The use of recommended daily allowances to assess dietary adequacy

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Using the recommended daily allowance (RDA) to assess dietary adequacy implies making a direct comparison between RDA and some measure of dietary intake. The value and usefulness of doing so must clearly depend on the limitations of each.

By definition the RDA are intended to cover 'the average amount of the nutrient, which should be provided per head in a group of people if the needs of practically all members of a group are to be met'. Philosophically and statistically speaking the RDA are set theoretically at two standard deviations above the mean requirement of the group. Thus the RDA as published in the summary table of the report by the Department of Health and Social Security (DHSS) (1979) have limitations for the assessment of dietary adequacy. If the mean intake of a group is above the RDA we can expect that only a few individuals with particularly high requirements and particularly low intakes might be deficient. However, if the mean intake is below the RDA, we do not know what interpretation to put on the value.

If we are to assess the probability of deficiency in a group, we need three pieces of information: (1) a good measure of the mean intake of that group and the range of intakes, (2) a good measure of the mean requirement and the range of requirements, (3) a knowledge of the correlation between individual intakes and requirements. These are now discussed in turn.

Limitations of dietary assessment

The main methods of dietary assessment are:

(1) *Weighed dietary record* (*WI*). A prospective method in which subjects are asked to weigh and record all food and drink taken over a given period of time, usually 7 d.

(2) *Record in household measures* (*HM*). As for WI but with portions described in spoonfuls, cupfuls, etc. instead of being weighed.

(3) *24 h recall* (*24R*). A retrospective interview method in which the subject is asked to recall the foods eaten on the previous day and to describe the portions in household measures possibly with the help of models, replica foods or photographs.

(4) *Diet history* (*DH*). A retrospective interview method that attempts to reconstruct a 'typical' food intake over 1 week. It usually begins with a 24 h recall and continues with further questioning about alternative menus, weekend patterns and the frequency of consumption of different foods.

There are many sources of errors in all these methods. We want to know how they affect the calculation of the mean and the range of intakes and in particular

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Table 1. *Effects of errors in dietary survey methods on the calculated nutrient intakes*

	Mean				Range			
	WI	HM	24R	DH	WI	HM	24R	DH
Food tables	=	=	=	=	=	=	⟷	=
Co-operation rates	??	??	?	?	??	??	?	?
Changed diet	↓	↓	×	×	←	←	←	←
Estimated weights	×	=	=	?	×	?	??	???
Poor memory	×	×	↓↓	?↑	×	×	←	?
Wrong 'perception' of diet	×	×	×	?↑	×	×	×	?
Variation with time	=	=	=	×	⟷	⟷	⟷⟷	×

WI, weighed diet record; HM, record in household measures; 24R, 24-h recall; DH, diet history; =, error has no significant effect on this measurement; ?, effect of error unknown; ↓, error probably causes an underestimate of mean intake; ↑, error probably causes an overestimate of mean intake; ⟷, error likely to exaggerate the range of both high and low intakes; ←, error likely to exaggerate the range of low intakes; ×, error not applicable to this survey method.

whether they lead to exaggerated estimates of the number of people with low intakes.

The sources of errors and their effects on the calculation of energy and protein intakes have been reviewed by Bingham (1983, 1986). Since nutrient intakes are correlated with energy intakes (for a majority of minerals and vitamins, the correlation coefficient (r) is between 0·6 and 0·7; for vitamins A and C it is 0·3–0·4), broad conclusions about the effects of the errors on the calculation of energy intake apply also to the nutrient intakes. These are summarized in Table 1.

Food tables. The use of food tables can contribute large errors to the calculated intakes of individual days, but as the number of days or subjects increases, those errors are much reduced. The use of food tables therefore probably does not significantly affect the calculation of mean intakes, but will tend to exaggerate the range found in single day surveys.

Co-operation rates. Since co-operation in surveys of random samples of the population is never 100%, some bias must be introduced. The degree and the direction are unknown, but will probably be greater in prospective surveys where average co-operation rates are about 68% compared with 77% for interview methods.

Changed diet. The fact of being observed may cause people to change their diet either to simplify recording or to impress the observer. It could have little effect, a second helping omitted to save bother may be compensated for at the next meal. However, in our weight-conscious society, I suspect the most likely effect is for intermittent dieters to diet while recording. This will almost certainly exaggerate the lower range. Whether it has a significant effect on calculated mean intake will depend on the proportion of dieters in the group under study.

Estimated weights. The use of estimated weights can contribute large errors to the calculated intakes of individuals; this may or may not affect the range found.

