The Vitalograph – A Study of Its Role in Pulmonary Function Testing in Childhood*

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SUMMARY

A dry spirometer (Vitalograph†) has been examined in relation to its mechanical reproducibility, and feasibility for use in paediatric pulmonary function testing. Measurements at ATPS and BTPS indicate a −2·10% to +13·47% variability in volume readings respectively. Measurements on 304 normal healthy children, aged 6 - 18 years, height 120 - 174 cm were made using this dry spirometer and statistically compared with normal available water spirometric data. Except for mid-expiratory flow rates, all compare favourably.

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'Pulmonary function tests' should now be performed on every patient with known or suspected cardiopulmonary disease, just as haemoglobin determination, blood pressure measurement and urine analysis are performed as a routine.[1] In general, however, laboratories, equipment and technical staff are expensive. The purpose of this study was to evaluate an easy-to-use cheap dry spirometer and delineate and statistically compare the results obtained from its use in children, to available normal values.[2]

MATERIALS AND METHODS

Experiment 1

A water spirometer was connected tightly to a Vitalograph, and fixed varying volumes (2 litres and 4 litres) were blown from one to the other at ATPS. Ten readings were measured at each volume.

Experiment 2

A volume-regulated respirator,‡ which fully saturated the air at 37°C, was attached first to the water spirometer, and then to the Vitalograph. A fixed volume was blown alternatively into each spirometer and recorded. Ten readings were taken from each instrument.

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†Vitalograph Limited, Buckingham, England.
‡Dragar Spiromat.

Experiment 3

The fixed volume respirator then introduced air fully saturated at 37°C into the Vitalograph via a copper tube 112 cm × 1·9 cm immersed in water at room temperature (25°C). Ten readings were then taken.

Experiment 4

Twenty-five normal boys, aged 14 - 17 years, mean height 175 cm, were utilized. Each standing subject forcibly exhaled through a Wright's peak flow meter, the best of 4 readings being taken. Vitalography and water spirometry were then carried out in a similar manner. Mean regression lines with their 95% confidence limits were calculated for FVC, FEV_1, and peak and mid-expiratory flow rates, for both machines, and then plotted and compared with standard water spirometric data.

Experiment 5

Standing pulmonary function studies (FVC, FEV_1 and MVV) were carried out using the Vitalograph alone on 279 normal healthy children (140 boys and 139 girls), aged 6 - 18 years, mean heights 156 cm and 149 cm for boys and girls respectively. The best of 4 readings were analysed, compared and presented as above.

RESULTS

Table I summarizes the results found for experiments 1, 2 and 3. Vitalograph readings at ATPS consistently underread the water spirometer readings by 2·10% and 3·36%

TABLE I. SPIROMETER READINGS

	Water	Dry mean ± SD	Water—dry % difference	Via tube
MI/ATPS	2 000	1 957·5	−2·10%	—
	4 000	3 865·0	−3·36%	—
MI/BTPS	1 700	1 930·0	+13·47%	—
	1 700	1 785·5		+5·03%

respectively for 2- and 4-litre deflections. At BTPS consistent Vitalograph over-reading (mean 230·0 ml) occurred, giving a 13·47% inaccuracy. When air was delivered via a copper tube to the Vitalograph, the over-reading that occurred was reduced by 8·43% to 5·03% (mean 85·5 ml).

Table II gives the relationship of height against Wright's peak flow meter and various Vitalograph flow and volume

TABLE II. CORRELATION COEFFICIENTS. HEIGHT AGAINST VITALOGRAPH PARAMETERS AND WRIGHT'S PEAK FLOW METER (279 CHILDREN)

		Males	Females
Wright's	**PEF**	**0·873**	**0·899**
Vitalograph	**PEF**	**0·717**	**0·820**
,,	**FMF**	**0·513***	**0·758***
,,	**$FEV_{1\cdot0}$**	**0·919**	**0·930**
,,	**FVC**	**0·930**	**0·928**
,,	**MVV**	**0·914**	**0·928**

* **Poor correlations for mid-expiratory flow (FMF).**

parameters for 279 normal children (experiment 5). Except for mid-expiratory flow rate, there is a good correlation in all measurements. Table III A gives the t values for comparisons of the mean standard water spirometer FVC and FEV_1 data, to our water spirometry data; the Vitalograph data compared to our water spirometric data and Vitalograph data against normal standard water spirometric data (experiment 4).

