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24-Hour national dietary survey data: how do we interpret them most effectively?

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Abstract

Objective: To illustrate the effect of common mistakes when using 24-hour national dietary survey data to estimate the prevalence of inadequate nutrient intakes.

Design: Raw data on nutrient intake from the Australian 1995 National Nutrition Survey were adjusted for within-person variance using standard techniques and corrected for underreporting using the criteria of Goldberg *et al*. The distributions for six nutrients were compared with current dietary reference values from the UK, USA and Australia.

Setting: A national sample of the Australian population with a 61.4% response rate.

Results: Adjusting for within-person variance reduced the range of nutrient intakes to 66–80% of the raw data range and the proportion with intakes below the estimated average requirement (EAR) by up to 20%. Excluding underreporters further reduced the proportion below the EAR by up to 10%. Using the dietary reference values from different countries also resulted in some markedly different estimates. For example, the prevalence of low folate intakes ranged from <1 to 92% for adult women depending on the reference used. Except for vitamin A and protein, the prevalence of low intakes was invariably higher for women than for men.

Conclusions: Estimates of the prevalence of low nutrient intakes based on raw 24-hour survey data are invariably misleading. However, even after adjustment for within-person variance and underreporting, estimates of the prevalence of low nutrient intakes may still be misleading unless interpreted in the light of the reference criteria used and supported by relevant biochemical and physiological measures of nutritional status.

Keywords
Dietary assessment
Estimated average requirement
Recommended dietary intake
Within-person variance
Underreporting

The food intake data from national dietary surveys are used for many different purposes. This should be encouraged, given the large investment of resources in such surveys. However, it is important not only to recognise but also to take positive steps to minimise, as far as possible, the limitations of these data. The specific purpose of the present paper is to illustrate what can and ought to be done when using national dietary survey data based on 24-hour intakes to estimate the proportion of the population at risk of inadequate nutrient intake. To assess the risk of nutrient inadequacy and, when relevant, excess, it is necessary to compare intake data with recommendations for nutrient needs. Until recently, the only recommendations available were single-level recommendations with a name such as the recommended dietary intake (RDI) or recommended dietary allowance (RDA). The specific definition of the Australian RDI is '*the levels of intake of essential nutrients considered, in the judgement of the National Health and Medical Research Council, on the basis of available scientific knowledge to be adequate to meet the known nutritional needs of practically all healthy people...*'[1]. There are only minor variations in definitional wording for the equivalent recommendation in other countries.

RDIs are derived from estimates of the *average* requirements of different age/sex/physiological groups and, with the exception of energy, incorporate factors to accommodate individual variation in absorption and metabolism. If the requirement distribution is normal, then the requirements of virtually all members of a group are met if the RDI is set at two standard deviations (SD) above the average requirement. However, the SD of requirements is often estimated owing to lack of information.

In 1991, revisions to recommended intakes in the UK introduced the notion of multiple requirement levels, rather than a single number (Box 1)[2], to enable the recommendations to be used appropriately both for

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Box 1 – UK terminology for describing dietary reference values[2]

There are three dietary reference values (DRVs) with different uses:

- Estimated average requirement (EAR): the notional mean requirement of a group.
- Reference nutrient intake (RNI): set a notional two standard deviations (SD) above the EAR.
- Lower reference nutrient intake (LRNI): set a notational 2SD below the EAR.

Safe intake is the level or range of intake at which there is no risk of deficiency but below a level where there is risk of undesirable effects. It is set only for nutrients with known important functions in humans where there are insufficient reliable data to set a DRV.

planning and evaluation of diets. Subsequently, the European Union[3] and the USA and Canada adopted a similar approach (Box 2)[4]. The UK reference nutrient intake (RNI) is conceptually equivalent to the US/Canadian RDA. The US/Canadian adequate intake (AI) is set when there is not enough information to determine even the estimated average requirement (EAR). As the AI is derived from the average intakes of apparently healthy populations, it is presumably higher than the unknown EAR. Building on earlier work by Beaton[5], the US/Canada document highlighted that different approaches are required for evaluating the diets of individuals and groups; specifically, that RDA/RNI should not be used for group assessment. If both the requirement and intake distributions are known, then the probability of inadequate intakes can be calculated[6]. More simply, provided that the distribution of requirements is approximately symmetrical and the variability in intakes is greater than the variability in requirements, the proportion with inadequate intakes can be approximated by calculating the proportion with usual intakes below the EAR[4].

