A NEW APPROACH TO THE DEFINITION AND EVALUATION OF NUTRITION STATUS AND ITS APPLICATION TO ADULT MALE LABOURERS*

MADELEINE L. NESER, *National Nutrition Research Institute, Council for Scientific and Industrial Research, Pretoria*

INADEQUACY OF PRESENT STANDARDS FOR INTERNATIONAL USE

A description of the nutritional status of a population group would be incomplete without reference to the adequacy or otherwise of the past food intake as judged by its effect on physical growth and development. The current food intake of a population adapted to a suboptimal food intake might, for instance, be adequate to maintain health because the population's requirements are low as a result of growth retardation, but it would be misleading to assign such a population to the same nutritional category as another which is being maintained in a state of optimal physical development.

Undernutrition as a national problem has largely disappeared from the nations of the West, but on the continents of Africa and South America, for instance, and in the densely populated countries of the East, there are hundreds of millions who have been chronically undernourished all their lives and whose true physical potential is unknown because they have never been observed under nutritionally favourable conditions. It is from this vast pool of nutritionally handicapped peoples that the greater proportion of the world's manual labour force is drawn, and it would be unrealistic at the present time to attempt to define for international use a set of criteria which will have practical relevance only in the countries of the West. It is clear, therefore, that international standards for evaluating the nutritional status of labourers or, for that matter, any other population group, cannot be satisfactorily defined in terms of a single well-nourished 'reference' individual, as has been done by the FAO in the case of calorie requirements.[1] A more flexible approach must be devised which will take differences in growth attainment into account and will have a direct application in any nutritional or racial context anywhere in the world.

The approach suggested here is simple and adaptable and will be applicable to adult male labourers of any class or type and characterized by any level of physical development. The present discussion will be limited to labourers, and the details of the approach as here presented have been worked out with this specific population group in mind, but the method to be described can easily be modified for application to any adult population group of either sex and may also prove applicable to children.

AIM AND SOMATOMETRIC BASIS OF THE NEW APPROACH

The main object in devising this approach was to simplify as far as possible the task of evaluating nutritional status and to create a system of recording results which would make the nutritional grading of the group being investigated apparent at a glance.

The first task, therefore, was to select the smallest, most easily obtainable set of body measurements that would make possible an effective evaluation of the growth attainment, the muscular development and the fat reserves of the group being investigated.

Height was selected as the most important single parameter for assessing growth attainment, for height is invariably reduced when there is growth failure and plays an important part in determining nutrient requirements. Since the true growth potentials of the various races of man are not known, it is suggested that the average or median height of a group be graded according to its position on a scale which includes the whole range that can be expected to occur in the population group under consideration anywhere in the world.

A simple and practical means had next to be decided upon of assessing muscularity, which in conjunction with height would be largely responsible for deciding the caloric requirements, and adiposity, which would influence the caloric requirement through its effect on body-weight. The diagrams in Fig. 1 are cross-sections through the middle of the upper arm, the thigh and the calf, and it can be seen that according to *Gray's Anatomy*[2] only the upper arm has a subcutaneous fat layer of more or less uniform thickness.

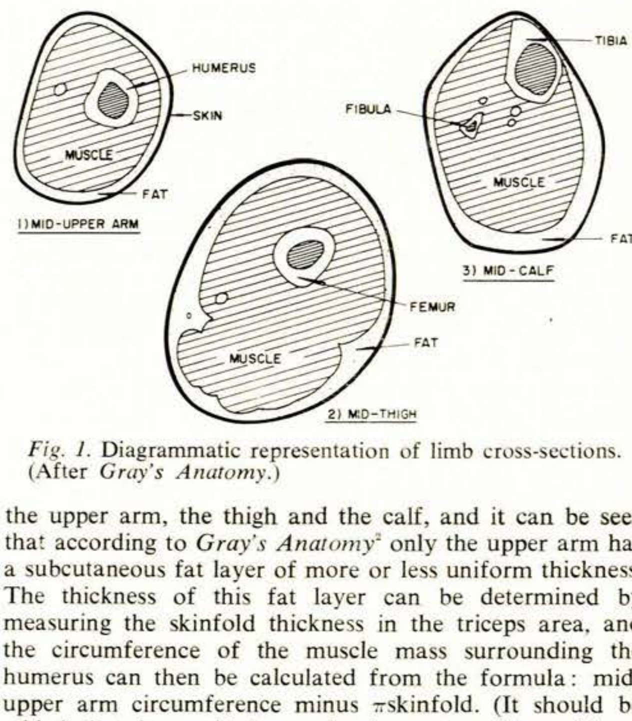

Fig. 1. Diagrammatic representation of limb cross-sections. (After *Gray's Anatomy*.)

The thickness of this fat layer can be determined by measuring the skinfold thickness in the triceps area, and the circumference of the muscle mass surrounding the humerus can then be calculated from the formula: mid-upper arm circumference minus πskinfold. (It should be added that it would be a simple matter, if considered desirable in the interests of accuracy, to measure both the anterior and the posterior upper-arm skinfolds and base the calculation on the 2 measurements instead of on the triceps skinfold only.) This formula assumes that the arm is circular in cross-section, which is not actually the case, but the discrepancy can safely be ignored, as the error arising from it will be negligible.