Table III B gives the mean flow rates for standard data, and our data utilizing a Wright's peak flow meter, Vitalograph and water spirometer; t value comparisons are indicated. With the exception of FMF, the calculated t values indicate that no significant differences exist between the means t value of $<1·96$ for the number of degrees of freedom is encountered more than 5% of the time (experiment 4).

Figs. 1 - 6 (a and b) show the relationships between height and Wrights peak flow, and Vitalograph peak flow FEV, FVC, FMF, and MVV for normal boys and girls.

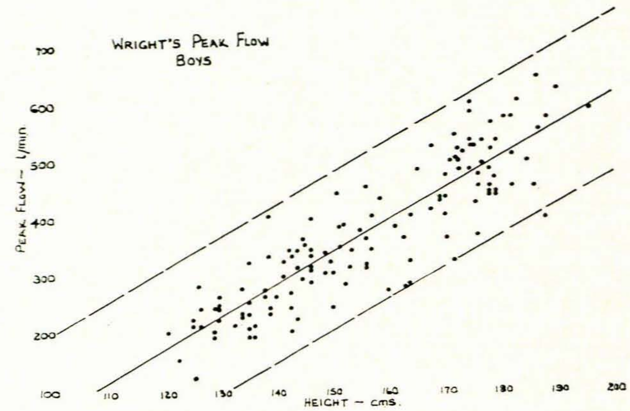

Fig. 1a. Wright's peak flow (litres/min—boys).

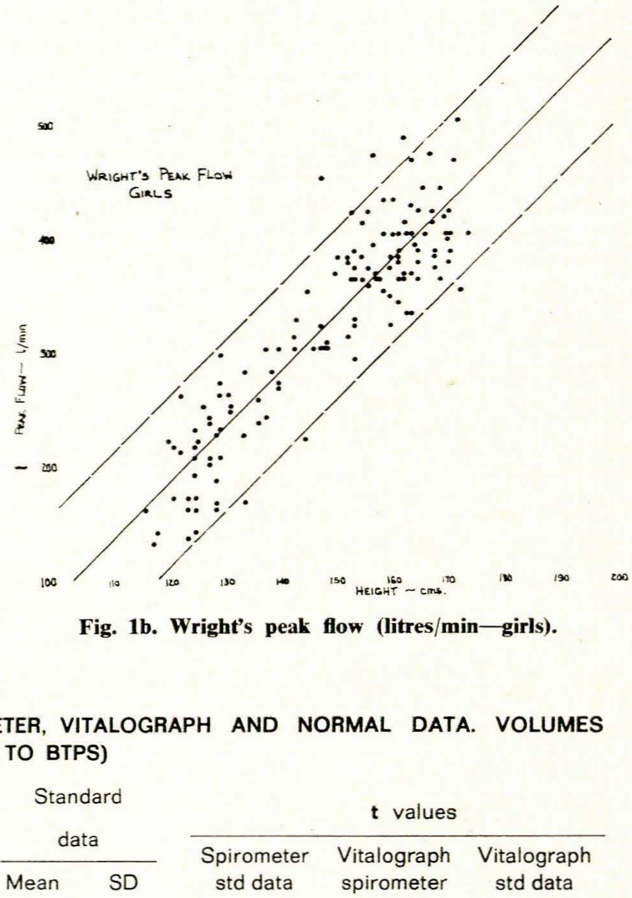

Fig. 1b. Wright's peak flow (litres/min—girls).

