

Long-term supplementation with selenate and selenomethionine: selenium and glutathione peroxidase (EC 1.11.1.9) in blood components of New Zealand women

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Thirty-three New Zealand women aged 18-23 years received daily for 32 weeks, 200 µg Se as Se-enriched yeast (selenomethionine), or brewer's yeast mixed with selenate, or no added Se (placebo) in a double-blind trial. Se supplementation raised ($P = 0.001$) platelet glutathione peroxidase (EC 1.11.1.9; GSHPx) activity, and also Se and GSHPx in whole blood, erythrocytes and plasma. Selenomethionine was more effective in raising blood Se concentrations than selenate, but both were equally effective in raising GSHPx activities in whole blood, erythrocytes and plasma, indicating a similar bioavailability for the two forms. These observations and those of gel filtration studies of erythrocytes and plasma proteins reported elsewhere (Butler *et al.* 1991) are consistent with the incorporation of Se from selenomethionine into a general tissue protein pool while selenate is directly available for GSHPx synthesis, and explain the poorer correlation between Se and GSHPx in individuals with higher Se status. However, selenate raised platelet GSHPx activities to a greater extent than did selenomethionine suggesting some other effect of selenate on platelets which needs further investigation. A response of GSHPx activity in these New Zealand subjects indicates that their dietary Se intake is insufficient to meet recommended intakes based on the criterion of saturation of GSHPx activity, and could reflect a marginal Se status. The level of blood Se necessary for saturation of GSHPx of about 100 ng Se/ml whole blood confirms observations in earlier studies.

Selenium: Glutathione peroxidase: Platelets: Women

Selenite, selenate, selenomethionine, Se-enriched yeast and food Se have been suggested as suitable forms for prolonged Se supplementation. Considerable information is available on the effects of short-term Se supplementation on glutathione peroxidase (EC 1.11.1.9; GSHPx) activities in human tissues (Thomson *et al.* 1978, 1982, 1985; Levander *et al.* 1983). Blood Se levels are always greater with selenomethionine supplementation than with the same amount of Se in the inorganic forms selenite (Thomson *et al.* 1978, 1982) and selenate (Levander *et al.* 1983), but both organic and inorganic forms are equally effective in raising erythrocyte GSHPx activities. Selenite and selenate were adopted for human supplementation by New Zealand self-dosers (Thomson & Robinson, 1986), and selenite was used for treatment of Keshan disease in China (Keshan Disease Research Group of the Chinese Academy of Medical Sciences, 1979), but there is concern about the long-term effects of prolonged selenite supplementation. Selenate is chemically more stable than selenite and was used instead as the control standard in the Finnish Se supplementation

studies (Levander *et al.* 1983). There is also increasing emphasis on the use of selenate for agricultural purposes (Koivistoinen & Huttunen, 1986; Stephen *et al.* 1989). Early studies in New Zealand showed that selenate-Se was better absorbed than selenite-Se in human subjects, but that urinary excretion was three times higher after selenate than after selenite (Thomson & Robinson, 1986). However, there is little other information on the metabolism of selenate or on the effects of prolonged Se supplementation in human subjects, apart from the study of Alfthan *et al.* (1991).

The aim of the present study was to compare the long-term effects of selenate and selenomethionine on Se metabolism in blood and urine, and the bioavailability of the two forms of Se as assessed by GSHPx activities in whole blood, plasma and platelets. A preliminary report of some of these results has been presented (Thomson *et al.* 1989). The effects of supplementation with these two forms of Se on the distribution of Se in erythrocyte and plasma proteins has been presented previously (Butler *et al.* 1991) as well as a preliminary report on the urinary Se excretion (Robinson *et al.* 1989).

