ABC of Nutrition

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MEASURING NUTRITION

Energy (calories)

The *nutritional state* for energy or for any essential nutrient depends on the balance (B) between intake (I) (dietary or parenteral) and output (O) or expenditure: $B = I - O$.

When the balance is negative the nutritional state tends to go down towards depletion, but there may be an adaptive reduction in output (losses). When the balance is positive the nutritional state tends to go up: the nutrient may be stored somewhere in the body and some nutrients can start to become toxic. "You can have too much of a good thing."

Distribution of weight change (kg) on 2078 occasions on consecutive days in healthy young men

Edholm, OG, Adam, JM, and Best, TW.
Annals of Human Biology 1974; 1: 3-12.

Methods of measuring calories (food energy) are different from those for the other essential nutrients.

Measurement of energy balance is technically difficult and can only be done in a specially equipped laboratory. Energy expenditure is measured by calorimetry, nearly always indirect calorimetry—that is, continuous measurement of oxygen consumption and carbon dioxide production. (Direct calorimetry measures a subject's heat output in a special insulated room. There are only two such human calorimeters in Britain and none in most countries.) Cumbersome gas measuring equipment impedes the subject's movements.

On the intake side the energy (calorie) content of foods eaten should be analysed chemically since energy values in food tables are only estimated averages.

The usual way of estimating energy balance is, of course, from the resultant changes in body weight. A gain or loss of energy by the body of about 6000 to 7000 kcal should, respectively, increase or reduce the weight by + or – 1.0 kg. Most of this weight change is in fat with a variable amount of water and a minority of muscle. Gain or loss of tissue needs to be over 1 kg to be detectable because, even with accurate weighing and on a constant regimen, healthy people's weights fluctuate within the day and from day to day. Furthermore, many scales and weighing techniques are not accurate.

Reference standards for body weights at different heights are given for adults in the article on Diagnosis and Risks of Obesity.

Weight measurement

Beam or lever balances are most reliable, not the usual bathroom scales. The best scales are not easily portable: they are heavy and the knife edge balancing part can be damaged. The patient should be brought to the scale. It should be serviced regularly (as recommended by the manufacturer) and checked frequently against known weights, such as a heavy weight kept nearby. Subjects should be weighed in light underclothing and no shoes and with any heavy jewellery removed. A meal or full bladder increases the reading and a bowel action reduces it.

Adults and older children should stand straight on both feet on the centre of the scale's platform without touching anything else.

Pictures of how to weigh young children are shown in Valman HB. *The First Year of Life*. London: BMJ, 1984:55.

Reference standards for mid-arm circumference (mm)

Age	MEN			WOMEN		
	50th	10th Centiles	5th	50th	10th Centiles	5th
19-24	308	272	262	265	230	221
25-34	319	282	271	277	240	233
35-44	326	287	278	290	251	241
45-54	322	281	267	299	256	242
55-64	317	273	258	303	254	243
65-74	307	263	248	299	252	240

Figures based on a large sample of healthy US citizens from Frisancho AR. *Am J Clin Nutr* 1981;34:2540-5, and Bishop CW, et al. *Am J Clin Nutr* 1981;34:2530-9.

It is difficult to weigh deformed or paralysed people. Very sick bedfast people cannot be weighed unless they are in a specially designed weighing bed. It is nearly always easy to weigh an ambulant patient—it just takes a little time and trouble. But in hospital patients confined to bed—for example, those with fluid lines or splints—some idea of loss of tissue can be obtained by measuring the arm circumference with or without one or more skinfold thicknesses.

Measuring arm circumference needs only a tape measure, put round the left arm (preferably) midway between the tip of the acromion and the olecranon. The enclosed area is made up of muscles and subcutaneous fat over the constant humerus.

Reference standards for triceps skinfold thickness (mm)

Age	MEN			WOMEN		
	50th	10th Centiles	5th	50th	10th Centiles	5th
18-24	9.5	5	4	18	11.5	10
25-34	12	6	4.5	21	12	10
35-44	12	6	5	23	14	12
45-54	12	6	6	25	16	12
55-64	11	6	5	25	16	12
65-74	11	6	4	24	14	12

Figures based on a large sample of healthy US citizens from Frisancho A R. *Am J Clin Nutr* 1981;34:2540-5, and Bishop C W, *et al. Am J Clin Nutr* 1981;34:2530-9.

