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Protein and Energy Requirements – Insights from Long-term Studies

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There is intense interest in the estimation of human protein and energy requirements. It is obviously an important issue, since decisions on allocation of national food resources, agricultural goals, design of feeding and other welfare programmes, and recommended diets depend to an important degree on estimated protein and energy requirements.

There is general agreement about the procedures that should be used to estimate the approximate magnitude of these requirements for populations. These procedures are, however, questioned by Sukhatme, who maintains that requirements for both energy and protein have been consistently and significantly overestimated by current technologies of short-term studies. In a series of papers (P.V. Sukhatme and S. Margen, *Am. J. Clin. Nutr.* 35: 355, 1982; *Am. J. Clin. Nutr.* 31: 1237, 1978), Sukhatme and his colleagues develop the hypothesis that individuals can "adapt" to different levels of intake, especially to intakes lower than those predicted by short-term studies. *Our own analysis of more extensive data has led us to the opposite conclusion.*

Arguments of Sukhatme

The most significant claim of Sukhatme and his colleagues is that individuals can lower their requirements for protein and energy without compromising their "health". To appraise the validity of this conclusion, it is necessary to examine the three key steps of their argument.

First: It is stated that the indicators of requirement are "autocorrelated". For protein requirements the usual indicator is daily nitrogen balance or daily nitrogen excretion. Positive autocorrelation arises when indicators collected on successive days over a period of time are closer in value than those collected on days that are some time apart.

Autocorrelation in time series data can result from a number of phenomena, ranging from variations in the mean of the underlying process, such as slow trends, or alternatively, brief, violent perturbations, to a complex error structure inherent in the way the data are generated. Sukhatme feels he has discovered a complex error structure in nitrogen balance data, the existence and magnitude of which lie at the foundation of his arguments. Sukhatme states that nitrogen balance is *inherently* "autocorrelated", and for him this implies that protein requirement is "regulated" (see below). Further, Sukhatme feels that the autocorrelation he has found manifests itself in variations in an individual's requirement that are large when compared to short-term variability and measurement error. Therefore, short-term observations are not likely to be representative of the situation. Our findings, summarised below, suggest that the autocorrelations that are often found in the data are *not* due to a complex error structure, but to changes in the mean requirement, and that these changes are *not* significant compared to measurement error.

Second: It is stated that autocorrelation implies "regulation" of requirements. Sukhatme never defines precisely what he means by regulation other than to state that it is a consequence of autocorrelation. If this merely says that the body's requirements vary with circumstances over time, this is well recognised. For example, stress increases nitrogen losses and therefore requirements.

If the suggestion is that individuals on either a low protein or a low calorie intake will reduce their losses and hence their requirements over time, this is a well known characteristic of individuals who are slowly wasting away and who will eventually die if their intake is not increased. If both protein and calories are low, deterioration will simply proceed more quickly.

Sukhatme and his colleagues seem to be labelling as "regulation" the changes that are usually considered to be physiological or pathological responses to varying external and internal stimuli. The imprecision of the language in which this argument is couched precludes either its further refutation or validation.

Third: The next argument is that regulation implies that the body can modify its requirements in response to different levels of intake. The argument seems to follow the line that, because the nitrogen output of individuals on constant intake varies, these individuals could adjust their requirements to the lower level of variation without detriment. We not only see no logical reason to assert this and no data to support it, but also feel that quite the reverse may be true. If an individual's requirement varies over time, would he not need to be assured the highest level that he required rather than the lowest? We consider that the observation that stimulated Sukhatme's original argument — the variability of the data for single individuals over time — has rather been a factor in the *underestimation* of protein requirements for the reasons described below.

The Current Approach to Protein Requirement Estimation

The current approach to estimating protein requirement is to determine the responses of a select number of individuals to a range of intakes and interpolate from this the minimum amount that should be sufficient to just maintain them in balance. Strict confirmation of these estimates

would require feeding this level for a time sufficiently long to prove its adequacy. This has been done in United Nations University-sponsored research (W.M. Rand, The United Nations University *Food and Nutrition Bulletin* Supplement 10, 1984: W.M. Rand, N.S. Scrimshaw, and V.R. Young, *Am. J. Clin. Nutr.* 32: 1408, 1979), and the results suggest, although not conclusively, that the levels predicted by the multi-level, short-term data may be too low.

To test the alternative hypothesis of Sukhatme, that these levels are too high, it would be necessary to feed a lesser amount for a comparable period and determine whether it is sufficient to maintain health in the expected proportion of subjects. While he cites one study of this kind (N. Durkin, D.A. Ogar, S.G. Tilve, and S. Margen, The United Nations University *Food and Nutrition Bulletin* Supplement 10,1984), the fact that most of the subjects lost weight throughout this study makes its interpretation questionable.

