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Trace Elements and Mineral Supplements

Among micronutrients, the trace elements have been the most recent to have their essentiality defined. Indeed, whether the list is complete (tables I and II) is still debated. Recently, evidence that boron is desirable, if not essential, for adequate bone mineralisation (Nielsen et al. 1987) has been forthcoming from the US Department of Agriculture Human Nutrition Research Centre and there are indications that arsenic may be essential in ultra trace amounts (Nielsen 1988).

Recommended Dietary Intakes

Wherever possible, national committees have established recommended dietary intakes or safe and adequate ranges of intakes for elements (tables I and II). These presume, in the first instance, that the elements will be obtained from food, as this provides the context or relationships among nutrients for their appropriate utilisation (Briggs & Wahlqvist 1988; Wahlqvist 1987). Elements are especially noted for competition for absorption, that between the divalent cations copper and zinc being classical. Excess zinc intake can lead to secondary copper deficiency and bone marrow depression (Wahlqvist 1988). As a second option, one can use the recommendations for preparing formula feeds or nutrient supplements. Recommendations, by their nature, exceed minimum requirements. They have been duly modified for elements which need to be administered parenterally (table III). The mean Australian dietary intakes and usual food sources of trace elements are shown in table IV.

Salient Points

The general approach to the management of trace elements is to consider the individual at high risk, to deal with food intake wherever possible, and to use supplements for the shortest period of time, at recommended dosages

Among micronutrients, the trace elements have been the most recent to have their essentiality defined

The most prevalent deficiency, and this is not common, is that of zinc

It is not usually necessary to suspect trace element deficiency unless particular risk factors are present

Selenium deficiency may be more common than is currently appreciated

There is evidence to suggest that cardiac indices may improve through selenium administration in some cases of cardiac decompensation

Functions of Trace Elements

Functions of trace elements vary widely as follows:

Chromium: Control of blood glucose.

Cobalt: Component of vitamin B_{12}.

Copper: Copper enzymes/proteins in oxidative metabolism and iron utilisation.

Fluorine: Component of hydroxyapatite in bones and teeth.

Iodine: Component of thyroid hormone.

Table I.
Australian recommended daily dietary intakes of essential elements (National Health and Medical Research Council, 1987)

Subject	Age	Iodine (μg)	Zinc (mg)	Iron (mg)	Magnesium (mg)	Calcium (mg)	Sodium		Potassium	
							(mmol)	(mg)	(mmol)	(mg)
Infants	0-6 months		3-6	0.5	40	300	6-12	140-280	10-15	390-580
	breast-fed	50	3-6	3.0	40	500	6-12	140-280	10-15	390-580
	formula-fed	50	4.5-6	9	60	550	14-25	320-580	12-35	470-1370
	7-12 months	60	4.5-6	6-8	80	700	14-50	320-1150	25-70	980-2730
Children (male and female)	1-3 years	70	6-9	6-8	110	800	20-75	460-1730	40-100	1560-3900
	4-7 years	90	9-14	6-8	180	800	26-100	600-2300	50-140	1950-5460
			12-18	10-13	260	1200	40-100	920-2300	50-140	1950-5460
Boys	8-11 years	120	12-18	10-13	320	1000	40-100	920-2300	50-140	1950-5460
	12-15 years	150	9-14	6-18	160	900	26-100	600-2300	50-140	1950-5460
	16-18 years	150	12-18	10-13	270	1000	40-100	920-2300	50-140	1950-5460
Girls	8-11 years	120	12-18	10-13	270	800	40-100	920-2300	50-140	1950-5460
	12-15 years	120	12-16	7	320	800	40-100	920-2300	50-140	1950-5460
	16-18 years	120	12-16	7	320	800	40-100	920-2300	50-140	1950-5460
Men	19-64 years	150	12-16	12-16	270	800	40-100	920-2300	50-140	1950-5460
	65+ years	150	12-16	5-7	270	1000	40-100	920-2300	50-140	1950-5460
Women	19-54 years	120	16-21	22-36	300	1100	40-100	920-2300	50-140	1950-5460
	55+ years	120	(+4 –5)	(+10)	(+30)	(+300)		(+0)		
Pregnancy		150 (+30)		(2nd and 3rd trimester)		(3rd trimester)				
Lactation		200 (+50)	18-22 (+6)	12-16 (+0)	340 (+70)	1200 (+400)	40-100 (+0)	(920-2300)	65-140 (+0)	(2540-5460)

Iron: Iron enzymes/proteins in oxygen transport and oxidative metabolism.

Manganese: Activator of many enzymes.

Molybdenum: Molybdenum enzymes.

Nickel: Possibly involved in membrane structure.

Selenium: Antioxidant function in part through enzyme glutathione peroxidase.

