. Most of the children whose condition exacerbates during exercise belong to the group of extrinsic asthma although the group with intrinsic asthma is also affected but to a lesser degree (3, 13). Such children need appropriate management to allow them to carry on with normal activity which is useful for their illness.

Several exercise models have been used to induce broncho-spasm and include free running, treadmill, cycloergometer and swimming (3). Free running has been found to be the most effective and easiest to perform in children. Other advantages are that it simulates the child's normal exercise pattern and can be performed in any health care setting.

It has also been shown that short term running less than four minutes results in bronchodilatation whereas long-term running four to twelve minutes results in bronchoconstriction (14). Therefore for any asthmagenic effect to appear, the child has to run for more than four minutes.

To my knowledge there has been no study on ventilatory function in asthmatic children in East African countries especially Kenya. Because of the value of ventilatory function tests in asthmatics, the author carried out this study at Kenyatta National Hospital among the asthmatic children with the following objectives.

OBJECTIVES.

1. To determine the pattern of ventilatory function in asthmatic children in stable state as compared to controls in K.N.H

2. To assess the effect of exercise on the ventilatory function of these children.

MATERIALS AND METHODS.

The study was carried out between February and October 1986. The tests were carried out once a week every Thursday from 2 pm to 5 pm.

The patients recruited for the tests were the boys and girls aged ≥ 5 - 13 years who were being followed up in paediatric chest clinic. This clinic was being held every Friday afternoon in outpatient clinics of KNH. The children normally seen in this clinic are all those with chest illnesses like pneumonia, pulmonary tuberculosis, bronchiectasis and bronchial asthma. However children with bronchial asthma make up the majority of the patients. A pilot study carried out by the author a few weeks previously revealed that no child younger than 5 years could perform the tests. This was mainly because the child was required to follow some instructions. The problem of not following the instructions was compounded by the fact that the tests were effort-dependent. Hence 5 years was chosen as the lowest age limit. The limit of the upper age as 13 years was determined after finding that this was the highest age of children seen in the clinic.

On the day of the clinic, all the files of the patients to be seen were put together. From these, every third file was extracted. Using these systematically selected files, the patients with bronchial asthma were selected basing the diagnosis on the following diagnostic criteria:

three previous attacks of breathlessness and wheezing (8). These patients were now reviewed by taking further history and doing a systemic physical examination so as to exclude any patient using the following exclusion criteria:

i) Recent surgical intervention in the chest and/or abdomen.

ii) Chest deformity like thoracic kyphoscoliosis, pectus excavatum and pectus cavinatum.

iii) Evidence of cardiac disease, pulmonary tuberculosis or pneumonia.

iv) Evidence of upper respiratory tract infection especially tonsillitis or adenoiditis.

v) Any neurological disease - for example cerebral palsy, myasthenia gravis.

vi) Refusal to co-operate.

Controls were selected from the nearby schools and were matched for age and sex with the patients. All these had no family history of bronchial asthma and were physically normal on examination with no evidence of allergic disease (see appendix II).

Each subject was subjected to a questionnaire (appendix I and II) after getting an informed consent from the parent or guardian. Then the appointment for tests was given. Patients were instructed not to take any medication for at least 6 hours before these tests.

On the appointment day, after ensuring that the patient was not in undue respiratory distress, anthropometric measurements (weight and height) were taken, followed by ventilatory function tests (FEV_1, FVC, FEV_1%, PEFR) in that order.

Anthropometry:

1. Standing height:
   This was measured once to the nearest 0.5 cm with the subject standing straight, without shoes and with the heels together and the heels, calfs, buttocks and back touching the scale while the lower orbital margin was level with the external auditory meatus and the scalp set resting on the scalp (15). A measuring rod model 2078 A fitted to Seca-scale model 712 was used throughout the study.

2. Weight.

This was measured once with a lever balance to the nearest 100 grams without shoes and in light clothing (15). The same instrument used for height above was used here.

Ventilatory Function.

These were done with the subject in the standing position. The instruments used would regularly be tested to check their consistency. All the subjects were oriented to the tests by a demonstration done by a trained technician. The same technician performed the tests on all the subjects. The tests included FVC, FEV_1 and PEFR. FEV_1% was subsequently calculated from this equation $\frac{FEV_1}{FVC} \times 100$.

The tests were basically of two types:

1. Spirometric tests

These included FVC and FEV_1. They were done using Bellows Vitalograph dry spirometer, model P, No. 54142. The level of the tuber with the mouth piece was adjusted such that the subject could blow into the instrument without learning forward. The subject was instructed to inspire fully, to place his mouth firmly over the mouth-piece and then expire until such a time when no further air emerged. The manouvre was repeated at least five times. The first two were for practice, the remaining three were replicate values. The greatest value attained was used for the analysis as recommended by the American Thoracic Society in 1979 (16). At the same time the ambient temperature and atmospheric pressure were recorded.

2. Peak flow rate.

The PEFR was measured using Wright's peak flow meter model W, No. 250 > 8. The procedure was similar to the one described above for spirometric tests except that the instrument was held by the subject and the forced expiration did not need to be continued till the end of expiration.

<u>Exercise</u>

After the first round of ventilatory function testing, each subject was instructed to run at a moderately tolerable speed to and fro, a distance of fifty metres for a period of five minutes. Then the child went back to the machines and repeated the ventilatory function tests in the same order as stated above. Five minutes was chosen as the most reasonable and convenient period of exercise within the recommended 4 - 12 minutes (14). Bronchodilator drugs in the form of injectable adrenaline and salbutamol inhaler were kept in the ready for any patient who developed bronchospasm.

Statistical analysis

The data was fed into IBM microcomputer using 'SPSS' (Statistical Package for Social Sciences) program. Manual calculation of some figures was also done. The t function of Student was applied to the statistical parameters and the probabilities were calculated. The subjects were analysed in two arbitrary groups namely, $\geqslant$ 5-9 years and $\geqslant$ 10 - 13 years. The author chose these age groups due to the fact that the older children are believed to be approaching puberty which might be reflected in the ventilatory function tests. FEV_1, FVC and PEFR measurements were adjusted for height by dividing each value by $height^2$. This was decided by doing correlation tables for each value by $height^1$ and $height^2$. It was found that the effect of height was nullified when $height^2$ was used.

For FEV_1 and FVC values again, the conversion to BTPS (Body Temperature and Pressure Saturation) was done.

R E S U L T S

Ventilatory function tests using four parameters (FEV_1, FVC, PEFR, $FEV_1\%$) were done on asthmatic children and their controls. The study population was composed of 183 children aged $\geq$ 5 - 13 years. There were 91 patients and 92 controls. The male to female ratio was 1 : 1 as is shown in Table 1 below which also groups the population into two arbitrary age groups. During the study 44 out of 91 patients (48%) developed bronchospasm which cleared over 15 - 30 minutes. Some required drug therapy to relieve the spasm. One 12 year old girl developed severe bronchospasm after exercise so that she could not perform the tests in the second round. She was therefore excluded from the study.

Table 1. Distribution of study patients and controls by sex and age group.