TABLE III A. COMPARISON BETWEEN WATER SPIROMETER, VITALOGRAPH AND NORMAL DATA. VOLUMES (CORRECTED TO BTPS)

	Experimental spirometer		Vitalograph		Standard data		t values		
	Mean	SD	Mean	SD	Mean	SD	Spirometer std data	Vitalograph spirometer	Vitalograph std data
FEV	**4·5**	**2·076**	**5·0**	**2·242**	**4·5**	**0·76**	**0·119**	**0·744**	**1·106**
$FEV_{1\cdot0}$	**3·7**	**1·70**	**3·9**	**1·65**	**3·8**	**1·48**	**0·243**	**0·377**	

TABLE III B. COMPARISON BETWEEN WATER SPIROMETER, VITALOGRAPH AND NORMAL DATA. FLOWS (LITRES/MIN)

	Wright's		Vitalograph		Spirometer		Std data		t values			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Std data	Wright's Vitalograph	Wright's std data	Std data Vitalograph
PEF	**485**	**58**	**485**	**102**			**486**	**49**		**0·025**	**0·040**	**0·052**
FMF			**240**	**52**	**243**	**89**	**274**	**104**	**1·565**			**2·54**

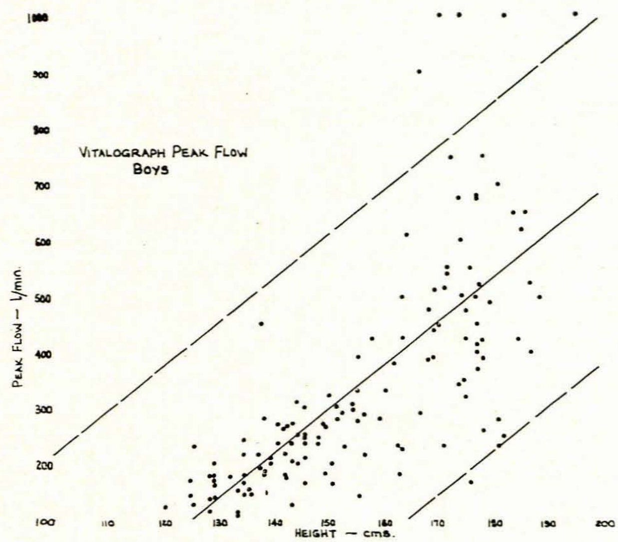

Fig. 2a. Vitalograph peak flow (litres/min—boys).

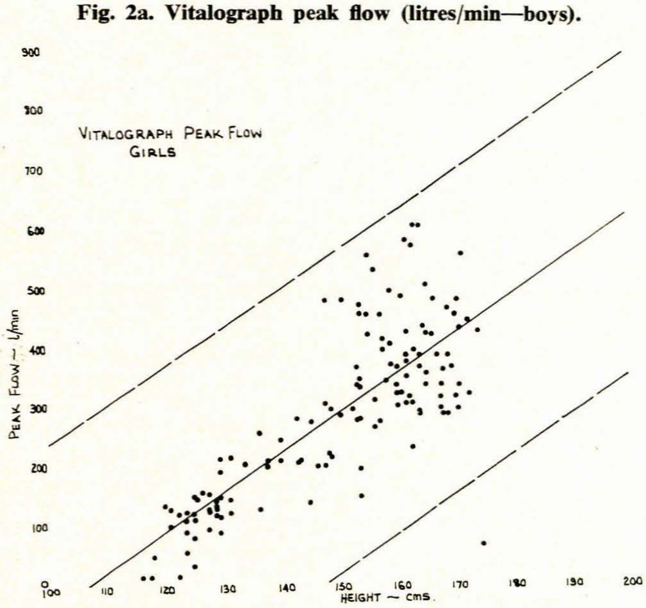

Fig. 2b. Vitalograph peak flow (litres/min—girls).

