

## Trace element intakes of women

BY ROSALIND S. GIBSON AND CINDY A. SCYTHES

*Applied Human Nutrition, Department of Family Studies, University of Guelph, Guelph, Ontario, Canada*

(Received 19 August 1981 – Accepted 30 March 1982)

1. Energy, protein, zinc, copper, manganese, selenium and dietary fibre intakes of 100 pre-menopausal women (mean age  $30.0 \pm 6.1$  years) from a university community, and consuming self-selected diets, were calculated using 3 d dietary records and food composition values. Subjects also collected a 24 h food composite during the 3 d record period for analysis of Zn, Cu and Mn by atomic absorption spectrophotometry. Daily analysed intakes were compared with those calculated from the corresponding record day.

2. Mean daily calculated intakes of energy, protein, Zn, Cu, Mn, Se and dietary fibre were  $7.54 \pm 1.61$  MJ,  $74 \pm 18$  g protein,  $10.1 \pm 3.3$  mg Zn,  $1.9 \pm 0.6$  mg Cu,  $3.1 \pm 1.5$  mg Mn,  $131 \pm 53$   $\mu$ g Se,  $19.4 \pm 6.6$  g dietary fibre.

3. Major food sources for each of the trace elements were (%): Zn meat + substitutes 43, dairy products 23.7; Cu breads and cereals 22, vegetables 21; Mn breads and cereals 47, fruits 12; Se meat + substitutes 38, breads and cereals 30.

4. Highly significant correlations ( $P = 0.001$ ) were noted for analysed intakes of Zn, Cu and Mn and those calculated from the corresponding record day. Mean calculated intakes were higher (%): Zn 138, Cu 142, Mn 121, than corresponding mean analysed intakes ( $P = 0.01$ ). However, the mean nutrient densities (mg/MJ) were comparable: Zn analysed 1.2, calculated 1.4; Cu analysed 0.2, calculated 0.2; Mn analysed 0.4, calculated 0.4.

5. All subjects met the Canadian Dietary Standard (CDS) recommended level for Cu but 48% received less than the CDS for Zn, 6% obtaining less than two-thirds of this recommended level. Daily Mn and Se intakes were similar to recent values for North American diets.

Recent advances in food production and processing have led to significant changes in the trace element content of foods (Schroeder, 1971). The increasing use of more highly refined foods and food analogues has led to a reduction of copper, zinc, manganese and chromium intakes, and nutritional deficiency states for some of these trace elements have been reported in certain population groups (Levine *et al.* 1968; Hambidge *et al.* 1972; Klevay *et al.* 1979).

Clearly, it is important to monitor periodically the trace element content of human diets to assess whether existing dietary trace element recommendations are being met or exceeded, and to assist in establishing dietary recommendations for some of the trace elements.

The purpose of this study was to determine the Zn, Cu, Mn, Se and dietary fibre intakes of a group of Canadian pre-menopausal women consuming self-selected diets. Dietary trace element intakes were calculated from 3 d food records using food composition values and by chemical analysis of a 1 d food composite collected during the 3 d record period.

### EXPERIMENTAL

#### *Daily trace element intakes from dietary records*

Pre-menopausal Canadian women (100; mean age  $30 \pm 6.1$  years) from a university community and consuming self-selected diets, participated in the study. Consent was obtained from the subjects after the nature of the study had been fully explained to them. The study protocol was approved by the Human Ethics Committee of the University of Guelph. Dietary information was collected using dietary records completed by the subjects in their own homes during three consecutive weekdays. Subjects recorded all foods and beverages consumed (including drinking water), in household measures and provided recipes for all prepared food items. Dietary records were checked on completion by a nutritionist. Daily intakes of energy, protein, Cu, Zn, Mn, Se and dietary fibre were

