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PROTEIN-ENERGY RATIOS

by

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Introduction

The Protein-Energy Ratio (PE ratio) is not a statement of requirements and is not intended to be used as such. Rather, the PE ratio is a descriptor of one aspect of the nutritional quality of foods or diets (1,2).

In current usage it is common to express the ratio as the proportional contribution of dietary protein to total dietary energy. It is possible, of course, also to describe the utilizable protein content of diets as in the calculation of Net Dietary Protein as % Calories (NDPCals%) and indeed this type of presentation has some distinct advantages.

In making practical use of descriptors of dietary protein concentration as a measure of quality, it is necessary to have a reference standard, a measure of the recommended or safe PE ratio (see definition later). With such a reference standard, a judgement can be made about the probable suitability of a diet, with reference to its protein content, for the feeding of specified classes of individuals. Such reference standard, then, must be specific to the specified class of individuals. It, or the mode of expression of food protein concentration, must take into account the biological value of the mixed dietary proteins.

Such reference standards, either calculated from estimates of requirements for energy and for protein, or based upon epidemiologic or experimental observations of the consequences of ingestion of diets with differing PE ratios, may be referred to individuals (i.e. the ratio that would be appropriate for a group of persons consuming a particular dietary combination with a fixed PE ratio) or may be referred to the average composition of the range of individual diets consumed by a group or population of free-living subjects (i.e. the PE ratio varies among the self-selected diets consumed by individuals). The latter reference concentration would have to be higher than the former to take into account the variability of the ratio among self-selected diets 1.

Confusion about the PE ratio and its application arises in the literature from three major sources: i) inappropriate calculation of reference ratios as a simple ratio of recommended protein intake (average requirement + 2 SD) to energy requirement (average), ii) failure to recognize the difference in the magnitude between a reference ratio appropriate to fixed diets as consumed by an individual and to per capita or population averages in which the diets consumed vary among individuals, and iii) failure to recognize that as energy requirement changes with differing physical activity, protein requirement does not; hence the reference PE ratio changes with the level of energy expenditure and thus to the defined social setting (see also 2.1.2).

[1] In the connotation of this report, “Protein-Energy Ratio” is taken to mean the proportion of total energy derived from protein with the assumption that protein energy = crude protein X 4 kcal/g.

In theory, reference PE ratios calculated from requirement estimates for protein and for energy, and ratios derived from epidemiologic and experimental studies should be in reasonable agreement <u>if</u> the requirement estimates and method of calculation are correct, <u>and if</u> the two data sets are on comparable conceptual bases. In this sense, comparison of theoretical and observed ratios can be a useful cross-check/confirmation of the requirement estimates. It must be emphasized that for such comparisons it must be ensured that the the two ratios have the same conceptual bases (i.e. both refer to a fixed diet consumed by an individual or group of individuals, or both refer to average composition of a range of diets consumed by free-living subjects; both refer to average ratios (appropriate for half of the individuals) or both refer to recommended or safe ratios (appropriate to almost all individuals; both take biological value into consideration; etc) An extremely important requirement is imposed by the nature of the calculation of reference ratios - it is assumed that all individuals are ingesting sufficient food to meet their own energy requirements. If this condition does not hold in the epidemiologic or experimental data, it is inappropriate to make comparison with the theoretical ratios (see later discussion of “Inadequate Energy Intake”).

<u>Definition of Recommended or Safe Protein Energy Ratio</u>

The following working definition and description of the reference PE ratio is suggested:

The recommended or safe protein energy ratio is that concentration of dietary protein, expressed as a proportion of total energy, that will ensure that the protein needs of almost all indivuals of a particular age, sex, physiological state, and activity level group will be met when those persons have consumed sufficient amount of the food to meet their individual energy needs.

Recommended or safe protein energy ratios may be referred to specific diets or to aggregate averages of ranges of diets with varying individual ratios. The reference ratios will differ between these two situations with the latter being higher.

The recommended or safe protein energy ratio will change with strata of activity level within defined age, sex and physiological state groups.

This definition and description of the recommended or sfae protein energy ratio relates to the maintenance of health in already healthy individuals consuming sufficient food to meet their energy needs. The definition does not refer to ratios appropriate to rehabilitation or catch-up growth (see later discussion) and does not address possible change in protein and energy requirements during infection. It does not address the question of protein requirements in the face of inadequate energy intake (e.g. in anorexia associated with infection). In these regards, the definition is consistent with the proposed definitions of recommended or safe level of protein intake and average requirement for energy. If those definitions are modified, the definition of of the recommended or safe protein energy ratio should be adjusted to maintain conceptual consistency.

