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Respiratory measurements in children using the Bennett respiratory ventilation meter

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RESPIRATORY MEASUREMENTS IN CHILDREN
USING THE BENNETT RESPIRATORY VENTILATION METER

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Much work has been done with the measurement of vital capacity with the spirometer, but this instrument has been on the whole, too clumsy to have wide clinical application. Furthermore its use with children is limited because full cooperation is required. The Bennett Respiratory Ventilation Meter has the advantages of being easy to handle and of not requiring the cooperation of the child. In this survey we hope to establish the average vital capacity and tidal air of children of all sizes and to compare these results with those that might be expected by spirometry. These measurements were taken on two hundred and ninety children entering the Children's Memorial Hospital during August and part of September of 1951. It is anticipated that this instrument may be of value in bulbar poliomyelitis, and since respiratory infections and fever are often seen in this disease, an estimate of the effect of these on vital capacity and tidal air is included. Finally, we have reviewed respiratory measurements in ten cases of bulbar poliomyelitis in an effort to evaluate the use of the instrument in this disease.

Most measurements of respiration have been taken with various spirometers and have been estimates of vital capacity. Christie(1) and Hutchinson (2) describe vital capacity as the greatest expiration after maximum inspiration, the complemental air as that inspired from mid-position, the residual air as the amount remaining after fullest expiration , the functional residual as the amount remaining after a normal expiration, and the tidal air as the amount exchanged in quiet breathing. Mills (3) studied expiration and inspiration and concluded that inspiration was more variable, but that there was no objective evidence that more air is expired than taken in.

In the study of vital capacity various types of instruments have been used. Smith (4) prepared an apparatus for infants which consists of a rigid container with a water manometer connected to a face mask. The mask is placed over the face at the end of a full inspiration. Deming and Washburn (5) prepared an airtight chamber with a float type spirometer. The child was placed in the chamber with the head out and the neck closed with an airtight collar. The excursion of the child's chest caused displacement of air in the chamber. Deming and Hanner (6) used this on eighteen infants from one to eleven days of age and got a vital capacity of 121-181 cc. Donald and Christie(7) used a Benedict spirometer in which there is a rubber bag containing gas to be inspired. They state that inertia causes a measurable, but constant error. Edwards and Wilson (8) measured children from six to sixteen years using various spirometers. The calibration was checked by checking water displacement with a Bohr meter. Of the various spirometers the 'Standard' made by Narragansett Machine Co. gave lower readings than the Gad-Krogh or Sanborn types by about 10%. A dry spirometer made by Upjohn gives readings lower by 11.6%. Metheny (9) found that temperature, resistence of the tube, and atmospheric pressure have little effect on vital capacity, but that difference in pressure inside and outside may affect it. Reduction in volume due to the force necessary to overcome this inertia will become larger as the vital capacity decreases. In working with small children she used a bell with a smaller diameter so it would rise higher and the results would be more apparent to the children. Another method, that of measuring volume by the ratio of gases was used by VanSlyke and Binger(10).

Mills (3) studied the reliability of vital capacity and found that there is a significant increase in two series several weeks apart. Emerson and Green (11) felt that the determination of vital capacity in children below the age of seven was unreliable. Both Metheny (9) and Jersild (12) found the most improvement with practise occured within the first six trials. Metheny (9) found that the variation with time of day was no greater than on different days.

