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Review Article

Recommended Dietary Allowances-Facts and Uncertainties

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For the purpose of evaluating diets of individuals and populations, the nutrient requirements were defined. Over the years, recommendations across several countries have evolved. In India the ICMR report has a single value for a particular population group while in other countries up to 4 values have been reported. Currently the commonly used definitions are for the average nutrient requirements, recommended nutrient intake or dietary allowances and the upper nutrient/tolerable upper limit. Using these requirement constructs, not only can the risk of inadequate intakes be calculated (using the probability approach) but the risk for excessive intakes that cross upper limit can also be determined. With the increase in consumption of packaged foods and fortification, there needs to be clarity on the upper limit of nutrients, particularly those that are stored in the body (e.g. iron), to prevent toxicity.Uncertainties regarding specific requirements and controversies still prevail. This is because the measurement of the daily requirement is very difficult when accurate measurements are to be made in controlled conditions or under various physiological states. These typically are measured as that intake which balances daily losses. Equally, robust nutrient intake data is also required to compute the risk of deficiency or excess.

Keywords: **Recommended Dietary Allowances (RDA); Recommended Nutrient Intake (RNI); Upper Nutrient Level (UNL); Acceptable Macronutrient Distribution Ranges (AMDR); Amino Acids; Fats Requirement Controversies; Sodium Requirement Controversies**

Introduction

Over the past one and a half centuries, the need for a dietary standard to evaluate individuals or populations to maintain optimal health has led to the evolution of the concept of nutrient requirements. The term "recommended dietary allowance" (RDA) was and is used by several countries to define requirements. This term has over the years evolved in several countries, with the term RDA being used for individuals rather than for populations due to the statistical concepts involved. During the early years the dietary standards were kept at the higher levels as it was used basically for planning and procuring food supplies (Harper, 1985). The use of nutrient requirements which are experimentally determined, became necessary to (a) evaluate the adequacy of intake by individuals and populations; (b) for planning diets, planning national food supplies, nutrition labelling and food regulations, (c) to evaluate the nutrient density and nutritional quality of foods, and (d) for development of nutritional policies.It must however, be remembered that these requirements defined by several countries are specifically for a healthy population. The values provided as requirements are for single nutrients assuming that the rest of the nutrients are provided at adequate levels.

Current Definition of Terms

The requirements are derived through experiments on individuals of the same gender, age, body size and in the case of energy and protein, the weight and physical activity. These values are then summarized for a population to obtain the average requirement and variability (FAO, 1985).

Over the years, the term 'RDA' has expanded to include several terms particularly with the recognition that individual level recommendations cannot be the same as recommendations at a

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population level. Both deficits and excesses in intake need to be defined for recommendations to be useful.

To plan and evaluate the nutrient intakes of healthy people, various countries have defined their recommended nutrient intakes (King *et al*., 2007). Each of these countries have proposed different recommended values. In India, the ICMR report proposes a single value for a population group (ICMR, 2010). Other countries, as for example, USA and Canada, propose 4 different values to define a 'lower reference intake', an 'average requirement', a 'recommended intake' for individuals from a specific population, and an 'upper tolerable intake' (ICMR, 2010; King *et al*., 2007). The following terms are used in various countries: Dietary Reference Values (DRV, UK), Nutrient Reference Values (NRV, Australia, New Zealand), Reference Values for nutrient supply (Germany, Austria, Switzerland), and Dietary Reference Intakes (DRI, USA, Canada) (King *et al*., 2007; King and Garza, 2007).

The term Nutrient Intake Values (NIV) was coined for the purpose of harmonizing the various recommendations used across several countries, bythe United Nations University's Food and Nutrition Program, in collaboration with the Food and Agriculture Organization (FAO), the World Health Organization (WHO), and the UNICEF from primary data across several countries. The terms used to define these values are:

1. The **Average Nutrient Requirement (ANR)** which is equivalent to the term Estimated Average Requirement (EAR), refers to the average daily nutrient intake level estimated to meet the requirements of half of the healthy individuals in a particular life stage and gender group. This term is used to evaluate populations or groups.

