Selenium status and dietary correlations in healthy jordanian adults: A population-based study

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Abstract. *Background:* Selenium (Se) is now recognized as a micronutrient necessary for human health. *Aims:* The study aimed to measure the selenium status among Jordanian adults. *Methods:* A cross-sectional study was completed by recruiting a total of 195 apparently healthy individuals were chosen from the Ma'an Governorate Hospital in Jordan, with 130 girls (66.6%) and 65 males (33.4%), ages ranging from 19 to 65, with an average age of 33. After examining serum selenium levels using hydride generation atomic absorption spectrometry, sociodemographic data were gathered, dietary history was completed, and selenium status was ascertained. *Results:* In males and females, the prevalence of low serum selenium concentrations (<60 μg/l) was 10.7% and 13.0%, respectively. Younger females had a much greater prevalence of selenium insufficiency than males. Overall, the mean serum selenium content was 80.5±17.6 μg/l for males and 74.4±16.1 μg for females. Selenium values in most of the population (82.0%) were within the normal range (78.6±9.7 μg/l). The average consumption of selenium was determined to be 49.27 micrograms per day for females and 53.31 micrograms per day for males. *Conclusion:* In a sample of adult Jordanians, the selenium serum levels seem safe and appropriate by international standards, however, the daily consumption values were unclear. Age and gender have also been linked to selenium status. (www.actabiomedica.it)

Key words: selenium levels, Jordanian adults, serum selenium, dietary intake, gender-specific selenium analysis, selenium status, selenium population study, selenium diet correlation, selenium biomarkers, selenium epidemiology

Introduction

Previously thought to be poisonous, selenium (Se) is now recognized as a micronutrient necessary for human health. Skeletal myopathies, cardiomyopathies, and weakened immunological responses are all linked to selenium deficiency (1-5). Adequate selenium intake has been linked to maximizing the activity of selenoproteins, among which it has been demonstrated that glutathione peroxidases play an essential role in cellular defense against oxidative stress brought on by an excess of reactive oxygen species (6). Also, selenium plays a role in immunological and viral illnesses (5, 7, 8), cancer (9-12), and other diseases.

Among plants that absorb selenium from the soil and frequently incorporate it into their proteins as either selenocysteine or selenomethionine, selenium enters the food chain (13). Selenium can be found in the diets of both people and animals in various foods, including meat, egg, fish, broccoli, leafy greens, nuts, and Brazil nuts (14). However, wheat and wheat products are humans' primary sources of Se. The availability of Se in the plant and the soil in which it is cultivated determine the amount of Se in the body. There is accumulating data about the effects of oxidative stress-causing lifestyle variables, including smoking, a high PUFA diet, exercise, and the interactions between nutrients and medications like vitamins E and C and selenium requirements (15-18). There has been little discussion of the distribution of blood selenium concentrations in various populations (19-22), but nothing is known about the levels in healthy Jordanians. Knowing the selenium levels in healthy Jordanians would give researchers a nutritional tool to investigate dietary changes and their links to human health. The primary goal of this study was to measure the blood selenium concentration of healthy Jordanians who reside in the Ma'an district of Jordan to assess selenium status. Additionally, the effects of several variables, including age, sex, and the daily consumption of selenium, were considered. Additionally, to contrast the selenium concentrations with information from earlier publications on the blood selenium levels in various nations.

Materials and Methodology

Subject selection

Serum blood samples were taken from 195 healthy subjects aged between 19-65 with an average age of 33 years (130 females and 65 males– aged between 19-65 years) during routine laboratory check-ups at Ma'an governorate hospital. Subjects who already had a history of diseases, including diabetes, arthritis, heart disease, cancer, gastrointestinal disease, and kidney disease, and took vitamin or mineral supplementation were excluded. Furthermore, subjects under continuous or recent medication, which is known to influence selenium status metabolism, women taking oral hormonal contraception, or any other form of hormone substitution, were also excluded. Subjects were instructed to fast overnight (at least 12 hours) before collecting the blood samples; qualified laboratory technicians collected the samples from the subjects. The study methodology was followed to Elhindi and colleagues (2016) (23).

