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Dietary selenium intake by men and women in high and low selenium areas of Punjab

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Abstract

Objective: To determine the selenium intake of adults residing in high and low selenium areas of rural Punjab.
Design: All food samples consumed by the subjects were collected and analysed for selenium content. Based on food intake data and selenium content of foods, the selenium intake of the subjects was calculated. Hair, fingernails and urine samples from a sub-sample of subjects were collected and analysed for selenium.
Setting: Three villages from the selenium-endemic area of Nawan Shahr District and two villages from the non-endemic area of Ludhiana District, Punjab, India, were covered.
Subjects: Forty families from each of the two areas, with one adult male and one adult female in the age range of 20–40 years, were surveyed. Thus a total of 80 men and 80 women constituted the study sample.
Results: In the selenium-endemic area, the average selenium intake of both men and women was more than nine times that in the non-endemic area and exceeded the maximum tolerable limit in more than 60% of men. Mean selenium content of the hair, nails and urine of both men and women was tens of times higher than in the non-endemic area.
Conclusions: High selenium intake in the endemic area resulted in high selenium content in the hair, nails and urine of men and women. In addition, clinical symptoms of selenium toxicity were also observed in some of the subjects. Selenium intake in the non-endemic area was marginally below the suggested value. Based on the study results, steps need to be taken to educate the public in the endemic area to avoid selenium toxicity.

Keywords
Selenium intake
Men
Women
Selenium toxicity
Urinary selenium

Selenium has been widely known as a toxic element since its discovery by Berzelius in 1817; however, during the recent past, research advances have shown selenium to be an essential nutrient required to combat a number of serious deficiency disorders. Biochemically, selenium is a component of the enzyme glutathione peroxidase, which, along with super dismutase, catalase and vitamin E, protects against damage to cellular components by preventing the accumulation of peroxides in the tissue. Selenium also helps in the prevention of cancer and ageing, and in the treatment of atopic dermatitis and asthma. Selenium is essential for growth and reproduction in rats and is associated with growth in man[1].

Selenium is efficiently transferred through the soil–plant–animal–human system. Geographic differences in the soil availability of selenium for uptake by plants account for most variations in the selenium content of plants[2]. The amount of selenium in food varies largely with its protein content and the area in which it is grown[3]. Among plant foods, wheat and pulses are rich sources of selenium. Selenium in food may vary from $< 10\ \mu g\ day^{-1}$ in selenium-deficient areas[4] to about $5000\ \mu g\ day^{-1}$ in areas where selenosis is endemic[5]. In general, selenium as selenomethionine is more easily absorbed when ingested than is selenite, selenate or selenocystine. Therefore, the selenium in wheat, dairy products and eggs is more easily available[6].

Severe deficiency of selenium is associated with cardiomyopathy, especially in children and women of childbearing age, which could be prevented by supplementation with sodium selenate[7]. Fatigue followed by sudden death, along with pulmonary oedema and tissue haemorrhage/oedema, are symptoms of acute selenium toxicosis. Chronic selenosis includes effects on keratinised tissue such as loss of hair and lesions on the nails, claws, horn and skin[8]. The role of selenium as an essential element for humans and the identification of pockets of selenium toxicity in the state of Punjab, India led to the present study to determine selenium intake and excretion by adult men and women residing in high and low selenium areas.

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Materials and methods

A two-stage sampling design was used for the study. The first stage was a purposive selection of the area: i.e. the villages of Bharwa, Jainpur and Simbli in Nawan Shahar District, identified as a high selenium area, and the villages of Gaunsgarh and Meharban in Ludhiana District, selected as a low selenium (non-endemic) area. The second stage involved random selection, from each area, of 40 families with at least one adult man and one adult woman in the age group 20–40 years.

