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METHODOLOGICAL ISSUES IN THE ESTIMATION OF THE PREVALENCE OF UNDERNOURISHMENT BASED ON DIETARY ENERGY CONSUMPTION DATA: A REVIEW AND CLARIFICATION

Loganaden Naiken

Food and Agriculture Organization of the United Nations

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Methodological issues in the estimation of the prevalence of undernourishment based on dietary energy consumption data: A review and clarification

By Loganaden Naiken[1]

Abstract:

Sukhatme had in the early 1960's originally formulated the estimate of the proportion of undernourished in a population (*PU*) within a bivariate distribution framework where dietary energy consumption (DEC) and dietary energy requirement (DER) are considered as random variables. However, in the absence of data on DEC and DER of individuals expressed in the form of bivariate distribution, Sukhatme had suggested a formula that considers the part of the distribution of DEC below a cut-off point representing the lower limit of the distribution of DER as an estimate of *PU*. However, this univariate approach has been criticised as yielding an underestimate of the magnitude of the prevalence undernourishment in a population. In response to this critic, Sukhatme has attempted to justify the approach by invoking the theory of intra-individual changes in DER. As this theory has led to a controversy rather than a clarification of the univariate approach, doubts regarding its validity still prevail. Following a review of these developments including the concept of DER, this article shows that the formulation of *PU* within the bivariate distribution framework is inappropriate. Subsequently, the relevance of the univariate approach is clarified. Finally, the article addresses certain issues relating to practical estimation of the prevalence measures based on household rather than individual data pertaining to DEC.

Keywords: **adequately nourishment; dietary energy requirement (DER); undernourishment; dietary energy consumption (DEC); depth of undernourishment; index of food security; over-nourishment.**

[1] Former Chief, Statistical Analysis Service, Statistics Division, Food and Agricultural Organization, Rome. E-mail: logan.naiken@intnet.mu

1. Background and Introduction

FAO has been traditionally estimating the prevalence of undernourishment in a population (*PU*) on the basis of observed food energy consumption or intake data, i.e. dietary energy consumption (DEC), and normatively specified dietery energy reference intake, i.e. dietary energy requirement (DER). In this context, both DEC and DER are expressed in terms of number of kilocalories (kcal) per individual/day and adequate nourishment is defined as the state whereby an individual's observed DEC matches his or her DER, i.e. DEC=DER. Consequently undernourishment and over-nourishment refer to DEC<DER and DEC>DER respectively. Thus the prevalence of undernourishment, refers to the proportion of individuals with DEC<DER. This measure, which is considered to be as an indicator of food insecurity, has been adopted by the UN as one of the indicators for tracking the Millennium Development Goals.

The approach of measuring undernourishment on the basis of food expressed in terms of dietary energy (kcal) alone is justified from two perspectives. Firstly, a certain amount of dietary energy is essential for the maintenance of the body-weight and work performance of an individual. Secondly, an increased amount of dietary energy, if derived from normal staple foods, brings with it more protein and other nutrients as well, while raising the latter, without ensuring a certain amount of dietary energy, is unlikely to be of much benefit in terms of meeting food needs. In other words, dietary energy is an appropriate measure of the amount of food consumed by individuals. The distinction between the measure of undernourishment based on food and those based on anthropometric indices such as weight-for age, weight-for-height, height-for-age and body mass index (BMI) is that while the former reflects the phenomenon food deprivation or hunger per se, the latter reflect the physical consequences of both food deprivation and adverse health and environmental conditions.

The estimation of *PU* faces problems on the side of both DEC and DER. On the one hand, nationally representative data sets pertaining to observations of DEC at the individual level are practically nonexistent. On the other hand, DER is not an observed fact but a normatively derived measure that is subject to random variation. However, information on DEC corresponding to a sample of households from the population is derivable from the food consumption data collected in national consumption/expenditure surveys. Hence, assuming the availability of such data and information pertaining to the mean and standard deviation of DER, Sukhatme, while being the Director of the FAO Statistics Division, had attempted to estimate *PU* in connection with a paper presented at a joint meeting of the *Royal Statistical Society* and the *Nutrition Societies of London* (Sukhatme, 1961). The methodology, which implies the definition undernourishment as the state whereby an individual's DEC is below a minimum DER level has been adopted by FAO in preparing its's estimates pf the prevalence of undernourishment in the world. However, some aspects of the methodology, mainly

concerning the consideration of the random component of the variation in DER and the definition of undernourishment are still subject to debate and controversy. Certain issues arise also in deriving the estimate based on household rather than individual consumption data from sample surveys. All these issues raise doubts abount the validity of the methodology adopted by FAO. Therefore the aim of this paper is to clarify these issues and consequently justify the FAO approach.