METHODS

Thirty-three women resident in Dunedin, New Zealand and aged 18–23 years participated in a double-blind Se supplementation study for 32 weeks in 1987. The subjects were randomly assigned to three groups and received daily tablets containing 200 μg Se as selenate mixed with brewer's yeast or as Se-enriched yeast (SeMet), or plain brewer's yeast with no added Se (placebo; < 1 μg Se/tablet). The tablets were manufactured by Vita Tech International, Inc, Tustin, CA, USA and supplied by Nutrition 21 (San Diego, CA). The majority of the Se in the Se-enriched yeast supplied by this company has been shown to be in the form of selenomethionine (Beilstein & Whanger, 1986). Each subject filled in a brief questionnaire giving details of residency, dietary habits, nutrient supplementation and other information which might influence Se status. The subjects were requested not to eat the Se-rich foods, fish, liver, kidney or brazil nuts, during the 2 d before the time blood samples were taken. Informed consent was obtained from all subjects and the study was approved by the Ethical Committee of the Otago Area Health Board.

Blood samples were drawn into heparinized vacutainers on the day before supplementation commenced (week 0), at 2 and 4 weeks, and monthly for a further 28 weeks. A portion of whole blood was removed and the remainder separated into plasma and erythrocytes for analysis of Se and GSHPx activity. Whole-blood GSHPx was assayed within a few days while plasma and erythrocytes were frozen at -80° for later analysis. Another bimonthly sample was similarly prepared and shipped by air while frozen to Oregon State University, Corvallis, Oregon, USA for gel-filtration chromatography studies (Butler *et al.* 1991).

Blood for platelet preparation was collected into siliconized vacutainer tubes containing citrate dextrose as anticoagulant. Platelet-rich plasma was separated from the erythrocytes and centrifuged to separate the platelet poor plasma. The platelet pellet was washed three times by resuspending in Tris-EDTA buffer (0.15 M-Tris-HCl, 0.15 M-NaCl, 77 mM-EDTA, pH 7.4), disrupted by sonication using a Wave Energy Systems Ultratip (Newtown, PA, USA) with a Model MTI probe under standardized conditions and ultracentrifuged at 108 000 *g*. The supernatant fraction was stored at -80° until analysis. Stored samples of plasma, erythrocytes and platelet supernatant fraction were assayed in batches together.

Se in whole blood, plasma and erythrocytes was analysed by the automated fluorimetric method (Brown & Watkinson, 1977). Sensitivity and sample reproducibility of the method for 1 ml whole-blood samples was 1 ng (SD 2.5% within the range 0–100 ng). Analysis of the National Bureau of Standards (Gaithersburg, MD, USA) reference material #1577,

bovine liver, gave a value of $1.11 \mu\text{g Se/g}$ (certified value $1.09 \pm 0.10 \mu\text{g/g}$). GSHPx activity was assayed in whole blood, plasma, erythrocytes and platelets as described previously (Thomson *et al.* 1982; Thomson, 1985) using t-butyl hydroperoxide as substrate. A stock sample of whole blood assayed with each series of samples gave a mean activity for nine assays of 22.3 (SD 0.94) U/g haemoglobin (Hb) (coefficient of variation 4.2%). Protein in plasma was measured by the standard Biuret method (Gornall *et al.* 1949) and in platelets by the method of Lowry *et al.* (1951).

Statistical analysis of the results was carried out using the 'Statview SE + Graphics' package on a Macintosh SE computer. Differences between the groups were calculated by one-factor ANOVA (Winer, 1971), and differences within each group over the 32 weeks by one-factor ANOVA for repeated measures (5% significance level; Winer, 1971). Simple regression was used to investigate possible relationships between variables.

RESULTS

Baseline Se concentrations in whole blood, erythrocytes and plasma, and GSHPx activities in whole blood, erythrocytes, plasma and platelets are shown in Table 1. Values did not differ among the three groups. However, the mean values for whole-blood Se and erythrocyte GSHPx activities were significantly greater for the placebo group than for the selenate group ($P = 0.0376$ and $P = 0.0166$ respectively; Student's *t* test).

Se concentrations

Se concentrations in whole blood, erythrocytes and plasma increased significantly ($P = 0.001$) in both supplemented groups, while no changes were seen in the placebo group except for a small increase ($P = 0.02$) in erythrocyte Se. Whole-blood Se (Fig. 1) reached a plateau of around 100 ng Se/ml at week 12 in the selenate group but continued to rise in the SeMet group to 280 ng/ml at week 32, such that significant differences ($P < 0.001$) in the mean values among the three groups were apparent from week 2. At the end of the supplementation period whole-blood Se in the SeMet group was nearly three times higher than in the selenate group.