It is a reasonable assumption that arm-muscle circumference expressed as a percentage of height, provided that

*A preliminary communication prepared by request for a panel discussion on 'The Definition of International Standards for the Evaluation of Nutritional Status' at the Seventh International Congress on Nutrition, Hamburg, August 1966.

it is calculated from standard measurements, will constitute a satisfactory index of muscularity for routine use and will, if used in conjunction with height, upper-arm skinfold and calf/arm ratio, be more reliable than weight and have a wider application as a basis for defining and estimating nutrient requirements, in particular protein and calorie requirements.

The presence of the humerus within the upper-arm muscle mass will not affect the usefulness of this index, which need not be linearly related to muscle mass to serve in the capacity defined, and is in fact more specifically an index of lean body mass than of muscularity. By expressing arm-muscle circumference as a percentage of height, the effect of differences in the diameter of the humerus due to differences in growth attainment is for practical purposes ruled out. The contribution made by the humerus will become relatively greater as the index becomes smaller, and this fact will have to be taken into account if it is desired to calculate the actual proportion of muscle in the cross-section of the arm at different levels of the index, but it is quite unnecessary to know this relationship in order to use the index as a basis for grading muscular development and defining nutrient requirements.

NOMOGRAM PROPOSED AS STANDARD METHOD FOR INTERNATIONAL USE

Fig. 2 shows a tentative design for a nomogram, which it is proposed should constitute the future basis for nutrition status evaluation in all population groups. This nomogram was specifically designed for application to labourers, but can easily be modified for application to other population groups with different physical characteristics and different

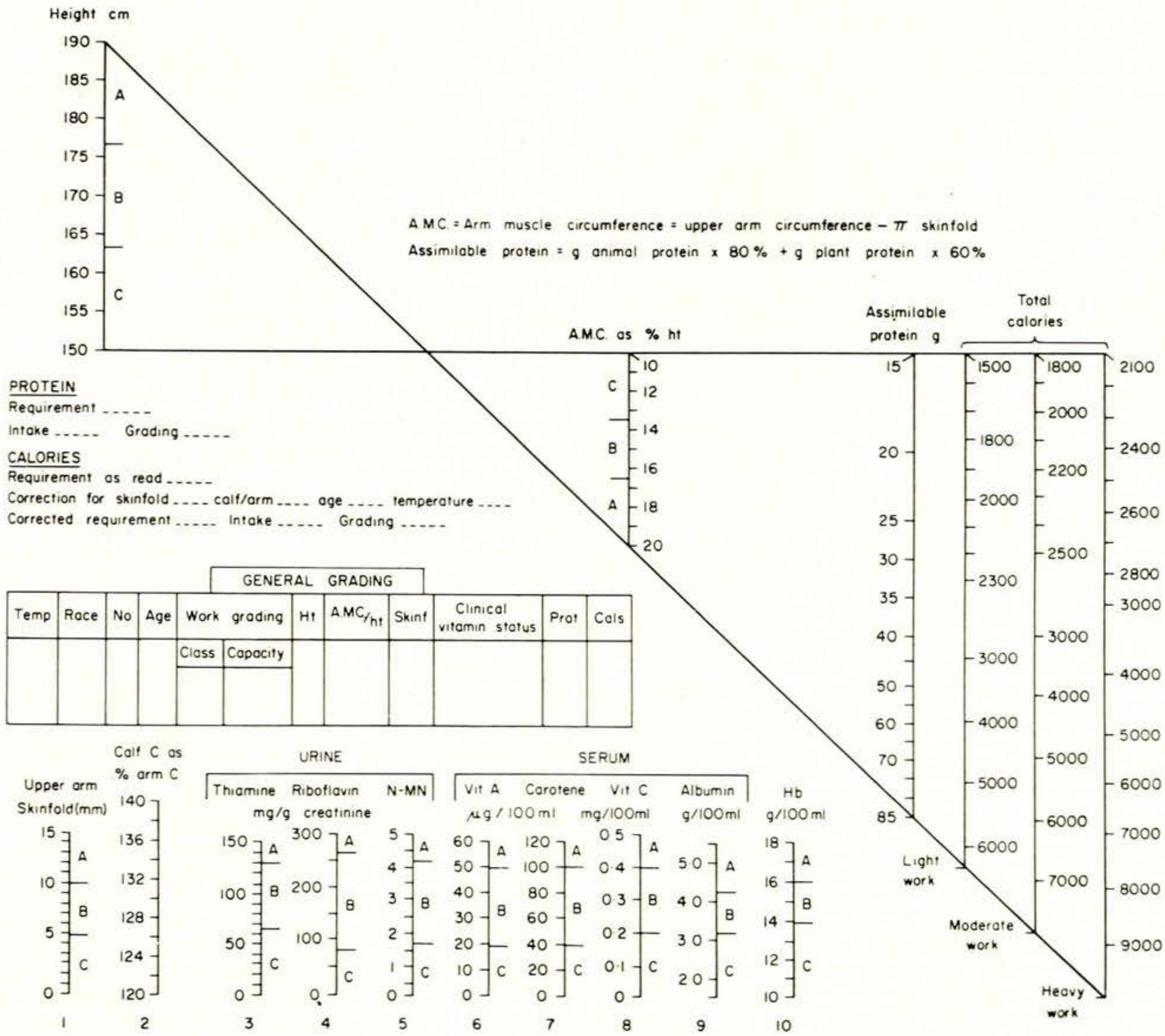

Fig. 2. Proposed nomogram for grading of nutritional status: maintenance requirements of adult male labourers with upper-arm skinfold of 6 mm. and calf/arm percentage of 126. Median age 25 years. Mean noon temperature 22°C. (Figures provisional and arbitrary.)

grades of activity. The rather unusual arrangement of scales has been chosen for a number of reasons, one of them being its immediate visual impact.