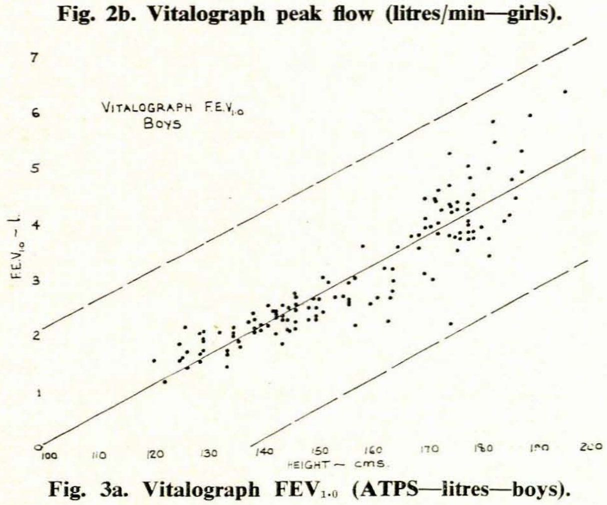

Fig. 3a. Vitalograph $FEV_{1\cdot 0}$ (ATPS—litres—boys).

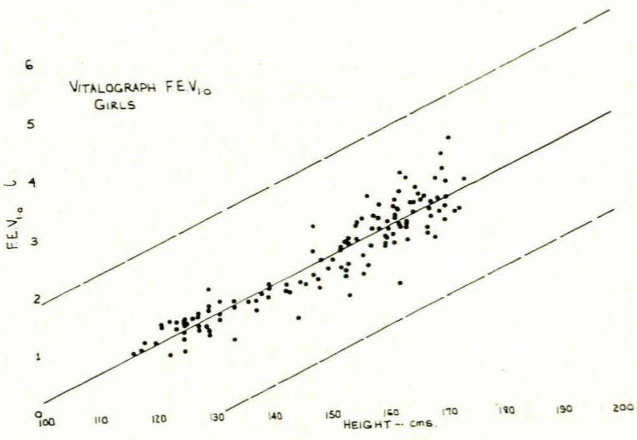

Fig. 3b. Vitalograph $FEV_{1\cdot 0}$ (ATPS—litres—girls).

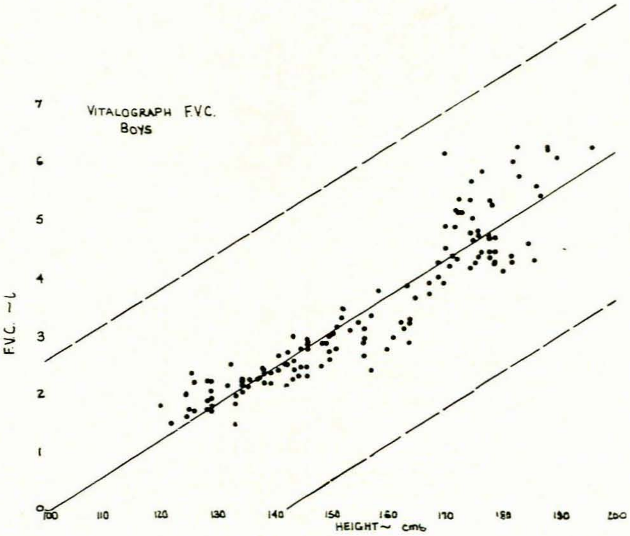

Fig. 4a. Vitalograph FVC (ATPS—litres—boys).

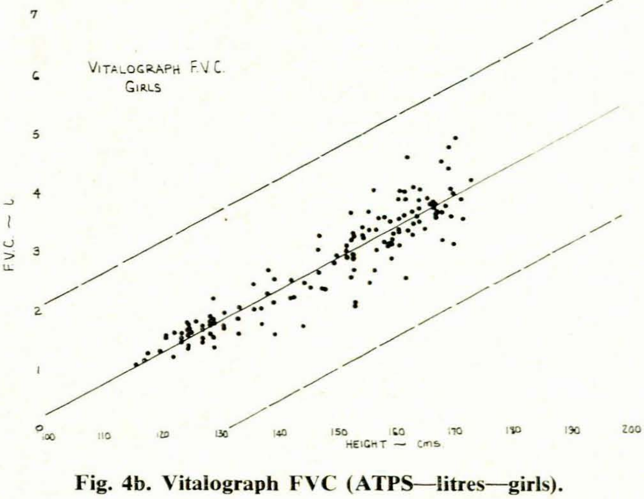

Fig. 4b. Vitalograph FVC (ATPS—litres—girls).

