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Assessing Human Energy Requirements: Methodological and Lifestyle Considerations

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It is the mandate of UN organisations such as the FAO and WHO to provide a neutral forum for scientists, representing the wider interests of the global community, to meet and make recommendations on human nutrient requirements that are universally applicable. Recommendations for human nutrient requirements (that is, energy, protein and amino acids, vitamins and minerals) are essential for assessing whether food supplies are adequate to meet a population's nutritional needs. It enables identification of those who do not meet the requisite level of nutrients considered as adequate and thus helps provide an estimate of the numbers of the undernourished, worldwide. It helps governments to monitor nutrition programmes, plan development activities, and help plan for agriculture production and food supplies.

The first meeting of experts on nutrient requirements was held in FAO in 1948 and many of the recommendations made by this first committee on calorie requirements are still pertinent today. This includes the assertion that the recommended requirements for energy were intended for groups of persons rather than individuals and offered the practical rule of thumb that if the person 'is in good health and calorie balance, that is, neither over- nor under-weight, then he or she is consuming food according to his or her calorie requirements'[1]. Subsequent committees in addition recognised the importance of maintaining an adequate level of energy expenditure, thus acknowledging that the level of physical activity including recreational activities were important to the overall health status of people[2]. Later committees refined and revised these early basic concepts.

The Expert Consultation of 1981 was jointly organised by FAO, WHO and the UNU in Rome[3]. It concluded that sufficient information was available to use energy expenditure to determine energy requirements of adults and the use of the basal metabolic rate (BMR) for this purpose gained importance. One significant departure of the 1981 expert group was the rejection of the concept of a reference man or woman since the 1971 group defined such persons as "arbitrarily selected convenient starting points for extrapolation ... and ... not intended to suggest ideal standards"[4]. The 1981 group found this concept too restrictive and not reflective of the wide range of both body size and patterns of physical activity worldwide.

In 2001, an Expert Consultation on human energy requirements again met under the joint auspices of FAO, WHO and the UNU in Rome. This group of experts met after a lapse of nearly 20 years and deliberated only on the requirements of energy since requirements of proteins and amino acids had advanced to a stage that they were required to be debated independently.

METHODOLOGICAL CONSIDERATIONS

The 1985 report was very clear that estimates of energy requirements should, as far as possible, be based on estimates of energy expenditure, since the prevailing method of determination – from observed intakes of food energy – was becoming unreliable and at the same time served to support a circular argument that access to food determined energy needs. The rationale for this conclusion was that both in developing and developed countries actual energy intakes are not necessarily those that either maintain a desirable body weight or provide for optimal levels of physical activity and, hence, health in its broadest sense. When the Expert Consultation on Energy met in 2001, the situation related to the lack of data to arrive at realistic and evidence-based recommendations had dramatically changed. Major technological advances using stable isotopes had made a dramatic impact on the measurement of energy expenditures of free-living individuals in real-life situations. Estimates

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based on these new measurements had replaced, to a large extent, the estimates using both direct and indirect calorimetry and the associated dependent methodologies such as heart rate monitoring, activity monitoring, pedometres and actometres. As a result almost all the recommendations that are made in the most recent report to be published are based on reliable measurements of total energy expenditure (TEE) obtained from infants, children, adolescents, adults and the elderly, as well as in special physiological states such as pregnancy and lactation.

Doubly-labelled water technique: A major breakthrough in our ability to obtain reliable and accurate estimates of habitual TEE was the application of the doubly-labelled water (DLW) technique to humans under free-living conditions. The DLW method was extensively validated and is now considered to be the "gold standard" for the measurement of TEE of humans throughout the lifecycle. The DLW technique for measuring TEE involves enriching the water within the body with the use of water labelled with a stable isotope of hydrogen (that is, deuterium, ^{2}H) and a stable isotope of oxygen (that is, ^{18}O). Following the administration of such doubly-labelled water, the manner in which these two isotopes are differentially washed out of the body over time is determined. The difference in the rate of excretion or washout of the isotopes from the body is a measure of the amount of carbon dioxide (CO_2) produced over that period of time from which the oxygen consumption and hence energy expended over the same time period can be computed.

