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OTIS (E. O.)

METHODS OF CHEST EXAMINATION

SUPPLEMENTARY TO AUSCULTATION AND PERCUSSION.

BY

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SOME METHODS OF CHEST EXAMINATION SUPPLEMENTARY TO AUSCULTATION AND PERCUSSION.[1]

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EXPERIENCE gained in the examination of over fifteen hundred chests of presumably well persons has convinced me that the means of determining the condition of the lungs other than auscultation and percussion are exceedingly valuable, and add not inconsiderably to the knowledge obtained by the latter methods. Moreover, they are applicable to most cases which consult us for suspected lung trouble.

The means I refer to are in use, some of them at least, in the gymnasiums where physical examinations are made, though probably not exactly with the same end in view which guided me in my investigations. They are:

Spirometry: the measure of the lung capacity, as well as the measure of the ordinary amount of air in the lungs.

Pneumatometry: the measure of the elastic power of the lungs, or strength of the lung tissue.

Thoracometry: the measure of the circumference and diameters of the chest — depth and breadth — both in natural and full inspiration, and tracings of the contour of the chest, also in natural and full inspiration.

[1] Read before the Boston Society for Medical Improvement, January 7, 1895.

These tests are of especial value in those incipient or suspected cases before we obtain any positive evidence of disease by auscultation and percussion. A class of cases in which any and all means of examination which will lead to a diagnosis are of especial value, for, as we all know, the earlier the diagnosis is made and the treatment begun, the better the prospect of arrest. Further, they naturally suggest a valuable means of treatment, namely, gymnastic exercise especially directed to chest and lung expansion.

The capacity of the lungs in health varies in the first place according to age, sex, and stature; and, secondly, according to the height, width, and depth of chest, mobility of the chest-walls, and also, which is of especial note, according as one has or has not been in the habit of fully expanding the lungs — practising breathing exercises. In 1,000 measurements of my own tabulation for an average height of 67 inches (170.2 centimetres) and an average age of 22.1 years, the average lung capacity was 240.6 cubic inches (3,944 cubic centimetres). In 8,000 measurements of Dr. Hitchcock, of Amherst College, for an average height of 67.9 inches (172.5 centimetres), and at an age of from seventeen to twenty-six years, the average lung capacity was 230 cubic inches (3,770 cubic centimetres). In 15,000 measurements of students, at about the same age as those tabulated by Dr. Hitchcock, collected by E. Hitchcock, Jr., of Cornell University, the average lung capacity was 236.6 cubic inches (3,880 cubic centimetres) for an average height of 67.8 inches (172.2 centimetres). I have also made from my own measurements of males from sixteen to forty years of age, averages of the lung capacity for heights from 66 to 72 inches, each average being the result of fifty observations, with the following results:

Height.	Lung Capacity.	Average for each Inch or Centimetre in Height.
66 to 67 inches, incl. 167.7 to 170.3 cms.	231.62 cubic inches. 3,797 cubic cms.	3.4+ cubic inches. 22.4 cubic cms.
67 to 68 inches, incl. 170.3 to 172.8 cms.	237.10 cubic inches. 3,903 cubic cms.	3.46 cubic inches. 22.7 cubic cms.
68 to 69 inches, incl. 172.8 to 175.4 cms.	244.44 cubic inches. 4,007 cubic cms.	3.5 cubic inches. 23.06 cubic cms.
69 to 70 inches, incl. 175.4 to 177.9 cms.	259.34 cubic inches. 4,250 cubic cms.	3.66 cubic inches. 24.06 cubic cms.
70 to 71 inches, incl. 177.9 to 180.5 cms.	261.38 cubic inches. 4,284 cubic cms.	3.64 cubic inches. 23.9 cubic cms.
71 to 72 inches, incl. 180.5 to 183 cms.	261.34 cubic inches. 4,284 cubic cms.	3.5 cubic inches. 23.03 cubic cms.
General average . . .		3.52 cubic inches. 23.19 cubic cms.

From this data we find that in males between sixteen and forty years of age for each inch in height, the lung capacity is 3.5 cubic inches or 22.5 to 23 cubic centimetres for each centimetre of height. From the observations of Hutchinson and Wintrich, Brehmer gives it as between 22 and 24 cubic centimetres for every centimetre in height, but 23 is a good working basis and sufficiently accurate.

