Determination of Nutritional Needs

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Summary

Optimal nutrition is indispensable for optimal health. This consideration subsumes the elaborated studies aimed at defining optimal nutrition in terms of amounts of nutrients to be consumed per unit time. In spite of many approaches, significant uncertainties remain.

Historically, the first nutritive norms were yielded by epidemiological studies. The limitations of the epidemiological approach (which has nonetheless produced a wealth of fundamental knowledge) consist of its lack of applicability to the individual and of the uncertainties inherent in determining food consumption in free-living populations.

Derivation of nutritional needs from measurement of obligatory losses has been undermined by the many criticisms, both theoretical and practical, leveled at balance techniques, and by our ignorance of the mechanism that regulates the efficient utilization of biological fuel.

Recently, combinations of anthropometric criteria and biochemical measurements have been used successfully to gauge the effects of hyperalimentation in malnourished patients. These methods nevertheless do not resolve the theoretical uncertainties.

An unresolved philosophical point is the degree of precision required in determining nutritional needs. It appears that adequate criteria exist for the practical purposes of refeeding a depleted patient; but for the more abstract task of understanding the theoretical basis of nutrition, current methods and criteria appear inadequate.

Optimal nutrition is a *sine qua non* for optimal health. This truism is born of the recognition that deficient, excessive, or otherwise inappropriate food intake is related etiologically to disease and is confirmed by the elimination of significant diseases by appropriate dietary manipulations.

Optimal nutrition *per se* is an abstract concept. It can be defined for a population and for an individual as the cluster of nutritional coordinates that is associated with minimal disease. It follows that the first approach to a practical definition of optimal nutrition, a definition expressed in terms of amounts of nutrients to be consumed per unit time, can only be epidemiological. In the algebraic sense, it requires the definition of linear transformations from the set of intakes of a given population into the set of diseases prevalent in the same. Historically, this approach was indeed the first to yield nutritional standards. Voit and Atwater produced them by observing the food eaten by groups or by populations considered to be healthy. This same approach continues to be productive today, as is shown clearly by a prior symposium (1).

Like most algebraic approaches, epidemiology makes a minimum of assumptions and is therefore likely to contain a minimum of hidden flaws. Its major limitation consists of its lack of applicability to the individual. Intakes less than the recommended norms do not imply a deficient dietary supply for a given individual but indicate only a probability of deficiency. The same considerations apply to intakes greater than the recommended levels. Another limitation of the epidemiological approach is that it yields recommendations applicable to healthy populations alone. Determination of nutritional needs for nonhealthy populations or individuals are not derived directly from the epidemiological data.

The other approach to the practical definition of optimal nutrition is based on the ever-growing and ever-changing body of knowledge about physiological mechanisms. Expressed in an oversimplified manner, the physiological approach aims at deriving, from the knowledge of a given process, the particular intake that will optimize the process *per se*. For example, from the knowledge of obligatory nitrogen losses in a given individual, the minimum nitrogen intake that will maintain equilibrium is estimated.

The physiological approach lends itself well to the study of the individual, both in health and in disease. It rests on numerous assumptions that may be proven inadequate from time to time and thus may force periodic revisions of its conclusions. The physiological approach needs prudent integration with the epidemiological data.

The vast field of determining specific requirements for all or most nutrients is clearly outside the scope of this paper. I shall therefore limit my discussion to the requirements for energy and protein, since these constitute the most relevant and possibly controversial area. For the sake of simplicity, I shall also omit any consideration relative to growth or pregnancy.

It appears reasonable to assume that optimal nutrition will maintain optimal biomass and that requirements might be assessed in terms of the effects that a given intake has on a definite body compartment. Methods for assessing optimal nutrition will therefore be reduced to methods for determining body spaces.

Physical Examination

Invaluable information about the consequences of improper nutrition can be obtained with the traditional tech-
Anthropometric Methods

Nutritional anthropometry was stimulated by the intuitive and, in part, naive assumption that severe changes in biomass can be detected by measuring body sizes.