Various attempts have been made to correlate body measurements with vital capacity. The earliest attempts were those made by Dreyer(13) who correlated vital capacity with weight, height, stem length, chest circumference, and surface area and found the latter to be most accurate. Since $\frac{Wt.^{.72}}{S.\ A.} = K$ and $\frac{Wt.^{.72}}{V.\ C.} = K$, this latter is the formula he used with $K = .69$. Surface area may be found with the formula $A = Wt.^{.425} \times Ht.^{.725} \times 71.84$, according to Dubois and Dubois. Stewart (14) applied this formula to children and found that the value of K varied from .955 at 40# to .701 at 140# for boys and from 1.089 at 40# to .850 at 90# for girls. He established regressive equations based on the formula $y = ax + b$ where y = vital capacity and a = ht. in cm; x is a given factor. He found that vital capacity increases with the growth curve. For boys it increases steadily from four to ten years, accelerates from twelve to fourteen, and increases less rapidly from fifteen to nineteen. For girls it increases rapidly from four to six, more slowly from seven to ten, is accelerated from eleven to thirteen and then slows down. Edwards and Wilson (8) point out the possibility that conditions altering vital capacity for long periods may also alter surface area. They suggest that different methods of calculating surface area may give different results; results are lower with the Benedict Talbot method. West (15) found that using Dreyer's formula, the number having a vital capacity within 10% of normal were only 2% less than when the formula of Dubois and Dubois was used. Edwards and Wilson (8) found most variation in correlation of surface area with body weight, especially in children weighing over 40 kg. There is a close correlation between height and surface area with more divergence in larger subjects. Various authors have correlated vital capacity with different measurements. Estimates based on weight have been made by Dreyer and Hanson (16), Stewart(14) who presented the regressive equations, Myers (17), Turner for adults (18), and Kelly (19) who stated that for boys vital capacity (cu. in.) = 1.8208 (wt. in #) x 1.004855, and for girls V.C.(cu. in.) = 7.1947 (wt. in #) x .6564. Estimates based on sitting height were made by Dreyer and Hanson (16), Roberts and Crabtree (20), and Stewart (14). Estimates based on chest circumference were made by Dreyer and Hanson(16) . Estimates based on surface area were made by Edwards and Wilson (21) with an average for boys of 1.90 l/sq.m. and for girls 1.84 l/sq. m. Kelly (19) stated that V.C. (cu. in.) = 108.10 $S.A.^{1.51601}$.

Estimates based on height have been made by Hastings (22), Myers (17), Kelly (19), Turner (18), Stewart(23), Hutchinson (2), who stated that for every inch from five to six feet, eight cubic inches of air were breathed, Roberts and Crabtree (20), who stated that from six to eighteen years each five cm = 139cc increase up to 140cm height for girls; above 140 cm, each 5 cm equal an increase of 194cc, and for boys up to 150 cm, each 5 cm is an increase of 167 cc; above 150 cm it is 386 cc, and Lemon and Moerch (24) who stated that vital capacity for males was height x 25 and for females, height x 20. Estimates on more than one variable have been made by Stewart and Sheets (25) using age and height, Stewart (14) using sex, age, sitting height , and height, Baldwin (26) using age and height, and Kelly (19) using age, height, and weight. Metheny (9) extended the age of children down to three years and found the highest correlation of vital capacity to be with height. She took the results of various studies and compared the actual means with the theoretical value calculated by various formulae. There was great variation, but the most accurate were Kelly's (19) height formula and Stewart's (14) height formula. The others have higher values than those observed. Since none were accurate for preschool children, she prepared tables from the formulae: for boys V.C.(cu. in.) = 1.4331 x ht. in cm. + 3.8133 x age - 111.3903; for girls V.C. = 1.1023 x ht. in cm. + 4.7294 x age - 84.9755; age was counted to the nearest half year. She devised the Breathing Capacity Quotient which equals $\frac{\text{actual B.C.} \times 100}{\text{expected B.C.}}$

The range was 70-141 with a standard deviation of 13.4..Metheny (27) comments that in her observation there is a greater difference in vital capacity between the sexes than can be accounted for by a difference in height.

