Iron stores in relation to dietary patterns in a multiethnic population: the SAMINOR study

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Abstract

Objective: We evaluated the association between serum ferritin (s-ferritin), transferrin saturation and dietary patterns, in connection with ethnicity, geographical settlement and lifestyle factors.

Design: In 2003–2004, a cross-sectional study of health and living conditions was carried out in northern Norway.

Setting: A questionnaire explored, among other factors, ethnicity and food consumption habits. Principal component analysis was used to assess the association between variables. Seven principal components were then used as input to a cluster analysis. To characterise food consumptions, five dietary patterns were identified and used to assess the effect of food consumption habits on Fe stores.

Subjects: A total of 16 323 men and women between the ages of 36 and 79 years participated.

Results: Participants who frequently consumed reindeer meat had higher levels of s-ferritin ($P < 0·0001$) than did individuals with other dietary patterns. This pattern was highly represented by subjects with three generations of Sami language (Sami I). Further, mean transferrin saturation in the reindeer group was higher compared with the other dietary clusters for men ($P < 0·04$) and women ($P < 0·02$). However, the reindeer pattern individuals also had the highest proportion of subjects with overweight and obesity. Obesity was positively associated with s-ferritin in both men and women ($P < 0·0001$).

Conclusions: The differences in Fe status described earlier between inland Sami and non-Sami can be explained by several factors such as food habits, age and obesity. High level of s-ferritin may reflect high intake of reindeer meat. Being overweight and obese is also associated with s-ferritin levels.

The Norwegian government has formally designated the Sami people as the indigenous people of Norway. The Sami live in the northern part of Scandinavia and in the Kola Peninsula of Russia. Norway has the greatest proportion of the total Sami population. Previous studies have reported differences in Fe status between indigenous groups and the majority population, mainly because of differences in dietary Fe intake[1]. A study from areas with both Sami and non-Sami inhabitants in central and northern Norway described differences in Fe levels between Sami and non-Sami populations[2]. The inland Sami had significantly higher serum ferritin (s-ferritin) than the coastal Sami and non-Sami populations, independent of sex. In addition, mean transferrin saturation was higher for inland residents, especially for male participants.

In northern Norway, there has been substantial social interaction between the Sami and non-Sami populations for several generations. However, some special characteristics in dietary traditions have influenced the Sami dietary habits, such as high consumption of reindeer meat by inland Sami and marine fish by coastal dwellers.

The s-ferritin level is the most specific biochemical test that correlates with total body Fe stores, and has been used as a key parameter in several epidemiological studies to assess Fe status[2–5]. Serum apoferritin (s-apoferritin) is included in measured s-ferritin and is an acute-phase reactant protein elevated in infectious, inflammatory and malignant diseases. However, the recent SAMINOR study[2] on Fe levels indicated that acute infection or inflammation was not prevalent in the study population. The high mean Fe levels among inland Sami groups could not be explained by differences in alcohol consumption, since the Sami participants consumed less alcohol compared with non-Sami participants. A likely explanation is differences in dietary habits.

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The aim of the present study was to investigate whether dietary habits could account for the observed differences in Fe status between the Sami and other Norwegian participants in the SAMINOR survey.

Methods

The SAMINOR study

A cross-sectional population-based study of health and living conditions in areas with a mixed Sami and non-Sami population, referred to as the SAMINOR study, was carried out in central and northern Norway in 2003–2004. The present study covered municipalities in Norway for which >5–10 % of the population was reported in the 1970 Census to be Sami[6]. In addition, some specific districts were included from municipalities with an overall lower proportion of subjects with Sami ethnicity. The SAMINOR study was the responsibility of the Centre for Sami Health Research, Institute of Community Medicine at the University of Tromsø, in collaboration with the National Screening Program for Cardiovascular Diseases (SHUS; now incorporated into the National Institute of Public Health). The study is described in detail by Lund *et al.*[7]. Study materials were collected from January 2003 to April 2004.

Subjects

In total, 16 538 men and women aged 36–79 years participated in the SAMINOR study and gave informed consent for medical research. The response rate was 61 %. Participation rates for the coastal and inland areas were 59·6 % and 65·5 %, respectively. More women than men participated, 65·6 % *v.* 56·6 %, respectively. Information about ethnicity and Fe status was available for 14 630 persons.

