Protein Requirements of Infants and Children

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Abstract

During the last 35 years there have been various published assessments of human protein needs, including those of infants and children. Most recently, the Institute of Medicine of the US National Academies has published its report on Dietary Reference Intakes (DRI) for Macronutrients, and WHO/FAO/UNU have convened a new Expert Consultation, which is due to be published soon.

Although there have been a number of published studies on children’s protein requirements determined by the nitrogen balance technique, the results of these studies in themselves are insufficient to derive requirement values for all ages. Instead, a meta-analysis of the data from a range of studies in children has been used to derive values for the requirement for maintenance (i.e. no growth), and for the efficiency of utilization of dietary protein for growth. These values were then combined with age-specific rates of protein deposition to calculate the average requirement at any age. New values for protein deposition in children have been derived from studies of potassium-40 accumulation in infants and children, and these have been employed in new calculations of the average protein requirement. By combining values for the maintenance requirement, derived from adults, with the requirement for growth, estimated by analysis of the data for total-body potassium at different ages, the age-specific average protein requirement was determined. The safe level of intake is the amount of dietary protein that will provide the needs of almost all of the specified age group, and this is usually taken as the average requirement plus 2 times the standard deviation (SD) of the requirement. The SD of the children’s requirement was determined by combining the SD for maintenance (from the adult data) with the SD for protein deposition, derived by combining data for rates of growth of body mass and data for the whole body potassium-40 content at different ages.

The resulting values for the average protein requirement range from 1.12 g/kg/day at age 6 months to 0.74 g/kg/day at 10 years, with a small decline towards the adult value thereafter. The corresponding values for the safe level are 1.43 g/kg/day at 6 months and 0.91 g/kg/day at 10 years.
Introduction

The proteins of the body are in a dynamic state, involving continuous degradation to free amino acids, and re-synthesis of new protein molecules, the process known as ‘protein turnover’. At the same time, free amino acids are continually being degraded and oxidized to carbon dioxide and nitrogenous end products, such as urea and ammonia. These losses of amino acids must therefore be replaced by consumption of dietary protein. Moreover, in children there must be an additional intake of protein from the diet to furnish new tissue growth. The ‘requirement’ for dietary protein is therefore the sum of these two separate needs for ‘maintenance’ and ‘growth’.

Over the last few decades, various committees have been convened to determine the values for the requirement for dietary protein of children and adults, notably the FAO/WHO/UNU report on ‘Energy and Protein Requirements’ in 1985 [1], the recently published ‘Dietary Reference Intakes’ report of the US National Academies [2], and the pending WHO/FAO/UNU report on ‘Protein and Amino Acid Requirements in Human Nutrition’ [3]. In addition, the requirements of infants and children were analyzed in detail by Dewey et al. [4].

Definitions

The protein requirement for an individual is defined as the minimum intake of high quality dietary protein that will provide the needs for maintenance at an appropriate body composition, and will permit growth at the normal rate for age, assuming energy balance and normal physical activity. However, the requirement is expressed in two different ways. The first is the ‘average requirement’, which is simply the mean value for the requirement of the population under study. The second is the ‘safe level’ [1, 3] or ‘recommended dietary allowance’ (DRI) [2], which is the amount of dietary protein that will provide for the requirements of almost all (97.5%) of the population. This is higher than the average requirement by two times (to be more precise, 1.96 times) the standard deviation (SD) of the mean requirement of the population under study. It is therefore important when considering the ‘requirement’ to make a clear distinction between these two.

The use of these two values is often misinterpreted. The average requirement is the amount of protein that will satisfy the needs of approximately 50% of the population. Thus, for a population that has an average intake equal to the average requirement, half of the individuals will be receiving less than their requirement. The safe level is set at a value higher than the average requirement so that only a very small proportion of the population will have inadequate intakes when consuming that amount. However, since the intake also has a distribution, one cannot assume that if the average intake is equal to the safe level, then there will be no prevalence of inadequacy. If the average and distribution of
Measurement of the Protein Requirement

The procedure known as ‘nitrogen balance’ has been, and still is, the basis of all the procedures used to estimate the protein requirement. Nitrogen balance is the difference between the dietary intake of nitrogen and the total losses of nitrogen (including urine, feces and miscellaneous losses such as sweat, skin and hair losses). As almost all the nitrogen in the body is in the form of protein, the nitrogen balance represents the protein balance, with protein equal to 6.25 times nitrogen.