Various factors have been said to alter vital capacity. Kaltreider et. al (28) report that in adults the vital capacity is decreased by 4.4% in the recumbent position. Gross (29) lists possible factors as pulmonary, cardiac, insufficient muscle strength, and psychological. Wilson and Edwards (30) found no difference between public and private schools reflecting economic groups; they found a lower vital capacity in children who are overweight, and a lower vital capacity in Negro children. They list various diseases affecting it: tracheobronchial adenopathy, acute bronchitis, broncnial asthma, emphysema, pleurisy with effusion, lobar pneumonia, pulmonary T.B., and organic heart disease. Plum and Whedon (31) report the use of spirometry in adult convalescent poliomyelitis. Using the Sanborn closed circuit recording spirometer they found that when the vital capacity reached 800-1000 cc, a respirator was needed. In convalescence when it was 600 cc at rest, they could stay out of a respirator all day, and when it reached 800 cc, no more help was needed.

The meter used in this study is about six inches in diameter, and is marked off in 50 cc units, one revolution of the hand being one liter. It has a one-way valve for exhaled air so that only inhaled air comes through the meter and is measured. The meter is connected by rubber tubing to a mask. It was found that the mask supplied by the manufacturer was too large for many of the smaller children, so the pneophore mask was substituted with all of them. The height of each child was measured. This is not only the simplest to get, but, according to Metheny (9), also gives the most accurate correlation with vital capacity. The children were tested while lying down since the mask is easiest to apply in that position. An attempt was made to get the cooperation of each child. They were instructed to first breathe quietly, then take a deep breath, several trials being given. The highest value was taken as the vital capacity, while the lowest figure for tidal air was used because there was a tendency to breathe more deeply with the mask covering the face. A few children were unable to get the idea of breathing deeply; in these cases they were allowed to breathe quietly for some time, and almost invariably they would eventually breathe deeply because the mask tended to give a smothery feeling. The children under three usually fought and cried, in the process of which they took a deep breath which was considered to be their vital capacity. Measurements were taken of infants under three months, but the mask was too large and the volume of air was usually under 50 cc, the smallest unit on the dial, so that an accurate determination is impossible with this instrument. However, the rough estimate that was obtained revealed lower values than those of Deming and Hanner (6). Because of the report of Wilson and Edwards (30) that Negro children tend to have a lower vital capacity, this study includes only white children.

To compare the results of this study with those expected by spirometry, the Breathing Capacity Quotient suggested by Metheny (9) is utilized. The expected vital capacity is calculated for each child according to Stewart's regressive equations (see above) for children above five, and according to Metheny's special formula for preschool children (see above) from three to five years. Since there has been no spirometry done on children under three, it is impossible to make the comparison. A child was considered to have a fever if it was 100 degrees by rectum. Since there was found to be no significant difference in respiration with fever, this group is combined with the non-fever group in those groups in which there were not enough cases of each. No attempt was made to distinguish between upper and lower respiratory diseases.

The symbols and formulae used in the following tables are given below.

'No.' refers to the number the child was given in this study.

V.C. is vital capacity.

T. A. is tidal air.

B. C. Q. is breathing capacity quotient.

S. D. is standard deviation. S. D. $= \sqrt{\frac{\Sigma x^2}{N}}$ where x is the deviations from arithmetic mean; N is number of cases.

S.E. is standard error for small samples.

$$S.E. = \frac{S.D.}{\sqrt{N-1}} \times \text{a factor representing 3 S.D.}$$

Significant Difference between two means:

$$\sqrt{\frac{S.D._1^2}{N} + \frac{S.D._2^2}{N}} \times 3 = a; \quad Mean_1 - Mean_2 = b.$$ If 'b' is larger than 'a', the difference is significant.

19-23 in.
40-56 cm.

Males			Females		
No.	V. C.	T.A.	No.	V.C.	T.A.
6	70	40	4	50	15
18	60	10	11	50	15
26	40	15	27	40	20
47	50	20	31	125	20
64	100	30	35	150	15
74	60	15	56	75	25
80	125	25	161	50	10
91	100	50	171	75	
95	50	10	211	150	30
96	60	10	218	40	10
116	65	25			
172	40	15			
216	50	10			
235	35	10			
252	40	10			
Mean	63	19	Mean	80	17
S.D.	±25	±12	S.D.	±42	±6
S.E.	±20	±9	S.E.	±44	±6

24-34 in.
57-85 cm.