On the upper left is a linear scale marked in centimetres for recording the average or median height of the group being investigated. The scale reads from 150 to 190 cm. (4 ft. 11 in.—6 ft. 3 in.) and thus caters for what might seem to be unnecessary extremes, but it is probable that even this wide range is too limited to allow for all the variation in height that can be expected to occur in the human race. The negrilloes or pygmies are usually stated to be well under 5 ft. in height, while the Watutsi of Africa are so tall that it would be surprising if there were not groups among them whose average height exceeded 6 ft. 3 in.

On its right-hand side the height scale has been divided into three segments marked A, B and C to illustrate the procedure that is recommended for the grading of physical and nutritional status. (The choice of 3 sub-divisions is quite arbitrary and should not be interpreted as a final recommendation.) The height grading of a population group according to this system will, of course, have no nutritional significance except as it compares with other findings for the same racial group, and it would be helpful to the investigator if the height scale of the final standardized nomogram were marked with a few key findings for different races which would assist him in the interpretation of his results.

The remaining scales in the nomogram are inverted, i.e. they read from above downwards. The first is a linear scale representing the important muscularity index, namely arm-muscle circumference as a percentage of height. Allowance has been made for a variation of 10 - 20%, which makes ample provision for every possible degree of muscular development than can be expected to occur in a working population. In any population group the mean or median value of this index will be related to nutritional status, though not necessarily determined by it alone, for provided that the diet contains the needed protein and calories, the muscle circumference of the arm, and hence the value of the index, can be increased through exercise without increasing the nutrient intake. Such an increase would occur at the expense of an associated decrease in fat storage.

Provided that their food intake is not too restricted, it is to be expected that the arm-muscle development of labourers will be greater relative to their height than that of white-collar workers. If the index differs in groups of persons similarly occupied, however, a nutritional cause should obviously be suspected. In the surveys done by our Institute on Pretoria school children of the 4 main racial groups, we found a definite difference between the relatively affluent White children and the children from the indigent non-White racial groups.* The median value based on a relaxed upper-arm measurement was 14·5% for White boys of 15 years, while the corresponding values for Bantu, Coloured and Indian boys were respectively 13·1, 13·3 and 13·2%. The maximum value for the White boys of 15 (16·6%) was substantially higher than the corresponding values for the boys of the other races, and this difference was apparent in the minimum values also, which ranged from 11·3% in the Bantu boys to 12·3% in the White boys. As far as could be determined from the limited data at present available,[3] the average index for South African males of 25 years (presumably white-collar workers) on the basis of a relaxed upper-arm measurement is also in the vicinity of 14·5%, and the range given in the nomogram was chosen on the assumption that our findings for 15-year-old boys were valid for adults also. Both the range of this scale, however, and its nutritional gradings, can only be decided finally after further investigation. It should be added that it would be useful for the investigator to indicate on this scale also, a few selected findings which would give perspective to his own results.

*Data to be published in the near future.

The nomogram in Fig. 2 is stated to give the maintenance requirements of adult male labourers (i.e. the intakes which will maintain them in their existing physical condition at the required level of activity) with an upper-arm skinfold of 6 mm. and a calf/arm percentage of 126. A skinfold thickness of 6 mm. was decided on because this was felt to be a realistic choice which would minimize the need for applying corrections, since the bulk of the world's labour force is likely to be drawn from populations characterized by low fat reserves. The triceps skinfold of the 33 15-year-old White boys surveyed by our Institute varied from 4·4 to 21·7 mm., two-fifths of the values being greater than 10 mm. and the median value just under 9 mm., this latter figure being slightly lower than the median value of 9·5 mm. recently obtained by us for a group of 50 young White paratroopers (unpublished data). The values we obtained for the 70 non-White boys of 15 years were much lower than those for the White boys, all but one being below 10 mm. and the medians ranging from 6·2 to 6·6 mm.

The reference to calf/arm percentage in the nomogram brings us to the fourth and last measurement that is recommended for the present nomogram, namely mid-calf circumference which is to be preferred to mid-thigh circumference, because of the greater accuracy with which it can be measured. Calf circumference expressed as a percentage of upper-arm circumference proved to be greater in the non-White than in the White boys of 15 years, presumably because the former do more walking. It was also found, as would naturally follow, that weight could be more accurately predicted from a combination of height, arm circumference and calf circumference than from height and arm circumference alone. It was clear, therefore, that it would be inadvisable to ignore the influence of calf circumference on protein and calorie requirements, especially since the relative development of arm and leg muscles would be bound to vary in different types of workers. The irregularity of the subcutaneous fat layer in the calf region, as attested to by the drawing reproduced in Fig. 1, would preclude the calculation of calf-muscle circumference as an additional measure of muscularity, but the protein and calorie scales could be standardized for a specified percentage value of calf/arm circumference and corrections applied where necessary. This is the procedure that has been adopted for the present. The figure of 126 specified in Fig. 2 is our own figure for White boys of 15 years, and was chosen for the sole reason that it is likely to be applicable to the Western male on the basis of whose recommended allowances the figures on the protein and calorie scales of the present nomogram had to be estimated.