Derivation of Recommended or Safe Protein Energy Ratios from Estimates of Requirements for Energy and for Protein

Since 1971 there have been two distinct proposals for the derivation of reference PE ratios based upon the 1971 FAO/WHO report on energy and protein requirements. One of these is a probability approach presented by Beaton and Swiss (1,2). The other is a more empirical approach presented by Payne (3). Both were discussed by the Joint FAO/WHO Informal Gathering of Experts in 1975 (4) which also presented a variant on the Payne approach. That group (4) emphasized the importance of considering activity level (strata of energy requirement) when calculating reference ratios; this aspect had been given proper emphasis in the paper by Payne (3). The group emphasized also the limitations of use of such ratios particularly at the national or per capita level. The two underlying approaches are described below. In this discussion, the protein energy ratios derived refer to the requirement estimates published in the 1971 FAO/WHO report (5). The numerical values will change if the requirement estimates are changed. The two approaches adopt identical parameters for protein requirement (stipulated in 1971) but assume different parameters for energy requirement (not completely specified in 1971). Further, Payne makes use of an estimate of maintenance energy requirement while Beaton and Swiss restrict themselves, in the original paper, to energy requirement associated with moderate activity.

As a preface to this discussion, let it be recognized (Table 1) that there is a wide range of potential ratios that can be derived from simple calculations (2). The question to be addressed is which of these ratios appropriately describes the level that is “safe” in the same connotation as the “safe level of protein intake”. Obviously this will relate to the situation in which the individual has a low requirement for energy (low total food intake) and a high requirement for protein. On that basis, in Table 1, the best approximation would be the ratio given for Energy Required = Average - 2 SD and Protein Required = Average + 2 SD. For the adult man, this would imply a PE ratio of about 7.1% as milk or egg protein. As will be presented below, this actually represents a much lower level of risk than is implied by the “safe level of protein intake”.

Table 1-SOME SIMPLE APPROACHES *to definition of protein energy ratios*[*]		
Protein requirement	**Energy required**	**Derived ratio (protein as % energy)**
Average	Average	3.8
Average + 2 standard deviations	Average	5.0
Average + 2 std dev.	Average - 2 std. dev.	7.1
Average - 2 std dev.	Average + 2 std. dev.	2.7

* For adult man, moderately active, based on egg or milk protein

(a) Probability Approach of Beaton and Swiss (1)

Beaton and Swiss accepted the view that, in an unconstrained situation, energy requirement determines energy intake (total food intake). If the ratio of protein: energy in the food is fixed, then the distribution of protein intakes is described by the distribution of energy requirements. By then considering the distribution of protein intakes on such a fixed diet with the distribution of protein requirements as described by the FAO/WHO committee, it was possible to derive a probability statement concerning the proportion of such individuals expected to ingest less protein than they require when they have s iated their own energy requirements. By repeating this for various fixed protein energy ratios, a family of probability statements is created. This family, in effect, describes the distribution of requirements for protein-energy ratios under the conditions that energy requirements are met (Fig. 1). From this family, the PE ratio that covers the protein needs of all but 2.5% (or 5% or 1%) of individuals can be selected as the recommended or safe protein-energy ratio. The results of such calculations for four age groups are shown in Table 2. Empirically, the results were similar for all age groups.

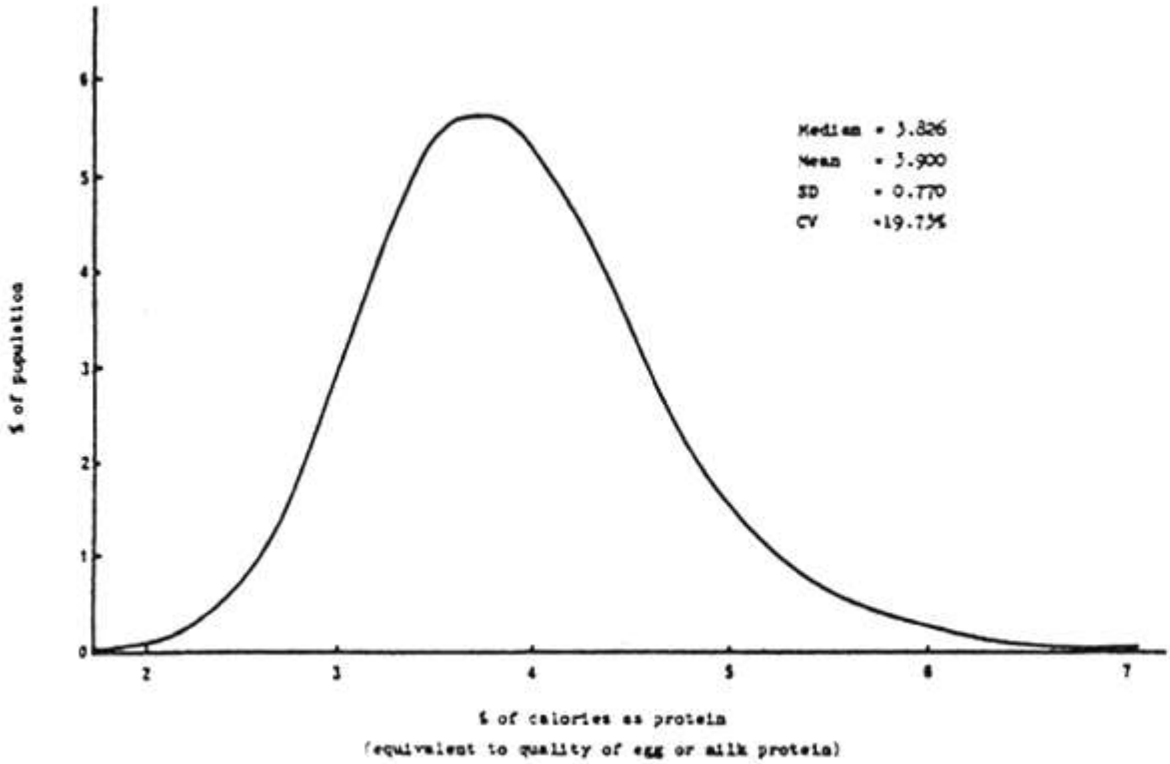

FIG. 1. Apparent distribution of individual requirements for milk or egg protein as percent of calories among adult males under the assumption that energy requirements have been met. From this distribution, a safe level of intake for the individual (associated with a risk of deficiency of approximately 2.5%) would be approximately 5.5% of calories as milk or egg protein.

