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Iodine and selenium: Dietary sources and nutritional status of the population of the Kurdistan Region in Northern Iraq

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ABSTRACT

Aim: The primary aim of this study was to determine the selenium (Se) and iodine (I) food concentrations and dietary intake of the population living in the Kurdish controlled region of northern Iraq. We also assessed the extent to which iodised salt contributes to dietary iodine intake.

Methodology: Foods and samples of salt and drinking water were analysed, including 300 crops samples from 40 local farms. The results, supplemented by food composition data, were used to assess dietary Se and I intake for 410 volunteers using a semi-quantitative food questionnaire. To directly investigate the nutritional status of individuals, urine samples were also collected from participants.

Results: Selenium intake was mainly supplied by protein and cereal sources. Calculated median dietary intake of Se was 62.7 μg d^{-1} (mean = 66.3 μg d^{-1}) with c. 72 % of participants meeting or exceeding dietary reference intake recommendations for age. Median dietary intake of I, excluding salt consumption, was 94.6 μg d^{-1} (mean 100.2 μg d^{-1}), increasing to 607.2 μg d^{-1} when salt (of which >90 % was iodized) was included. Salt intake was estimated to be c.13.5 g d^{-1} (5400 mg Na d^{-1}) which greatly exceeds WHO recommended intake (< 2000 mg d^{-1} of Na). Urine iodine concentrations indicated that 98 % of school aged children had excessive iodine intake (≥300 μg L^{-1}) and 80–90 % of all study participants had above average or excessive iodine intake (≥200 μg L^{-1}).

Conclusions: Poultry and rice are the main sources of dietary Se to this population but around a third of children receive an inadequate Se intake. Fresh fruit and vegetables are the main sources of dietary I, but consumption of local foods cannot supply adequate I without iodised salt supplementation. Consumption of iodized salt well above recommended amounts is supplying this population with substantial iodine intake. Interventions to reduce salt intake would help to limit excessive iodine intake whilst also reducing cardio-vascular risks from Na consumption.

1. Introduction

Iodine (I) and selenium (Se) are essential micronutrients important for the function of several physiological processes in the body [20]. Iodine is a vital component of thyroid hormones, specifically thyroxine (T4) and triiodothyronine (T3), and deficiency is a significant global public health issue [30]. Low dietary intake of I can lead to functional and developmental abnormalities categorized as iodine deficiency disorders (IDD) of which the most well-known are goitre and mental retardation [46,47]. However, excessive I intake may result in pathological issues, including hypo- and hyperthyroidism [7]. Selenium is a critical component of deiodinase enzymes which convert the less active thyroid hormone T_4 into the more active T_3 form, it regulates tissue T_3 levels and helps to protect thyroid tissue from H_2O_2 produced as a by-product of thyroid hormone synthesis. Selenium deficiency therefore impairs thyroid function and may be important in the onset of IDDs [5,29]. Selenium also acts as an enzymatic cofactor of glutathione peroxidase and its deficiency may increase cardiovascular disease and muscle weakness [8,14].

Many diets include suboptimal concentrations of essential dietary micronutrients, including I and Se, and assessment of the dietary status of populations is essential to enable countries to work towards meeting UN Sustainable Development Goals e.g. 'Zero Hunger' (SDG2) and 'Health and Wellbeing (SDG3) [22]. To address IDDs in their

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Table 1
Analytical results for certified reference materials.

		I	Se	Na
1573a - Tomato leaves (μg kg^{-1})	Measured:	840	59.5	
	Certified:	850[a]	54.3[b]	
	Recovery:	99 %	109 %	
1567b-Wheat Flour (μg kg^{-1})	Measured:		113	
	Certified:		114	
	Recovery:		*99 %*	
Seronorm L-1 (μg L^{-1})	Measured:	90	13.9	2310
	Certified:	105[c]	14.4	2777–2782[d]
	Recovery:	*86 %*	*97 %*	*83 %*
Seronorm L-2 (μg L^{-1})	Measured:	263		
	Certified:	297[e]		
	Recovery:	*89 %*		

[a] Non-certified value.
[b] 95 % confidence interval 54.1–54.5 μg kg^{-1}.
[c] 95 % confidence interval 84–126 μg L^{-1}.
[d] Approximate value.
[e] 95% confidence interval 237 - 356 μL^{-1}.

Table 2
Iodine and selenium fresh weight concentrations of locally collected and sourced foods.

Food items		n	Iodine Mean (SD) μg kg^{-1} FW	Iodine Median μg kg^{-1} FW	Selenium Mean (SD) μg kg^{-1} FW	Selenium Median μg kg^{-1} FW
Basil	Leaf	4	63.0 (8)	62.8	10.9 (2)	11.60
Celery	Leaf	20	157 (101)	94.9	59.8 (49)	47.7
Chard	Leaf	20	112 (63)	85.5	23.4 (16)	15.0
Cress	Leaf	4	77.2 (24)	57.6	13.2 (6)	11.6
Dill	Leaf	17	93.5 (53)	76.4	36.1 (21)	32.9
Leek	Leaf	16	141 (77)	48.8	31.0 (24)	17.6
Mint	Leaf	2	157 (130)	158	16.7 (8)	
Parsley	Leaf	10	184 (73)	117	35.3 (15)	28.6
Pennyroyal	Leaf	1	55.3		12.0	
Purslane	Leaf	14	83.3 (53)	74.3	6.34 (2)	4.48
Radish Leaves	Leaf	6	101 (43)	64.7	20.2 (9)	20.7
Spinach	Leaf	1	52.7		13.4	
Spring Onion	Leaf	13	33.9 (23)	28.4	20.3 (10)	18.6
Tarragon	Leaf	4	86.7 (64)	86.4	43.0 (33)	38.7
Thyme	Leaf	2	31.8 (6)	31.8	12.1 (1)	
Courgette	Fruit	6	24.4 (19)	16.3	4.43 (2)	3.96
Cucumber	Fruit	11	25.0 (10)	9.64	11.4 (14)	4.53
Egg plant	Fruit	10	52.2 (36)	42.9	10.1 (13)	3.90
Melon	Fruit	2	37.9	37.9	3.26 (3)	
Okra	Fruit	15	86.3 (34)	82.8	13.1 (12)	8.17
Pepper	Fruit	13	72.9 (42)	53.8	10.4 (9)	6.91
Tomato	Fruit	8	65.5 (32)	58.2	13.1 (8)	10.7
Watermelon	Fruit	4	17.8 (9)	15.7	6.89 (6)	7.10
Cow pea	Pod	9	270 (128)	253	44.9 (27)	45.1
Fava Bean	Pod	6	84.2 (65)	81.9	13.8 (9)	10.5
Garlic	Tuber	1	18.2		67.7	
Onion	Tuber	5	26.7 (16)	6.64	8.92 (5)	8.43
Radish	Root	5	31.0 (2)	11.4	19.7 (22)	7.68
Bread	Cereal	50			25.6 (10)	23.0
Rice	Cereal	85	14.7 (20)	7.94	115 (100)	94.3
Wheat	Cereal	13	12.5 (12)	9.83	49.4 (27)	40.8
Yogurt	Dairy	9	52.0 (57)	31.8	10.9 (6)	7.94

populations many countries, including Iraq, encourage the use of iodized salt [16]. Iodized salt is, however, a major contributor to daily sodium (Na) intake. The WHO has recommended a Na intake of <2000 mg d^{-1} (equivalent to 5 g salt; [51]). High Na consumption may predispose individuals to hypertension which has been estimated to

Table 3
Literature values of iodine and selenium concentrations in common foods.