The dietary intake of respondents was recorded for 1 day by interview, with some additional weighing of items, during November 1997 to January 1998. In addition to all the food items consumed, the amount of water consumed by the individuals was also noted. Amounts of raw foods consumed by an individual were calculated from the cooked quantity using the standardised cup method, where cups previously standardised in the laboratory for weight and volume of different cooked foods were used. Various raw food items consumed by the subjects from both areas, including milk, were collected. Drinking water samples were also collected from both areas, as were samples of urine, hair and nails from those subjects who agreed. All samples were collected and stored in decontaminated plastic ware. Food samples except milk were dried in a dehydrator at a temperature of 50 ± 2°C. Dried food samples, hair and nail samples were digested using a mixture of three acids (HNO_3/HClO/H_2SO_4, 9:3:1). For water samples, 500 ml of water sample was evaporated on a hot plate after the addition of 4 ml of HCl to 15–20 ml and the volume made to 25 ml with de-ionised water. Milk and urine samples (25 ml) were oven-dried, digested with the triple acid mixture and diluted with de-ionised water to known volume. Acid-digested samples were analysed for selenium by atomic absorption spectrometry (AA Varian spectrometer) using the hydride generation method[9]. From the amount of food consumed and the selenium contents of food and water, selenium intake by the subjects was calculated. Urine samples were analysed for creatinine using the method of Karamkar *et al.*[10] to express the selenium excretion per unit of creatinine.

In addition to food samples, the height and weight of the subjects were also measured to the nearest 0.1 cm and 0.5 kg, respectively. Body mass index (BMI) of the subjects was calculated as weight in kg divided by the square of height in m. Various clinical symptoms of selenium toxicity/deficiency were also recorded in all subjects.

The data were analysed statistically using analysis of variance and *F*-ratios were calculated using standard equations.

Results and discussion

The study was carried out purposively in a rural area where 70–80% of the selected subjects belonged to farming families and the remainder were involved in other occupations like labour, small business and service. All the families selected consumed underground water as the sole source of drinking water, which was taken out either through hand-pumps or through tube-wells in both areas. Nearly 45% of the families used milk from their own animals in both areas and between 40 and 47% of the families procured milk from milk vendors of the same area. The staple cereal (wheat) consumed was home-grown by nearly 45% of families in both areas. Consumption of farm-grown legumes and vegetables in the high selenium area (40 and 37.5%, respectively) was greater than in the low selenium area (15 and 25%, respectively).

Data on anthropometric measurements (Table 1) indicated that the height of men and women in both areas was comparable, while the weight of men and women in the low selenium area (non-endemic) was significantly higher ($P < 0.01$) than that of their counterparts in the high selenium area (endemic). In a study conducted in eight states of India, the National Nutrition Monitoring Bureau[11] reported that the average height of Indian men and women was 163.4 and 150.6 cm, respectively, and the corresponding values for weight were 56.0 and 43.3 kg. A recent survey carried out by the Government of India[12] found that the average height of men and women in Punjab was 167.5 and 155.5 cm, respectively, with the corresponding values for weight

Table 1 Height, weight and body mass index (BMI) of men and women from endemic and non-endemic areas. Values are expressed as mean ± standard error (range)

Subjects/area	Height (m)	Weight (kg)	BMI (kg m^{-2})
Males ($n = 40$)			
Endemic area	1.74 ± 0.01 (1.60–1.88)	67.70 ± 2.7 (62.0–73.2)	22.30 ± 0.7 (20.2–24.0)
Non-endemic area	1.75 ± 0.01 (1.70–1.80)	77.65 ± 1.3 (70.0–85.5)	25.04 ± 0.9 (22.0–28.1)
F-ratio	NS	10.66*	7.12*
Females ($n = 40$)			
Endemic area	1.61 ± 0.01 (1.60–1.64)	54.50 ± 2.2 (45.0–64.0)	21.05 ± 0.7 (18.5–23.6)
Non-endemic area	1.62 ± 0.01 (1.60–1.65)	63.14 ± 2.0 (55.0–72.0)	24.23 ± 0.7 (19.0–30.0)
F-ratio	NS	9.5*	10.1*

NS–not significant.
* Significant at the 1% level.

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being 60 and 52.8 kg. Thus both the height and weight of men and women in our sample are higher than the average values for Indian men and women reported previously[11,12]. BMI calculated as weight/(height)^2 indicated that more than 90% of subjects had a BMI between 20 and 30 kg m^{-2} and could therefore be classified as normal or obese Grade 1 as per the classification of the World Health Organization (WHO)[13].