Although EARs, RNIs and RDIs are expressed as daily amounts, all documents clearly state that this is for convenience only and that they actually refer to the long-term averaged intake, not to intake on any one day[1,2,4,7]. With the notable exception of the UK, where national dietary surveys have collected 4–7 days of intake information from participants, most national dietary surveys collect intake information for only 1 day from each participant. The data collected in most surveys are thus conceptually incompatible with the dietary references. Failure to appreciate this point has led to a number of misleading statements about the adequacy of intakes of population groups. One approach to dealing with this problem is to collect a second 24-hour intake on a subset of the sample, as was done in the 1995 Australian National Nutrition Survey (NNS), and to correct the distribution statistically to reflect usual intakes before comparison with dietary references.

A further problem affecting surveys, including national surveys, using self-reported or self-recorded dietary information is underreporting[8]. Although authors frequently caution readers about this, there is rarely an explicit statement about either the impact of underreporting or how it could be allowed for when interpreting the data. Failure to deal with this data problem inflates the prevalence of low intakes and also reduces the prevalence of excessive intakes.

In the present paper, we illustrate the consequences of failing to take into account these problems, for six nutrients (protein, iron, zinc, calcium, folate and vitamin A), using data from the 1995 NNS. Specifically we show how the median and the range of intakes in the population change as appropriate adjustments to remove within-person variance and the effect of underreporting are made

Box 2 – US/Canadian terminology for describing dietary reference intakes[4]

Dietary reference intakes (DRIs) are reference values that are quantitative estimates of nutrient intakes to be used for planning and assessing diets for apparently healthy people. This is an umbrella term that includes:

- Estimated average requirement (EAR): the average daily level of nutrient intake estimated to meet the requirement of half the healthy individuals in a life stage–sex group.
- Recommended dietary allowance (RDA): the average daily level of nutrient intake sufficient to meet the nutrient requirement of nearly all healthy individuals in a life stage–sex group.
  - If the standard deviation (SD) of the EAR is available and the requirement for the nutrient is symmetrically distributed, the RDA is set at 2SD above the EAR;
  - If data are insufficient to calculate an SD, a coefficient of variation (CV) for the EAR of 10% is assumed (unless data indicate a greater variation in requirements) and twice this amount is added to the EAR, e.g. RDA = 1.2 × EAR if CV = 10%;
  - If the distribution of the nutrient requirement for a population is known to be skewed, as with iron, other approaches are used to find the 97th–98th centile to set the RDA.
- Adequate intake (AI): set for nutrients for which an EAR cannot be determined. It is the average daily intake level of a group (or groups) of apparently healthy people.
- Tolerable upper intake level (UL): the highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population.

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to the raw single-day data. We also show the impact of using different reference criteria by calculating the prevalence of low intakes using both the UK and US EARs. Countries that do not yet have multiple recommendation levels commonly use some criterion such as 70% of the RDI when analysing surveys. This is equivalent to assuming that a coefficient of variation of 20% was used to derive the RDI for all nutrients (i.e. if RDI is set 40% (2SD) above the EAR, then it follows that the EAR is equal to 100/140 or ~70% of RDI). Examination of the background papers for the current Australian RDIs[9], for example, indicates that the factors used to allow for individual variation were equivalent to SDs of between 10 and 50% of the average requirement. Hence using a constant 70% RDI as the criterion for all nutrients could lead to incorrect assessment of which nutrients are truly in shortest supply relative to requirements in the population. We illustrate this point by including the proportion falling below 70% of the Australian RDI in this analysis.

Methods

The dietary data used for this paper are those from the Confidentialised Unit Record File produced from the 1995 NNS by the Australian Bureau of Statistics and documented in various reports[10–12]. In brief, the 1995 National Health Survey was a multistage probability sample of private and non-private dwellings in Australia. The 1995 NNS was conducted on a systematic sample of individuals aged 2 years and older selected from the private dwellings from the National Health Survey and had a 61.4% response rate. Interviews were conducted throughout the year and on all days of the week. A sub-sample (approximately 10%) was selected for a second 24-hour recall interview, which was conducted on a different day of the week within 10 days of the first interview[12].

