

A Comparison of Levels of Select Minerals in Scalp Hair Samples with Estimated Dietary Intakes of These Minerals in Women of Reproductive Age

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Abstract The objective of this study was to evaluate daily intake of minerals and concentrations of minerals in hair in women of reproductive age. The study included 77 menstruating women, aged 35.9 ± 9.7 years. Subjects were divided into three groups according to age. All women were healthy. Hair samples were taken from several points of the occipital scalp. The content of minerals in hair samples was determined by flame atomic absorption spectrometry. Dietary intake of the analysed minerals was assayed on the basis of dietary intake interviews from three preceding days and evaluated using the dietetic computer programme. It was shown that calcium and iron daily intake by the women was below the recommended value. Only few women had low concentrations (below reference values) of magnesium, copper and zinc in hair. Statistically significant differences were shown between age groups. Generally, the concentrations of minerals in hair in the younger (19–30 years) and the older women (41–50 years) were higher than in hair of middle-aged women (31–40 years). The content of calcium, magnesium, iron and zinc in daily diets of women correlated inversely with copper level in their hair. Food products with good bioavailability of iron and calcium should be recommended for women of childbearing age in all age groups.

Keywords Women · Minerals · Hair · Nutrition

Introduction

Women of child bearing age are at high risk of mineral deficiency, especially of iron. Iron deficiency is the most common nutrient deficiency in the developed countries. Low iron stores occur with relatively high frequencies in fertile women and with lower frequencies in postmenopausal women. Young women are at high risk because of the effects of menstruation and pregnancy [1, 2]. Osteoporosis is a significant source of morbidity for older women. However, it has been found that low calcium stores in premenopausal women expose them to the risk of development of this disease at an old age [3, 4].

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Some health disorders common in women are closely associated with mineral status in their organisms and with eating habits. Poor diet quality and low bioavailability of dietary minerals are important factors that contribute to iron deficiency. Low dietary intake of calcium could be involved in the pathogenesis of osteoporosis in women. Zinc, copper and magnesium disorders lead to metabolic diseases [5–7].

To assess mineral status of the organism, mineral concentrations are determined in various biological materials (e.g. serum, urine). Some authors believe that head hair may be a good mineral body biomarker and it provides retrospective information on the exposure and nutritional status of individuals, making it possible to trace nutrient intake [8].

Wójciak et al. [5] are of the opinion that the first inch of hair closest to the scalp can give a good indication of the nutrient mineral exposure over the previous 6–8 weeks. It is assumed that trace elements in hair reflect trace elements in organs or important body pools. The studies of other authors showed that copper in hair correlates significantly with copper in the liver, heart and kidneys. Similarly, zinc in hair correlates significantly with zinc in bones [9]. Song et al. [10] reported an association of serum and hair levels of calcium and magnesium with bone density in premenopausal women.

The objective of this study was to evaluate daily intake of minerals and concentrations of minerals in hair in reproductive age women.

Subjects and Methods

Subjects

The study protocol was approved by the Bioethics Commission at the Poznan University of Medical Sciences—bioethics commission approval no. 07/08.

The study was carried out on 77 menstruating women, aged 35.9 ± 9.7 years. Subjects were divided into three groups according to their age. All women were healthy. Obese and smoking women were excluded from this study. Some of the subjects (40%) suffered from hypermenorrhoea. About 30% of the women took oral contraceptives. Before the study, participants were asked to restrain from mineral supplementation. Most of the women (60%) gave birth to at least one child. The full characteristics for the subjects are presented in Table 1. All subjects were informed about the study aim, procedures and measurement methods, and the individual consent of each patient was obtained.

Table 1 Characteristics of women participating in the study

Parameter	All ($n=77$)	Age 19–30 ($n=28$)	Age 31–40 ($n=25$)	Age 41–50 ($n=24$)
Age (years)	35.9 ± 9.7	24.2 ± 4.3	34.8 ± 5.2	44.8 ± 4.6
BMI (kg/m^2)	23.9 ± 3.5	20.9 ± 2.1	24.2 ± 4.6	25.2 ± 3.8
Hypermenorrhoea (% of subjects)	39.5	32.0	29.0	58.0
Oral contraceptive (% of subjects) (for at least 3 months)	28.6	39.0	36.0	8.0
Mineral supplementation (% of subjects) (for at least 3 months)	0	0	0	0
Births (% of subjects)	59.7	18.0	76.0	92.0

Anthropometric Assessment

Anthropometric measurements of individuals wearing light clothing and no shoes were conducted. Weight was measured to the nearest 0.1 kg, and height was measured to the nearest 0.1 cm. BMI was calculated by dividing weight (kilogrammes) by height squared (square metre).