To measure the protein requirement of an individual, it is necessary to measure the nitrogen balance at a series of different intakes above and below the estimated requirement value. For the adult, the requirement is then the amount of dietary protein at which the intake equals the total losses, as the healthy adult is not gaining or losing body protein. For the child, the interpretation is somewhat more complex due to growth, which is accounted for as follows.

The total literature on children’s protein requirements includes a number of investigations, from various parts of the world, of nitrogen balance in infants and children, in each of whom a series of different protein intakes was studied [5–13]. For each individual a straight line relating the nitrogen balance to the protein (as nitrogen) intake was plotted and expressed mathematically as the intercept (on the intake axis) and the gradient. The intercept is the amount of nitrogen intake that is required to balance the nitrogen losses (i.e. maintenance), and the gradient of the line is the efficiency of the utilization of dietary nitrogen. In reality, and as illustrated in figure 1, the scatter of points is usually large, so that calculation of the requirement for an individual from their own data would be subject to considerable error. Hence, in practice the data from all of the published studies in which nitrogen balance was determined in children at various levels of nitrogen intake have been utilized. Ten studies of nitrogen balance in children have been published, and analysis has been performed to determine the average values for the parameters of the line [2–4]. These are conveniently expressed as the value for maintenance (i.e. when nitrogen balance is zero and there is no growth), and the gradient which expresses the efficiency of utilization of dietary protein for growth. The requirement can then be calculated for any target rate of growth, as maintenance + (rate of protein deposition × efficiency).

The analysis included 10 studies with measurements on 53 individual subjects, varying in age between 9 months and 14 years, over a range of dietary protein intakes. In addition, there were 4 more studies that only determined the basal loss of nitrogen, i.e. the nitrogen excretion when a protein-free diet is given. When all studies were included in the analysis, the value for maintenance would be...
was 110 mg nitrogen/kg/day (0.687 g protein/kg/day) and the slope was 0.58. However, when those studies that included only animal protein (milk and egg) in the diets were used in the analysis, the maintenance value was 93 mg nitrogen/kg/day (0.58 g protein/kg/day) and the slope was 0.66.

In order to use the data from the analysis of nitrogen balance vs. nitrogen intake for determining the protein requirements of infants or children, it is also necessary to know the rate of protein deposition (i.e. growth) at each age. The following therefore describes the methods that have been used to determine age-specific rates of growth and protein deposition.

### Rates of Protein Deposition in Infants and Children

In the analysis of the protein requirement of infants by Dewey et al. [4], the rate of growth of body mass, adjusted for the percentage of deposition as fat from the data of Fomon et al. [7], was employed to estimate the growth of protein mass. The potential errors in this assessment have been discussed in detail, as well as their impact on the recommendations. More recently, there have been more direct determinations of the rate of gain of protein mass in infants and children by measurements of total body potassium, which can be used to calculate total body protein content [14]. Butte et al. [14] assessed total body potassium in infants longitudinally from 2 weeks to 2 years of age, whereas Ellis et al. [15] made cross-sectional measurements in children from 4 to 18 years. These studies provide the most comprehensive data set so far of protein growth in children, and have been used by the DRI [2] and WHO/FAO [3] committees in their determinations of children’s protein requirement. However, because the data for the two age ranges were collected differently (cross-sectional for ages 0–2 vs. longitudinal for ages 4–18), and no measurements were made between ages