Protein

Tests for protein status estimate two variables: total body protein and visceral protein.

Total body protein (predominantly muscle) can be estimated in several ways, though the first two given below are research procedures.

(1) Total body nitrogen may be measured by in vivo neutron activation with simultaneous counting of the 10.8 MeV γ rays produced from the nitrogen; then total body protein = $N \times 6.25$.

(2) Total body potassium may be measured by counting in a heavily screened whole body counter the characteristic γ rays from the natural radioisotope ^{40}K mixed as 0.012% with the stable ^{39}K isotope throughout our bodies. Potassium is predominantly intracellular and normally proportional to body protein.

(3) Body weight for height partly reflects total protein.

(4) Total protein may also be estimated from the mid-arm muscle circumference (mid-arm circumference - $\pi \times$ triceps skinfold).

(5) 24 Hour urinary creatinine gives a biochemical measure of muscle mass since creatinine is a metabolite from the turnover of muscle creatine. 1 g creatinine/day comes from about 20 kg of muscle but urinary creatinine shows quite large day to day fluctuations even if collection is complete, and it is spuriously increased by eating meat and by exercise.

Visceral protein is sometimes disproportionately reduced in protein deficiency, as most strikingly seen in kwashiorkor. There is fatty liver, intestinal mucosal and pancreatic atrophy, and impaired lymphocyte function. The usual tests are to measure concentrations of plasma albumin or transferrin, proteins synthesised in the liver. Plasma albumin concentrations are also moderately reduced in the reaction to infections as well as in liver cirrhosis and nephrotic syndrome. Transferrin concentrations are increased in iron deficiency.

Measuring skinfold thickness requires special calipers. The best are obtainable from Holtain Ltd Crymych, Dyfed (SA41 3UF). Cheap plastic ones are unreliable. The most common sites for measuring skinfold thickness are over the mid-triceps, halfway between the acromion and the olecranon, and the subscapular skinfold, 1 cm below the inferior angle of the scapula. Reference standards are available for skinfolds at these sites.

The triceps skinfold measurement can be used to calculate the mid-arm muscle circumference, which is calculated as:

$$\text{arm circumference} - \pi \times \text{triceps skinfold (mm)}$$

Before substantial weight changes are detectable or if weight cannot be measured a rough idea of energy balance can be got by calculating the calories per day in recent food intake from food tables and comparing this with the recommended daily amounts published by the DHSS.

Recommended daily amounts of energy are estimates of the average energy requirement for the different age and sex subgroups of present day British people. About half of any group of similar people can be expected to need more and half to need less than these amounts. Individual requirements might well range from 50% to 150% of these averages. Furthermore, on any single day an individual might consume considerably less or more than his average daily intake.

There are no biochemical tests that reliably indicate energy balance. Acetone appears on the breath in people who fast for longer than 12 hours and β hydroxybutyrate concentrations increase in body fluids but these cannot be used to show the extent of energy deficit.

Recommended daily amounts of food energy for population groups in the UK (DHSS, 1981)

Age	Men (kcal/day)	Women (kcal/day)
1	1200	1100
2	1400	1300
3-4	1560	1500
5-6	1740	1680
7-8	1980	1900
9-11	2280	2050
12-14	2640	2150
15-17	2880	2150
Young adults*	2510†	2150†
Middle aged†	2400†	1900†
Over 75	2150	1680

* Men 18-34, women 18-54. †Men 35-74, women 55-74.

†This is for sedentary adults; energy needs higher if more physically active.

Other nutrients

Check list on patient's diet

In a busy practice a short check list about the patient's eating habits is a useful screening method.

- What is your appetite like?
- Do you eat more or less than other comparable people?
- Has what you eat changed—type of food or amount?
- Are you on a special diet?
- Is there any food you can't eat because it doesn't agree with you?
- Are you losing or gaining in body weight?
- What do you usually have for the main meal of the day?
- Do you eat meat/fruit/fat on meat/salt/etc?
- What sort of bread do you eat?
- What sort of alcohol do you drink, how many drinks per week or per day?
- What do you have for breakfast and lunch?
- Do you take vitamin tablets?