2. **Recommended Nutrient Intake (RNI)** which is equivalent to the term Recommended Dietary Allowance (RDA) refers to the daily dietary nutrient intake level sufficient to meet the nutrient requirements of nearly all (97–98 percent) healthy individuals in a particular life stage and gender group. This is calculated as: ANR plus 2 Standard Deviations of the distribution of requirements. The term is specifically used to evaluate individual diets and hence is inappropriate for dietary assessment of groups as it is the intake level that exceeds the requirement of a large proportion of individuals within the group. Even though these requirements are specified for the healthy population, they can be used to assess and plan diets in the clinical setting by modification or adjustment of these requirements for the disease process (as for example HIV infection) and for nutrient metabolism as there are no other standards available.

3. **Upper Nutrient Level (UNL)** which is equivalent to the term Tolerable Upper Level (TUL) refers to the highest average daily nutrient intake level likely to pose no risk of adverse health effects to almost all individuals in the general population. This term is particularly relevant now with increasing use of fortified and enriched foods as with increasing intakes above this level, the possibility of adverse effects increases.

4. **Safe Intake** also termed as Adequate Intake (AI) are values that are used when ANR or RDA cannot be determined. It is the recommended average daily intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group/s of apparently healthy people that are assumed to be adequate. Particularly for infants, they are set as nutrient targets based on the nutrient content of breast milk.The requirement of calcium is also based on adequate intake.

5. **Lower reference nutrient intake (LRNI)** also termed as Lower threshold intake (LTI) refers to a value derived from the ANR/EAR and evaluates nutrient insufficiency. It is calculated as the ANR/EAR minus 2 SD of the distribution of requirements and is sufficient to meet the needs of the bottom 2% (in some countries 5% or 10%) of individuals.

6. **Acceptable Macronutrient Distribution Ranges (AMDR)** is a range of macronutrient intakes that is associated with a reduced risk of chronic diseases, while providing adequate intakes of essential nutrients. It is usually expressed as a percentage of energy, with a

lower and upper limit. In the US and Canada (IOM, 2006), the AMDR's refer to appropriate ranges of usual intakes of individuals, whereas the WHO standards are population mean intake goals. As per the WHO, the mean intake goal for total fat intake is 15% to 30% of the energy intake, and implies that it is acceptable for half of the individuals in a population to have intakes below 15% (King *et al*., 2007; WHO, 2003).

Of these the first 3 are represented in Fig. 1 using an example for the requirement of folate.

Calculating the Risk of Inadequate Intakes

When the intake of an individual does not meet his requirement, he/she has an inadequate intake. However, it is not possible to actually measure the requirement of every individual. At the population level, an average requirement (ANR or EAR) is taken as representative of all individual requirements, and the proportion of people who are at risk of a deficient intake is calculated as the proportion whose daily intake of a nutrient falls below the ANR. One important caveat is that this is usually performed for nutrients whose intake distribution does not correlate with the requirement distribution; for example, this cannot be used to calculate the risk of energy deficiency. For this purpose, population level data on usual intakes and requirement is needed. Obtaining such data may be impractical and statistical approximations such as the probability approach, are used to assess inadequate intakes. In the probability approach a continuous risk curve of probability that any intake is inadequate is plotted against the intake

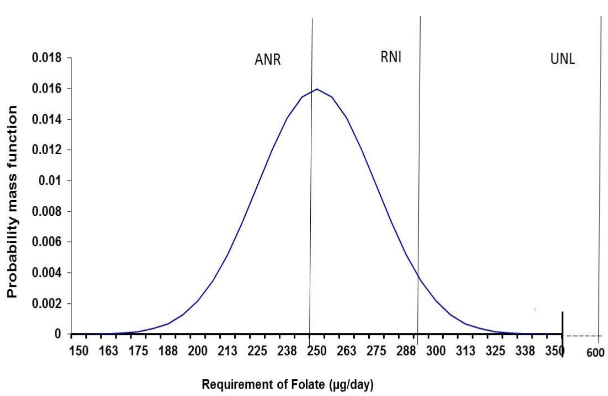

Fig. 1: The concept of Average Nutrient Requirement (ANR), Recommended Nutrient Intake (RNI) and Upper Nutrient Level (UNL) using the requirement of folate in 9 to 13 year old female children

value, where the lower levels of intake will have probabilities close to 100. This declines with increasing intakes such that higher levels of intake have zero probability of inadequate intake. Plotting of the usual intake distribution against this probability plot, determines the proportion with inadequate intake.