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**Fig. 1.** Simulated nitrogen balance data.
2 and 4 years, the calculation is not straightforward. The DRI committee took the mean values for total body protein at each age over the full age range, 2 weeks to 18 years, and used nonlinear regression to derive a fourth-order polynomial function for age vs. protein content. This equation was then differentiated, enabling the gradient of the curve, which is the growth rate, to be calculated for any chosen age. This approach, although theoretically sound, has several drawbacks. The first is that it did not take advantage of the longitudinal nature of the data on each individual infant during the first 2 years, and second, it was not possible to derive the SD of growth (needed to calculate the recommended daily allowance/safe level) from the curves. A single value of 43%, derived from the data of Butte et al. [14], was employed. Subsequently, the WHO/FAO Committee employed more sophisticated curve-fitting techniques to derive the growth rates. In particular, the SDs of growth rates were calculated by the following procedure: (1) for the first 2 years, each infant’s data were fitted to a polynomial function, so that growth rates at any age in the range could be calculated for each infant, and the mean value and the SD were determined; (2) for the ages 4–18 years the mean values for body protein were fitted to a polynomial function to obtain the mean rate of growth at any age; (3) a separate function was used to bridge the gap in experimental data between 2 and 4 years, and (4) because the cross-sectional data between 4 and 18 years did not allow calculation of the between individual SD for the rate of protein growth, values from a separate longitudinal database on growth of body weight of children [16] were used to calculate the between individual SD of the body growth rate at each age. This was then adjusted for the proportion of body weight that is protein, using the total body potassium data. By this process, it was possible to calculate the rate of growth plus its SD at each age. A subset of these values is shown in table 1.

### Table 1. Protein deposition for infants and children

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Protein deposition, g protein/kg/day</th>
<th>Females</th>
<th>Males</th>
<th>SDb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5c</td>
<td>0.266</td>
<td>0.266</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td>1.0c</td>
<td>0.168</td>
<td>0.168</td>
<td>0.031</td>
<td></td>
</tr>
<tr>
<td>1.5c</td>
<td>0.108</td>
<td>0.108</td>
<td>0.029</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>0.076</td>
<td>0.073</td>
<td>0.026</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>0.044</td>
<td>0.034</td>
<td>0.022</td>
<td></td>
</tr>
<tr>
<td>4–5</td>
<td>0.024</td>
<td>0.011</td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>6–10</td>
<td>0.047</td>
<td>0.049</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>11–15</td>
<td>0.031</td>
<td>0.041</td>
<td>0.017</td>
<td></td>
</tr>
<tr>
<td>16–18</td>
<td>0.009</td>
<td>0.023</td>
<td>0.008</td>
<td></td>
</tr>
</tbody>
</table>

aDerived from Butte et al. [15] and Ellis et al. [16] (see text).
bSee text.
cBefore age 3, data for males and females were pooled.
In table 1, the selected age ranges are chosen because they represent phases of faster or slower growth. Growth is very rapid at 6 months of age, but declines quickly until the end of the 5th year. There is then an acceleration in growth in both genders between 6 and 10 years, declining somewhat between 11 and 15 years. By 16 years, growth has almost ceased in females, but continues at a relatively slow rate for a further 3 years in males.

**Determination of Protein Requirements for Infants and Children**

**Infants**

Various groups have concluded that for infants up to age 6 months, breast milk is the best source of nutrition [2–4]. Thus, the recommended intakes have been modeled on the intake of milk by healthy breastfed infants [2]. Dewey et al. [4] compared the intake of milk with the requirement calculated by the factorial method, on the basis that the calculated requirement should not be greater than the intake. However, this comparison is complicated by the fact that human milk contains about 25% of nitrogen that is not in protein. Some of this non-protein nitrogen (NPN) is in the form of free amino acids, which would be utilized as if it were protein, but a substantial part of the NPN consists of urea and other compounds that might not be utilized as well as protein. It is therefore of interest to examine how the requirement for infants predicted by the factorial approach compares with the actual intake of milk protein and NPN.

For the factorial calculation, the values for maintenance and efficiency of utilization of dietary protein are those derived from the analysis of nitrogen balance in children described earlier. In particular, it is most appropriate to use the values that are derived from children consuming only animal protein, mostly from milk and eggs. For these children the value for maintenance was 0.58 g protein/kg/day and the slope (efficiency) was 0.66. Table 2 shows the details of the factorial calculation for the 6-month-old infant.

With the above derivation it is also possible to calculate the prevalence of inadequacy by relating the mean values and the SDs for requirement and intake using the unit normal distribution [1, 3]. This indicates a prevalence of inadequacy in the above example of about 15%.

