4

A Theoretical Approach Using Nutrient Density to Plan Diets for Groups

SUMMARY

In this chapter the use of nutrient densities is proposed as a means to plan diets for groups comprised of distinct subgroups with different nutrient requirements and different usual energy intakes. Two approaches are described. The first relates the median of the target nutrient intake distribution to the mean energy intake of each subgroup within the larger group, for which a diet is being planned. These values are then compared to set a planning goal for the whole group. This approach, however, does not consider the variability of energy intakes within a subgroup, so it may require repeated iterations of planning and assessment. The second approach involves planning for an acceptable nutrient density ratio. This approach takes into account the differences both in energy and nutrient needs of the distinct subgroups to derive target nutrient intake distributions expressed as nutrient densities. The medians of the target nutrient density intake distributions for the various subgroups are then compared to set planning goals for the whole group. Importantly, the methods described here are not designed to plan for desirable body weights (which might require weight loss or gain), but to ensure that nutrients are provided in sufficient concentrations in the diet to satisfy individuals' nutrient needs if they consume sufficient food to maintain energy balance. These approaches are theoretical in nature at this time and should be further explored.

INTRODUCTION

The methods presented in Chapter 3 assume that the planning activity will be conducted for a group of people possessing similar energy and nutrient requirements; for example, girls aged 9 to 13 years or adult men aged 31 to 50 years. Nutrient requirements are specific to life stage and gender, but there are many situations in which planning diets for groups means planning for population groups that include individuals of different genders and ages and thus different nutrient and energy requirements. Planning school meals, for example, typically involves offering meals to both boys and girls of ages ranging from 5 to 18 years. Planning the benefit levels for the U.S. Food Stamp Program must include consideration of the combination of ages and genders present in recipient households. Planning the meals in institutional settings such as prisons or hospitals must recognize differences in residents' requirements related to age, weight, gender, and possibly marked differences in habitual levels of physical activity.

When applying the concept of a target usual intake distribution to planning for groups that include individuals with different energy and nutrient requirements, the heterogeneity of the group must be considered. One approach that has been used is to calculate the average nutrient requirement for individual group members and use this average requirement in planning. The problem with this approach, however, is that even if the planning appears to meet the group need for the nutrient, there is no guarantee that nutrient intakes will be distributed among individuals in the group in a manner to satisfy nutrient requirements. For example, in planning for iron intakes for a group of men and women, simply computing the average iron requirement and planning accordingly does not ensure that individual group members will have their iron requirement satisfied. In fact, when planning diets or menus that provide the average iron requirement, it is likely that food (and iron) will be distributed according to energy needs of the individuals in the group. As a result, there will almost certainly be serious deficits in iron intakes for the women, who have lower energy requirements, and surplus iron intakes for the men with their higher energy requirements (FAO/WHO, 1970). Thus, to achieve a targeted group prevalence of inadequacy, subgroup differences in both nutrient and energy requirements need to be taken into account in the planning process.

The use of nutrient densities has been proposed as one means to account for known differences in the energy and nutrient requirements of specific population subgroups (FAO/WHO, 1970; FAO/WHO/UNU, 1985; IOM, 1995, 2002b). This approach involves calculating the required nutrient density for the diet such that when individuals' requirements for food energy are achieved, there is a high likelihood that the nutrient requirement for individuals within the group also will be satisfied. In planning for nutrient adequacy, it must be assumed that individuals' usual energy intakes are sufficient for them to maintain energy balance with current levels of physical activity and body energy stores, or in other words, that their energy intake equals their energy expenditure.

Nutrient density is the ratio of the amount of a nutrient in foods to the energy provided by these same foods. Nutrient density is frequently expressed as the amount of the nutrient per 1,000 kcal or MJ of energy.

Although nutrient density may be used to describe foods, meals, diets, or food supplies, its use in dietary planning is primarily to describe daily intake targets.

Using the nutrient density concept, a number of approaches to planning the diets of heterogeneous groups could be considered. The approach used depends in part on whether the intakes being planned will be based on consumption of a single food (e.g., an emergency relief ration) or of varied amounts of multiple foods, the more common planning scenario. A method that can be used to plan for diets consisting of a single food is presented in Appendix C, while two approaches are presented below that could be used to plan intakes when the diet consists of multiple foods.