	$\geq$ 5 - 9 YEARS			$\geq$ 10 - 13 YEARS			TOTAL FOR ALL AGES		TOTAL FOR BOTH SEXES
	MALES	FEMALES	TOTAL	MALES	FEMALES	TOTAL	MALES	FEMALES	MALES + FEMALES
Patients	24	22	46	25	20	46	49	42	91
Controls	24	22	46	25	21	46	49	43	92
Grand Total	48	44	92	50	41	92	98	85	183

The study patients were significantly shorter than the controls in the younger age group ≥5 - 9 years (P = 0.01, 0.02). There was no marked difference between the patients and the controls in the age group ≥ 10 - 13 years (P>0.1). Table 2 below exemplifies this.

Table 2: Mean height (m) of patients and controls by sex and age group.

		Patients		Controls		
Sex	Age Group (Years)	Mean Ht. (m)	SD	Mean Ht. (m)	SD	P Value
Males	≥ 5 - 9	1.19	0.08	1.25	0.07	0.01
	≥10-13	1.39	0.09	1.43	0.08	> 0.1
Females	≥ 5 - 9	1.18	0.07	1.25	0.10	0.02
	≥10-13	1.38	0.1	1.44	0.12	> 0.1

The significant difference in height affects the values of the ventilatory function tests. Previous studies have shown that if the values are divided by height, the effect of height is nullified. In this study, correlations between the values and height to one power and two powers (ht^1, ht^2) were done and it was found that the effect was nullified when all values were divided by ht^2 as is shown in Table 3 below.

Table 3. Correlation values of FEV_1, FVC and PEFR to height.

	FEV_1	FVC	PEFR	FEV_1/HT	FEV_1/HT^2	FVC/HT	FVC/HT^2	PEFR/HT	$PEFR/HT^2$
MALES	xx 0.8683	xx 0.8792	xx 0.8121	xx 0.7149	0.2713	xx 0.7388	0.2839	xx 0.7256	0.2455
FEMALES	xx 0.8855	xx 0.8571	xx 0.8332	xx 0.7613	x 0.4170	xx 0.7158	0.3325	xx 0.6526	0.2917

K E Y :

xx - Significant dependence on height.

x - Less significant dependence on height

No star - No dependence on height.

When the values of ventilatory function were not altered at all, there was marked dependence on height. The same applied when the values were divided by $height^1$. This disappeared for both males and females when the values were divided by $height^2$. So for all parameters of ventilatory function in this study, the values were divided by $height^2$. $FEV_1\%$ was not altered as it is a ratio.

There was a highly significant difference in PEFR/HT² (P<0.001, P<0.05) between the male patients and controls before and after exercise in both age groups. Table 4a below shows this.

Table 4a: Mean PEFR/HT² of male patients and controls by age group.

Sex	Age Group (Years)	Time	Patients		Controls		
			Mean PEFR/HT²	SD	Mean PEFR/HT²	SD	P Value
Males	≥5-9	Before Exercise	128.59	26.33	142.61	21.23	<0.05
		After Exercise	104.06	28.45	136.80	27.41	<0.001
	≥10-13	Before Exercise	136.39	24.63	155.26	21.46	<0.01
		After Exercise	109.80	34.59	153.49	26.42	<0.001

The 2 graphs below (Fig.1 and 2) serve to illustrate the point. The graphs further serve to illustrate that the difference in PEFR/HT² between the patients and controls before exercise though significant was less than that after exercise.

Fig 1. Mean PEFR/HT^2 of male patients and controls ≥ 5 - 13 years before exercise.

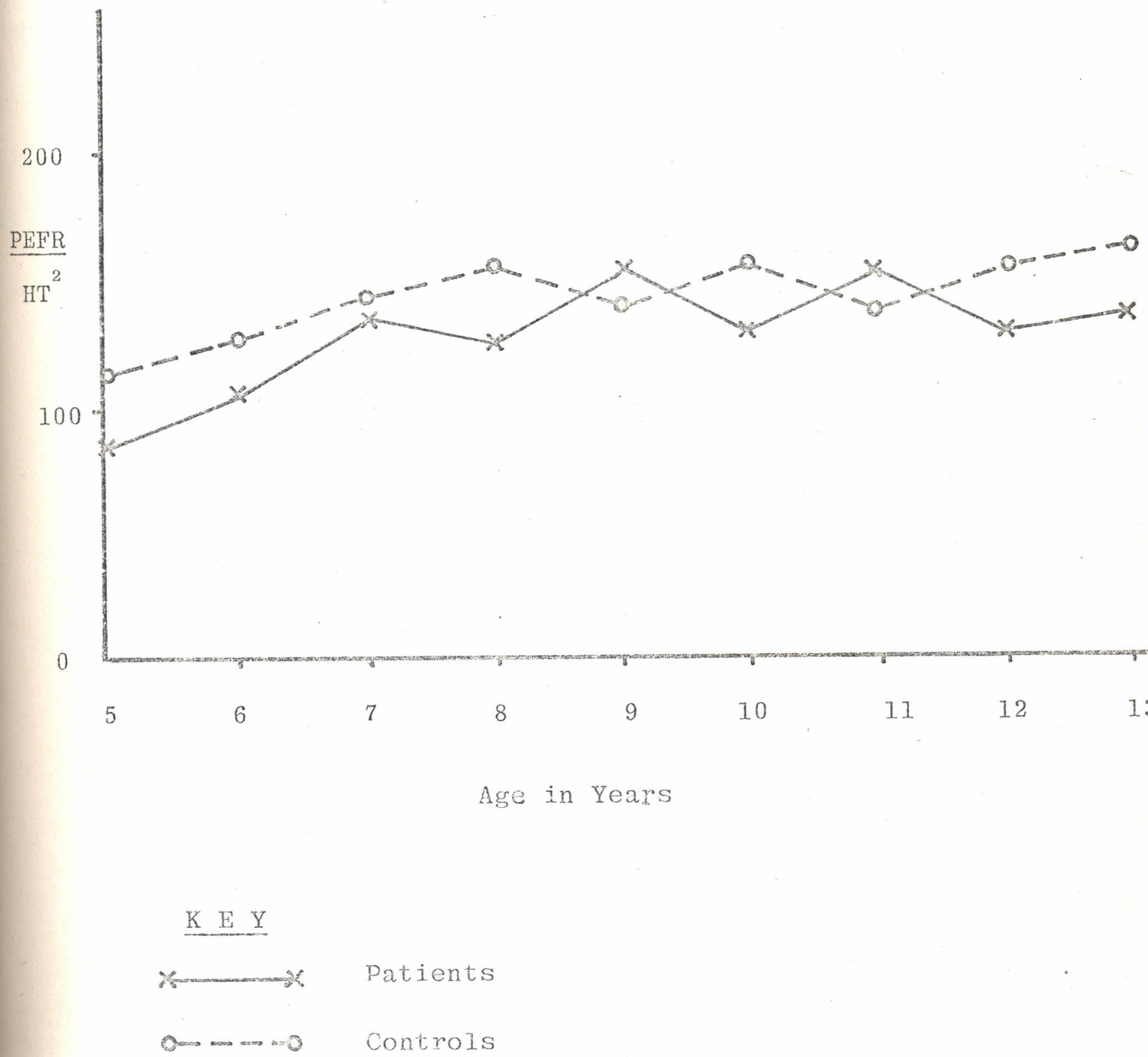
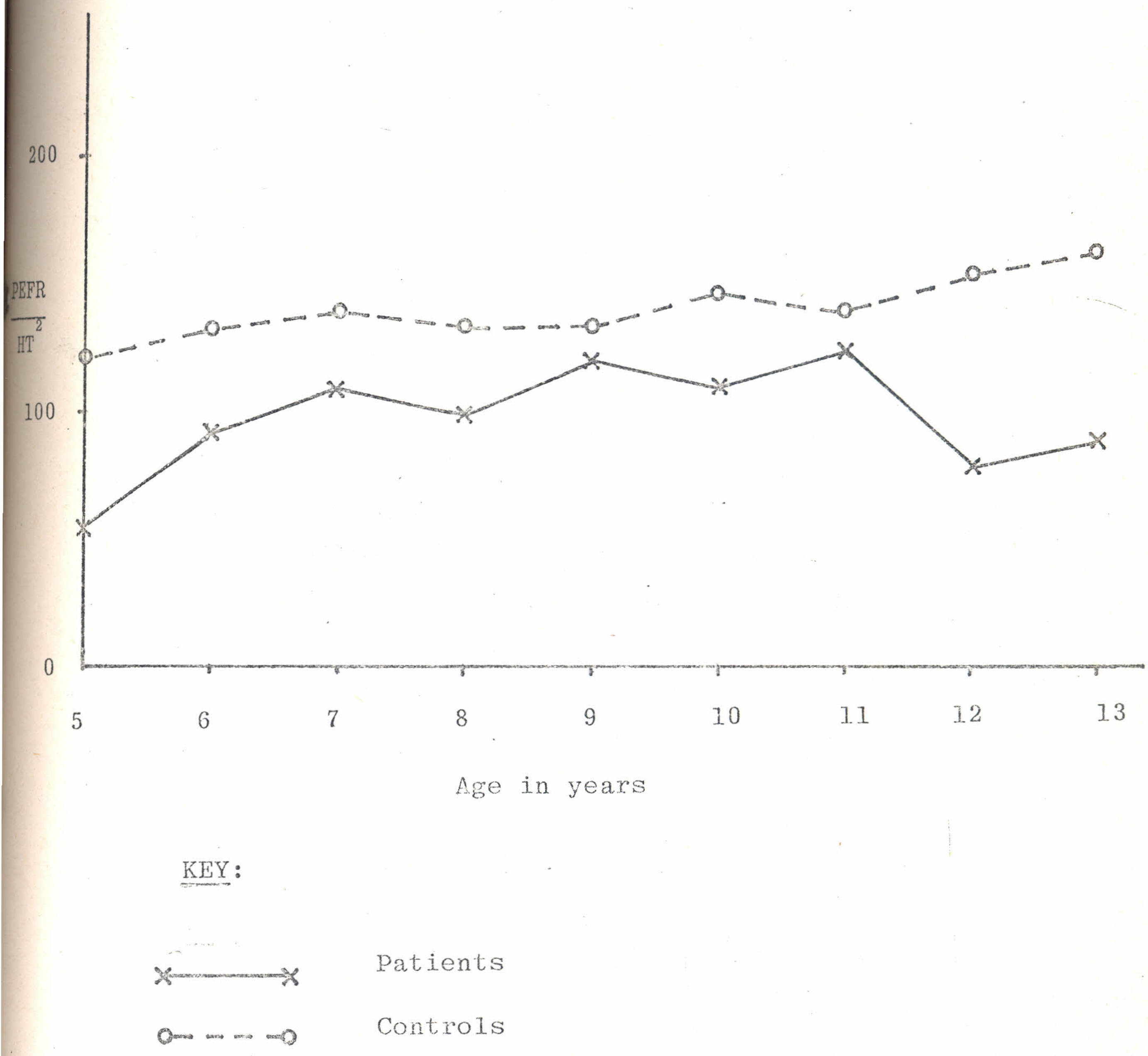