The analysis of samples showed that the selenium content of water and milk in the endemic area was 9.4 ± 1.0 and 5.92 ± 1.0 μg/100 ml, compared with 0.6 ± 1.0 and 1.6 ± 0.5 μg/100 ml, respectively, in the non-endemic area. Selenium content of wheat *chapati* was 74.2 ± 19.0 μg/100 g in the endemic area while it was less than 0.01 ± 1.0 μg/100 g in non-endemic area. Similarly, the selenium content of most legumes and vegetables in the endemic area was also high compared with the non-endemic area.

Perusal of the dietary survey data indicated that wheat and milk were the major contributors of energy and protein in the diets of the subjects. Wheat was the staple cereal and was consumed as *chapati* with pulses and/or seasonal vegetables. Wheat intake by men was 346 and 450 g day^{-1} in the endemic and non-endemic area, respectively, and contributed 66.5–69.8% of total protein and 53.3–57.9% of energy in the daily diet. Similarly, in the diets of women in both areas, wheat contributed 57.5–60.7% of protein and 46.1–49.5% of energy. Intake of milk was 315 and 504 ml day^{-1} in men and 268 and 394 ml day^{-1} in women in the endemic and non-endemic area, respectively. Milk contributed 16.6–22.9% of energy and 21.5–29.7% of protein in the diets of men, and 18.6–22.6% of energy and 24.0–28.7% of protein in the diets of women.

Data on the selenium intake of the subjects (Table 2) revealed that selenium intake in the endemic area was more than nine times that in the non-endemic area. Cereals contributed 91 and 80% of selenium for men and women, respectively, of the endemic area, with corresponding values being 31 and 25% in the non-endemic area. Selenium contribution from milk was 3 and 3.3% for men and women in the endemic area, compared with 12.4 and 12.0%, respectively, in the non-endemic area. For adults, selenium intakes were 60–125 μg day^{-1} in Japan, 99–102 μg day^{-1} in the USA, 63–122 μg day^{-1} in Bangladesh and 234 μg day^{-1} in Scotland[14]. However, Yang *et al.*[15] reported daily selenium intakes ranging from 7–11 μg in an area affected by Keshan's disease to 4990 μg in an area affected by chronic selenosis in China. A daily intake of 50–400 μg has been suggested as optimum[16]. The US Food and Nutrition Board[17] has suggested 70 and 50 μg as the daily requirement for men and women, respectively. Yang *et al.*[18] suggested 17 μg day^{-1} as the minimum dietary selenium requirement for the prevention of Keshan's disease, while 40 μg day^{-1} was considered as an adequate dietary requirement. They further suggested 600 and 400 μg as the daily maximum and safe intake of dietary selenium, respectively. Daily selenium intake required to maintain characteristic fingernail changes resulting from toxicity was reported to be 1600 μg, while the intake needed to recover from fingernail lesions resulting from deficiency was 819 μg day^{-1}. Based on studies carried out in China, WHO[19] has suggested 0.39 and 0.42 μg Se kg^{-1} body weight as the lower safe limit for adult women and men, respectively, which translates into 19.5 and 25.2 μg for reference Indian women and men. It has further been reported that a dietary selenium intake of 41 μg day^{-1} was sufficient to saturate the plasma glutathione level of a 60-kg man. Thus, considering 40 μg day^{-1} of selenium as the desired intake, subjects in the non-endemic area of the present study were consuming adequate selenium but their intake ranged from the sub-maintenance to maintenance allowance considering the 70 and 50 μg daily selenium requirement for men and women, respectively. However, their intake was far lower than the safe level of 400 μg day^{-1}. In the endemic area, 15% of men and one woman consumed more than the 819 μg day^{-1} that results in metabolic changes. Furthermore, 60% of men and 7.5% of women consumed more than 600 μg day^{-1}, which is considered to be the maximum limit of selenium intake (Table 3).

Mean selenium content of hair from men and women from the high selenium area was 40–50 times that for subjects in the low selenium area (Table 2). Yang *et al.*[5] reported that selenium content of hair in men from a high selenium area with chronic selenosis was 3220 μg/100 g, which decreased to 370 μg/100 g among men in an area with high selenium without selenosis and 36 μg/100 g for men residing in an adequate selenium area. Dhillon and Dhillon[20] have reported values of 1311 and 188 μg Se/100 g of fingernails and hair, respectively. The selenium content of the hair of subjects in the

Table 2 Selenium intake and selenium content of hair, nails and urine of subjects from endemic and non-endemic areas