The anthropometric assessment of nutritional status was developed primarily for and found its best application in the detection of protein-calorie malnutrition through cross-sectional surveys of populations (81). Four measurements are essential: weight, height, midarm circumference, and triceps skinfold. In addition, head and chest circumference might be added.

The value of body weight/height determinations used in discriminating between various stages of protein-calorie malnutrition has been pointed out by Yarbrough et al. (88), who have noted that a weight change of as little as 1 kg in children of the same height can differentiate between well-fed children and children with mild disease or between moderate and severe disease, as defined by other clinical criteria.

Upperarm circumference, triceps skinfold, and derivatives of these measurements have been used extensively for the nutritional assessment of muscle and fat reserves (61, 71, 88). Although arm circumference and triceps skinfold may be useful as a rough measurement of muscle and fat, they are not as satisfactory as the cross-sectional arm muscle area, which is derived from arm circumference and triceps skinfold data that assume that the upperarm is cylindrical and neglect both the presence of bone and the variable skinfold compressibility. The linearity between muscle area thus calculated and body weight has been shown recently by Martorell et al. (71).

Recent studies based on the 4 measurements discussed above suggest that different patterns might relate to not only the severity of protein-calorie malnutrition but also its acuteness or chronicity and its type, predominantly in terms of calorie or protein stores (14, 47, 48).

Anthropometric measurements, which are simple and inexpensive, have been used primarily in children in whom the effects of malnutrition result in retardation or even cessation of growth. More recently, Bistrian et al. (9–11) and Blackburn et al. (13) have used effectively anthropometric measurements for assessing protein stores and the prevalence of malnutrition in adult patients.

In obtaining anthropometric measurements, careful standardization of techniques is of the utmost importance to ensure comparability of data. Conclusions are drawn by comparison against reference data (11, 18, 44, 71).

A number of surveys used as primary standards were obtained from developing countries or were designed to place primary emphasis on the low-income segment of a population (11, 18, 44, 71). Recent data have indicated that measurements of preschool children from affluent Ethiopian or Malayan families were significantly different from those of Ethiopians or Malayans at large (81), while Martorell et al. (71) have noted differences between Puerto Rican and American children. Therefore, prudence must be exercised in the selection of appropriate standards.

Methods Based on Intakes and Outputs

The rationale for using dietary data in assessing nutritional requirements rests on the sound knowledge that the body is subject to obligatory losses and that such losses must be matched by an appropriate intake if health is to be maintained. It also rests with lesser certainty on the assumption that a regulatory mechanism exists that matches spontaneous intake of food with needs. Therefore, needs can be estimated either from spontaneous intakes of healthy individuals or from their obligatory losses.

Two elements are necessary to validate the dietary methods. First, one must stipulate that the obligatory losses can be measured precisely under a wide variety of circumstances. Moreover, one must have available sound methods for measuring spontaneous consumption of food by free-living populations. As we shall discuss below, neither obligatory losses nor spontaneous consumption of food is known with a high degree of precision.

Estimation of Losses

Energy Losses. The subject of energy expenditures has been discussed extensively elsewhere in this symposium (89). In principle, energy expenditures depend on 4 variables interrelated in a most complex way (41): (a) basal metabolic expenditures as an expression of body size and composition; (b) physical activity, (c) age, and (d) climate and other ecological factors.

Basal metabolic expenditures are measurable. The age of the subject is often obtainable without difficulty.

Among individuals of the same sex, body size, and age, the amount of physical activity is thought to be one of the most important factors in determining variations in metabolic and mechanical energy expenditures. Yet, it is quite difficult to measure physical activity accurately. Various approximations have been evolved by nutritionists and, more recently, by cardiologists to assess energy expenditures associated with various types of activity. Thus one is confronted with the problem of fitting imprecise data into the concepts of thermodynamics, a most precise science.