Adjustment for within-person variance

We adjusted for within-person variance using the method described in 1986 by the Subcommittee on Criteria for Dietary Evaluation of the Food and Nutrition Board of the National Research Council[6], rather than the more comprehensive but more complex approach developed by Nusser *et al.*[13], for three reasons. First and most importantly, it was the method used by the Australian Bureau of Statistics to derive the published adjusted percentile distributions for nutrients from the 1995 NNS[10]; second, it can be described in simple statistical terms; and third, it does not require access to a dedicated software package. Briefly, the method shrinks the distribution of 24-hour intakes, to one more closely approximating the distribution of habitual intakes, by using analysis of variance to remove the effect of day-to-day variation on the distribution, using data from a sub-sample of individuals who completed a second 24-hour recall. Apart from retinol, provitamin A and total vitamin A, all of which were log-transformed prior to analysis of variance, intakes of the remaining nutrients were approximately normally distributed. The between-person SD was estimated in the replicate sample for the following age groups: 2–11, 12–24, 25–44, 45–64 and 65 years and older. For this paper only data from individuals aged 10 years and over were used. The between-person SD was used to adjust each individual's value from the single-day intake as follows:

$$\text{Individual adjusted value} = \text{group mean} + (\text{group mean} - \text{individual value}) \times (S_b/S_{obs}),$$

where S_b is the between-person SD estimated from the replicate sample and S_{obs} is the SD from the raw (24-hour) nutrient intake distribution of the total sample.

Although the adjusted values can be used to derive the adjusted distributions for the population, they do not give correct values for individuals[7] and so cannot be used in an individual-based analysis e.g. examining the association between blood pressure and intakes of particular nutrients. For vitamin A, distributions were back-transformed to the original scale before calculating the distribution centiles.

Correction for underreporting

Based on the cut-off values derived by Goldberg *et al.*[14] to identify energy intakes unlikely to be plausible (lower 95% confidence limit) for weight-stable individuals during a single 24 h period, 12% of adult men and 21% of adult women in the NNS underreported their intakes[7,10]. We have used the same criteria to identify underreporters to estimate the impact of underreporting on the prevalence of low nutrient intakes. Exclusion of underreporters in the age groups used for analysis reduced the dataset by 4–15% for men and 8–28% for women. The intake distributions of these groups were corrected for within-person variability as described above. Children under the age of 10 years were omitted from the analysis because estimates of basal metabolic rate based on the equations of Schofield *et al.*[15] were not available from the survey and because the Goldberg cut-offs were derived from adult data.

Calculation of centiles

The 10th, 50th (median) and 90th centile of each of the three distributions (raw, adjusted, adjusted and corrected) were calculated for each age–sex group for each nutrient.

Comparison with dietary reference values

To illustrate the impact of using the above adjustments and corrections, the prevalence of low intakes was calculated for each of the three distributions for age–sex groups for each nutrient using the UK EAR[2] as the criterion. The adjusted and corrected distribution was also used to examine the effect of differences in the definition and derivation of the reference criteria, by calculating the proportion below the US EAR[16–19] and 70% of

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the Australian RDI[1]. The current Australian RDI gives a range rather than a single figure for iron and so we chose the mid-point of the range for the calculations in Tables 3 and 4. The age groups in Tables 3 and 4 are those used for the Australian RDIs and differ slightly from those used for the UK and US EARs for children aged 10–18 years.

Analyses and ethics

All analyses described in this paper were carried out using the survey commands available in Stata version 6[20]. Ethics permission for the NNS was granted by the Australian Institute of Health and Welfare and for the current analysis by the Joint Ethics Committee of the Menzies School of Health Research and the Royal Darwin Hospital.