Dietary Assessment

Dietary intake of the analysed minerals was assayed on the basis of dietary intake interviews from three preceding days (3×24 -h recall) developed by the National Food and Nutrition Institute [11]. Dietary interviews were taken in the middle of the menstrual cycle. The amount of minerals in the daily diet was processed and evaluated using the dietetic computer programme.

Biochemical Assay

Hair samples (1 cm from the scalp; ~ 0.5 g) taken from six points of the occipital scalp were collected from each individual. Samples were washed in acetone, deionised water and acetone, then dried to constant weight at 105°C , and subsequently mineralized in a mixture of concentrated nitric (65%) and perchloric (60%) acids (suprapure, Merck) (v/v 1:1) in the MW oven (Milestone). Calcium, magnesium, iron, copper and zinc concentrations were assayed in each hair sample.

Contents of minerals in hair samples were determined by flame atomic absorption spectrometry (a Zeiss AAS-3 spectrometer with deuterium background correction). The accuracy of the method was verified by certified reference material. It amounted to 95%, 99%, 94%, 99% and 102% for Ca, Mg, Fe, Zn and Cu, respectively. Reference values for the contents of hair minerals were established on the basis of published data [5].

Statistical Analysis

Data were analysed using Statistica 6.0 (StatSoft). The key descriptive parameters, i.e. arithmetic mean, standard deviation and median, were calculated. Mann–Whitney's test was used to establish the significance of differences between groups for independent variables. Statistical correlations between parameters were analysed by Spearman's correlation test. A p value of less than 0.05 was considered statistically significant.

Results

The results obtained in this study are presented in Tables 2 and 3. Table 2 shows that the contents of calcium and iron in the daily food rations (DFR) of each studied group were inadequate. However, the intake of minerals with DFR by women aged 41–50 years was the highest. An extremely low intake of iron (slightly above 50% of recommended daily allowance (RDA)) was recorded in younger women (19–30 years). There were no statistically significant differences in DFR minerals content between age groups.

Mean hair calcium, magnesium, iron, copper and zinc contents were within (Fe, Cu) or above (Ca, Mg, Zn) reference ranges (Table 3). Only few women had low concentrations (below reference values) of magnesium, iron, copper and zinc in hair. Statistically

Table 2 Contents of minerals in DFR of women in terms of their age

Parameter	Ca (mg/person/day)	Mg	Fe	Cu	Zn
Age 19–30 (<i>n</i> =28)					
Mean±SD	751 ±251	291±74.6	9.7±2.66	1.09±0.3	8.61±2.27
Median	778	294	9.23	1.06	8.62
Min–max	244–1,171	146–443	5.11–14.9	0.60–1.84	4.47–12.7
% Realization of norm ^a	75.1	93.9	53.9	121.1	107.6
Age 31–40 (<i>n</i> =25)					
Mean±SD	780±287	298±85.1	10.1±3.01	1.09±0.29	9.17±2.65
Median	814	277	9.46	1.03	8.85
Min–max	291–1,288	151–461	6.45–18.0	0.66–1.82	4.6–15.9
% Realization of norm	78.0	93.1	56.1	121.1	114.6
Age 41–50 (<i>n</i> =24)					
Mean±SD	818±337	321±70.5	10.5±1.34	1.22±0.21	9.92±1.98
Median	866	310	10.8	1.29	9.63
Min–max	444–1,688	215–452	7.3–12.3	0.88–1.55	6.81–14.4
% Realization of norm	81.8	100.3	58.3	135.6	124.0

mean arithmetic mean, SD standard deviation, min minimum, max maximum

^a Allowances according to Jarosz and Bulhak-Jachymczyk [39]; Ca, % AI, Mg, Fe, Zn and Cu, % RDA

