A comparison of methods of assessment of dietary selenium intakes in Otago, New Zealand

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The aims of the present study were (1) to compare three methods of assessment of dietary Se intake, i.e. chemical analysis of duplicate diets, diet records and a food-frequency questionnaire (FFQ) designed specifically for Se, and (2) to determine dietary Se intakes of residents of Otago, New Zealand. The FFQ was completed by 110 free-living adults. Diet records (3 d) and duplicate diet collections were carried out by forty-three of these subjects chosen on the basis of low blood Se concentration, and during a period when consumption of the high-Se foods fish, kidney, liver and Brazil nuts was discouraged. Mean Se intakes were similar for duplicate diet analysis (29 (SD 13) μg/d) and diet record assessments (28 (SD 15) μg/d). Estimates of intakes from the FFQ for the subgroup of forty-three subjects were higher (51 (SD 26) μg/d) than those from duplicate diets and diet records. Values from duplicate diet analysis and diet record assessments were strongly correlated (r 0·7, $P = 0{\cdot}0001$), but difference plots indicated a lack of agreement between the two methods. Thus, diet record assessment was not adequate for predicting dietary Se intakes of individuals. Significant correlations were found for relationships between Se intake from duplicate diets (μg/kg body weight per d) and plasma Se, Se intake from diet records (μg/d and μg/kg body weight per d) and plasma Se; and Se intake from the FFQ and whole-blood Se. Se intakes from duplicate diets and diet records were similar to those reported previously for New Zealanders, but lower than the recommended intakes in the USA (National Research Council, 1989), Australia (Truswell *et al*. 1990) and the UK (Department of Health, 1991) and the World Health Organization/Food and Agriculture Organization/International Atomic Energy Agency (1996) normative requirement.

Selenium: Dietary intake assessment: New Zealand

Se concentrations in foods and dietary Se intakes vary considerably from country to country due to variations in soil Se levels (Thomson & Robinson, 1990). New Zealand has long been recognized as a low-soil-Se area where low food Se concentrations and dietary intakes result in low Se status of the population (Thomson & Robinson, 1980; Robinson & Thomson, 1983; Robinson, 1988). However, dietary Se intakes are also influenced by the importation of foods from countries or regions with higher or lower soil Se content (Thomson & Robinson, 1990), illustrated in New Zealand by the influence of importation of Australian wheat and breakfast cereals on blood Se status in different parts of the country (Watkinson, 1981; Thomson & Robinson, 1988, 1996; Winterbourne *et al*. 1992).

The wide variation in Se concentrations in foods from different regions has made assessment of dietary intake difficult, particularly in New Zealand where until recently, food composition data for Se were inadequate. Analysis of duplicate diets is reported to give the most valid estimate of nutrient intake available (West & van Staveren, 1991), and was the only method for accurate determination of Se intake in New Zealand until Se data were added to the food composition database (NZ Institute for Crop & Food Research Ltd, 1994). However both diet record assessment and duplicate diet collections demand a high degree of motivation and cooperation from subjects. In contrast the food-frequency questionnaire (FFQ) method involves a comparatively low burden to respondents and has been shown to reliably place individuals into broad categories of nutrient intake (Willett *et al*. 1985; Block *et al*. 1986; Pietinen *et al*. 1988*a*,*b*). The aim of the present study was, therefore, to evaluate methods of assessment of Se intake in New Zealand by comparing chemical analysis of duplicate diets, diet records and a short FFQ designed specifically for Se. The strength of relationships among the three methods was investigated, and the diet record method based on the New Zealand food composition database was evaluated for its adequacy in assessing Se intake. The relationships

Abbreviation: FFQ, food-frequency questionnaire.

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among measures of dietary intake and measures of Se status are also reported. A second aim was to determine Se intakes of a group of residents of a low-Se area of New Zealand, which are compared with previously reported Se intakes, intakes in other countries, and recommended dietary intakes.

