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The Selenium Levels of Mothers and Their Neonates Using Hair, Breast Milk, Meconium, and Maternal and Umbilical Cord Blood in Van Basin

Mother 0.330
30 < baby 1.124

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Abstract The objective of the present study is to calculate linear regressions between a mother and her child with respect to their selenium concentration (ng/g) in the following traits: maternal blood and umbilical cord blood, maternal and child hair, maternal milk and child umbilical cord blood, maternal milk and meconium, maternal blood plasma, and child meconium. The data were collected at Research Hospital of the University of Yüzüncü Yıl from 30 pairs of mothers and their newborn baby. The mean maternal serum Se level in 30 mothers was 68.52±3.57 ng/g and cord plasma level was 119.90±18.08 ng/g. The Se concentration in maternal and neonatal hair was 330.84±39.03 and 1,124.76±186.84 ng/g, respectively. The Se concentration of maternal milk at day 14 after delivery was determined as 68.63±7.78 ng/g (n=13) and the concentration of Se was 418.90±45.49 ng/g (n=22) for meconium of neonatal. There was no significant difference between maternal blood and milk Se levels. However, hair Se concentration was significantly higher than milk and maternal blood Se level. For each trait comparison, the average absolute difference in $\log_{10}$-transformed Se concentration was calculated between a mother and her child. The observed

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average absolute difference was compared with a test distribution of 1,000 resampled bootstrap averages where the number of samples was maintained but the relationship between a mother and her child was randomized among samples (α=0.05).

Keywords Fetal · Hair · Maternal · Meconium · Milk · Se · Umbilical cord (UC)

Introduction

It is well known that physiological, metabolic, and hormonal changes during pregnancy affect the metabolic and bodily needs for micronutrients and minerals [1].

Selenium plays an important role in maintaining the integrity of the cell and the organelles within the cell and may facilitate, through these mechanisms, to protect the early fetus from mortality caused by oxidative damage [2]. It has been reported that the concentration of Se in maternal and fetal liver and in whole blood and serum are highly correlated [3]. Selenium is generally recognized to be a trace mineral of great importance for human health, which protects our cells from the harmful effects of rancidity [4].

Newborn offspring of dams with insufficient mineral intake during pregnancy have low body reserves and are susceptible to trace mineral deficiencies in early life [5]. For example, Se supplementation of cows during the last 60 days of gestation not only greatly increases endogenous Se reserves of newborn calves but also results in the improved Se status being still present in calves at 42 days of age [6]. The mechanisms that control nutrient utilization during pregnancy are not well defined [2]. Similar results have been reported in chickens where maternally Se-supplemented diets affected progeny Se concentration in tissues until 28 days [7] after hatching.

There is increasing evidence that Se is vital for fetal and neonatal development. This is emphatically demonstrated by the embryonically lethal consequences of disruption of the gene coding for the Sec $tRNA^{[Ser]Sec}$, suggesting an essential function for one or more selenoproteins in development [8]. Likewise, disruption of the mouse thioredoxin gene is lethal to the early embryo [9]. During embryogenesis in the zebrafish, 21 selenoprotein genes are expressed in a defined spatial and temporal pattern, indicating tissue-specific roles at particular developmental stages [10]. It is notable that mutant mice deficient in the Se transport protein, selenoprotein P, exhibit a disturbed Se distribution, reduced activities of selenoenzymes, and defects in growth and motor coordination and that these consequences can be prevented in the neonates by supplementing their nursing mothers with selenite [11]. Low plasma Se levels were associated with increased risk of fetal death, neonatal death, and HIV transmission through the intrapartum route. Low Se status was not associated with risks of low birth weight or preterm birth and was associated with an apparently lower risk of small size for gestational age [12].

The human infant is born with Se reserves but also depends on the Se supplied by maternally derived breast milk. Thus, human milk is fundamental for an infant's optimum Se status [13]. In mammals, maternal Se deficiency induces oxidative stress in the fetus, as measured by increased generation of lipid peroxides in the fetal liver [14], and also impairs the development of the neonatal immune system [15]. Consequently, the importance of Se in the nutrition of the human infant is gaining wide acceptance [13].