Table 3 The content of selected minerals in hair of women in terms of their age

Parameter	Ca (µg/g)	Mg (µg/g)	Fe (µg/g)	Cu (µg/g)	Zn (µg/g)
Age 19–30 (<i>n</i> =28)					
Mean±SD	1,989±855	110±52.4	22.1±10.5	25.8±19.4	257.0±87.8
Median	1,735b	87.8ab	20.4b	17.5b	232b
Min–max	819–3,932	56.9–223	8.11–53.7	7.60–67.7	152–450
<RV (% of subjects)	0	0	4	7	7
Age 31–40 (<i>n</i> =25)					
Mean±SD	1,400±627	102±43.7	12.3±10.9	12.9±5.43	219.0±28.7
Median	1,180a	76.5a	11.8a	13.5a	198a
Min–max	914–2,108	56.8–167	7.20–25.2	7.17–17.9	102–289
<RV (% of subjects)	0	0	10	10	20
Age 41–50 (<i>n</i> =24)					
Mean±SD	1,713±1,044	128±61.1	16.8±8.21	17.6±4.15	249±83.9
Median	1348ab	133b	15.5ab	16.6b	255b
Min–max	909–3,247	37.4–208	9.95–27.5	13.9–23.7	149–335
<RV (% of subjects)	0	7	7	0	7

Significant correlation between Cu in hair and minerals in DFR: Cu–Fe, $R=-0.35$; Cu–Zn, $R=-0.35$; Cu–Ca, $R=-0.43$; Cu–Mg, $R=-0.50$. The letters a, b denote significant differences between age groups $p<0.05$, Mann–Whitney's test

RV reference values [5] Ca, 400–1,000 µg/g; Mg, 40–60 µg/g; Fe, 10–20 µg/g; Cu, 10–20 µg/g; Zn, 160–200 µg/g

significant differences were shown between age groups (Table 3). Generally, the concentrations of minerals in hair of the younger (19–30 years) and the older women (41–50 years) were higher than in hair of middle-aged women (31–40 years). Women aged 31–40 years had significantly lower calcium and iron levels in hair than women aged 19–30 years. Moreover, copper and zinc in hair of women between 31 and 40 years of age were markedly lower in comparison with the other groups. The concentration of magnesium in hair of women aged 19–30 years was significantly lower than in women aged 41–50 years. It was also found that a relatively high percentage of middle-aged women had concentrations of iron (10%), copper (10%) and zinc (20%) in hair below reference values.

A significant relationship was observed between copper in hair and other minerals in DFR (Table 3). The contents of calcium, magnesium, iron and zinc in daily diets of women correlated inversely with copper level in hair of women.

Discussion

Studies conducted worldwide reported that women of reproductive age consumed low amounts of calcium, magnesium and iron.

In some studied populations, over 60% of women had calcium intakes lower than 200 mg per day [12, 13]. The results of a study by Islam et al. [12] suggested that a low calcium intake could reduce bone accretion rates and increase the risk of osteoporosis in women aged 16–40 years. In this study, it was also observed that daily supply of calcium in women was below the recommended value. The National Health and Nutrition Survey reported that young women consumed approximately 75% of the recommended calcium amount of 1,000 mg/day. Both in the United States and in Poland in young women the largest and most frequently consumed calcium sources are milk and dairy products [14, 15]. In addition, the use of oral contraceptives (OC) may decrease calcium level in the organism. National, population-based data showed lower bone mass density (BMD) in premenopausal women who have used OC as compared with those who have never used OC [16]. Low BMD indicates osteoporosis that is often caused by a low calcium intake. The studies showed that a low magnesium level in the serum is also correlated with low bone mass density [6].

Iron deficiency is also common among women at reproductive age [17, 18]. Ortega et al. [19], Shams et al. [20] and Haidar [21] observed that female adolescents are a group susceptible to anemia and micronutrient (especially iron) deficiencies. Kabir et al. [22] showed that the prevalence of anemia among adolescent girls was 23%, and their habitual dietary pattern indicated poor consumption of iron-rich foods. In the Polish study, it was also found that dietary supply of iron in female students was below the recommended intake (only 47–65% RDA) [13, 15]. For comparison in this study, iron content in the diet of women ranged from 54% to 58% of the recommended value.

Analyses of Backstrand [18] showed that a better iron status was associated with higher intakes of non-heme iron, ascorbic acid and foods that contain ascorbic acid. The low bioavailability of iron from diets in developing and industrialized countries is an additional problem influencing poor iron availability and body iron stores and contributing to an increased risk of iron deficiency anemia among female populations [23]. The most important sources of dietary iron are foods that are rich in highly bioavailable forms of iron (supplemental iron and red meat) and fruit promoting high iron stores [24]. In other studies, it was observed that polyphenols and phytic acid in food decreased iron

bioavailability in young women, while lowering the level of inhibitors in the diet increased iron absorption [25].