Food	Category	I* μg kg^{-1} fw	Se*,[l] μg kg^{-1} fw
Bread	Cereal	31.2[a,b,c]	
Spaghetti	Cereal	44.4[d]	121
Bulgur	Grain	107[c]	120
Chickpea	Grain	164[e]	118
Lentil	Grain	186[c]	119
White bean	Grain	104[c]	117
Red meat	Protein	115[c,d,e]	133
Chicken	Protein	117[a,b,d,f]	180
Fish	Protein	282[c,d,g]	403
Egg	Protein	398[c,d,e,h]	219
Fresh fruits	Fruit	32.1[b,e,i]	8.9
Nuts	Fruit	172[c,d]	335
Cheese	Dairy	77.1[b,c,h,j]	58.3
Sugar	Additives	57.3[c,e]	1.0
		μg L^{-1}	μg L-1
Cream	Dairy	78.5 [h,j]	16.0
Milk	Dairy	120[c,d,e,j,k]	18.8
Oil	Additives	67[c,h]	0
Tea	Beverage	11[c]	0.308

*uncooked
a [32]
b [4]
c [19]
d [24]
e [26]
f [37]
g [33]
h [9]
i [31]
j [21]
k [15]
l [44]

cause 1.65 million cardiovascular-related deaths each year [25,48]; more recent data predicts an increase to 2.2 million and 7 million by 2025 and 2030 respectively [51]. In response to concern over Se deficiency, the use of Se-enriched fertilizers has been adopted in some countries, most notably Finland [34].

Locally generated food composition data, which would enable the assessment of I and Se status, are not currently available for many countries, including Iraq. The aim of this study was therefore to assess the I and Se status of the Iraqi population, specifically those living in the mountainous Kurdistan region with objectives;

(i) to determine the I and Se concentration of commonly consumed foods, collected from local farms, households, or purchased locally, to provide food composition data relevant to the region,
(ii) undertake a food amount questionnaire (FAQ) to calculate dietary intakes alongside collection of urine samples to confirm survey data,
(iii) establish the role of iodised salt as a source of dietary I for this population.

2. Material and methods

2.1. Survey of local foods

Vegetable crops, including leafy and non-leafy vegetables and tubers, were sampled from 40 farms across Sulaimani province in the Kurdistan Region of Iraq in April-May 2017. A total of 300 samples covering 27 crop species commonly consumed in the Iraqi Kurdish diet were collected. All samples were weighed, washed in deionised water, oven dried (50°C) and then finely ground in an ultra-centrifugal mill (Retsch, Model ZM200; Germany). Ground samples (c. 0.2 g) were microwave-digested (Anton Paar, Multiwave) with 68 % HNO_3 (Primar plus™

Table 4
Calculated mean and median daily iodine and selenium intake in the Iraqi Kurd diet.

Food group	Description	Consumption	Mean I intake	Median I intake	Mean Se intake	Median Se intake
		*mL d^{-1} or g d^{-1}	µg d^{-1}	µg d^{-1}	µg d^{-1}	µg d^{-1}
Cereal and grains						
Rice	Long and short grain white rice	114	1.63	1.57	12.75	12.31
Bread	Naan bread	95.1	2.77	2.49	2.28	2.05
Beans and grains	Bulgur, Chickpea, Lentil, White bean	45.25	5.72	4.36	5.35	3.88
Meat and protein						
Red meat	Beef, Lamb, Veal	30.9	3.41	2.99	3.95	3.46
Poultry	Chicken	91.3	10.20	9.83	15.69	15.12
Fish	Freshwater fish	19.3	5.24	2.26	7.48	3.22
Egg	Whole egg	24.8	9.81	7.96	5.40	4.38
Fruits and vegetables						
Fresh fruits	Apple, Apricot, Banana, Cherry, Date Grape, Grapefruit, Kiwi, Lemon, Melon, Orange, Peach, Pear, Pomegranate, Watermelon	322	9.88	7.55	2.15	1.68
Leafy vegetables	Basil, Celery, Chard, Cress, Dill, Leek, Lettuce. Mint, Parsley, Purslane, Radish leaves, Spinach, Spring onion, Tarragon	64.2	11.38	6.54	1.35	0.99
Non-leafy vegetables	Carrot, Courgette, Cowpea, Cucumber, Eggplant, Fava bean, Garlic, Okra, Onion, Pepper, Potato, Tomato	312	18.84	14.58	3.43	2.76
Nuts and seeds	Mixed nuts, Sunflower seed, Walnut	15.47	2.13	1.55	3.93	2.48
Dairy products						
Cheese	All available cheese	11.3	0.88	0.85	0.66	0.64
Cream	Mostly industrially processed	4.08	0.29	0	0.06	0
Milk	Mostly industrially processed	37.9	4.60	3.00	0.72	0.47
Yogurt	Locally and industrially made	75.5	3.83	3.69	0.80	0.77
Additives and flavours						
Oil	Sunflower oil, Corn oil	61.5	2.85	2.35	0	0
Tomato Paste	Canned	24.8	1.56	1.57	1.26	1.27
Salt	>90 % Iodised salt	13.78	552	508	0	0
Sugar	White Sugar	37.1	1.98	1.72	0.03	0.03
Beverages						
Water	Tap and bottled water	1154	2.40	2.17	0.26	0.23
Tea		282	2.72	2.20	0.07	0.06
Total:	*Excluding iodised salt*		***100***	***94.6***	***66.3***	***62.7***
	Including iodised salt		***649***	***607***		

* The units of oil, water and tea are mL d^{-1}.

grade) for determination of total Se concentration or extracted with 5 % tetra methyl ammonium hydroxide (TMAH) to determine I concentration; analysis was by ICP-MS (Thermo Fisher, Model iCAP-Q™), employing 5 µg L^{-1} Ge (acid matrix) or Re (alkaline matrix) as internal standard.