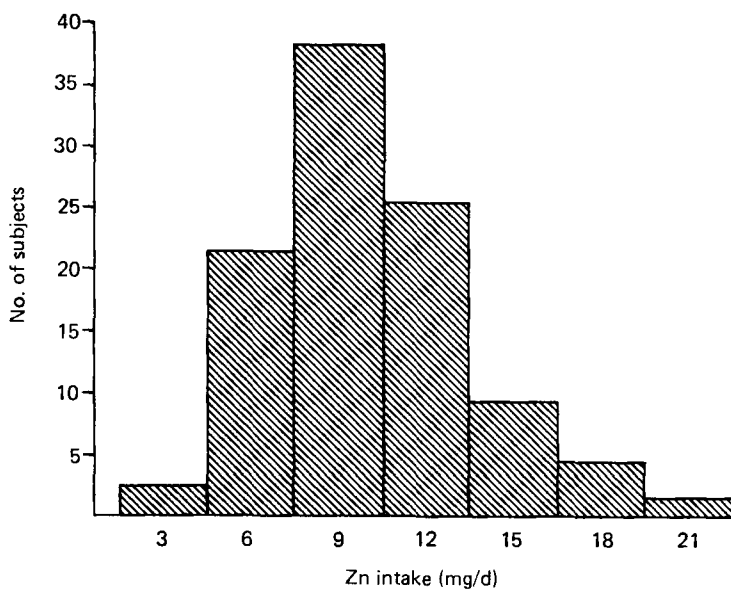


Fig. 1. Daily Zn intakes.  $\bar{x} = 10.1$ ,  $SD = 3.3$ ,  $n = 100$ .

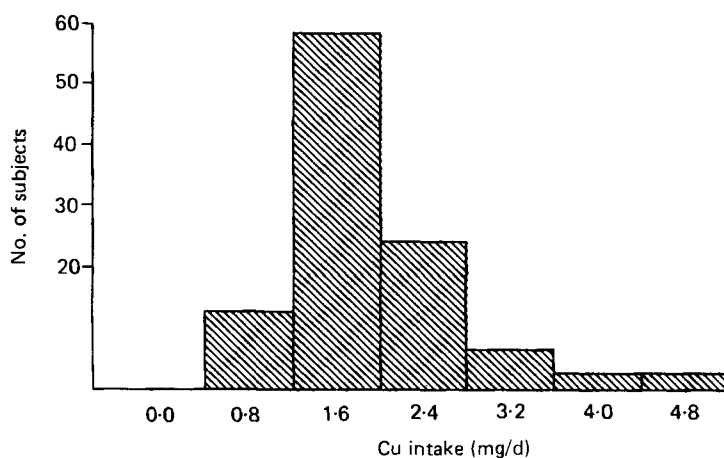


Fig. 2. Daily Cu intakes.  $\bar{x} = 1.9$ ,  $SD = 0.6$ ,  $n = 100$ .

calculated using the appropriate values for foods obtained from company product information, food composition tables (Agriculture Handbook, 1976, 1977, 1979 *a, b*, 1980 *a, b*) and the literature (Morris & Levander, 1970; Schlettwein-Gsell & Mommsen-Straub, 1971 *a, b*, 1972; Arthur, 1972; Meiners *et al.* 1976; Southgate *et al.* 1976; Allen *et al.* 1977; Ganapathy *et al.* 1978; Freeland-Graves *et al.* 1980). Foodstuffs were divided into food groups to determine the most important sources for each of the trace elements investigated.

#### *Food composite collection and laboratory analysis*

During one of the three record days, each subject collected a duplicate portion of all foods and beverages consumed, including drinking water, in acid-washed polyethylene bags and jugs with non-metal lids respectively.

Table 1. Mean calculated daily intakes of energy, protein, trace elements and dietary fibre by Canadian women

	Mean	SD
Energy (MJ)	7.54	1.61
Protein (g)	73.8	18.2
Zn (mg)	10.1	3.3
Cu (mg)	1.9	0.6
Mn (mg)	3.1	1.5
Se ( $\mu$ g)	131	53.4
Dietary fibre (g)	19.4	6.6

Food composites were returned to the laboratory and homogenized in a large stainless steel Waring Blendor (model no. CB5) coated with Teflon. To check for possible trace element contamination in this homogenization step, distilled deionized water was treated in the same manner as the food composite. No detectable Cu, Zn or Mn were found. Beverages were combined gradually with the solid food items during the blending to produce a single homogenous sample.