For women we have the measurements of about 500 students taken at Mt. Holyoke and Wellesley Colleges by Dr. Colton and Miss Wood, which gives for an average height of 62.6 inches (159.1 centimetres), an average lung capacity of 145.8 cubic inches (2,390 cubic centimetres); and also 50 per cent. of 1,500 Wellesley students, the observations made by Miss Wood for a height of 63.2 inches (160.5 centimetres), giving a lung capacity of 150.3 cubic inches (2,447 cubic centimetres). The average age in each case was about nineteen years. From this we find that, with women, for every inch in height the lung capacity is about 2.3 cubic inches or 15 cubic centimetres for each centimetre. Brehmer makes it a lit-

tle higher, between 16 and 17.5 cubic centimetres. Hutchinson found in his investigations, made many years ago, that the lung capacity varied from 174 cubic inches for a height of five feet to 262 cubic inches for a height of six, or for every inch of stature above five feet the lung capacity increased eight cubic inches. According to Waldenburg the lung capacity decreases after thirty and up to sixty years of age, nearly 1½ cubic inches per year of age. This I should doubt to be the case provided the individual continues the habit of deep breathing.

With the data then already given, knowing the height, we can estimate pretty nearly how much the lung capacity of each individual ought to be. If, on a spirometic test, it varies to any great extent from this, the man is either better or worse than we thought as to his chest expansive ability and lung capacity. If much below, either his method of respiration is faulty or his lungs are not normal. If the first supposition is true, the measurements of the circumference, depth and breadth of the chest in repose and full expansion will indicate this, for the difference of these three measurements under these two conditions of repose and expansion will be below the average, indicating insufficient mobility of the chest-walls.

Now, this may all happen in the latter case, namely, that the lungs are not normal and some of their tissue is disabled and thrown out of use, but we shall have the evidence which auscultation and percussion give us. If the evidence, however, from these tests is negative, and yet we have certain suspicious general symptoms, the failure of the spirometic test together with these measurements to come up to the average by a considerable degree, will, at least, make one suspicious as to the integrity of the lung tissue. I wish here incidentally to make an especial point

upon the amount of air exhaled after an ordinary quiet inspiration, the way one generally breathes when one is thinking nothing about it. This, it seems to me, is a valuable bit of evidence, as showing how successfully and normally one is performing the act of respiration.

In examining patients with incipient pulmonary tuberculosis, the lung capacity was found to be below, and generally much so, the average. According to Waldenburg from 10 to 70 per cent. To illustrate: E. C., of medium stature, in fair general condition as to strength, appetite, digestion, etc., and attending daily to business, was found to have a small area of tubercular infiltration at the apex of the right lung; the vital capacity was 195 cubic inches, the average being about 235 cubic inches. J. M. with evidence of induration and softening at the apex of the right lung, had a vital capacity of 85 cubic inches. H. A. S. with evidence of a moderate amount of tubercular disease at the left base from old pleuritic trouble, had a vital capacity of 185 cubic inches. W. H. D. with a slight infiltration in the outer clavicular region of the left apex, but with the perfect appearance of health and attending to his usual occupation, had a vital capacity of 150 cubic inches. In all of these cases the diagnosis was verified by the finding of tubercle bacilli in larger or smaller quantities.

Brehmer[2] goes so far as to say that the physician can with the aid of the spirometer determine whether the individual who comes to him for the first time to be examined, or is seen by him for the first time, has pulmonary tuberculosis or not, and that the spirometer is, *par excellence*, the means, and indeed the only one, to determine with certainty under all conditions the first beginnings of pulmonary trouble. "By it," he says, "we can determine whether or not any, even a

[2] Die Chronische Lungenschwindsucht und Tuberculose der Lunge, Dr. Herman Brehmer, Berlin, 1869.

very small portion of the lung tissue is unaccessible to air, and whether there exists any induration, although it may be surrounded by air-permeated lung tissue." Says Renzi, in his recent work upon phthisis,[3] "spirometry shows a diminution of the lung capacity even in the beginning of the disease."

On the other hand, if the general symptoms were suggestive of tubercular trouble but if the vital capacity was up to or beyond the average, it was a favorable piece of evidence against actual lung invasion. For example, E. J. T., a young woman with a marked family history of tubercular trouble, and with general symptoms strongly suggestive of it, came to me with a communication from her family physician that two months previous he had found the right apex suspicious. She had a vital capacity of 150 cubic inches, the average for a women, and the examination of the lungs by auscultation and percussion was negative, and no bacilli were found in the sputum.

Wintrich — quoted by Brehmer — narrates two cases in which the spirometer test determined the fact that no lung trouble existed in spite of suspicious symptoms. One was a governess who had suffered from an annoying cough, accompanied sometimes with a little blood. Her general condition was good but her friends were much alarmed, fearing disease of the lungs. The spirometer test, however, gave the average lung capacity for her height, namely, 17 cubic centimetres to one centimetre of height — about $2\frac{1}{2}$ cubic inches to one inch in height — and consequently the cough was considered hysterical. The other, also a young woman, had for a long time a severe, troublesome cough, and it was feared that she also might have some deep-seated lung disease; but the spirometic test gave 2,720 cubic centimetres of lung capacity —