Silicon: Possibly cross-linking agent in organic matrix of early bone.

Tin: Possibly involved in redox reactions.

Vanadium: Possibly involved in redox reactions.

Zinc: Zinc enzymes involved in all aspects of metabolism and growth.

Trace Element Deficiency

Australian agricultural science has been pioneering in its work on trace element deficiency in farm animals (Underwood 1977), but only relatively recently has the extent of trace element deficiency been investigated in the Australian people, as elsewhere. There is much misunderstanding about the biochemical investigation of trace element deficiency. This is largely because there are several compartments in which distribution occurs and these are related to metallo-enzyme function or element sequestration in certain tissues such as hair and nails. In any case, measurements of this kind are rarely required in clinical practice.

Table II.
USA estimated safe and adequate oral intakes of essential elements (Committee on Dietary Allowances, Food and Nutrition Board, 1980)

Element	Men and women
Copper (mg)	2-3
Manganese (mg)	2.5-5.0
Fluoride (mg)	1.5-4.0
Chromium (mg)	0.05-0.2
Selenium (mg)	0.05-0.2
Molybdenum (mg)	0.15-0.5
Sodium (mg)	1100-3300
Potassium (mg)	1875-5625
Chloride (mg)	1700-5100

Table III.
Recommended daily supplements of minerals for total parenteral nutrition (Australian Society for Parenteral and Enteral Nutrition Newsletter 1986)

Mineral	Infants 0-2 years (per kg BW/24 hr)	Children 2-16 years (per kg BW/24 hr)	Adults (Total dose)
Sodium[1] (mmol)	3.0	2.0	100
Potassium[1] (mmol)	2.0	1.4	80
Chloride/Acetate[2] (mmol)	3.0	2.1	150
Calcium (mmol)	0.9	0.2	7.5
Phosphate (mmol)	0.9	0.4	15
Magnesium (mmol)	0.3	0.1	5
Zinc[3] (μmol)	1.4	0.4	30
Copper[4] (μmol)	0.6	0.4	16
Manganese[5] (μmol)	0.04	0.15	8
Iodine[6] (μmol)	0.05	0.01	0.4
Chromium (μmol)	0.005	0.002	0.4
Iron (μmol)	1.8	0.6	20
Selenium[7] (μmol)	0.04	0.03	1.5
Molybdenum (μmol)	–	–	0.2

1. Adjustments for age, cardiac status and renal function may be required.
2. Excess chloride administration may produce hyperchloraemic acidosis. This can be prevented by giving part of this anion as acetate, usually in the form of potassium acetate.
3. Increased zinc supplements may be required with diarrhoea, or increased losses from ileostomy, fistula or stoma.
4. Increased copper supplements may be required with abnormal gastrointestinal fluid loss. Reduced copper supplements should be given in presence of liver or biliary tract disease.
5. Reduced manganese supplements should be given in presence of cholestasis.
6. Povidine-iodine may be a significant source of iodine.
7. Supplements of selenium may not be required in short-term parenteral nutrition. In long-term parenteral nutrition additional supplementation with selenium may be required.
8. Molybdenum requirements for infants and children are unknown.

It should be noted that these recommendations are only GUIDELINES to the estimated daily requirements of minerals when administered intravenously to maintain normal body composition. Requirements are likely to be higher in anabolic states and in the presence of abnormal losses (in urine, faeces or other body fluids). In the presence of catabolic states, requirements may be lower. Glucose and amino acid solutions for intravenous use may contain minerals as contaminants. These factors should be taken into consideration when determining mineral supplements to be given to individual patients.

Perhaps the most prevalent deficiency, and this is not common, is that of zinc (Dreosti & Wahlqvist 1989; Prasad & Oberleas 1976). Certain at-risk groups need special consideration – those on restricted diets (especially where animal-derived foods are limited), the elderly, people consuming excessive quantities of alcohol, those receiving certain medications (such as diuretics or chelating agents like penicillamine), in certain disease states like malabsorption or psoriasis, and in those receiving long-term enteral or parenteral nutrition.

It is therefore not usually necessary to suspect trace element deficiency unless particular factors are present (Dreosti & Wahlqvist 1989; Wahlqvist 1987). Supplementation, beyond initial catch-up, should relate to recommended daily amounts.