Erythrocyte Se (Fig. 2) rose from 24 ng/g Hb at week 2 to 110 ng/g Hb at week 28 in the SeMet group, but in the selenate group it plateaued at about 7 weeks at 30 ng/g Hb . Significant differences ($P < 0.005$) were seen between the SeMet and selenate groups from week 2 and the SeMet and placebo groups from week 4 but not between the selenate and placebo groups. Erythrocyte Se was more than three times greater in the SeMet group than in the selenate group by week 32.

Plasma Se (Fig. 3) in the selenate group plateaued at about 7 weeks at 110 ng/ml but rose further in the SeMet group reaching a plateau of 190 ng/ml at week 16. Significant differences in mean concentrations were apparent among the three groups from week 2 ($P = 0.0001$), and at the end of supplementation plasma Se in the SeMet group was nearly 2-fold greater than in the selenate group.

GSHPx activities

GSHPx activities in whole blood, erythrocytes, plasma and platelets rose significantly ($P = 0.001$) in both selenate and SeMet groups. No changes were seen in the placebo group except for erythrocyte GSHPx ($P = 0.008$) and plasma GSHPx ($P = 0.013$). In the whole blood (Fig. 4) GSHPx activities reached a plateau at 35 U/g Hb at about 12 weeks in both

Table 1. *Baseline values for selenium concentrations and glutathione peroxidase (EC 1.11.1.9; GSHPx) activities in blood components of New Zealand women*
(Mean values and standard deviations)

Group†... n...	Selenate 12		SeMet 11		Placebo 10	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	21	1	21	1	20	1
Whole-blood Se (ng/ml)	65	9*	68	5	72	5
Erythrocyte Se (ng/g Hb)	22	4	23	5	25	3
Plasma Se (ng/ml)	53	7	53	5	56	6
Whole-blood GSHPx (U/g Hb)	22	4	24	4	27	5
Erythrocyte GSHPx (U/g Hb)	21	4†	23	5	26	5
Plasma GSHPx (U/g protein)	3.0	0.5	3.0	0.2	2.9	0.4
Platelet GSHPx (U/g protein)	326	77	286	104	339	67

Hb, haemoglobin.

Mean value was significantly different from that for placebo group (Student's *t* test): * $P = 0.0376$.

Mean value was significantly different from that for placebo group (Student's *t* test): † $P = 0.0166$.

‡ For details of dietary groups, see p. 578.

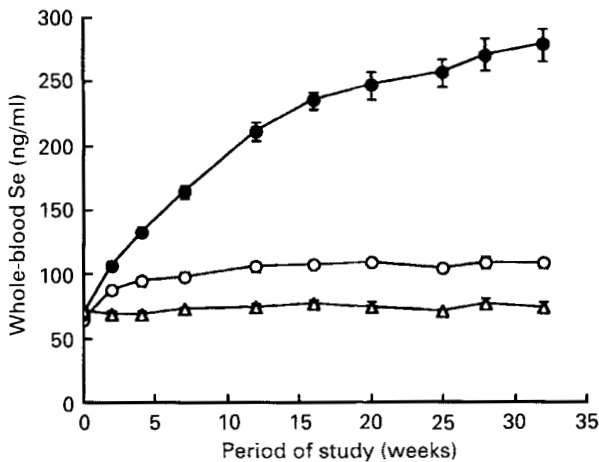


Fig. 1. Se concentrations in whole blood of New Zealand women supplemented with Se either as selenate (○) or Se-enriched yeast (●), or a placebo (△) for 32 weeks. For details of dietary treatments, see p. 578. Values are means with their standard errors represented by vertical bars.

selenate and SeMet groups and the mean values at each week did not differ between these two groups. Because of the somewhat higher baseline activity in the placebo group, differences between the means for this group and the supplemented groups were not apparent until week 12 ($P < 0.01$). GSHPx activities were similar in erythrocytes to those in whole blood and behaved in a similar manner with both selenate and SeMet groups plateauing at about 12 weeks at 32 U/g Hb, and not differing from each other.