It can be seen from the calculation that the predicted safe level of intake is intermediate between the intake of milk protein and the intake of milk nitrogen, suggesting that unless some infants are receiving less than their requirements, some of the NPN must be utilized. Alternatively, there is the possibility that the efficiency of utilization of dietary protein employed in the calculation is too low for infants at this age, giving rise to an apparent requirement that is too high. In practice it may be better to produce a requirement value that is on the high side (i.e. conservative) as the alternative, to have a value that is too low, might place some infants at risk of receiving too little protein.
Children Aged 6 Months to 18 Years

The procedure for calculating the average requirement and safe level for children follows the same procedure as that for infants, with the exception that different values have been used for the maintenance and efficiency of utilization. As these children will no longer be relying on breast milk, it is assumed that they will be taking a mixed diet from normal food. Therefore, in selecting the appropriate values for maintenance and the efficiency of utilization

Table 2. Factorial calculation of the protein requirements of the 6-month-old infant compared with total nitrogen and milk protein intake

<table>
<thead>
<tr>
<th>Body weight, kg</th>
<th>7.54</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total nitrogen intake, g/kg/day</td>
<td>14.9</td>
</tr>
<tr>
<td>Crude protein intake (nitrogen × 6.38), g/kg/day</td>
<td>1.26</td>
</tr>
<tr>
<td>Milk protein intake (crude intake × 0.75), g/kg/day</td>
<td>0.94</td>
</tr>
<tr>
<td>Maintenance requirement, g/kg/day</td>
<td>0.58</td>
</tr>
<tr>
<td>Growth rate, g/kg/day</td>
<td>0.266</td>
</tr>
<tr>
<td>Efficiency of utilization</td>
<td>0.66</td>
</tr>
<tr>
<td>Requirement for growth (growth/efficiency), g/kg/day</td>
<td>0.40</td>
</tr>
<tr>
<td>Average requirement (maintenance plus growth/efficiency), g/kg/day</td>
<td>0.98</td>
</tr>
<tr>
<td>Safe level of intake (average plus 2 × SD)a, g/kg/day</td>
<td>1.14</td>
</tr>
</tbody>
</table>

aThe SD of growth of protein is taken from table 1, and the SD of maintenance is assumed to be the same as the SD for maintenance in adults, i.e. 12%, derived from a meta-analysis of data from nitrogen balance studies in adults [17]. The combined SD is given by the expression \(\sqrt{(SD1^2 + SD2^2)}\).

Table 3. Average requirement and safe level of protein intake (g protein/kg body weight/day) for weaned infants and children up to 10 years of age

<table>
<thead>
<tr>
<th>Age years</th>
<th>Maintenance requirement</th>
<th>Growth requirement</th>
<th>Average requirement</th>
<th>Safe levelc (+1.96 SD)</th>
<th>1985 committee</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.66</td>
<td>0.266</td>
<td>1.12</td>
<td>1.43</td>
<td>1.75</td>
</tr>
<tr>
<td>1</td>
<td>0.66</td>
<td>0.168</td>
<td>0.95</td>
<td>1.18</td>
<td>1.37</td>
</tr>
<tr>
<td>1.5</td>
<td>0.66</td>
<td>0.108</td>
<td>0.85</td>
<td>1.04</td>
<td>1.23</td>
</tr>
<tr>
<td>2</td>
<td>0.66</td>
<td>0.075</td>
<td>0.79</td>
<td>0.96</td>
<td>1.14</td>
</tr>
<tr>
<td>3</td>
<td>0.66</td>
<td>0.039</td>
<td>0.73</td>
<td>0.90</td>
<td>1.11</td>
</tr>
<tr>
<td>4–5</td>
<td>0.66</td>
<td>0.018</td>
<td>0.69</td>
<td>0.86</td>
<td>1.06</td>
</tr>
<tr>
<td>6–10</td>
<td>0.66</td>
<td>0.048</td>
<td>0.74</td>
<td>0.91</td>
<td>1.00</td>
</tr>
</tbody>
</table>

aDerived from the regression of nitrogen balance against intake in adults [17]: see text.
bFrom table 1, adjusted for 58% efficiency of utilization derived from the regression analysis of nitrogen balance in children.
cSD for maintenance based on a CV of 12% in adults [17]: SD for growth calculated from SD of deposition in table 1/0.58(efficiency of utilization). SDs for maintenance and growth are calculated as described in the text.
from the analysis of nitrogen balance studies in children described above, values for all children, including those taking mixed diets, have been used. This is appropriate, as children older than 6 months will progressively be consuming diets with a wide range of constituents of both animal and plant origin. However, in view of the close similarity of the value for maintenance in children (0.68) with the value derived from a much larger data set in adults (0.66), the adult value was also used for maintenance in children.