2.2. Dietary intakes

A semi-quantitative 'food amount questionnaire' (FAQ) based on the regional diet was constructed and included 65 commonly consumed food items (see Annex 1). Such questionnaires are an efficient and practical means of collecting dietary information but to be reliable must be appropriate for the target population and include consideration of ethnic, social and cultural factors [23]. Our questionnaire was designed specifically for this population and tested prior to implementation although it was not formally validated. Healthy participants (n = 406) from volunteer households (n = 115) were interviewed during March-April 2017. All members of a family older than 6 years were included. The questionnaire recorded the frequency and amount of food purchased, cooked, and eaten by the family. Households were asked about the quantity of a food bought and the frequence of purchase, how many times they cooked/ate that food (per day/week/month), the amount of food cooked for a family meal, the number of family members eating the food, and the number of months of the year the food was available. Individual participants were also asked about additional foods eaten, their iodised salt consumption, whether they took supplements or had a medical diagnosis of thyroid problems. Estimates of food waste, arising from peeling vegetables and fruit and from the discarded outer leaves of leafy vegetables, were used to adjust the reported amounts from the questionnaire participants. In addition, a seasonal availability correction was applied by multiplying reported amounts in the questionnaire by the proportion of the year in which the food was actually available.

From each household a sample of drinking water (n = 83), rice (n = 85) a widely consumed staple food, and salt (n = 82) were also collected where possible for determination of I and Se concentrations. Salt I content was determined in a salt solution (0.4 % w/v) by ICP-MS. Samples of bread (n = 50) and yoghurt (n = 9) were purchased from shops in the area and also analysed. Dietary intakes of Se and I were calculated on the basis of the FAQ using the local food I and Se concentrations supplemented by data in food composition tables where local data was unavailable. The extent to which the population exceeded recommended intakes and was at risk of inadequate or excessive intake was calculated using recommended daily amounts (RDA, [47]) and harmonised-Nutrient Reference Values (h-NRV, [1]) respectively.

2.3. Urine sampling and analysis

Each participant provided a 'first void' urine sample on the morning after the dietary questionnaire was completed. Samples were collected, transported to the laboratory and frozen (-18°C) pending analysis. Urinary creatinine was measured (Randox RX-imola) using a colorimetric method [2]. Correction of measured urinary concentrations for hydration was tested using both creatinine and osmolality [35]. For example,

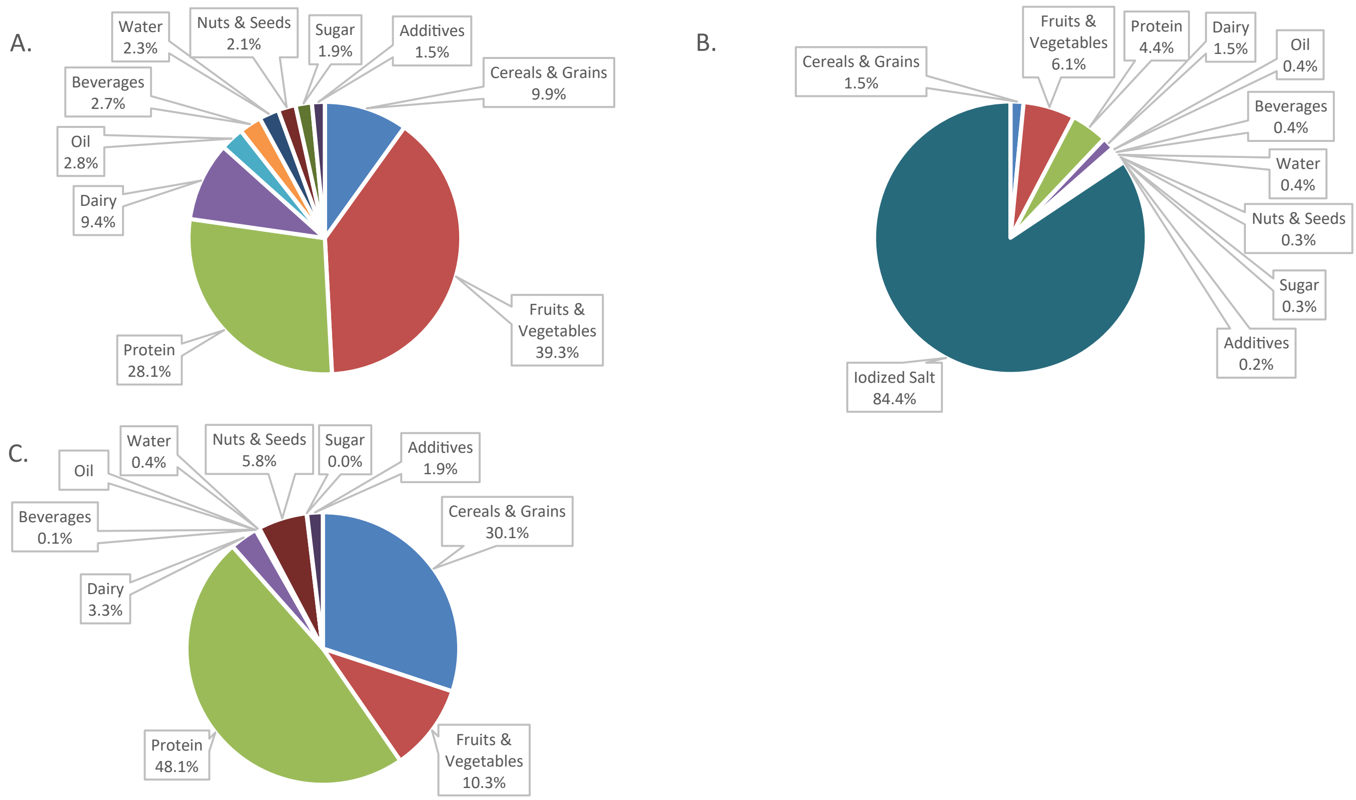

Fig. 1. Percentage of daily iodine and selenium intake from different food groups: A. Iodine intake excluding salt, B. Iodine intake including salt, C. Selenium intake.

for creatinine:

$$UI_{CRT} = UI/U_{CRT} \quad (1)$$

where UI_{CRT} is the creatinine corrected urinary I concentration, UI is the measured urinary iodine concentration (μg L^{-1}) and U_{CRT} is the corresponding urinary creatinine concentration (g L^{-1}).

