THE CRITERIA OF A DEPENDABLE BASAL METABOLISM REPORT*

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The clinical use of the Basal Metabolism test, marks a new era in medicine. It dates back to the publication, twenty-one years ago, of Standards for the Normal elaborated by Aub and Dubois (1917)¹, and by Harris and Benedict (1919)². The fundamental data previously accumulated in 1914 and 1915 and which offered the basis for these original and indispensable standards, are given in full on pp. 31–48 of the last mentioned publication. Heretofore, clinical medicine had profited relatively little from the tremendous amount of fundamental research done in the field of body calorimetry for nearly a century by physiologists of Europe and of the United States.

Up to 1917 metabolimetry had remained confined to the experimental laboratory and was under the control of highly trained technicians. According to one of these pioneers, the number of technicians in the United States capable of manipulating successfully the complicated apparatus and technic then in use could be counted on the fingers of one hand. With the subsequent introduction of simpler and less costly equipment and, in particular, of the long hoped for normal standards, clinical metabolimetry rapidly spread the world over.

The ease with which anyone of ordinary intelligence can master the universally adopted technic in conducting a “basal metabolism test” with the newer types of apparatus, resulted in a rapid multiplication of number of operators. Many of these technicians, educated over night merely to run a machine, lacked the

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training and experience necessary to face the multiplicity of problems to be otherwise encountered. The indispensable ability to secure the cooperation of the individual under observation is sadly wanting in the majority of inexperienced operators but the reliability of their work and reports was generally unquestioned because there were few capable of checking up and passing judgment upon it.

High class technicians are no longer indispensable for the manipulation of the type of metabolimetric apparatus now in general use. As a result we have with us a large number of technicians who operate beyond their rightful limitations.

More than one authority has stated, on the basis of extensive travel and observation, that as many as 70 per cent of the basal metabolism reports made today by the average operator may not be worth the paper upon which they are written. Although such a distressing situation calls for a remedy, it is not the slightest wish of the unprejudiced critic to return to the days of not long ago, when only highly trained technicians could be entrusted with the delicate method of gas analysis then and still required by the so called "open circuit" method of body calorimetry. The general acceptance of the "closed circuit" type of apparatus did not reduce in any way the dependability and the accuracy of the determination. On the contrary, valuable technical improvements made these newer and simpler facilities better suited for their wide application in clinical medicine. However, the universal adoption of this method has often placed clinical metabolimetry beyond the judicious control desirable for the maintenance of high medical standards. It is regrettable that to a large extent the blame lies at the door of the internist and even of the pathologist.

To come to the point, a plea is here offered to the Society of Clinical Pathologists to extend more definitely its constructive influence in this important branch of pathology as an important, timely remedy for the present state of affairs. It is needless to discuss before this specialized group the harm which results from the misleading information now often accepted without question
from a large number of unapproved or unsponsored laboratories or technicians.

The metabolism operator and his department are too often not under the supervision of an approved clinical laboratory or pathologist. Whether his services are regarded as reliable usually depends merely on his general reputation. It is the purpose of this paper to present criteria by which independent judgment may be passed on the reliability of metabolism tests.

The first essential in reliable metabolism testing is an adequately trained technician, sponsored by a competent director or clinical pathologist. The technician should see that every report includes all the routine notations which are the indispensable earmarks of a complete and properly conducted test.

In the use of the "closed circuit" method the kymograph plays an important part not only in simplifying the technic, but also in increasing the accuracy of the spirometric measurements on which are based the determination of the rate of oxygen consumption. More than that, the spirogram is a permanent and trustworthy record of the kind of technic pursued in the performance of the test, as well as of the general behavior or cooperation of the subject.

We have repeatedly had proof of the fact that, in general, little meaning is attached to the spirogram aside from its being a convenient means of measuring oxygen consumption. The spirogram of each determination should accompany the report because it furnishes the most important evidence of a successfully conducted test. In fact, no disturbance which would materially affect the results can occur without leaving some significant telltale in the respiratory tracing. It should be preserved as a permanent record, either in the laboratory or in the doctor's files.

With the spirogram and certain other information which will be mentioned, one can verify to his own satisfaction the dependability and accuracy of any metabolism test. One does not need to have observed the test, even in part. Such verification, of course, might not detect sheer dishonesty and intentional
fraudulent action on the part of the operator. But the simple check-up here proposed should at least reveal possible carelessness and ineptitude. If this check is routinely imposed as an every day rule in the laboratory, it will act as a persistent spur in inculcating habits of carefulness and accuracy in the work of the technicians.