Males			Females		
No.	V.C.	T.A.	No.	V.C.	T.A.
2	300	100	52	120	40
8	125	75	67	100	25
20	350	25	101	250	
28	175	40	115	175	25
32	200	40	139	200	50
36	100	30	153	250	100
39	250	100	170	200	
41	350	100	184	200	100
63	200	75	215	200	10
72	300	75	233	100	30
82	450	100	236	200	30
93	400	150	249	200	25
103	150	50	282	200	100
110	350	150	289	75	33
112	500	150			
119	300	75			
154	300	50			
169	250				
173	200	50			
187	300	50			
230	200	100			

24-34 in.
57-85 cm.

Males			Females		
No.	V.C.	T.A.	No.	V.C.	T.A.
234	150	25			
254	250	100			
256	250	50			
Mean	266	77	Mean	176	47
S.D.	±99	±38	S.D.	±53	±31
S.E.	±59	±22	S.E.	±45	±28
Respiratory Infections					
23	200	50	44	200	50
48	250	50	97	400	100
65	150	75	98	350	100
81	250	50	225	200	50
83	500	150	274	350	100
128	400	50			
150	150	50			
154	300	50			
192	150	50			
Mean	261	64	Too few.		
S.D.	±115	±31			
S.E.	±142	±36			

35-46 in.
86-115 cm.

Males				Females			
No.	V.C.	T.A.	BCQ.	No.	V.C.	T.A.	B.C.Q.
251	442	100	56				
255	300	75	36				
257	650	200	73				
260	500	100	82				
265	300	100	54				
270	300	150	34				
276	400	100	69				
280	300	100	45				
292	350	100	43				
Mean	415	112	58	Mean	426	98	64
S.D.	±172	±53	±21	S.D.	±153	±49	±31
S.E.	±88	±27	±11	S.E.	±96	±31	±19
			Fever				
9	600	150	136	10	300	50	41
12	450	250	42	38	500	150	117
37	500	100	76	46	400	100	94
60	350	75	34	49	400	75	36
109	400	150	46	51	650	150	68
182	300			70	600	150	74
183	400	150	49	90	500	200	95
198	600	100	56	147	600	200	50

35-46 in.
86-115 cm.

Fever

Males				Females			
No.	V.C.	T.A.	B.C.Q.	No.	V.C.	T.A.	B.C.Q.
199	300	100	25	190	500	150	47
287	600	100	51	193	250	100	41
				269	500	200	48
				286	450	100	39
Mean	450	130	57	Mean	470	135	62
S.D.	±114	±50	±31	S.D.	±114	±48	±26
S.E.	±123	±60	±36	S.E.	±105	±46	±25

Respiratory Infections

Males				Females			
No.	V.C.	T.A.	B.C.Q.	No.	V.C.	T.A.	B.C.Q.
19	200	50	30	77	300	100	57
22	350	40		158	300	50	63
43	350	75	52	165	250	100	63
140	300	150	59	210	300	100	68
156	300	100		232	350	100	46
208	400	100	90	237	500	100	81
224	250	100	30	266	400	50	37
228	350	150	51	271	300	50	73
244	200	50	37				
Mean	311	90	49	Mean	337	81	59
S.D.	± 67	±39	±19	S.D.	±74	±24	±11
S.E.	±80	±47	±26	S.E.	±98	±31	±14

46-56 in.
116-140 cm.