In assessing energy needs from expenditures, one has been led, in honor of the 1st law of thermodynamics, to equate needs with expenditures represented by useful biological and biomechanical work. Little attention has been directed to the biological equivalent of the 2nd law of thermodynamics that relates energy input with work output. It has been observed that many individuals maintain their body weight over long periods of time with very irregular patterns of physical activity or food consumption (52). Furthermore, estimates of the total energy content of foods consumed by individuals engaged in very similar activities

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[such as military cadets (33)] show rather large differences.

Moreover, it has been observed that individuals of nearly the same anthropometric characteristics, maintained on a uniform exercise regimen and overfed by the same amount of calories, gain weight at sharply different rates (84).

Finally, it has been repeatedly observed among hyperalimented patients (S. J. Dudrick, personal communication), that only approximately one-half gain weight, whereas one-quarter actually lose weight in spite of large, nutritionally complete intakes.

These considerations raise difficulty with the thought expressed by FAO/WHO* (41) that seems to equate energy requirements with expenditures for biomechanical work. Therefore, one is led to consider the possibility that biological fuel might be converted into biological work with variable efficiency and that this option might be very important in homeostasis. The biochemical machinery that would allow for such regulation is known (89). Aberations in regulation are also well described (30, 68, 79). This area undoubtedly requires much critical new data.

Protein Losses. A number of studies have reviewed in detail the protein requirements of man and the approaches used for their determination (59, 72, 74-76, 83, 87, 90, 91). Basically, protein requirements of adult subjects have been assessed by either the factorial method or the monitoring of nitrogen balance responses to graded intakes of dietary protein.

In using the factorial approach for estimating protein requirements, the obligatory losses of nitrogen through urine and feces are measured and added to the losses through skin, hair, and other routes, losses that are usually estimated. The aim of this method is to determine the total nitrogen lost from the body if the subject receives a protein-free although otherwise adequate diet. This loss, which is measured after a period of stabilization during which the urinary nitrogen tends to reach constant values, is thought to represent the obligatory loss that is accepted as the minimum nitrogen output consistent with a healthy status. The minimum dietary protein requirement is then computed by amount of high-quality protein necessary to balance the endogenous loss. Corrections have then to be introduced to account for the variable nutritive quality of different food protein sources. FAO/WHO has estimated that obligatory nitrogen losses of adult men on a protein-free diet amount to an average 54 mg per kg body weight per day.

Direct evidence on nitrogen requirements can be obtained from measurements of the lowest protein intake at which nitrogen equilibrium can be achieved in adults. FAO/WHO has accepted, as the average nitrogen intake required to maintain balance (allowing 5 mg per kg body weight per day for miscellaneous and cutaneous losses), 77 mg per kg body weight per day if the nitrogen is derived from food such as milk, eggs, casein, or animal protein (41); this value is an average based on the observations of 75 subjects of both sexes.

Some fundamental objections can be leveled at either technique. It has been assumed, without sufficient critical evaluation, that the efficiency of dietary utilization is constant for protein intakes at or below the minimum maintenance requirements of adult humans. This assumption is crucial to the factorial method. Recent data by a number of well-established laboratories have shown that adaptive changes occur in amino acid and protein metabolism in response to changes in protein intake and therefore cast serious doubt on the assumption that the efficiency of dietary protein is independent of nitrogen at least over the submaintenance range of intakes (16, 58, 92).

The validity of the nitrogen balance technique is at present controversial (24, 25, 28, 40, 42, 53, 60, 86). The criticisms have been based on 2 sets of considerations. The 1st set has to do with the length of the observations. The 2nd set involves conceptual difficulties dealing with the inherent inaccuracies of the method and with the possibilities of unmeasured losses. The data, which suggest unmeasured losses, rest on nitrogen balance experiments that have been conducted in adult animals fed moderate to high levels of dietary protein and that have shown that if only urinary and fecal output of nitrogen were considered, positive values would be obtained. The retention of nitrogen was not associated with a commensurate gain in body weight (16, 17, 24, 37, 39, 40, 62, 73). The discrepancy persisted although allowances were made for other measurable routes of nitrogen loss, such as intestinal loss (62). Furthermore, carcass analyses have failed to demonstrate increased body protein or nonprotein nitrogen in amounts predicted by the balance data (3, 29, 54, 60, 78). These data therefore are consistent with a loss of nitrogen through an unmeasured pathway (2, 4, 23, 34, 35, 56, 57, 65) or with unresolved problems with the technique per se (53).