Ethical consideration

All the study participants gave voluntary informed written consent forms before participation. Those who refused to take part in the study were excluded. The Helsinki Declaration and the Institutional Board Review (IRB) approval number (No. 2/3/2023/2024), Faculty of Applied Medical Sciences, conducted the research procedures.

Nutritional habits of the subjects

All participants were asked to complete a questionnaire composed of three parts: the first one was about the socio-demographic data (age, gender, living area, and education); the second part was about personal habits and medical information (nutrition status, current nutritional supplement, current medication from GP and general health during the last 12 months); and the third part was a dietary questionnaire to estimate the consumed amount of macronutrients daily (24), the food frequency questionnaire (FFQ) was used to estimate the dietary intake belonging to several food groups consumed daily (including fruit and vegetables; bread, rice, noodles, cereals, and potatoes, and other food containing starches; milk, yoghurt, cheeses, and dairy foods; meat, poultry, fish, eggs, and alternatives; butter, margarine, mayonnaise, oil, salad dressing, sour cream, and other food containing fats; and candy, cake, regular soda, juice, sweets, and other food containing sugar). To ensure cultural sensitivity, the food frequency questionnaire included the top ten food items (bread, chicken, rice, eggs, pasta, flour, lamb meat, milk, luncheon meat, beans) of selenium in the Jordanian diet (24). The participants were then asked in what quantity they consumed the food items. The participants were required to fill the questionnaire in one sitting and the filled questionnaires were handed back to the investigators for further analysis. The frequency was recorded in terms of serving per day, per week, per month and never. The quantification of food item was done according to approximate weight. Responses regarding the frequency of consumption for each food item were converted into average daily intake of macronutrients among the study population. The dietary questionnaire was completed by a specially trained person (dietician, nurse, or physician), the questions referred to the food groups or foodstuff consumption (weekly/monthly), and the amounts consumed were estimated based on typical household measures. The questionnaires were centrally analyzed with a specially constructed computer program at the coordination center (The Medical Center of Jordan University, Amman, Jordan). The results were expressed as the daily energy intake in kJ, while the carbohydrate, protein, total fiber, and fat intake were expressed as g/day contribution to the energy intake/day. Reliability of the FFQ was assessed using test-retest method based on a previous study (25). A modified version of the questionnaire known as Diet History Questionnaire I, which measures dietary intakes over a 1-year period, was administrated to 101 apparently healthy men and women recruited from three large medical centers in Jordan. Fifty-five participants completed the modified FFQ and three 24-hour recalls. Participants (N=101) completed the FFQ two times separated by a 1-month period. Reliability of the FFQ was assessed using test-retest method. Mean age of participants was 33.4±18.5 years. Energy, carbohydrate, fiber, fat, saturated fat, calcium, and iron had deattenuated correlations of .732, .563, .544, .487, .484, .451, and .459, respectively. The FFQ and 24-hour recalls produced similar agreement percentages ranging between 25.5% and 43.6%. Mean energy-adjusted reliability coefficients ranged from .695 to .943. A Cronbach's α for the total FFQ items of .857 was found. The modified FFQ has reasonable relative validity and reliability for energy, carbohydrate, fiber, fat, saturated fat, calcium, and iron intakes in Jordanian adults over a 1-year period (25).