One page from *The Composition of Foods*. For each set of foods there are four pages of nutrients.

Other nutrients do not affect anthropometric measurements directly. Inadequate intake can be suspected from the dietary intake or shown by specific biochemical tests.

Assessment of nutrient intake

The sequence of assessing nutrient intake is to

- (a) estimate *food intake* as g/day of different foods;
- (b) use *food tables* to convert g/day of each individual food to g, mg, or µg/day of various nutrients. These calculations can and always used to be done manually but nutritionists are increasingly using computers;
- (c) compare this patient's intake of one or several nutrients likely to be inadequate with the *recommended daily amounts* of food energy and nutrients.

Food intake measurements

In dietetic work and nutritional surveys four types of method are used. Reliability depends more on the attention to detail and knowledge of foods of the interviewer than on the method chosen.

- **Dietary history**—"What do you eat on a typical day?" This is a good method in the hands of a skilled and patient interviewer. Food models, cups, plates, and spoons are used to estimate portion sizes.
- **24 Hour recall**—"Tell me everything you've had to eat and drink in the last 24 hours?" This is less subject to wishful thinking about what the person ought to have eaten. The weakness is that yesterday may have been atypical.
- **Food diary or record**—"Please write down (and describe) *everything* you eat and drink (and estimate the amount) for the next 3 (4 or 7) days." Amounts are usually recorded in household measures but for more accuracy subjects can be provided with quick reading scales to weigh food before it goes on the plate (and any leftovers).
- **Food frequency**—"Do you eat meat/fish/bread/milk ... on average: more than once a day/once a day/2 or 3 times a week/once a week/once a month etc?" Estimating food intake quantitatively is labour intensive (and so expensive). It depends on adequate memory and the honesty of the subject. Some people's food habits are very irregular and most people eat differently on Saturday and Sunday than during the rest of the week and on holiday.

Food tables

The British food tables are the best in the world thanks to the original work of McCance and Widdowson, their continuation by Paul and Southgate and colleagues, and the support of the Medical Research Council, Ministry of Agriculture, Fisheries and Food, and the Agriculture and Food Research Council.

In the main volume 969 foods and drinks arranged in 13 groups are given code numbers (which can be used for computer input). For most of these foods figures are given (per 100 g edible portion) for the following categories:

- **The proximates**—Water, sugars, starch, available carbohydrate, dietary fibre, protein, fat (alcohol where appropriate), food energy (both in kcal and kJ).
- **Essential inorganic elements**—Sodium, potassium, calcium, magnesium, phosphorus, iron, copper, zinc, sulphur, and chlorine.
- **Vitamins**—A, carotene, D, thiamine, riboflavin, niacin preformed and from tryptophan, C, E, B-6, folate (free and total), pantothenate, and biotin.

No	Food	Description and number of samples	Water g	Sugars g	Starch and dextrins g	Dietary fibre g	Total nitrogen g
<i>Grains, flours and starches contd</i>							
19	Rice polished, raw	5 samples from different shops	11.7	Tr	86.8	2.4	1.09
20	boiled	5 samples from different shops, boiled in water	69.9	Tr	29.6	0.8	0.37
21	Rye flour (100%)	Commercial grist of all-English rye	15.0	Tr	75.9	—	1.40
22	Sago raw	2 samples from different shops	12.6	Tr	94.0	—	0.04
23	Semolina raw	2 samples from different shops, coarse and fine	14.0	Tr	77.5	—	1.87
24	Soya flour, full fat	Mixed sample	7.0	11.2	12.3	11.9	6.45
25	low fat	Mixed sample	7.0	13.4	14.8	14.3	7.94
26	Spaghetti raw	6 samples from different shops	10.5	2.7	81.3	—	2.39
27	boiled	6 samples from different shops, boiled in water	71.7	0.8	25.2	—	0.74
28	canned in tomato sauce	6 large cans from different shops	83.1	3.4	8.8	—	0.30
29	Tapioxa raw	4 varieties, medium pearl, seed pearl, coarse and flake	12.2	Tr	95.0	—	0.07
<i>Bread and Rolls</i>							
<i>Bread</i>							
30	wholemeal	Analytical and calculated values, mixed samples	40.0	2.1	39.7	8.5	1.51
31	brown	Calculated from brown flour	39.0	1.8	42.9	5.1	1.56
32	Hovis	Bulked sample	40.0	2.4	42.7	4.6	1.70
33	white	Analytical and calculated values, mixed samples	39.0	1.8	47.9	2.7	1.40