The first approach to planning using nutrient densities is based on a comparison of the target median nutrient intake to the average energy requirement. This simple approach is based on the methods presented in Chapter 3 and is referred to as the simple nutrient density approach. It involves planning nutrient intakes for the subgroup with the highest median nutrient needs relative to their energy needs (e.g., the most vulnerable subgroup); it is assumed that the other subgroups will obtain adequate nutrient intakes if they fulfill their energy requirements. This approach, while simple and straightforward to implement, does not consider the variability in energy intakes within a subgroup and may therefore result in a prevalence of inadequacy that differs from the planning goal.

The second approach to planning using nutrient densities is based on the distribution of intakes expressed as a nutrient density. Although this approach has not been tested in practical situations, it considers the variability of energy intakes within a subgroup as well as the distribution of nutrient intakes, and therefore offers the most theoretically correct method of determining the appropriate nutrient density to use for planning. It includes examining the distribution of intakes expressed as a nutrient density for each subgroup and determining the target nutrient density distribution for each. The nutrient density to be used for planning should be the highest target nutrient density among the subgroups.

For each of these approaches, an assessment and adjustment of the target distribution as needed should follow the planning activity. For the first approach, which does not consider variability in energy intakes, several iterations of planning and assessment may be needed. The second approach should more accurately identify the correct target nutrient density so fewer assessment iterations would be expected. In addition, each approach should include a comparison of the projected target usual intake distribution to the Tolerable Upper Intake Level (UL) for each subgroup. By planning for a nutrient density that is adequate for the subgroup with the highest needs, it is possible that a substantial proportion of some of the other subgroups will consume diets that exceed the UL.

Each of the methods proposed above requires an estimate of the distribution of usual nutrient intakes in the various subgroups of interest. As described in Chapter 3 and more fully elsewhere (IOM, 2000a), the distribution of usual nutrient intakes for each subgroup can be estimated by assessing the nutrient intakes of a representative sample over at least two nonconsecutive or three consecutive days, and adjusting the observed distribution of nutrient intakes for within-person variation.

An estimate of energy intake is also required. Assuming that the group is in energy balance, one could use estimates of either energy intake or energy expenditure. For the first approach, the *mean* energy intake or expenditure in each subgroup of interest is used, while for the more theoretically correct approach, an estimate of the *distribution* of usual energy intakes or expenditures is needed. As is the case with nutrients, in principle, the distribution of usual energy intakes in each subgroup can be estimated by assessing the energy intakes of a representative sample over two or more days and adjusting the observed distribution of energy intakes for within-person variation. The distribution of energy expenditures in each subgroup can be estimated using the equations developed to estimate the energy expenditure of individuals in the group (IOM, 2002a).

However, both of these estimates (energy intake and energy expenditure) are subject to error. Estimates of energy expenditure obtained using energy expenditure equations require data on height, weight, age, and physical activity level. These estimates may be biased if self-reported values for height and weight are used, as height is frequently overreported and weight underreported, particularly among older adults (Kuczmarski et al., 2001).

Error may also be introduced by assumptions regarding the physical activity level of group members. Because the energy expenditure equations were developed very recently, no data are available on the extent of this error.

On the other hand, as discussed in Chapter 1, problems of systematic underreporting of energy intakes in dietary intake surveys have been documented repeatedly, suggesting that this is likely a widespread problem in intake assessments (Black and Cole, 2001). There is also evidence of systematic overreporting of energy intakes among some individuals (Black and Cole, 2001).

The following discussion assumes that one can approximate the distribution of usual energy intakes in the subgroup of interest by using self-reported energy intake data. It is important to recognize, however, that insofar as systematic reporting errors distort the distribution of usual energy intakes, these errors may seriously bias estimates of the distribution of both nutrient requirements and nutrient intakes expressed as densities. Bias would also exist in estimates of the target median nutrient intake expressed in relation to the mean energy intake. Unfortunately, well-established, validated statistical methods to identify and correct for under- or overreporting energy intakes are currently lacking. Implications of systematic reporting errors on the planning methods presented here are examined at the end of this chapter.

The methods described in this chapter are not designed to plan for desirable body weights (which might require weight gain or loss), but rather to ensure that the nutrients are provided in sufficient concentrations in the individuals' diets to satisfy their nutrient needs if they consume sufficient food to maintain energy balance (e.g., to maintain current body weight).