Determination of serum selenium concentration

Blood samples were centrifuged within an hour at the survey site at 3000 x g for 5 minutes, and then an aliquot of serum was frozen at – 20 °C. The serum was treated using the Clinton method (26). One gram of serum was digested with 3 ml of $HNO3/HCLO4$ (2:1 v/v). The temperature was slowly increased to 210 °C until fumes of $HCLO4$ appeared after adding 2ml of hydrochloric acid (6N). After cooling at room temperature, Se concentration was determined using the continuous hydride generator "Thermo VP-100 Continuous Flow Vapor System" connected with "Thermo Atomic Absorption Spectrophotometer, Model SI." Sodium borohydride solution (0.5% m/v $NaBH4$, 0.5% m/v NaOH) was used as a reducing agent. The formed Se Hydride was carried in a carrier Argon gas stream to a heated cell using Air/Acetylene flame for measurement. The daily Se intake was calculated as the mean ± SD/1.5 (27).

Statistical analysis

The prevalence of selenium status was compared across all individuals' genders and age groups using the chi-square test. Age and gender-specific mean serum selenium values were obtained. Socio-demographic information underwent a descriptive analysis, and selenium proportions and concentrations were calculated. Tukey's test was used to compare the means of the study variables between groups to look for any differences when the differences had values below 0.05.

Results

General characteristics and macronutrient intake assessment of the study population

The personal habits and general health of the subjects in this study is shown in Figure 1. Most subjects, 193 (98.8%), were nonvegetarians, but 2 (1.2%) were vegetarians. Five subjects (2.5%) took vitamin or mineral supplements with antioxidant properties compared with 190 (97.3%) who did not, suggesting that using these supplements was less common in subjects in this study than those who did not. Use of medication (e.g., Antibiotics, aspirin, paracetamol-containing drugs, and analgesic drugs) was limited, with only 8 (3.9%) subjects using these drugs. 114 (58.5%) of subjects felt that their general health had been about