Fig 2: Mean PEFR/HT^2 of male patients and controls ≥ 5 - 13 years after exercise.



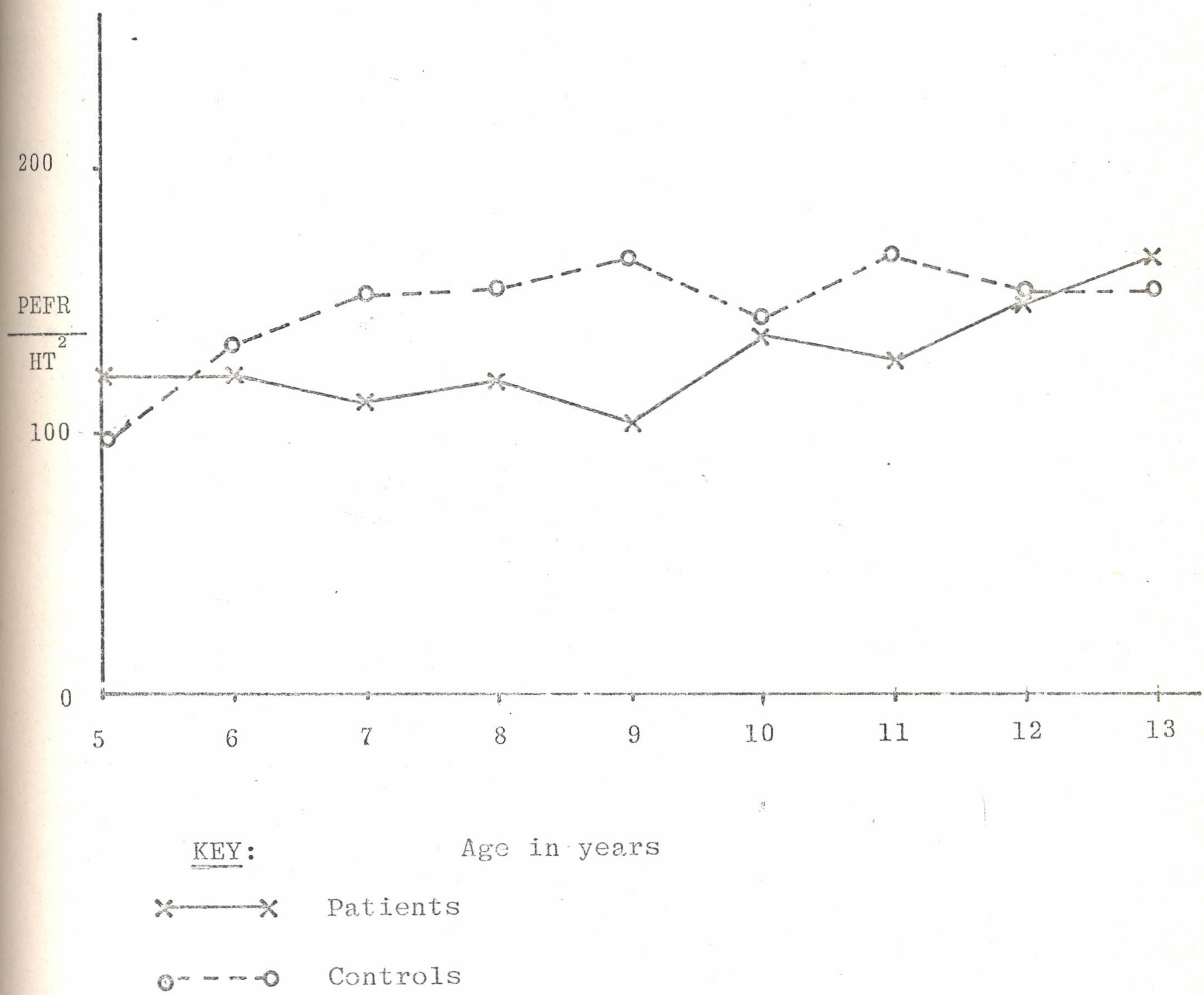
There was a highly significant difference in PEFR/HT^2 ($P<0.001$) between the female patients and controls before and after exercise in the age group ≥5-9 years. In the age group ≥10-13 years there was no statistically significant difference in PEFR/HT^2 before the exercise ($P=0.20$) but there was after the exercise ($P=0.02$). Table 4b below exemplifies the points.