Males				Females			
No.	V.C.	T.A.	B.C.Q.	No.	V.C.	T.A.	B.C.Q.
15	1150	400	68	5	700	300	50
16	525	110	41	42	700	200	55
24	650	150	50	85	1200	300	73
50	750	130	37	94	950	150	67
87	800	250	55	106	550	150	30
126	650	150	31	107	800	250	65
127	900	200	43	111	600	300	32
144	1100	400	59	124	1000	200	71
146	650	250	34	131	1200	200	73
149	650	150	46	132		100	
151	800	150	43	138	500	100	37
152	1050	250	68	143	500	150	40
155	600	150	33	148	700	150	48
162	700	100	36	181	1000	150	70
163	450	150	37	185	1300	350	68
166	1300	400	85	194	850	200	61
177	600	150	47	222	800	150	45
189	700	150	42	239	500	100	36
191	1300	300	74	245	900	250	47
197	750	200	41	258	600	200	53
247	800	150	59	262	700	150	50

46-56 in.
116-140 cm.

Males				Females			
No.	V.C.	T.A.	B.C.Q.	No.	V.C.	T.A.	B.C.Q.
248	800	250	39	267	700	100	59
272	700	300	41	268	700	200	62
290	600	150	35	275	550	200	41
				277	700	250	40
				288	700	150	57
				291	700	150	50
Mean	790	210	48	Mean	773	191	53
S.D.	±226	±90	±14	S.D.	±218	±67	±13
S.E.	±131	±53	±8	S.E.	±121	±36	±7

Fever

1	1500	350	77	3	700	100	50
59	1000	350	72	34	600	60	35
62	450	100	21	122	450	100	35
100	700	150	44	279	600	150	45
104	800	250	55				
123	1750	400	94				
167	1150	150	75				
195	950	250	65				
Mean	1037	250	63	Too few			
S.D.	±398	±103	±21				
S.E.	±523	±136	±28				

56/ -67 in.
141-165 cm.

Males				Females			
No.	V.C.	T.A.	B.C.Q.	No.	V.C.	T.A.	B.C.Q.
21	1500	500	49	57	600	250	28
53	1200	300	34	105	1700	250	84
61	800	150	29	108	750	300	32
66	1500	500	65	125	1050	400	45
71	1050	200	47	136	1650	150	74
86	1400	300	59	176	1200	250	48
92	800	200	33	186	1400	500	55
113	1150	350	50	217	1250	300	48
133	1400	250	48	243	1500	250	
134	1950	400	75				
141	1000	450	28				
142	400	100	17				
145	850	300	28				
157	1400	200	61				
159	1350	400	62				
160	2000	150	86				
188	1300	150	51				
196	1650	200	69				
206	1500	200	54				
209	750	200	33				
	1150	300					
Mean	1242	276	49	Mean	1233	294	52
S.D.	±387	±116	±17	S.D.	±153	±95	±17
S.E.	±244	±74	±11	S.E.	±184	±114	±20

Significant Difference Between Fever and Non-fever Groups

Vital Capacity

	'a'(see above)	'b'	Significance
35-46 Males	143.4	35	Not significant
35-46 Females	140.7	44	Not significant
46-56 Males	444	247	Not significant

Tidal Air

35-46 Males	57.9	18	Not significant
35-46 Females	53.1	37	Not significant
46-56 Males	122.4	40	Not significant

Breathing Capacity Quotient

35-46 Males	33	1	Not significant
35-46 Females	30.3	2	Not significant
46-56 Males	23.7	15	Not significant

Significant Difference With Respiratory Infections

Vital Capacity

24-34 Males	129.9	5	Not significant
35-46 Males	115.5	104	Not significant
35-46 Females	97.2	89	Not significant

Tidal Air

24-34 Males	39	13	Not significant
35-46 Males	48.9	22	Not significant
35-46 Females	41.4	17	Not significant