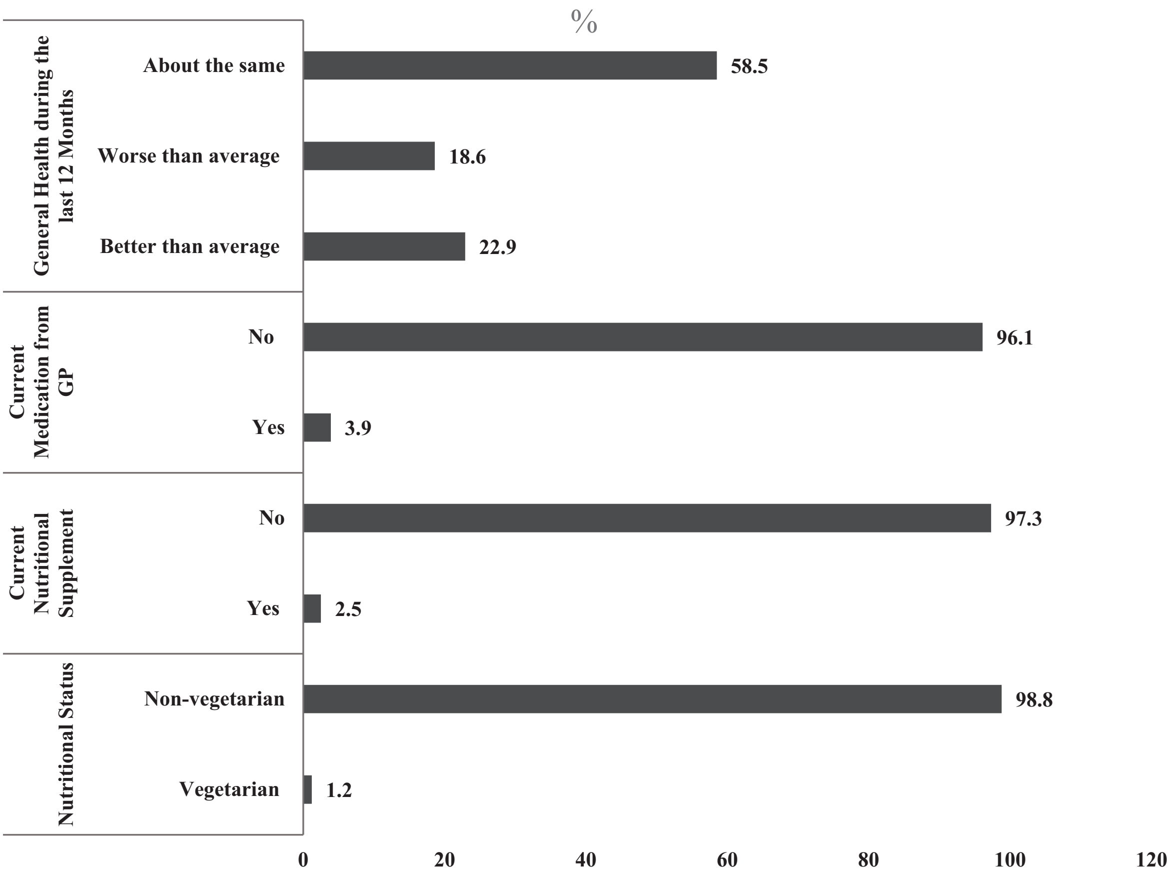

Figure 1. Description of the personal habits and general health among study population.

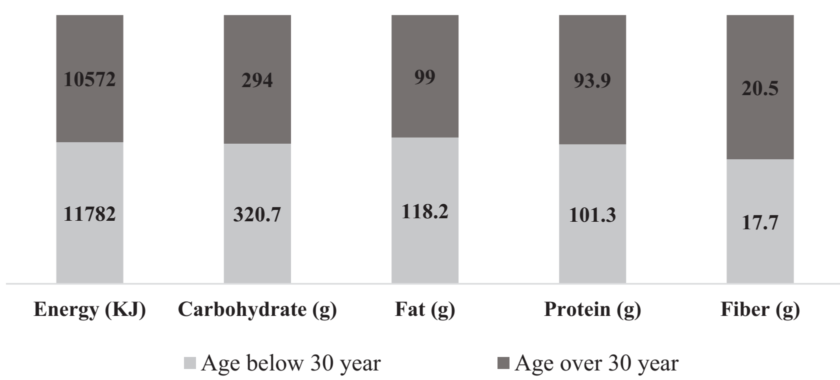

Figure 2. The daily intake of macronutrients among the study population.

the same during the previous 12 months, compared with 36 (18.6%) and 45 (22.9%) who reported that their health was either worse or better than the average, respectively. On the other hand, for total energy and macronutrients (carbohydrate, protein, fat, and fiber), there were no significant differences in the daily intakes between the different sex and age groups, as shown in Figure 2.

The prevalence of selenium deficiency

The prevalence of low serum selenium concentrations (<60 µg/l) was 10.7% in males and 13.0% in females. An 82.0% of participants had average selenium concentrations (60-100 µg/l) (75.3% and 85.3% in males and females, respectively). At the same time, high selenium concentrations (>100 µg/l) were detected in 5.6% of participants regardless of age group and gender. Significant differences were found in the prevalence of selenium concentrations and gender stratified by age, as shown in Table 1 and Figure 3; approximately 8.4% (n=11) of females below the 30-year-old age group had a significantly higher prevalence of selenium deficiency (<60 µg/l) compared to 3.0% (n=2) of males (i.e., The prevalence of selenium deficiency was affected by age (p=0.03).

However, the risk of serum selenium deficiency tended to be significantly higher in men than in women over the 30-year-old age group (p=0.07). The prevalence of high serum selenium concentrations (>100 µg/l) was 13.8% in males regardless of the age group, while it was 1.53% among all females. The majority of females (85.3%) had normal selenium concentrations (60-100 µg/l) compared to 75.3% (n=160) of males regardless of the age group.

The mean serum concentrations of selenium status and mean daily intake

The mean serum concentrations of selenium were compared for both males and females in both age groups. The results in Table 2 indicate that the mean serum concentrations of selenium were not significantly affected by sex and age group, although mean values of selenium appeared to be lower for females (74.4±16.1 µg/l) than males (80.5±17.6 µg/l).