We are not introducing a new technic. It is fundamentally the same as that introduced by one of us, in 1922, and now universally adapted to all different makes of the Benedict type of metabolism apparatus. A discussion of their differential features is not necessary because the plan here suggested can be followed in the use of any type of apparatus with little modification.

It may not be sufficiently appreciated how much information can be obtained from the spirogram in addition to the rate of oxygen consumption. Here are enumerated the most important items:

1. The spirogram gives good evidence that the subject has, in all probability, reached the required standard or basal state and maintained the proper degree of relaxation necessary for the accuracy of the test. If, as is often the case, this state of relaxation has been temporarily disturbed by the process of connecting the subject to the apparatus, the respiration tracing will show a steeper trend than that which it will assume later, barring any other disturbance which may again increase oxygen consumption (fig. 1, A). Similar disturbances of a material degree may occur during any portion of the test, as, for instance, towards the end of a too prolonged ordeal, which is always likely to become fatiguing. Any disturbance which may alter the trend or slope of the tracing as a whole must be avoided. Nevertheless, the tendency is toward a too short rather than a too prolonged test period. Ten minutes is a good average.

In types of apparatus which will allow it, a tracing which shows considerable irregularity can be given a fresh start by merely adding oxygen while the patient continues to breathe into the apparatus (fig. 1, B).

We deem it indispensable to have a proof of the absence of a
leak during the test. Fig. 1, B, as well as several others, gives this evidence. We know of no other satisfactory test for leak than this simple one which is performed by placing on the spirometer bell, for a period of one and one-half or two minutes, (at about midway through the test) a weight of not over two ounces. A steeper slope of the spirogram while the weight is on is a positive indication of a leak (fig. 2, H).

2. The oxygen consumption line. The slope of this "O₂ line," so called, serves for the accurate measure of the oxygen consumed in a given time during the test.

This O₂ line must be accurately located in the following manner (fig. 1, C): Select that portion of the graph which presents the most uniform trend for about five or six minutes or longer, and draw the O₂ line according to the general trend of the slope of the graph. This line is drawn close to, but preferably under the expiration points, avoiding intersection of the deeper ones which may have been picked out as the very best for the purpose, especially when found distributed more or less periodically throughout the graph. Shorter portions, if particularly steady though less reliable because of their shortness, are not to be ignored entirely if nothing better is available. These short portions may sometimes be more trustworthy than longer ones with an erratic course.

Figure 1, D gives evidence of a satisfactory state and behavior of the patient throughout the test. This is the most frequently encountered type of tracing.

A respiratory pause in normal, quiet breathing takes place at the end of each passive expiratory movement, therefore at the time when the lungs are at a uniform degree of deflation. A peculiar reversal of events is occasionally observed, the graph revealing instead a respiratory pause with a coincident uniform lung inflation at the end of each inspiratory movement. Figure 1, F, G and H shows this rare, "inverted" type of breathing which, incidentally has been found by Nielsen and Roth to occur almost exclusively in women. In such cases the O₂ line is preferably traced along the inspiration line.

3. Possible errors due to change of lung expansion during a
metabolism test. Little or no stress is laid, as a rule, on the considerable degree of error that can be introduced in metabolimetric measurements by possible changes in the degree of lung expansion during the period selected for measurement (fig. 1, I, J, K, and L). It stands to reason that whether only two or many expiration points are to serve as a basis for the location of the O₂ line, reasonable assurance must be had that at the time of their occurrence a like degree of lung expansion is present. While one can assume that such is the case whenever the selected period or the entire graph presents a uniform appearance from beginning to end, alteration of lung volume at the end of expiration is the most frequent direct cause of irregular shifts in the respiration tracing. It is evident that these shifts are not accompanied by an increased or decreased oxygen absorption during an ordinary basal test, unless at the time the subject is also more or less disturbed.

The "open circuit" method presents some very definite advantages, particularly in conducting certain types of research. We agree, for instance, with the argument of Boothby, Berkson and Dunn that when using this type of apparatus a possible change in the "reserve" or "supplementary" respiratory volume, in a subject under test, does not vitiate the determination, as can happen during a test made with a closed circuit apparatus. However, the possibility of a change of that nature is rarely encountered during a uniform period of quiet, effortless breathing, as should be insured during any metabolism test whether performed by the closed or open circuit method. We also feel confident that whenever any material change of this nature occurs the graph will reveal it, and efforts such as are suggested in this paper can be made to preclude any consequent error.