Methods

Subjects and study design

A total of 110 New Zealand residents (thirty males and eighty females) aged 19–64 years participated in a Se screening study in February and March 1995 in Otago, New Zealand. Blood samples and weight and height measures were taken and a FFQ, which included details of residency, dietary habits, nutrient supplementation and other information which might influence Se status, was completed by all subjects. Forty-three subjects (fifteen males and twenty-eight females) with whole-blood Se concentrations less than 1·26 μmol/l (100 ng/ml) were recruited to take part in a Se supplementation trial (Duffield *et al*. 1999). Before this study, baseline blood and 24 h urine collections were taken from the forty-three recruited subjects. Diet records (3 d) and duplicate diet collections were made at the subjects' convenience. All subjects gave their informed consent, and the protocol was approved by the Southern Regional Health Authority Ethics Committee, Otago, New Zealand.

Dietary assessment

Food-frequency questionnaire. All screened subjects (*n* 110) completed the FFQ which was based on their usual self-selected diet over the previous 12 months. The FFQ was designed specifically for Se to categorize subjects into low, moderately low, moderate or high Se intake groups. The questionnaire requested information on intakes of thirty-three food items which were either high in Se content (e.g. Brazil nuts, fish and kidney) or good sources of Se when eaten frequently (e.g. bread, poultry, red meats, cereals). The Se content of each food was obtained from the New Zealand food composition database (NZ Institute for Crop & Food Research Ltd, 1994), while the Se content of Australian breakfast cereals, if not known, was nominated as twice that of the New Zealand equivalent. Se intake was estimated as the sum of the Se content in each serving of food using a scoring system developed by us using the Microsoft Excel spreadsheet application (Microsoft Corporation, Redmond, WA, USA). The formula for the scoring system included frequency of consumption of each food, standard serving sizes and Se concentrations in the food.

Weighed diet records and duplicate diet collections. All recruited subjects (*n* 43) were requested to weigh, record and collect foods consumed on three non-consecutive days (including one weekend day). Subjects were given thorough training in the use of weighing scales and on the completion of diet records and collection of duplicate diets. Subjects had been requested not to eat Se-rich foods such as fish, liver, kidney or Brazil nuts while participating in the supplementation trial. The diet record and duplicate diet collections may therefore provide an underestimate of the usual diet for these subjects.

Subjects were instructed to keep a detailed diet record of all food consumed for the 3 d of diet records. This included a description of the type of food (including cooking method and additions to foods) and a weighed quantity of amount eaten. At the end of the dietary assessment period, record sheets were checked for the presence of unlikely amounts or inadequate description to ensure accuracy and clarity of the records. Nutrient intakes were calculated from the weighed diet records using a computer database (Nutricomp Diet Entry and Storage, Version 1.5.4 database and Dietcruncher 1.9 application program) based on the New Zealand food composition database (NZ Institute for Crop & Food Research Ltd, 1994).

Duplicates of all foods and beverages consumed during the day by each subject were collected and stored in polypropylene containers. Seeds, cores, peelings, bones or any portions of foods not eaten were not included. Food and beverage collections were frozen and stored until all three collection days had been completed. Containers were then weighed to obtain total weight and blended in a large Waring blender. Portions of the 3 d diet composite were dried to constant weight in a convection oven, ground and stored in an air-tight container until analysis.

Estimated BMR was calculated from weight and height using equations outlined by Schofield *et al*. (1985). Goldberg *et al*. (1991) tabulated cut-off limits identifying minimum plausible levels of energy expenditure expressed as multiples of BMR predicted from the Schofield equations. The validity of energy intakes reported by our subjects was evaluated by comparing them with the 99·7 % confidence limits of these cut-off limits developed by Goldberg *et al*. (1991) to test whether reported energy intake is a plausible measure of food consumed during the measurement period. Intakes falling below this limit were recognized as incompatible with long-term maintenance of energy balance and survival and therefore likely to be incorrect estimates of actual energy intake.

Blood and urine collections

Blood samples were drawn in the morning from subjects at screening and a baseline sample was taken before the start of the supplementation study for recruited subjects. Portions of whole blood and plasma were stored at −80° until analysis. Baseline 24 h urine collections were made by recruited subjects. Urine was collected into acid-washed plastic containers without preservative, the volume measured and 50 ml portions stored at −20°.