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However, studies that have compared records with estimated weights against weighed records have not found any systematic bias in the calculated mean intakes. In prospective records, the subject estimates the portion in front of him; in 24R, however, it is the portions eaten yesterday; and in a DH it is the probable or imagined portions. The errors are probably greater in the latter two methods.

Memory errors. There is a systematic bias towards the underestimation of intake using 24R. Out of twenty-four studies which compared 24R with written records or observed intakes, thirteen found a significant underestimation of mean intake while only four found a significant overestimation (Bingham, 1983, 1986). The range also is likely to be extended towards lower intakes.

'Perception' of diet. The DH combines errors of memory with errors in the perception of the total diet. A person will tell you what they think they eat which is not necessarily what they actually do eat. Thirteen studies have compared DH with prospective written records and, on balance, DH gives a higher mean intake. There was generally poor agreement between the two methods for the intakes of individuals (Bingham, 1983, 1986). Supporters of DH argue that it actually measures 'habitual' intake whereas records only measure short time-periods. However, there have been two studies where records were kept to 30 and 42 d respectively; long enough to establish habitual energy intakes to within 4% standard error (Huenemann & Turner, 1942; Jain *et al.* 1980). In these studies DH still gave higher energy intakes, by 11 and 28%, and the intakes of some or all

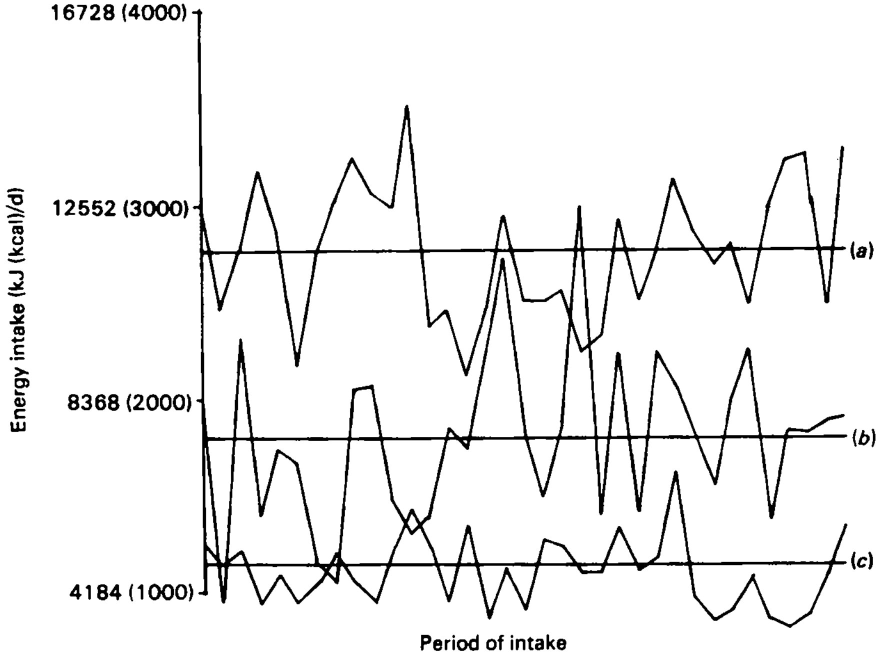

Fig. 1. Daily energy intakes of three individuals who took part in a long-term dietary survey weighing their food intake every 6th day (Black *et al.* 1984). Mean daily intakes and their standard deviations: (*a*) 11 550 (SD 1485) kJ, 2760 (SD 355) kcal; (*b*) 7530 (SD 2050) kJ, 1800 (SD 490) kcal; (*c*) 4770 (SD 900) kJ, 1140 (SD 215) kcal.

Table 2. *Within-subject coefficient of variation of nutrient intake in forty-three dietitians studied for* 14–72 (*mean* 40) *d* (*C. Ravenscroft, unpublished results*)

Nutrient	Pooled mean (%)	Range (%)
Energy	26	10–50
Protein	26	11–66
Fat	35	17–67
Carbohydrate	28	14–54
Fibre	33	19–55
Zinc	32	14–66
Thiamin	33	15–57
Calcium	33	20–66
Iron	40	18–60
Riboflavin	46	17–87
Vitamin C	61	29–99

nutrients were increased by similar or greater amounts; there was also poor agreement on individual intakes. However, this still leaves unresolved the question of whether WI underestimate or whether DH overestimate intake.

Variation with time. Day-to-day variation of food intake is considerable, as illustrated in Fig. 1. This shows the daily energy intake of three individuals who took part in a long-term study weighing their food intake every 6th day. Day-to-day variation in nutrient intake was even greater than for energy intake, as shown in Table 2.