The four non-linear scales on the right-hand side of the nomogram cover the whole range of protein and calorie requirements needed for the maintenance of 3 different grades of workers characterized by any level of physical development within the limits defined by the first 2 scales of the nomogram. The points marked on the 4 nutrient scales were estimated from recommended allowances for persons of stated body-weight by calculating the probable body-weights associated with various combinations of height and muscularity and applying correction factors based on weight, body build and, in the case of calories, work grading. The correction factors were of necessity somewhat arbitrary, and the results had to be further modified to bring them in line with the implications inherent in the present arrangements of the scales. It will nevertheless be interesting to compare these make-shift estimates, which are the best that can be offered at the present time, with the final estimates arrived at on an experimental basis.

EXPERIMENTAL ASPECTS OF STANDARDIZATION AND CALIBRATION OF NOMOGRAM

Need for a Basic Survey

The experimental calibration of this nomogram can probably be done by means of a single survey on a few—perhaps several — hundred subjects, provided that they show enough variation in body build and work grading to supply the basic information that will be needed. It will obviously be necessary to choose subjects who are stabilized in respect of diet and occupation, and who are neither gaining nor losing weight, if the dietary findings are to be valid as a measure of the maintenance requirements. The first step will be to construct a mathematical model describing the expected interrelationships between the variables concerned, including where possible those whose influence has been represented on the present nomogram in terms of correction factors. The extensive data already available as a result of calorimetry studies might prove to be of some assistance in this task.

We have found it possible with the resources available at our Institute, to do far more elaborate surveys than will be necessary for the calibration of this nomogram on sample sizes ranging from 500 to 900, and a project such as that contemplated should present no serious obstacle. It will be necessary to measure only the height, upper-arm circumference, calf circumference and triceps skinfold of the subjects according to agreed and standard methods and to determine their total calorie and differential protein (i.e. animal and plant protein) intake. No provision has been made on the nomogram for any other nutrients, as it is felt that vitamin and mineral status can be more easily assessed by clinical examination and biochemical methods, than by doing the exacting dietary surveys that are necessary if the intake of these nutrients is to be determined with any accuracy. Even clinical examination alone might contribute all the additional information that was strictly necessary if we were to adopt the approach of grading vitamin status, for instance, according to the percentage of subjects showing definite evidence of a specific deficiency, instead of concerning ourselves with non-specific signs and symptoms that we do not know how to interpret. It should be added, however, that it would be a simple matter to introduce additional scales on the nomogram for other nutrients if this were considered desirable.

Work Grading

The most difficult aspect of the standardization and application of this nomogram will be the question of making a consistent and objective distinction between light, moderate and heavy work. It is obvious for various reasons that the type of work engaged in will not by itself constitute an adequate guide. A poorly-developed and poorly-nourished individual employed to do heavy work may, for instance, spend more time resting than working because he is incapable of the sustained effort that comes easily to the physically powerful and well-nourished individual. On the other hand, if we base our classification on the actual amount of work done—number of bricks laid, for instance, or loads handled—we shall find ourselves with no workers in the 'heavy' class except those of outstanding physical capacity. In addition, the work grading must take into account the after-work activities of the subjects studied, which will obviously play an important part in deciding their maintenance requirements. For the purpose of this particular nomogram, therefore, with its provision for 3 grades of workers at every level of physical development, a method will have to be devised which distinguishes between workers of any type of body build whose work capacity is heavily taxed when assessed on a 24-hour basis and those whose powers, whatever they may be, are only moderately or lightly taxed in terms of their total activity during 24 hours.

This approach assumes a reasonably consistent relationship between body build as analysed by the method recommended and work capacity as reflected by maximal oxygen consumption, and there can be little doubt that in labourers, at any rate—that is, persons whose musculature is trained and efficient—*potential* work capacity (i.e. maximal capacity when calorie intake is not a limiting factor) will for practical purposes be a function of body build as defined by the nomogram. The extent to which this capacity can be mobilized in regular employment—in other words the *effective* work capacity—will be determined by the dietary intake, which, if inadequate to maintain the worker in his existing physical condition at the required level of activity, will inevitably result in tissue retrenchment. The habitual food intake of a worker relative to the energy demands of his life will thus be a decisive factor in determining his body build to the extent that this is a product of immediate environmental factors, and working populations which are poorly developed physically without being obviously unhealthy can be assumed to be in this condition as a result of long-continued undernutrition. Such populations, which are probably the rule rather than the exception in countries where the population density is high and the food resources limited, seem to be successfully adapted to a low nutrient intake and evidently maintain their effective work capacity at a level that will meet the demands of a working life by limiting their physical development so as to decrease their energy requirements.

If the diet is not so deficient as to preclude successful adaptation, it appears that a balance can be struck which is compatible with reasonable health and vigour and the maintenance of a constant body-weight. The effective work capacity of such groups will naturally not be so high as that of better-developed groups with a higher nutrient intake, but would be even lower if they were to increase their muscle mass and thereby increase the amount of energy needed to maintain their work output. It is to be expected, however, that an improvement in the diet of labourers adapted to a low nutrient intake will produce an increase in muscle mass commensurate with the increase in nutrient intake, and that this increase, being accompanied by an energy intake sufficient to maintain it, will result in a corresponding increase in effective work capacity.

We can thus be reasonably sure that the average body build and hence the potential work capacity of labourers stabilized in respect of diet and activity, will represent a specific response to specific conditions, and further, that groups of labourers with the same average body build as defined by the recommended method will have the same potential capacity for work and the same energy requirement when that capacity is exercised to a comparable extent. The provisional assumption that this relationship is for practical purposes independent of race is felt to be justified, at any rate for the present. If the contrary were assumed, it would be necessary to think from the start in terms of separate nomograms for a large variety of racial and ethnic groups.