The suggestion that N₀ might well be the unmeasured end product of protein metabolism can be summarized as follows.

1. The evidence that N₀ does not participate in the respiratory exchange is circumstantial at best (49, 50, 63, 69).
2. Both conventional and germ-free mice, studied in a closed system that could be flushed practically free from preexisting N₀ and in which atmospheric contamination was excluded with confidence, have shown evolution of N₀ (28).
3. A recent reevaluation by a number of respiratory physiologists (19-21, 31, 43, 55, 66, 77, 85) of the Lavoisier-Haldane postulate of equality between inspired and expired nitrogen has revealed small excesses of expiratory N₀. The quantities involved are small enough to be negligible with the methods commonly used for gas analysis. Nevertheless, at least in the most precise of these studies, they are certainly not due to technical artifacts (55, 77) and are quite congruent with the discrepancy observed between nitrogen balance data and nitrogen retention measured by carcass analysis or ⁴⁰K data.
4. Measurements of pN₀ from both venous and arterial sides of the heart have shown, in certain circumstances, higher values for the venous side, which suggest excretion of N₀ by the lungs (Refs. 6, 26, and 35; M. Nesarajhan and L. E. Fahrni, personal communication).
5. Fertilized chicken eggs incubated until 3 days prior to hatching have shown a loss of 10 to 15% of their Kjeldahl nitrogen (27). When such eggs were studied in closed sys-
tems, evolution of $N_2$ in amounts predicted by the loss of Kjeldahl nitrogen was observed. When nonfertilized eggs were used as a control, these changes were not observed.

6. A patient with exceptionally positive nitrogen balance (observed while he was losing weight on a 3000-cal diet and a 20-g nitrogen intake) and with exceptionally high, mixed venous-arterial $pN_2$ difference has been described recently (26). The suggestion that this patient's morbidity was due to overproduction of $N_2$ was provocative.

Finally, questions have been raised recently concerning the interrelationship between nitrogen and calorie intake (12, 36, 38, 46, 64). Our concepts in this area are rapidly changing. The unstable nature of our knowledge has been pointed out in a recent paper by Garza et al. (45). These investigators have tested the recommendations of FAO/WHO with regard to healthy adults studied for 59 to 77 days while receiving 0.56 g egg protein per kg body weight per day. The authors noted that, at this level of nitrogen intake, nitrogen equilibrium could be maintained only by administration of excess calories (as much as 20% of the recommended values), something that cannot be enacted as a general health measure in view of the prevalence of obesity.

It is in general fortunate that various surgical groups, confronted with the necessity of replenishing critically depleted patients, have empirically administered an amount about 4 times that recommended by FAO/WHO. Our theoretical uncertainties unfortunately persist.

**Estimation of Intakes.** Food intakes can be assessed with a fair degree of accuracy in hospitalized or otherwise restricted patients. In free-living individuals, the determination of intakes has been a continuous source of perplexity, which stems from the necessity of relying on the patient's own recollection of quantities and frequency of food intakes. A number of techniques have been devised: (a) the 7-day food diary in which the patient, after being educated about sizes of servings through the use of food models, is requested to record for 7 consecutive days everything that he or she eats; (b) the 3-day food diary, an abbreviated version of the 7-day food diary, that includes either a Saturday or a Sunday, which allows for the reasonable assumption that food consumption during the weekend is different from that during the week; (c) the 24-hr recall in which the patient, properly instructed by a dietitian, is requested to recall food consumption during the previous 24 hr; (d) the dietary interview method (15); (e) the food frequency method.