The pooled mean within-subject coefficient of variation (CV) on energy for the forty-three individuals studied was 26%: similar values were found for protein and carbohydrate. For fat, fibre, thiamin, zinc and calcium the CV were about 35%, and for iron, riboflavin and vitamin C between 40 and 60%. The ranges show that some individuals have even more variable intakes. Similar results have been found in other studies that have looked at within-subject variation. There is no reason to expect that variation with time will cause any bias in calculated mean intakes of a group. However, it clearly has considerable effect on the precision of measuring individual intakes, as shown in Fig. 2.

Fig. 2. shows that for a 7 d diet survey, the energy intake of the average individual could be measured with 95% confidence to within 20%, i.e. with a standard error of the mean of 10%. However, thiamin and Ca would be measured to within 25%, and Fe to within 30%.

Clearly, single-day records such as 24R cannot possibly measure 'habitual' intake of an individual, and will exaggerate the range of both high and low intakes.

This is illustrated another way in Fig. 3. Here the line (σ) represents the 'true', but unobservable, variation between-subjects, and the line (δ) the within-subject variation due to day-to-day changes in intake. The vector gives the observed overall variation. We would like to reduce δ until the vector equals σ. If we increase the number of days of study (m), the reduction of δ will be proportional to m. Thus by studying 4 d, we halve the error, but we have to study 16 d to halve it

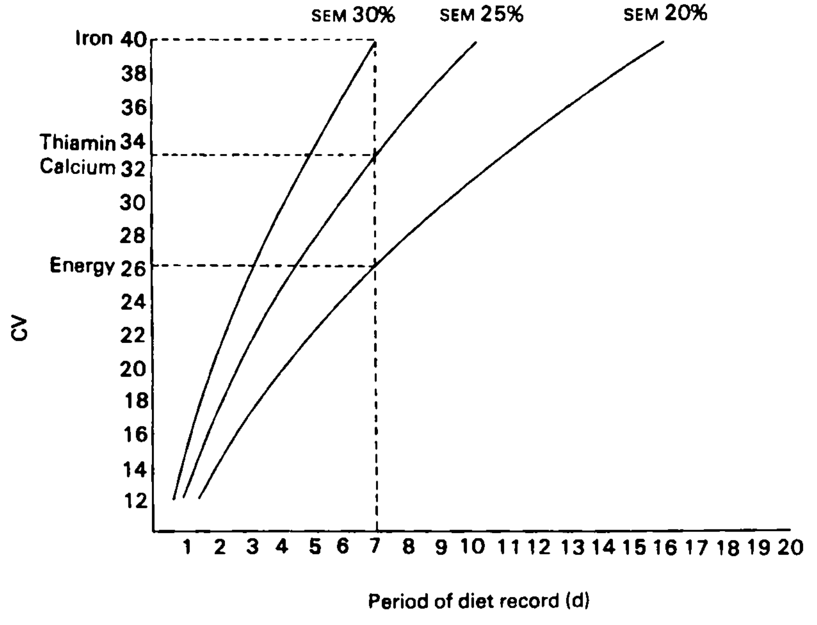

Fig. 2. Nomogram for estimating the precision of the measurement of nutrient intake for an individual given the within-subject coefficient of variation (CV) for that nutrient and the period of dietary record (d). Individual records: number of days needed to estimate usual intake with 95% confidence.

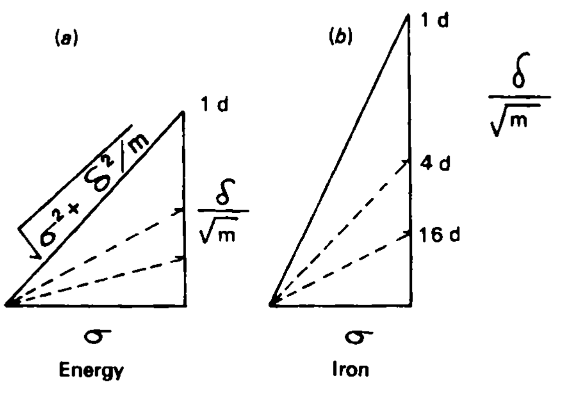

Fig. 3. (*a*) Between- (σ^2) and (*b*) within- (δ^2) subject variation to show the effect on δ^2 of increasing the number of days (m) of a dietary survey.