PLANNING FOR HETEROGENEOUS GROUPS USING A COMPARISON OF TARGET MEDIAN NUTRIENT INTAKE TO MEAN ENERGY INTAKE (OR EXPENDITURE)

The approach presented in this section is an extension of the approach presented in Chapter 3 to plan nutrient intakes of homogeneous groups. It is possible that it may be less accurate than the approach described in the following section that uses the distribution of nutrient intakes expressed as a density; however, because it is less complex to implement, it may serve as an interim approach for planners. Chapter 5 provides specific examples of the two approaches and discusses the differences in results.

Four steps are necessary to derive a target median nutrient intake relative to energy for a heterogeneous group:

1. Obtain the median of the target nutrient intake distribution for each subgroup of interest (as described in Chapter 3).
2. Divide this target median nutrient intake by the mean energy intake or expenditure in each subgroup to obtain the target median nutrient intake relative to energy.
3. Compare the target median nutrient intakes relative to energy for each discrete subgroup to identify the subgroup with the highest nutrient intake required relative to its mean energy intake. Use this to set planning goals for the whole group, but ensure that nutrient intakes of other subgroups will not be above the Tolerable Upper Intake Level.
4. Assess whether the plan was successfully implemented. (This step is particularly important with this approach.)

Step 1. Obtain the target median nutrient intake.

The first step in this approach is to obtain the median of the target nutrient intake distribution for each subgroup, following the approach described in Chapter 3. For nutrients for which an Estimated Average Requirement (EAR) has been determined, the target median nutrient intake is the median of the distribution obtained by repositioning (if necessary) the usual nutrient intake distribution in the subgroup of interest so that an acceptably low proportion of individuals in the subgroup has intakes below the EAR. In the case of iron, for which the requirement distribution is skewed, the probability approach is used in place of the EAR cut-point method in order to estimate the target median nutrient intake.

For nutrients with an Adequate Intake (AI), the AI may be used as a target median nutrient intake. Median intake at the AI should lead to a low prevalence of inadequacy if the AI was set as the median intake of a healthy group and if the variability in usual intake of the group of interest is similar to the variability in intake of the population used to set the AI. When either of these conditions is not satisfied, there will be less confidence that achieving a median intake at the AI will result in a low prevalence of inadequacy.

Step 2. Divide the target median intake by the mean energy intake (or expenditure) for each subgroup of interest.

Once the target median nutrient intake has been identified for each subgroup within the larger group, it is possible to express the nutrient intake in relation to energy, typically per 1,000 kcal. This is done by dividing the target median nutrient intake by the mean energy intake or expenditure. For example, if the target median zinc intake for a group of girls 9 to 13 years of age was 10.1 mg and their mean energy intake was 2,200 kcal, this would represent a target of 4.6 mg/1,000 kcal. This would be done for each subgroup.

Step 3. Identify the subgroup with the reference intake and set planning goals for the entire group.

Once the target median nutrient intakes have been expressed relative to the mean energy intake or expenditure for each subgroup, a decision can be made regarding which subgroup's needs will be used to plan intakes for the entire group. In many cases, one might choose to plan using the needs of the most vulnerable subgroup (e.g., the subgroup with the highest target median nutrient intake relative to mean energy intake or expenditure). Diets that would lead to intakes providing that amount of the nutrient per 1,000 kcal would then be planned (e.g., for zinc, if the vulnerable subgroup was girls 9 to 13 years of age, the goal for intake would be 4.6 mg of zinc/1,000 kcal). If the needs of this subgroup are met, the needs of other subgroups should be satisfied and the group prevalence of inadequacy should be low. Alternatively, if the needs of the most vulnerable subgroup would lead to intakes by other subgroups that are excessive (and perhaps above the UL), it may be preferable to use a less vulnerable subgroup to plan for the group as a whole and to target the most vulnerable subgroup using education programs, special foods, or targeted supplementation.

Step 4. Assess whether the plan was successfully implemented.

Assessing the adequacy of the group's nutrient intakes is particularly critical when this approach to dietary planning is used. By using only the mean energy intake or requirement of each subgroup, it fails to consider the variability of energy intakes among members of a subgroup. Accordingly, those with very low energy intakes may not meet their nutrient requirements. Planners using this approach must be willing to alternate planning and assessment until the goals are achieved because the actual prevalence of inadequacy that results from this approach may be quite different from the level that was the target.