Results

Population distributions

The median and 10th–90th centile range of the raw nutrient intake distributions, the distributions adjusted for within-person variability and the distributions adjusted for within-person variability and corrected for underreporting are shown in Tables 1 and 2 for men and women, respectively. The median is expressed in g, mg or μg as appropriate for the nutrient. The 10th–90th centile range is expressed as a percentage of its median, so that the relative size of this range can be compared across ages, sexes and nutrients.

The 10th–90th centile range of the raw intakes is approximately 50–190% of the median for all nutrients except vitamin A, for which the 90th centile is greater than 200% of the median. Adjusting for within-person variability reduces the range to approximately 70–150% of the median for all nutrients including vitamin A and, on average, increases the median by about 3%. The impact of adjustment on the range of actual intakes is marked. For example, for iron for adult women, the raw 10th–90th centile range is 4.7–15.5 mg, whereas the adjusted range is 7.5–12.5 mg.

Correcting for underreporting in addition to adjusting for within-person variability increases the median further,

Table 1 Comparison of median intake and 10th–90th centile range (expressed as a percentage of the median) for selected nutrients calculated from Australian, single day, 24-hour recall data and published adjusted 24-hour data from the Australian Bureau of Statistics[10,11]: men

Nutrient/age group (years)	Median (10–90*)		
	Raw 24-hour data	Adjusted 24-hour data	Adjusted 24-hour data corrected for underreporting
Protein (g)			
10–11	81.4 (61–153)	83.0 (76–132)	83.7 (76–131)
12–15	95.1 (58–169)	96.5 (68–152)	99.7 (68–150)
16–18	107.5 (56–176)	110.4 (67–157)	116.5 (70–153)
19 and over	100.1 (57–170)	105.3 (72–140)	108.4 (75–138)
Iron (mg)			
10–11	12.8 (51–172)	13.2 (67–149)	13.3 (71–148)
12–15	14.8 (50–170)	15.1 (61–154)	15.5 (63–152)
16–18	15.8 (50–198)	16.2 (62–176)	17.2 (64–167)
19 and over	15.2 (54–172)	15.7 (71–145)	16.2 (73–142)
Zinc (mg)			
10–11	10.0 (57–168)	10.3 (79–134)	10.5 (79–132)
12–15	11.2 (61–189)	12.2 (86–130)	12.4 (86–129)
16–18	13.6 (52–186)	14.3 (83–130)	14.5 (84–130)
19 and over	12.8 (54–182)	14.0 (77–129)	14.3 (79–129)
Calcium (mg)			
10–11	823 (48–204)	883 (70–160)	890 (70–158)
12–15	967 (46–199)	1006 (64–166)	1041 (63–164)
16–18	1083 (42–218)	1144 (62–178)	1173 (65–181)
19 and over	827 (44–199)	866 (59–171)	910 (62–168)
Folate (μg)			
10–11	209.1 (63–181)	220.2 (82–140)	221.3 (82–139)
12–15	238.7 (52–189)	251.1 (72–152)	256.6 (73–153)
16–18	278.0 (56–176)	291.1 (74–145)	299.6 (76–147)
19 and over	285.3 (55–170)	293.1 (72–143)	302.9 (75–140)
Vitamin A (μg)			
10–11	877 (37–220)	858 (47–181)	870 (50–178)
12–15	908 (33–231)	902 (45–183)	919 (50–181)
16–18	980 (35–239)	953 (47–187)	1000 (48–179)
19 and over	941 (37–242)	922 (61–160)	959 (63–157)

*10–90 centile range is expressed as a percentage of median intake.

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Table 2 Comparison of median intake and 10th–90th centile range (expressed as a percentage of the median) for selected nutrients calculated from Australian, single day, 24-hour recall data and published adjusted 24-hour data from the Australian Bureau of Statistics[10,11]: women