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again. The two triangles are drawn proportional to the calculated between- and within-subject CV for energy and Fe intakes. For energy these are roughly equal and the within-subject variation is considerably reduced by 4 d studies. With Fe, however, the within-subject variation is so much greater that a 4 d study is required before the within-subject variation approximates to the between-subject variation.

In summary, variation with time does not affect mean intakes, but in short surveys there will be overestimation of the number of individuals with high or low intakes, this overestimation being greater for single-day records than for longer studies, and for nutrients with greater day-to-day variation.

Summary: diet methods

We find that prospective records whether WI or HM perform very similarly; there may be underestimation of mean intakes due to people changing or under-recording their diet and the range of observed individual intakes will be greater than the true range of 'habitual' intakes, particularly at lower intakes.

24R has a definite bias towards underestimation of mean intake and exaggerates the range of intakes at both high and low intakes.

DH is an unstandardized method open to very variable application by different workers. It tends to give mean intakes higher than prospective methods, but it is still unclear whether DH overestimates or prospective methods underestimate. The effect of errors on the range of intakes is unknown.

'Requirements' and RDA

The RDA do not represent 'average' requirements; they are intended to cover the needs of 'practically all members of a group' (DHSS, 1979). Neither do the RDA represent the absolute requirements for any individual. Unfortunately, it is easy for those with a new, marginal or uninformed interest in nutrition to extract RDA values from the summary table in the published report and use them as if they were absolute requirements for individuals.

One problem lies in defining the requirement. As far as vitamins are concerned there could be a whole spectrum of requirements ranging from the intake that just prevents the appearance of clinical deficiency, through intakes that maintain certain biochemical indices to intakes that maintain saturated tissue stores. Where along this spectrum should we place the requirement? Is there a concept of optimum health to be considered, or would we all be just as well off with intakes anywhere above clinical deficiency and below saturated stores? What view does one take of an apparent requirement that is higher than can be provided in the diet?

Results from studies that examine all these levels of intake are used in establishing the measure of 'requirement' that becomes the basis for the actual RDA. It is possible to extract this information from the reports, to find out what safety factor has been added, and to make a more informed judgement about the likelihood of deficiency in a population than can be done by simple comparison with the RDA. Unfortunately, the 1979 report by the DHSS does not give this

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information in detail, since for many nutrients, earlier conclusions remained unaltered. For vitamin A, for example, it merely says 'The recommendations in the table are based on those of the Food and Agriculture Organization/World Health Organization (FAO/WHO) (World Health Organization, 1967)'. The 1969 report by the DHSS gives more detail, but to get full information one has also to consult the two FAO/WHO reports on vitamin and mineral requirements of 1967 and 1970 (World Health Organization, 1967, 1970).

Table 3. *The bases of the recommended daily allowances (RDA)*

Thiamin

1. The requirement is related to carbohydrate intake
2. Little distortion if related to energy intake
3. Intakes <0·2 mg/4184 kJ (1000 kcal) lead to signs of biochemical deficiency, i.e. low urinary excretion, low erythrocyte transketolase (*EC* 2.2.1.1) activity, raised thiamin pyrophosphate
4. Intakes >0·3 mg/4184 kJ (1000 kcal) bring about tissue saturation, i.e. excess excreted in urine
5. A safety factor of 20% to cover individual variation is based on variation in basal metabolic rate found in a study of adult men
6. RDA: DHSS (1979) 0·3×20%=0·4 mg/4184 kJ (1000 kcal)

Vitamin C

1. 5–10 mg prevents/cures scurvy
2. 10–22 mg raises leucocyte ascorbic acid (LAA) in subjects taking <10 mg/d
3. 10–22 mg maintains maximum LAA levels for up to 90 d
4. 21·5 (SD 8·1) mg are catabolized daily in young men taking 73–350 mg vitamin C/d
5. 60 mg are needed to maintain tissue saturation
6. RDA: DHSS (1969) 10 mg trebled = 30 mg
   DHSS (1979) 20 mg × 50% = 30 mg
   NRC (1980) 60 mg

Iron

1. Mean daily losses in men are 14 μg/d per kg body-wt
2. The coefficient of variation of total daily losses is 25%, thus a 65 kg man loses 0·9 (0·4–1·4) mg/d, 55 kg woman loses 0·8 (0·4–1·2) mg/d
3. Menstrual losses: average 1·0 mg/d*, 90th percentile 1·4 mg/d, 95th percentile 2·0 mg/d. Thus total losses for women 0·4–3·2 mg/d
4. Absorption: men 10% of intake, women 18% of intake. Thus requirements for men 5–14 mg/d, women 0·4–1·8 at 10% absorption = 4–18 mg/d, women 1·8–3·2 at 18% absorption = 10–18 mg/d
5. RDA: DHSS (1979) men 10 mg, women 12 mg