Breathing Capacity Quotient

35-46 Males	24.6	9	Not significant
35-46 Females	23.4	5	Not significant

Significant Difference Between Size Groups

Vital Capacity

	'a'	'b'	Significance
19-23 Male	63.6	203	Significant
&			
24-34 Female	58.2	96	Significant
24-34 Male	111.9	149	Significant
&			
35-46 Female	108.9	250	Significant
35-46 Male	167.4	375	Significant
&			
46-56 Female	162.6	436	Significant
46-56 Male	288.6	452	Significant
&			
56-67 Female	199.5	460	Significant

Tidal Air

	'a'	'b'	Significance
19-23 Male	25.5	58	Significant
&			
24-34 Female	27.6	30	Significant
24-34 Male	37.8	35	Not significant
35-46 Female	42.3	51	Significant
35-46 Male		98	Significant
&			
46-56 Female	50.7	110	Significant
46-56 Male	93.9	66	Not significant
&			
56-67 Female	102.6	103	Significant

Breathing Capacity Quotient

	'a'	'b'	Significance
35-46 Male	14.7	10	Not significant
&			
46-56 Female		11	Not significant
46-56 Male	13.8	1	Not significant
&			
56-67 Female		1	Not significant

Significant Difference Between Male and Female

Vital Capacity

	'a'	'b'	Significance
19-23	44.4	17	Not significant
24-34	74.1	90	Significant
35-46	137.4	11	Not significant
46-56	188.7	17	Not significant
56-67	295.8	9	Not significant

Tidal Air

19-23	11.1	2	Not significant
24-34	35.7	30	Not significant
35-46	44.1	8	Not significant
46-56	63.9	19	Not significant
56-67	121.5	18	Not significant

Breathing Capacity Quotient

35-46	23.4	6	Not significant
46-56	11.4	5	Not significant
56-67	20	3	Not significant

Cases of Bulbar Poliomyelitis Requiring Respirator

No.	V.C.	T.A.	Mean V.C.	S.D.	Mean T.A.	S.D.
33	750	100	1242	±387	276	±116
78	700	250	790	±226	210	±90
114	400	100	1242	±387	276	±116
118	100	50	415	±172	112	±53
179.	900	150	790	±226	210	±90
200	1100	250	1233	±153	294	±95
201		15			276	±116
202	1200	60	1242	±387	276	±116
203	200	100	426	±153	98	±49
204		75			112	±53

Interpretation of Results

In using the Breathing Capacity Quotient,an actual vital capacity equal to the theoretical estimate would give a value of one hundred. Thus it can be seen that the values obtained with this instrument are considerably lower than would probably be found by spirometry. Metheny (9) states that in similar calculations using actual measurements by spirometry, the theoretical values tend to be high, but that Stewart's (14) regressive equations which are used in this study, are one of the most accurate estimates. It seems quite likely, since the equations were derived from a different group of children than used in this study, that this is a major source of error. Errors of spirometry, such as friction and difference in pressure inside and outside the bell, which is mentioned by Metheny (9), would tend to decrease the value rather than increase it. To have a fair comparison, the same group of children should be tested on both instruments. It is also possible that the Bennett Respiratory Ventilation Meter is inaccurate. The use of inspiration instead of expiration must also be considered as a source of the different values. Another possibility is leakage of air about the mask. However the same reading may be obtained holding the mask loosely as holding it tightly. Furthermore one would expect a lower Breathing Capacity Quotient in the lower age groups where less cooperation is available. This is not the case; there is no significant difference between the means of the Breathing Capacity Quotients of any of the size groups. This fact is also evidence against an emotional factor being of prime importance; one would expect higher Breathing Capacity Quotients in older, more cooperative age groups, whereas the actual tendency seems to be toward lower values. The children in this study were measured lying down, whereas they stand for spirometry. In adults there is only a 4.4% difference in vital capacity in the two positions. However, this must remain a possible source of error.

The differences in vital capacity of the size groups were significant. Two of the differences in tidal air were not, which suggests that vital capacity is a more valid measurement.

There was no significant difference in any age groups between those with fever and those without fever. Thus it is not necessary to consider this in testing patients with bulbar poliomyelitis.