A possible solution to the problem of work grading will be to draw up an 'energy expenditure budget', applicable either to individuals or to groups, along the lines suggested by the FAO Committee on Calorie Requirements,[3] although not, as they suggest, on the basis of actual energy expenditure, for this would have the same effect as a grading based on amount of work done, namely to exclude from the heavy-labourer class all but those of outstanding physical development. A system will have to be drawn up which differentiates between light, moderate and heavy workers on such a basis that a worker's grading will be an evaluation of the extent to which his own individual work capacity is taxed during a period of 24 hours. The different degrees of exertion that need to be distinguished will have to be clearly defined in such a way that they can be recognized without the aid of special tests, and each will then have to be allocated an appropriate 'score' at so many points per hour. Much work has already been done on the work capacity of labourers as reflected by their maximal oxygen consumption,[4] and this work should be of great assistance in the task of distinguishing, defining and scoring different degrees of exertion. Sleep and other resting states will also have to be scored in proportion to the difference in energy expenditure between these and active states, and a worker's final grading would be based on his total score for 24 hours, the most suitable range for each work grading having been previously decided upon. The grading of groups could be done on a collective basis or by determining each individual's score for 24 hours and basing the grading of the group on the relevant mean or median value.

Nutrient Scales

The first of the 4 scales for nutrient requirements is marked 'assimilable protein', which offers a reasonably sound practical basis for defining protein requirements, at any rate in adults. The term 'reference protein' introduced by the FAO Committee on Protein Requirements[5] has been avoided, since the use of this term would imply a more detailed analysis of the dietary protein intake than is at present contemplated. The 'reference protein' concept is furthermore concerned only with the biological value of protein, and we need to think in terms of digestibility also. The suggestion has been made on the nomogram that animal and plant protein be considered respectively 80% and 60% assimilable, but these figures are not submitted as a final recommendation, nor are they meant to exclude the possibility of further sub-divisions which will take into account the differences, for instance, between high and low quality plant proteins. It can be seen that the protein scale is non-linear, the rate of progression increasing from above downwards. The figures on the scale, as previously indicated, are rough estimates based on the limited data at present available, and they cover a very wide range of intakes. It should be borne in mind, however, that the range of body-weights catered for by the nomogram is probably in the order of 20 - 160 kg. (43 - 350 lb.).

The 3 calorie scales also show very wide ranges which may seem quite unrealistic in the light of the figures so far reported, but most of the latter have been based on population samples which would fall into the middle regions of the present scales, and this nomogram is intended to make provision for every type of active group that might possibly be encountered anywhere in the world, from undernourished pygmies to such highly select groups as heavyweight boxers and wrestlers. It might be mentioned that the lowest figure on the calorie scales in Fig. 2 (1,500 cal.) is significantly higher than the figure of 1,350 cal. mentioned by McArthur[6] as the intake per head per day reported by Bailey[7] for an undernourished Javanese working population.

The arrangement of the scales on the present nomogram presupposes that, within the ranges chosen, muscular development exerts a greater influence on protein and calorie requirements than does height. In other words, the requirements recommended for the maintenance of the shortest, most muscular category are greater than those recommended for the tallest, thinnest category. This supposition is undoubtedly valid, for the first category will be characterized by a substantially greater body-weight than the second.

The scales as they stand also presuppose that a tall, thin group with the same calorie requirement for light work as a shorter, more muscular group would require greater energy increments for the performance of moderate and heavy work than would the other group. At the present stage no opinion can be vouchsafed about the validity or otherwise of this assumption. If it is valid, it will be because the muscular person, because of his greater efficiency (enhanced, perhaps, by more effective leverage), is more economical in his energy expenditure on additional work, though having a greater initial requirement for light work. If the assumption is not valid, which might easily be the case, the nomogram will have to be slightly modified, for instance by treating the first of the 3 calorie scales as a reference axis and reading all three at the same horizontal level.

It should be noted that the present arrangement of scales also implies a difference in the protein requirement of groups differing in body build but having the same calorie requirement at one or other of the work levels. The direction of this difference is in accordance with what would be expected on the basis of the contribution made by muscle mass to total body mass in the different types of body build, and it seems unlikely, therefore, that this third inherent property of the nomogram will constitute any serious drawback.

USE OF THE NOMOGRAM IN PRACTICE

To make full and correct use of the nomogram it will be necessary to measure height, upper-arm circumference, calf circumference and triceps skinfold and determine calorie and differential protein intake on a statistically representative sample of the population to be investigated.

The minimum sample size necessary for an acceptable degree of accuracy cannot at this stage be decided, but will probably lie between 20 and 40. The upper-arm muscle circumference of each individual must be calculated from the formula given on the nomogram chart and expressed as a percentage of height, and the calf circumference expressed as a percentage of the upper-arm circumference. The mean or median value must be determined for height, arm-muscle circumference as a percentage of height, calf/arm percentage, triceps skinfold, assimilable protein intake and calorie intake, and the work grading of the group determined by the specified standard method. (It should be mentioned that the rival merits of mean and median values have not yet been finally evaluated in the context of this particular approach, and this is the reason why they are everywhere given as alternatives.)