Zinc

1. From factorial calculation, daily losses are 2 mg
2. From studies using total parenteral nutrition, the daily requirement is 1·8–2·0 mg absorbed Zn
3. Absorption 25–40%
4. From turnover studies, the total daily requirement is 6 mg (equivalent to 2 mg absorbed Zn and 35% absorption)
5. From balance studies, the total daily requirement is 8–12 mg
6. RDA: NRC (1980) 15 mg
   Dreosti (1982) (Australia), based on requirements of 6–12 mg, at 30–40% absorption 12–16 mg

DHSS, Department of Health and Social Security; NRC, (US) National Research Council.
*From Davidson *et al.* (1979).

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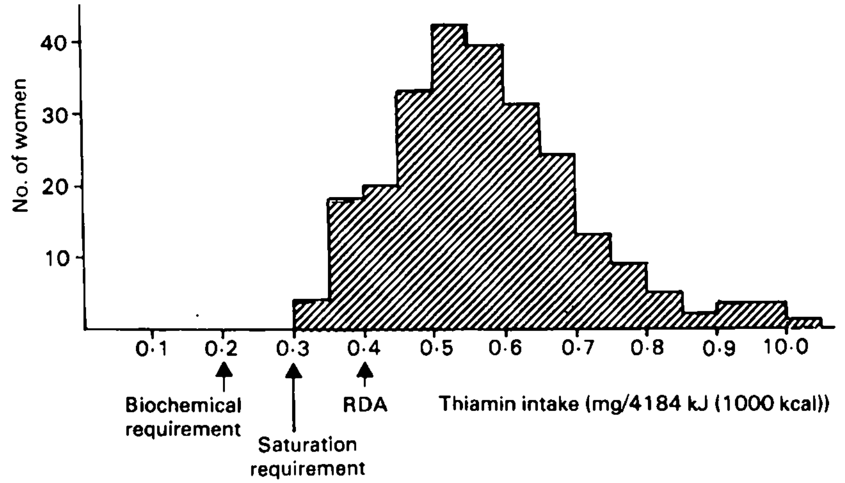

Fig. 4. Thiamin 'requirements' and intakes (mg/4184 kJ (1000 kcal)) in 249 women. RDA, recommended daily allowance (Department of Health and Social Security, 1979). Mean intake 0·57 (SD 0·13) mg/4184 kJ (1000 kcal).

In Table 3 the information on which the RDA are based has been extracted from these reports for two vitamins and two minerals. It has then been compared with the distribution of intakes as found in four Cambridge studies of adult women to see how well the information can be used to assess the probability of deficiency in this population.

The information on which the RDA for thiamin, vitamin C, Fe and Zn are based is shown in Table 3. There is no UK RDA for Zn, but it is a nutrient of interest and other countries have set an RDA. The information is taken from the American (National Research Council, 1980) and Australian (Dreosti, 1982) reports.

The distribution of intakes of these four nutrients in adult women is shown in Figs. 4–7. It is compiled from two longitudinal studies (106 women) with individual intakes based on twenty or more days of study (Black *et al.* 1984, 1986), and two cross-sectional studies (143 women) using 7 d records on random samples from the electoral register (Bingham *et al.* 1981; Nelson *et al.* 1985). The position of the 'requirements' and the RDA are indicated in Figs. 4–7.

(1) *Thiamin.* Fig. 4 indicates that none of this population are likely to be thiamin deficient.

(2) *Vitamin C.* The range of requirements (mean and 2 SD) as calculated from the information in item 4, Table 3, is 5–38 mg. In 1969 the DHSS stated the requirement to be 10 mg/d to cure or prevent scurvy, a value that was based largely on the classic Sheffield studies of long-term vitamin C deprivation in the 1940s (Bartley *et al.* 1953). This was trebled to give the RDA. In 1979 presumably weight was given to the more recent turnover studies (Kallner *et al.* 1979) and the

amount of vitamin C to cure or prevent scurvy was stated to be 20 mg (DHSS, 1979). The RDA, however, remained unchanged, giving an effective safety factor of 50%. The Americans prefer to base their RDA on tissue saturation and so set it at 60 mg (National Research Council, 1980).