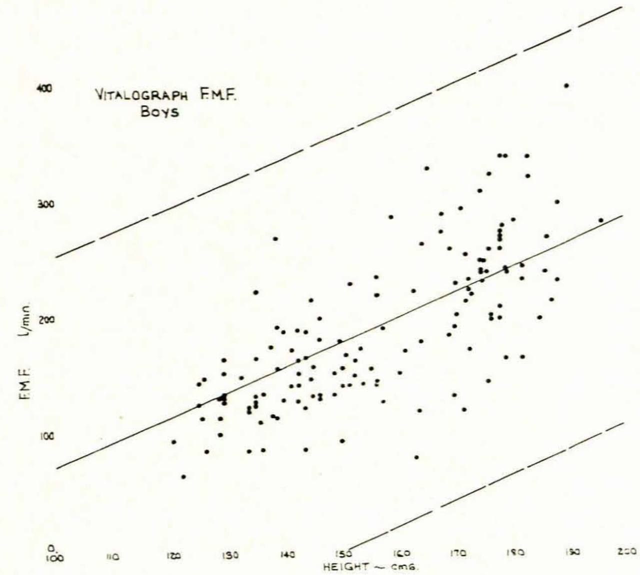

Fig. 5a. Vitalograph FMF (litres/min—boys).

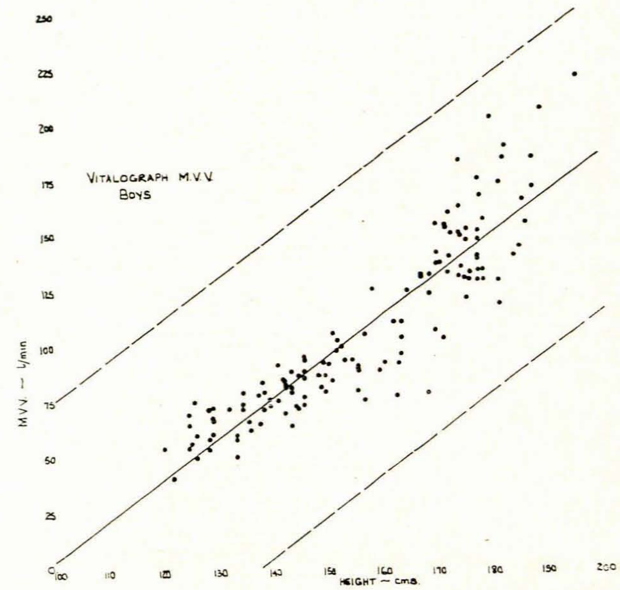

Fig. 6a. Vitalograph MVV (ATPS—litre/min—boys).

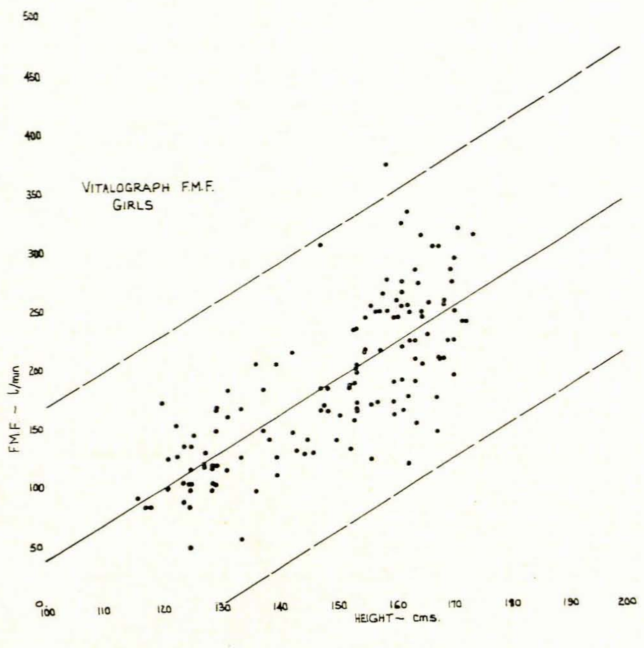

Fig. 5b. Vitalograph FMF (litres/min—girls).