The mean (or median) height of the group is now marked on the height scale and the corresponding value for arm-muscle circumference as a percentage of height on the scale provided for that index. If the straight line joining these 2 points is now extended through the nutrient scales, the maintenance requirements (this term being used strictly in the sense previously defined) associated with a 6 mm. skinfold and a calf/arm percentage of 126 can be read off for this group on the protein scale and the relevant calorie scale.

A space is provided on the nomogram chart just below the height scale, for filling in the protein requirement of the group as given by the nomogram, the intake as determined experimentally and the grading as decided from the relationship between the first 2 values. The system recommended for grading protein and calorie intakes, is that the degree of variation above and below the recommended intake that can be regarded as defining the limits of an 'acceptable' grading be decided upon, and that all intakes above and below that range (the extent of which will be dependent on the natural variation and the expected experimental error) be graded as 'high' and 'low' respectively. No provision has been made in Fig. 2 for applying corrections to the protein requirement as given by the nomogram, and it is perhaps desirable that allowance should be made for differences in the calf/arm percentage, since the provisional calculations on which the present nomogram is based indicate that a difference of 10 units in that parameter can affect the body-weight, and hence probably the protein requirement, by as much as 8%.

Provision is made for the analysis of the calorie intake just below the section dealing with protein intake. Four corrections are here allowed for, the first being for skinfold thickness, which it is estimated will affect the maintenance requirement by only about 3 - 5% per 3 mm., although the corresponding effect on weight will possibly be as high as 10% in the shortest, most undernourished category. The second correction is for calf/arm percentage, and here the effect of a 10% difference on the maintenance requirement will apparently vary from about 3 to 8%. The extent to which the maintenance requirement is influenced by skinfold thickness and calf/arm percentage will depend on the body build, skinfold thickness being the more important factor in short and undernourished persons, and calf/arm percentage in tall and muscular persons. The problem arising out of these differences can perhaps best be solved by introducing an additional axis on the nomogram with a scale on either side on which can be read off the appropriate corrections for the various types of body build.

Allowance is also made for corrections in respect of age and environmental temperature, the reference here being to variations from the median age of 25 years and the mean noon temperature of 22°C specified in the legend to Fig. 2. These figures are purely arbitrary and should not be regarded as recommendations. It is problematical at the moment what will be the best approach to the age factor, since ageing will eventually affect not only the basal metabolic rate (and hence the basal caloric requirement) but also the muscular efficiency and the work capacity of the subjects concerned.[1] It is possible that the latter two effects are associated with corresponding changes in body build as analysed by the nomogram, and will create no special problem, and it is furthermore unlikely that labourers will be hampered in their later decades by such an obvious deterioration in muscular efficiency as is seen in sedentary workers.[8] However, this question will have to be gone into and an answer found which will allow appropriate recommendations to be made.

The influence of environmental temperature will also have to be gone into and a suitable approach decided upon. The FAO Committee on Calorie Requirements recommends the application of corrections based on the mean annual environmental temperature,[1] but this approach will hardly be suitable for the present purpose, which will be to evaluate the adequacy or otherwise of a given food intake at a given time of year. It is suggested that mean noon temperature or some suitable equivalent be used as a guide, and the provisional figure of 22°C (about 72°F) has been chosen in the belief that it will have a reasonably wide application. No mention is made on the nomogram chart of a correction for altitude, and this factor should possibly also be taken into account for standardization purposes.[9]

A fact that should be borne in mind is that none of the corrections allowed for will be of such an order as to make a very substantial difference to the recommended intake. The maximal error that can be caused by ignoring them will probably be quite small in comparison with the errors that can be caused by misclassifications in respect of work category and inaccuracies in the determination of dietary intake. This fact is not considered to be sufficient justification, however, for dispensing with the use of corrections.

ASSIGNATION OF PHYSICAL AND NUTRITIONAL GRADINGS

A scheme is given under the heading 'General grading' on the left-hand side of the chart, for noting down the essential information that must be given for any group that is studied and for summarizing the nutritional grading as determined. The first 4 spaces are for temperature rating, race, number of subjects studied and age rating. Under the heading of 'Work grading', provision is next made for recording the class of work (light, moderate or heavy) and for an efficiency grading determined on the basis of appropriate tests or simply (and preferably) by asking suitable questions. This latter grading has been included for the purpose of drawing attention to groups whose effective work capacity is low in relation to their body build as a result of an acute calorie deficiency. A low grading would not be given to undernourished groups effectively adapted to their low food intake. Next come spaces for recording the gradings for height, arm-muscle circumference as a percentage of height and triceps skinfold, as these are given by the relevant scales. (The scale for skinfold thickness is the one in the lower left-hand corner.) The clinical vitamin status grading allowed for in the following space is meant to be one based on the number of individuals suffering from frank deficiency. The last two spaces are reserved for recording the protein and calorie gradings as given by the recommended procedure.

Next to the triceps skinfold scale in the lower left-hand corner (on which scale could also be indicated some key findings which would aid in the interpretation of results) is a scale for recording the calf/arm percentage. No gradings are shown on this scale, as the index has no nutritional significance, but here again it is suggested that key values be given for certain types of workers as they become known.

The remaining scales (nos. 3 - 10) to the right of the calf/arm scale have been included for the convenience of those who have the facilities available for evaluating protein, vitamin and haemoglobin status by means of biochemical investigations. These scales contain no new information, but the information is so presented that the findings for any group can be recorded in a way that will make their nutritional implications apparent at a glance. The ranges indicated on the right-hand sides of the albumin and vitamin scales are those recommended by the United States Interdepartmental Committee on Nutrition for National Defense,[10] but with the extra-low 'deficient' category omitted. It should be added that much work is being done in our laboratories on the biochemical evaluation of nutritional status, and new standards are likely to be recommended from time to time as our work progresses. Work has already been published on the evaluation of nicotinic acid status in children and adults[11] and of protein[12,13] and riboflavin[14,15] status in children.