Table 4b: Mean PEFR/HT^2 of female patients and controls by age group.

Sex	Age Group (Years)	Time	Patients		Controls		
			Mean PEFR/HT^2	SD	Mean PEFR/HT^2	SD	P Value
Females	≥5-9	Before Exercise	114.28	24.75	146.42	30.67	<0.001
		After Exercise	82.49	32.84	139.35	33.93	<0.001
	≥10-13	Before Exercise	142.71	26.13	151.45	25.89	0.20
		After Exercise	124.73	38.64	150.59	28.98	0.02

The graphs below (Fig. 3 and 4) illustrate these points. Like with males, it is clear that the overall difference between the female patients and controls was less before the exercise than after.

Fig 3: Mean PEFR/HT^2 of female patients and controls $\geq$ 5 - 13 years before exercise.



Age in years

Fig 4: Mean PEFR/HT^2 of female patients and controls $\geq$ 5 - 13 years after excercise.

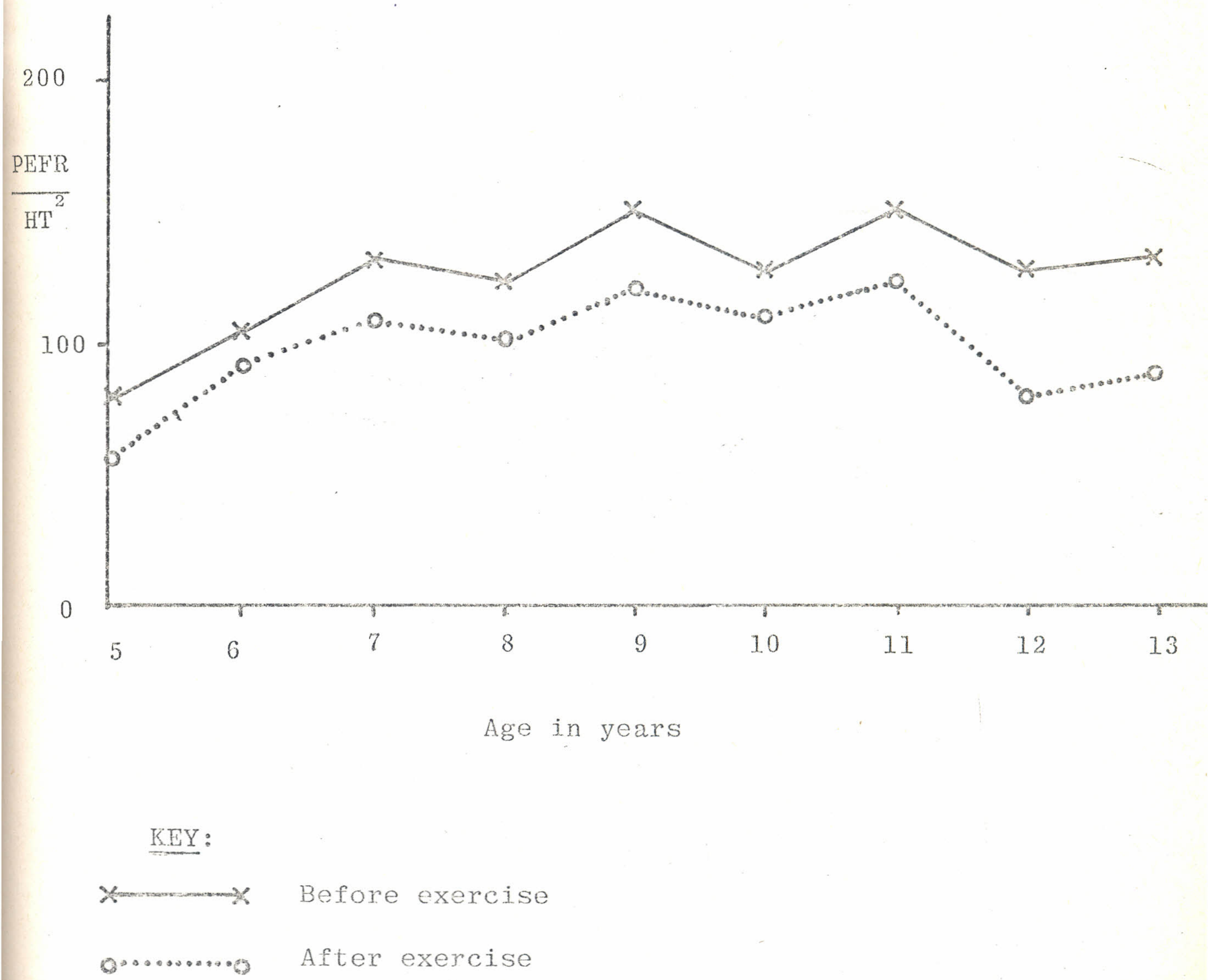
In the age group ⩾5-9 years and in both sexes, there was a highly significant difference (P<0.001) in PEFR/HT² values between the times before and after exercise. However, in the age group ⩾10-13 years, there was a highly significant difference of the same only in the male patients. No significant change was observed in the females ⩾10-13 years (P=0.10). See Table 4c below.

Table 4c: Mean PEFR/HT² of all patients before and after exercise by age group.

		Patients				
Sex	Age Group (Years)	Before Exercise		After Exercise		
		Mean PEFR/HT²	SD	Mean PEFR/HT²	SD	P Value
Males	⩾5-9	128.59	26.33	104.06	28.45	<0.001
	⩾10-13	136.39	24.63	109.80	34.59	0.001
Females	⩾ 5-9	114.28	24.75	82.49	32.84	<0.001
	⩾10-13	142.71	26.13	124.73	38.64	0.10

Fig. 5 below illustrates the point in the male patients. This contrasts with Fig. 6 illustrating the findings in the male controls.

Fig 5: Mean PEFR/HT^2 of male patients ≥ 5 - 13 years before and after exercise.