Screening

Non-fasting blood samples were obtained at enrolment. Blood samples were drawn by venepuncture at normal venous pressure in sitting position. Serum was separated immediately and s-ferritin, s-Fe and transferrin were measured by standard techniques used routinely in the clinical laboratory. s-Ferritin measurements were taken with a Hitachi Modular P analyser (Roche Diagnostics, Mannheim, Germany); details of the analytical methods used have been described previously by Broderstad *et al.*[2]. In the current statistical analyses, we chose only s-ferritin as a measure of Fe status so as to limit the length of the paper. Fe depletion is defined as s-ferritin concentrations <13 µg/l, which is consistent with earlier surveys[3,8]. The WHO defines Fe depletion to occur when s-ferritin <15 µg/l[9].

Body weight (in kg, one decimal) and height (in cm, one decimal) were measured using an electronic height and weight scale with the participants wearing light clothing without shoes. According to WHO, underweight is defined as $BMI < 18 \cdot 5 \, kg/m^2$, standard weight as between 18·5 and $24 \cdot 9 \, kg/m^2$, overweight as between 25·0 and $29 \cdot 9 \, kg/m^2$ and obese as $\geq 30 \cdot 0 \, kg/m^2$[10].

C-reactive protein (CRP) concentrations were measured with a turbidimetric assay. The method was standardised against 470 (RPPHS – Reference Preparation for Proteins in Human Serum).

FFQ data

The dietary cluster analysis was based on FFQ data[11]. Respondents were asked to report their usual intake of the following foods: fruit, berries, cheese (all types), potatoes, cooked vegetables and raw vegetables/salad. Questions were asked about the usual intake of different beverages. In addition, the respondents were asked questions about traditional and modern food items assumed to be a part of the current diet of the study population.

Dietary habits

Information on consumption of different foods, both modern and traditional, was obtained through questionnaires with a food frequency design, as described in detail by Brustad *et al.*[11]. On the basis of factor and cluster analyses for fifty-six different food variables, Brustad *et al.*[11] defined five different dietary groupings or patterns: 'reindeer', 'fish', 'average', 'fruit and vegetables' and 'Westernised, traditional marine'. The reindeer pattern was characterised by frequent consumption of reindeer meat and other reindeer products, in addition to moose meat and cured/salted fish. The use of boiled (non-filtered) coffee was also frequent in this cluster. The second pattern was named 'fish' because it consisted of subjects with frequent use of all marine food items in the questionnaire. Pattern three was labelled 'average' and characterised by average intakes of most food items, except whole milk, and processed fish (smoked or cured/salted), which were significantly higher in this group. In addition, this pattern showed a high intake of both boiled (non-filtered) and 'other' coffee, as well as sausages, pork and mutton. The fourth pattern was labelled 'fruit and vegetables' because of the frequent intake of these items in addition to water, tea, pasta and chicken. The last pattern was named 'Western, traditional marine'. This was dominated by Westernised products such as hamburgers, pizza, sausages, casseroles, pork and beef. This pattern also had the highest frequency of the traditional food, namely, fish liver and hard roe, in addition to whale meat and filtered coffee. These dietary patterns are used to assess the effect of food habits on Fe stores.

Ethnicity

The sample was divided into three ethnic groups: (i) Sami I – speaking the Sami language for three generations (all grandparents, both parents and the participants used Sami as the language spoken at home); (ii) Sami II – mixed group with Sami and non-Sami affiliation (at least

one Sami indicator as Sami language, ethnic background or self-perceived ethnicity); and (iii) the remaining population – non-Sami. Each of these groups was divided into inland and coastal domiciles.

Reference groups

The reference groups in the multiple linear regression analyses were the youngest age groups, the non-Sami group, those consuming the average dietary pattern and the normal weight group in each category.

Ethical approval

All participants gave written informed consent before screening. The study was accredited by the Regional Board of Research Ethics in Northern Norway, including the Sami consultant of the Board. The survey is in accordance with the Helsinki Declaration of 1975. The National Data Protection Authority (Datatilsynet) gave approval for storing of individual information and for later linkages.