	Endemic area		Non-endemic area		
Sample/subjects	*n*	Mean ± SE	*n*	Mean ± SE	*F*-ratio
Se intake (μg day^{-1})					
Men	40	632 ± 31.2	40	65 ± 2.2	328.5*
Women	40	475 ± 52.8	40	52 ± 1.0	64.5*
Hair (μg Se/100 g)					
Men	10	255 ± 25	18	4.97 ± 1.4	30.2*
Women	11	231 ± 20	14	4.77 ± 1.6	26.9*
Nails (μg Se/100 g)					
Men	12	440 ± 193	13	10.21 ± 1.80	28.4*
Women	4	390 ± 94	17	8.52 ± 1.75	29.8*
Urine (μg Se/100 ml)					
Men	25	26.7 ± 6.3	37	1.20 ± 0.3	21.8*
Women	29	17.0 ± 3.9	36	0.96 ± 0.1	7.9*
Urine (μg Se/g creatinine)					
Men	25	292 ± 4.3	37	9.15 ± 0.02	12.28*
Women	29	225 ± 4.6	36	9.05 ± 0.3	30.4*

SE–standard error.
* Significant at the 1% level.

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Table 3 Classification of subjects based on selenium intake. Values are expressed as number of subjects (%)

Selenium intake (μg day^{-1})	Men ($n = 40$)	Women ($n = 40$)
Endemic area		
< 300	1 (2.5)	1 (2.5)
300–600	15 (37.5)	36 (90.0)
600–900	21 (52.5)	2 (5.0)
900–1200	3 (7.5)	0
> 1200	0	1 (2.5)
Non-endemic area		
< 40	0	0
40–50	9 (22.5)	15 (37.5)
50–70	8 (20.0)	25 (62.5)
> 70	23 (57.5)	0

Table 4 Clinical symptoms of selenosis in subjects from the endemic area. Values are expressed as number of subjects experiencing the symptom

Symptom	Men ($n = 40$)	Women ($n = 40$)
Loss of hair	7	6
Tooth decay	0	2
Black teeth	0	3
Brown stains on teeth	0	1
Longitudinal streaks on nails	1	1
Blackening of nails	2	6
Breaking of nails	1	2
Brittle nails	0	1
Loss of nails	1	5
Headache	2	1

More than one symptom was allowed per subject.

present study was less than in subjects showing clinical symptoms of selenosis but higher than in healthy subjects. Similarly, the mean selenium content of fingernails among men and women from the endemic area (440 and 390 μg/100 g, respectively) was much higher than in those from the non-endemic area (10.21 and 8.52 μg/100 g, respectively). Bratakos *et al.*[21] reported that mean selenium content of the fingernails of healthy Greeks was 53.6 μg/100 g and that the differences between males and females were significant. Dhillon and Dhillon[20] reported that the fingernail selenium content of individuals with selenosis and healthy subjects from a high selenium area was 1582 and 228 μg/100 g, respectively. The results indicate that, since the study by Dhillon and Dhillon in 1997[20], awareness campaigns in the high selenium area have resulted in significant decreases in hair and nail selenium contents of subjects residing in that area. Although the fingernail selenium content of subjects in the endemic area was much higher than that reported for healthy subjects, the values in the non-endemic area were lower and may indicate selenium deficiency among those subjects. In the endemic area, selenium concentrations in hair and nails were found to be significantly and positively associated ($r = 0.826$, $P < 0.01$). Furthermore, urinary selenium excretion in the endemic area was much higher in both men and women (26.7 and 17.01 μg/100 ml), compared with their counterparts in the non-endemic area (1.2 and 0.96 μg/100 ml). Novarro *et al.*[9] reported that persons consuming 54.9 μg of dietary selenium in daily diets excreted 0.46 to 5.03 μg Se/100 ml of urine. Urinary selenium excretion of subjects from the non-endemic area was towards the lower side of this range, while in the endemic area it was three to five times higher than the upper range. The data on clinical symptoms of toxicity (Table 4) revealed that 17.5% of men and 15% of women showed loss of hair. However, more women showed blackening and loss of nails than did men.

Thus it may be concluded that the mean selenium intake by men and women in the endemic area was more than 600 μg day^{-1}, which is the upper safe limit, and the mean selenium content in their hair, nails and urine content was also high. Therefore, education of the people in this area is recommended.

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