Various comparisons between indirect methods, such as the ones discussed above, and observed food intakes have been published (Refs. 7, 8, 22, 67, 70, and 80; M. Aragon and G. Costa, unpublished observations). In general, there is a loss of information as one goes from the cumbersome 7-day diary to the simple and inexpensive 24-hr recall (70), although the loss is modest. Pleas for validating dietary methods continue to appear in the literature, reflecting a real need (5). The indirect methods discussed are probably adequate in comparing populations; they probably underestimate high intakes and overestimate low intakes. Selection of the most appropriate method depends on the particular problem addressed.

In summary, it would appear that estimation of spontaneous consumption of food is uncertain, whereas estimation of expenditures contains a number of significant conceptual flaws.

**Biochemical Methods**

A number of biochemical markers have been found in man to be intake dependent and have therefore been used to define nutritional status. Of these, one of the most significant is serum albumin. The relationship of serum albumin levels to nutritional status has been discussed elsewhere in this symposium (25). To apply serum albumin levels to the nutritional assessment of cancer patients, one must remember the possibility that serum albumin synthesis might be depressed as a manifestation of systemic effects of cancer, in addition to the depression due to poor nutrition alone.

Other parameters are hemoglobin, transferrin, fasting amino acid profile, creatinine/height ratio, lymphocyte count, and skin immunoreactivity (9–11, 13). Rather than being used individually, biochemical markers are used as aggregates to define pragmatically nutritional status. Combinations of biochemical methods, especially if associated with anthropometric parameters (9–11, 13), probably represent the most effective practical method for assessing trends and effects of realimentation. Their values in defining requirements directly remain unproven.

**Conclusions and Projected Research**

Our discussion appears to point out the deficiencies of our methods for deriving nutritional needs rather than their usefulness. This is meant as a constructive critique in keeping with the thoughts expressed by other investigators. Thus, a group of eminent British nutritionists (32) have stated recently, "We believe that the energy requirement of man and his balance of intake and expenditure are not known. Paradoxically, we conclude this from results of the increasingly sophisticated studies of food intake and energy expenditures." In the same vein, Hegsted (51) in discussing nutritional needs of adolescents stated, "practically nothing is known about the requirements for calories, fats, protein, or amino acids in adolescents."

Our discussion has pointed out the limitations of anthropometric methods and, especially, the theoretical flaws that beset our method for determining calorie and nitrogen intakes and losses. Yet, adequate solutions to the problems of determining nutritional needs are at hand although it appears that they require the following components.

1. Precise measurement of intakes is needed. This is possible in a reasonable group of healthy individuals and is increasingly possible in a relatively large number of patients undergoing hyperalimentation.

2. Careful measurement of body compartments and, primarily, of protein stores is required. Available technology is expensive and limited to a few centers. Yet, $^{4}$K counting can be refined and applied easily. It is a noninvasive technique that can be applied even to critically ill patients. Neutron activation analysis holds great promise and could be developed as soon as possible.

3. Adequate calorimeters that can assess precisely and...
with a minimum of assumption the total flux of energy through the body surface are needed.

4. Tracer techniques that will allow independent validation of the completeness of collections and will allow detection of unmeasured losses, if they exist, are also needed.

An unresolved philosophical point, which deserves much consideration, is how well we need to define nutrient needs and what use we need to make of precise data.

It appears that, for the practical purposes of refeeding undernourished patients, we have adequate guidelines (9-11, 13). We administer nutrients until the criteria by which we define undernutrition no longer apply. It is fair to mention that this same philosophy, when adopted by the healthy, free-living population of industrialized countries, has resulted in a rise in the frequency of obesity, heart disease, diabetes, and possibly cancer. It is therefore important that, while caring for undernourished patients, we address ourselves to the more abstract task of understanding the theoretical basis of nutrition. For this task, current methods and criteria appear to this reviewer to be fundamentally inadequate.

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