These analyses require two important assumptions. The first is that intake and requirement are uncorrelated, while the second assumption is that the requirement distribution is known. In addition, the requirement distribution is assumed to be normal. A simplified method to determine the proportion of individuals who are at risk of a deficient intake is through the EAR cut point method where the proportion of the population with intakes lower than the EAR for the nutrient are considered to be at risk for inadequate intake. The assumptions made for this method are: (1) intakes and requirements are independent of each other (2) the distribution of the requirement is symmetrical around the EAR (3) the variance in intakes is higher than the variance of requirements (4) true prevalence of inadequacy in the population is not less than 8-10 percent or not above 90-92 percent. However, for nutrients such as iron, whose distributions violate these assumptions certain adjustments need to be made (IOM, 2000).

The Need for the UNL or TUL

With many foods being supplemented or fortified and for the purposes of food labelling it has become necessary to define the maximum quantity of the nutrient that an individual or a population should take without the risk of an excess intake, using the concept of UNL (Swaminathan *et al.*, 2015). This has become important given the number of staple food fortification initiatives. These staple foods are distributed through schemes such as the PDS or the mid-day meal, and it is incumbent on governments to calculate the total daily intake of nutrients (including fortified and non-fortified foods) to evaluate the proportion of individuals who will be at risk of excessive intake or exposure to the nutrient. This is relevant for iron in particular, but cannot be calculated until the UNL or TUL is defined. Once this is known, government regulations therefore need to be sensitive to the possibility that the consumption of specific nutrients through fortified food products do not exceed the limit.

In terms of retail food products that are fortified, the present Indian government regulations permit the addition of up to 1 RDA. This is a sensible limitation, given that those with purchasing power could buy many such fortified products and eventually have an intake of specific that approaches or crosses the UNL/ TUL.

From Nutrient Requirements to Nutrient and Food Based Guidelines

To assess diets, there needs to be a unifying concept that describes the quality of the diet consumed. The estimation of the nutrient density of a food or diet helps in evaluating quality, and refers to the proportion of a particular nutrient in relation to the energy content. This is usually represented as the specific nutrient per unit energy or per gram or 100 grams of food (Drewnoski, 2005). This helps in planning for the delivery of the maximum amount of nutrients for a particular energy intake, particularly in diets of infants and children and also ensures that the requirements of micronutrients are met either through good planning or if required through fortification. Using nutrient density as the basis, there have been attempts to define the requirements of malnourished children (Golden, 2009). Using the requirements of normal healthy children as minimum requirements, these can be converted to nutrient densities using the energy requirements of female children, such that the highest nutrient densities among the various age group categories can be calculated. This is then used as the baseline value, but note that the *minimum* requirement is the EAR of normal children. At this point, to define requirements of the malnourished children, the factorial method was used for those nutrients associated with growth and for those nutrients associated with specific functions. Finally, small increments were added to account for oxidative stress, and other stresses due to unhygienic conditions.

When populations are micronutrient deficient, simple food based strategies to improve micronutrient density can be used by economically feasible diversification of diets, as for example, increasing the intake of those foods with high ascorbic acid content to increase absorption of available iron.

Uncertainties in Using the Recommended Allowances

The requirements for the macronutrients and some of the micronutrients are based on the balance approach that is the daily requirement is that intake that balances daily losses. Measuring losses of a nutrient from the body is very difficult, and is usually done in well- equipped laboratories. That is also part of the problem – the laboratories (or metabolic wards) in which requirement studies are done are 'clean' and do not reflect the real world environment, where stresses from sub clinical infections or pollution/ sanitation may elevate the requirement. Equally, the chronic poor intake of nutrients has led some to propose that conserving physiological adaptations may occur, to reduce the daily requirement. For example, it is known that during pregnancy, the oxidation of amino acids reduces as pregnancy progresses; this has been postulated to be one way by which the mother diverts amino acids towards foetal protein synthesis, such that her daily requirement does not increase too much.