Selenium deficiency may be more common than is currently appreciated. It accounts for a form of cardiomyopathy found in China (Keshan disease) and doxorubicin-induced cardiomyopathy may be avoided by its prior use (Combs et al. 1987). There is also evidence to suggest that cardiac indices may improve through selenium administration in some cases of cardiac decompensation (Shaffer et al. 1988), however, much more work is required in this area. In particular, the interaction between selenium and other nutrients such as tocopherol and sulphur-containing amino acids remains poorly understood. It is known, however, that glu-

Table IV.
Intakes and food sources of trace elements (adapted from Dreosti & Wahlqvist 1989)

Trace element	Mean Australian dietary intake (mg/day)	Food source and amount of trace element (mg/100g fresh food)
Chromium (Cr)	0.06	Seafood 0.07; eggs, meat, whole grains 0.04
Cobalt (Co)	Cobalt must be supplied as vitamin B_{12} (cyanocobalamin) in the human diet	
Copper (Cu)	1.9	Liver 8-12; shellfish 2-7; legumes 1-20
Fluorine (F)	0.5-1.5 in non-fluoridated areas. Up to 3.5 with fluoridation	Seafood 0.5; meat 0.1; fluoridated water 0.1
Iodine (I)	0.7-0.8 including iodised salt	Milk contaminated with iodophores 0.1; seafood, meat, vegetables 0.03-0.07
Iron (Fe)	13.5	Liver, meat 10-20; enriched breakfast cereals 10-20; green vegetables 2-8
Manganese (Mn)	4.3	Wheat bran 10; oatmeal 3-4; wholemeal bread 2-5
Molybdenum (Mo)	0.1-0.5	Meat 0.1-0.3; legumes 0.02-0.5; cereal grains 0.01-0.15
Nickel (Ni)	0.3-0.5	Vegetables 2.5; whole grains 0.15; nuts 0.15
Selenium (Se)	0.11	Brazil nuts 1.5; kidneys 0.35; seafood 0.07
Silicon (Si)	Up to 1200	Whole grains, legumes approx 1000; meat 0.2 (connective tissues 5 times higher)
Tin (Sn)	0.2-3.5 – level depends on degree of consumption of food from unlacquered tinned cans	Acidic foods in unlacquered tinned cans 1-10; whole grains 0.5; nuts 0.25
Vanadium (V)	1-2	Radish 0.08; other food < 0.01
Zinc (Zn)	11.6	Oysters 45; meat 4-8; nuts and legumes 2-4

tathione peroxidase is a selenium-containing metalloenzyme.

Trace Element Toxicity

Trace element toxicity can be a problem, as mentioned for zinc. This usually occurs in regions of the world where soil content and local agriculture provide excessive quantities for human ingestion – as in the case of selenosis in regions of China and North America (Combs et al. 1987) and fluorosis in parts of India (Krishnamachari 1986). An overview of trace element toxicity is given in table V (Dreosti & Wahlqvist 1989).

Conclusion

The general approach to trace element nutrition assessment and management is to consider the high-risk individual, to deal with food intake wherever possible, and to use supplements for the shortest periods of time, at the recommended dosages.

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Table V.
Trace element toxicity (after Dreosti & Wahlqvist 1989)

Trace element	Toxic intake (mg/day)	Toxicity symptoms
Chromium	Chronic > 100	Growth depression, liver and kidney damage, cardiomyopathy
Cobalt	Chronic > 30	Polycythaemia, thyroid hyperplasia, myxoedema, cardiomyopathy, heart failure. Potentiated by alcohol
Copper	Acute > 1000 Chronic > 10	Acute – vomiting, diarrhoea, shock, hypotension, renal and liver damage. Chronic – reduced absorption of zinc and iron
Fluorine	Acute > 100mg/L in water Chronic > 10 mg/L in water	Acute – angioedema and oedema of larynx. Polyarteritis nodosa. Chronic – mottled teeth, anorexia, exostoses
Iodine	Acute > 10 Chronic > 2	Acute and chronic – thyrotoxicosis, iodide goitre
Iron	Acute several grams Chronic > 500	Acute – vomiting, cyanosis, shock Chronic – siderosis, liver and myocardial damage. Aggravated by alcohol
Manganese	Chronic – by inhalation of > 5 mg/m^3 in ambient air	Neurological and psychological disorders
Molybdenum	Chronic > 10	Possibly increased serum uric acid and gout
Nickel	–	–
Selenium	Acute > 7 Chronic > 0.6	Acute – blindness, tetany, paralysis Chronic – gastric disturbance, dermatitis, brittle fingernails, hair loss, garlic breath, paraesthesia and polyneuritis
Silicon	Chronic > 0.5	Silica urolithiasis, nephropathy. Suggested cause of Balkan nephropathy in countries bordering River Danube
Tin	Chronic > 0.5	Nausea, vomiting, diarrhoea
Vanadium	Acute > 50	Intestinal cramps, vomiting, fever, chills
Zinc	Acute > 1000 Chronic > 150	Acute – nausea, vomiting, gastric pain, muscular incoordination, dizziness. Chronic – reduced copper absorption and copper deficiency anaemia

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