Statistical analyses

Analyses were stratified by sex. Since distributions for s-ferritin showed positive skewness, concentrations were logarithmically transformed (log(e) scale), which resulted in normal distributions. s-Ferritin concentrations are reported as geometric means and their 95 % CI. Differences in Fe levels across ethnic groups were tested by ANOVA, stratified for geographical residence and two age groups (36–49 and 50–79 years). The Tukey–Kramer test was used for pairwise comparisons. ANCOVA was used to test for differences in Fe levels between geographical residences, adjusted for age group and ethnicity. Age-adjusted effects of ethnicity, BMI and dietary habits on log-ferritin were modelled by multiple linear regressions for inland residents only. Finally, log-ferritin was the dependent variable in a predefined multiple regression model, mutually adjusting for ethnicity, age group, BMI and dietary habits. We used the SAS statistical software package version 9·1 (SAS Institute, Cary, NC, USA).

Results

Table 1 shows selected characteristics of the study participants. Sami affiliation was reported by 4932 participants (34 %) for whom s-ferritin was available. Almost 80 % of the individuals had BMI >24·9 kg/m². Obesity rates were somewhat higher in women than in men: 21·5 % $v.$ 17·4 %, respectively. Mean s-ferritin levels for men and women were 99 (95 % CI 97, 101) μg/l and 42 (95 % CI 41, 43) μg/l, respectively.

Twenty-one (0·30 %) men and twenty-two (0·29 %) women had CRP between 50 and 100 mg/l. In addition, seven (0·09 %) men and five (0·06 %) women had CRP > 100 mg/l. None of them had s-ferritin >300 μg/l. The linear association between CRP and s-ferritin was weak but

Table 1 Selected characteristics of the study sample (n 14 630)*

Characteristic	Women		Men	
	n	%	n	%
Age group (years)				
36–39	765	10·1	606	8·6
40–49	2068	27·4	1843	26·1
50–59	2270	30·0	2253	31·8
60–69	1539	20·4	1524	21·5
70–79	916	12·1	846	12·0
Ethnicity				
Sami I	845	11·2	817	11·5
Sami II	1623	21·5	1647	23·3
Non-Sami	5090	67·3	4608	65·2
BMI (kg/m²)				
<18·5	40	0·5	16	0·2
18·5–24·9	1851	24·5	1121	15·9
25·0–29·9	4030	53·5	4697	66·5
≥30·0	1618	21·5	1228	17·4
Dietary pattern				
Reindeer	370	5·8	376	6·4
Fish	980	15·2	705	11·9
Average	1404	21·9	1710	28·9
Fruit/vegetables	1667	26·0	700	11·8
Western/marine	1999	31·1	2422	41·0
Ethnicity by geographical area				
Sami (inland)	734	9·7	669	9·4
Sami (coastal)	1734	22·9	1795	24·4
Norwegian (inland)	769	10·2	678	9·6
Norwegian (coastal)	4321	57·2	3930	55·6

*Subgroups may not add up to 14 630 for all variables because of missing values.

significant ($r = 0·06$, $P < 0·0001$). Seven individuals had s-ferritin >1000 μg/l, but all had CRP < 10 mg/l.

Distribution of Fe stores

The mean s-ferritin level was significantly higher for men than for women, independent of ethnic affiliation. Levels by age group, ethnic and geographical categories (both sex) are presented in Table 2. Regardless of ethnicity, s-ferritin levels for men declined with advancing age, whereas they increased after the age of 50 years for women. There was a significantly higher s-ferritin concentration among inland participants compared with coastal residents (both sexes). For inland men, the Sami I group aged 36–49 years had a significantly higher mean s-ferritin than the Sami II group (Tukey–Kramer test). The Sami I group also had significantly higher mean s-ferritin than the non-Sami group (Tukey–Kramer test). Inland women older than 50 years in the Sami I group had significantly higher mean s-ferritin than the corresponding Sami II and non-Sami groups (Tukey–Kramer test). Table 3 shows mean s-ferritin by dietary patterns. The reindeer group had significant higher mean s-ferritin in both sexes when adjusted for age.

For the coastal settlements, there were no differences in mean s-ferritin between ethnic categories. Table 4 presents mean transferrin saturation by dietary patterns. Transferrin saturation showed less variation than s-ferritin both among men and women. Mean transferrin saturation in the reindeer group was slightly higher compared with