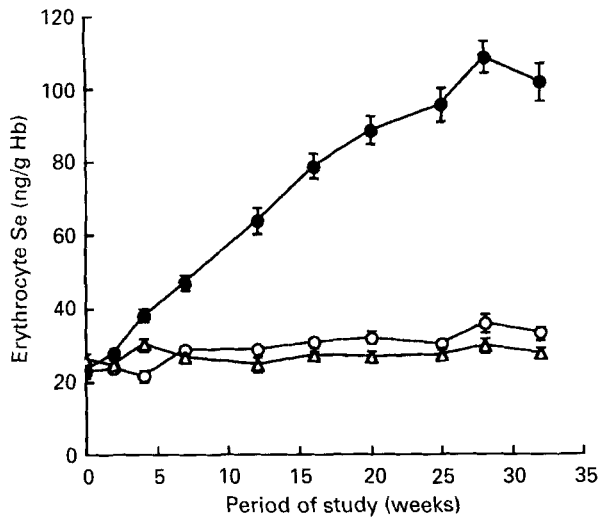


Fig. 2. Se concentrations in erythrocytes of New Zealand women supplemented with Se either as selenate (○) or Se-enriched yeast (●), or a placebo (△) for 32 weeks. For details of dietary treatments, see p. 578. Values are means with their standard errors represented by vertical bars. Hb, haemoglobin.

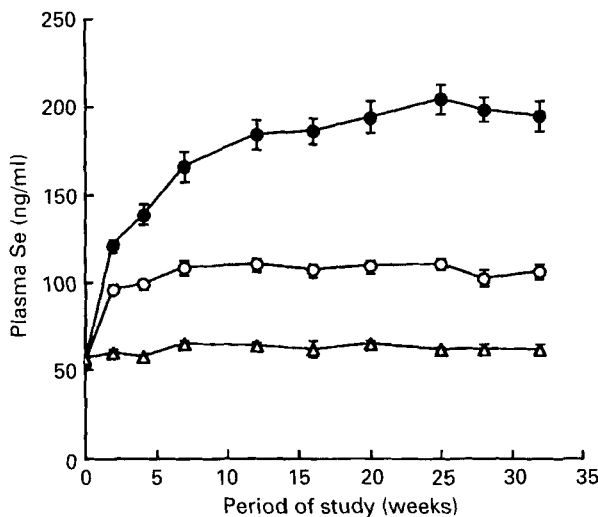


Fig. 3. Se concentrations in plasma of New Zealand women supplemented with Se either as selenate (○) or Se-enriched yeast (●), or a placebo (△) for 32 weeks. For details of dietary treatments, see p. 578. Values are means with their standard errors represented by vertical bars.

Plasma GSHPx (Fig. 5) rose rapidly from 2.9 to 4.1 U/g protein between weeks 0 and 2 in both supplemented groups and then rose slowly until week 25. There were no differences between the means at each week for these two groups, but both differed from the placebo group from weeks 2 to 32 ($P < 0.05$). Platelet GSHPx (Fig. 6) activities rose rapidly from about 295 U/g protein to a plateau at 2–4 weeks of 650 U/g protein in the selenate group and only 470 U/g protein in the SeMet group. Mean GSHPx activities

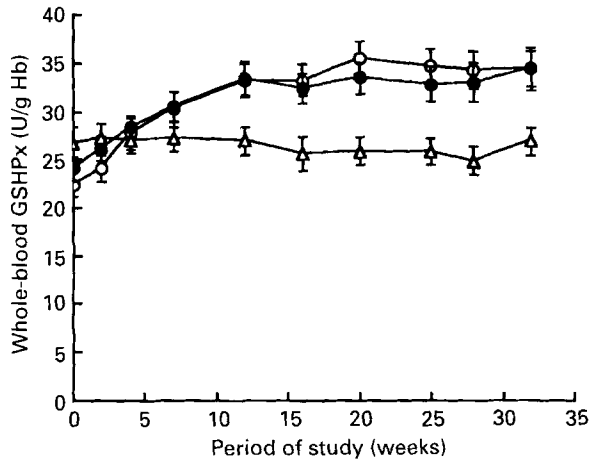


Fig. 4. Glutathione peroxidase (*EC* 1.11.1.9; GSHPx) activities in whole blood of New Zealand women supplemented with Se either as selenate (○) or Se-enriched yeast (●), or a placebo (△) for 32 weeks. For details of dietary treatment, see p. 578. Values are means with their standard errors represented by vertical bars. Hb, haemoglobin.