The lack of evidence to support Sukhatme's views, and the imprecision with which they have been articulated, make it important to clarify the basis for the FAO/WHO/UNU Expert Consultation approach to requirements. The protein requirement of an individual can be identified as consisting of three components:

1. A fixed amount that is a function of the size, body composition, sex, and age of the specific individual.
2. An amount that varies over the long term (on the order of weeks or months), reflecting the metabolic state of the individual in response to physiological, pathological, and psychological factors.
3. A component that reflects short-term (on the order of less than a day) biological variability. To an observer, this component is compounded by methodological and analytical variability. This term is random and uncorrelated from day to day within any specific individual.

Given this model of protein requirement, it is obvious, in order to use short-term data for the estimation of requirement, that an additional assumption must be made: that the long-term variability (2.above) is small compared to daily variability (3.above). Any investigation of this model must address this assumption, as well as ask whether daily variability is random, after long-term variability is removed.

Our Analysis

We have analysed the data of 42 individuals participating in six different studies for periods of two to three months. These studies have all been individually published and the data have been previously summarised and discussed by us (W.M. Rand, N.S. Scrimshaw, and V.R. Young, *Am. J. Clin. Nutr.* 32: 1408, 1979). Examination of these data enabled us to quantify changes over time associated with environmental effects, to ascertain whether correction for these trends leaves only the random error expected, and finally to measure the relative contributions of these effects. A further exposition is currently being prepared, elaborating the issues in more detail.

1. Examination of the *raw* data suggests significant serial autocorrelation as defined by Sukhatme et al. in 19 of 42 subjects. Correction of the data for variations in weight and creatinine excretion as a measure of urine collection errors reduces the number of cases of serial correlation to 17.
2. The removal of *long-term trends*, however, reduces the number of subjects with serial autocorrelation as defined by Sukhatme et al. to four. Moreover, in these four the autocorrelation was produced by obvious, large *short-term disturbances*, not phenomena sustained over the entire study period as Sukhatme postulates.
3. Comparison of the variability of the data before and after the removal of trends permits estimation of how much each of the components of variation contributes. It turns out that, on average, for all individuals almost 90% of the variation is ascribable to random day-to-day fluctuations. Only 10% is ascribable to the kinds of long-term variations that give rise to serial correlations.

These results lead quite unequivocally to the conclusion that the imprecision introduced into requirement estimates by long-term fluctuations that produce autocorrelations in the observed indicators is minimal and probably negligible. Further, there is no basis for concluding that this variability should lead to a reduction in requirement estimates, since the body needs sufficient protein and dietary energy to cover these variations.

It is in this latter aspect that the suggestions of Sukhatme et al. are misleading. Their findings of serial correlations in some subjects merely reflects changing requirements of the body in response to stress caused by various environmental and host factors. Most importantly, we conclude that Sukhatme et al. have the interpretation backwards when they suggest reducing the requirement estimate because of such fluctuations. To the extent that they represent metabolic variability, they represent real needs, and requirement estimates need to take them into account. Thus, our analyses support the current procedures for estimating protein requirements by short-term nitrogen balance studies.

Implications for Dietary Energy Needs

The above discussion focuses on protein requirement, where some good data are available and where balance can be well estimated. However, when we turn to energy, the situation becomes much more complex, in part because energy can be stored, and in part because energy costs of activity are so difficult to estimate. Thus, energy balance is hard to calculate. For these reasons, there is dearth of good data with which to explore autocorrelation in energy requirement. In this absence, Sukhatme et al. extrapolate from their interpretation of the protein situation to propose that energy is similarly managed by the body. Since we find no justification for their conclusions with respect to protein requirement, we must also reject their views on energy that are based on the same argument and not on primary data.

In addition, there is an interaction between protein and calorie adequacy. Within limits, excess calories spare protein and deficient calories result in increased loss of protein from the body (G.Inoue, Y. Fugita, and Y. Niiyama, *J. Nutr.* 103: 1673, 1973; D.H. Calloway, *J. Nutr.* 105: 914, 1975; C. Garza, N.S. Scrimshaw, and V.R. Young, *Am. J. Clin. Nutr.* 29: 280, 1976). There is little or no correlation, however, between the requirements of an *individual* for calories and protein relative to the mean requirement of a *population* (G.H. Beaton and L.D. Swiss, *Am. J. Clin. Nutr.* 27: 485, 1974). Sukhatme's suggestions that individuals can adapt to the lower end of the distribution curve for both is inherently dangerous for most of the population.

There are further social dangers in the Sukhatme argument that most persons in underprivileged populations have successfully "adapted" to intakes of calories that are less than requirements as currently estimated. The principal adaptation to low energy intakes is reduced physical activity. For adults this may progress as far as minimum energy expenditure for eating and personal hygiene, with little or no social or economic activity. For children it may mean so little interaction with their environment that cognitive development is impaired. Any country that accepts with complacence such "adaptation" on the part of a portion of its population is likely to suffer serious long-term consequences.

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