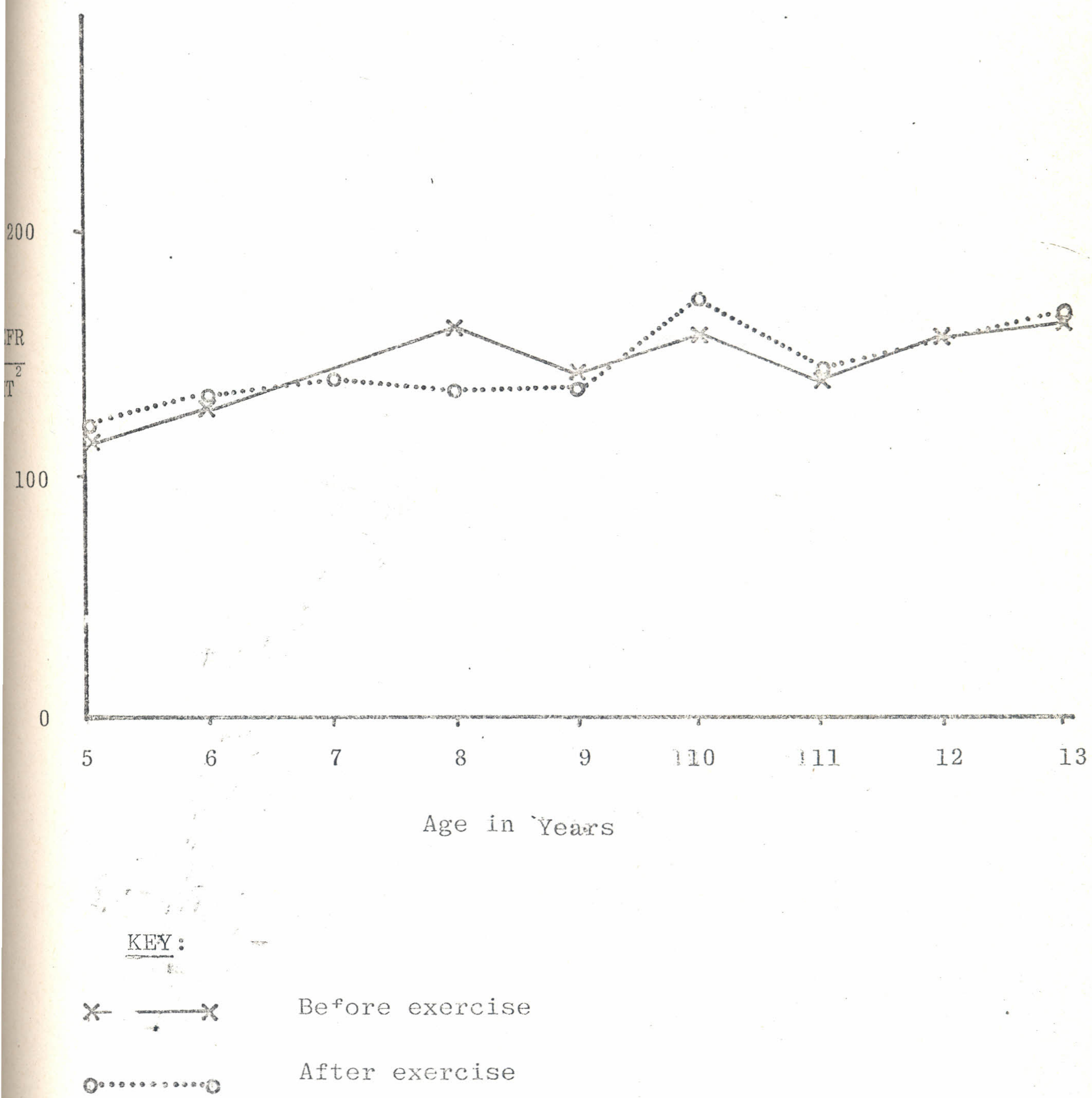
In both age groups and both sexes, there was no statistically significant difference (P>0.25) in PEFR/HT^2 values between the times before and after the exercise (Table 4d).

Table 4d: Mean PEFR/HT^2 of all controls before and after exercise by age group.

Sex	Age Group (Years)	Controls				
		Before Exercise		After Exercise		
		Mean PEFR/HT^2	SD	Mean PEFR/HT^2	SD	P Value
Males	≥ 5-9	142.61	21.23	136.30	27.41	> 0.25
	≥10-13	155.26	21.46	153.49	26.42	> 0.5
Females	≥ 5-9	146.42	30.67	139.35	33.93	> 0.25
	≥10-13	151.45	25.89	150.59	28.98	> 0.50

Fig. 6 below explains the outcome graphically.

Fig 6: Mean PEFR/HT^2 of male controls > 5 - 13 years before and after exercise.



In age group ≥ 5 - 9 years, there was no significant difference in PEFR/HT^2 values between sexes before the exercise ($P>0.05$) but there was a significant difference after the exercise ($P<0.05$). In this case the males had less reduction of PEFR than the females after exercise. In the age group ≥ 10-13 years, there was no significant difference in PEFR/HT^2 between the sexes both before and after the exercise. However, the females in this case had less reduction in PEFR/HT^2 after the exercise though statistically insignificant (Table 4e).

Table 4e: Mean PEFR/HT^2 of male patients versus female patients by age group.

		Sex				
Age Group (Years)	Time	Males		Females		
		Mean PEFR/HT^2	SD	Mean PEFR/HT^2	SD	P Value
≥5-9	Before Exercise	128.59	26.33	114.28	24.75	>0.05
	After Exercise	104.06	28.45	82.49	32.84	<0.05
≥10-13	Before Exercise	136.39	24.63	142.71	26.13	>0.05
	After Exercise	109.80	34.59	124.73	38.64	>0.05

In both age groups, there was no statistically significant difference in FEV_1/HT^2 values between patients and controls before the exercise. After the exercise, there was a significant difference ($P<0.02$) observed in the ⩾10-13 years age group while that of ⩾5-9 years age group was nearly significant ($P>0.1$). Table 5a below show this.

<u>Table 5a</u>: Mean FEV_1/HT^2 of male patients and controls by age group.

	Age Group (Years)	Time	Patients		Controls		
			Mean FEV_1/HT^2	SD	Mean FEV_1/HT^2	SD	P Value
Males	⩾5-9	Before Exercise	0.89	0.12	0.88	0.12	>0.5
		After Exercise	0.69	0.16	0.76	0.17	>0.1
	⩾10-13	Before Exercise	0.93	0.14	0.98	0.10	>0.2
		After Exercise	0.77	0.19	0.90	0.14	<0.02

In both age groups, there was no statistically significant difference in FEV_1/HT^2 values between patients and controls both before and after exercise. However, after the exercise in both age groups, there was a nearly statistically significant difference ($P \geq 0.1$, Table 5b).

Table 5b: Mean FEV_1/HT^2 of female patients and controls by age group.

Sex	Age Group (Years)	Time	Patients		Controls		
			Mean FEV_1/HT^2	SD	Mean FEV_1/HT^2	SD	P Value
Females	≥5–9	Before Exercise	0.78	0.11	0.81	0.13	>0.2
		After Exercise	0.62	0.17	0.70	0.18	>0.1
	≥10–13	Before Exercise	0.91	0.27	0.96	0.16	>0.2
		After Exercise	0.76	0.16	0.86	0.24	0.1

In the age group ≥5-9 years, there was a significant difference in FEV_1/HT^2 values between sexes before the exercise. In this case the males had better FEV_1 than the females. In the age group ≥10-13 years, there was no statistically significant difference in FEV_1/HT^2 values between sexes (Table 5c).

<u>Table 5c</u>: Mean FEV_1/HT^2 of male patients versus female patients by age group.

Age Group (Years)	Time	Patients: Males		Patients: Females		
		Mean FEV_1/HT^2	SD	Mean FEV_1/HT^2	SD	P Value
≥5-9	Before Exercise	0.89	0.12	0.78	0.11	<0.01
	After Exercise	0.69	0.16	0.62	0.17	>0.05
≥10-13	Before Exercise	0.93	0.14	0.91	0.27	>0.05
	After Exercise	0.77	0.19	0.76	0.16	>0.05

In both age groups and in both sexes there was a highly statistically significant difference ($P<0.001$, <0.05) in FEV_1/HT^2 values both before and after exercise (Table 5d).