A study of Chandyo [26] indicated that there was a high prevalence of zinc deficiency in women of reproductive age in Nepal. Moreover, the above-mentioned authors showed that foods rich in zinc contain also phytate, which reduces zinc absorption. Gibson and Huddle [27] showed that zinc deficiency in women is associated with low intakes of poorly available zinc. Yokoi et al. [28] found that premenopausal hypozincemic women had higher hair Zn concentrations than the normozincemic women. Those authors explained that in adults' hair, Zn was increased by Zn deprivation. In this study, no relationship was observed between the supply of zinc and zinc level in hair.

The concentration of minerals in hair of young women found in this study corresponded with the literature data [29]; however, in older women these data were slightly higher than the results reported by Skalnaya and Demidov [30] and Suliburska et al. [31]. Interestingly, markedly higher concentrations of copper and markedly lower levels of zinc were observed in hair of women from India [32].

There are only few data on hair mineral analyses in women and their correlation with dietary intake. In this study, no association was found between mineral intake and their content in hair of women. It may be caused by the fact that mineral contents in hair reflect the nutritional status of the organism over a longer period of time (about 6–8 weeks), while the data on consumption were collected in the middle of the menstrual cycle (3 days).

What is more, some authors did not confirm any relationship between hair concentration of minerals and their daily intake in adult subjects. Lahti-Koski et al. [1] found that food consumption was poorly associated with iron status [1]. Gonzalez-Munoz et al. [33] did not observe any correlation between trace element intakes and their corresponding levels in hair [33]. However, other studies showed that hair mineral content reflects exposure of elements from the diet [34].

Interestingly, a significant negative correlation was found between copper in hair and other minerals in daily food rations. The negative correlation between copper in hair and the intake of other elements, demonstrated in this study, is probably due to the interaction between the minerals. These interactions occur at the stage of their absorption and transport. Copper is essential for iron transport between tissues [35]. It was found that the intake of zinc affects copper status. The zinc–copper interaction probably takes place at the absorption level [35].

Other studies showed that the concentrations of zinc and copper in hair were lower in patients with iron deficiency anemia [36]. In this study, the lowest concentration of zinc and copper was recorded in hair of women aged between 31 and 40 years. It was found that the intake of iron was very low in all women, and it is possible that iron deficit in the organism could increase with age, especially in pregnant and breastfeeding women.

Wlazlak et al. [37] found that hair copper concentration in perimenopausal women decreases with age. This study did not completely confirm this conclusion; however, these data showed that the arithmetic average of copper content in hair in women under 30 was higher than in older women (Table 3).

Deeming and Weber [38] showed that mean hair copper level decreased and mean hair zinc content increased with oral contraceptive use in women. In this study, a large proportion of women aged 31–40 years took oral contraceptives, and it was observed that hair copper level was the lowest in this age group as compared with other groups of women.

For an appropriate functioning of the organism, not only contents of minerals are important, but also appropriate proportions between them. Proportions between copper and

zinc in the body are particularly important, since antagonistic interactions occur between them. In this study, the highest mean contents of copper and zinc were recorded in the group of the youngest women, in which the highest mean copper to zinc ratio was found (Cu to Zn=0.075). With age, the contents of copper and zinc in hair of women decreased, but the reduction of copper content was much higher than that of zinc, in women aged 31–40 years the Cu to Zn ratio was 0.068 and it was similar to the value of the copper to zinc ratio in the oldest women (Cu to Zn=0.065).

The reduction of copper and zinc levels in women aged 31–40 years was most probably a consequence of the fact that at present women most frequently in that decade of their lives become pregnant, they also frequently use contraceptives. These elements play a very important role in the development of the embryo and readily penetrate the placenta, as a result of which their content in the organism of the mother decreases. Moreover, as it was already mentioned, copper content in hair decreases, while zinc content increases as a result of the administration of contraceptives. The reduction of copper content in relation to zinc in hair of women in the second and third age groups could have resulted from the more rapid changes in the state of nutrition of the organism with copper and secondly, also from the antagonism between elements, e.g. at the stage of absorption.

Conclusions

1. The intake of calcium and iron is markedly below the recommended value in women of reproductive age.
2. The concentration of minerals in hair of women is associated with age. The lowest content of analysed minerals is found in women between 31 and 40 years.
3. The content of copper in hair inversely correlates with the daily intake of calcium, magnesium, iron and zinc in women.
4. Food products with good bioavailability of calcium and iron should be recommended for women of childbearing age in all age groups.

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