PLANNING FOR HETEROGENEOUS GROUPS USING THE DISTRIBUTION OF NUTRIENT INTAKES EXPRESSED AS A DENSITY

This section describes an approach to establish a target nutrient density intake distribution for each of the subgroups in a heterogeneous group, assuming multiple foods with different densities are consumed. It could also be used to plan for a group consisting of a single life stage and gender. The first step in the procedure is as described in Chapter 3: obtain a target usual nutrient intake distribution in each of the subgroups so that an acceptably low proportion of individuals in each subgroup have an inadequate intake of the nutrient. The target distribution of usual intakes expressed as nutrient densities in each of the subgroups is derived relative to the distribution of nutrient and energy requirements in each of the subgroups directly, and provides the planning goal for each subgroup.

Three steps are necessary to derive a target usual density intake distribution.

1. Obtain the target distribution of usual nutrient intakes for each subgroup of interest.
2. Combine the target distribution of usual nutrient intakes with the usual energy intake (or expenditure) distribution in each subgroup to obtain the target distribution of usual nutrient intakes expressed as densities.
3. Compare the estimated target median density intake for each discrete subgroup to identify the reference nutrient density and set planning goals for the whole group, but ensure that nutrient intakes by other subgroups do not exceed the Tolerable Upper Intake Level (UL).

Step 1. Obtain the target distribution of usual nutrient intake.

The first step in planning intakes for a heterogeneous group is to obtain the target usual nutrient intake distributions for each subgroup, following the approach described in Chapter 3. For nutrients for which an Estimated Average Requirement (EAR) has been determined, the target usual nutrient intake distribution is obtained by repositioning (if necessary) the usual nutrient intake distribution in the subgroup so that an acceptably low proportion of individuals in the subgroup have intakes below the EAR. In the case of iron, for which the requirements distribution is skewed, the probability approach is used in place of the EAR cut-point method in order to estimate the position of the target usual nutrient intake distribution.

In Chapter 3 and in the simple approach described in the previous section in this chapter, the planning tool of interest was the *median* of the target usual intake distribution. Here, however, the entire *target usual nutrient intake distribution* is of interest. In order to establish a target nutrient density intake distribution, it is necessary to account for the variability in nutrient and energy intakes among individuals. If the goal is to plan intakes when each of the subgroups is provided a separate diet (as would be the case, for example, in an institution that houses men, women, and young individuals separately), then the planner needs to proceed no further. The methods presented in Chapter 3, and briefly revisited here, suffice to plan intakes for a subgroup that is homogeneous with respect to age and gender. However, if a single diet will be provided to a larger group composed of individuals from the various subgroups, then the planner needs to account for the differences in energy consumption among individuals in different life stage and gender groups.

Step 2. Obtain the target nutrient density intake distributions.

Once the target usual nutrient intake distribution for each life stage and gender subgroup of the larger group has been established (Step 1), it is possible to determine the target usual intake distribution of the nutrient expressed as a density. The target distribution of usual intakes estimated in terms of nutrient densities will be such that an acceptably low proportion of individuals in each subgroup (in the example, 2 to 3 percent) have inadequate nutrient intakes.

While the method presented in Chapter 3 essentially consisted of repositioning the usual nutrient intake distribution, an additional step is needed when planning for a heterogeneous group. The target usual nutrient intake distribution must be combined with the distribution of usual energy intakes in each subgroup to obtain the target nutrient density intake distribution. The difference here is that while the objective is to obtain a target intake distribution for the nutrient expressed as a density, the density intake distribution cannot be directly compared to the nutrient requirement distribution to determine how it should be repositioned. Thus it is necessary to add an intermediate step to the procedure which consists of deriving first the target usual nutrient intake distribution for each subgroup, as was described in Step 1 above. The steps necessary to carry out this derivation are explained in detail below.

Recall that nutrient density intake is defined as the units of a nutrient consumed per 1,000 kcal. Thus, if an individual consumes 2,000 kcal and 104 mg of vitamin C, then that individual consumes a diet with a vitamin C density of 52 mg/1,000 kcal. Therefore, if one knows an individual's usual nutrient intake and her or his usual energy intake, it is possible to calculate the nutrient density intake for that individual. The calculation above can be taken one step further if one considers a group in which individuals vary in their usual nutrient intake. In the unlikely case in which everyone in the group has the exact same usual energy intakes, say 2,000 kcal, then given the distribution of usual nutrient intakes in the group, it is a simple matter to calculate the usual intake distribution of the nutrient expressed as a density: simply divide each usual nutrient intake in the group by 2,000 and multiply by 1,000. However, individuals vary in the amount of energy they consume, and therefore the derivation of the *distribution* of usual intakes of the nutrient expressed as a density given the usual nutrient and energy intake distributions is a bit more challenging. In this more realistic scenario, it is necessary to take into account that individuals vary not only on the amount of the nutrient they consume, but also on the amount of energy they consume.