Cereals continued

Proximate and inorganic constituents per 100g

No	Food	Energy value		Protein (see p 7) g	Fat g	Carbo- hydrate g	mg										
		kcal	kJ				Na	K	Ca	Mg	P	Fe	Cu	Zn	S	Cl	
<i>Grains, flours and starches cont'd</i>																	
19	Rice polished, raw	361	1536	6.5	1.0	86.8	8	110	4	13	100	0.5	0.06	1.3	78	27	
20	boiled	123	522	2.2	0.3	28.6	2	38	1	4	34	0.2	0.02	0.4	27	9	
21	Rye flour (100%)	335	1428	8.2	2.0	75.9	(1)	410	32	92	380	2.7	0.42	(2.8)	—	—	
22	Sago raw	365	1515	0.2	0.2	84.0	3	5	10	3	29	1.2	0.03	—	1	13	
23	Semolina raw	350	1489	10.7	1.8	77.5	12	170	18	32	110	1.0	0.15	—	92	71	
24	Soya flour, full fat	447	1871	38.8	23.5	23.5	1	1880	210	240	800	8.9	—	—	—	—	
25	low fat	352	1488	45.3	7.2	28.2	1	2030	240	290	840	9.1	—	—	—	—	
26	Spaghetti raw	378	1612	13.8	1.0	84.0	5	160	23	35	120	1.2	0.27	(1.0)	97	63	
27	boiled	117	499	4.2	0.3	28.0	2	50	7	11	37	0.4	0.08	(0.3)	30	20	
28	canned in tomato sauce	89	250	1.7	0.7	12.2	500	130	21	11	30	0.4	0.13	—	—	800	
29	Teapicos raw	359	1531	0.4	0.1	95.0	4	20	8	2	30	0.3	0.07	—	4	13	
<i>Bread and rolls</i>																	
<i>Bread</i>																	
30	wholemeal	216	918	8.8	2.7	41.8	540	220	23	93	230	2.5	0.27	2.0	81	880	
31	brown	223	948	8.9	2.2	44.7	550	210	100	75	190	2.5	0.23	1.8	85	880	
32	Hoivis	228	968	9.7	2.2	45.1	580	210	150	80	190	4.5	0.18	—	88	790	
33	white	233	991	7.8	1.7	49.7	540*	100	100	26	97	1.7	0.15	0.8	79	890	

* Batch loaves contain 610mg Na and 1000mg Cl per 100g

Representative RDAs: recommended daily amounts (recommended dietary allowances in USA)

Nutrient	Men 18-34 (sedentary)	Infants	Nutrient	Younger men	Infants
Energy (kcal)	2500	530→980	Vitamin B-6 (mg) ^U	2.2	0.3
Protein (g)	63	13→25	Folate (total, µg) ^A	200	50→70
Thiamine (mg)	1.0	0.3	Vitamin B-12 (µg) ^U	3.0	0.5→1.5
Riboflavin (mg)	1.6	0.4	Vitamin E (mg) ^U	10	3→4
Niacin (equivalent mg)	18	5	Magnesium (mg) ^U	350	50
Vitamin C (mg)	30	20	Zinc (mg) ^U	15	3
Vitamin A (RE µg)	750	450	Iodine (µg) ^U	150	40
Vitamin D (µg)	(only if housebound)	7.5	Sodium (mmol) ^A	40-100	6→25
Calcium (mg)	600	600	Potassium (mmol) ^A	50-140	10→35
Iron (mg)	12	6			

DHSS (UK) 1981 recommendations where available (on left hand side). But there are at present no British RDAs for the nutrients on right of table. ^U=USA; ^A=Australian recommendations.

Figures for women are generally about 80% those for younger men, except for iron and during pregnancy and lactation. Figures for men are higher for energy if they are active; for older men figures are generally smaller.