After measuring the volume of the total homogenate, portions were poured immediately into three acid-washed polyethylene containers and frozen at  $-17^{\circ}$  for retrospective analysis. After thawing, each of these three sub-samples were recombined and blended before removal of a 25 ml portion using an acid-washed pipette. These portions were dried in acid-washed Pyrex beakers at  $105^{\circ}$  to remove moisture and then ashed in a muffle furnace for 24–48 h at  $450^{\circ}$ . The ash was dissolved in 10 ml 6 M-hydrochloric acid and analysed for Zn, Cu and Mn by established atomic absorption procedures using a Perkin Elmer AA spectrophotometer (model 372). Replicates of one 24 h food composite were analysed to check on the homogeneity of the portions removed from the food composite and the reproducibility of the method. Mean ( $\pm$ SD) concentrations ( $\mu$ g/g) for four replicates of the 24 h diet were: Zn  $4.88 \pm 0.23$ , Cu  $0.70 \pm 0.06$  and Mn  $2.06 \pm 0.05$ . The amounts of added Zn, Cu and Mn recovered were also determined at regular intervals. The mean percentages of recovery for Zn, Cu and Mn were  $94.7 \pm 0.3$ ,  $95.2 \pm 0.03$  and  $94.8 \pm 0.3$  respectively. The accuracy of the method was studied by analysing Orchard Leaves Standard Reference Material no. 1571, National Bureau of Standards (NBS). Mean ( $\pm$ SD) values ( $\mu$ g/g) for three replicates were: Zn  $25.3 \pm 2.2$ , Cu  $13.5 \pm 0.2$  and Mn  $91.7 \pm 4$ . Certified NBS mean values ( $\mu$ g/g) were: Zn  $25 \pm 3$ , Cu  $12 \pm 1$  and Mn  $91 \pm 4$ . Analysed intakes were compared with those calculated from the corresponding record day using the paired Student's *t* test.

## RESULTS

### *Calculated daily trace element intakes*

The calculated mean daily energy, protein, Zn, Cu, Mn, Se and dietary fibre intakes are presented in Table 1. Frequency distributions of the daily trace element intakes are shown in Figs. 1–4. Zn intakes ranged from 4.1 to 21.7 mg/d, with a mean value of 10.1 mg/d, slightly above the Canadian Dietary Standard (CDS) recommendation of 9 mg/d (Department of Health & Welfare Canada, 1975) but below the US Recommended Dietary Allowance (RDA) of 15 mg/d (National Research Council, Food & Nutrition Board, 1980). Of the subjects, 48 and 91% failed to meet the CDS and RDA for Zn respectively, with 6 and 55% receiving intakes of less than two-thirds of these recommended levels.

All subjects met the current CDS estimated Cu requirement (0.2 mg/MJ) although 69% received intakes below the RDA safe and adequate level (2–3 mg/d) and 5% had intakes above 3 mg/d.

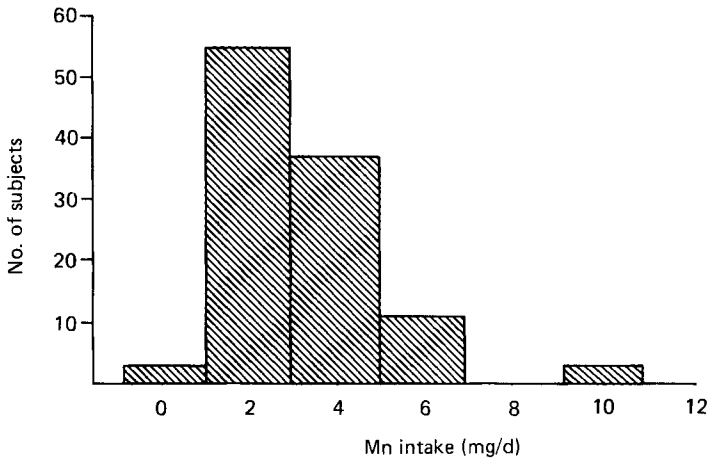


Fig. 3. Daily Mn intakes.  $\bar{x} = 3.1$ ,  $SD = 1.5$ ,  $n = 100$ .