Suppose that an individual from the subgroup has a vitamin C intake of 70 mg. If it is assumed that the correlation between vitamin C intake and energy intake is moderate to low, then that nutrient intake level may correspond to different combinations of energy intakes and thus vitamin C intakes per 1,000 kcal. For example, the usual intake of 70 mg may result in a vitamin C density intake of 46.7 mg/1,000 kcal if the individual consumes 1,500 kcal/day or in a density intake of 31.8 mg/1,000 kcal if the individual's energy consumption is 2,200 kcal/day.

The simple example above illustrates the importance of accounting for the variability in usual energy intakes among individuals in the subgroups that comprise the larger group. Given each possible usual nutrient intake in the subgroup, one must calculate each of the nutrient density intakes that may result given the distribution of energy intakes in the same subgroup. To account for the variability in energy intakes among individuals in the subgroup, average the nutrient density intakes over the distribution of energy intakes in the subgroup. The average is weighted by the frequency of consumption of each energy level in the group. To obtain this average density intake corresponding to each nutrient intake in the subgroup, the following calculation is used:

$$\text{Average nutrient density intake} = (1/\Sigma_j \text{ frequency}_j)\ \Sigma_{j=1}^{n} (\text{usual nutrient intake/usual energy intake}_j) \times \text{frequency}_j \times 1{,}000 \quad (1)$$

where n denotes the number of energy intake levels in the subgroup, and the subscript j indicates that for each nutrient intake in the subgroup, the summation above must be carried out for each energy intake level. The weights in the summation above are given by the frequencies of consumption of each energy level. For example, in a group of women aged 19 to 50 years, consumption of energy below 500 kcal or above 8,000 kcal would be associated with low frequencies, whereas energy consumption of around 1,500 to 3,000 kcal would be observed more frequently. The calculation above is carried out for each nutrient intake level in the subgroup. As a result, a distribution of density intakes is obtained in the subgroup by combining a target nutrient intake distribution and an actual (unchanged) usual energy intake distribution.

To illustrate this, consider a hypothetical group of 25 men. Intake data were collected from each of these men on two nonconsecutive days, and the intakes were adjusted to estimate usual intake of nutrient Y and usual intake of energy. This group is very unusual, as its nutrient intake distribution at baseline is flat: five men each have usual intakes of 8 units, 9 units, 10 units, 11 units, and 12 units of nutrient Y. The group's energy intake distribution is also unusual: five men each have intakes of 2,000, 2,200, 2,300, 2,500, and 3,000 kcal. Further, these energy intakes are distributed so that each nutrient intake level is represented by all five energy intakes.

The EAR for nutrient Y is 10 units, so at baseline, 10 of the men have usual intakes below the EAR. In this scenario, the planning goal is to have a prevalence of inadequacy that is essentially zero. Accordingly, the target usual nutrient intake distribution is obtained by shifting the baseline distribution up by 2 units, leading to usual intakes of 10, 11, 12, 13, and 14 units of nutrient Y for the men.

To derive the target usual nutrient *density* distribution, each value in the target nutrient intake distribution is paired with each value from the energy intake distribution, as shown in Table 4-1. As shown in the fourth column of the table, the target nutrient density intake distribution ranges from 3.33 units/1,000 kcal to 7.0 units/1,000

TABLE 4-1 Deriving a Target Nutrient Density Distribution for a Hypothetical Group of 25 Individuals

Usual Nutrient Intake Distribution (units of nutrient Y)	Usual Energy Intake Distribution (kcal)	Target Nutrient Intake Distribution (units of nutrient Y)	Target Nutrient Density Intake Distribution (units/ 1,000 kcal)	Intake Resulting from Meals with Average Density
8	2,000	10	5.0	10.18
8	2,200	10	4.55	11.20
8	2,300	10	4.35	11.71
8	2,500	10	4.0	12.72
8	3,000	10	3.33	15.27
9	2,000	11	5.5	10.18
9	2,200	11	5.0	11.20
9	2,300	11	4.78	11.71
9	2,500	11	4.4	12.72
9	3,000	11	3.67	15.27
10	2,000	12	6.0	10.18
10	2,200	12	5.45	11.20
10	2,300	12	5.22	11.71
10	2,500	12	4.8	12.72
10	3,000	12	4.0	15.27
11	2,000	13	6.5	10.18
11	2,200	13	5.91	11.20
11	2,300	13	5.65	11.71
11	2,500	13	5.2	12.72
11	3,000	13	4.33	15.27
12	2,000	14	7.0	10.18
12	2,200	14	6.36	11.20
12	2,300	14	6.09	11.71
12	2,500	14	5.6	12.72
12	3,000	14	4.67	15.27
Average			5.09	