Figures for children are interpolated between infants and adults. Some recommendations for infants differ between breast fed and formula fed infants and most increase during the four quarters of the first year of life. RE=retinol equivalents.

Recommended daily amounts of nutrients

The recommended daily amounts of nutrients are reference standards of nutritional intakes. Expert committees recommend that healthy people should eat these amounts of the nutrient (or more) on average over a period of days.

The recommendation is estimated to meet the requirements of practically all healthy people—that is, most people's requirements are less than the recommended amount (except for energy). A lower intake does not therefore necessarily mean inadequacy but the further the intake below the recommended amount the greater the probability of this.

The recommendation is for the intake over several days. An intake below the recommended daily amount on Monday is harmless if followed by a higher intake on Tuesday.

Sick people have requirements not covered by the recommendations. For example, with bed rest energy requirements are reduced; with fever they are increased. Losses of several nutrients are increased in different ways by illness, such as protein loss in nephrotic syndrome, potassium loss in diarrhoea, iron loss with bleeding. The allowances apply to oral feeding of conventional foods. For total parenteral nutrition the requirements are different; absorption is 100%, but minor vitamins and trace elements like pantothenate, molybdenum, manganese, chromium, etc, cannot be taken for granted.

● **Amino acids**—For major foods 18 amino acids are given: ile, leu, lys, met, cys, phe, tyr, thr, trp, val, arg, his, ala, asp, glu, pro, and ser.

● **Cholesterol and fatty acids**—For foods containing fat, cholesterol and 16 or more fatty acids are given: 14:0, 15:0, 16:0, 17:0, 18:0, 16:1, 18:1, 20:1, 22:1, 18:2, 18:3, 18:4, 20:4, 20:5, 22:5, and 22:6.

Thus for most foods there are 70 nutrient compounds in Paul and Southgate's tables, though there are occasional gaps where analyses have not yet been done. These tables have to be constantly revised as new foods are introduced, the recipes and processing for established foods change, and additional food components are asked for by doctors. (The second supplement (1985) to McCance and Widdowson's *The Composition of Foods* (by Tan S P, Wenlock R W, and Buss D H published by HMSO) gives the composition of foods used by immigrants in the UK.)

Variability of nutrient content—The British tables give a single value for each nutrient in each food—an estimated average. The new American tables, which are being published in loose leaf sections as analyses are completed, give an indication of variability to be expected round each average figure. There is no legal guarantee that any food contains what the food tables say it should. For some constituents—for example, fat—the food could easily contain 25% less or 25% more.

The Manual of Nutrition gives calories and 11 nutrients for 150 common foods.

Biochemical methods for diagnosing nutritional deficiencies

Nutrient	Principal methods		
	Indicating reduced intake	Indicating impaired function (IF) or cell depletion (CD)	Supplementary methods
Protein	Urinary nitrogen	Plasma albumin (IF)	Fasting plasma amino acid pattern
Vitamin A	Plasma carotene	Plasma retinol	
Thiamine	Urinary thiamine	Red blood cell transketolase and TPP effect (IF)	
Riboflavin	Urinary riboflavin	Red blood cell glutathione reductase and FAD effect (IF)	
Niacin	Urinary N'-methyl-nicotinamide		Fasting plasma tryptophan
Vitamin B-6	Urinary 4 pyridoxic acid and/or plasma pyridoxal phosphate	Red blood glutamic oxalacetic trans-aminase and PP effect (IF)	Urinary xanthurenic acid after tryptophan load
Folate	Plasma folate	Red blood cell folate (CD) (haemoglobin, packed cell volume, and bone marrow)	Urinary FIGLU after histidine load
Vitamin B-12	Plasma vitamin B-12	Reduced vitamin B-12 or transcobalamin II (haemoglobin, packed cell volume, and bone marrow)	Schilling test
Vitamin C	Plasma ascorbate	Leucocyte ascorbate (CD)	Urinary ascorbate
Vitamin D	Plasma 25-hydroxy-cholecalciferol	Raised plasma alkaline phosphatase (bone isoenzyme) (IF)	
Vitamin E	Plasma tocopherol	Red cell haemolysis with H ₂ O ₂ in vitro (IF)	
Vitamin K		Plasma prothrombin	
Sodium	Urinary sodium	Plasma sodium	
Potassium	Urinary potassium	Plasma potassium	Total body potassium by counting ⁴⁰ K
Iron	Plasma iron and transferrin	Plasma ferritin (CD) (haemoglobin, packed cell volume, and smear)	Stainable iron in bone marrow
Magnesium	Plasma magnesium		
Iodine	Urinary (stable) iodide	Plasma protein-bound iodide (IF), plasma thyroxine (IF)	Radioactive iodine uptake by thyroid gland
Zinc	Plasma zinc	White blood cell zinc	Hair zinc