The methodology using the DLW technique involves the administration of carefully weighed doses of ^{18}O and deuterium to the subject followed by the collection of urine or saliva samples over time periods ranging from days to weeks depending on the rate at which the water moves through the body. For instance, in tropical climates, large amounts of water are consumed and excreted mostly as sweat, and hence the rate of movement or turnover of water is much higher. The samples are not radioactive, the stable isotopes do not decay over time and the samples are readily transportable as long as they are well sealed. These properties make it possible for specimens to be transported to countries where facilities exist to analyse the samples for isotopic enrichment. DLW thus has several advantages but it is important to recognise that the method also has limitations. The DLW technique is expensive as it requires the use of sophisticated equipment to estimate concentration of the isotope. In addition, there is a global shortage of ^{18}O, which has driven its price beyond the reach of most investigators.

The DLW technique of measuring TEE permits the determination of habitual free-living energy expenditure integrated over a period of days. Between 1982 and 1994 sufficient data on TEE in human subjects were accumulated to form the basis for its use in arriving at energy requirements. A database of 1,614 DLW measurements from 1,156 individuals (aged two to 90 years) was collated and comprehensively analysed in 1995[5]. The main analysis was made using a subset of 574 subjects for whom both TEEs by DLW and BMR measurements were available, under normal free-living conditions, although exclusively from subjects from affluent societies in the developed world. Three years after this compilation, it was estimated that the number of subjects on whom DLW measurements of TEE were available had tripled[6].

The expert consultation of 2001 benefited for the first time from this large database of actual estimates of TEE throughout the life course, from infancy to adulthood and the elderly, using the DLW technique from different regions of the world. However, the number of studies carried out using this technique in the developing countries was limited. A review by Coward[7] provided an analysis of DLW data from 12 published papers. Since then there have been more publications from the developing world although the lack of data from well-nourished individuals in the developing world is a serious issue. It is evident that more data need to be generated in a systematic way from the developing countries if DLW estimates of TEE are to be used as the basis for arriving at energy requirements of adults worldwide.

Implications of DLW measurements for the recent expert consultation: The DLW technique is an important technological advance that provided the 2001 Expert Consultation with the enormous database of TEE measurements needed to arrive at evidence-based recommendations for human energy requirements, from newborn infants to the very elderly, and to assess the increased physiological needs during pregnancy and lactation. This recent consultation reiterated very strongly that energy requirement estimates need to be based on measurements of energy expenditure and not intakes and that estimates of energy requirement refer to groups and not to the individual *per se*.

It also restated that the recommendations for energy requirements of individuals are the mean of the group with no safe margin as with other nutrients. Noting the importance of the data provided by DLW technique, the expert group recognised the limitations relative to the cost and availability of ^{18}O as well as lack of expertise and infrastructure to undertake DLW measurements, especially in developing countries, which needed to be addressed urgently. More effort to help developing countries with the DLW technology and other appropriate technologies was identified as a priority.

The 2001 consultation also made a strong plea that when DLW measurements are taken to assess TEE, information on the lifestyle and the pattern of activities over a day should also be recorded. The pattern and level of physical activities undertaken by individuals are important, given the reductions in levels of activity both in the occupational and social spheres of urbanised modern lifestyles. These increasingly sedentary lifestyles are contributing to the problem of obesity in developed industrialised countries and are now also appearing in developing societies, particularly in urban settings.

The data obtained by using the DLW method were considered a valuable resource for the estimation of the TEE of infants. Although this database was derived almost exclusively from studies in the developed world, the assumption that the requirements of infants for normal growth and development are the same worldwide provided the basis for energy recommendations for infants. Evidence had been emerging that the energy requirements of infants are lower than previously recommended, a view that was not supported by earlier consultations. However, evidence of TEE in infants based on DLW supported the view that energy requirements of infants needed to be lowered, as the 2001 consultation has now done.