TABLE 2
Effect of age on the predicted prevalence of deficiency (percent at risk) among homogeneous groups consuming diets of fixed composition[a]

Concentration of egg or milk protein in diet. % of calories	Age (years) and sex group			
	Male adults PR[b] = 0.44 ER = 46	**Male adolescents 12–14 PR = 0.62 ER = 71**	**Children 6–8 PR = 0.72 ER = 83**	**Children 2–3 PR = 0.89 ER = 100**
1.0	100.0	100.0	100.0	100.0
2.0	99.9	99.7	99.6	99.7
3.0	89.6	78.8	77.6	81.4
4.0	40.9	23.9	22.7	27.1
5.0	8.4	3.4	3.1	4.1
6.0	1.2	0.4	0.4	0.5
7.0	0.2	0.1	0.1	0.1
8.0	0.0	0.0	0.0	0.0

[a] It is assumed that all individuals consume sufficient food to meet their energy requirements. “Deficiency”represents a situation in which habitual intake is less than the individual's true requirement.
[b] PR = average protein requirement (grams/kg/day) from FAO/WHO report (6). ER = average energy requirement (kcal/kg/day)from FAO/WHO report (6).

Mean requirements for protein and for energy, and the variability of protein requirements were stipulated in the 1971 FAO/WHO report (5). The Beaton and Swiss approach required two more descriptors of requirements: the variability of energy requirement and the correlation between energy requirement and protein requirement. After reviewing the literature (see Annex) they accepted an estimate of 15% as the CV of energy requirement per kg body weight within uniform age-sex groups. After examining available data they concluded that, when expressed on a per unit body weight basis, there was a very low order of correlation between energy requirement and protein requirement of individuals. Indeed, the correlation was low enough to be ignored[2]. (The data reviewed are summarized in the Annex.) They cautioned however that this may not be true for the young infant, and perhaps for pregnant or lactating women, where major parts of the requirements for energy and for protein both relate to growth; the correlation for this part of requirement might be expected to be high (and hence the required PE ratio would be reduced somewhat).

The calculations shown in Table 2 (and in the Annex) all assume that the activity level of the subjects falls in the “moderate” category (i.e. the primary requirement estimate in the FAO/WHO report). Payne (3) correctly pointed out that this was a serious oversight in the original Beaton and Swiss calculations. As activity levels and food intakes fall (decreased energy requirements), the required PE ratio would rise. The effect is readily apparent in the recalculations reported by Beaton (2) changing only the mean energy requirement estimate (Table 3).

Table 3-EFFECT OF LEVEL OF VOLUNTARY ACTIVITY *on safe protein-energy ratios*		
Age group	**Activity level**	**Protein as % energy***
Child. 2–3 yr	Average	5.3
	"Maintenance"	6.7
Male adults. 25–35 yr	Moderate	5.4
	Light	5.1
	U.S. figures for energy requirement	6.4
Male adults. 65 + yr	Observed values for Canada	8.1

* As egg or milk protein

All of these calculations refer to egg or milk protein. Table 4 illustrates the impact of assuming different dietary protein qualities, selecting the moderately active man as the reference point. As was pointed out earlier, an alternative approach would be to adjust intake data to the equivalent of milk or egg protein and then leave the recommended or safe PE ratio unadjusted.

Table 4-EFFECT OF PROTEIN QUALITY *on safe protein-energy ratios for moderately-active man*	
Relative Net Protein Utilization	**Proteinas % energy**
Egg or milk = 100	5.4
80	6.75
70	7.7
60	9.0

[2] As the correlation between protein requirement and energy requirement increases, the recommended or safe PE ratio decreases (See Annex for examples)

It was emphasized earlier that the calculation of recommended or safe PE ratios can be referred to particular diets (all individuals consuming the same PE ratio diet) or to the aggregate average of self-selected diets (as in per capita figures). The calculations above, those of Payne, and most others presented in the literature refer to the former situation. They are inappropriate criteria for use in considering aggregate or per capita data. Beaton and Swiss (1) examined the latter situation and offered PE ratios appropriate to aggregate data assuming various variabilities of the PE ratio among self-selected diets. These are presented in detail in the Annex and are shown in summary form, together with the activity differential in Table 5 (2).