ALTERNATIVE METHOD OF APPLYING CORRECTIONS

In Fig. 3 is shown a slightly modified nomogram which illustrates an alternative method of applying corrections for skinfold thickness, calf/arm percentage or any other variable for which it is desired to make allowance. In this nomogram the axis for the height scale is marked on the right-hand side with a scale for skinfold thickness ranging from 3 to 12 mm. The line joining the lower end of this axis to the upper end of the muscularity axis and forming the upper boundary of the nutrient scales represents as before a group with a height rating of 150 cm. and a muscularity index of 10%, but with a triceps skinfold of only 3 instead of 6 mm. The figures at the top ends of the calorie scales are therefore slightly lower than those in Fig. 2. The figures at the lower ends of these scales are higher, however, than those in Fig. 2, because the line which joins the top of the height scale to the lower end of the

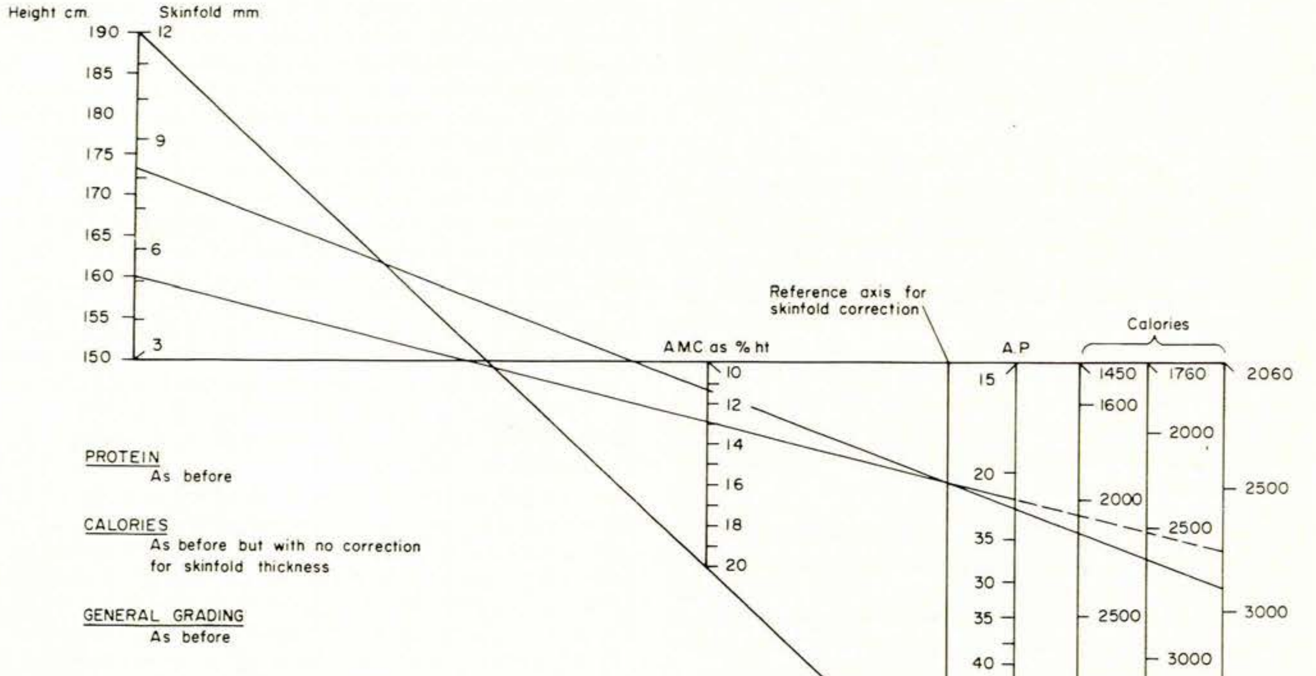

Fig. 3. Same nomogram as in Fig. 2 but with additional scale for skinfold thickness and with calorie scales modified for application of correction. (Figures provisional and arbitrary.)

muscularity scale and defines the lower boundaries of the nutrient scales, now represents a group with a 12 mm. instead of a 6 mm. skinfold, though as before with a height rating of 190 cm. and a muscularity index of 20%.

To the left of the protein scale is a reference axis which is used for applying the skinfold correction. The height rating and muscularity index of the group are marked as before on the relevant scales, and the straight line joining these two points is extended at least as far as its point of intersection with the protein scale, where the protein requirement, which is independent of skinfold thickness, is read off. The calorie requirements given by this line will be valid only for the skinfold thickness read off at the level of the height rating, and if this is not the correct value for the group, a correction must be applied. This is done by marking the true skinfold value on the scale and drawing a straight line from this point to the point of intersection of the first line with the reference axis. This new line is extended through the calorie scales and the corrected requirement read off.

In Fig. 3 a correction is applied for a skinfold of 8·3 mm. to a group with a height rating of 160 cm. and a muscularity index of 13%, the skinfold associated with a height of 160 cm. on this nomogram being only 5·3 mm., and the calorie allowances given by the line joining the height and muscularity ratings being therefore too low. It can be seen that the application of a correction by this method is a cumbersome procedure, and although it constitutes a more sophisticated approach than that recommended in Fig. 2, and can be adapted to include a series of corrections, it is not recommended for use in this particular context.