Although some research results reveal that supplementary Se in the maternal diet readily elevates the Se status of domestic chickens [7, 16, 17], few studies measure the relationship between normal healthy maternal and fetal tissues in human subjects [18, 19]. The object of the present study was to measure Se concentration in the maternal and newborn tissues in

Van Basin and test for direct associations between lifestyle and pregnancy-related traits and Se concentration in the maternal plasma. In addition, we tested for correlations between a mother and her neonate with respect to their Se concentration (ng/ml) in the following traits: maternal and newborn blood plasma, maternal and newborn hair, maternal milk and newborn blood plasma, maternal milk and child meconium, and maternal blood plasma and neonatal meconium).

Materials and Methods

Twenty-nine pairs of mothers and their newborns (delivered at term ≥37 completed weeks of gestation) were recruited at the Hospital of Research in Van after all mothers had signed informed consent releases. The study was in accordance with the ethical standards of the Helsinki Declaration of 1975 as revised in 1983 and was approved by the Ethics Committee at the University of Yüzüncü Yıl Hospital of Research in Van. All mothers and their newborn babies participating in the study were treated according to standard delivery room and newborn nursery protocols. After delivery, we collected information on the gender, length, and weight of the baby.

A standardized questionnaire was administered to the mothers by the same observer prospectively on the day after delivery. Survey information included age at delivery, number of pregnancies, socioeconomic status (below, average, or above local socioeconomic standards), education status (did not complete school, completed school, completed higher education), lifestyle habits (daily consumption of tea, local cheese, and dried fish; number of cigarettes smoked; and vitamin supplementation). Mothers were classified as "smokers" if they smoked at least one cigarette a day; mothers are considered to be "tea drinkers" if they drank at least one cup of tea daily throughout the pregnancy. None of the mothers consumed alcohol or coffee during pregnancy.

Sampling

Only healthy mothers (and their babies) who delivered normally satisfied the sampling protocol. Blood samples from mothers and their babies (umbilical cord blood) were collected for measurement of serum Se concentration. Mixed venous–arterial cord blood was collected in glass tubes at delivery. Maternal blood samples were collected as soon as possible after delivery. Blood samples were centrifuged (3,000 rpm; 10 min) and plasma was removed and stored at −20°C until analysis. Hair strands of mothers and babies were collected after delivery and stored until analyses. Milk samples from mothers were collected on the 14th day after delivery and stored in −20°C until analysis. Meconium was collected during the first two postnatal days and pooled into one sample and frozen at −20°C until analysis.

Laboratory Analyses

Selenium concentration was determined using hydride generation atomic fluorescence spectroscopy of the acid digest of the samples followed [20]. The method used a hydride generator, a fluorescence detector (Model 10-033, PS Analytical Ltd., Kent, UK) fitted with a boosted discharge hollow cathode lamp (Superlamp Se, Photon, PTY Ltd., Australia), an autosampler (Model 20-099, PS Analytical Ltd., Kent, UK), and Avalon™ Software (PS Analytical Ltd., Kent, UK). Concentrations in the samples were calculated from the linear relationship (r^2=0.999) obtained using sodium selenite standards.

Statistical Analyses

We used generalized linear mixed models (controlling for the Se plasma concentration of the mother) to explore the relationship between the neonate plasma Se concentration and 11 variables pertaining to the health and environmental conditions of the mother.

We calculated the average paired absolute differences and linear regressions in $\log_{10}$-transformed Se concentration between a mother and her newborn in the following traits: maternal and infant blood plasma, maternal and infant hair, maternal milk and infant blood plasma, maternal milk and infant meconium, and maternal blood plasma and infant meconium. The observed average paired absolute differences and regression slopes were compared with test distributions from 1,000 resampled bootstrap averages and slopes where the number of samples were maintained, but the relationship between a mother and her newborn was randomized among samples (α=0.05).

All Se concentrations were $\log_{10}$-transformed for analysis. Statistical calculations were performed in SAS v8.0 and the bootstrap resampling test was written in the Interactive Matrix Language Proc IML (http://www.sas.com/technologies analytics/statistics).