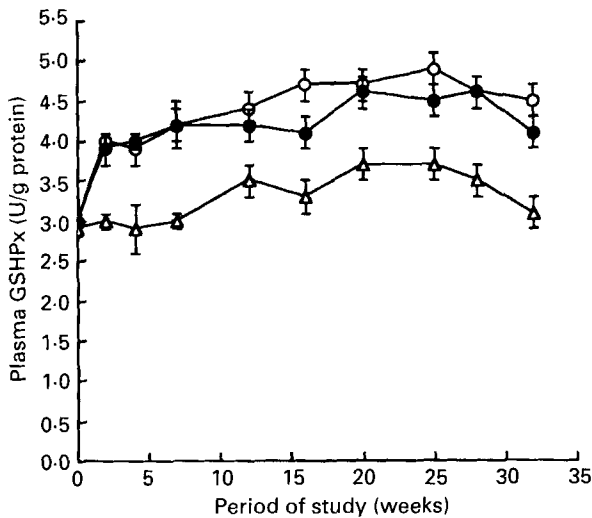


Fig. 5. Glutathione peroxidase (*EC* 1.11.1.9; GSHPx) activities in plasma of New Zealand women supplemented with Se either as selenate (○) or Se-enriched yeast (●), or a placebo (△) for 32 weeks. For details of dietary treatments, see p. 578. Values are means with their standard errors represented by vertical bars.

differed amongst the three groups ($P < 0.001$) from week 2, except for week 16 when the mean for the SeMet group was not different from that of the placebo group.

Correlation coefficients for relationships between Se and GSHPx activities in whole blood, erythrocytes and plasma are given in Table 2. Significant correlations were found for all measures, but the correlation coefficients were greater for the selenate group than for the SeMet group. Correlation coefficients for the relationships between platelet GSHPx activity and other blood measures are given in Table 3. Again these are greater for the selenate than the SeMet group.

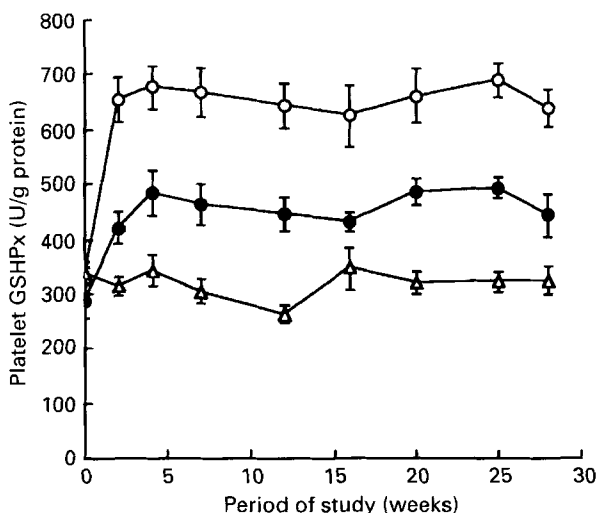


Fig. 6. Glutathione peroxidase (EC 1.11.1.9; GSHPx) activities in platelets of New Zealand women supplemented with Se either as selenate (○) or Se-enriched yeast (●), or a placebo (△) for 32 weeks. For details of dietary treatment, see p. 578. Values are means with their standard errors represented by vertical bars.

Table 2. Correlation coefficients (r)* for relationship between Se concentrations and Se-glutathione peroxidase (EC 1.11.1.9) activity for all subjects for all weeks

Group†	Whole blood		Erythrocytes		Plasma	
	<i>n</i>	<i>r</i>	<i>n</i>	<i>r</i>	<i>n</i>	<i>r</i>
Selenate	117	0.713	116	0.661	114	0.578
SeMet	109	0.496	107	0.540	106	0.437
Placebo	88	0.409	83	0.520	84	0.551

* $P = 0.0001$.