4. Methods of retaining deep expiration points when desired. Figure 2, A and C illustrates a type of tracing which is very unsatisfactory and even useless. In most cases a satisfactory spirogram will usually be obtained after one or more tests on the same or on a subsequent day. Stubborn cases of erratic breathers are seldom encountered. They are often difficult or impossible to account for and may be found in perfectly normal subjects. They generally can be trained to be fairly regular breathers, provided several days can be spent in the attempt.
**Method A.** By Voluntary Deep and Full Expiration Only. In one of our most refractory cases we contrived and successfully applied the following method of obtaining, at will, deep expiration points for the location of the O₂ line. Before the test starts, the patient is told that near the beginning and again near the end, he will be asked to exhale as deeply as possible, and that he is to do so only after having taken in an ordinary, normal breath. The signal should not be given unless there is sufficient capacity for the additional exhaled air in the spirometer. In other words, sufficient space must be allowed for the pen to trace a full expiration without running off the paper (fig. 2, B). This tracing also illustrates how this was accomplished successfully in a typical case in which no satisfactory check could be obtained after several training attempts.

**Method B.** By Voluntary Deep and Full Expiration, with Manual Compression (by Operator) Over Costal Margins. This modification of Method A is usually advisable because many subjects cannot be trusted to exhale with the same degree of effort and completeness at the beginning and at the end of the test. The difficulty can readily be overcome by the simple manual application of pressure over the costal margins, by the operator, at the time the subject is asked to “breathe out completely.” In doing so, a still deeper, and more uniform deflation of the lungs is obtained. Graphs show, as illustrated in figure 2, D and E that a remarkably constant degree of deflation is registered though variable but sufficient compression force is applied. This is well shown in figure 2, F which shows the tracing obtained when manual chest compression over the costal margins was applied in succession by three operators of different muscular strength.

The choice between Method A and Method B will depend on the degree of intelligent cooperation which may be expected from the patient. The technician will do well to try one or both of these methods, and to be prepared to apply them without hesitation when necessary. Though they may seldom be needed, they may sometimes be of valuable service.

5. **Technical objections to relying on results obtained from the first metabolism test a given patient may have had.** If a patient has never had a metabolism test before, we believe that there is
enough chance of unreliable results to warrant taking a second test on a different day with rare exceptions, or unless absolutely impossible. Our experience shows that for clinical purposes subjects who have had the experience of even a single metabolism test may thereafter be considered "trained" even if they have no further tests for years. This may not be true if their first test was poorly conducted.

Whenever possible, we follow a patient's first test with another on the following or a closely succeeding day. During this second test, before the patient is allowed to arise from the couch or even while the test is still in progress, we find it easy to roughly measure the approximate fall of the spirometer bell in six minutes. We thus determine whether the results of this second test will probably check within the required five per cent of the first. If it does not, we immediately obtain another tracing before dismissing the patient, often without removing the mouthpiece.

In a study of 2000 patients having the test for the first time, we found that the first tracing of the second day's test checked with the first day's test, within the required five per cent, in 63 per cent of our cases. In 28 per cent of the cases, the third tracing (that is, the second tracing during the second day's test) afforded the desired check. In 4\(\frac{1}{2}\) per cent of the cases, they were asked to return for further study in a day or two, when we were able to obtain good results. A final 4\(\frac{1}{2}\) per cent of cases, though not presenting the usual desirable five per cent agreement, but differences of six to eight per cent instead, were not asked to return for further checking because they were, as a rule, unusually difficult to deal with, and also because they all happened to have rates within the accepted normal range.

The most significant fact revealed in another study of 1000 successive and uninitiated patients, is that without repeated determinations eight per cent of the cases would have been definitely wrongly diagnosed. That is, 4\(\frac{1}{2}\) per cent would have been classed above the normal (over +10 per cent) when they proved later to be within the normal range, and 3\(\frac{1}{2}\) per cent would have been classed as normal when they were below the lower limit of the normal range, or below −10 per cent. These statistics are based on the metabolic rates as computed by the Harris-Benedict
normal standards. Were these same 1000 determinations based on the Dubois normals or their later modifications, including the Mayo Foundation Standards, a larger proportion would have been included in the group classed below the normal range.