Table 5-PROTEIN-ENERGY RATIOS *applicable to per-capita data*		
Coefficient of variation of protein concentration (%)	**Protein as % energy**	
	At moderate activity levels	**At low activity levels**

Egg or milk protein		
10	5.3	6.7
15	5.8	7.3
20	6.4	8.1
25	7.5	9.5
Protein with utilization 80% that of egg or milk		
10	6.6	8.3
15	7.2	9.1
20	8.1	10.2
25	9.4	11.8
Protein with utilization 70% that of egg or milk		
10	7.6	9.6
15	8.2	10.3
20	9.2	11.6
25	10.7	13.5

To offer some sense of perspective, Tables 6 and 7 present some information about per capita protein energy ratios of various regions and about the ratios for various classes of foods (1,2). Although these data do not take into account protein quality, general comparison with Table 5 serves to suggest where protein may be in short supply in relation to energy (the Far East) and which types of foods would either increase or decrease the concentration of protein if introduced on an equicaloric substitution basis. Perhaps this is an example of the limit of appropriate use of the aggregate PE ratio criterion.

Table 6-APPARENT AVERAGE PROTEIN CONCENTRATIONS *observed in dietary surveys conducted by the ICNND (Interdepartmental Committee on Nutrition in National Defense / Development)*

Area and group	**Average protein concentration as % energy**
Latin America	
Bolivia[a] families	12.2
Chile, families	12.6
Colombia, families	10.2
Ecuador[a]. families	13.0
Northeast Brazil[a]	
Families	14.0
Pregnant women	16.5
Infants under 2 yr	11.9
Uruguay[a]	
Families	14.0
Children, 3–4 yr	21.1
Children, 1–2 yr	21.1
Caribbean	

Trinidad, families	13.2
St. Lucia families	12.8
St. Kirts, families	17.1
Nevis, families	17.3
Anguilla, families	13.6
Alaska, males, all ages	29.3
Middle East	
Ethiopia, families	12.4
Jordan[b], families	12.8
Lebanon[a], families	12.6
Far East	
Burma, families	9.1
East Pakistan, families	
Rural	10.2
Urban	11.2
Malaya	
Families	11.2
Children	10.7
Thailand, families	10.7
Vietnam, families	
Vietnamese[b]	14.5
Highlanders	10.4

[a] Two or more regions studied concentrations generally comparable
[b] Refugees and non-refugees studied concentrations generally comparable

Table 7-APPARENT PROTEIN-ENERGY RATIOS *in some common foods*

Type of food	Protein as % energy
Milk, whole	22
2%	29
Skim	40
Cheese, Cheddar	24
Ice cream	9
Meat, lean	50–60
fat	18–25
Poultry	50–65
Fish	50–80
Vegetables, general	15–35

Beans, peas	15–25
Soybean	30–40
Fruits, general	2–7
Nuts, seeds	5–20
Cereals	7–15
Sugar	0
Fats	0

b) Approach of Payne

In his published paper, Payne (3) departs from the Beaton and Swiss approach in two important ways. First, he adopts a different procedure for estimating the necessary PE ratio, a procedure which combines biological principles and an element of empiricism in place of statistical probability calculations, and which yields a somewhat higher PE ratio if all other variables are held constant. Second, he addresses the fundamental issue of the magnitude of energy requirements and attempts to derive and make use of lower limits to energy requirement (see also discussion of Maintenance Energy Requirement, Agenda Item 3.1.2, background paper by Beaton). Finally, in his final interpretation of these calculations, Payne applies an element of judgement in selecting the PE ratio he would recommend. An attempt will be made to deal with these items separately. Although the final PE ratios seem quite similar, the two approaches are quite different at a conceptual level. If the present committee is to adopt either, it is appropriate to examine the underlying concepts.

Payne first calculated a curve portraying the ratios of protein to energy required if the diets were consumed in amount to meet average protein requirements at different levels of energy intake. He then plotted an analagous curve representing the relationship if average protein requirement + 2 SD were to be ingested (the safe level of protein intake). This curve, referred to as the safe level in Fig. 2, portrays the needed ratio at any given level of energy intake. Payne then asked what the lower limit of energy intake might be. Fig. 2 portrays the assumption adopted by Beaton and Swiss, that the CV of energy requirement was 15% and hence that the average - 2 SD covered all but 2.5% of the population. Point k_o then describes the PE ratio required to meet the recommended protein intake at this lower limit of energy intake. (reading from Fig. 2, this appears to be about 6.5%. This may be compared to the Beaton and Swiss estimate of about 5.3% in Table 3 and to the Table 1 estimate of 7.1% for the adult). The lower PE ratio derived by Beaton and Swiss simply reflects the low probability that an individuals will fall into this extreme situation of both high protein requirement and low energy requirement.