**Conclusions**

The protein requirement of the 6-month-old infant is 75% higher than in the adult due to the dominance of the requirement for growth. However, growth slows rapidly over the first 2 years of life, at which time the protein requirement is less than 20% higher than that of the adult. The new values for children are about 25% higher than those derived 20 years ago by FAO/WHO/UNU [1], but for teenagers the difference is much less apparent. The differences are mostly the result of more sophisticated statistical analysis of the data, as well as the new techniques of body composition measurement (total body potassium), which have enabled the growth of protein mass in children and its variability to be evaluated more accurately.

**References**


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**Table 4.** Safe level of protein intake (g protein/kg body weight/day) for adolescent girls and boys

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Maintenance</th>
<th>Growth</th>
<th>Average requirement</th>
<th>Safe level (+1.96 SD)</th>
<th>1985 Committee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11–15</td>
<td>0.66</td>
<td>0.03</td>
<td>0.71</td>
<td>0.88</td>
<td>0.94</td>
</tr>
<tr>
<td>16–18</td>
<td>0.66</td>
<td>0.01</td>
<td>0.67</td>
<td>0.83</td>
<td>0.83</td>
</tr>
<tr>
<td>Boys</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11–15</td>
<td>0.66</td>
<td>0.04</td>
<td>0.73</td>
<td>0.90</td>
<td>0.98</td>
</tr>
<tr>
<td>16–18</td>
<td>0.66</td>
<td>0.02</td>
<td>0.70</td>
<td>0.86</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Calculations and notes as in table 3.
Protein Requirements of Infants and Children

12 Intengan CLI: Protein requirements of Filipino children 20 to 29 months old consuming local diets; in Rand WM, Uauy R, Scrimshaw NS (eds): Protein-Energy Requirement Studies in Developing Countries: Results of International Research. Tokyo, United Nations University, 1984, pp 258–264.

Discussion

Dr. Penncharz: Something I would like everyone to appreciate is that the late Peter Reeds worked on this a great deal, and a lot of the work Dr. Garlick has presented, and has worked very hard on, was worked on first by Peter Reeds as well as Nancy Butte. The one thing that is also a new and which you didn't emphasize was the work by Butte and Ellis. I mean the maintenance components are really reworking of existing data, but the growth data are much more sophisticated from Beila and Butte.

Dr. Koletzeko: You discussed the question of maintenance requirements and the standard deviation (SD) and pointed out that there might be some limitations in the statistical approach you used, but basically you are confident with the assumption that maintenance requirement and SD for adults can be used for infants and children as well. I wonder whether we should take into account that there might be differences. One factor that could probably contribute is the intestinal physiology. I am not sure how large the contribution of intestinal cell turnover and shedding is to the total maintenance requirement. I would assume that there might well be a difference between
infants and young children and adults if you consider intestinal cell mass to total body size, if you think about cell turnover in the intestine, and also if you consider that it is almost intrinsic to young age, to preschool age and toddler age to have enteric infection. It is a sort of physiological phenomenon to have frequent intestinal infection which of course will enhance the intestinal cell turnover even more, particularly if you think about less privileged populations. So my question simply is, do we need to put a caveat in that assumption? I was noting that you assume 75% non-protein nitrogen utilization in 3- to 4-month-old infants. My question here is how good are the data that we can base this on, both for breastfed and formula-fed infants? In formula-fed infants we usually assume much less than 50% non-protein nitrogen utilization. Can you comment on that, on how good databases are?