Table 2 s-Ferritin by geographical area and ethnicity for 14 630 participants in northern Norway: the SAMINOR survey

	s-Ferritin (μg/l)											
	Inland						Coastal					
	Sami I		Sami II		Non-Sami		Sami I		Sami II		Non-Sami		
	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	P value*
Men	(n 452)		(n 217)		(n 690)		(n 365)		(n 1430)		(n 4001)		
Age group (years)													
36–39	157	129, 191	129	106, 158	119	98, 145	121	93, 158	98	88, 109	111	105, 118	<0·0001
40–49	148	131, 169	117	98, 139	128	116, 141	100	79, 127	108	101, 115	107	103, 111	
50–59	136	121, 152	124	100, 154	122	110, 136	104	93, 116	108	101, 115	107	103, 111	
60–69	108	92, 126	109	77, 155	95	83, 107	79	67, 95	80	73, 88	87	83, 92	
70–79	88	67, 116	77	52, 114	70	60, 82	67	55, 81	66	58, 77	63	59, 69	
P value†	<0·0001		<0·0001		<0·0001		<0·0001		<0·0001		<0·0001		
Women	(n 516)		(n 218)		(n 793)		(n 329)		(n 1405)		(n 4457)		
Age group (years)													
36–39	30	23, 38	43	35, 52	26	21, 32	24	15, 38	26	23, 30	28	26, 30	0·0019
40–49	35	31, 40	28	23, 34	30	26, 34	25	21, 31	26	24, 29	26	25, 28	
50–59	61	53, 70	52	42, 65	49	44, 55	51	43, 60	51	47, 55	50	48, 52	
60–69	97	84, 111	74	57, 95	62	56, 69	72	60, 86	59	54, 65	61	58, 64	
70–79	79	63, 99	39	24, 65	56	47, 66	58	46, 73	46	41, 52	55	51, 59	
P value†	<0·0001		<0·0001		<0·0001		<0·0001		<0·0001		<0·0001		

s-Ferritin, serum ferritin.
*Test for differences between geographical areas adjusted for age and ethnicity.
†Test for differences between age groups.

Table 3 s-Ferritin by dietary pattern for 14 630 participants in northern Norway: the SAMINOR survey

| | s-Ferritin (μg/l) | | | | | | | | | | |
| | Reindeer | | Fish | | Average | | Fruit/vegetables | | Western/marine | | |
	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	P value*
Men	(n 376)		(n 705)		(n 1710)		(n 700)		(n 2422)		
Age group (years)											
36–39	169	140, 203	126	98, 160	108	97, 121	117	100, 137	114	105, 123	<0·0001
40–49	153	133, 175	112	99, 131	109	102, 116	104	95, 114	108	103, 114	
50–59	146	129, 164	113	102, 125	109	103, 117	109	99, 119	107	102, 112	
60–69	112	92, 135	80	73, 89	86	80, 94	94	84, 106	87	81, 94	
70–79	84	64, 108	76	66, 89	66	59, 73	68	56, 83	68	61, 76	
P value†	<0·0001		<0·0001		<0·0001		<0·0001		<0·0001		
Women	(n 370)		(n 980)		(n 1404)		(n 1667)		(n 1999)		
Age group (years)											
36–39	32	24, 44	30	23, 40	30	26, 34	28	25, 31	25	23, 28	<0·0001
40–49	36	30, 42	27	24, 31	25	23, 28	27	25, 30	27	25, 29	
50–59	61	51, 72	53	48, 57	50	46, 54	47	44, 51	51	48, 54	
60–69	103	88, 120	64	59, 70	64	58, 70	66	61, 72	57	53, 62	
70–79	77	56, 104	55	48, 61	54	48, 62	60	52, 66	50	45, 57	
P value†	<0·0001		<0·0001		<0·0001		<0·0001		<0·0001		

s-Ferritin, serum ferritin.
*Test for differences between dietary patterns adjusted for age.
†Test for differences between age groups.

that in the other dietary clusters in both sexes. Transferrin saturation decreased significantly with increasing age, especially among men in the reindeer group.

Fe levels influenced by dietary patterns

Table 5 presents the results from multiple linear regression analyses for the effects of age, ethnic groups, geographical residence, BMI and dietary patterns on s-ferritin, stratified by sex. In this model, all independent variables were mutually adjusted for each of the other variables, men and women separately. For both sexes living inland, the reindeer dietary subgroup, overweight ($25 \cdot 0$–$29 \cdot 0 \, kg/m^2$) and obesity ($\geqslant 30 \cdot 0 \, kg/m^2$) were positively associated with s-ferritin. s-Ferritin among obese individuals was 25 % higher in women ($\beta = 0 \cdot 22$) and 43 % higher in men ($\beta = 0 \cdot 31$), compared with the normal weight group ($18 \cdot 5$–$25 \cdot 0 \, kg/m^2$). In women, the Sami I group was positively associated with higher s-ferritin.