kcal, and has an average of 5.09 units/1,000 kcal. The intakes that would result from meals planned to contain this density of nutrient Y are shown in the fifth column of Table 4.1. It can be seen that none of the men would have intakes below the EAR of 10 units, so the planned-for very low prevalence of inadequacy would be attained.

In practice, it is not really necessary to proceed with the average over all energy consumption levels as above, nor is it necessary to know the frequency of consumption associated with each energy level. The average above can be more easily calculated using a sampling, or Monte Carlo, approach as follows: first, for each usual nutrient intake, randomly select a number *m* of usual energy intakes from the distribution of energy intakes, and second, compute the following quantity:

$$\text{Average nutrient density intake} = (1/m)\ \Sigma_{j=1}^{m}\ (\text{usual nutrient intake}/\text{energy intake}_j) \times 1{,}000 \quad (2)$$

Here, *m* is typically much smaller than *n*, so that the sum in expression (2) is less computationally demanding than that shown in expression (1). As a guideline, in the example presented in Chapter 5, the value of *n* for women is approximately 4,500, but only 400 randomly selected energy consumption levels were drawn from the usual energy intake distribution in the group in order to compute the approximation in (2). In fact, a value of *m* as low as 50 or 100 would have provided a good approximation to the average given in (1). If the *m* energy intakes are drawn at random from the distribution of usual energy intakes in the subgroup, then the average in (2) is self-weighting. This is because energy intake levels will be drawn more or less frequently depending on the probability associated with each energy intake level in the usual energy intake distribution. That is why the frequency associated with each level of energy consumption does not appear in equation (2).

Either one of the two calculations presented above would produce an average (over the individual's likely levels of energy consumption) nutrient density intake. To simplify the calculations even further, the weighted average above does not have to be computed for each nutrient intake level in the subgroup in order to obtain an approximation of the density intake distribution of the subgroup. Just like in the case of the Monte Carlo average, it is possible to draw at random a number *q*, also typically smaller than *n*, of usual nutrient intakes from the target usual nutrient intake distribution in the subgroup. The average (over the range of likely levels of energy consumption) density for each of the *q* usual nutrient intakes drawn from the distribution in the subgroup would then be calculated as indicated in either of the two expressions presented above. In the example in Chapter 5, $q = 400$, so that about 10 percent of the usual vitamin C intakes for women were drawn from the target usual intake distribution to compute the individual weighted averages using equation (2). Except in the unlikely event in which the correlation between usual nutrient intakes and usual energy intakes is high, the numerical approach detailed in either expression (1) or (2) will produce a usable approximation of the distribution of target nutrient density intakes for a group.

Step 3. Identify the reference nutrient density distribution and set planning goals for the whole group.

Once the target nutrient density distributions have been defined for each distinct subgroup in the population of interest, it is recommended that the distribution with the highest median nutrient density intake among the subgroups be considered the reference nutrient density distribution for the population for planning purposes.

For the subgroup with the highest target median nutrient density, the planned diet should achieve the targeted prevalence of inadequacy. For all other subgroups, the prevalence of inadequacy will be even lower since the nutrient density of the planned diet will exceed their needs. Thus for the population as a whole, the risk of inadequacy will be lower than the level set for the subgroup with the highest target nutrient density.

The target nutrient density intake distribution is obtained from an adequate target nutrient intake distribution, and therefore the resulting target distribution of nutrient density intakes meets the criterion for adequacy that was selected. It is also important to monitor the proportion of individuals whose intakes of the nutrient might exceed the UL.