6. Clinical and physiological metabolimetric standards. There are two schools of thought with regard to normal standards in basal metabolimetry. One supports the so-called "clinical standards," the other, what may be termed "physiological standards." The clinical standards are based on data collected chiefly from first tests on supposedly normal subjects. As is well known, first tests, even with well relaxed subjects, tend to have somewhat higher results than are obtained when the subject has had more or less training. These standards, therefore, tend to have values somewhat higher than those of the physiological standards, which are based on the lower range of values obtained in a series of tests on the same subject.

In interpreting metabolism tests by one or another standard, it is perhaps less important to use a particular standard than it is to understand which type of standard one is using. Since the clinical standards have higher values, the metabolic rates computed by them will tend to run lower than if the physiological standards are used. They will be fairly reliable for first tests, and with untrained subjects. But when a subject has become trained or accustomed to metabolism tests, allowance will have to be made for this factor.

On the other hand, when interpreting tests by physiological standards, the results will tend to be high for untrained subjects, and to be more reliable when the subjects have had a certain amount of training. That is, allowance must be made for lack of training, when using the physiological standards.

For the sake of emphasis, I will say again that the choice of the standard itself is probably less important than knowing which type it is, and, therefore, what allowance must be made in its application under various conditions. We place our main reliance in the physiological standards although we generally report tests on the basis of several standards in our laboratory.

The reason for this choice lies in the fact that the patients who have to be given repeated tests, in the course of checking up the
results of therapy, form the largest and also the most important group. Since they are, by virtue of repeated tests, trained subjects, the physiological standards seem the most logical choice for routine use.

The most commonly used clinical standards have been the Boothby-Sandiford modification of the Dubois normals, though these are superseded now by the new Mayo Foundation Standards. The Harris-Benedict normal standards are the physiological standards most frequently used in this country.*

**CONDENSED SUMMARY OF ESSENTIALS FOR THE FINAL APPROVAL OF A METABOLISM REPORT**

1. A trustworthy technician or approved operator.
2. Neatness of both the spirogram and the report.
3. A carefully located oxygen consumption line.
4. Evidence of a negative test for leak in the spirogram.
5. Evidence that the subject was relaxed; at physical rest and breathing quietly, at least during the portion of the graph which has served as a basis for the O₂ line.
6. Evidence of the efficiency of the soda lime in maintaining the air inspired by the subject CO₂ free (fig. 2, G).
7. Temperature of the patient: Subtracting from the B.M.R. 7 per cent for each degree F. rise of body temperature above the normal.
   Subnormal body temperature is a different phenomenon and should not be corrected for.
8. Pulse rate: An increase during the test of more than a few counts denotes some cause of disturbance.
9. Respiration rate: Labored breathing or excessive ventilation indicates either a poorly conditioned apparatus, or sometimes an unrelaxed or uneasy patient, who, as a rule, can easily be induced to do better without interrupting the test.
11. Type of apparatus used.
12. Normal standards: The standards upon which the rate is reported should always be mentioned, especially for children. Occasionally it may be very helpful to the clinician to have rates calculated on the basis of two or more applicable normal standards.

The above condensed summary might well be the basis of a mutual agreement among the following parties concerned in the elaboration and the clinical application of a metabolism report:

**First:** The clinical pathologist, or anyone acting as a medical consultant or expert.
Second: The laboratory director whose duty is to systematically check and endorse the work of technicians under his supervision.

Third: Any physician who may have to assume the duty of approving a report when this responsibility is not shouldered by at least one of the other parties here mentioned.

Fourth: The technician, who should clearly understand his duties and what should be included in a metabolism report to be acceptable for final inspection and approval.

SUMMARY

1. A plea is offered to the Society of Clinical Pathologists to extend its constructive influence for the maintenance of high standards in metabolimetry.

2. Valuable information can be obtained from a comprehensive spirogram in addition to the rate of oxygen consumption obtained from an accurately located O₂ line.

3. Possible errors due to alterations in the subject’s lung expansion during a metabolism test.

4. Deep expiration points are of particular value in locating the O₂ line. Methods of obtaining them at will and at any desired moment, with or without manual compression over the costal margins, are described.

5. Technical objections to relying on results obtained from “first” metabolism tests are given. A subject may usually be considered “trained” after having had one properly conducted test. Clinical versus physiological normal standards. We place chief reliance on physiological standards.

6. Condensed summary of essentials for the final approval of a metabolism report for the use, in particular, of the clinical pathologist, laboratory director, and physician.

REFERENCES

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