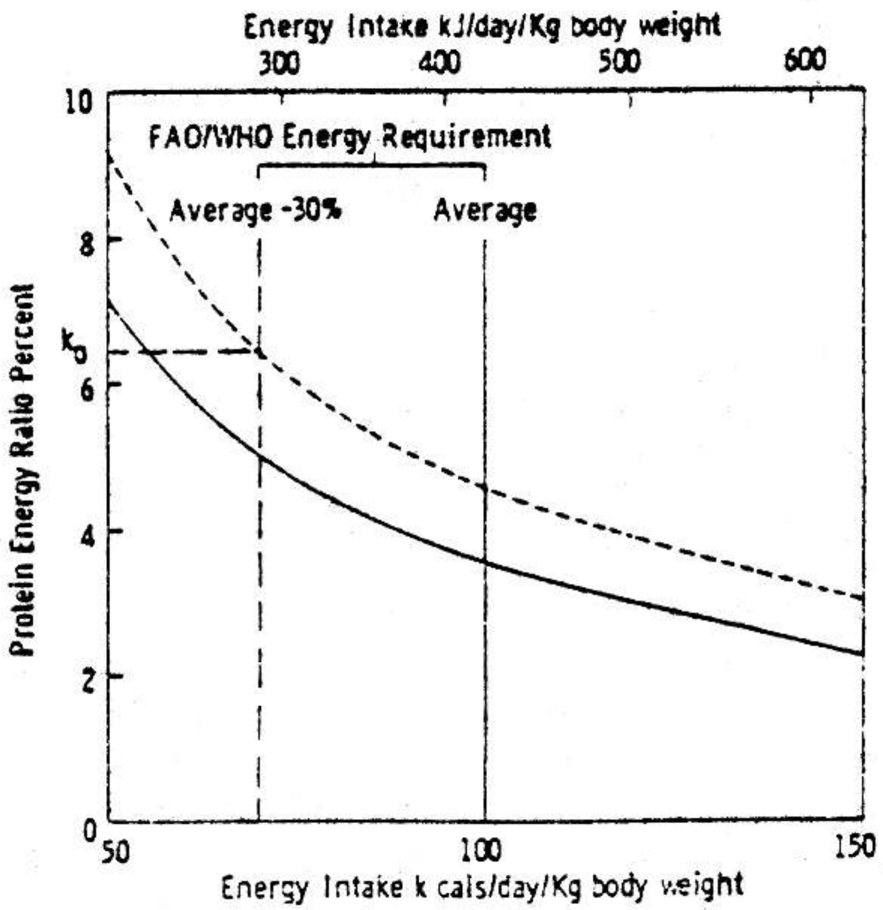

FIG. 2. Protein concentrations of diets which will provide the average requirement (solid curve) and safe level (dotted curve) of protein for a 2- to 3-year-old child. Vertical line (broken) shows the lower limit of observed energy intakes.

Payne then took the lower limit of energy intake as having a group average = 1.5 X BMR, the maintenance figure suggested in 1971 (5) and assumed a coefficient of variation of 6–7% on the basis of that reported for BMR. Using these data, Payne prepared Fig. 3. Point H, the extreme situation, requires a PE ratio of 6.5%, a figure close to that derived from Fig. 2. However Payne argues, as did Beaton and Swiss, that it is unlikely that situations exist in which this requirement would be valid. However, Payne basis his arguments more heavily upon biological than statistical arguments. He concluded that point M, corresponding to a PE ratio of 5.3% was the appropriate reference criterion. In essence, he suggests that if PEM is a problem in situations to the left of or below this point, then there is little likelihood of protein deficiency without concurrent energy inadequacy and hence little expected benefit to raising the PE ratio.