Urinary osmolality was determined by freezing-point depression (Cryoscopic Osmometer, Model Osmomat 030 series M, [41]). Urine concentrations were corrected for osmolality by applying a Levine-Fahy specific gravity adjustment e.g.:

$$UI_{OSM} = UI \times (REF_{OSM}/U_{OSM}) \quad (2)$$

where UI_{OSM} is the osmolality corrected urinary I concentration, REF_{OSM} is the median osmolality for all urine samples (674 mOsm kg^{-1}, n = 410) and U_{OSM} is the osmolality measured in an individual sample (mOsm kg^{-1}). Urinary I, Se and Na concentrations were measured by ICP-MS (0.5 mL of urine diluted with 9.5 mL 1 % TMAH). Urinary I was classified according to WHO recommendations [50] whereby a UI value in the range 100–199 μg L^{-1} indicates adequate I nutrition with values of UI ≥300 μg L^{-1} classified as excessive iodine intake which may have negative consequences for health.

2.4. Ethics

Ethical approval for the questionnaire and urine sampling was granted by both the University of Nottingham, UK (Ethics Reference No OVS10022017; Feb-2017) and Sulaimani Polytechnic University, Iraq. Written informed consent was obtained from all adult participants, and parents or legal guardians on behalf of children, before data collection.

2.5. Quality control

Standard reference materials (National Institute of Standards and Technology standards NIST 1573a Tomato leaves and NIST 1567b Wheat Flour) were digested (HNO_3) and extracted (TMAH) in triplicate alongside food and crop samples for quality assurance. Seronorm certified urine reference materials (designated L-1 & L-2) were prepared and analysed alongside the urine samples for quality control of urine trace element analysis.

3. Results and discussion

Analytical results and recoveries for the reference standards are given in Table 1.

3.1. Iodine and selenium concentrations of local foods

Iodine and Se concentrations of local crops are shown in Table 2. The mean concentration of I for all leafy vegetables was 92 μg kg_{fw}^{-1}, lower mean concentrations were found in root and tuber crops, 25.3 μg kg_{fw}^{-1}, and for other fruit and vegetable crops the mean concentration was 74 μg kg_{fw}^{-1}. The I concentrations of locally grown wheat (n = 13) and imported rice (n = 85) were 12.5 and 14.7 μg kg_{fw}^{-1} respectively; rice I concentrations were generally lower than those of the vegetable crops. The mean and median drinking water (n = 83) I concentrations were 2.18 and 2.17 μg L^{-1} respectively. The mean Se concentrations of leafy vegetables, roots/tubers, and other fruit and vegetables were 23.1, 32.1 and 13.1 μg kg_{fw}^{-1} respectively. Unlike I, mean Se concentrations in rice were typically greater (115 μg kg_{fw}^{-1}) than those in vegetable crops; wheat Se concentrations (49.4 μg kg_{fw}^{-1}) were also lower than in rice but comparable to some vegetable crops, including cow pea, tarragon and celery. The mean Se concentration of locally sourced bread (n = 50) was 25.6 μg kg_{fw}^{-1} which is lower than values reported in the literature [3, 19]. The mean and median Se concentrations in drinking water (n = 82) were 0.308 and 0.255 μg L^{-1} respectively.

Table 3 provides information on I and Se concentration in other common foods from a range of sources (mean value of different

Table 5
Comparison of the percentage of different age groups falling below RDAs [47] with estimates of inadequacy and excessive intakes using physiologically based harmonised-Nutrient Reference Values [1].

Age (yr) WHO	RDA[#] µg d^{-1}	% < RDA - Salt	% <RDA + Salt	Age (yr) DRI[^]	RDA[#] µg d^{-1}	% <RDA	Age (yr) h-NRV	h-NRV AR[$] µg d^{-1}	h-NRV UL[*] µg d^{-1}	% <AR - Salt	% <AR + Salt	% >UL - Salt	% >UL + Salt	h-NRV AR[£] µg d^{-1}	h-NRV UL[@] µg d^{-1}	% <AR	% >UL
	I	I	I		Se	Se		I	I	I	I	I	I	Se	Se	Se	Se
All	-	91.1	0	All	-	28.1	All	-	-	41.4	0	0	61.6	-	-	9.1	0
Children	-	93.4	0	Children	-	33.1	Children	-	-	39.7	0	0	82.6	-	-	4.1	0
4–5	*90*	87.5	0	*4–8*	*30*	19.4	4–6	*65*	*250*	59.1	0	0	86.4	*23*	*90*	0	0
6–12	*120*	89.1	0	*9–13*	*40*	47.7	7–10	*65*	*300*	38.2	0	0	91.2	*23*	*130*	0	0
13–17	*150*	100	0	*14–18*	*55*	30.6	11–14	*73*	*450*	11.1	0	0	80.6	*35*	*200*	0	0
							15–17	*95*	*500*	62.1	0	0	72.4	*45*	*250*	17.2	0
Adults[+]	*150*	90.2	0	Adults[+]		26.0	Adults[+]	*95*	*600*	42.1	0	0	52.6	*45*	*300*	11.2	0
				19–50	*55*	29.9											
				>51	*45*	7.5											

[#]Recommended daily amount (RDA) for I is 150 µg d^{-1} for adolescents (over 12 years) and adults, 120 µg d^{-1} for school age children (6–11 years) and 90 µg d^{-1} for infants (0–59 months) [47]; [^]RDA for Se is 20 µg d^{-1} for infants (1–3 years), 30 µg d^{-1} for ages 4–8, 40 µg d^{-1} for ages 9–13, 55 µg d^{-1} for age groups 14–18, 19–30, and 31–50 and 45 µg d^{-1} for >51 years, DRI [12]; [$]Harmonised-Nutrient Reference Value Average Requirement (h-NRV AR) for iodine defined by the functional outcome of thyroid accumulation and turnover [1]; [*]Harmonised-Nutrient Reference Value Upper Limit (h-NRV UL) for iodine defined by the functional outcome of changes in thyroid hormones [1]; [£]Harmonised-Nutrient Reference Value Average Requirement (h-NRV AR) for selenium defined by the functional outcome of plasma glutathione peroxidase activity; [@]Harmonised-Nutrient Reference Value Upper Limit (h-NRV UL) for selenium defined by the functional outcome of selenosis (e.g. loss of hair and nails); [+]Adults defined as 18 years of age and above.

analysis). The data demonstrates that foods high in protein are richer sources of Se than cereal crops and vegetables.

3.2. Dietary energy intake

For the study population, cereals and grains, oils, protein sources and fruits supplied 78 % of daily energy intake (35 %, 20 %, 13 % and 10 % respectively). Vegetables collectively supplied only 6 % of daily energy intake although c.60 % of daily food consumption by weight was from this food group. The mean total daily energy intake according to the questionnaire responses was 2432 kcal d^{-1} per person, which is in line with the normal range reported by the FAO/WHO of 2000–3000 kcal d^{-1} [17].