**Dr. Garlick:** Firstly the non-protein nitrogen utilization is a chemical point, as to how much of the milk nitrogen is not protein. We assumed about 75% just as an example to see how much of that would have to be used by making that assumption. Obviously it is going to be somewhat variable, but those are the figures in the literature, the approximate percentage. We are not trying to claim this is the requirement for infants of that age. That wasn't the reason for the exercise. The reason was to see if by making these assumptions, do we get a requirement which is consistent with their intake, which is obviously what is needed. If it had been inconsistent we would have had to alter the calculation in some way to try and make it consistent. So we are not trying to claim this is the requirement for children of that age, it is merely a check on the numbers we are getting.

**Dr. Koletzko:** Are the maintenance requirement and SD for adults appropriate for infants and young children, specifically considering differences in intestinal physiology?

**Dr. Garlick:** It is only a small assumption really because the data that came from children for the maintenance was 0.68. We chose 0.66 because simply they are so close that they are not statistically significantly different. So we used 0.66 simply because the adult data have a much larger number of subjects. Statistically I don't think it is a bad assumption to make.

**Dr. Dewey:** You mentioned that the studies used were on children between 9 months and 14 years of age, and my recollection is that there were very few studies of children under 12 months, perhaps one or two. So I think that question is still very important. We just don't have enough nitrogen balance data for children under 12 months, especially healthy children living in a normal environment. Many of the earlier studies were from malnourished recovering infants who were confined to their beds and not active. So it is questionable whether to use those data. There were some earlier studies by Dr. Fomon and his colleagues on nitrogen balance in healthy young infants under 6 months of age that showed a quite low basal nitrogen requirement. Were you able to use that information in trying to assess this? The reason I bring it up is that in the 1995 calculations that we did with the factorial approach, we used that information and came up with lower levels of requirements than you have shown here for infants, which meant that the utilization of non-protein nitrogen did not have to be anywhere nearly as high as 75%, it was more in the order of 30% or so as I recall.

**Dr. Garlick:** There is an almost complete absence of really good nitrogen balance data in small infants. I looked at Fomon's data, tried to plot graphs and curves from them and get some idea of the reliability of the numbers, and they were so variable that we decided not to use them. The other reason was if we had been using these data for older children then we would have had to include these data obviously, but we weren't producing a requirement for children below 6 months of age, it was the real thing. Neither the IOM nor WHO are dealing with children of that age group who they say should be breastfed. So in other words the recommendations we are producing are only for children 6 months and older.
**Dr. Hilmanto:** Can you give a reason or equation why total body potassium can be used to calculate the total body protein? If we look at the last table, the safe level is about 1.2 times the average requirement, but in the introduction you mentioned that the safe level is about 2 times the average.

**Dr. Garlick:** On the second point, if I said it was above 2 times I was wrong; the safe level is the average requirement plus 2 times the SD, which usually comes to about 25% higher than the average requirement. About the total body potassium in relation to protein, there is a relationship between the potassium content of lean tissue and the protein content of lean tissue that enables the calculation. I think it will be better if Dr. Butte answers that question in more detail because they are her data.

**Dr. Butte:** There is a constant relationship between the potassium to nitrogen ratio, and it does change with growth and the actual value that we used was 2.15. This is the same value that was used in the reference infant that Dr. Fomon and Dr. Ziegler had taken to look at body composition of infants. At the time we applied it, I did search the animal literature trying to see how confident we are of that ratio. It does change with growth and there are values that are different during pregnancy in adult animals and such, but I really could not come up with anything better than what Dr. Fomon and Dr. Ziegler used many years ago. So that is the value we used.

**Dr. Ziegler:** Most of the protein in the body is intracellular, and almost all of the potassium is intracellular, and therefore the ratio of potassium to protein is quite constant. That is the basis for estimating the protein content by determining total body potassium.