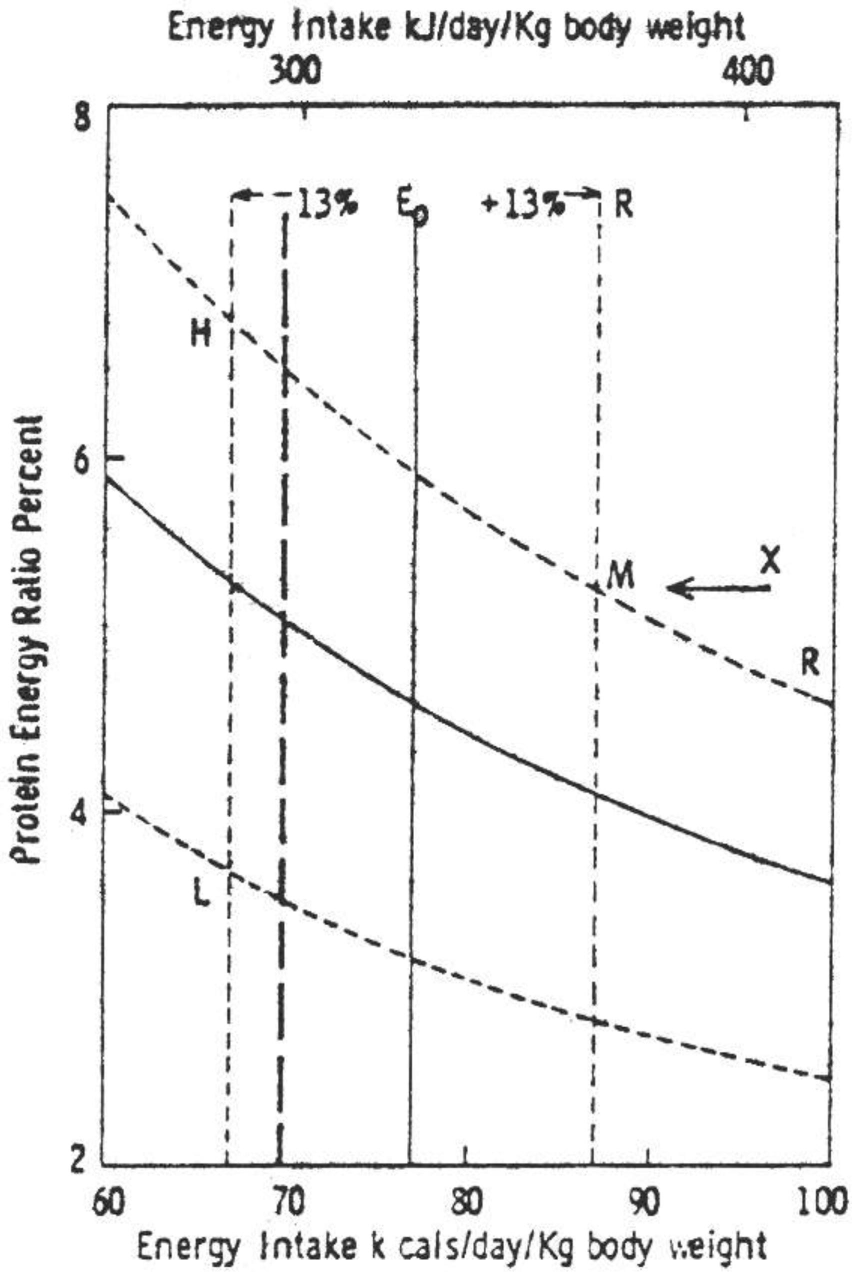

FIG. 3. Protein concentrations of diets which will provide the average requirement (solid curve) and average = two standard deviations (dotted curves) of protein for a 2- to 3-year-old child. Vertical lines are estimates of minimum energy intake (broken line) and the average and individual range of minimum physiological energy requirements (solid and dotted lines).

Payne does not address the calculation of per capita ratios. Rather, he argues that emphasis should be placed upon diets consumed by individuals in the population rather than upon national aggregates and national food supplies.

The 1975 Informal Gathering of Experts (4) presented a variant on Payne's model as portrayed in Fig. 2 which, in that report, led to a PE ratio of 6.9%. Note that a similar and much simpler approach to this estimate is to simply calculate average protein + 2 SD/average energy - 2 SD as was done in Table 1. This figure is appreciably higher than the probability estimate for moderately active individuals prepared by Beaton and Swiss. Interestingly, and purely be coincidence, it is very close to the probability estimate for persons classified in the light activity category (see Table 3) and in that sense may indeed be safe for almost all individuals.

Infants, Pregnancy and Lactation: Special Cases

Beaton and Swiss intentionally avoided making calculations for young infants and for pregnancy and lactation. Although requirement estimates are available for these groups and calculations can be made, there was available no clear estimate of the correlation between energy requirement and protein requirement in the face of high "growth" rates.

If a consensus can be achieved as to whether or not energy and protein requirements do correlate for the growth (and milk secretion requirement) among individuals, then it is theoretically possible to derive an estimate of the correlation during these periods assuming a very low correlation for the non-growth part of requirement (1).

Infants present a second special situation with regard to the use of "per capita/aggregate" criteria. Infancy is the one period of life when it can be reasonably expected that all individuals consume diets with approximately the same PE ratio. That is, the criteria developed for individuals and the criteria developed for population aggregates might be very similar for infants. This has conceptual relevance when one is considering epidemiologic data. To many it has seemed surprising that the PE ratio of infant diets is often much less than that of self-selected adult diets - meaning the aggregate figures for adult diets. But this makes teleological sense if it is recognized that all infants consume a fixed ratio diet (or nearly so) while adults consume diets with a wide range of ratios - the difference in required ratios should be apparent from Table 5 vs. Table 6 or from the different assumed variances of Table 6.

Catch-up Growth

In 1979, UNU issued a report on Protein-Energy Requirements Under Conditions Prevailing in Developing Countries (6). One of the many points made in that report was that calculations such as those of Beaton and Swiss or of Payne assume median growth rates in children (actually they assume average + 2 SD). The authors reported that, for short periods, growth rates as much as 18 times higher than median could be found in children undergoing catch-up growth. The report presented calculations of energy and protein requirements for such states and argued that protein need increased much more than did energy need. Therefore, the required PE ratio would be higher than previously suggested.

An FAO/WHO Informal Consultation (7) also undertook calculations for this situation. That group was more conservative in its estimate of maximal growth rates that might be achieved under field conditions (outside the hospital) but also concluded that the safe or recommended PE ratio would have to increase if catch-up growth was to be included. The group gave emphasis to the fact that there would have to be a substantial increase in energy intake in catch-up growth and expressed the pessimistic view that under field conditions, failure to increase food intake (energy intake) was more likely to limit growth response than the concentration of protein in the food. The utility of adjusting the PE ratio criterion was questioned.

The point to be made is that PE ratio calculations for various rates of catch-up growth can be made if there is agreement on the protein and energy requirements for this growth and upon the correlation between these requirements. However, whether or not such calculations should be made as a part of the 1981 report depends upon the decision of the committee and how it plans to deal with topics such as catch-up growth, rehabilitation, anorexia, infection, etc. It must be asked whether these are to be included as adjustments to requirement estimates (and hence automatic adjustments to any derived PE ratio). It would seem inappropriate to discuss these matters only under the heading of PE ratios.