3.3. Dietary iodine and selenium intake

The median daily dietary intake of I from all foods, excluding salt intake, was calculated to be 94.6 µg d^{-1} (mean 100.2 µg d^{-1}) (Table 4). Vegetables and fruits supplied 48 %, protein sources 29 %, cereal and grains 10 %, dairy products 9 % and water 5 % of daily I intake (Fig. 1a). Low consumption of dairy products in the Kurdish diet resulted in only 9 % of I intake coming from these sources. The daily per capita intake of salt estimated from the questionnaire was 13.8 g indicating a high level of consumption. The majority (>90 %) of salt samples collected from households were iodised with a median I concentration of 43 mg kg^{-1} (mean= 40 mg kg^{-1}, range= 8.4–77 mg kg^{-1}). This is a typical average I concentration for iodized salt; the Food and Drug administration of the USA (USFDA) recommend 46–76 mg kg^{-1} [10] and the Iraqi specification is 20–80 mg kg^{-1} [6]. Including salt consumption, average I intake increases to 649 µg d^{-1}, considerably greater than the WHO recommended dietary allowance of 150 µg d^{-1} for those aged 13 and above [47], with salt supplying 84 % of I daily intake (Table 4, Fig. 1b) [47]. Comparison of the percentage of different age groups falling below RDAs [47] with those at risk of inadequacy or excessive intakes using physiologically based harmonised-Nutrient Reference Values (h-NRV) [18] is shown in Table 5. In the absence of iodised salt consumption, the data indicates that 91.1 % of the participants (93.4 % of children) would be iodine deficient based on the RDA for their age [47]. This decreased to 41.4 % of participants (39.7 % of children) estimated to have inadequate intake when based upon the h-NRV average requirement (AR) (Table 5) defined as the average daily nutrient intake estimated to meet the requirements of half of healthy individuals in that life stage [1]. When consuming iodised salt 61.6 % of participants (82.6 % of children) are estimated to be at risk of excessive iodine intake (Table 5) because they exceed the upper level, the nutrient intake that is likely to pose no risk of adverse health effects [1].

Median total daily intake of Se for adults, according to the questionnaire, was 62.7 µg d^{-1} (range = 24–166 µg d^{-1}; mean= 66.3 µg d^{-1}). These figures exceed the recommended dietary intake value of 55 µg d^{-1} for those aged 14–50 years [12] (Table 4), but 28.1 % of participants had a Se intake below the RDA for their age. Protein sources and cereals supplied c.78 % of daily intake (48 and 30 % respectively). Other contributions included fruit and vegetables (10 %), nuts (8 %) and dairy products (3 %); the contribution from drinking water (0.05 %) was negligible (Fig. 1c). The percentage of the population deemed to be at risk of inadequate Se intake decreased to 9.1 % of participants (4.1 % of children) when the h-NRV AR was considered (Table 5). No participants exceeded the h-NRV UL for Se [1].

3.4. Urinary iodine

A good correlation (r = 0.70, p <0.0001) was observed between urinary creatinine (U_{CRT}) and osmolality (U_{OSM}) (Fig. 2a) and the adjusted urinary I concentrations, UI_{CRT} and UI_{OSM}, (r = 0.62; p <0.0001) (Fig. 2b). Mean and median values of UI_{CRT} (µg g^{-1}) for all participants were 417 and 379 µg L^{-1} respectively (range