† For details of dietary groups, see p. 578.

Table 3. Correlation coefficients* for relationship between platelet glutathione peroxidase (EC 1.11.1.9; GSHPx) activity and other blood measures for New Zealand women

Group	<i>n</i>	Whole blood		Plasma	
		Se	GSHPx	Se	GSHPx
Selenate	105	0.480	0.360†	0.629	0.421
SeMet	94	0.319‡	0.303	0.427	0.325
Placebo	74	NS	NS	NS	0.244§

NS, not significant.

* $P = 0.0001$ except where otherwise stated.

† $P = 0.0002$.

‡ $P = 0.0015$.

§ $P = 0.0387$.

|| For details of dietary groups, see p. 578.

DISCUSSION

The trends in Se concentrations and GSHPx activities in blood components were similar to those observed in previous studies in New Zealand (Thomson *et al.* 1982, 1988) and also by other workers (Levander *et al.* 1983; Neve *et al.* 1988; Alfthan *et al.* 1991). However, the present study is the first study comparing the long-term supplementation with selenate and selenomethionine in all blood components, the longest period of supplementation in previous studies being 17 weeks (Thomson *et al.* 1982). Furthermore the present study was carried out in women from a low Se status population, markedly lower than that of the Finnish men when first studied by Levander *et al.* (1983), and considerably lower than these same men when studied later after supplementation of the Finnish diet by topdressing wheat (Alfthan *et al.* 1991), and also of Belgian residents (Neve *et al.* 1988) and Dutch subjects (van der Torre *et al.* 1991).

In spite of the greater increase in Se concentrations with selenomethionine, GSHPx activities in whole blood and erythrocytes rose to about 150% of the presupplementation value at 12 weeks with both selenate and selenomethionine, indicating a similar bioavailability for the two forms of Se. This confirmed observations with selenite and selenomethionine in earlier studies (Thomson *et al.* 1982). In the present study plasma GSHPx activities also increased to a similar level of about 150% baseline values after both selenate and selenomethionine but with an earlier plateau at 2 weeks. Plasma GSHPx did not increase in Finnish men (Levander *et al.* 1983; Alfthan *et al.* 1991) or in Dutch men with higher Se status (van der Torre *et al.* 1991), in spite of increases in plasma Se.

In contrast, platelet GSHPx activities plateaued at 200% of the presupplementation value at 2 weeks in the selenate group, while in the SeMet group the plateau occurred at only 160% of the baseline value and later at 4 weeks. This difference persisted throughout the study, in contrast to the Finnish study in which platelet GSHPx in the Se-enriched yeast group rose more slowly than that for selenate or Se-rich wheat, but by the end of the 11-week supplementation period appeared possibly to be approaching a similar level (Levander *et al.* 1983). In a later study by the same authors using subjects with higher Se status, inorganic Se (both selenate and selenite) but not Se-rich yeast increased platelet GSHPx (Alfthan *et al.* 1991). These authors suggested that the slow response of platelet GSHPx activity to organic Se may result because selenomethionine is first deposited into tissue pools before being converted into the precursor available for GSHPx. Neve *et al.* (1988) also suggested that the different response of platelet GSHPx to inorganic and organic Se may be due to the preference of organic Se compounds for binding to Hb. This was confirmed by our results from gel-filtration studies of erythrocyte lysates and plasma from these New Zealand women (Butler *et al.* 1991). Although this might explain the more rapid increase in platelet GSHPx with selenate supplementation than with selenomethionine, it does not explain why activity in the selenomethionine group did not continue to rise and plateau at a similar level as for selenate even after 32 weeks of supplementation. This suggests some effect of inorganic Se on platelet GSHPx independent of Se intake which needs further investigation.