For some nutrients (notably iron), prioritization of the needs of the subgroup with the highest requirement relative to energy can result in the selection of a target median nutrient density that far exceeds the needs of all other subgroups. Under these circumstances, planners must consider the risk that members of subgroups with lower nutrient requirements relative to energy may achieve intake levels in excess of the UL. They must also consider the cost-effectiveness of providing such a nutrient-dense diet for all subgroups. Under some circumstances, it might be deemed more appropriate to select a lower target nutrient density for the group as a whole and employ direct interventions for the one or two population subgroups in which the prevalence of inadequacy would be above the desired level. This should not be seen as a weakness of the nutrient density approach. Rather, this approach enables the identification of such planning issues.

The strength of the nutrient density approach to planning for groups comprised of individuals from different life stage and gender groups is that the method enables planners to systematically take into account both the specific nutrient requirements of various subgroups and their differing energy needs. The effectiveness of this approach hinges on the ability to implement it and on the validity of the assumptions that underpin it.

TECHNICAL CONSIDERATIONS OF THE NUTRIENT DENSITY DISTRIBUTION APPROACH

Although the nutrient density distribution approach described above is a promising tool for planning group diets, several important issues must be considered.

Nutrients for Which an Adequate Intake Has Been Established

The nutrient density distribution approach to planning group diets cannot be used for nutrients with an Adequate Intake (AI). The reference nutrient density ratio links the requirement distribution of the nutrient and the usual intake distribution of the nutrient to obtain a target nutrient intake distribution (as described in Chapter 3), and then expresses this distribution as a density. Thus, this approach cannot be used in planning for nutrients with AIs because in these cases there is no knowledge of the requirement distribution of the nutrient. Although the simple approach using the median nutrient density presented in the previous section can be used for nutrients with an AI, planners need to be aware of the limitations of this method.

Correlation Between Nutrient Intakes and Energy Intakes

A premise of the nutrient density distribution approach to planning intakes of heterogeneous groups is that the correlation between usual nutrient intakes and usual energy intakes is moderate to low. This assumption permits computing the simple Monte Carlo average that results in a target distribution of nutrient density intakes in each subgroup. The low correlation assumption may not hold since it would be expected that, in general, higher energy consumption would imply higher intake of the nutrient. However, as discussed above, planning intakes for a group in terms of densities would most often imply a change in the relationship between energy and nutrient consumption, one objective being to provide more units of the nutrient per 1,000 kcal of energy in the diet. If, however, assuming low correlation between nutrient and energy intake is deemed unrealistic, in principle their relationship could be modeled, and the Monte Carlo average presented in equation (2) above could be improved. Otherwise, the target density intake distribution in each subgroup could be derived directly from the target *joint* intake distribution of the nutrient and energy. In the latter case, the methods presented in Chapter 3 for a single nutrient would need to be extended accordingly to address the problem of estimating the target intake distribution of two nutrients jointly (one of them being energy). A simplified first approximation of the density approach to planning intakes for heterogeneous groups is presented here, on the assumption that the correlation between energy and nutrient intakes may not be so high as to significantly affect the derivation of the target median nutrient density for the group. However, more research is needed to explore the full implications of this assumption.

The Impact of Reporting Errors

As noted previously, there is ample evidence to suggest that underreporting is a serious problem in dietary intake surveys. The use of doubly labeled water methods to determine energy expenditure has facilitated identification of underreporting in energy intakes, but it is unclear how the reporting of other nutrients is affected by this phenomenon. At present, well-established, validated methods are lacking to identify and correct for systematic reporting errors in individual intakes. Thus it is impossible to determine the impact of underreporting on the planning methods proposed here. Nonetheless, the sources and probable direction of errors associated with underreporting are explored below, considering the particular ways in which self-reported intake data are used in the proposed application of the distribution of nutrient densities to plan for heterogeneous groups. Note that while the discussion below relates primarily to the nutrient density distribution approach, the issues raised are equally relevant to the simple approach that relies on the estimated median energy intake.

The estimated distribution of usual energy intakes is required to derive a distribution of nutrient requirements expressed as densities when planning intakes of a single food or of a diet composed of a variety of foods with similar nutrient density. In planning for heterogeneous groups under normal circumstances (e.g., where individuals consume diets that comprise multiple foods with varying nutrient densities), both nutrient and energy intake data are required. The estimated distribution of usual nutrient intakes is required to estimate the target nutrient intake distribution (see Chapter 3). The estimated distribution of usual energy intakes is necessary to express the target usual nutrient intake distribution in terms of target nutrient densities. Underreporting may bias both the nutrient and energy intake distributions.