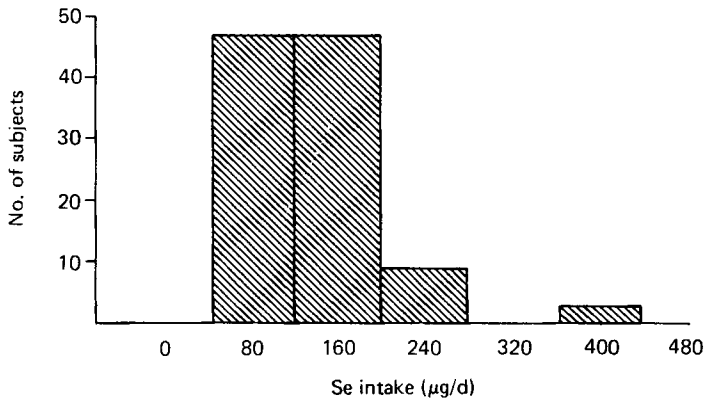


Fig. 4. Daily Se intakes.  $\bar{x} = 131$ ,  $SD = 53.4$ ,  $n = 100$ .

Daily Mn intakes ranged from 0.7 to 10.8 mg/d with a mean daily intake of 3.1 mg/d. A CDS recommendation has not been established for Mn and the RDA gives an estimated safe and adequate intake level of 2.5–5.0 mg/d. Of the subjects, 37% received Mn intakes below this suggested safe limit and 10% exceeded this range.

Similarly, there is no CDS recommendation for Se. None of the subjects received less than the lower limit of the RDA safe and adequate level (50 µg/d) but nine of the subjects received intakes above the upper limit (200 µg/d) of this range.

The percentage contribution of six food groups to the daily trace element intakes are given in Table 2. Major food sources of both dietary Zn and Se were meat plus substitutes (includes legumes and soya-bean products), providing 43 and 38% respectively. In contrast, bread and cereals were the most important dietary sources of Cu (22%) and Mn (47%).

#### *Analysed Zn, Cu and Mn intakes*

Table 3 compares the mean daily intakes of Zn, Cu and Mn derived from laboratory analysis of the 1 d food composites with mean values obtained from calculation of the corresponding record day. As might be expected, highly significant positive correlations

Table 2. Mean percentage contribution of six food groups to mean Zn, Cu, Mn and Se intakes of Canadian women

Food group	Zn	Cu	Mn	Se
Milk and milk products	23.7	4.5	2.1	9.2
Meat and substitutes	43.0	16.8	7.9	38.0
Vegetables	9.0	21.1	6.3	7.9
Fruit	3.5	14.7	12.0	5.3
Bread and cereals	19.0	22.0	47.0	30.0
Fats, sugars, beverages, alcohol	1.7	20.7	24.6	9.4

Table 3. Mean intakes (mg/d) of Zn, Cu and Mn of Canadian women determined by chemical analysis and calculation

	Analysed		Calculated	
	Mean	SD	Mean	SD
Zn	7.3	3.0	10.1	4.9*
Cu	1.2	0.5	1.7	0.7*
Mn	2.4	1.1	2.9	1.4*

\*  $P < 0.0001$ .

were noted for the analysed trace element intakes and those obtained by calculation ( $P = 0.001$ ). The calculated intakes of Zn, Cu and Mn were 138, 142, and 121% higher than the analysed values respectively, and these differences were statistically significant ( $P < 0.0001$ ). However, the ratios of the mean of each trace element per MJ of total dietary energy (i.e. mean nutrient density) obtained from chemical analysis of the 1 d food composite and by calculation of the corresponding record day were comparable: Zn analysed 1.2 mg/MJ, calculated 1.4 mg/MJ; Cu analysed 0.2 mg/MJ, calculated 0.2 mg/MJ; Mn analysed 0.4 mg/MJ, calculated 0.4 mg/MJ.

## DISCUSSION

The Zn intakes reported in the recent literature for mixed Western diets range from 8–18.6 mg/d (Guthrie & Robinson, 1977; Holden *et al.* 1979; Lyon & Smith, 1979; Milne *et al.* 1980) with the majority falling near the lower limit of this range and below the RDA for Zn. It is possible that the RDA for Zn may be too high. Canadian university students consuming cafeteria meals received a mean Zn intake of 11.6 mg/d (Srivastava *et al.* 1977). This is slightly higher than the mean calculated Zn intake reported here (10.1 mg/d) but comparable to that recently calculated for post-menopausal, Canadian women (11.0 mg/d) (Anderson *et al.* 1981). Zinc intakes in this study were also highly correlated with protein intakes ( $r 0.739$ ), a finding noted in earlier studies (Hunt *et al.* 1979; Anderson *et al.* 1981).