Inadequate Energy Intake

The authors of the Joint FAO/WHO Memorandum (7) pointed out that in the range surrounding requirement, there is an interaction between energy intake and protein requirement. They suggested that the effect could be as high as 0.04 g protein/kg for a 1.0 kcal/kg change in energy intake. This would imply that if energy intakes fell below requirements, protein requirements would increase and, of course, the appropriate PE ratio would be strongly affected. Using the estimate cited above, the ratio for the adult might increase by about 10–12% for a drop of 1 kcal/kg below energy requirement (a 2% reduction).

The question might be asked, then, should recommended or safe PE ratios be adjusted upward to take this into account? In answer, this reviewer suggests that recognition be given to the fact that all requirement estimates (and hence PE ratios) refer to usual intakes - the average intake of an individual over extended periods. If people can continue for extended periods on energy intakes below the suggested requirement without becoming undernourished, then it is logical to conclude that the energy requirement must have been incorrectly estimated. Rather than adjusting the PE ratio, it would seem to be more appropriate to reconsider the energy requirement statement.

Comparison of Epidemiologic and Experimental Studies vs Theoretical Calculations

It is understood that UNU will present data arising from studies it has sponsored. This information will be welcome. It is urged however, that great care be taken to ensure that, if these or other data are to be compared with theoretical calculations of the type reviewed in this paper, the conceptual bases be kept consistent (e.g. individuals on fixed diets vs groups on self-selected diets, protein quality, assumed and actual level of activity, group mean ratio vs. “safe” ratio, etc.)

Is There Merit in Addressing Protein-Energy Ratios

In the opinion of this reviewer, the answer is yes, although it is stated with some regret. Payne (3) has given the most convincing argument for doing so although that may not have been his intent. If indeed energy requirements can adapt downward to much lower levels than had been generally emphasized in 1971, and if there is no comparable change in protein requirements, then the issue of protein-energy ratio, the concentration of protein in indigenous diets must be reopened. Will such diets be adequate if consumed in amounts that satiate the energy requirements of socially adapted populations?

While the present reviewer remains convinced that the answer to the question will be affirmative, he points out that many others have expressed contrary opinions - and continue to express contrary opinions! Further, this reviewer along with many others, has argued that the margin between existing protein-energy ratios and recommended or safe PE ratios may not be large in all regions. There would appear to be legitimate concern about agricultural or other policies that might lower the ratio in diets as consumed in some areas of the world. For both of these reasons, it seems appropriate that the committee attempt to make some statement on what remains an important issue.

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ANNEX

Observed coefficient of correlation between energy requirement and protein requirement

Author	No. and sex of subjects	Observed coefficient of correlation	Statistical significance
Nitrogen balance studies (kcal/kg/day vs. g/kg/day)			
Bricker et al. (72)	9 F	0.55	NS
Huang et al. (73)	9 M	-0.16	NS
Scrimshaw et al (74)	11 M	0.69	P<0.02
Scrimshaw et al. (75)	21 M	0.31	NS
Clark et al. (6)	5 M	0.68	NS
Prothro et al. (27)	7 M	0.23	NS
	5 M[a]	0.04	NS
Young and Scrimshaw	11 M	-0.36	NS
(unpublished)	7 M	-0.16	NS
Calloway and Margen (data from (67))	6 M	0.41	NS
BMR and endogenous urinary nitrogen (kcal/kg/day vs. mg/kg/day)			
Murlin et al. (28)	5 M	-0.06	NS

	5 M[b]	0.35	NS
Hawley et al. (77)	6 F	0.77	NS
	7 M	0.23	NS
Young and Scrimshaw (78)	7 M	0.06	NS
Huang et al. (73)	6 M	0.56	NS
Calloway and Margen (data from (67))	12 M	0.06	NS
Young and Scrimshaw (data from (26))	83 M	0.23	$P<0.03$

[a] Same subjects studied 1 year later.
[b] Same subjects studied 1 month later.

Predicted prevalence of "deficiency" among adult men consuming diets of fixed composition[a]

Concentration of egg or milk protein in diet, % of calories	**Accepted values, CV_{ER} = 15% r = 0.2**	**Effect of variation in CV_{ER} and r[b]**		
		CV_{ER} = 15% r = 0	**CV_{ER} = 15% r = 0.4**	**CV_{ER} = 20% r = 0.2**
1.0	100.0	100.0	100.0	100.0
2.0	99.9	99.8	100.0	99.8
3.0	89.6	87.1	92.7	86.7
4.0	40.9	41.7	39.4	42.1
5.0	8.4	10.8	5.6	13.1
6.0	1.2	2.0	0.5	3.8
7.0	0.2	0.4	0.1	1.2
8.0	0.0	0.1	0.0	0.4
9.0	0.0	0.0	0.0	0.2
10.0	0.0	0.0	0.0	0.1

[a] Risk to the individual associated with specific protein concentrations. It is assumed that all individuals consume sufficient food to meet their energy requirements. Deficiency represents a situation in which habitual protein intake is less than the individual's true requirement.
[b] CV_{ER} = coefficient of variation of energy requirements; r = coefficient of correlation between requirements for energy and for protein.