Results

This study was conducted on a group of healthy Turkish women in the city of Van, who give birth to healthy neonates through normal vaginal delivery. The mean age of the pregnant women was 26.4±2.1 years and the mean birth weight of neonates was 3.12± 0.10 kg. The length of the babies was 49.53±0.42 cm. For 34.5% of the mothers, it was their first delivery, and for 48.0% it was their fourth or more delivery. Furthermore, 31% of the mothers kept smoking during pregnancy, and 62.1% continued to consume more than three cups of tea per day. Only 10.3% of the mothers had above-average socioeconomic status, whereas 44.8% were below average. Significant Spearman correlation coefficients (α=0.05) between maternal traits (Table 1) included negative associations between the number of deliveries and a mother's socioeconomic status and her daily consumption of dried fish. Mothers of higher education status were also generally of a higher

Table 1 Correlations Coefficients Between Maternal Traits Ascertained from a Standardized Questionnaire Administered to Mothers Prospectively after Delivery

	Pregnancy	Status		Lifestyle habits				
	No. of deliveries	Socioeconomic	Education	Smoking	Tea drinking	Vitamin supplements	Local cheese	Dried fish
No. of deliveries		−0.224	**−0.400**	0.060	−0.178	0.126	−0.240	**−0.426**
Socioeconomic			**0.599**	0.000	0.206	0.076	0.171	0.450
Education				0.288	0.291	0.148	−0.243	0.208
Smoking					−0.173	−0.165	**−0.515**	0.032
Tea drinking						0.204	−0.012	−0.057
Vitamin supplements							0.130	−0.057
Local cheese								0.283

Highlighted traits are significantly correlated (α=0.05).

socioeconomic status. Mothers who smoked during pregnancy had a lower average daily consumption of local cheese. We note that, because of the small sample of mothers (n=25) using a sequential Bonferroni test to control for the large number of correlation tests (n=28), none of the correlations was statistically significant.

While the mother's plasma Se concentration was controlled, neonate plasma Se was significantly correlated with mother's plasma Se (r=0.578, n=25, P=0.002). Neonate plasma Se was significantly higher in babies whose mothers had a low daily consumption of dried fish (estimate=0.198±0.08, t=2.38, P=0.028) but was not significantly associated with the following: mother's age (estimate=0.128±0.39, t=0.32, P=0.750), method of delivery ($F_{5,\ 18}$=0.83, P=0.545; estimate=0.010±0.02, t=0.47, P=0.644), mother's socioeconomic status ($F_{2,\ 21}$=1.01, P=0.382), level of mother's education ($F_{2,\ 21}$=1.03, P=0.375), the mother smoking during pregnancy (estimate=−0.021±0.09, t=0.22, P=0.827), daily tea consumption during the pregnancy (estimate=0.140±0.10, t=1.40, P=0.176), vitamin supplementation during pregnancy (estimate=−0.001±0.08, t=−0.01, P=0.995), level of daily cheese consumption during pregnancy (estimate=0.053±0.04, t=1.21, P=0.238), neonate gender (male c.f. female; estimate=0.079±0.08, t=0.97, P=0.345), neonate length (estimate=2.310±3.54, t=0.65, P=0.527), or neonate weight (estimate=0.12± 0.93, t=0.13, P=0.895).

The average maternal serum plasma Se level in 30 mothers was 68.52±3.57 ng/g compared with an average fetus cord plasma Se level of 119.90±18.08 ng/g. The Se concentration in mother and neonatal hair was 330.84±39.03 ng/g and 1,124.76± 186.84 ng/g respectively. In both cases, the fetal concentrations are significantly positively related to the maternal concentrations (Fig. 1; Table 2). In addition, the fetal concentrations ($\log_{10}$-transformed) are statistically greater (unpaired differences) than the maternal concentrations (unequal variance t test: plasma t_{53}=2.71, P=0.009; hair t_{38}=6.22, $P<$ 0.001). The Se concentration of maternal milk 14 days after delivery (n=13) was 68.63± 7.78 ng/g and the concentration of fetus meconium Se after delivery (n=22) was 418.90± 45.49 ng/g (Table 1).

The average paired differences in Se concentrations between a mother and her newborn infant were significantly greater in the infant cord plasma (c.f., maternal serum plasma), infant hair (c.f., maternal hair), infant cord plasma (c.f., maternal milk), and infant meconium (c.f., maternal serum plasma) but not infant meconium compared with maternal breast milk (Table 2). Observed positive relationships between infant Se concentrations and maternal Se concentrations were significantly greater than expected by chance (from a bootstrap distribution of 1,000 resampled regression slopes) for infant cord plasma and maternal serum plasma, infant hair and maternal hair, and infant cord plasma and maternal milk (Table 2).