The plateau or saturation of GSHPx activities probably occurs at a dietary intake that represents a low risk Se requirement or recommended intake (Thomson, 1991). An intriguing aspect of this study is that regression analysis showed that GSHPx activity in whole blood, erythrocytes, platelets and plasma plateaued at the same blood Se concentration for each supplemented group, i.e. 100 ng Se/ml whole blood for selenate and 260 ng/ml whole blood for selenomethionine, or 95 and 200 ng Se/ml plasma respectively. Therefore, there seems to be one level of whole-blood Se at which saturation of GSHPx occurs in all the blood components, which is higher for selenomethionine group than for

selenate. It is likely that 100 ng Se/ml whole blood is the minimum concentration necessary for saturation of GSHPx since selenate and other inorganic Se enter directly into the Se pool available for synthesis of functional forms of Se such as GSHPx, whereas selenomethionine is taken into tissue proteins such as Hb and is not available for GSHPx until catabolized (Levander & Burk, 1990). It is interesting that this Se level of 100 ng/ml whole blood for the selenate group corresponds to the value (100 ng/ml whole blood, or 140 ng/ml erythrocytes) arrived at in earlier New Zealand studies above in which there was no correlation between Se and GSHPx (Thomson *et al.* 1977; Rea *et al.* 1979). Furthermore, the value for plasma Se of 95 ng Se/ml necessary for saturation of plasma GSHPx activity agrees with that of about 98–114 ng Se/ml (1.25–1.45 $\mu\text{mol/l}$) arrived at by Alfthan *et al.* (1991) by plotting the percentage increments in enzyme activity in various supplementation studies (Levander *et al.* 1983; Thomson *et al.* 1985, 1988, 1989; Tarp *et al.* 1987) *v.* plasma Se.

One striking observation in the present study was the large individual variation in response of GSHPx activities to Se supplementation, also seen in a number of other studies (Levander *et al.* 1983; Stead *et al.* 1985). This supports the suggestion that each individual may reach his or her own optimal level of GSHPx activity which is determined by a balance between Se intake and other factors such as oxidant stress, dietary factors, age, gender and hormones (Thomson *et al.* 1982). However, there was also some evidence to indicate that the increase in GSHPx activity was negatively related to baseline values and, therefore, that the extent of the response may depend upon pre-existing Se status. Furthermore the response of GSHPx was not always consistent for platelets or other blood components for one subject, which could mean that different homeostatic mechanisms operate for GSHPx in different blood components.

The poorer correlations between Se concentrations and GSHPx activities for those subjects supplementing with selenomethionine than for those taking selenate reflect the different pathways for metabolism of inorganic forms of Se and selenomethionine in the body. Gel filtration studies of erythrocyte lysates and plasma from our subjects (Butler *et al.* 1991) showed a similar amount of Se was associated with GSHPx in the two groups after supplementation, while that associated with Hb in erythrocytes was almost 10-fold greater in the SeMet group, and in plasma the amount associated with albumin is 4-fold. The forms of Se ingested, therefore, greatly influence the correlation between Se and GSHPx which provides some explanation for the lack of a relationship in individuals with high Se status. For example, selenomethionine, the major form of Se in cereal foods, will contribute significantly to the total Se intake in high-Se areas, whereas in low-Se areas meat sources will make up a greater proportion of dietary Se. Therefore, vegetarians with higher intakes of selenomethionine-containing plant foods will have higher blood Se status than non-vegetarians, but which may not necessarily mean a higher functional status. This consideration weakens any possible link between blood Se levels and cancer protection (Burk, 1986) or cardiovascular disease.

The lack of correlation between GSHPx activities and Se concentrations at high blood Se levels means that blood GSHPx activity, although very useful for assessing Se status in New Zealand, is of little use in countries such as North America where blood Se levels are usually above 100 ng/ml. Another limitation in the use of erythrocyte or plasma GSHPx is that only a small fraction of blood Se is associated with GSHPx. Other Se-containing enzymes in plasma are selenoprotein P and albumin (Deagen *et al.* 1991), while Hb contains a major proportion of erythrocyte Se. Values reported for the percentages of Se due to GSHPx in human blood are inconsistent, probably due to different methods of estimation, and range from 12 to 46% in plasma and from 9 to 57% in erythrocytes (Behne & Wolters, 1979; Beilstein & Whanger, 1983; Takahashi *et al.* 1987; Avissar *et al.* 1989). However,