Required average concentration of dietary protein to cover the protein requirements of all but 1.0, 2.5, or 5.0% of the population (percent of calories as protein[a]

Observed coefficients of variation of dietary protein	**To cover all but 1.0% of individuals**				**To cover all but 2.5% of individuals**				**To cover all but 5.0% of individuals**			
	Adults	**Adolescents**	**Children**	**Preschool children**	**Adults**	**Adolescents**	**Children**	**Preschool children**	**Adults**	**Adolescents**	**Children**	**Preschool children**

concentrations												
A) Egg or milk protein												
10	6.20	5.67	5.63	5.81	5.79	5.29	5.25	5.42	5.45	4.99	4.95	5.10
15	6.90	6.31	6.26	6.46	6.28	5.75	5.71	5.88	5.81	5.32	5.28	5.44
20	8.05	7.36	7.31	7.54	7.05	6.44	6.40	6.60	6.34	5.80	5.76	5.93
25	9.96	9.11	9.06	9.32	8.18	7.48	7.45	7.66	7.07	6.47	6.43	6.62
B) Protein with utilization 80% that of milk or egg protein												
10	7.75[b]	7.09	7.04	7.26	7.24[b]	6.61	6.56	6.78	6.81[b]	6.24	6.19	6.38
15	8.63	7.89	7.83	8.08	7.85	7.19	7.14	7.35	7.26	6.65	6.60	6.80
20	10.06	9.20	9.14	9.43	8.81	8.05	8.00	8.25	7.93	7.25	7.20	7.41
25	12.45	11.39	11.33	11.65	10.22	9.35	9.31	9.58	8.84	8.09	8.04	8.28
C) Protein with utilization 70% that of milk or egg protein												
10	8.86[b]	8.10	8.04	8.30	8.27[b]	7.56	7.50	7.74	7.78[b]	7.13	7.07	7.29
15	9.86	9.01	8.94	9.23	8.97	8.21	8.16	8.40	8.30	7.60	7.54	7.77
20	11.50	10.51	10.44	10.77	10.07	9.20	9.14	9.43	9.06	8.30	8.23	8.47
25	14.23	13.01	12.94	13.31	11.69	10.69	10.64	10.94	10.10	9.24	9.19	9.46
D) Protein with utilization 60% that of milk or egg protein												
10	10.33[b]	9.45	9.38	9.68	9.65[b]	8.82	8.75	9.03	9.08[b]	8.32	8.25	8.50
15	11.50	10.52	10.43	10.77	10.47	9.58	9.52	9.80	9.68	8.87	8.80	9.07
20	13.42	12.27	12.18	12.57	11.75	10.73	10.67	11.00	10.57	9.67	9.60	9.88
25	16.60	15.18	15.10	15.53	13.63	12.47	12.42	12.77	11.78	10.78	10.72	11.03

[a] The calculations assume that sufficient food is consumed to meet energy requirements. See text for other constraints to interpretation.
[b] May overestimate requirements of adults (6).

Observed coefficient of variation of energy requirements, kilocalories/kilogram/day[a]						
Age, years	**Observed energy intake**		**Calculated energy expenditure**		**Basal metabolic rate**	
	n	**CV,%**	**n**	**CV,%**	**n**	**CV,%**
Children						
<1	67	17.6			8	9.5
1–3	318	21.9			10	6.8
4–6	482	20.4				

7–9	767	20.4			10	9.0
Mean ± SD	1,634	20.6 ± 0.9			28	8.4 ± 1.2
Male adolescent						
10–12	400	23.7				
13–15	209	21.7				
16–19	153	19.3	57	10.5		
Mean ± SD	762	22.3 ± 1.7	57	10.5		
Female adolescent						
10–12	397	24.5			12	8.9
13–15	223	25.2				
16–19	153	17.6	4	13.7	4	18.3
Mean ± SD	773	23.3 ± 2.9	4	13.7	16	11.3 ± 4.2
Male adult						
20–39	125	19.8	81	13.0	250	11.4
40–49	15	21.2			199	15.2
50–59	14	17.2	9	15.4	115	14.5
60–69	24	12.0	24	14.0	115	13.5
70+	11	24.1	6	23.7	90	13.8
Mean ± SD	189	19.0 ± 3.0	120	13.9 ± 2.4	769	13.4 ± 1.5
Female adult						
20–39	289	19.7	21	14.4	70	8.5
40–49	4	14.4				
50–59	23	20.0	12	15.3		
60–69	38	18.6	38	13.3		
70+	10	15.2	10	22.1		
Mean ± SD	364	19.4 ± 1.0	81	15.0 ± 2.8	70	8.5
All data, mean ± SD	3,722	21.3 ± 2.3	262	13.5 ± 2.8	883	12.8 ± 2.2

[a] Standard deviation as percent of mean. Sources of data, (30), (32–64), and original data provided by Beal (65), Dubuc (66), Calloway (67), Scrimshaw and Young (26), and Sabry (unpublished).