Analytical methods

Duplicate diets. Se in duplicate diets was analysed using the digestion procedure described by Pettersson *et al*. (1988) coupled with a modification of the semi-automated diamino-naphthalene fluorimetric method of Watkinson (1979).

Blood and urine samples. Whole-blood samples of all screened subjects were analysed using HNO_3–$HClO_4$

digestion coupled with the diamino-naphthalene fluorimetric method (Watkinson, 1979). Baseline whole blood and urine samples of recruited subjects were digested at a later date by the procedure of Tiran *et al*. (1993) and plasma was digested using HNO_3–$HClO_4$ digestion. Analyses were carried out by flow injection hydride generation atomic absorption spectrometry with a Perkin-Elmer Model 3100 atomic absorption spectrometer (Perkin-Elmer Corp., 761 Main Avenue, Norwalk, CT, USA), in combination with an MHS-FIAS-200 flow injection hydride generation system and an AS-90 autosampler.

Pooled portions of the corresponding sample matrix were used for internal quality control in each batch of duplicate diet, whole blood, plasma or urinary Se analyses. Inter-assay analysis of pooled samples gave mean values of 0·68 (SD 0·07) μmol/kg, CV 9·9 % for nine assays of duplicate diet using the fluorimetric method. Using spectrometry inter-assay values for pooled samples were 0·99 (SD 0·06) μmol/l, CV 6·1 % (*n* 28) for whole blood, 0·69 (SD 0·05) μmol/l, CV 7·9 % (*n* 19) for plasma and 0·31 (SD 0·03) μmol/l, CV 8·7 % (*n* 18) for urine. The intra-assay CV were 6·6 % (*n* 8), 6·1 % (*n* 28), 4·7 % (*n* 5) and 6·9 % (*n* 5) for duplicate diet, whole blood, plasma and urine respectively.

Analysis of non-fat milk powder, batch no. 1549 (US Department of Commerce, National Institute of Standards and Technology, Gaithersburg, MD, USA), with a certified mean of 1·39 μmol Se/kg gave a value of 1·40 (SD 0·13) μmol/kg, CV 9·2 % (*n* 9). Seronorm reference whole blood, batch no. 2030566, product no. 210611 (Nycomed, Pharma Diagnostics, Oslo, Norway), with a certified mean of 1·17 μmol Se/l gave a value of 1·17 (SD 0·07) μmol/l, CV 6·3 % (*n* 28), while analysis of Seronorm reference plasma, lot 605113, with a certified mean of 0·98 μmol Se/l gave 0·98 (SD 0·05) μmol/l, CV 4·8 % (*n* 5). Analysis of Seronorm reference urine, batch no. 009024, certified at 0·38 μmol Se/l gave a value of 0·29 (SD 0·02) μmol/l, CV 7·5 % (*n* 5).

Statistical analysis

Statistical analysis was carried out using the Statview SE + Graphics version 1.03 Statistical Package (Abacus Concepts Inc., Berkeley, CA, USA). Two-tailed unpaired Student's *t* test was used to determine the statistical significance of differences between recruited and screened groups and male and female subjects. Simple regression was used to investigate possible relationships between variables. Agreement between Se intake estimates from duplicate diet and diet record methods was assessed using difference plots (Bland & Altman, 1986). The proportion of intakes classified into quartiles by the three methods of assessment was compared using the χ^2 test.

Results

Physical characteristics and baseline indices of Se status of the forty-three recruited subjects who completed duplicate diets and diet records are shown in Table 1.

Selenium intake

Se intakes of recruited subjects from duplicate diets, diet records and FFQ are summarized in Table 2. When subjects with reported energy intakes below the Goldberg *et al*. (1991) cut-off value (*n* 5) were excluded from the statistical analysis, there was a very small increase in mean Se intake (diet records: all subjects (*n* 38), 29 (SD 14) μg/d; males (*n* 14), 30 (SD 13) μg/d; females (*n* 24), 29 (SD 16) μg/d; duplicate diets: all subjects 30 (SD 13) μg/d; males 36 (SD 6) μg/d; females 27 (SD 15) μg/d.