Calculated 3 d mean daily Cu intakes (mean 1.9 mg, range 0.9–4.0 mg) were comparable to recently reported values for North Americans consuming self-selected mixed diets (Holden *et al.* 1979; Milne *et al.* 1980) but below earlier estimates (Klevay, 1975). In general, the majority of the dietary Cu intakes were within the range of recently estimated adult Cu requirements from balance studies (Cartwright & Wintrobe, 1964; Klevay *et al.* 1980). Low intakes of Cu were associated with low energy ( $r 0.527$ ) and low protein intakes ( $r 0.412$ )

compared to the CDS recommendations (Department of Health & Welfare Canada, 1975), a finding also noted by Holden *et al.* (1979).

The mean Mn intake (3.1 mg/d) of these pre-menopausal women fell within the range (2–4 mg/d) reported in recent North American studies (Meranger & Smith, 1972; Kirkpatrick & Coffin, 1974; Srivastava & Nadeau, 1978) and was lower than earlier estimates (Schroeder *et al.* 1966). These differences may be attributed in part to the increased use of refined cereals which are lower in Mn (Schroeder, 1971) than unrefined cereals; cereals being a major source of dietary Mn. In this study, breads and cereals contributed 47% of dietary Mn, and fruits 12% of dietary Mn. Tea is also a rich source (World Health Organization, 1973) and subjects with high Mn intakes (i.e. > 5 mg/d) in this study consumed frequent cups of tea (World Health Organization, 1973).

There are major differences in the Se dietary intakes reported from several countries. This is attributed, in part, to varying levels of Se in the soil and hence dietary components, as well as differences in dietary patterns (Thomson & Robinson, 1980). In Canada, the availability of foods originating from many different areas and supplementation of animal feeds with Se in North America alleviates any potential problems associated with soils low in Se (Morris & Levander, 1970). Currently Se deficiency in human populations has not been described in North America. The calculated mean daily Se intake ( $\mu\text{g}/\text{d}$ ) of the women in this study (131) was higher than those estimates for persons living in New Zealand (24), Italy (12.6), UK (60) and Japan (88.3) (Thomson & Robinson, 1980) but comparable to the levels reported in Canadian Toronto mixed diets (98–148  $\mu\text{g}/\text{d}$ ; Thompson *et al.* 1975) and the estimated typical daily Se intakes in the USA (132  $\mu\text{g}/\text{d}$ ; Morris & Levander, 1970). The dietary requirements for Se are not well established. At least three recent reports have described features characteristic of acute over-exposure to Se in man (e.g. Diskin *et al.* 1979; Van Hubbard *et al.* 1980). Hence, regular intakes of Se above the level of 200  $\mu\text{g}/\text{d}$ , received by nine of the subjects in this study, are probably undesirable if the risk of long-term chronic over-exposure is to be prevented. The major food sources of Se for these pre-menopausal women were meat plus substitutes (38%) and bread plus cereals (30%).

Both dietary fibre and phytate have been implicated in reducing the availability of Zn and possibly other trace elements in the diet (Oberleas & Harland, 1977). In this study, animal products were the most important sources of dietary Zn and Se (Table 2) and dietary fibre intakes were within the range noted by others for subjects consuming mixed diets (Anderson *et al.* 1981; Marlett & Bokram, 1981). It appears unlikely that absorption of trace elements from these mixed diets was adversely affected by dietary fibre and phytate.

The discrepancies between the analysed and calculated trace element intakes were not associated with inaccuracies in the laboratory analysis, as mean ( $\pm$ SD) values obtained for the NBS Orchard Leaves compared very closely to the certified NBS values for Zn, Cu and Mn. Inadequate homogeneity of the food composite was also not a source of error as Zn, Cu and Mn analyses of four replicates of a selected 24 h food composite were comparable. Furthermore, losses of trace elements due to volatilization during the ashing procedure did not occur as recoveries were satisfactory. It is possible that subjects either failed to include certain foods and beverages in their 24 h food composite, or retained smaller portions for their 1 d food composite than were recorded in their food records. Alternatively, portion sizes for the record day were over-estimated. Certainly the comparable nutrient densities obtained for the analysed and calculated 1 d trace element intakes suggests that discrepancies in portion size, rather than omission of specific food items from the food composite, were responsible for the reported differences in the analysed and calculated 1 d trace element intakes. Greger *et al.* (1978) observed similar relative differences between analysed and calculated dietary Zn values determined from 51 d menus in two metabolic studies. However, their differences were apparently due to discrepancies in analysed *v.* food table values.