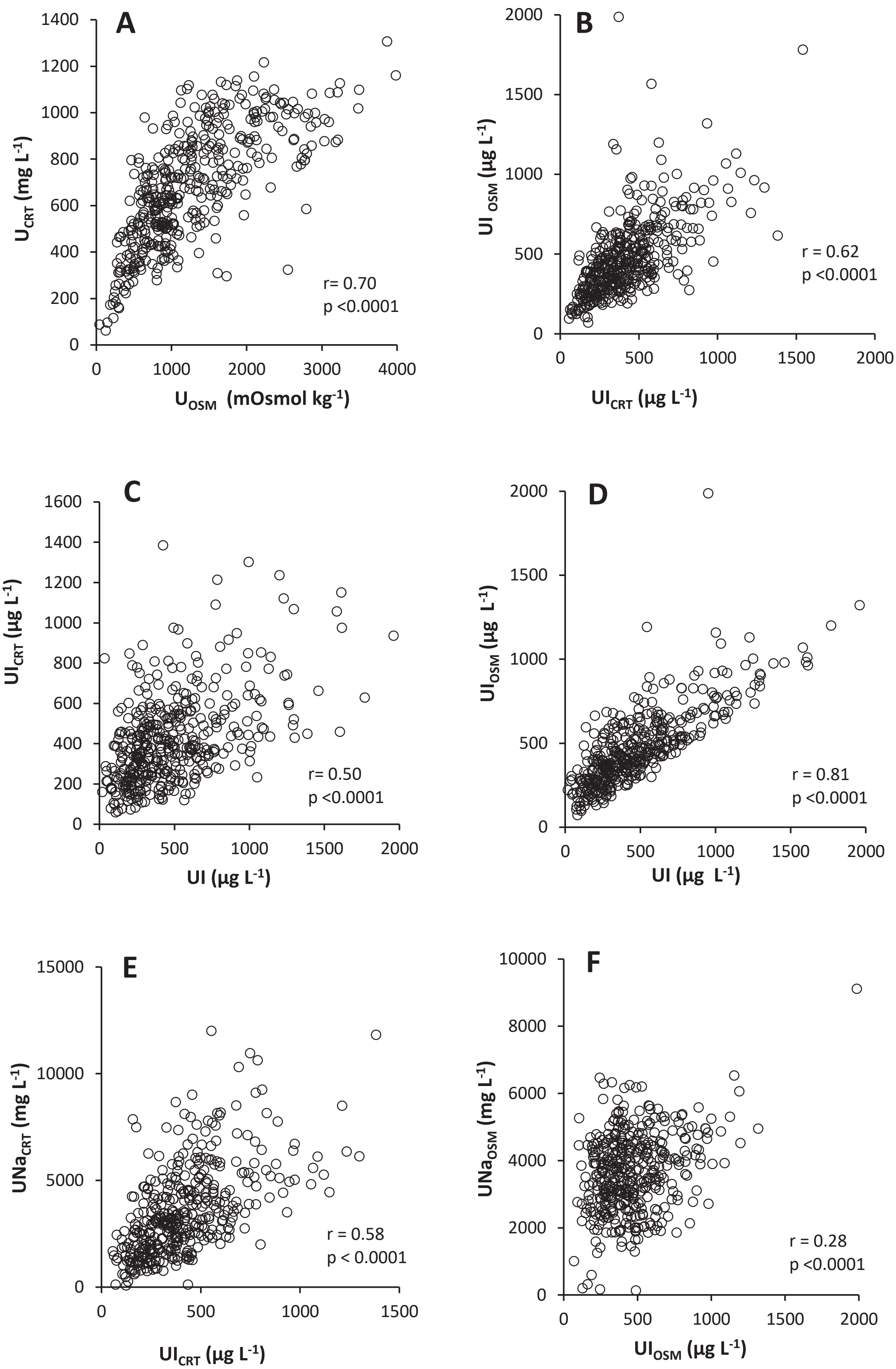

Fig. 2. A. Correlation of urine creatinine (U_{CRT}) and osmolality (U_{OSM}) values, B. Correlation of UI for both correction methods (creatinine and osmolality), C. Correlation of uncorrected UI and creatinine corrected values (UI_{CRT}), D. Correlation of uncorrected UI and osmolality corrected values (UI_{OSM}), E. Correlation between creatinine corrected urinary iodine (UI_{CRT}) and sodium creatinine (UNa_{CRT}) corrected values F. Correlation between osmolality corrected urinary iodine (UI_{OSM}) and sodium osmolality (UNa_{OSM}) corrected values.

Table 6
Summary of corrected urinary iodine concentration (UI) by age group.

Age group	Population	UI_{CRT}		UI_{OSM}	
		Mean (SD)	Median	Mean (SD)	Median
	%	$\mu g\ L^{-1}$	$\mu g\ L^{-1}$	$\mu g\ L^{-1}$	$\mu g\ L^{-1}$
6–14	20.3	565 (250)	503	533 (268)	469
15–24	18.1	370 (200)	331	522 (256)	480
25–39	29.8	393 (189)	363	470 (209)	434
40–60	18.1	418 (204)	390	446 (205)	394
≥ 60	13.7	351 (173)	320	344 (139)	312
All	100	417 (221)	379	470 (233)	424

Table 7
Iodine intake status based on measured, corrected urinary iodine concentration (UI) and WHO classification for each age group.

Age (yr)	UI ($\mu g\ L^{-1}$):	Percentage (%)			
		< 100	100–199	200–299	≥ 300
		Insufficient	Adequate	Above Requirements	Excessive
Creatinine Corrected:					
6–14		0	3.4	4.5	92.1
15–24		5.1	12.8	26.9	55.1
25–39		0.8	12.6	22.0	64.7
40–59		0	11.4	16.5	72.2
≥60		3.7	7.4	33.3	55.6
Osmolality Corrected:					
6–14		0	1.1	12.4	86.5
15–24		1.3	6.6	7.9	84.2
25–39		0	4.7	18.1	77.2
40–59		0	6.4	14.1	79.5
≥60		3.7	3.7	37.0	55.6

Table 8
Summary of corrected urinary selenium concentration (USe) by age group.

Age group	Population	USe_{CRT}		USe_{OSM}	
		Mean (SD)	Median	Mean (SD)	Median
	%	$\mu g\ L^{-1}$	$\mu g\ L^{-1}$	$\mu g\ L^{-1}$	$\mu g\ L^{-1}$
6–14	20.3	28.8 (9)	27.5	27.4 (11)	24.6
15–24	18.1	19.3 (8)	18.4	28.3 (9)	27.0
25–39	29.8	19.8 (6)	18.3	24.6 (9)	23.3
40–60	18.1	19.2 (6)	17.3	21.4 (8)	19.8
≥ 60	13.7	18.8 (4)	18.2	19.1 (7)	18.4
All	100	21.2 (7)	19.7	24.8 (10)	23.2

58–1380 $\mu g\ L^{-1}$; n = 410), slightly lower than equivalent values for UI_{OSM} of 470 and 424 $\mu g\ L^{-1}$ respectively (range 71–1990 $\mu g\ L^{-1}$; n= 410) (Table 6). School-age children typically had the greatest UI and participants >60 years old had the lowest UI (Table 6). According to the WHO classification a UI value in the range 100–199 $\mu g\ L^{-1}$ indicates adequate I nutrition with values of UI ≥300 $\mu g\ L^{-1}$ classified as excessive iodine intake which may result in consequences for health [50]. Based upon these guidelines c. 98 % of school-age children had I intakes that were above requirements or excessive, 2 % had an adequate intake and none had an inadequate intake (Table 7). Only < 13 % of all participants had UI in the adequate range with 80–90 % (depending upon correction method applied) classed as having intakes that were above requirements or excessive. Considering all the age groups, 55 % of participants had I intakes classed as excessive (Table 7).

3.5. Urinary selenium

The mean and median creatinine-adjusted urinary Se concentrations (USe_{CRT}) for all participants were 21.2 and 19.7 $\mu g\ g^{-1}$ respectively; equivalent osmolality-adjusted values (USe_{OSM}) were 24.8 and 23.2 $\mu g\ L^{-1}$ respectively. The USe_{CRT} of school age children was significantly greater than other age groups ($p < 0.0001$) while there was not any significant difference in this value between all other age groups ($p > 0.9$); values of USe_{OSM} varied between age groups (Table 8).

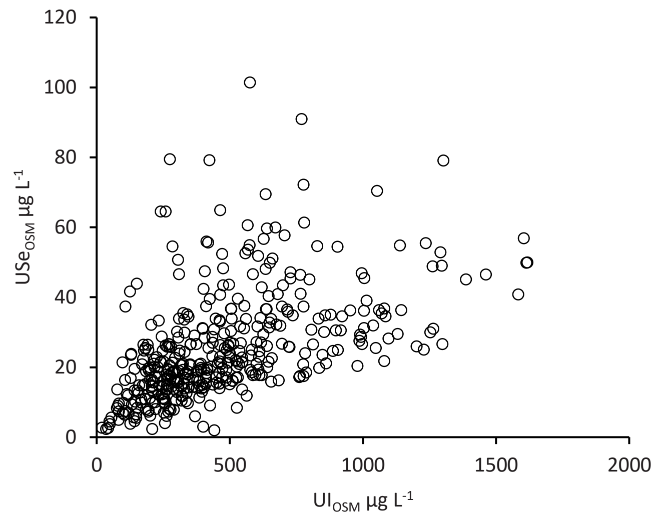

Fig. 3. Correlation between osmolarity corrected urinary iodine (UI_{OSM}) and selenium (USe_{OSM}).