Table 5d: Mean FEV_1/HT^2 of all patients before and after exercise by age group.

Sex	Age Group (Years)	Patients: Before Exercise		Patients: After Exercise		
		Mean FEV_1/HT^2	SD	Mean FEV_1/HT^2	SD	P Value
Males	≥5-9	0.89	0.12	0.69	0.16	<0.001
	≥10-13	0.93	0.14	0.77	0.19	<0.01
Females	≥5-9	0.78	0.11	0.62	0.17	<0.001
	≥10-13	0.91	0.27	0.76	0.16	<0.05

There was no statistically significant difference between patients and controls in the values of FVC/HT^2 except in the age group ≥5-9 years before exercise. Despite this, the values in patients are paradoxically higher than the values in controls (Table 6a).

Table 6a: Mean FVC/HT^2 of male patients and controls by age group.

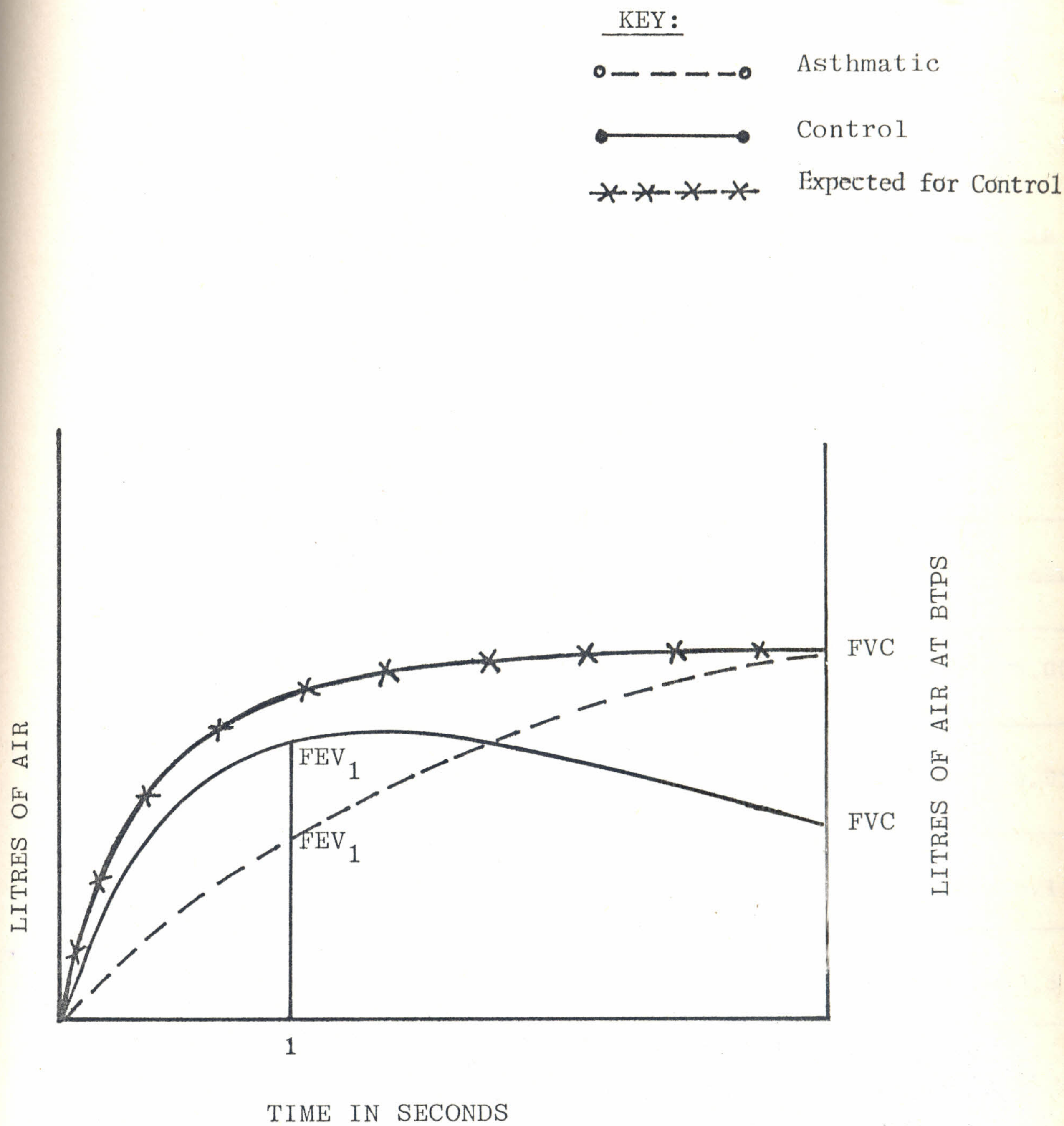
Sex	Age Group (Years)	Time	Patients		Controls		
			Mean FVC/HT^2	SD	Mean FVC/HT^2	SD	P Value
Males	≥5-9	Before Exercise	1.05	0.11	0.94	0.12	<0.01
		After Exercise	0.86	0.16	0.80	0.16	>0.1
	≥10-13	Before Exercise	1.12	0.16	1.06	0.11	>0.1
		After Exercise	0.97	0.20	0.96	0.17	>0.5

Nearly the same observations as in males were found in females. Table 6b below shows the findings.

<u>Table 6b</u>: Mean FVC/HT^2 of female patients and controls by age group.

Sex	Age Group (Years)	Time	Patients		Controls		
			Mean FVC/HT^2	SD	Mean FVC/HT^2	SD	P Va
Females	≥5-9	Before Exercise	0.91	0.12	0.83	0.18	0.1
		After Exercise	0.71	0.16	0.76	0.18	>0.2
	≥10-13	Before Exercise	1.02	0.16	0.98	0.17	>0.5
		After Exercise	0.89	0.15	0.89	0.23	>0.5

Fig 7: Vitalograph showing tracing of an asthmatic child as compared to that of control.



There is no statistically significant difference in FVC/HT^2 between patients and controls. The only exception is the males ≥ 5-9 years. Nevertheless the values are higher in patients than in controls except in 2 instances as shown by table 6c below.

Table 6c   Corrected mean FVC/HT^2 of all patients versus controls by age group and sex.

Sex	Age group (years)	Time	Patients		Controls			
			Mean FVC/HT^2	SD	N	Mean FVC/HT^2	SD	Pvalue
males	≥5-9 N=23	Before exercise	1.06	0.11	20	0.92	0.10	< 0.001
		After exercise	0.87	0.16		0.80	0.14	> 0.05
	≥10-13 N=25	Before exercise	1.12	0.16	18	1.06	0.12	> 0.1
		After exercise	0.97	0.20		0.99	0.14	> 0.5
females	≥5-9 N=21	Before exercise	0.91	0.12	18	0.88	0.13	< 0.5
		After exercise	0.73	0.15		0.77	0.17	< 0.5
	≥10-13 N=17	Before Exercise	1.04	0.17	14	0.96	0.15	>0.05
		After exercise	0.89	0.16		0.87	0.21	>0.5

There was a statistically significant difference in FVC/HT^2 values between sexes both before and after exercise. In all cases, the females had lower values than the males (Table 6c).

Table 6d: Mean FVC/HT^2 of male patients versus female patients by age group.