Energy and selected nutrient intakes derived by calculation from the one record day set aside for the food composite collection, were also compared using a paired Student's *t* test with mean intakes calculated from the other two record days. Differences were significant ( $P < 0.01$ ) suggesting that energy and nutrient intakes on the day of the food composite collection were not representative of the other 2 d. This suggests that when subjects were asked to reserve a duplicate portion of all foods and beverages consumed, their eating pattern was altered. White (1969) attributed the low energy intake of college women (18–30 years), determined by chemical analysis, to the collection of a 1 d food composite. In this study results suggest that chemical analyses of a 1 d food composite does not necessarily provide a more accurate assessment of dietary trace element intakes than those calculated from 3 d food records.

Notwithstanding the uncertainties associated with dietary information calculated from food records, it is clear from the results of this study that valuable information can be obtained using this methodology. The calculated and analysed trace element intakes when expressed on a per MJ basis were comparable, and the values from this study provide new information on the trace element intakes of Canadian pre-menopausal women consuming self-selected diets.

## REFERENCES

- Agriculture Handbook No. 8-1 (rev. 1976). *Composition of Foods: Dairy and Egg Products, Raw-Processed-Prepared*. Agriculture Research Service. Consumer and Food Economics Institute, USDA.
- Agricultural Handbook, No. 8-2 (rev. 1977). *Composition of Foods: Spices and Herbs, Raw-Processed-Prepared*. Agriculture Research Service. Consumer and Food Economics Institute, USDA.
- Agriculture Handbook, No. 8-4 (rev. 1979a). *Composition of Foods: Fats and Oils, Raw-Processed-Prepared*. Agriculture Research Service. Consumer and Food Economics Institute, USDA.
- Agriculture Handbook, No. 8-5 (rev. 1979b). *Composition of Foods: Poultry Products, Raw-Processed-Prepared*. Agriculture Research Service. Consumer and Food Economics Institute, USDA.
- Agriculture Handbook, No. 8-6 (rev. 1980a). *Composition of Foods: Soups, Sauces and Gravies, Raw-Processed-Prepared*. Agriculture Research Service. Consumer and Food Economics Institute, USDA.
- Agriculture Handbook, No. 8-7 (rev. 1980b). *Composition of Foods: Sausages and Luncheon Meats, Raw-Processed-Prepared*. Agriculture Research Service. Consumer and Food Economics Institute, USDA.
- Allen, K. G. D., Klevay, L. M. & Springer, H. L. (1977). *Nutr. Rep. int.* **16**, 227.
- Anderson, B. M., Gibson, R. S. & Sabry, J. H. (1981). *Am. J. clin. Nutr.* **34**, 1042.
- Arthur, D. (1972). *J. Inst. Can. Sci. Techn. Aliment.* **5**, 165.
- Cartwright, G. E. & Wintrobe, M. M. (1964). *Am. J. clin. Nutr.* **14**, 224.
- Department of Health & Welfare Canada (1975). *Dietary Standard for Canada*. Ottawa: Bureau of Nutritional Sciences, Health Protection Branch, Department of National Health & Welfare.
- Diskin, C. J., Tomasso, C. L., Alper, J. C., Glaser, M. L. & Fliegel, S.E. (1979). *Archs intern. Med.* **139**, 824.
- Freeland-Graves, J. H., Ebangit, M. L. & Bodzy, P. W. (1980). *J. Am. diet. Ass.* **77**, 648.
- Ganapathy, S. N., Joyner, B. T., Sawyer, D. R. & Hafner, K. M. (1978). In *Trace Element Metabolism in Man and Animals*, Vol. 4, p. 322. Freising-Weihen-Stephan: Arbeitskreis für Tierernährungs-forschung Weihenstephan.
- Greger, J. L., Marhefka, S., Huffman, J., Baliger, P., Peterson, T., Zaikis, S. & Sickles, V. (1978). *Nutr. Rep. int.* **18**, 345.
- Guthrie, B. & Robinson, M. F. (1977). *Br. J. Nutr.* **38**, 55.
- Hambidge, K. M., Hambidge, C., Jacobs, M. & Baum, J. D. (1972). *Pediat. Res.* **6**, 868.
- Holden, J. M., Wolf, W. R. & Mertz, W. (1979). *J. Am. diet. Ass.* **75**, 23.
- Hunt, I. F., Murphy, N. J., Gomez, J. & Smith, J. C. (1979). *Am. J. clin. Nutr.* **32**, 1511.
- Kirkpatrick, D. C. & Coffin, D. E. (1974). *J. Inst. Can. Sci Techn. Aliment.* **7**, 56.
- Klevay, L. M. (1975). *Nutr. Rep. int.* **11**, 237.
- Klevay, L. M., Reck, S. J., & Barcome, D. F. (1979). *J. Am. med. Ass.* **241**, 1916.
- Klevay, L. M., Reck, S. J., Jacob, R. A., Logan, G. M., Monoz, J. M. & Sandstead, H. Y. (1980). *Am. J. clin. Nutr.* **33**, 45.
- Levine, R. A., Streeten, D. H. P. & Doisy, R. J. (1968). *Metabolism* **17**, 114.
- Lyon, T. D. B. & Smith, H. (1979). *Br. J. Nutr.* **42**, 413.
- Marlett, J. A. & Bokram, R. L. (1981). *Am. J. clin. Nutr.* **34**, 335.
- Meiners, C. R., Derise, N. L., Lau, H. C., Crew, M. G., Ritchey, S. J. & Murphy, E. W. (1976). *J. agric. Fd Chem.* **24**, 1126.
- Meranger, J. C. & Smith, D. C. (1972). *Can. J. publ. Hlth* **63**, 53.