Nutrient/age group (years)	Median (10–90*)		
	Raw 24-hour data	Adjusted 24-hour data	Adjusted 24-hour data corrected for underreporting
Protein (g)			
10–11	65.7 (66–160)	67.8 (81–133)	68.6 (83–133)
12–15	71.1 (55–160)	71.9 (68–143)	74.6 (69–140)
16–18	75.0 (53–175)	76.5 (67–153)	82.4 (66–147)
19 and over	69.5 (55–164)	71.4 (72–138)	75.4 (77–136)
Iron (mg)			
10–11	9.8 (59–176)	10.1 (70–156)	10.3 (71–161)
12–15	10.3 (51–159)	10.5 (65–143)	11.0 (67–146)
16–18	9.7 (51–190)	10.1 (66–162)	10.6 (65–163)
19 and over	11.1 (54–168)	11.4 (71–143)	12.1 (75–139)
Zinc (mg)			
10–11	7.9 (61–172)	8.4 (86–126)	8.5 (88–126)
12–15	8.4 (51–180)	8.6 (70–154)	9.1 (68–148)
16–18	8.1 (54–212)	8.7 (71–171)	9.2 (75–162)
19 and over	8.7 (54–178)	9.3 (80–134)	9.7 (83–133)
Calcium (mg)			
10–11	720 (42–210)	768 (74–150)	776 (77–151)
12–15	722 (38–194)	732 (48–178)	780 (53–175)
16–18	688 (49–208)	706 (58–189)	779 (57–174)
19 and over	663 (45–192)	688 (60–172)	743 (63–160)
Folate (μg)			
10–11	191.5 (55–154)	194.7 (75–130)	195.0 (76–135)
12–15	181.4 (61–176)	192.5 (80–139)	197.3 (81–139)
16–18	195.3 (50–182)	205.1 (74–142)	216.7 (75–138)
19 and over	216.7 (52–167)	224.9 (74–135)	233.6 (77–132)
Vitamin A (μg)			
10–11	782 (34–253)	754 (53–171)	772 (56–169)
12–15	718 (34–242)	701 (58–154)	718 (66–152)
16–18	670 (39–252)	661 (63–157)	690 (71–152)
19 and over	754 (34–244)	733 (61–150)	773 (65–146)

*10–90 centile range is expressed as a percentage of median intake.

as expected, to between 5 and 13% above the raw median for all nutrients except vitamin A. Compared with adjusting for within-person variability only, alterations in the range are minimal.

Prevalence of low intakes

Tables 3 and 4 show estimates of the prevalence of low intakes for men and women, respectively. Table 4 shows iron data only for women aged 50 years and older, because the iron requirement distribution for menstruating women is highly skewed and the EAR cut-off approach is not appropriate[4]. The first set of columns in Tables 3 and 4 illustrates the effect of making adjustments and corrections to the raw data on the prevalence of intakes below the UK EARs. There is little impact for protein, for which the median intake lies far above the EAR. For the other nutrients, use of the raw intakes results in a substantially higher prevalence of low intakes (up to 20%) in some age groups. Most of these reduce to a prevalence of 0–5% when the raw data are adjusted and corrected. Tables 3 and 4 also show the prevalence calculated when the US EAR and 70% of the Australian RDI are applied to the adjusted and corrected distributions. There is broad agreement between the reference criteria for all three countries for men and women for protein and vitamin A, and for men for zinc and iron. There is important disagreement between the US and UK for folate for both men and women. For example, low folate intakes would appear to be a major problem in Australia for both men and women based on US EARs but not if the UK EARs are used. For calcium and zinc, 70% of the Australian RDI gives somewhat higher estimates of inadequate intakes for most age–sex groups than does the UK EAR.

Discussion

These results highlight the importance of making appropriate allowance for the limitations of 1-day dietary survey data and, in particular, the erroneous conclusions about population intakes that would be drawn if analyses were based on the unadjusted (raw) intakes. The results also highlight large differences in the prevalence of low

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Table 3 Effect of adjustment for within-person variation and correction for underreporting of the 24-hour recall data on the percentage of Australian men with nutrient intake below the UK or US estimated average requirement (EAR) and 70% of the Australian recommended dietary intake (RDI)