FAD=flavine adenine dinucleotide. There are no reliable simple methods for assessing calcium status.

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The second illustration is reproduced, by permission, from Edholm OG, *et al.* *Ann Hum Biol* 1974;i:3-12, and the pages from *The Composition of Foods* by permission of HMSO.

Biochemical methods

Biochemical tests are an integral part of modern medical diagnosis. Plasma sodium and potassium concentrations, for example, are essential for diagnosing and treating difficult electrolyte disorders, and plasma or red cell folate and plasma vitamin B-12 should be measured before treating a patient with megaloblastic anaemia.

With most of the other nutrients also biochemical tests have been developed which can be used (a) to confirm the diagnosis of a deficiency disease in places where it is uncommonly seen or where the clinical picture is complicated, or (b) in community surveys and general practice to find individuals with subclinical nutrient deficiencies.

Tests which can be used for the major nutrients are listed in the table. As with other tests in chemical pathology, there may be false positive and false negative results. For example plasma vitamin B-12 concentrations are increased in acute hepatitis and alkaline phosphatase may not be raised if rickets is accompanied by protein-energy deficiency.

When his intake of a nutrient is inadequate (less than obligatory losses) an individual generally goes through three stages. Firstly, he adapts to the low intake: urinary excretion of the nutrient or its metabolites typically falls but there is no evidence of abnormal function or of depletion of the cells.

In the second stage there are also biochemical changes indicating either impaired function or cellular depletion, but clinical manifestations of deficiency are absent or non-specific. A good example of a test showing impaired function is red cell transketolase activity. For each blood sample this enzyme is assayed in two test tubes, one with extra thiamine pyrophosphate (TPP), the other without. If the activity is more than 25% higher in the supplemented tube (TPP effect + 25%) this indicates functional thiamine deficiency.

The third stage of depletion is that of clinical deficiency disease.

Most clinical biochemistry laboratories provide only some of the methods in this table as a routine but others could be set up in special circumstances or, alternatively, a laboratory specialising in nutrition research could be asked to help.

What might be the cause of a 7 year old child in Sri Lanka, who is otherwise normal and active, weighing only 18 kg? She has a poor appetite which is not improved by intermittent antihelminthic treatment (pyrantel). Urine examination (except for microbiological investigations) shows no abnormality. She has been given sodium fluoride tablets from the age of 1 year until a month ago when it was withdrawn on suspicion that it might have caused her anorexia.

Sodium fluoride can cause anorexia in children. Tablets of 1.1 mg strength are usually prescribed for children under 2 years and 2.2 mg strength for those of 2-10 years. Where fluoride is found naturally in drinking water at 1 ppm or less protection against dental caries is acquired without symptoms occurring. At a level of 2 ppm fluoride can cause slight yellowing of the teeth.

At greater concentration symptoms of fluorosis may occur.¹ If a child is taking sodium fluoride tablets in addition to drinking water with a naturally high fluoride level symptoms of anorexia may occur. In parts of India the fluoride level in some areas can be as high as 14 ppm.² Fluorosis has been reported from Sri Lanka.³ This 7 year old child was given intermittent courses of pyrantel, which can cause anorexia and nausea, but these symptoms should not long persist after the end of a course of treatment.—R L BROADHEAD, senior lecturer in paediatrics, Liverpool.

1 World Health Organisation. *Fluoride and human health*. Geneva: WHO, 1970. (Monograph series No 59.)

2 Singh A, Jolly SS. Endemic fluorosis. *Q J Med* 1961;30:357.

3 Clark A. Further notes on the effects of inhibitory substances in foods. *J Trop Med Hyg* 1942;45:49.