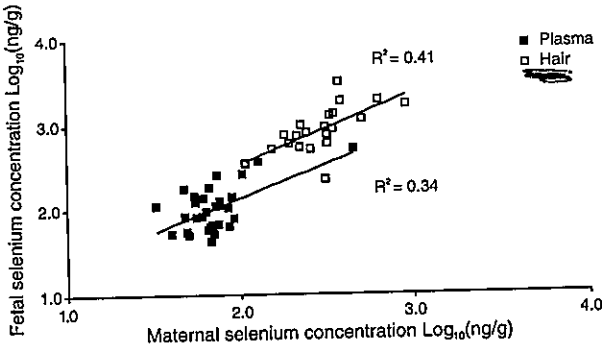

Fig. 1 Bivariate relationships in $\log_{10}$-transformed Se concentration (ng/g) of paired maternal and fetal plasma and hair (see Table 2 for linear model statistics and available sample sizes)

Table 2 Summary Statistics for the Bootstrap Resample Tests of the Average Absolute Paired Differences between Se Concentrations (ng/g), and Linear Regressions among Mother and Child for 37 Different Human Pairs Across Five Independent Trait Comparisons

Maternal trait	Average Se concentration (ng/g)	Fetal trait	Average Se concentration (ng/g)	Sample size (n)	Average paired differences ± SE	Paired t test [a]	Regression slope ± SE	R-square	Bootstrap significance level [b]
Blood plasma	68.5±3.6	Umbilical cord blood plasma	119.9±18.1	30	52.3±10.3	4.08 ***	0.79±0.21	0.34	***
Hair	330.8±39.0	Hair	1,124.8±186.8	21	695.3±130.2	5.50 ***	0.86±0.24	0.41	**
Breast milk	68.6±7.8	Excreta	418.9±45.9	9	286.8±68.2	2.37 *	1.34±0.42	0.63	*
Breast milk	68.6±7.8	Umbilical cord blood plasma	119.9±18.1	12	114.5±39.3	1.52	−0.02±0.24	0.01	
Blood plasma	68.5±3.6	Excreta	418.9±45.9	18	347.5±53.5	8.10 ***	0.16±0.30	0.02	

Not all samples were available for all comparisons (see "Materials and Methods").

*P<0.05; **P<0.01; *** P<0.001

[a] Significance levels for paired t tests of the average differences in Se concentration (H_0: $\mu_1=\mu_2$; $\alpha=0.05$)

[b] Significance levels for the observed regression slopes between fetal Se concentration and maternal Se concentration compared with a distribution of 1000 bootstrap regression slopes (H_0: $\beta_0=0$; $\alpha=0.05$)

Discussion

Our results are the first to report maternal plasma and infant cord blood Se level from Van Basin. The average concentration of Se in the maternal blood was 68.5 ng/ml (Table 2). This value is similar to previously reported values from [21, 22] Arctic Canada [23] and for five communities from Norway [24]. Interestingly, however, our values are much greater than those reported for another study of Se in mothers in Kayseri, Turkey [18], which ranged from 23.22 to 53.86 ng/ml with a mean value of 35.14±6.71 ng/ml.

The average Se concentration in umbilical cord blood was 119.9 ng/ml (Table 2). Our data are 1.38-fold higher than the results of Lorenzo-Alonso et al. [20] who reported a range between 51.1 and 104.2 µg/l (mean of 76.3±6.5 µg/l) from the volunteers at the University Clinic Hospital of Santiago de Compostela. Umbilical cord plasma concentrations of Se were also significantly greater than the maternal serum plasma concentration. These results contradict previous findings that infant cord plasma Se concentration is lower than maternal plasma concentration [18, 19, 21, 22, 25–28]. However, we cannot be sure if the high concentration of Se in the umbilical cord results from pleasant stocks and if that maintains constant levels in the fetus via the umbilical cord vein [29]. However, our Se concentrations of umbilical cord plasma values were very close to the previously published mean value of 139±14 ng/ml (range 112–147 ng/ml) for cord blood collected in San Diego, California [30].