In a final model, all independent variables were mutually adjusted for each other; in addition, an interaction

Table 4 Transferrin saturation by dietary pattern for 14 630 participants in northern Norway: the SAMINOR survey

	Transferrin saturation (%)										
	Reindeer		Fish		Average		Fruit/vegetables		Western/marine		
	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	P value*
Men	(n 376)		(n 705)		(n 1710)		(n 700)		(n 2422)		
Age group (years)											
36–39	31	27, 34	27	22, 33	29	27, 31	31	27, 34	28	27, 29	<0·04
40–49	31	29, 33	29	27, 30	29	28, 30	30	28, 31	29	28, 30	
50–59	29	28, 31	31	29, 32	30	29, 31	30	28, 31	29	29, 30	
60–69	31	28, 34	29	28, 30	31	30, 32	30	29, 32	29	28, 30	
70–79	27	23, 30	29	27, 30	29	27, 30	30	28, 33	29	28, 31	
P value†	<0·0009		<0·08		<0·02		<0·04		<0·36		
Women	(n 370)		(n 980)		(n 1404)		(n 1667)		(n 1999)		
Age group (years)											
36–39	28	24, 32	26	21, 32	27	25, 29	24	23, 26	26	24, 27	<0·02
40–49	26	24, 28	26	24, 28	27	26, 28	26	25, 27	26	25, 27	
50–59	26	25, 28	27	26, 28	28	27, 29	27	26, 28	26	26, 27	
60–69	28	25, 32	27	26, 28	28	27, 29	27	26, 28	27	26, 28	
70–79	24	21, 26	28	27, 30	26	25, 28	27	25, 29	27	25, 28	
P value†	<0·34		<0·57		<0·12		<0·09		<0·67		

*Test for differences between dietary patterns adjusted for age.
†Test for differences between age groups.

Table 5 Effect of age, ethnicity, geographical area, BMI and dietary pattern on serum ferritin level: results from multiple linear regression analyses

	Women			Men		
	β Coefficient*	95 % CI	P value	β Coefficient*	95 % CI	P value
Age group (years)						
36–39	Ref.			Ref.		
40–49	−0·02	−0·09, 0·05	0·51	−0·01	−0·08, 0·06	0·75
50–59	0·58	0·51, 0·65	<0·0001	−0·03	−0·09, 0·04	0·44
60–69	0·79	0·71, 0·86	<0·0001	−0·25	−0·32, −0·19	<0·0001
70–79	0·62	0·54, 0·70	<0·0001	−0·51	−0·59, −0·44	<0·0001
Ethnic group						
Non-Sami	Ref.			Ref.		
Sami I	0·08	0·009, 0·15	0·03	0·006	−0·06, 0·06	0·98
Sami II	−0·03	−0·08, 0·01	0·18	−0·028	−0·07, 0·01	0·17
Geographical area						
Coastal	Ref.			Ref.		
Inland	0·05	0·002, 0·11	0·03	0·13	0·08, 0·17	<0·0001
BMI (kg/m²)						
18·5–25·0	Ref.			Ref.		
<18·5	0·03	−0·18, 0·24	0·78	0·04	−0·24, 0·31	0·80
25·0–29·0	0·07	0·03, 0·12	0·0005	0·16	0·12, 0·20	<0·0001
≥30·0	0·22	0·17, 0·27	<0·0001	0·31	0·26, 0·35	<0·0001
Dietary pattern						
Average	Ref.			Ref.		
Reindeer	0·17	0·06, 0·27	0·002	0·22	0·14, 0·31	<0·0001
Fish	0·03	−0·04, 0·09	0·41	0·02	−0·04, 0·08	0·51
Fruit/vegetables	0·002	−0·05, 0·05	0·95	0·013	−0·05, 0·07	0·67
Western/marine	−0·02	−0·07, 0·03	0·49	0·008	−0·03, 0·05	0·70

Ref., reference group.
*Mutually adjusted for each of the other variables, men and women separately.

term was included between the effects of ethnicity and geographical residence (Table 6). In this model, the positive association between s-ferritin and Sami I disappeared. Inland residence was, however, significant among men. Other lifestyle factors such as light/hard physical activity, and, in addition, for women the number of childbirths, were considered as confounders. However, they were not added to the model as they did not change the associations presented in Tables 5 and 6.