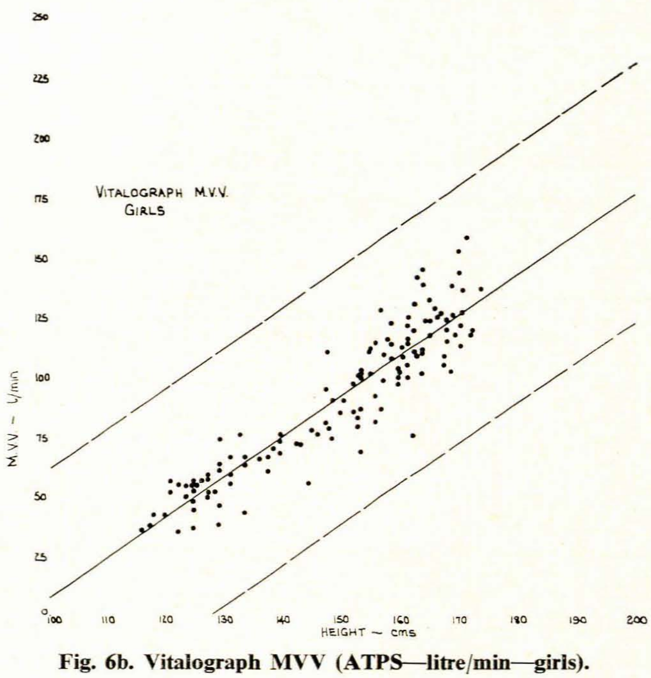

Fig. 6b. Vitalograph MVV (ATPS—litre/min—girls).

Table IV gives the means, standard deviations and *t* values comparing Vitalograph FVC, FEV_1, and MVV with standard available data for boys. No significant difference exists between the means. Although no similar data is available for girls due to the incompleteness of published results, the similarity of their means to normal data lends confidence to the assumption that their standard deviations and *t* values would be comparable.

TABLE IV. BOYS*—VITALOGRAPH vs STANDARD DATA. VOLUMES—LITRE/BTPS

	Vitalograph		Standard data		
	Mean	SD	Mean	SD	t value
FVC	3·0	1·27	3·01	0·457	0·040
$FEV_{1\cdot0}$	3·0	1·064	2·86	0·448	1·489
MVV	105	42·38	102·5	14·03	0·662

*Mean height 156 cms.

DISCUSSION

The Vitalograph is a low-priced, direct-writing light-weight (5·6 kg) portable (40 × 38 × 24 cm) robust, dry spirometer which utilizes a wedge-type plastic bell (maximum volume

6·612 litres BTPS) as its volume-measuring member. Inertia and resistance are compensated for by spring forces. Timed volumes and flows may be measured as recorder speed compares to the time recorded on the graph trace to an accuracy of 0·01 seconds.[2] In spite of its fairly widespread use in the USA, Britain and Africa, only one critical report on its performance, and this utilizing adult patients, has been published. Drew and Hughes[3] have shown that recorder speed, activation volume, volume calibration and linearity accuracy comply well with laid down international standards at ATPS. In a small series using normal adults they measured forced vital capacity and timed expiratory volume, and stated that biological calibration for these parameters was good. Resistance and inertia were found to be higher than was acceptable, and they suggested that flow rates would be inaccurate utilizing this machine.

The results reported here show that in absolute terms at ATPS, volume readings on the Vitalograph are fairly accurate. At BTPS however, as air is a poor conductor of heat as compared with water, no instantaneous correction to ATPS is possible in the dry bellows, and consistent over-readings are recorded. The error being in the order of 1% for every 3°C above ATPS. The fact that the introduction of a cooled copper pipe between the heated, fully saturated volume source and the Vitalograph recorder corrects this over-reading to a significant extent, supports the above postulate.

In biological terms where spirometry data may normally vary widely within height groups, a 13% over-reading variability need not necessarily preclude the use of a machine. The second part of this study which statistically compares the various volume and flow values achieved using the Vitalograph on normal children and data which has previously been published, strongly suggests that other than for mid-expiratory flow rates, the Vitalograph may be freely used in the routine assessment of pulmonary function in childhood.

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