Of the 110 subjects who completed FFQ, two reported regular consumption of Brazil nuts, a food especially high in Se (1 cup provides 1927 μg) and three reported regular Se supplementation. The latter three subjects were in the recruited subject group. Intakes from FFQ of these five subjects were excluded from statistical analyses as they increased mean estimated Se intakes and strongly affected all correlations.

Comparison of methods of dietary analysis. The mean Se intake of the forty-three recruited subjects determined from diet records was similar to that from duplicate diet analysis, while intake estimated from FFQ was higher (Table 2). Regression analyses of individual Se intakes showed a strong correlation between duplicate diet and diet record assessments (r 0·7, $P = 0·0001$). Log transformation of FFQ data was necessary and was less strongly associated with duplicate diet data (r 0·4, $P = 0·002$). Although mean intakes were similar for duplicate diet and diet records,

Table 1. Physical characteristics and baseline indices of selenium status of forty-three subjects selected on the basis of low blood selenium levels in Otago, New Zealand

(Mean values and standard deviations)

	Male		Female		All subjects	
	Mean	SD	Mean	SD	Mean	SD
n	15		28		43	
Age (years)	43	10	37	12	39	11
Weight (kg)	81**	12	68	16	72	16
Height (m)	1·8***	0·05	1·6	0·06	1·7	0·09
BMI (kg/m^2)	25	4	26	6	26	5
Whole-blood Se (μmol/l)	1·10	0·13	1·06	0·14	1·07	0·13
Plasma Se (μmol/l)	0·78	0·16	0·84	0·15	0·82	0·15
24 h urinary Se output (μg/d)	18	9	16	7	17	8

Mean values were significantly higher than those for females: **$P = 0·01$, ***$P = 0·0001$.

Table 2. Dietary selenium intakes estimated using duplicate diet analysis, diet records and food-frequency questionnaires (FFQ) of forty-three subjects recruited from Otago, New Zealand†
(Mean values and standard deviations)

	Male		Female		All subjects	
	Mean	SD	Mean	SD	Mean	SD
n	15		28		43	
Duplicate diets‡						
(μg/d)	35*	7	26	14	29	13
(μg/kg per d)	0·44	0·12	0·40	0·23	0·42	0·20
Diet record‡						
(μg/d)	30	13	27	16	28	15
(μg/kg per d)	0·35	0·13	0·43	0·27	0·40	0·24
FFQ						
(μg/d)	60	25	46§	26	51§	26
(μg/kg per d)	0·80	0·38	0·71§	0·44	0·74§	0·42

Mean value was significantly different from that for females: * $P = 0{\cdot}03$.
† For details of procedures, see pp. 132–133.
‡ Subjects were discouraged from consuming the high-Se foods fish, liver, kidney and Brazil nuts during the study period.
§ Three subjects were excluded because of inclusion of supplements in FFQ.

difference plots (Bland & Altman, 1986) displayed a lack of agreement between intakes from the two methods. Discrepancies of up to 22 μg/d indicated that diet record assessment was unacceptable for determining individual Se intakes for research purposes. However, the χ^2 test indicated a significant association ($P = 0{\cdot}02$) between the two methods when distribution of Se intakes as quartiles was compared. Duplicate diet analysis and FFQ estimates as quartiles were found not to be significantly associated.

Male v. *female intakes*. Mean Se intake of males from duplicate diets was 33 % greater than that of females ($P = 0{\cdot}03$). When intake was expressed per kg body weight (Table 2) and per 1000 kJ (males, 4·3 (SD 0·91); females, 4.6 (SD 2·5) μg/1000 kJ per d) the difference was no longer significant. There was no difference for intakes from diet records or from FFQ (Table 2).

Contribution of food groups to selenium intake

The contribution of each different food group to Se intake was calculated from diet record data. Cereal products including bakery products, cereals and breakfast cereals contributed 30 % of total dietary Se intake. Meat contributed 19 %, eggs 6 %, fish 5 % and dairy products 6 %. Total animal products (meat, eggs, dairy products and seafood) was therefore the most important source of Se, contributing 36 % of total intake. Fast foods including burgers, Chinese take-aways, fried chicken and pizza contributed 10 % of total Se intake, while fruit and vegetables contributed only 6 %. The recipe category including composite food items such as pasta dishes, pies, muffins and cakes also contributed little to total Se intake (5 %).