Whether anyone in Fig. 5 is to be judged deficient depends entirely on whether one considers tissue saturation to be important. Two conflicting factors also need to be considered. On the one hand the high mean within-subject variation for vitamin C (CV_w 60%) suggests an overestimate of individuals on low intakes; on the other hand, vitamin C also has a high between-subject variation (CV_b 30–70% from various studies) and there is a proportion of the UK population who eat little fruit or vegetables and who have very low intakes (and low within-subject variation).

(3) *Fe*. From the information on mean daily losses in men and the CV on total losses (Table 3), the average and range of requirements for absorbed Fe for men and post-menopausal women have been calculated. To the latter must be added the menstrual losses. The average is said to be 1·0 mg, although this was not in the reports but was taken from a textbook of nutrition (Davidson *et al.* 1979); maximum losses are of the order of 2 mg/d.

Average absorption of Fe from the diet is said to be 10% for men, and 18% for those with low blood levels or high Fe losses. The value of 10% has been used to calculate a range of requirements for men. For women, 18% has been used to calculate a range of requirements for above average losses and 10% for a range of requirements for below average losses.

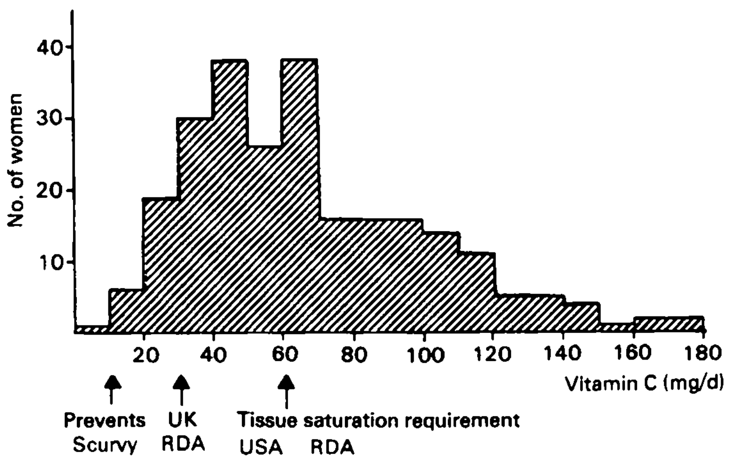

Fig. 5. Vitamin C 'requirements' and intakes (mg/d) in 249 women. RDA, recommended daily allowance. UK RDA, Department of Health and Social Security (1979); USA RDA, National Research Council (1980). Mean intake 69 (SD 36) mg/d. Range of requirements from turnover studies is 5–38 mg/d.

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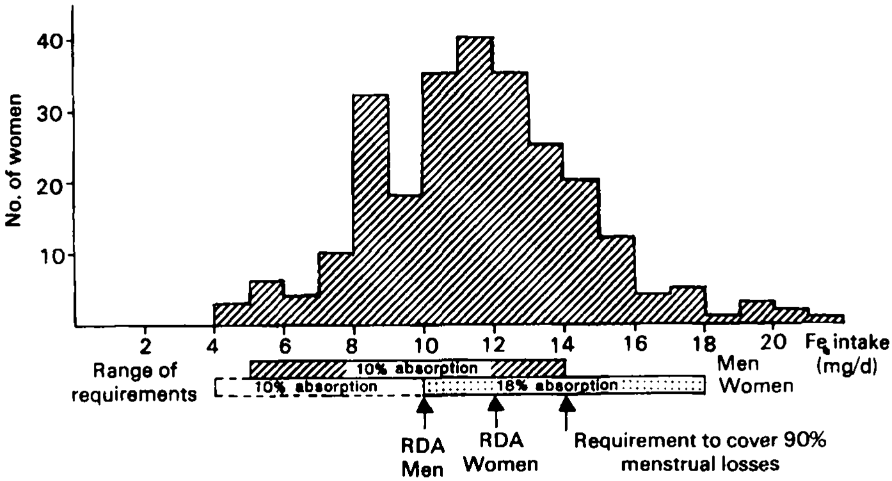

Fig. 6. Iron 'requirements' and intakes (mg/d) in 249 women. RDA, recommended daily allowance (Department of Health and Social Security, 1979). Mean intake 12 (SD 4) mg/d.

Fig. 6 gives the range of requirements for women and this is not very different from the range of intakes; the RDA is the same as the mean intake. If we assume the distribution of requirements and intakes to be the same, then 50% of this population would be receiving less than they need. However, the within-subject variation in Fe intake, as shown in Table 2, is high (CV_w 40%), tending to overestimate the number of individuals with low intakes. The between-subject variation is lower than that for vitamin C (CV_b approximately 20%) and, in an omniverous group, very low intakes are less likely. In Fig. 6, intakes of subjects with twenty or more days of values were all above 8 mg/d. Even allowing for this, Fig. 6 suggests that a significant proportion of this group might be receiving less than their requirement.