Discussion

In the present cross-sectional survey of the Sami and non-Sami population in northern Norway, we have observed an association between s-ferritin level and several lifestyle factors. Participants who frequently consumed reindeer meat and other reindeer products had higher levels of s-ferritin than did individuals with other dietary patterns. However, the reindeer pattern individuals

Table 6 Effect of age, ethnicity where interaction of geographical area is included, BMI and dietary pattern on serum ferritin level: results from multiple linear regression analyses

	Women			Men		
	β Coefficient*	95 % CI	P value	β Coefficient*	95 % CI	P value
Age group (years)						
36–39	Ref.			Ref.		
40–49	−0·02	−0·09, 0·05	0·52	−0·01	−0·07, 0·06	0·74
50–59	0·58	0·51, 0·65	<0·0001	−0·02	−0·09, 0·04	0·45
60–69	0·79	0·72, 0·87	<0·0001	−0·25	−0·32, −0·19	<0·0001
70–79	0·63	0·55, 0·71	<0·0001	−0·51	−0·59, −0·44	<0·0001
Ethnic group						
Non-Sami	Ref.			Ref.		
Sami I	0·01	−0·08, 0·10	0·83	−0·05	−0·12, 0·03	0·25
Sami II	−0·04	−0·089, 0·01	0·10	−0·02	−0·07, 0·02	0·28
Geographical area						
Coastal	Ref.			Ref.		
Inland	0·01	−0·05, 0·08	0·72	0·11	0·06, 0·17	<0·0001
Interaction term						
Sami I × inland	0·16	0·03, 0·30	0·02	0·10	−0·02, 0·22	0·09
Sami II × inland	0·08	−0·05, 0·22	0·23	−0·03	−0·15, 0·09	0·64
BMI (kg/m^2)						
18·5–25·0	Ref.			Ref.		
<18·5	0·03	−0·18, 0·24	0·80	0·04	−0·24, 0·31	0·79
25·0–29·0	0·07	0·03, 0·12	0·0004	0·16	0·12, 0·20	<0·0001
≥30·0	0·22	0·17, 0·27	<0·0001	0·31	0·26, 0·35	<0·0001
Dietary pattern						
Average	Ref.			Ref.		
Reindeer	0·13	0·02, 0·24	0·02	0·221	0·11, 0·30	<0·0001
Fish	0·03	−0·04, 0·09	0·42	0·02	−0·04, 0·08	0·50
Fruit/vegetables	0·002	−0·05, 0·05	0·93	0·013	−0·04, 0·07	0·63
Western/marine	−0·02	−0·07, 0·03	0·48	0·008	−0·03, 0·05	0·69

Ref., reference group.
*Mutually adjusted for each of the other variables, men and women separately.

also had the highest proportion of subjects with overweight and obesity.

In the SAMINOR survey, food consumption frequency was estimated, although the questionnaire did not cover the total diet. The questionnaire was not designed to cover the total diet but rather to gather information on the use of selected foods relevant for the northern area. The analyses of food patterns, rather than of single nutrients, are considered an alternative way to focus on diet and health outcomes, because nutrient intake could not be derived from the FFQ[12,13]. Brustad *et al.*[12] have published dietary pattern analyses from the SAMINOR survey, which showed that ethnicity did not play a major role in predicting dietary patterns, except for the reindeer group of foods in inland areas[11,14]. For coastal settlements, marine fish and different types of meat constitute primary nutritional sources for both ethnic groups. Dietary traditions are important markers for cultural identity. Because of changes in occupation among indigenous people, such as from primary trades to service professions, traditions are being altered that can affect dietary patterns. In addition, increased access to many different food products also establishes new food habits. These changes are global and are described, among others, by Kuhnlein *et al.*[15] for Arctic indigenous people in Canada. However, in inland areas in northern Norway, reindeer meat is easily accessible and has a high Fe content of 3·8 mg/

100 g wet weight[16]. Frequent use affects Fe levels. The present study showed that geographical residence, inland, had a significant influence in both sexes. Sami I women had significantly higher s-ferritin levels compared with the comparable groups. To examine interactions between ethnic groups and those living inland, interaction terms were created. The combined effect of both exposures is less than the combination of their separate effects, which means that it is unlikely that ethnicity is the explanation for higher s-ferritin levels. The causality is most probably explained by dietary habits, geographical settlement and BMI. It is therefore unlikely that genetic inheritance will explain the observed differences between ethnic groups.