Intakes of other nutrients

Mean daily energy intake was 6866 (SD 1696) kJ for all subjects (males, 8143 (SD 1356) kJ; females, 6182 (SD 1459) $P = 0{\cdot}02$). Four female subjects and one male subject reported energy intakes below the 99·7 % cut-off value (Goldberg *et al*. 1991). When these subjects were excluded from the analysis, energy intakes became 8193 (SD 1471) kJ for males and 6542 (SD 1192) kJ for females. Macronutrient intakes as a percentage of energy intake for males and females were not significantly different. Carbohydrate contributed 49 %, fat 35 %, protein 15 % and alcohol 1 % total energy.

Relationship between selenium intake and energy and protein intakes

Se and energy intakes from diet records were strongly correlated (r 0·56, $P = 0{\cdot}0001$), as were Se and protein intakes (r 0·60, $P = 0{\cdot}0001$). The latter association became weaker and not significant (r 0·28, $P = 0{\cdot}082$) when Se intake was expressed per kg body weight.

Relationship between selenium intake and selenium status

Correlation coefficients for relationships among Se intakes determined from duplicate diets, diet records and FFQ, and Se concentrations in whole blood, plasma and urine of recruited subjects are given in Table 3. Significant correlations were found for Se intake from duplicate diets (μg/kg body weight per d) and plasma Se; Se intake from diet records (μg/d and μg/kg body weight per d) and plasma Se; and Se intake from FFQ (μg/d and μg/kg body weight per d) and whole-blood Se.

Se intakes from FFQ of recruited subjects were grouped into categories of < 25 (n 6), 25–40 (n 9), 40–53 (n 11) and > 53 μg/d (n 14) for regression analyses with blood Se status. Regression was not significant for whole blood or plasma. However, ANOVA showed that the means for whole-blood Se for each category of intake were significantly different ($P = 0{\cdot}02$), and that those in the high-Se-intake group had a significantly higher blood Se level (1·08 (SD 0·13) μmol/l) than those in the low intake group (0·92 (SD 0·16) μmol/l; $P = 0{\cdot}03$). This analysis was not significant for plasma or for FFQ data of all screened subjects.

Table 3. Pearson correlation coefficients (*r*) for relationships between selenium intake determined from proximate analysis, diet records and food-frequency questionnaires (FFQ) and selenium in whole blood, plasma and urine for forty-three subjects recruited in Otago, New Zealand

Selenium intake	Whole-blood Se (μmol/l)	Plasma Se (μmol/l)	24 h urinary Se (μg/d)
Duplicate diets†			
(μg/d)	0·3	0·3	0·1
(μg/kg per d)	0·3	0·3*	0·0001
Diet records†			
(μg/d)	0·3	0·4*	0·2
(μg/kg per d)	0·3	0·4**	0·1
FFQ			
log(μg/d)	0·3*	0·2	0·1
log(μg/kg per d)	0·4**	0·2	0·2
categories of Se intake	0·2	0·2	0·2

* $P < 0·05$, ** $P < 0·01$.
† Subjects were discouraged from consuming the high-Se foods fish, liver, kidney and Brazil nuts during the study.

Mean whole-blood Se concentration of all screened subjects (*n* 110) was 1·23 (SD 0·25) μmol/l (males, 1·25 (SD 0·25); females, 1·22 (SD 0·25) μmol/l), significantly higher than the mean for recruited subjects ($P = 0·0001$; Table 1). Se intakes calculated from FFQ in recruited (51 (SD 26) μg/d) and screened subjects (56 (SD 32) μg/d) were not significantly different and the distribution of subjects when grouped into the categories of low, moderately low, moderate and high intakes was also similar.

Discussion

This study provides a unique contribution to dietary Se research as the only one reported in which three different methods of dietary assessment (duplicate diet analysis, diet records and FFQ) have been used to determine Se intake.