The paper is divided into six main sections in addition to the present one. Section **2** reviews and clarifies the concept of DER and its variation. Section **3** refers to the statistical posed in attempting to estimate the prevalent of undernourishment. Section **4** introduces the probability distribution framework for estimating of *PU*, thus providing the opportunity to present the bivariate distribution formula that Sukhatme initially indicated as a mathematical expression for *PU* as well as the formula that he actually proposed and applied in the early 1960's (henceforth for convenience referred to as the "univariate distribution formula"). Section **5** discusses the criticism of the univariate distribution formula originally raised by Lörstad (1974) and includes a discussion of the theory of intra-individual variation in DER that Sukhatme later proposed in response to this criticism as well as the resulting controversy and belief in the superiority of the bivariate distribution formula. Section **6** clarifies the problem in the formulation of *PU* within the bivariate distribution framework, and subsequently explains the relevance of the univariate distribution framework which enables the derivation of not only *PU* but also the prevalence of adequate nourishment (*PA)* and over-nourishment (*PO*). Subsequently two additional measures relating to the nutritional situation status are presented. Section **7** discusses the approach regarding the estimation based on household DEC data from sample surveys data and in this connection clarifies an issue raised by an alternative approach proposed by researchers at the International Food Policy Research Institute (IFPRI). Section **8** concludes the paper and refers to the way forward.

2. The concept of DER and its variation

As DER is not an observed fact and the methodological issues being clarified in this article mainly concern the treatment of it's random variation in the estimation of *PU*, it is appropriate to begin with a review and clarification of this concept and its variation.

At the international level DER is derived according to principles established by expert groups on nutritional requirements. It actually refers to the dietary energy expenditure (DEE) needed by individuals in order to remain healthy and physically active. However, as according to the law of thermodynamics energy output must equal energy input, the past practice of the international expert groups on nutritional requirements was to base the DER on studies of DEC (energy input) corresponding to reference groups composed of apparently well

nourished individuals having fixed sex, age, and physical activity and body-weight (FAO, 1957 and FAO, 1973). However, because of the presence of random day-to-day variation in DEC, the daily DECs were averaged over a number days (a week) to reflect usual DEC and hence DER per individual/day.

However, even after averaging the daily energy intakes of each individual in the reference group over a number of days to reflect usual DEC, significant differences remained between the usual DECs of the individuals in the reference group. The variation in DER refers to these inter-individual differences. Widdowson (1947) had hypothetically attributed this variation among similar individuals to differences in the efficiency of energy utilization, i.e. some individuals metabolise energy more or less efficiently than others and hence need less or more energy as compared to others. However, the specified DER actually referred to the overall average DEC in the reference group with the dispersion around this average referring to the inter-individual differences.

Sex, age, body-weight and physical activity are factors that systematically affect the level of DER. Therefore, the practice of basing DER on the usual DEC of well-nourished individuals having fixed sex, age, body-weight and physical activity reflects an attempt to exclude the effects of these known systematic factors on the DER. As the effects of the systematic factors have been removed, it follows that the remaining inter-individual variation may be considered to be of random nature. Hence, if we assume the DER in a population, composed of individuals of the same sex, age body-weight and physical activity, to be normally distributed we may be express it as follows:

$$R = \mu_R + \epsilon \qquad \epsilon \approx N(0, \sigma^2_\epsilon) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

where μ_R is the specified average DER and ϵ is a random term which, according to Widdowson, represents the effect of the unknown efficiency of energy utilization

The sex-age specific average DERs recommended in the past by the international expert groups actually started with the specification of μ_R for individuals of the "reference man" and "reference woman" types. The reference man and woman referred to an adult male and female respectively in age group *20 – 29* living in a climate with mean annual temperature of 10^0 *C* with fixed body-weight (*65 kg*. for males and *55 kg.* for females) and performing moderate physical activity. By adjusting the averages for the "reference man" and "reference woman" to account for different states and situations such as growth in children, pregnancy and lactation for women in the reproductive age groups, age, climate etc, the averages for individuals in the other sex-age groups were obtained.

However, the practice of basing the DER on the usual DEC of reference groups composed of apparently well nourished individuals and specifying the averages for reference man and woman was reviewed by the *FAO/WHO/UNU Expert Consultation on Energy and Protein*

Requirement that met in 1981 (WHO, 1985). The Expert Consultation felt that this approach implied the assumption that the individuals' respective body-weights and physical activity levels were consistent with good health and productive activity but this might not have been so in reality. Moreover, basing the DER on the concepts of reference man and woman having fixed body-weight and physical activity (moderate) was considered to be too restrictive in a world where there is a wide range of body-size as well as physical activity level that are consistent with good health and productive physical activity among individuals in a given sex-age class.

In view of the above, the Expert Consultation introduced major changes in the definition and derivation of DER. The DER was thus defined as the "energy intake level that will balance energy expenditure when individuals have a body-size and physical activity level that are consistent with good health and that will allow for the maintenance of economically necessary and socially desirable physical activity". This definition clearly implied that "body-size and physical activity level that are consistent with good health and that will allow for the maintenance of economically necessary and socially desirable physical activity" became the basis for the derivation of DER. Moreover, it meant that the DER for individuals in a given sex-age class should be based on normatively specified body-weight and physical activity rather than the actual ones. Hence the Expert Consultation discontinued the approach based on the DEC of well nourished individuals and, instead, expressed DER in terms of the DEE needed to maintain normatively specified body-weight and physical activity. In line with this new approach, the Expert Consultation formalized the estimation of the DER by sex-age classes for adolescents and adults in terms of the DEE needed for maintaining normatively specified body-weight and a multiplying factor to account for the normatively specified physical activity level (referred to as the PAL index). However, for children the Expert Consultation was unable to make similar recommendations and hence provided sex-age specific average DERs based on the DEC of healthy and active children in the developed countries.

The *FAO/WHO/UNU Expert Consultation on Human Energy Requirements* that met in 2001 (FAO, 2004) consolidated the normatively derived DEE approach and extended it to