Age Group (Years)	Time	Patients				
		Males		Females		
		Mean FVC/HT^2	SD	Mean FVC/HT^2	SD	P Value
$\geq$5-9	Before Exercise	1.05	0.11	0.91	0.12	<0.01
	After Exercise	0.86	0.16	0.71	0.16	<0.01
$\geq$10-13	Before Exercise	1.12	0.16	1.02	0.16	0.02
	After Exercise	0.97	0.20	0.89	0.15	0.05

There was a highly significant difference in FVC/HT² (P<0.001, <0.02) in both age groups before and after exercise in both sexes (Table 6d).

Table 6e: Mean FVC/HT² of all patients before and after exercise by age group.

Sex	Age Group (Years)	Patients				
		Before Exercise		After Exercise		
		Mean FVC/HT²	SD	Mean FVC/HT²	SD	P Value
Males	≥5-9	1.05	0.11	0.86	0.16	<0.001
	≥10-13	1.12	0.16	0.97	0.20	<0.01
Females	≥5-9	0.91	0.12	0.71	0.16	<0.001
	≥10-13	1.02	0.16	0.89	0.15	<0.02

In both age groups, there is a highly significant difference in $FEV_1\%$ between patients and controls both before and after exercise (P=0.01, Table 7a).

Table 7a: Mean $FEV_1\%$ of male patients and controls by age group.

Sex	Age Group (Years)	Time	Patients		Controls		
			Mean $FEV_1\%$	SD	Mean $FEV_1\%$	SD	P Value
Males	≥5-9	Before Exercise	84.32	6.98	93.25	12.23	0.001
		After Exercise	80.63	12.24	93.32	13.90	0.001
	≥10-13	Before Exercise	83.54	7.40	93.56	6.168	0.001
		After Exercise	79.44	10.76	95.26	8.76	0.001

Like with males, there was a highly statistically significant difference in $FEV_1\%$ values in both age groups before and after exercise (Table 7b).

Table 7b: Mean $FEV_1\%$ of female patients and controls by age group.

Sex	Age Group (Years)	Time	Patients		Controls		
			Mean $FEV_1\%$	SD	Mean $FEV_1\%$	SD	P Value
Females	≥5–9	Before Exercise	85.83	7.93	100.35	21.86	<0.01
		After Exercise	82.15	9.78	92.25	12.99	<0.01
	≥10–13	Before Exercise	88.24	10.31	95.45	7.27	<0.02
		After Exercise	85.87	9.19	95.93	13.34	<0.01

There was no statistically significant difference in $FEV_1\%$ ($P>0.1$) values before and after exercise in all patients.

Table 7c: Mean $FEV_1\%$ of all patients before and after exercise by age group.

Sex	Age Group (Years)	Patients: Before Exercise		Patients: After Exercise		
		Mean $FEV_1\%$	SD	Mean $FEV_1\%$	SD	P Valu
Males	$\geq$5-9	84.32	6.98	80.63	12.24	>0.2
	$\geq$10-13	83.54	7.40	79.44	10.76	>0.1
Females	$\geq$5-9	85.83	7.93	82.15	9.78	>0.1
	$\geq$10-13	88.24	10.31	85.87	9.19	>0.2

There was no statistically significant difference in $FEV_1\%$ values before and after exercise in all controls (Table 7d).

Table 7d: Mean $FEV_1\%$ of all controls before and after exercise by age group.

Sex	Age Group (Years)	Controls: Before Exercise Mean $FEV_1\%$	SD	Controls: After Exercise Mean $FEV_1\%$	SD	P Value
Males	≥5-9	93.25	12.23	93.32	13.90	>0.5
	≥10-13	93.56	6.17	95.26	8.76	0.5
Females	≥5-9	100.35	21.86	92.25	12.99	0.2
	≥10-13	95.45	7.27	95.93	13.34	>0.5

DISCUSSION

The results of this study have shown that there is already airway obstruction in asthmatic patients which becomes even more marked with exercise. However, not all the parameters of ventilatory function used here have been able to show it vividly.

The results have also shown that there can be airway obstruction after exercise even in normal children but this is less marked.

PEFR showed the most consistent findings. There was a significant difference between patients and controls before and after exercise. In most cases the p value was <0.001 or 0.01 (Tables 4a and 4b). Significant change with exercise was seen in patients but this was not observed in controls using PEFR parameter ($P>0.25$, Table 4d).
Gerd and Cropp (17) working in Colorado showed that of the 4 parameters used here, PEFR was the most sensitive. It is the parameter most often used especially in evaluation of drug efficacy (23).

FEV_1 showed significant or nearly significant difference between patients and controls only after exercise, (Tables 5a and 5b). This was in contrast to FVC that did not show any significant change between patients and controls before or after exercise (Table 6a and 6b). The only exception in FVC was males aged $\geq$ 5-9 years who showed a significant airway obstruction even before the exercise. However, when both parameters, that is, FEV_1 and FVC are analysed for the patients before and after the exercise, there is a highly statistically significant airway obstruction after exercise as shown in Tables 5d and 6e ($P<0.01$). This goes to show that whereas these parameters are not useful in showing airway obstruction in patients as compared to controls, they would be useful in the follow up of asthmatic patients while on treatment using the patient's initial readings as the standard. However FEV_1 is better than FVC as shown in the tabulation between the patients and controls.

Previous studies done elsewhere (11,12,18,21) have shown that if only severely affected patients are selected and compared to controls, a more significant difference would be found using these parameters. This was not attempted in this study.

There was a consistent highly significant difference between patients and controls shown by $FEV_1\%$ with p values most often at 0.001 for males and 0.01 for females (Tables 7a and 7b) but there was no significant change seen within the patients or controls after the exercise (Tables 7c and 7d). This shows that $FEV_1\%$ is a useful parameter to distinguish between asthmatic patients and normal people but is not a useful parameter for the follow up of a patient on treatment.

One observation with FVC was the tendency to have higher values in patients than in controls. This is shown in tables 6a and 6b. However this was not statistically significant except in one case in the males ≥ 5-9 years. This finding is in disagreement with the standard knowledge where FVC is lower in asthmatics than in normal people because of the airway obstruction that is already present (19). In this study it was observed that in performance of FVC 5(5%) asthmatics and 22(24%) controls traced a curve slunting downwards to the right (Fig.7). This phenomenon was initially thought to be due to an error in technique. However similar observations were verbally reported in as yet unpublished data on a study carried out among the normal people in Kenya (20). Most of the subjects who showed the phenomenon in that study were young adolescents. In this study, of the 27 subjects showing the phenomenon 17(63%) were in the older age group ≥10-13 years who are approaching puberty and adolescence. These are the same subjects who must have got the instructions more easily. This rules out error on the part of the patient. Since this is the same machine model used by the other investigators in the field, the question arises as to whether the fault lies with the machine model.

To try and eliminate the "error" any subject showing the phenomenon that is, with an FEV_1% over 100% was eliminated from the analysis for table 6c. Despite this the FVC values were not much altered. The controls on the whole still had lower FVC than the patients though still statistically insignificant.

A study done by Ahuja and Ahuja (24) working in Nigeria is partly in agreement with this finding in that young adolescent males were found to have lower FVC values than caucasians.

It would be useful to carry out another comparative study like this one on a much wider scale to see the FVC values in our normal children. This would also call for development of nomograms and prediction equations as recommended by Howard (25).