[3] Pathogense, Symptomatologie, und Behandlung der Lungenschwindsucht, von Dr. E. De Renzi, Wien, 1894.

her height being 165 centimetres, or 17 cubic centimetres to one centimetre of height — indicating that the cough was not the result of any lung invasion. One might naturally ask why could not auscultation and percussion have as well determined this fact, and also the examination of the sputum; but Brehmer answers this by saying that examples are by no means rare where neither the subjective symptoms nor the most exact examination by means of auscultation and percussion will, with certainty, reveal infiltration, but where the spirometer shows an important diminution of the lung capacity, and only after a year and a half or two years will auscultation and percussion give evidence of infiltration at the apices; and that the patients have after some years died of lung disease. As to the examination of the sputum — in one of the cases above quoted by Brehmer, there was no sputum, and in the other the slightest amount, if any. And further, a spirometic test requires but the slightest amount of skill and experience, and there are no sources of error if the spirometer is, to begin with, accurate, while examination of the sputum, if there is any, requires experience and skill and expensive appliances.

Further, when the diagnosis of tubercular invasion has been established, the test of the vital capacity is a factor of more or less value in forming a prognosis. As Renzi says: "It has especially a high prognostic worth, for when the breathing capacity is very considerably diminished, the prognosis is unfavorable." There may possibly be a slight danger of hemorrhage in taking this test, but as one would generally apply it only in incipient cases, this, it seems to me, is inconsiderable. It is a test which is very readily made and the sources of error are small. Either a dry or a water spirometer may be used. I am accustomed to

both, with a preference for the latter; it seems to me to be rather more accurate and less likely to become disarranged. As illustrative of this part of the subject, I give the lung capacity of thirteen consumptives with more or less advanced disease.

A, male	145	cubic inches.
B, male	115	"
C, male	76	"
D, male	50	"
E, male	75	"
F, male	70	"
G, male	75	"
H, male	132	"
I, male	103	"
J, male	102	"
K, male	95	"
L, male	52	"
M, female	85	"

The average lung capacity for males being 235.7 cubic inches, and for women about 150 cubic inches.

The pneumatometer or pressure spirometer is the instrument used in measuring the so-called strength of the lungs — or the inspiratory and expiratory forces. Under normal conditions, according to Waldenburg, the expiratory force exceeds the inspiratory by 20 to 30 millimetres. In cases of tubercular disease, however, even in the earliest stages, "the inspiratory power is diminished, whilst the expiratory remains normal."[4] Renzi has repeated Waldenburg's experiments, and finds that both the inspiratory and expiratory forces are diminished in tuberculosis of the lungs, but the former more so than the latter and earlier. In emphysema the expiratory pressure is lowered. I have made a large number of observations upon the expiratory force, "strength of lungs" so-called, and I am unable to find that there is any constant ratio between it and the lung capacity. The test

[4] Powell: Diseases of the Lungs.

has a certain value, however, I think, as a gymnastic exercise. Waldenburg used a mercurial manometer. I have used what is in common use in the gymnasiums, an ordinary steam-gauge made for recording low pressure. Dr. Denison, of Denver, Col., has also devised a mercurial instrument, which I have here.

In thoracometry two circumferences of the chest are taken, one at the level of the nipples, and the other about two inches below, the "respiratory chest" so-called. These may be taken under three conditions: extreme inspiration, extreme expiration, and in calm breathing. I have been accustomed to take them in calm breathing and extreme inspiration only. The important fact to be ascertained in these tests is the mobility of the chest-walls as a whole. To determine the amount of excursion of the chest-walls antero-posteriorly and laterally we measure these two diameters in repose and full inspiration: this is important, for I have often found that the expansion comes almost entirely from the increase of one diameter alone, as the accompanying charts illustrate. I take them at the level of the nipple, the antero-posterior one, by metal calipers — the self-registering ones I think, are more convenient — and the lateral one either with the same instrument or a pair of wooden slide calipers.

These measurements of the circumference and diameters of the chest taken in repose and inflation tell us of its size and mobility, but not of its shape or of the symmetry or asymmetry of the respiratory movements. It is a fact I have frequently verified that the apparent and real shape of the chest often differs very largely; and further we know that it frequently expands unsymmetrically, the amount of excursion of one side of the chest-walls being larger than that of the other, or the expansion being mostly

either anteriorly or laterally. In order to make apparent these facts of shape and variations of expansion we can trace the contour of the chest in repose and inflation, which will still further complete our knowledge of the respiratory chest, its movements and contents. For this purpose we can either make use of a simple band of lead with a rubber hinge as I have done, or the more complicated and accurate apparatus of Démény, of Paris. Generally for the purpose of the clinician the simpler instrument will suffice. The contour of the chest is first taken in repose and charted, and superimposed upon this its shape when fully expanded, thus giving us a representation of the shape under the two conditions. By this method, for example, we can see at a glance if the two sides of the chest expand unequally, as in a case of previous pleuritic trouble.