There was likewise no significant difference between those with respiratory infections and those without. This is contrary to what might be expected since there are reports that the vital capacity is lowered under such conditions. This may be explained, in part at least, by the fact that all types and severity of respiratory infections are included. If it were restricted to severe bronchial asthma, for instance, the results might be different, but apparently an upper respiratory infection is not significant.

The differences between male and female were not significant with the exception of one group, that which includes children approximately three months to over one year. This is an age of very rapid growth, which may exaggerate the difference between the sexes, the males being larger and having higher vital capacities. It is also possible that the statistics give an inaccurate picture, although this is one of the larger groups, and would thus tend to be representative. The overall picture of no difference is not in agreement with Metheny's(27) work. She states that there is a greater difference in vital capacity than can be accounted for by difference in height. She does not say what statistical methods were used. In our study the males did not consistently have a larger vital capacity and the differences were not significant.

There were ten cases of bulbar poliomyelitis, the vital capacity and tidal air having been taken on entrance to the hospital or just before going into the respirator. In three cases both vital capacity and tidal air were decreased below 1 S.D. In one, the vital capacity only, was decreased and in one it was decreased, but still within 1 S.D. In two cases the tidal air, only, was available; both were decreased and one below 1 S.D. In one case the tidal air was below 1 S.D. while the vital capacity was normal. In two cases both values were normal. Thus in eight of the ten, the respiration was measurably diminished before the respirator was used. There is no indication from these ten cases as to whether vital capacity or tidal air tends to be most valuable. More work should be done on this subject. This instrument would probably be of most value in following individual cases. A consistent decrease would be more significant than any one value in itself. It could be invaluable in determining when a patient is ready to be out of a respirator.

Summary

This paper contains a brief survey of the literature on spirometry and a description of the methods used in obtaining the vital capacity and tidal air of two hundred and ninety children. The measurements are grouped according to the height of the child. Male and female are separated, as well as those with fever, respiratory conditions, and bulbar poliomyelitis. The measurements are compared with those expected by spirometry for each child. For each group the standard deviation and standard error are calculated, as well as the significant difference between groups, fever and non-fever, male and female, and respiratory and non-respiratory conditions. It was found that:

1. Measurements with the Bennett Respiratory Ventilation Meter are lower than it is estimated that spirometric measurements would be.
2. Vital capacity is probably a more valid measurement than tidal air.
3. There is no significant difference between fever and non-fever in vital capacity and tidal air.
4. Respiratory infections do not cause a significant difference in vital capacity and tidal air.

5. There is no dignificant difference between the vital capacity of males and females except in the 24-34 in. size group, in which case the males have a higher vital capacity.

6. The Bennett Respiratory Ventilation Meter may be of great value in following cases of bulbar poliomyelitis, both in judging when the patient needs a respirator and when he may be out of one. It is felt that the norms established in this study may be useful in determining the amount of respiratory depression.

BIBLIOGRAPHY

1. Christie, R. V. Lung Volume and Its Subdivisions, J. Clin. Invest. 1932, vol. 11, p. 1099.

2. Hutchinson, John The Capacity of the Lungs, Lancet, 1846, vol. I, p. 630.

3. Mills, J. N. Variability of Vital Capacity of the Normal Human Subject, J. Phys. 1949, vol. 110, p. 76.

4. Smith, Hugh H., McLanahan, Samuel, and Davison, Wilburt C. Apparatus for Determination of Vital Capacity in Infants, Am. J. Dis. Child. 1942, vol. 63, p. 92.

5. Deming, Jean, and Washburn, Alfred H. Respiration in Infancy. Am. J. Dis. Child. 1935, vol. 49, p. 108.

6. Deming, Jean, and Hanner, James P. Respiration in Infancy. Am. J. Dis. Child. 1936, vol. 51, p. 823.

7. Donald, K. W. and Christie, R. V. New Method of Clinical Spirometry. Clin. Sc. 1949, vol. 8, p. 21.

8. Edwards, D. J. and Wilson, May G. Analysis of Factors of Variability in the Vital Capacity Measurements of Children. Arch. Int. Med. 1922, vol. 30, p. 638.