CONCLUDING REMARKS

One of the objects in devising the approach that has been described was to create a means of ascertaining at a glance what intake of protein and calories will be necessary to maintain any population group that is being investigated in its existing physical condition, whatever that may be. This will enable the investigator to state whether the condition of the group is likely to deteriorate, to remain static or to improve on its current food intake as determined. Appropriate recommendations can be made on the basis of the information given in the nomogram, from which the desired intake for well-nourished persons in any height category can be read off, but it should be remembered that food supplies are not everywhere so abundant that the nutritionist can afford to assert in every situation the necessity for intakes of the order usually recommended for the upkeep of the well-nourished Western male.

In conclusion it must be emphasized that this approach has been expressly designed for application to groups and not to individuals. The groups catered for by the present nomogram are furthermore selected in the sense that they are on their feet and in active employment, which excludes those so disabled by disease, obesity, malnutrition or starvation that they are incapacitated for regular employment as labourers. The information given on a nomogram of this type will be valid within certain limits of accuracy if errors due to individual variation are cancelled out by working with mean or median values based on samples of adequate size. This does not mean, however, that such a nomogram cannot also be used for certain purposes and in certain types of studies as a yardstick for grading the physical status of individuals and evaluating their nutrient intake in terms of the average recommendations for persons of their particular body build, provided that the limitations of such individual gradings are kept in mind. It would appear, in fact, that there may be more advantages in this approach than those which have been considered here, and we look forward to initiating a project at our Institute for the calibration of a standard nomogram that can be launched for use in the field.

SUMMARY

The prevalence of undernutrition in the world's most densely populated countries has made it imperative to devise a new and simple approach to the evaluation of nutritional status that is based on the maintenance requirements of population groups at different levels of physical development, and will enable the investigator to state whether the current food intake of a particular group is adequate to maintain it in its existing condition or will cause a deterioration or an improvement. At the same time he must be able to assign a nutritional grading which adequately describes the current condition of the group and make such recommendations as may be indicated, bearing in mind the limitations imposed by restricted access to food.

The method suggested is that a series of nomograms be calibrated which will give the maintenance requirements of different population groups at any level of physical development.

A simple nomogram designed for application to 3 different grades of labourers is described. The physical grading is based on 4 standard measurements, viz. height, upper-arm circumference, triceps skinfold and calf circumference, these being considered adequate, when used as recommended, to evaluate growth attainment, muscularity and adiposity. The maintenance requirements of the group being investigated are ascertained from the nomogram on the basis of the height and musculalarity ratings, corrections being applied where necessary for skinfold thickness and certain other factors.

The physical and nutritional grading of the group is given by ranges indicated on the reverse sides of the relevant scales, by a standardized clinical assessment of vitamin status and by protein and calorie gradings based on a comparison of the intake as determined, with the requirement as given by the nomogram.

Provision is also made on the nomogram chart for recording biochemical findings on scales divided into class intervals which correspond to recommended gradings, the nutritional significance of the biochemical findings being thus made apparent at a glance.

I should like to thank Dr. A. R. P. Walker of the South African Institute for Medical Research and Messrs. J. J. Dreyer and P. J. Smit of the National Nutrition Research Institute for their critical reading of the manuscript, for certain suggestions made and for additional literature references supplied. I am particularly indebted to Mr. Smit for having proved experimentally that the anterior upper-arm skinfold measurement may differ substantially from the posterior measurement in the same individual, and for drawing my attention to work already done in the fields of calorimetry and ergometrics.

REFERENCES

1. Food and Agricultural Organization (1957): *Calorie Requirements*. FAO Nutritional Studies, No. 15. Rome: FAO.
2. Davies, D. V. and Davies, F., eds. (1964): *Gray's Anatomy*, 23rd ed., pp. 650, 689 and 700. London: Longmans.
3. Grobbelaar, C. S. (1964): *Suggested Norms of Physical Status for White South African Males Aged 10-26 Years, Based on an Anthropometric Survey*. Cape Town: Struik.
4. Maritz, J. S., Morrison, J. F., Peter, J., Strydom, N. B. and Wyndham, C. H. (1961): Ergometrics, **4**, 97.
5. Food and Agricultural Organization (1957): *Protein Requirements*. FAO Nutritional Studies, No. 16. Rome: FAO.
6. McArthur, M. (1964): Journal of the Royal Statistical Society, **127**, 392.
7. Bailey, K. V. (1959): 'Rural nutrition studies in Indonesia', M.D. thesis, University of Melbourne.
8. Gsell, D. and Mayer, J. (1962): Amer. J. Clin. Nutr., **10**, 471.
9. Pugh, L. G. C. E. (1965): Nature (Lond.), **207**, 1397.
10. Interdepartmental Committee on Nutrition for National Defense (1960): Pbl. Hlth Rep. (Wash.), **75**, 687.
11. De Lange, D. J. and Joubert, C. P. (1964): Amer. J. Clin. Nutr., **15**, 169.
12. Du Plessis, J. P., De Lange, D. J. and Fellingham, S. A. (1965): S. Afr. Med. J., **39**, 1181.
13. *Idem* (1966): *Ibid.*, **40**, 509.
14. *Idem* (1965): *Ibid.*, **39**, 1176.
15. *Idem* (1966): *Ibid.*, **40**, 518.