Table 9
Summary of corrected urinary sodium concentration (U_{Na}; mmol per gram of creatinine) by age group.

Age group	Population	UNa_{CRT}		UNa_{OSM}	
		Mean (SD)	Median	Mean (SD)	Median
	%	mmol g^{-1}	mmol g^{-1}	mmol g^{-1}	mmol g^{-1}
6–14	20.3	193 (96)	186	167 (54)	170
15–24	18.1	110 (70)	92	144 (51)	138
25–39	29.8	145 (86)	130	159 (49)	158
40–60	18.1	174 (88)	168	172 (48)	184
≥ 60	13.7	167 (83)	146	154 (45)	161
All	100	158 (107)	136	161 (60)	160

A correlation was observed between UI_{OSM} and USe_{OSM} ($p < 0.0001$; r = 0.50) (Fig. 3) but not when concentrations of I and Se were adjusted using creatinine. Thomson et al. [43] found a similar correlation between osmolality adjusted urinary I and Se when they analysed both spot samples and 24 hr urine samples from 62 adults, but this was also absent when data were creatinine-adjusted.

A limitation of our study is that urinary Se is not the recommended biomarker for assessing Se status, the approved marker is plasma or serum Se, however a strong correlation has been observed between urinary Se and daily dietary Se intake [27,40]. Doubling measured 24 h urinary excreted Se has been shown to give a reasonable estimation of Se intake, which may be more accurate than food recording approaches [39,43]. Using this approach the estimated dietary Se intake in this study was 59.4 $\mu g\ d^{-1}$ which is in line with recommended levels of Se intake (55 $\mu g\ d^{-1}$ for ages 14–50) but less than both the mean (66.3 $\mu g\ d^{-1}$) and median (62.7 $\mu g\ d^{-1}$) Se intakes estimated from the dietary questionnaire. Hurst et al. [27], in a study of dietary Se in a Malawian population, observed a linear relationship between Se dietary intake (Se_{DI}, mg d^{-1}) and USe_{CRT} ($\mu g\ L^{-1}$) where $USe_{CRT} = 7.8 + (318 \times Se_{DI})$, $r^2 = 0.5707$, $P < 0.0001$. Estimated Se_{DI} in this study using their equation was 42 $\mu g\ d^{-1}$ when all participants were considered; this is lower than both the recommended dietary intake values (55 $\mu g\ d^{-1}$ for those aged 14–50 and 45 $\mu g\ d^{-1}$ for those aged 51 and above, [12]) and the mean and median dietary intake estimated from the questionnaire, suggesting

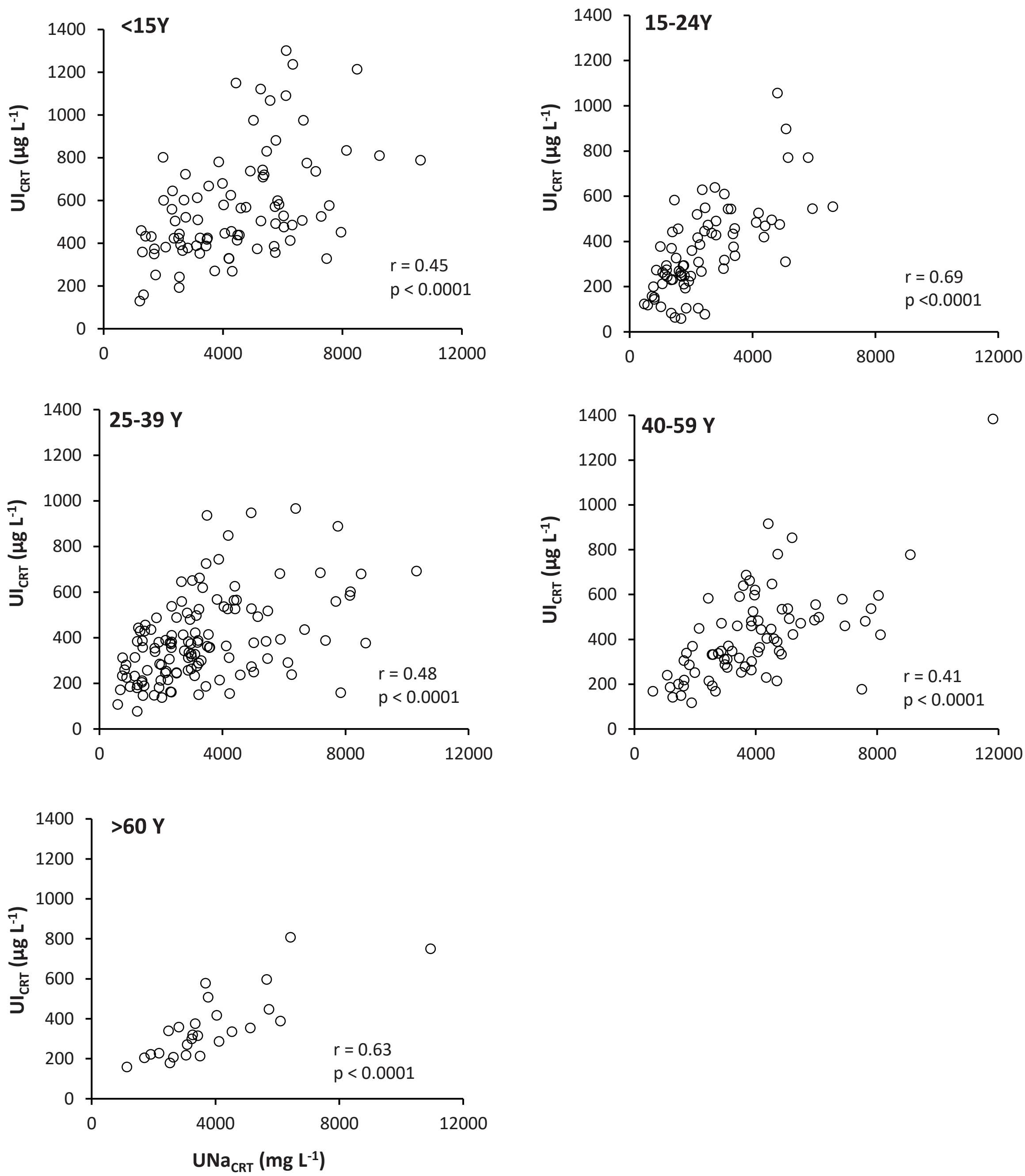

Fig. 4. Correlation between creatinine corrected urinary sodium and iodine for participants in different age groups.

59–76 % of participants had a Se intake below the recommended value.