- Milne, D. B., Schnakenberg, D. D., Johnson, H. L. & Kuhl, G. L. (1980). *J. Am. diet. Ass.* **76**, 41.
- Morris, V. C. & Levander, O. A. (1970). *J. Nutr.* **100**, 1383.
- National Research Council, Food & Nutrition Board (1980). *Recommended Dietary Allowances* (9th ed.). Washington, DC: National Academy of Sciences.
- Oberleas, D. & Harland, B. F. (1977). In *Zinc Metabolism. Current aspects in Health and Disease*, p. 11 [A. S. Prasad, editor]. New York: Alan R. Liss Inc.
- Schlettwein-Gsell, D. & Mommsen-Straub, S. G. (1971*a*). *Int. Z. Vitam. Forsch.* **40**, 659.
- Schlettwein-Gsell, D. & Mommsen-Straub, S. G. (1971*b*). *Int. Z. Vitam. Forsch.* **41**, 269.
- Schlettwein-Gsell, D. & Mommsen-Straub, S. G. (1972). *Int. Z. Vitam. Forsch.* **42**, 607.
- Schroeder, H. A. (1971). *Am. J. clin. Nutr.* **24**, 562.
- Schroeder, H. A., Nason, A. P., Tipton, I. H. & Balassa, J. J. (1966). *J. chron. Dis.* **19**, 1007.
- Southgate, D. A. T., Bailey, B., Collinson, E. & Walker, A. F. (1976). *J. human Nutr.* **30**, 303.
- Srivastava, U. S. & Nadeau, M. H. (1978). *Nutr. Rep. int.* **18**, 325.
- Srivastava, U. S., Nadeau, M. H. & Carbonneau, N. (1977). *J. Can. diet. Ass.* **38**, 302.
- Thompson, J. N., Erdy, P. & Smith, D. C. (1975). *J. Nutr.* **105**, 274.
- Thomson, C. D. & Robinson, M. F. (1980). *Am. J. clin. Nutr.* **33**, 303.
- Van Hubbard, S., Barbero, G. & Chase, H. P. (1980). *J. Pediat.* **96**, 421.
- White, H. S. (1969). *J. Am. diet. Ass.* **55**, 38.
- World Health Organization (1973). *Tech. Rep. Ser. WHO* no. 532.