Also, the mean total serum selenium concentration for the total population was 76.4±16.8 µg/l regardless of gender and age group. The calculated daily intake of selenium among the study population was estimated by using the median correlation factor (MCF) of various countries (1.51) for the estimation of the daily intake of Se, this factor is the result of the division of the serum Se concentration by the amount of Se ingested in the daily diet of each country (27). The mean daily selenium intake was calculated as (49.27 µg) among the females and (53.31 µg) among the males (Table 3).

Discussion

The present study demonstrated that the prevalence of selenium deficiency in males did not differ from females, while it was significantly higher among younger age females compared with all males, indicating that the prevalence of selenium deficiency was affected by age. Overall, 12.3% of the studied population were Se deficient Se<60 µg/l, which was lower than the one reported in 8 African countries (14.1 to 81.2 µg/l based on Se deficient Se<70 µg/l) (19). Hence, selenium status was acceptable in both males and females since the prevalence of normal selenium levels was observed in 85.3% of females and 75.3% of males of the studied population, which was higher than other surveys reported. These results suggest that Jordanian

Table 1. The prevalence of selenium status among males and females stratified by sex and age group.

Sex^{a}	Age groups^{b}	Se<60 µg/l (n)%	Se:60-100 µg/l (n)%	Se>100µg/l (n)%	p-values
Males^{a1}	**Below 30^{b1}**	(2)3.0	(27)41.5	(4)6.1	0.38 ^{a1}
	Over 30^{b2}	(5)7.6	(22)33.8	(5)7.6	0.22 ^{a2}
	Total	(7)10.7	(49)75.3	(9)13.8	0.03 ^{b1}
Females^{a2}	**Below 30^{b1}**	(11)8.4	(47)36.1	(1)0.76	0.07 ^{b2}
	Over 30^{b2}	(6)4.6	(64)49.2	(1)0.76	
	Total	(17)13.0	(111)85.3	(2)1.53	
Overall (n)%		(24)12.3	(160)82.0	(11)5.6	

Statistical significance was considered as p<0.05.

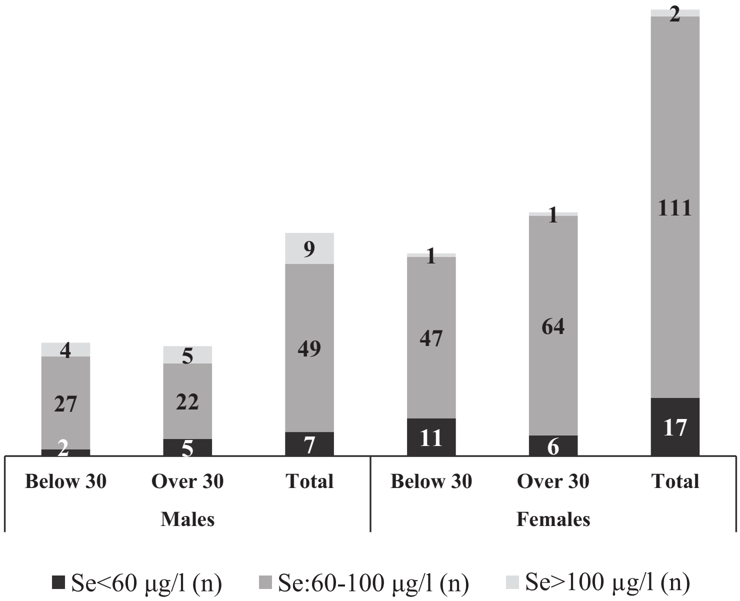

Figure 3. Selenium status among males and females stratified by sex and age groups.

Table 2. Mean serum concentrations of selenium among the study population stratified by age and gender.