The impact of underreporting on estimates of target usual intake distributions expressed as nutrient densities is likely to vary depending on the nutrient of interest. If some of the energy intakes are systematically underreported, but the target nutrient intake distribution is less affected by underreporting, then some overestimation of nutrient requirements in relation to energy would occur. If energy and nutrient intakes have both been underreported to the same extent, then the target density intake distribution may be less biased. However, this assumption of "proportional underreporting" is probably not valid. A more likely scenario is that intakes of energy and the nutrient in question have been disproportionately underreported. The distribution of target usual nutrient intakes expressed as densities will then also be estimated with error, but the nature and magnitude of the error is unknown. The extent of this problem would depend on the number of underreported intakes, the extent of underreporting in energy versus nutrient intakes, and the magnitude of underreporting in the intake data used.

One way to avoid the potential for systematic errors in self-reported energy intakes to skew the distribution of nutrient density requirements might be to approximate the distribution of usual energy intakes from the distribution of energy requirements in the group. Given the high correlation between individuals' energy intakes and energy expenditure, usual energy intake should equal energy expenditure if individuals are in energy balance. Thus, the distribution of usual energy intakes could be constructed by estimating the distribution of energy requirements for the subgroup. Equations to predict energy requirements are provided for individuals with a body mass index (BMI) of > 18.5 and < 25 (IOM, 2002a). Another set of equations is provided to predict total energy expenditure for individuals with BMI ≥ 25. Application of these equations requires knowledge of each individual's age, sex, height, and weight, and sufficient information to classify the individual into one of four broad categories of physical activity levels. In applying the equations to estimate the distribution of usual energy intakes, it is also necessary to take into account the variation in requirements of individuals, estimated by the standard deviation of the prediction.

While this approach provides an alternative to the use of self-reported intake data, it also has some serious limitations. The accuracy of the energy expenditure estimates hinges on the applicability of the equations (and their variance estimates) for the particular group of interest and on the accuracy of the available data on an individual's height, weight, and physical activity level. All of these parameters are subject to measurement error, particularly if self-reported data are used. Furthermore, use of the energy expenditure equations does not eliminate the need to use self-reported nutrient intake data to obtain an estimate of the target nutrient intake distribution.

The use of self-reported dietary intake data is likely to be unavoidable in planning for groups. Clearly, more research is needed to enable planners to identify the nature and magnitude of systematic reporting errors in these data and to statistically adjust planning applications when such errors are present.

An algorithm for the group planning applications presented here and in Chapter 3 is summarized in Figure 4-1. It should be noted, however, that the approaches described are largely theoretical at this stage. More research is required to address specific technical issues, test the effectiveness of the proposed approaches in "real-life" settings, and refine their practical application.

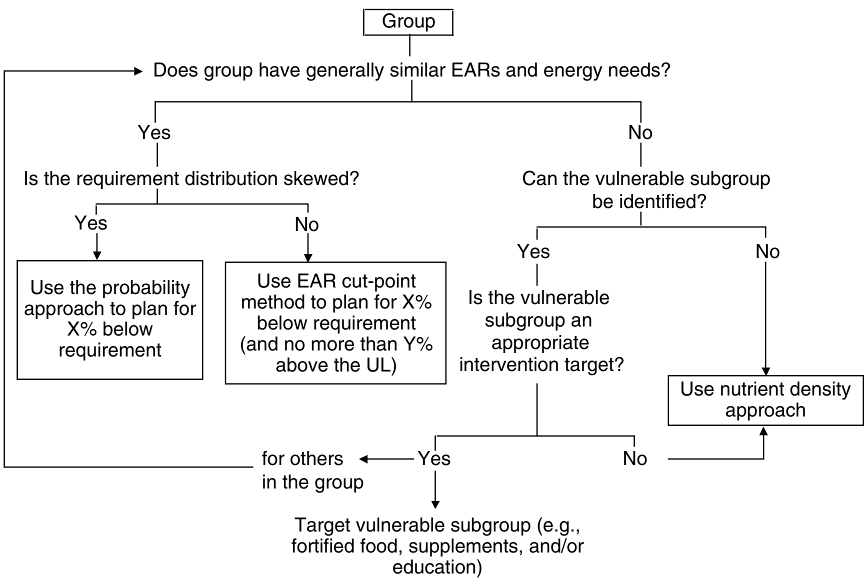

FIGURE 4-1 Schematic decision tree for planning group diets.