**Dr. Do Van Dung:** You gave us a new approach in the calculation of nutritional requirements. Because I work mostly in the methodology of nutrition I would like to raise some questions on your methodology and especially your assumption. First I would like to challenge your assumption on the regression of the nitrogen composition on nitrogen intake because we think that if we have a low nitrogen intake the deposition efficiency will be increased and if you have more nitrogen intake you will waste a lot of nitrogen. Therefore I wonder why you use the linear regression model. The second question concerns the graph from the study by Ellis et al. [1] on body composition and I would like to know why there are some negative values in that chart? The last question, you said that the distribution of the nitrogen requirement is not normal and I wonder why you used a rather complicated formula and you admit that it is not particularly correct. Why don't you use the percentile instead of using the mean value plus 2 times the SD. You said that the SD of the estimated average requirement is equal to the square of SD for maintenance plus the square of SD for growth. Is the formula correct if the two variables are independent, that means when the maintenance and growth are independent?

**Dr. Garlick:** As I said previously, the data are limited. We don't have sufficient data to be able to do any perfect calculations. We just have to make do with what we have. You can see from the actual distribution of data that it isn't normal. We satisfy ourselves that by making it into log normal then at least we can calculate the reasonably correct safe level, and I think that is a sound way of doing it. So statistically I don't think we really have a problem with that, we are just finding a different way of calculating the 97.5 or 98th percentile, that is all. The assumption that the maintenance for the children is the same as the average requirement for the adult, the average numbers are almost the same, so I don't think there is any problem there.

**Dr. Do Van Dung:** Why do you use linear regression?

**Dr. Garlick:** That is the way the data are. You cannot statistically show any difference from linearity. We have no basis to assume any other relationship. If the data suggested a curve then we would have to use the curve, but it doesn't. The data show it to be pretty linear. So statistically one always starts with the simplest model and proves it wrong and before moving to a more complex one. In this case we could not prove that the simple linear model was not valid.
Dr. van Goudevoer: Protein deposition is basically based upon the availability of the most limiting amino acid. I think that the quality of milk proteins around the world is rather standard, but whenever you go up into higher ages the intake of proteins differs and also the quality of the proteins that you eat is different. So are you justifying making recommendations on a whole protein intake level, whereas the quality of that protein might differ quite substantially?

Dr. Garlick: The assumption throughout the calculation, which I should have stated, was that it is high quality protein. This is the requirement for high quality protein. If we are dealing with populations who typically have diets that consist of lower quality protein, that has to be allowed for in the calculation.

Dr. Rigo: As you show there is a gap in the data of protein accretion between 2 and 4 years. So you make the assumption that we can calculate the protein accretion according to the data that we obtain before and after with an extrapolation of the polynomial data. If we look at your data you suggest that protein accretion during this period between 2 and 4 years of age was lower than before and after. Do you think that your extrapolation was correct or not? If we look at the curve of growth velocity between birth and adolescence, it does not show this decrease between 2 and 4 years of life.

Dr. Garlick: I didn’t emphasize this because it gets too complicated to explain. But the actual body weight of children was used in the interpretation of those data, which were not from Dr. Butte or Ellis. Separate standard curves for growth were used to construct that bridging function. So I think it does take account of the actual growth.

Dr. Rigo: How do you explain that the protein accretion was lower at that period of time?

Dr. Garlick: I am showing rates of protein accretion, so they slow down slightly and then speed up again. That would not be seen unless you plot the actual rates of growth, the gradients of the growth curve.

Dr. Axelsson: I know it is a very hard work to make recommendations. We have many recommendations. What are the consequences of the new recommendations? Is it possible to follow them because when intake is calculated, even if milk and egg proteins are considered, it is very difficult. What are the practical consequences of the new recommendations to make diets consistent to this?

Dr. Garlick: They are slightly lower for children than the previous recommendations.

Dr. Axelsson: But still we have problems to follow them; even the recommendations we have today are difficult to follow in practice. If you calculate the intake of a child or an infant and then look at the intake and the requirement, there is a big difference. The intake is much higher than the requirements.

Dr. Garlick: The reason for that is that we are in a society which has ample food. For many areas of the world that would not be the case. The children will be eating a much lower protein content in relation to energy, and they are getting less than the requirements. The total intake is usually determined by energy intake.

Dr. Yates: One of the reasons, although the protein might be higher, is that there are other nutrients that a food-based diet would be providing and that might not be met even where there are high levels of protein consumed. If you are talking about a formula that is one thing, if you are talking about food-based diets it would be different.

Reference