A significant finding amongst the parameters including height is the more significant difference between patients and controls in the younger children. Probably this is exaplained by the known natural history of extrinsic asthma which most children have.

Studies have shown that 50% of the children outgrow their bronchial asthma by adulthood (2). In this study, the patients were all being followed up in the clinic. It can be assumed that some of the older children had long ceased to have active disease but were still being held on to the clinic. This in effect diluted the degree of severity of airway obstruction seen in the older children

Another finding with these ventilatory function tests is the tendency for the values to rise after exercise in some subjects. Nine out of 91 patients (10%) and 40 out of 92 controls (43%) had a rise in either one, two or all of FVC, FEV_1 and PEFR after exercise. Gerd (18) observed similar findings in that 10% of asthmatics had a slight but definite improvement in the ventilatory function after exercise. This is thought to be due to mobilisation of secretions and their expectoration brought about by deep breathing.

The parameters PEFR, FEV_1 and FVC have agreed on sex differences. The males have better ventilatory function than the females (Tables 4e, 5c, 6c). The reason for this is not evident. Some studies have found boys to be more affected than girls and some vice versa, others no difference at all (12,18,21,22). There are also many varied reasons given. For example when girls have done better, some authors have felt it may be a factor in girls getting into puberty earlier.

According to the findings in this study a pattern of sensitivity and reliability of ventilatory function tests used has ome out. In order of merit, this is as follows: PEFR, $FEV_1\%$, FEV_1, FVC. This compares with the findings of Gerd (18) who found the following pattern in order of merit:-

(i) Specific airway conductance (SG_{aw}). This is derived from airway resistance value (R_{aw}).

(ii) Airway resistance (R_{aw}).

(iii) Peak expiratory flow rate (PEFR).

(iv) Maximum - mid - expiratory flow performed at 25 - 75% of FVC ($MMEF_{25-75\%}$)

(v) Forced expiratory volume at 1 second (FEV_1)

(vi) Forced vital capacity (FVC).

(vii) FEV_1 per cent ($FEV_1\%$).

The first six tests require three different types of instruments to perform. Depending on the condition of the patient, convenience and availability, some are preferred to others. For example, R_{aw} and SG_{aw} tests require plethylsmograph, FEV_1, FVC and $MMEF_{25-75\%}$ require spirometer and PEFR requires a flow meter. Plethylsmograph tests are difficult to perform in the first five minutes after exercise though they more specifically show mainly large airway obstruction which commonly occurs in exercise induced asthma.

Some authors (41) have gone on to do the exercise for longer periods like 8 minutes (still within the recommended 4-12 minutes). Maybe the significance between patients and controls could have been seen more clearly if the test was done for longer than 5 minutes. Also the fact that there was no measure of the amount of exercise done meant that some subjects could have gone with less amount of exercise hence reflecting on the results of ventilatory function. These two elements could explain the one or two irregularities in the results.

CONCLUSIONS:

The study has shown that:

1. There is significant difference in ventilatory function tests between asthmatic children in stable state and healthy children especially as shown by PEFR and $FEV_1\%$.

2. PEFR and $FEV_1\%$ are the most reliable tests in our setting.
   Peak flow meter is low cost and convenient to carry out. It is also easier to instruct the subject on how to use it.

3. Bronchial asthma in older children seems to be less severe.

4. FEV_1 and FVC parameters would be useful for follow up of asthamatic patients when using the patient's initial readings as the standard.

RECOMMENDATIONS

1. Another study with clinical grading of severity of asthma and ventilatory function tests need to be carried out.

2. A longer period of exercise more than 5 minutes should be tried in any other work related to this.

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APPENDIX I

Questionnaire for patients

Date ....

Study Number ....,

Ambient Temperature .... °C

Atmospheric pressure .... Millibars

Child's Name ....

Date of birth

Day	Month	Year
....	....	....

Sex: Male ....

Female ....

1) Does he/she usually cough?

(exclude clearing throat or single cough).

Yes ....

No..............

2) Does he/she usually cough like this

for about 3 consecutive months in a

year?

Yes ....

No ....

3) Do you notice that he/she is short of breath when playing with other children?

Yes ....

No ....

4) If yes do you think that this is more than in other children of the same age?

Yes ....

No ....

5) Does the chest ever wheeze or whistle

Yes ....

No ....

6) If yes, does he/she get this often?

Yes ....

No ....

7) Medication.

Is he currently on any type of medication for his chest problem?

Yes ....

No ....

APPENDIX II

Questionnaire for controls

Date ....

Ambient Temperature ....°C

Atmospheric pressure ....Millibars

Child's Name ....

Date of birth

Day	month	year
....	....	....

Sex: Male ....

Female ....

1) Do you hear the child coughing ?

(Exclude clearing throat or single cough).

Yes ....

No ....

2) If yes, does he/she cough like this for about 3 consecutive months in a year?

Yes ....

No ....

3) Do you notice that he/she is short of breath when playing with other children?

Yes ....

No ....

4) If yes, do you think that this is more than in other children of same age?

Yes ....

No ....

5) Does the chest ever wheeze or whistle?

Yes ....

No ....

6) If yes, how many times since birth?

Many ....

One ....

Two ....

7) Has any of his/her brothers and sisters or any of his parents ever had wheezing or whistling?

Yes ....

No ....

8) Was the disease called ASTHMA?

Yes ....

No ....

9) Has he/she had cough and running nose in the last 6 months lasting for 3 weeks or more?

Yes ....

No ....

APPENDIX III

1. Anthropometry

Wt .... kg

Ht .... cm

2. Examination of respiratory system.

Before Exercise

		YES	NO
i)	Flaring of alae nasi	....	....
ii)	Intercostal/Subcostal retractions	......	....
iii)	Wheezes	......	....
iv)	Crackles	......	....

After Exercise

i)	Flaring of alae nasi	......	....
ii)	Intercostal/Subcostal retractions	....	....
iii)	Wheezes	....	....
iv)	Crackles	....	....

3. Ventilatory Function Tests.

Before Exercise.

FVC .... litres

FEV_1 .... litres

FEV_1 .... %

PEFR .... litres/min

After Exercise

FVC .... litres

FEV_1 .... litres

FEV_1 .... %

PEFR .... litres/min

A P P E N D I X IV

Determination of sample size

The incidence of asthmatics of 7.8% was assumed in the population (referred from data in Tanzania).

Using FEV_1% parameter and given that the study is a cohort one, then both patients and controls were to be analysed. FEV_1% of 70% was taken as the value in patients for the purposes of calculation. A difference of 25% between patients and controls was desired. Hence FEV_1% level of 95% was assumed in controls.

Let P_1 the incidence of FEV_1% in the patients be 70%.
Let P_2 the incidence of FEV_1% in controls be 95%.
Assuming 95% confidence or an alpha error of 0.5% and a study power of 90%, the sample size was obtained by the formula below:

$$n = [\, Z_{\alpha} (2p(1-p)^{\frac{1}{2}} + Z_{\beta} (p_1(1-p_1)+p_2(1-p_2)^{\frac{1}{2}}]^2 \, [p_1-p_2]^2$$

n = 46.

That is, 46 patients and 46 controls. In this study, since the analysis was going to be done in two age groups independent of each other, 46 subjects were taken for each of age groups $\geq$ 5 - 9 years, and $\geq$ 10-13 years in both patients and controls. Therefore 92 patients and 92 controls were recruited.

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