CONCEPTUAL SHIFTS THAT INFLUENCED THE 2001 EXPERT CONSULTATION

The 1981 expert consultation considered issues related to the concept of "adaptation" when estimating energy requirements to be important. This is evidenced by the number of pages devoted to this topic in the 1985 report, which provided a working definition of adaptation as "a process by which a new or different steady state is reached in response to a change or difference in the intake of food and nutrients". The 1981 consultation had to wrestle with this concept largely because of the need to deal with the problem of variations in the energy intakes of individuals, both inter- and intra-individual. In addition, they were confronted with data from food consumption surveys that showed that individuals were living active lives on energy intakes that were considerably lower than those hitherto recommended on physiological grounds. The accumulation of considerable physiological and other scientific evidence in the interim period of nearly two decades has, however, resolved this issue such that the concept of adaptation is no longer considered significant when recommending energy requirements.

The reported low energy intakes from food consumption studies conducted in developed and developing countries are now known to be unreliable and physiologically unsustainable. These low intakes are often just above or below the basal or resting energy levels and provide for nothing more than a day lying in bed. They are unlikely to reflect the true intakes of individuals who are leading an active life. DLW studies, when conducted in such supposedly low-intake individuals, have clearly shown that such intakes are unsustainable over the short or the long term without serious loss of body weight. The TEE estimates by DLW in these individuals provided evidence of serious under-reporting of energy intakes[8]. This evidence has more or less settled the debate on whether adaptation can be considered a serious enough physiological mechanism to adjust to lowered energy intakes when individuals continue to maintain their body weights and habitual physical activity levels.

Implications of the concept of adaptation for the 2001 expert consultation: The recent consultation was confronted with scientific evidence accumulated over the last 20 years, which indicated that while metabolic adaptation and improvements in metabolic efficiency may occur during energy restriction of individuals, this was of a trivial nature and could not form the basis for any alteration in an individual's requirements for energy. It was also observed that there were costs to this adaptation, which may manifest in an increased risk of infection and disease. The 2001 consultation recognised that while behavioural adaptation did in fact take place to a considerable extent, it was at a cost to the individual in terms of reductions in socially desirable activities. The costs to the individual and to society were compromises that should not be reflected in recommendations of energy requirements. Thus the question of adaptation that occupied the minds of the expert consultation in 1981 was not an issue when the experts deliberated on energy requirements in 2001.

Recommendations of the FAO/WHO/UNU Joint Expert Consultation on human energy requirements, 2001: When FAO and WHO decided to recently review energy and protein requirements in two separate but closely linked meetings, they also decided that the expert consultations were to be preceded by a select working group meetings that reviewed any unresolved issues to help advice the expert group. The Expert Consultation on Energy met subsequently from October 17 to 24, 2001 in FAO, Rome and the principal findings in their new report include:

- The calculation of energy requirements for all ages should be based on measurements and estimates of total daily energy expenditure, including the energy needs for growth.
- New values for energy requirements of infants, children and adolescents were proposed because they had been overestimated for children less than 10 years of age, and underestimated for children over 11 and adolescents.
- Different requirement levels were proposed for populations with various lifestyles and levels of habitual physical activity, beginning with six years of age.
- A review of the available BMR databases was carried out to determine whether new equations for estimating BMR groups were needed; it was decided that the current equations were adequate.
- New factorial estimates of the additional energy needs imposed by pregnancy and lactation were applied.
- Recommendations for the levels of physical activity required to maintain fitness and health and reduce the risk of developing obesity and diseases associated with sedentary lifestyles were made and physical activity levels based on the degree of habitual activity recommended for long-term good health were classified.

CONCLUSIONS

When international agencies began operations 50 years ago, there was comparatively little information on nutrient requirements and there were only a few experts in the field. In the early years, the limited information on requirements came largely from developed regions of the world and mostly from laboratory settings. Scientific advances are continuously adding to our knowledge and evidence from studies conducted in different parts of the world have made it possible for the experts to evaluate the importance of differences in individuals and environments while considering its relevance to recommendations for nutrient requirements. Changing scientific concepts based on the application of new technology or on a better understanding of the physiological mechanisms continue to influence the recommendations being made. However, scientists do not have all the information they desire, and this must be kept in mind. Conversely, there is now a problem of wealth of information, and more time and resources are needed to assess the scientific evidence.

Nutritional science has grown more complex, each nutrient is studied by many scientists and there are more competing views. When experts come together for a meeting, they sometimes have difficulty arriving at definitive conclusions concerning complicated and specialised topics. From the start, most expert groups have sought