9. Metheny, Eleanor Vital Capacity in Preschool Children Uni. of Iowa Studies in Child Welfare, 1941, vol. 18, p. 207.

10. Van Slyke, D.D. and Binger, C.A.L. The Determination of Lung Volume Without Forced Breathing, J. Exp. Med. 1923, vol. 37, p. 57.

11. Emerson, Paul W. and Green, Hyman, Vital Capacity of the Lungs of Children, Am. J. Dis. Child. 1921, vol. 22, p. 202.

12. Jersild, Arthus T. et. al. Vital Capacity in Children, Child Developement Monograph, Columbia Univ. 1932, No. 10, pp.ix, 73.

13. Dreyer, Georges Normal Vital Capacity and Relation to Body Size, Lancet, 1919, vol. 2, p. 227.

14. Stewart, Chester A. Vital Capacity of the Lungs of Children in Health and Disease, Am. J. Dis. Child. 1922, vol.24, p. 451.

15. West, Howard F. Clinical Studies on the Respiration, Arch. Int. Med. 1920, vol. 25, p. 307.

16. Dreyer, Georges, and Hanson, G. F. Assessment of Physical Fitness by Correlation of Vital Capacity and Certain Measurements of the Body. New York City, P. B. Hoeber, 1921, p.1.

17. Myers, J. A. Vital Capacity of the Lungs, Williams and Wilkins, 1925, p. 140.

18. Turner, R. A. Vital Capacity in College Women, Arch. Int. Med. 1930, vol. 46, p. 930.

19. Kelly, Helen Garside, Studies in Child Welfare, Univ. Iowa Stud. 1933, vol. 7, p. 59.

20. Roberts, Frank L., and Crabtree, James A. Vital Capacity of the Negro Child, J.A.M.A. 1927, vol. 88, p. 1950.

21. Edwards, D. J., and Wilson, May G. Standard for Comparing the Vital Capacity of Subjects of Different Size, J. Lab. and Clin. Med. 1939, vol. 24, p. 543.

22. Hastings, William W. A Manuel for Physical Measurements. Springfield, Mass. The International Young Men's Christian Association Training School, 1902, pp.xviii, 112.

23. Stewart, Chester A. A Consideration of the Extent of the Normal Variability of the Vital Capacity of the Lungs of Children. Am. Rev. T. B. 1926, vol. 13, p. 272.

24. Lemon, Willis S. and Moersch, Herman J. Comparison of Constants for Determination of Vital Capacity. Arch. Int. Med. 1924, vol. 33, p. 118.

25. Stewart, Chester A., and Sheets, O. B. Vital Capacity of the Lungs of Children. Am. J. Dis. Child. 1922, vol. 24, p. 83.

26. Baldwin, Bird T. Vital Capacity and Physical Measurements, Am. J. Phys. Anthropol. 1928, vol. 12, p. 257.

27. Metheny, Eleanor Vital Capacity in the First Decade, J. Ped. 1941, vol. 19, p. 841.

28. Kaltreider, Nolan L. Fray, W.W. and Hyde, H.V. Z. Effect of Age on Pulmonary Capacity, Am. Rev. T.B. 1938, vol. 37, p.662.

29. Gross, Desiderio, Investigation Concerning Vital Capacity, Am. Heart J. 1943, vol. 25, p. 335.

30. Wilson, May G. and Edwards, D. J. Diagnostic Value of Determining the Vital Capacity of the Lungs of Children. J.A.M.A. 1922, vol. 78, p. 1107.

31. Plum, Fred, and Whedon, Donald. The Rapid Rocking Bed, 1951, N.E. J. of Med. vol, 245, p. 235.