Sex [a]	Age groups [b]	Se<60 μg/l (low) mean±SD	Se:60-100 μg/l (normal) mean±SD	Se>100 μg/l (high) mean±SD	Overall Mean mean±SD	*p*-value
Males	**Below 30** **Over 30** **Total**	49.2±7.8 (2) 49.6±11.6 (5) 49.5±10.0 (7)	79.4±10.4 (27) 80.1±10.0 (2) 79.7±10.1 (49)	110.4±7.9 (4) 107.3±7.6 (5) 108.6±7.4 (9)	81.3±16.4 (33) 79.6±19.0 (32) 80.5±17.6 (65)	0.77[a] 0.10[b] 0.14[ab]
Females	**Below 30** **Over 30** **Total**	44.2±16.3 (11) 48.0±15.2 (6) 45.5±15.6 (17)	77.8±10.0 (47) 78.2±9.1 (64) 78.1±9.5 (111)	102.2±0.0 (1) 131.2±0.0 (1) 116.2±20.6 (2)	72.0±17.7 (59) 76.4±14.3 (71) 74.4±16.1 (130)	
Overall Mean mean±SD[a]		46.7±14.1 (24)	78.6±9.7 (160)	110.6±98 (11)	76.4±16.8 (195)	

Statistical significance was considered as *p* value<0.05.

Table 3. The calculated daily intake of selenium among study population.

Sex	Age groups	Overall Mean mean±SD μg/l	Daily intake of Se μg/day	Median Correlation Factor (MCF)
Males	**Below 30 y** **Over 30 y** **Total**	81.3±16.4 (33) 79.6±19.0 (32) 80.5±17.6 (65)	53.84 52.72 53.31	1.51
Females	**Below 30 y** **Over 30 y** **Total**	72.0±17.7 (59) 76.4±14.3 (71) 74.4±16.1 (130)	47.68 50.59 49.27	

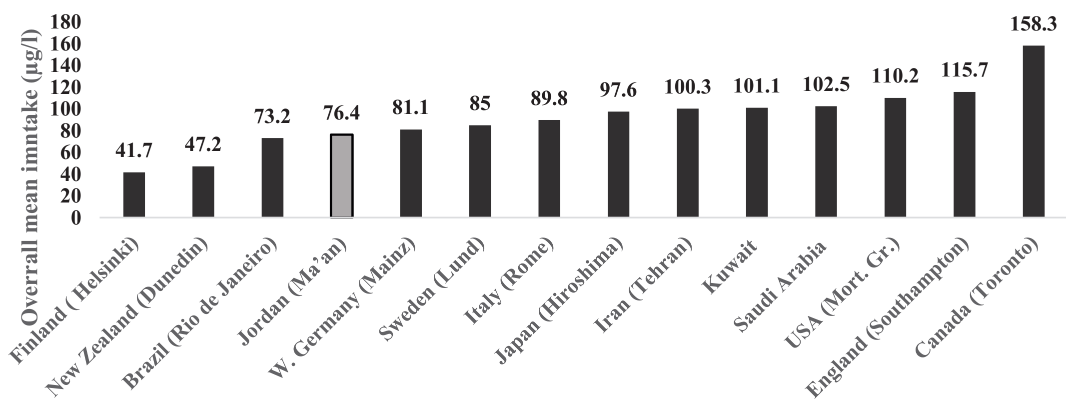

Figure 4. Comparison between the mean serum levels of selenium among adults in different countries and the one observed in the current study.