4. *Zn*. From the information given in Table 3 the Australians decided that the minimum requirement for dietary Zn was 6–12 mg at an assumed average absorption of 35%. They then added a generous safety factor and set the RDA at 12–16 mg.

Fig. 7 shows that, in women, the RDA for Zn cannot be achieved except by those with high-energy intakes or unusual food patterns. The individual with an intake of 17 mg, for instance, received 26% of her energy from protein and Zn intake is highly correlated (r 0·9) with protein intake.

The interpretation of this value depends on your point of view. Those who agree with the studies which claim to have found signs of Zn deficiency in the population (e.g. Lyon *et al.* 1979), will accept the range of intake seen here as 6–12 mg and conclude perhaps that, as with Fe, needs and intakes coincide and 50% of the population are receiving less than their requirement. Those who think that the

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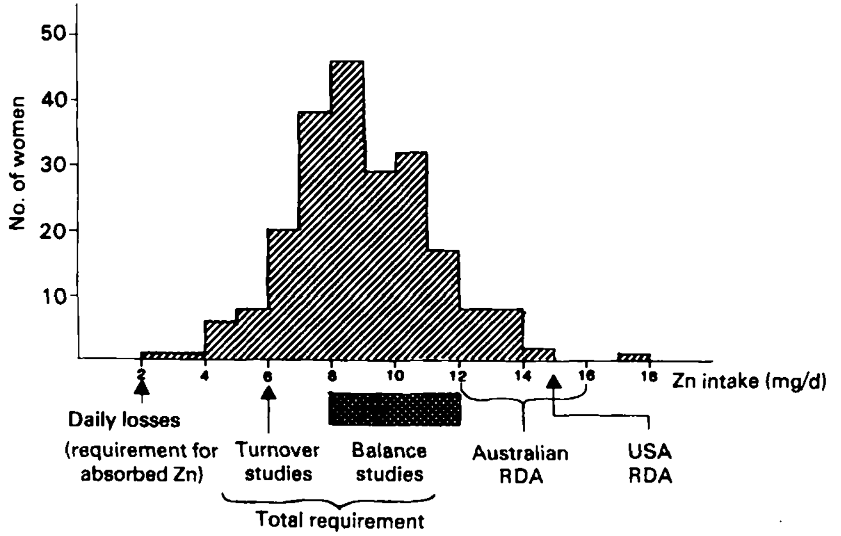

Fig. 7. Zinc 'requirements' and intakes (mg/d) in 249 women. RDA, recommended daily allowance. Australian RDA, Dreosti (1982); USA RDA, National Research Council (1980). Mean intake 9 (SD 2) mg/d.

evidence for Zn deficiency is equivocal, will be more inclined to accept the value from the turnover studies, and to suggest that more weight should be given to evidence of population intakes when establishing RDA.

Correlations between intakes and requirements

The 1979 report by the DHSS stated in the introduction: 'As far as is known, consumption of nutrients is not related to need'. However, this is not entirely true. The report itself goes on to point out that thiamin requirement is related to carbohydrate intake and to express the RDA as mg/4184 kJ (1000 kcal) energy intake. Additionally, riboflavin and nicotinic acid requirements are related to lean cell mass and the RDA is expressed per unit resting metabolism. There is also evidence that vitamin B_6 requirements are greater at higher levels of protein intake and, although there is no UK RDA, other countries have suggested one expressed per g protein intake ((US) National Research Council, 1980; Rutishauser, 1982).

Nutrient consumption is strongly correlated with energy intake. Thus, as carbohydrate intake increases, so will that of thiamin; as protein intake increases so will that of vitamin B_6; and as energy intake increases so will that of riboflavin and nicotinic acid. So for these four nutrients at least there must be some degree of correlation between consumption and need.

It is undoubtedly simplistic, but I would like to suggest that there may be a concept of 'total metabolic turnover' to which nutrient requirements might be related, particularly for those nutrients involved in several enzyme systems.

We know that energy requirements are related to body size whether expressed as lean cell mass or body-weight. In simple terms, bigger people need more food.

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More active people also need more food. Do they also need more nutrients? If they do, then requirements could be related to this 'total metabolic turnover', which is energy driven and includes the components of both body size and activity.