By these additional methods of physical examination, which I have enumerated and briefly described above, I feel convinced that we can often obtain valuable knowledge of the respiratory chest and its contents in addition to that obtained by auscultation and percussion; and in doubtful cases, as I have said, of suspected tubercular trouble, their evidence will often, I believe, render the diagnosis clearer.

I do not by any means consider all these tests of equal value; indeed, taken by themselves some have very limited value, such as the strength test of the lungs and the tape measure of the chest expansion, but the sum total of them does, I believe, very materially supplement the knowledge obtained by auscultation and percussion, as well as suggest to us possible defects in the respiratory function when all other evidence is negative. Moreover, by an examination of this kind one gets into the habit of looking at his patient from rather a different point of view, a physio-

logical one, if I may so denominate it, in addition to the pathological one. And further, if in an examination of a suspected case we obtain no evidence of disease, we do gain information by these additional methods which we could not obtain, or but indifferently, by auscultation and percussion, namely, how the function of respiration is being performed.

If the vital capacity is low and the expansion poor, we are enabled, by the knowledge of these deficiencies, to warn our patient of possible tubercular trouble in the future encouraged by his faulty habits of respiration, and teach him how to correct them by gymnastic exercises arranged to obviate these deficiencies. As Renzi says, in speaking of spirometry, "One can in some degree form a reliable opinion as to a possible future lung invasion, and, therefore," he adds, "it is important that this means of examination should be used in the schools and gymnasiums."

These methods of examination are of value also in keeping before one's mind this valuable means of treatment and prophylaxis, namely, lung-expanding exercises, a treatment all too much neglected, it seems to me, but which, when properly arranged and supervised, can produce striking results.

Says Dr. Butler in his conclusions to a recent paper read before the American Climatological Association, upon "The Methods and Value of Supervised Exercise in the Prophylaxis of Pulmonary Phthisis": "Among many therapeutic agencies for imminent or incipient phthisis, one of the most useful is respiratory exercise. . . . Of all methods of obtaining increase of respiratory strength, capacity and nutrition, supervised exercise secures the most permanent and lasting results."

I give, on the following page, a table, previously published, of measurements and averages of the chest

and its vital capacity. I also present a variety of chest contours with the vital capacity and expansion.

MEASUREMENTS OF THE CHEST AND LUNG CAPACITY.

TABLE I. — *Chest Measurements.*

CHEST MEASUREMENTS.	Repose, inches.	Inflated, inches.	Difference, inches.
Girth, Muscular.			
MEN.			
Average of Dr. E. O. Otis, 1,000 measurements, between sixteen and forty years of age	34.0	36.1	2.1
Average of Dr. Hitchcock, of Amherst College, 8,000 measurements	34.6	36.5	1.9
Average of E. Hitchcock, Jr., of Cornell College, 15,000 measurements . .	34.5	36.3	1.8
WOMEN.			
Mt. Holyoke and Wellesley students. Measurements Miss Wood and Dr. Mary Colton	29.5	31.5	3.0
Chest, Respiratory.			
MEN.			
Average of Dr. E. O. Otis, 1,000 measurements . . .	31.1	33.1	2.0
WOMEN.			
Fifty per ct. of 1,500 Wellesley students, Miss Wood .	24.6	27.2	2.6
Depth of Chest.			
MEN.			
Average of Dr. E. O. Otis, 1,250 measurements in repose and 362 inflated . .	7.5	8.3	0.8
WOMEN.			
Fifty per cent. of 1,500 students at Wellesley, Miss Wood	6.9	....	....
Breadth of Chest.			
MEN.			
Average of Dr. E. O. Otis, 400 measurements . . .	9.9	10.8	0.9

TABLE II. — *Capacity of Lungs.*

	Cubic Inches.
MEN.	
Average of Dr. E. O. Otis, 1,000 measurements	240.6
Hitchcock, 8,000 measurements	230.0
Hitchcock, Jr., 15,000 measurements	236.6
WOMEN.	
Mt. Holyoke and Wellesley students, measurements of Miss Wood and Dr. Mary Colton	145.8
Fifty per cent. of 1,500 Wellesley students, Miss Wood	150.3

TABLE III. — *Comparison of the "Vital" or Lung Capacity and the Amount of Air Expelled after an Ordinary Quiet Inspiration. Average of Dr. E. O. Otis. One Hundred and Fifty Measurements.*

	Cubic Inches.
Vital capacity, or the amount of air exhaled after a full inspiration	230.5
Amount of air exhaled after an ordinary quiet respiration	129.3
Difference, or "complemental" or "reserve" air	101.2
Difference as given by Hermann	97.6