subjects eat a higher intake of vegetables, fruits, cereals, and herbs, which is adequate to maintain a favourable selenium status with a low prevalence of selenium. Although the findings do not suggest that the Jordanian population is at risk of a highly low-selenium status, they suggest that females could be considered at high risk of selenium deficiency if it is not considered early. The mean serum selenium level observed in this study (76.4±16.8 µg/l) (Figure 4) was similar to the one reported in a survey in Brazil (73.18 µg/l), and it is higher than levels observed in New Zealand (47.24 µg/l). In Finland (41.73 µg/l), on the other hand, the present finding was lower than that reported in Saudi Arabia (102.5 µg/l), the USA (110.2 µg/l), England (115.7 µg/l) and Canada (158.3 µg/l)(10, 12). This variance in values is influenced by the selenium content of the soil in various regions of the world; gender, age, or the interaction of these factors had no impact (10, 12). Using the medium correlation factor of various countries (1.51) for the daily intake of nutrients as introduced by a previous study (27), the mean daily intake of selenium was calculated as 49.27 µg among females and 53.31µg among males. Considering the World Health Organization (WHO) normative requirements (NR) of selenium in adults (30 µg/day and 40 µg/day, for females and males, respectively), it seems that the regular Jordanian diet introduces an adequate amount of selenium for males and females (16).

Despite the selenium daily intake being sufficient in both genders based on NR, the Dietary Reference Intake (DRI) and recommended daily intake (RDI) give inadequate intake of selenium in both genders (DRI:55 µg/day for both; RDI:85 and 70 µg/day for males and females; respectively)(16). An explanation for such a finding may point to the fact that Jordanian males were heavier primary smokers than light or moderate female smokers, this can be attributed to the smoking effect that may cause changes in selenium levels in human tissue. These results are in line with previous reports (28-30). However, there may be other important factors that may affect selenium requirement as well as selenium absorption, like the bio-availability of different forms of selenium such as GPX enzymatic activity (28, 29), the interaction of selenium with other nutrients and drugs (15), lifestyle factors involving oxidative stress such as smoking, high PUFA, and strenuous exercise (16), genetic factors (relevant genetic polymorphisms) influence Se metabolism (17, 18), that were not taken in consideration in this study that could influence the selenium status of those subjects this warrants further study. Moreover, because there is such a wide range in the amount of selenium in food across different locations, the consumption of dietary selenium varies significantly between individuals (29). Hence this was not the case in Ma'an soil and selected foods in the traditional Jordanian foods, as Qatatsheh and colleagues found that selenium content in selected fruits, vegetables, herbs, and cereals in the Southern Jordan varied from 27.7±17.53 µg/kg wet weight (watermelon) to

525.1±190.44 μg/kg wet weight (garlic). Furthermore, the average of all the plant species analyzed was 194.5 146.14 g/kg. The soils where these plant species were grown had an average Se concentration of 1323 g/kg, rising with increasing soil depth. Also, these values were good for covering Jordanian daily requirements(31). The present study subjects included women of reproductive age (18-45 years), by which selenium requirements increased in pregnant and lactating women for the growing fetus and newborn (32). There are several potential solutions to increase human selenium consumption. These include manufacturing functional foods, direct supplementation, soil fertilization, and supplementation of dietary staples like flour (13). There are some significant limitations to the current investigation. First, the degree of the insufficiency can be assessed using the serum selenium results alone, without the use of biochemical markers of selenoprotein activity. Second, the population under study had a smaller sample size. Third, the current study did not identify the dietary risk factor of Se deficit because it did not quantify the dietary intake determined by the age of food introduction. Fourth, because the current study was limited to Ma'an Governate (part of Southern Jordan), and adults (excluding children, adolescents, and the elderly), it is impossible to extrapolate its findings to the entire Jordanian population. Finally, due to the study's design (cross-sectional design), it is impossible to determine the causal link between Se insufficiency and various causes.

Conclusion

The majority of the studied population had average selenium concentrations, which are adequate and safe per international standards. Hence, the daily intake amounts were confusing for both genders. Further studies with larger sample sizes are recommended. Also, soil in the middle and southern Jordan and food samples should be analyzed to determine the selenium contents in Jordan in different areas.

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Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Data Availability: All data support our published claims and comply with field standards.

Ethics Approval: This study was performed in line with the principles of the Declaration of Helsinki.

Consent to Participate: The participants signed an informed consent form.

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