whatever the true value, it seems that the percentage of Se associated with GSHPx is greater in populations with low Se status such as in New Zealand than in residents of high Se countries (Whanger *et al.* 1988; Butler *et al.* 1991). Plasma GSHPx for assessment of Se status would seem to be further limited in that it comprises less than 5% of total whole-blood GSHPx activity as measured by the coupled method of Paglia & Valentine (1967) using t-butyl hydroperoxide, H_2O_2 or cumene hydroperoxide. However, plasma GSHPx is distinct from the erythrocyte enzyme (Takahashi *et al.* 1987) and in fact may have greater specificity for other substrates. Moreover, if separated carefully and assayed and stored quickly, plasma can be a good indicator of rapid changes in selenium status. The significance of GSHPx in plasma, however, requires further investigation.

In an earlier study of New Zealand women who supplemented with selenite for 4 weeks, an extremely good correlation was found between platelet GSHPx activities and both Se and Se-dependent GSHPx in liver (Thomson *et al.* 1988). The correlation was still good when the Se-supplemented group was not included in the analysis, indicating that the relationship still applied with food Se alone. Those observations validated the use of platelet GSHPx for assessing Se status. Furthermore, the fact that platelet GSHPx responds to Se supplementation in populations with higher Se status whereas erythrocyte and plasma GSHPx do not suggests that this may be a suitable measure over a wider range of Se status. However, the confusing observation that the response of platelet GSHPx activity depends on the form of Se given needs further investigation with dose-dependent studies of different forms of Se.

A response of GSHPx activity to Se supplementation could reflect a marginal Se status. Maximization of plasma GSHPx was accepted by the US National Research Council as the basis for its recommended dietary allowance (RDA) for Se in 1989, resulting in a RDA of 70 μg and 55 μg Se/d for adult men and women respectively. This intake can easily be achieved from a mixed diet in the US but residents living in the low-Se countries such as New Zealand would have difficulty in attaining such intakes. The average daily dietary intake of Se of New Zealanders derived from food intake data and food Se concentrations is 36 μg for males and 25 μg for females (Thomson & Robinson, 1988). However, intakes may be lower than 10 μg Se if no eggs or poultry are consumed, and above 40 μg Se only if fish, liver or kidney are included (Robinson & Thomson, 1987). Results of the recent study of Alfthan *et al.* (1991) indicate that the present Finnish intake of 100–110 μg Se/d is more than sufficient for saturation of plasma and erythrocyte GSHPx activities and approaches the level at which platelet GSHPx is maximal. The daily intake required for saturation of GSHPx, therefore, appears to be greater than 40 μg but less than 100 μg Se/d. From the New Zealand findings (Thomson *et al.* 1977; Rea *et al.* 1979) that suggest that activity of erythrocyte GSHPx is maximal when the erythrocyte Se concentration exceeds 140 ng/ml, Alfthan *et al.* (1991) have deduced that this corresponds to an estimated Se intake of 60–80 $\mu\text{g}/\text{d}$.

This present study indicates that the dietary intake of Se and Se status of New Zealanders is insufficient to meet recommended intakes based on the criterion of saturation of GSHPx activity. Since Se-responsive conditions are not seen in the general population of New Zealand, our intakes are not low enough to result in deficiency syndromes, but these might surface in times of additional need or stress. The Se-responsive condition observed in a patient on total parenteral nutrition (van Rij *et al.* 1979) is an extreme example of this, and other groups such as premature infants, pregnant and lactating women, smokers (Beaglehole *et al.* 1990) and cancer patients on chemotherapy may be at risk of a subclinical deficiency. Should Se supplementation be considered desirable in this country then careful consideration of the form in which it is administered will be necessary. Non-specific incorporation of Se into tissue proteins is higher for selenomethionine than for inorganic

forms of Se and, therefore, the risk of toxicity is greater (Behne *et al.* 1991). The longer-term effect of the topdressing of wheat crops in Finland on blood Se levels will be of interest in this respect. We also need to consider the fact that New Zealanders appear to have adapted to their low Se environment by conserving urinary excretion of Se (Robinson *et al.* 1985).

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