	UK				USA		Australia	
		% <EAR			% <EAR		% <70% RDI	
Nutrient/age group (years)*	EAR	Raw 24-hour	Adjusted 24-hour	Adjusted & corrected 24-hour	EAR	Adjusted & corrected 24-hour	70% RDI	Adjusted & corrected 24-hour
Protein								
10–11	22.8	<1	0	0	27.4	0	22.8	0
12–15	33.8	2.0	0	0	27.4	0	35.7	0
16–18	46.1	3.6	<1	0	44.5	0	46.9	0
19 and over	44.4	4.1	<1	<1	46.2	<1	38.5	<1
Iron								
10–11	6.7	10.1	<1	0	5.9	0	4.9	0
12–15	8.7	17.0	5.5	3.4	5.9	0	8.1	2.6
16–18	8.7	12.7	5.5	1.8	7.7	<1	8.1	1.2
19 and over	6.7	4.9	<1	<1	6.0	<1	4.9	<1
Zinc								
10–11	5.4	7.0	0	0	7.0	<1	6.3	0
12–15	7.0	12.3	0	0	7.0	0	8.4	0
16–18	7.3	10.5	0	0	8.5	0	8.4	0
19 and over	7.3	12.2	0	0	9.4	1.1	8.4	<1
Calcium								
10–11	425	12.3	0	0	AI = 1300	†	560	5.1
12–15	750	31.1	19.3	17.1	AI = 1300	†	840	26.7
16–18	750	32.0	11.8	8.3	AI = 1300	†	700	6.1
19–49	525	21.3	7.5	4.7	AI = 1000	†	560	7.1
50 and over	525	23.8	19.2	13.3	AI = 1200	†	560	16.0
Folate								
10–11	110	5.1	0	0	250	70.7	105	0
12–15	150	17.4	1.0	<1	250	45.1	140	<1
16–18	150	7.0	1.1	0	330	65.9	140	0
19 and over	150	8.5	<1	<1	320	58.6	140	<1
Vitamin A								
10–11	350	10.2	5.7	4.8	445	10.9	350	4.8
12–15	400	14.8	8.4	6.8	445	9.4	508	12.5
16–18	500	20.7	12.5	10.3	630	23.8	525	13.9
19 and over	500	20.7	6.6	4.3	625	11.2	525	5.3

*The age groups used for the UK and US EARs for children aged 10–18 years differ slightly from those used in this table.
†The proportion of a group with intake below the adequate intake (AI) cannot be used to estimate the proportion with inadequate intake since the AI probably exceeds both the EAR and RDI and has no relationship with either.

intakes when current reference criteria from different countries are applied to the same dataset.

The need to correct 24-hour data for within-person variation is unequivocal since the distribution of 1-day intakes for a group is invariably wider than the distribution of usual intakes for the same group. For this reason, using raw data almost invariably overestimates the proportion of the population below a given cut-off irrespective of whether this is an EAR, an RDI/RNI/RDA or a fraction of the RDI, when the cut-off is below the population median intake. Although not reported here, the effects of adjusting the intake distribution for intra-individual variability are similar in children aged below 10 years and so it is important to adjust the data for this group too. Two recent national nutrition surveys in New Zealand, based on 24-hour intakes, have used the more complex C-SIDE software package instead of the EAR cut-off method to estimate the distribution of usual nutrient intakes to assess the prevalence of low nutrient intakes, but have published only the raw and not the adjusted intake distributions[21,22]. C-SIDE estimates the distribution of usual intakes based on the method described by Nusser *et al.*[13] and described in detail by Dodd[23]. It differs from the National Research Council method[6] used in the 1995 NNS and this paper by first making preliminary adjustments to the raw data to allow for nuisance effects, such as day of the week and interview sequence, and then applying a combination of power and semi-parametric transformations to allow for varying degrees of departure from normality in the raw data for different nutrients. In a Monte Carlo study carried out to evaluate the performance of their procedure, Nusser *et al.*[13] were able to show that it estimated the 5th–95th centile range of a simulated usual intake distribution to within 1% of the true values while 'a 2-day mean' approach resulted in the upper and lower bounds of the 5th–95th centile range being 10% below and 7% above the true

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Table 4 Effect of adjusting for within-person variation and correcting for underreporting of the 24-hour recall data on the estimated percentage of Australian women with nutrient intake below the UK or US estimated average requirement (EAR) and 70% of the Australian recommended dietary intake (RDI)