Next, a major uncertainty relates to the robustness of the nutrient intake data. One of the greatest challenges in this century will be the accurate measurement of food/nutrient intake by populations and individuals. The method presently relies heavily on memory, usually of a key informant in a household. The food frequency method is a very useful method to *rank* the intake in a population (in other words, to provide a *relative* intake), in order to associate these with the risk of developing an adverse outcome. However, the *absolute value* of the derived nutrient intake is very unsatisfactory, and frequently overestimated. For the purpose of defining the risk of inadequate or excess intakes, one needs a far more accurate *absolute* value. At present the only method available at scale is the 24h recall, often done over 3 days to represent different parts of the week. However, it is still memory based, and inaccurate, in that many intakes will be found to be either very low or very high. While one can 'clean' the data using cut-offs that define a 'reasonable' value of intake, such that a reasonable mean intake can be calculated, it is also unsatisfactory. This is because the wider the distribution of the intake (higher SD), the greater the proportion of individuals who will be deemed to be at risk. In effect, one overestimates the risk. The only way forward is to get well executed recall data, over several days, from reliable informants, such that a real distribution of data is obtained. However, memory based methods lead to quite significant over- or underestimation, in well conducted surveys, as has been shown in an analysis of NHANES data, in which many repeat surveys showed that implausible dietary intakes were observed in over 50% of reporters, particularly in those who were overweight and conscious of what they were reporting (Archer *et al.*, 2015). Several innovative electronic methods are now being tested, however, the only data available in India is household based recall data from the National Nutrition Monitoring Bureau, in which household based food intake recalls were obtained. Other surveys of intake, such as the household food basket from the NSSO are also useful, but limited, in that within-household distribution (to the individual level) is not known, and foods eaten outside the house are not captured.

Finally, we do not eat nutrients, but we eat food. The concept of defining individual nutrient requirements is inherently unsatisfactory, since the delivery of nutrients and their benefits from food is greater than the sum of all the nutrients. Nutrients interact with each other and the requirements are affected by the physiological state of the individual. Although allowances and overages have been added after taking all these into consideration, more research in these areas are needed. Currently many fortification programmes use multiple micronutrients rather than single nutrients, but the effects of interactions are not necessarily factored in.

Recent Controversies

Amino Acid Requirement

The estimation of the requirement for essential amino acids is based on defining the level of intake at which nitrogen (N) homeostasis is maintained. This was earlier done by nitrogen balance estimations, but these were very inaccurate, since N is lost from the body in sweat, skin and hair, all of which are difficult to measure. In addition, N balance is derived from the difference between N intake and N output, two large numbers with little precision in their measurement, such that it is often overestimated. Recently, the measurement of amino acid oxidation (irreversible, and an accurate measurement of loss from the body), through accurate and rigorous stable isotopic methods have been developed (Kurpad *et al.*, 2001). This has led to a major re-appraisal of essential amino acid requirements (FAO/WHO/UNU, 2007, Table 1), such that the quality of protein intake has come under scrutiny, since cereal based diets are now defined as limiting in lysine. This indeed may be an underestimate in light of widespread stunting in developing countries, where poor sanitation and subclinical infections can impose their additional demands on requirements. Clearly, further studies on protein requirements in stressed environments with simple non-invasive methods are required to accurately define the requirement; this may even relate to inefficiencies in digestion and absorption. For example, we have recently observed that Indian women living in Bangalore had about half the gut absorptive capacity for sugars compared with American and Jamaican women (Kao *et al.*, 2016). Many factors could give rise to this, such as environmental enteric dysfunction.

The question then is whether functional deficits (such as growth, or organ function) are present if essential amino acid intakes are limiting, since many individuals and children are at risk of a low intake. The balance methods are short-term studies, which may or may not predict function and health. In infancy,

Table 1: Comparison of the 1985 and 2007 WHO/FAO/UNU recommendations for essential amino acid requirements in man

	FAO/WHO/UNU 2007		FAO/WHO/UNU 1985	
Amino acid	mg/kg/d	mg/g protein	mg/kg/d	mg/g protein
Histidine	10	15	8-12	15
Isoleucine	20	30	10	15
Leucine	39	59	14	21
Lysine	30	45	12	18
Methionine	10	16	-	-
Cysteine	4	6	-	-
Methionine + Cysteine	15	22	13	20
Threonine	15	23	7	11
Phenylalanine + Tyrosine	25	38	14	21
Tryptophan	4	6	3.5	5.0
Valine	26	39	10	15
Total EAA	184	277	93.5	141

Reference: FAO, 1985; FAO, FAO/WHO/UNU, 2007 inadequate protein (based on animal studies) would be expected to affect growth of lean mass and length/ height, and in adults, functional studies such as those measuring glutathione homeostasis are relevant (Jackson *et al.*, 2004). We have shown that muscle strength declines with low levels of lysine intake, and is improved when generous intakes of lysine are eaten over a longer period (3 weeks and 8 weeks, Kurpad *et al.*, 2002; Unni *et al.*, 2012). In addition, recent evidence on lower plasma amino acid levels in undernourished children is also indicative of the role amino acids may play in growth (Semba *et al.*, 2016). The evidence base needs to be strengthened in this regard, with measurements of function, such as growth, body composition, strength, immune and gut function.