Evaluation of dietary assessment methods for selenium

Mean dietary Se intakes calculated from FFQ were considerably higher than those determined from duplicate diets or diet records. A number of possible reasons could explain this observation. The Goldberg evaluation (Goldberg *et al*. 1991) indicated that energy intakes from diet records of five of the forty-three subjects were underestimated and therefore not true estimates of habitual intake (Shortt *et al*. 1997). This suggested either under-recording or restricted food intake during the collection period, which would no doubt be reflected in intakes of other nutrients. However, for Se the difference in mean intakes was small when those subjects were omitted from the evaluation. A second possible reason is that subjects were recruited to the supplementation study on the basis of low blood Se levels and therefore might be expected to have lower intakes. However, an unexpected observation was the similar mean Se intakes calculated from FFQ in the recruited and screened subjects despite a higher whole-blood Se level for screened subjects. A third possible explanation for the difference is that the FFQ was designed to estimate long-term Se intake while the other two methods measured intake over 3 d, when consumption of Se-rich foods was discouraged. In an early study in our laboratory of dietary intakes of four women who collected a total of fifty-six duplicate diets, mean Se intake was 33 % higher when days (*n* 13) in which fish, liver and kidney were included in comparison with the mean for days (*n* 43) which did not include these foods (24·2 *v*. 18·5 μg/d respectively) (Robinson & Thomson, 1987). A similar difference would increase our Se intakes from duplicate diets and diet records to approximately 40 μg/d. However, some fish was consumed by our subjects. Furthermore, blood Se levels did not fall in the placebo group over the 5-month study period (Duffield *et al*. 1999) suggesting that these measured intakes were not very different from habitual intakes. These high-Se foods are in fact not frequently consumed by New Zealanders because of cost and individual preference. Another more likely factor contributing to higher FFQ intakes is the tendency of FFQ to overestimate intakes of certain food groups such as vegetables and meats when estimating servings of a variety of food types over a period of time. In a study of Se intakes of pregnant women in New Zealand, correction for this factor reduced FFQ Se intakes by as much as 15 % (CD Thomson, JA Butler and PD Whanger, unpublished results). However, the FFQ intakes did reflect whole-blood Se status and with some refinement may be a useful rapid method of monitoring Se intake and status.

Another aim of the present study was to evaluate the diet record method using the New Zealand food composition database (NZ Institute for Crop & Food Research Ltd, 1994) by measuring the strength of the relationship between intakes from duplicate diets and diet records on the same day. Mean intakes were almost identical and there was a strong positive relationship between the two dietary assessments (*r* 0·7) and a significant association when intakes were classified into quartiles. However, difference plots (Bland & Altman, 1986) indicated that diet record assessment was not adequate for predicting Se intakes of individuals, and that duplicate diet analysis remains the recommended measure for research purposes. It is possible that the New Zealand food composition data may not reflect accurately the variation in Se concentration which can occur in foods, in particular cereals, from different areas. Welsh

et al. (1981) also reported a good correlation (*r* 0·88) between diets analysed and those calculated for Se, but difference plot analyses were not performed on their data.

Relationship between selenium intake and selenium status

Serum and whole-blood Se levels have been associated with Se intake in geographic correlation studies (Levander, 1982) but attempts to demonstrate similar associations within specific geographic sites have been less successful (Swanson *et al*. 1990). Plasma Se was only weakly associated (*r* 0·119) and whole-blood Se was not significantly associated with dietary Se in Amish subjects (Snook *et al*. 1983), and in elderly subjects dietary Se was associated with erythrocyte Se (*r* 0·38) but not with plasma Se (Lane *et al*. 1983). In our subjects, Se intakes from duplicate diets and diet records were significantly correlated with plasma Se concentrations, intake from FFQ was significantly associated with whole-blood Se, and whole-blood Se levels of subjects grouped according to categories of Se intake from FFQ were significantly different. These observations reflect the fact that duplicate diets, diet records and plasma concentrations are indicators of short-term intake and status while FFQ and whole blood are longer-term measures. In adults living in South Dakota whole blood, serum and toenail Se contents were all strongly associated with Se intake (Swanson *et al*. 1990), and the clear association between intake and tissue Se content can be attributed to the relatively wide range of Se intakes.