	UK				USA		Australia	
		% < EAR				% < EAR		% < 70% RDI
Nutrient/age group (years)*	EAR	Raw 24-hour	Adjusted 24-hour	Adjusted & corrected 24-hour	EAR	Adjusted & corrected 24-hour	70% RDI	Adjusted & corrected 24-hour
Protein								
10–11	22.8	1.5	0	0	28.1	0	23.1	0
12–15	33.1	4.4	<1	0	28.1	0	34.7	0
16–18	37.1	8.1	1.7	0	38.3	0	39.9	<1
19 and over	37.2	9.0	1.4	<1	37.6	<1	31.5	0
Iron†								
50 and over	6.7	12.2	4.2	<1	5.0	0	4.2	0
Zinc								
10–11	5.4	15.4	0	0	7.0	4.2	6.3	0
12–15	7.0	32.2	22.2	16.2	7.0	16.2	8.4	35.7
16–18	5.5	17.2	5.4	<1	7.3	15.5	8.4	29.9
19 and over	5.5	15.6	<1	<1	6.8	1.3	8.4	17.9
Calcium								
10–11	425	17.3	<1	0	AI = 1300	‡	630	16.0
12–15	625	40.4	36.9	30.5	AI = 1300	‡	700	39.9
16–18	625	43.3	37.3	27.0	AI = 1300	‡	560	22.3
19–49	525	34.0	22.9	16.1	AI = 1000	‡	560	21.3
50 and over	525	33.2	27.7	19.3	AI = 1200	‡	700	46.2
Folate								
10–11	110	12.5	<1	0	250	88.7	105	0
12–15	150	30.1	8.0	5.8	250	79.3	140	3.6
16–18	150	29.1	9.3	4.5	330	94.0	140	1.5
19 and over	150	21.1	4.4	1.4	320	92.0	200	<1
Vitamin A								
10–11	350	15.1	5.6	2.8	420	8.8	350	2.8
12–15	400	21.3	9.1	5.9	420	6.9	508	12.6
16–18	400	20.7	7.7	4.1	485	9.9	525	15.6
19 and over	400	21.7	6.1	3.2	500	9.9	525	12.3

*The age groups are those used for the 1991 Australian RDIs; the UK and US EAR age groups for children aged 10–18 years differ slightly from those used in this table.
†The iron requirement distribution is asymmetrical in menstruating women; therefore it would be inappropriate to estimate the prevalence of inadequate intakes in women aged less than 50 years using the EAR cut-off method.
‡The proportion of a group with intake below the adequate intake (AI) cannot be used to estimate the proportion with inadequate intake since the AI probably exceeds both the EAR and RDI and has no relationship with either.

values. It is not clear from their paper whether the '2-day mean approach' refers to a distribution of average intakes over 2 days or to a distribution adjusted for within-person variation based on data from two 24-hour replicates, but it is likely that had we used C-SIDE for our data the prevalence of low intakes would have been further reduced. In the Australian NNS data, only vitamin A exhibited important departure from normality and so our use of the simpler procedure may explain the unexpectedly high apparent prevalence of inadequate vitamin A intakes.

The feeding, depletion and repletion studies that form the basis of the EAR usually measure and control the intakes of the subjects with great care. Hence the intakes described in these studies are not equivalent to the intakes described by populations in surveys where people commonly, either deliberately or not, omit to report all that was eaten. From this point of view, it is appropriate to exclude those whose dietary reports show signs of omissions before comparing population intakes with EARs. However, it would not be reasonable to exclude underreporters when comparing intakes with AIs based on intake data derived from population surveys that had not excluded underreporters. In this analysis we excluded all persons whose ratio of energy intake to basal metabolic rate was <0.9; the lower 95% confidence limit derived by Goldberg *et al.*[14] for plausible energy intake on a single day in weight-stable individuals. This resulted in the exclusion of data for ~15% of males and 25% of females aged 16 years and over, and 4–13% of data for younger males and females. Omission of the data for these individuals had very little impact on the range of intakes expressed as a percentage of the median but had the effect of shifting the median, and thus the whole distribution, upwards by between 2 and 10%. This upward bias in the median is at least in part due to the fact that, in the absence

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of population-specific data on energy expenditure, individuals with unusually high intakes were not excluded. To obtain unbiased population estimates of median nutrient intake, however, it is clearly necessary to exclude both under- and overreporters.