Fat Requirement

The RDA for fats in 1990 (ICMR, 1990) was based on FAO/WHO 1977 recommendations (FAO/WHO, 1977). At that time the recommendations were based on the minimum fat required to prevent calorie and essential fatty acid (EFA) deficiency, that is, (a) total fat should be at least 15% of energy (E) and (b) linoleic acid (LA, 18:2 n-6) in adults should be about 3% of energy.

Since vegetable oils were the main source of fat, and assuming that vegetable oils had at least 20% LA, this was calculated as a minimal intake of 12 g fat/day/person. A safe intake of 20g/d was however recommended to provide energy density and palatability. The upper limit of fat intake was set at 30%E. Considering the amount of fat from all foods in the diets of urban high income group to be ~10-15%E, the visible fat upper limit was set to ~ 50g/d (< 20%E). However in 2010, the recommendations were revised again (ICMR, 2010) based on FAO/WHO recommendations (considering the unfavourable effects of low fat-high CHO diets). Assuming ~10%E fat from all foods (invisible fat), the minimal intakes of visible fat was set to 20-40 g/day.

The FAO/WHO requirements set for countries like the US was based on the fact that their consumption of fat was around 40%E, and therefore the recommendation to 'limit' fat intake was directly applicable to the population at large. The scenario in India is however completely different, and except for a small proportion of the urban rich, the intake of fat in most parts of the country was (and continues, on average, to be) low (<15%E). In combination with ~ 10%E from protein, this low level of fat intake means that the remaining calories are made up of carbohydrates (~75%E). The recommendation therefore should have stressed on normalizing or 'increasing' fat intake to at least 25-30%E.

The RDA for individual fatty acids have been set based on different criteria. Saturated fatty acids (SFA) can be synthesized de novo, and therefore are not essential in the diet. However, they are present in all foods consumed, and therefore an upper limit of intake (<10 %E) has been recommended based on FAO/WHO data on possible deleterious effects of high SFA diets. On the other hand the AMDR for the essential fatty acids, LA and alpha-linolenic acid (ALNA, 18:3 n-3) as 2.5–9 %E and 0.5–2 %E respectively, have been set based on the minimum levels required to prevent EFA deficiency.

Indian diets in general contain very low levels of SFA and ALNA, (and negligible levels of LC n-3 PUFA), along with relatively high levels of LA (Micha *et al.*, 2014). Therefore recommendations of – 'reduce intake of 'bad fats' such as SFA and increase intake of 'good fats' such as n-3 polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA)' is misleading. What this has done is to essentially further decrease the already low SFA intake and increase the n-6 PUFA intake. However, since the common perception of differences between n-6 and n-3 PUFA is not very clear, the net result has been a disproportionate increase in n-6 PUFA intake, which is the predominant PUFA in vegetable oils that have been marketed so enthusiastically in India. This is a problem that needs to be highlighted, especially in the light of recent studies that indicate that low fat-high n-6 PUFA diets are very pro-inflammatory and highly obesogenic (Patterson *et al.*, 2012)

The dietary recommendations by ICMR have always stressed on increasing n-3 PUFA intake in Indian diets, however it is not quite clear how that can be achieved. One suggestion given is to use a combination of vegetable oils. However the only oils that contain reasonable amounts of n-3 FA and ALNA, are mustard oil, soybean oil and canola oil. While mustard oil is commonly consumed in the northern and eastern states, the abundance of erucic acid (22:1

Table 2: Amount of fatty acids provided by using different oils available in India

	RDA	Sunflower oil	Rice bran oil	Palm oil	Mustard oil	Groundnut oil	Coconut oil
Energy	2700				2465		
Fat (%E)	20-35				21.4		
SFA (%E)	<10	8.5	9.1	10.7	8.7	8.8	12.8
LA	2.5 – 9.0	5.4	3.6	2.2	2.5	3.5	1.7
ALNA	0.5 – 1.0	0.23	0.31	0.24	0.53	0.23	0.23
n-6/n-3 PUFA	<10	23.4	11.6	9.0	4.7	15.1	7.6

n-9) in this oil (~45%) has always raised a question about its overall nutritive value. Moreover, oils such as mustard and soybean contain a flavour that is not acceptable to the southern and western states of India. Canola oil is a good option. However the main issues here are to do with cost and availability of the oil, especially since attempts to produce it in India have failed.