Although men had higher Se intakes than women, these were not reflected in higher blood Se concentrations, an observation also made by other workers (Swanson *et al*. 1990; Longnecker *et al*. 1996). Swanson *et al*. (1990) concluded that differences in body composition could be the reason, and this is supported by an increase in significance in the relationship between our Se intakes from FFQ expressed in relation to body weight and whole-blood Se. However, Longnecker *et al*. (1996) used estimated lean body mass and sex as potential predictor variables in their analysis and only sex was found to be important. A more likely explanation for higher intakes in male subjects is the greater energy intakes, which were strongly correlated with Se intakes (*r* 0·56) in the present study. Welsh *et al*. (1981) also reported strong Se–energy correlations. In our subjects and those of Lane *et al*. (1983), there was an even stronger relationship between dietary Se and protein (*r* 0·60), accounted for by a direct correlation between Se content and protein percentage in foodstuffs (Ferreti & Levander, 1976; Weaver *et al*. 1988).

Dietary selenium intake in New Zealand

Mean Se intakes in recruited subjects from duplicate diets and diet records were similar to the 28–32 μg/d reported previously for New Zealanders (Thomson & Robinson, 1988; Robinson, 1989). This was unexpected since Thomson & Robinson (1996) reported that blood Se status in Otago had increased during the early 1990s due to the importation of Australian wheat. If intakes in the present study were underestimated by as much as 33 % and FFQ intakes overestimated, then an intake of about 40 μg/d would be consistent with a small increase in Se status. However, wheat importation is spasmodic, making its impact on total Se intake inconsistent, and the present study was carried out during a period when no imported wheat was being used in Otago. The increase in blood Se status may also reflect the greater impact that selenomethionine, the major form of Se in cereals, has on blood Se because of its non-specific incorporation into tissue proteins. Therefore a small increase in selenomethionine intake may have a significant effect on blood Se.

The present study also demonstrates the impact of wheat and cereal importation on the contribution of different food groups to daily Se intake, documented also in Finland before supplementation of fertilizers in 1984 (Mutanen, 1984). Diet record data indicated that 30 % of total Se intake was contributed by cereal products, in contrast to 13 % in 1980 (Thomson & Robinson, 1980), and a temporary increase to 21 % in 1985 due to importation of one shipment of Australian wheat (Thomson & Robinson, 1996). It is interesting that total Se intake is presently not much greater than that reported in the 1980s, yet the contribution of cereals is now twice the earlier value. This probably reflects changes in both dietary and food importation patterns which have led to greater availability and consumption of wholewheat and mixed meal varieties of breads and Australian breakfast cereals with higher Se contents (Thomson & Robinson, 1980, 1996). The contribution of cereals to Se intake in New Zealand is still low when compared with the 50 % in countries such as Canada (Thompson *et al*. 1975), which reflects higher soil and plant Se concentrations. On the other hand, in New Zealand along with Belgium, Germany and France with low soil Se levels, most of the Se intake comes from animal protein (Oster & Prellwitz, 1989). An exception is the Keshan disease areas of China where a low animal protein content of diets means that cereals provide most of the Se in spite of the low soil Se concentrations (Yang *et al*. 1988).

Mean daily Se intakes reported from other countries range from 11 μg/d in Keshan disease areas of China to 5000 μg/d in seleniferous areas of the same country. New Zealand still has one of the lowest Se intakes in the world, appreciably lower than the Australian recommended nutrient intakes for Se of 85 and 70 μg/d for adult men and women respectively (Truswell *et al*. 1990) that have been adopted by New Zealand, the 1989 US recommended dietary allowances of 70 and 55 μg (National Research Council, 1989) and the British reference nutrient intakes of 75 and 60 μg/d for adult men and women (Department of Health, 1991). Our intakes approach the British lower reference nutrient intake of 40 μg/d which is the same as the World Health Organization/Food and Agriculture Organization/International Atomic Energy Agency (1996) normative requirement. With continued consumption of high-Se wheat and cereals from Australia and the inclusion of some of the high-Se foods not included in the diets of our subjects, the lower recommendation of 40 μg/d would easily be achieved by residents of Otago. Higher recommendations would realistically be achieved only with some sort of intervention and the question of whether additional Se should be obtained from high-Se foods or from a Se supplement needs to be debated.

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