Although the Goldberg criteria used to identify underreporters have high specificity (99%), they have only limited sensitivity (50%) unless individuals can also be classified according to their usual level of energy expenditure[24]. Information to classify individuals into low, medium and high categories of energy expenditure, however, was not available from the 1995 Australian NNS. In addition, underreporting of energy intake is unlikely to apply equally to other nutrients since it depends on what is underreported. Data from the OPEN (Observing Protein and Energy) study, which used both doubly labelled water and urinary nitrogen to evaluate measurement error in reported energy and protein intakes, found that underreporting of protein intake was less common than underreporting of energy intake and that energy adjustment (expressing protein intake as a percentage of energy intake) virtually eliminated underreporting of protein intake[25]. Similar data for micronutrients, for which intake is less correlated with energy, are not presently available. The decrease in the estimated prevalence of low intakes observed in the present study in all age–sex groups and for all nutrients assessed suggests that exclusion of energy underreporters also has an impact on the distribution of micronutrient intakes. However, without supporting data on appropriate biomarkers, it is not possible to assess the extent to which the estimates obtained after exclusion of underreporters reflect the true prevalence of low intakes.

The problem associated with using the RDI/RNI/RDA as the criterion for assessing population intakes has been known for some time. A method to deal with this, the 'probability approach', was described in 1986, although it was noted at the time that lack of information about assumptions underlying the RDI limited its use[5,6]. This group also showed that the proportion of a population with usual intakes below the EAR approximates the proportion with inadequate intakes for their own needs provided that the intake is reasonably symmetrical, although it does not identify which individuals have inadequate intakes. When the distribution of requirements is clearly skewed, as for iron requirements in menstruating women, the probability approach should be used since the 'EAR cut-off method' will underestimate the true prevalence of inadequate intakes[4]. The performance of the 'EAR cut-off method' has been investigated in some detail[4], but both it and the full probability approach can only be used for assessing nutrient adequacy or excess if national committees specify an EAR for a nutrient.

Comparison of recommendations from the three countries shows some substantial variation in EARs. Primarily this is because a range of possible markers or assumptions exists for many nutrients. The US recommendations for iron were previously[26] almost identical to the current UK recommendations. The current US values assume that a lower level of iron stores is adequate[16]. If stores are lower, bioavailability increases and, therefore, intake can be lower[16].

The much higher current folate recommendations in the USA[17] than in the UK or Australia are not based on a consideration of its role in preventing neural tube defects, but on a metabolic study, in five women, of the average amount of folic acid required to maintain normal plasma homocysteine, erythrocyte folate and plasma folate. In contrast, the current UK EAR is based on mean intakes of at least 150 μg in a population with adequate liver stores[2] (p. 110). These comments should alert the reader to the extent to which assumptions are used in setting dietary recommendations, be they EAR or RDI/RNI/RDA. The problem facing countries which have no articulated EAR, such as Australia, is that either a foreign EAR or else a dubious criterion such as 70% of the RDI must be used to assess a national survey. This paper shows that the prevalence of inadequate intakes depends on the choice of reference values even after appropriate adjustments are made to the data. The 1997 New Zealand survey of persons aged 15 years and older used the UK references because it was analysed prior to the release of the American references[21]. At present, Australia and New Zealand are jointly considering whether it would be appropriate to adopt the American references. Our analyses show that a decision to adopt the American rather than UK references would lead to identifying different nutrients as of potential concern. However, it should be remembered that, regardless of the origin of the reference, population dietary information can only suggest where a problem may lie, and supporting biochemical, physiological or other objective data are needed to identify conclusively that a problem exists.

In this paper, we have shown the extent to which inaccurate estimates of the prevalence of low intakes can be obtained if the limitations of 24-hour dietary intake data from population surveys are not taken into account in analysis. The paper also indicates that current dietary reference values have limitations that need to be recognised and taken into consideration when population dietary data are evaluated. The limitations of both dietary data and dietary recommendations highlight a clear need to corroborate any dietary findings suggestive of inadequacy with objective measurements of nutrient status before these are used for developing and/or assessing public health policy.

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