Overweight and obesity had a significant effect on s-ferritin in both sexes. The study showed a high prevalence of overweight and obesity in the study population. The reindeer pattern had the highest proportion of subjects with overweight. A newly published article from the same series, the SAMINOR study, showed that both obesity and central obesity were most pronounced in Sami women, whereas the opposite was true for men[17]. General obesity among Sami women has been previously reported by Njølstad *et al.*[18] in 1998. However, data on the prevalence of metabolic syndrome in this population are not available at present, but can be a crucial confounding factor in this context. The metabolic syndrome

is a cluster of unfavourable health factors such as obesity, insulin resistance, dyslipidaemia and hypertension[19,20]. These core components are all metabolically related cardiovascular risk factors. Individuals with metabolic syndrome have an increased risk of developing athero-sclerosis and CVD. s-Apoferritin is a part of measured s-ferritin and is an acute-phase reactant protein elevated in infectious, inflammatory and malignant diseases. High levels of acute-phase reactants such as high-sensitivity CRP and Fe stores have been reported to correlate with metabolic syndrome[21,22]. The presumed reason is that inflammation plays a key role in the development of atherosclerosis. Obesity-related insulin resistance and inflammation are generally considered to be central elements in the pathogenesis of metabolic syndrome[23,24]. Elevated s-ferritin levels are also associated with increased diabetes mellitus risk among healthy individuals, where s-ferritin is an important and independent predictor of the development of diabetes[25].

Fe may contribute to the pathogenesis of type 2 diabetes mellitus by inducing oxidative stress and interfering with insulin secretion. Glucose and macronutrient intakes cause oxidative stress and inflammatory changes[23]. The increased concentrations of TNF-α and IL-6, associated with obesity and type 2 diabetes, might interfere with insulin action by suppressing insulin signal transduction. This might interfere with the anti-inflammatory effect of insulin, which in turn might promote inflammation[23]. Chronic overnutrition (obesity) might thus be a pro-inflammatory state with oxidative stress.

The pro-inflammatory state of obesity and metabolic syndrome originates with excessive energy intake and is probably a result of overnutrition leading to clinical and biochemical manifestations of the metabolic syndrome.

However, the study revealed a few participants with elevated CRP. Nevertheless, the reindeer pattern individuals continued to have significantly higher s-ferritin after including the interaction term as well. This was the case in both sexes, although overweight and obesity were not as pronounced among Sami men. Another factor that affects Fe levels is coffee consumption. A high rate of intake inhibits Fe absorption[8,26]. The habit of coffee consumption is prevalent among the Sami I group and reindeer pattern members, but it has no apparent negative association with s-ferritin. On the other hand, Nystad et al.[27] found that total coffee consumption in the same population was positively associated with total cholesterol levels. Dyslipidaemia may therefore be a confounding variable in this relationship.

Food patterns and health-related behaviours such as the level of physical activity may confound an association with s-ferritin. In a 1993–1994 Norwegian survey of the adult population, a quantitative FFQ was used to evaluate dietary habits and to relate these to other lifestyle factors[28]. That survey showed that daily total intakes of vitamins B_1 and B_2, Ca and Fe by men and women were higher among the youngest age groups compared with the older participants. In women, intakes of vitamin C was highest in the oldest age groups. However, regardless of age, women did not have adequate intakes of vitamin D and Fe. In another study conducted in 1996 of breast cancer among Norwegian female citizens, dietary habits were analysed on the basis of an FFQ involving approximately 10 000 women[29]. In addition, the study showed that older women did have a more vitamin C-rich diet than the younger participants. Although these surveys were national, they did not focus specifically on ethnic groups or geographical areas. A smaller study conducted among a Sami population living in traditional reindeer herding areas of northern Norway concluded that, traditionally, there is low consumption of fruit and vegetables among inhabitants of northern Norway, especially among the elderly[30]. However, the sample size was small.

Conclusion

The present study shows that there is an association between s-ferritin and lifestyle factors. High level of s-ferritin may reflect high intake of reindeer meat. However, no causal relationships between Fe stores and reindeer meat consumption can be inferred from the present study. The differences in Fe status described earlier between inland Sami and non-Sami can be explained by several factors such as food habits, age and obesity. Clearly, being overweight and obese are associated with s-ferritin levels. On the basis of our findings, additional analyses on metabolic syndrome and Fe overload in the present population should be carried out.

Acknowledgements

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