Overall, the recommendations to reduce SFA and increase PUFA intake has in the last 30 years increased the consumption of n-6 PUFA rich oils such as safflower and sunflower, at the expense of more traditional oils such as coconut, groundnut and sesame (Jha, 2012). A balanced vegetarian diet (for a normal man performing moderate amount of work) as recommended by ICMR, would provide the amounts of FA as shown in Table 2 if cooked using different vegetable oils

Sodium Requirement

In healthy individuals, practically all the sodium ingested is absorbed and sodium balance is maintained largely through its excretion in urine, with some losses through sweat and faeces (WHO, 2012). As human beings adapt to the intake of different levels of electrolytes including sodium, and with temperature and activity affecting the sodium balance further, it has not been possible to compute the average nutrient requirement for sodium. These limitations lead to the requirements of sodium being based on adequate intakes. Equally, the UNL was set based on increased risk for cardiovascular disease and stroke (IOM, 2005). At different levels of sodium intake, the reduction in blood pressure thus became the surrogate end point for risk of cardiovascular disease and stroke (IOM, 2013) thereby arriving at the UNL for sodium. The requirement for adults was thus set at 1500 mg/day (3.75 g salt) with an upper limit of 2300 g (5.75 g salt per day). These were based on randomized controlled trials where reported reductions in blood pressure with reductions in sodium intake occurred at levels of sodium intake below 1500 mg (O'Donnell, 2015). The WHO (2012) however, examined evidence on the effect of the reduction of sodium intake to blood pressure in both adults (> 16 years) and children (2-15 years) leading to the recommendation on sodium intakes to below 2000 mg of sodium per day (<5 g of salt) in adults and a downward adjustment based on the energy requirements of children relative to those of adults. The recommended dietary allowance for Indians, however, set the adequate level at 1100 to 3300 mg sodium (2.75 g to 8.25 g salt) per day, a minimum requirement of 500 mg (1.25 g salt) per day sodium for adults and 58mg/day for infants, with maximum levels of sodium chloride intake not exceeding 5 g/day (ICMR, 2010), based on an earlier article (Blackburn & Prineas, 1983). Recommendations therefore, have not been consistent across various organizations and countries. Subsequently in 2013, the IOM revisited the guidelines and came to the conclusion that the evidence on health outcomes was not consistent with efforts to encourage lowering of dietary sodium in the general population to 1500 mg/day and sufficient evidence was lacking to support benefits of intakes between 1500 to 2300 mg/day (IOM, 2013) leading to further confusion on the recommendations set earlier.

In the Prospective Urban and Rural Epidemiological (PURE) study, which was a survey among populations studied across 17 countries, very few individuals had intakes lower than 2300 mg per day and none below 1500 mg/day. The study also reported the lowest risk of death and cardiovascular events in those who consumed moderate amounts of sodium intake (3000 to 6000 mg per day, that is 7.5 to

15 gm of salt), with an increased risk above and below that range (O'Donnell *et al*., 2014), thus showing a J shaped relationship. This then questions the present recommendations, where this relationship was assumed to be linear. A meta-analysis also indicated that range of sodium intake of 2645-4945 mg per day (equivalent to 6.6 to 12.4 g of salt) was associated with the minimal risk of all-cause mortality and cardiovascular events (Graudal *et al*., 2014). Thus, the recommendations were based on studies with methodological limitations of inaccurate self-reported sodium intake, incomplete urine collections, and variations in study designs (Davy *et al*., 2015). More robust designs at varying levels of intake need to be carried out to revise recommendations.

Summary

Optimal health is the ultimate goal in the recommendation of diet to individuals or populations. Although the present recommendations serve as standards that need to be attained, one also needs to understand the inherent flaws associated with their development. The recommendations for each of the nutrients must be viewed collectively to ensure a diet of optimal quality, not just quantity that could prevent morbidity and mortality and maintain the physiological homeostasis of the nutrient. With increase in packaged foods and the use of fortification, the recommendations need to evolve still further through a solid evidence base. To be relevant, these studies also need to be location and context specific especially in countries like India, a developing country with a great deal of deficiencies already prevailing, where adaptations may occur and upper limits may be different; and not the least, with diverse diets across the length and breadth of the country.

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