I am not suggesting that any such correlation would be high. Needs would not be totally related to 'metabolic turnover'; individual variation would dilute the relation; individuals of the same age, sex and weight may have differences in metabolic rate of more than 30% (Warwick *et al.* 1978) for example; and correlations between energy and nutrient intake, which are between 0·6 and 0·7 for B vitamins and some minerals, fall to 0·3 for vitamins C and A (Thomson, 1959; A. E. Black, unpublished results). I am saying, however, that we need not assume that there is no correlation between consumption and need.

There are other points to consider. I have been talking as if intake (consumption) and need (requirement) were both finite and directly comparable; x mg of a nutrient are presented to the body; y mg are needed by the body; x is compared directly with y. But there are a number of intermediate steps.

First, there is the question of biological availability, the quantity in the food that is actually available for absorption. In terms of total diets as actually eaten, we have very little information on this.

Second, there are controlling mechanisms in the body which regulate how much of the available nutrient is actually absorbed. We know that Fe absorption is affected by Fe status (Moore, 1965).

Third, there may be adaptive mechanisms in the body that tend to conserve nutrients that are in limited supply. Vitamin C turnover, for example, is related to the size of the total body pool (Kallner *et al.* 1979).

All these factors could operate to bridge the gap between supposed requirement and observed low intake in individuals on limited intakes and so reduce our estimate of the number of individuals likely to be deficient.

Conclusions

1. There are many sources of errors in dietary assessments. Several lead to underestimates of mean intakes, and overestimations of the number of individuals on very low intakes.

2. The DHSS (1969, 1979) and FAO/WHO (World Health Organization, 1967, 1970) reports contain the information on which the RDA are based and which can be used to make a more informed judgement about the likely extent of deficiency in a population than can be obtained from a simple comparison with the RDA.

3. Since intakes of the majority of minerals and vitamins are correlated with energy (total food) intake (r 0·6–0·7) there must be some correlation between intake and requirements for any nutrient where the requirement is related to energy, or energy-providing nutrients.

REFERENCES

Bartley, W., Krebs, H. A. & O'Brien, J. R. P. (1953). *Medical Research Council's Special Report Series* no. 280. London: H.M. Stationery Office.

Bingham, S. A. (1983). The use of urinary metabolites as an independent marker for the assessment of dietary protein intake in individuals. PhD Thesis, University of London.

Bingham, S. A. (1986). *Nutrition Abstracts and Reviews* (In the Press).

Bingham, S. A., McNeil, N. I. & Cummings, J. H. (1981). *British Journal of Nutrition* **45**, 23–35.

Black, A. E., Ravenscroft, C. & Sims, A. J. (1984). *Human Nutrition: Applied Nutrition* **38A**, 165–174.

Black, A. E., Wiles, S. J. & Paul, A. A. (1986). *British Journal of Nutrition* **56**, 59–72.

Davidson, S., Passmore, R., Brock, J. K. & Truswell, A. S. (1979). *Human Nutrition and Dietetics.* Edinburgh: Churchill Livingstone.

Department of Health and Social Security (1969). *Report on Public Health and Medical Subjects* no. 120. London: H.M. Stationery Office.

Department of Health and Social Security (1979). *Report on Health and Social Subjects* no. 15. London: H.M. Stationery Office.

Dreosti, I. (1982). *Journal of Food and Nutrition* **39**, 167–173.

Huenemann, R. L. & Turner, D. (1942). *Journal of the American Dietetic Association* **18**, 562–568.

Jain, M., Howe, G. R., Johnson, K. C. & Miver, A. B. (1980). *American Journal of Epidemiology* **111**, 212–219.

Kallner, A., Hartman, D. & Hornig, D. (1979). *American Journal of Clinical Nutrition* **32**, 530–539.

Lyon, T. D. B., Smith, H. & Smith, L. B. (1979). *British Journal of Nutrition* **42**, 413–416.

Moore, C. V. (1965). *Series Haematologica* **6**, 1–14.

National Research Council (1980). *Recommended Dietary Allowances*, 9th revised ed. Washington DC: National Academy of Sciences.

Nelson, M., Dyson, P. A. & Paul, A. A. (1985). *British Journal of Nutrition* **54**, 373–387.

Rutishauser, I. H. E. (1982). *Journal of Food and Nutrition* **39**, 158–167.

Thomson, A. M. (1959). *British Journal of Nutrition* **13**, 190–204.

Warwick, P. M., Toft, R. & Garrow, J. S. (1978). *International Journal of Obesity*, **2**, 396.

World Health Organization (1967). *Technical Report Series* no. 362. Geneva: WHO.

World Health Organization (1970). *Technical Report Series* no. 452. Geneva: WHO.

Printed in Great Britain