3.6. Urinary sodium

Urinary Na concentrations (UNa; mmol g^{-1} of creatinine) were determined and adjusted using measured creatinine or osmolality (Table 9). The normal range for urinary Na excretion rate is 40–220 mmol d^{-1} [11]. The mean concentration of UNa in this study was c.160 mmol L^{-1} (3680 mg L^{-1}). Normal urinary excretion volume varies; for example, studies in Mexico (n=711), Morocco (n=119) and South Korea (n=242) found average urine volumes of 1.56, 1.12 and 1.7 L respectively [11,28,45]. Assuming a total daily urine volume of 1.4 L suggests that the daily Na excretion in the current study was 224 mmol L^{-1}, slightly exceeding the high end of the normal range.

3.7. Relationship between urinary iodine and sodium

A significant correlation between UI and UNa was observed when all participants were considered (Fig. 2e & 2 f). Significant correlations were also observed for all age groups (Fig. 4). Du et al. [13] reported that salt is the major source of dietary sodium with only 6.8 % of sodium originating from processed foods, which are uncommon in Iraq. The correlation between UI_{CRT} and UNa_{CRT} (Fig. 2e) supports the suggestion that iodized salt consumption is the main source of I for this population. If correct, then daily I intake calculated from UNa might be expected to correlate with intake calculated from measured UI; Fig. 5 confirms such a correlation and implies that estimation of I intake from UNa may be an acceptable approach for populations where I intake is mainly from iodized salt.

Calculating iodine intake from UNa for all participants in this study

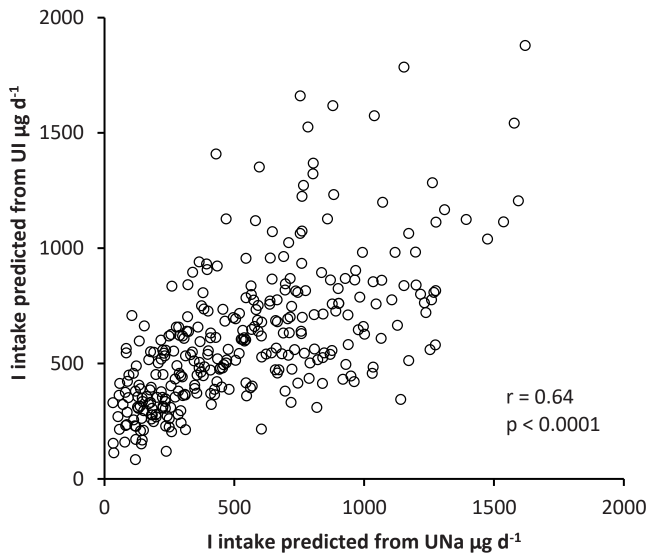

Fig. 5. Correlation between daily iodine intake estimated from UI and using UNa as a proxy for salt intake accounting for salt iodine concentration for individual households.

on the basis that I intake arises from their individual household iodized salt consumption, average I intake is estimated to be 604 µg d^{-1} assuming a urine excretion of 1.4 L over 24 h and 15 % non-renal Na loss [11]. This compares well with values calculated from the dietary questionnaire (649 µg d^{-1}) and from UI (689 µg d^{-1}).

Salt consumption estimated from UNa (160 mmol L^{-1}) considering all Na as NaCl [36], 15 % non-renal Na loss and a 24 h urine excretion volume of 1.4 L gives a calculated Na intake of 263 mmol d^{-1} (6044 mg d^{-1}) which equates to 15.3 g d^{-1} salt intake. This amount is only slightly higher than estimated daily salt intake from the questionnaire (13.8 g d^{-1}) probably because of other sources of Na in the diet alongside salt. The estimated Na intake of participants in this study was substantially greater than the WHO-recommended salt intake of 5 g d^{-1} which may predispose the study population to diseases related to high Na intake such as hypertension and kidney disease [38,49]. The WHO report estimated mean global Na intake in 2019 as 4310 mg d^{-1} (10.78 g d^{-1}salt) [51],

more than double the recommended level. The same report provides an estimated Na intake for Iraq of 2520 mg d^{-1} (6.4 g d^{-1} salt), which is significantly lower than the current study [51]. However, salt intake reported in the current study is comparable to values reported for other countries in the region which share similar diets and culinary practices. For example, Turkey, Iran and Kuwait have reported dietary salt intakes of 15, 10.6 and 8.8 g d^{-1}; the UK, US and France have intakes of 8.1, 8.8 and 8.4 g d^{-1} with the lowest reported salt intakes in Cyprus and Malaysia of 5.0 and 6.4 g d^{-1} respectively [42].

4. Conclusions

Findings from the dietary questionnaire indicate that Se intake in this population is mainly from protein and cereal sources and is broadly in line with dietary intake recommendations with c. 71.9 % of the population reaching or exceeding this intake level. The percentage of the population at risk of inadequate Se intake was between 9.1 % and 28.1 % depending upon which dietary intake values are used. Urinary Se concentrations broadly confirmed this observation but further confirmation using blood serum, the approved biomarker, may be prudent.

Iodized salt was the main source of I in the diet of this population. In the absence of salt, locally grown or sourced food typically supplied 100 µg d^{-1} of iodine which suggests that at least 90 % of the participants would be below WHO intakes for age [47]. Results of a household food questionnaire together with measured UI, and a strong correlation between UI and UNa, all suggest a daily iodine intake well above requirements (c.600 µg d^{-1}) due to high consumption of salt. Consumption of iodized salt increased daily I intake to 649 µg d^{-1} supplying 84 % of total dietary I intake from an estimated intake of c. 13.5 g d^{-1} of iodized salt which is significantly greater than recent WHO estimates of 6.4 g d^{-1} salt (2520 mg d^{-1} Na) [51]. In total 61.6 % of the participants and 82.6 % of children appear to be at risk of long-term adverse health effects due to excessive iodine intake. Urine iodine measurements confirmed this indicating that 98 % of school aged children had excessive iodine intake (≥300 µg L^{-1}) and, overall, 80–90 % of study participants had above average or excessive iodine intakes (≥200 µg L^{-1}) WHO [50].

These findings suggest that policies to reduce salt intake within the study population should be considered to reduce the risks of cardiovascular disease and bring dietary iodine intake down to recommended levels. These findings may also be relevant in other regions where dietary habits are culturally similar to the Kurdish region of northern Iraq. The current study also suggests that urinary Na concentration could represent an acceptable biomarker to estimate dietary I and salt intake in populations where the principal source of I and Na is iodized salt.

CRediT authorship contribution statement

Abdolbaset Karim: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Scott D. Young**: Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **Karzan A. M. Hawrami**: Investigation. **ELIZABETH BAILEY**: Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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