The average breast milk concentration of Se was 68.63 ng/ml. The mean Se concentration from studies with maternal intake of Se from natural foods is 26, 18, 15, and 17 µg/l for colostrum (0–5 days), transitional milk (6–21 days), mature milk (1–3 months), and late lactation (>5 months), respectively [13]. For a maternal mean Se intake meeting 100% of the recommended daily allowance, mean milk Se concentration was 14.06 ng/ml (range 10.0–24.7 ng/ml) according to reports by Bianchi et al. 1999 [31]. The Se level in milk was reported as 10.24±2.82 ng/ml in Poland by Zachara and Pilecki [32].

It is clear that our results are higher than the mean Se concentration of breast milk reported in studies conducted in other parts of the world. It is known that human infants are born with Se reserves but also depend on the Se concentration of the human milk. Thus, Se-rich human milk is fundamental for the infant optimum Se concentration. Similar results for breast milk Se levels were by Brätter et al. [33] who found 42–56.6 µg Se per liter of milk at 20–24 days of lactation in Venezuela. Other reports give an average of 18 µg/l for mothers who live in South Arabia [34], while in Niger [35] and for China 8.4 µg/l [36]. It could be that dietary habits of women in the Van Basin might influence Se status and modulate breast milk Se. This is attributed in particular to their high consumption of meat and canned Van fish. Because of the long winter, they consume less vegetables; the cheapest food (moderate economical status) for them is meat, milk, herbal Van cheese, and wheat products. This might be the reason for the high concentration of Se in breast milk. Future research should examine the Se concentration in the most common foods consumed in Van.

The levels of Se in hair of the mothers and newborns were 330.84±39.03 and 1124.76± 186.84 ng/g, respectively, and newborn hair had significantly high concentration of Se compared (3.39-fold) to maternal hair. Similar results have been reported by Lorenzo-Alonso et al. [20] and in their study newborn baby's hair Se concentration (1.04±0.48 µg/g) is higher than maternal hair Se (0.60±0.37 µg/g) concentration by about 1.73-fold, which is almost half of our results. It has been reported that measurements of Se content in hair offers a long-term marker, and hair has been shown to be a major vehicle for excretion of toxic metals and the concentration of metals in hair is up to tenfold higher than the levels

found in blood samples [21]. In our results, baby hair's Se concentration was tenfold the maternal hair Se concentration and 4.79-fold higher than blood Se level.

The Se concentration in the meconium of newborn was determined in this study. It is known that meconium is the first fecal matter passed by a neonate. It begins to form between the 12th and 16th week of gestation and usually accumulates thereafter until birth [37]. As the content of meconium provides a history of fetal swallowing and bile excretion, we therefore thought that a more accurate history of Se accumulation during pregnancy will be determined by the meconium. The Se concentration of meconium was 418.90±45.90 and 2.68-fold less than the Se concentration of baby hair.

The average observed absolute difference in Se concentration (ng/g ± SE) between maternal and newborn blood plasma (52.3±10.3; Table 1) was significantly less than expected from the test distribution of resampled bootstrap samples ($P<0.001$). All other average observed absolute differences were not significantly different from their respective test distributions ($P>0.05$). Linear regressions between a maternal trait and a child's trait (Fig. 1) were significantly positive for comparisons between maternal and cord blood plasma. Similarly, a positive correlation with regression coefficient of 0.78 between maternal blood and cord blood was reported by Lorenzo-Alonso et al. [20]. However, linear relationships between maternal breast milk and child blood plasma were not significantly different from zero (Table 1). Although it has been reported that values of mean serum or plasma Se/milk Se ratios are highly variable, there is a direct relationship between these two variables [13], and a significant correlation have been reported [38, 39]. There are some reports in agreement with our results [40, 19]. Linear regressions (Fig. 1) were significantly positive between maternal and child hair and between maternal breast milk and child excreta (Table 1). However, linear relationships between maternal breast milk and child blood plasma and between maternal blood plasma and child excreta were not significantly different from zero (Table 1).

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Abstract

A sample of 70 high school students (aged 16 to 20) studied from the Pendik District Istanbul-Turkey in order to determine the levels of zinc in their hair. Levels of Zn were measured by using Varian AA200 model atomic absorption spectrometry. The student's personal data such as age, sex, location, general state of health, diet habits, possible use of pharmaceuticals, alcohol, coffee and tobacco, etc was considered and only healthy student's hair were used as experimental materials. The mean values of Zn in student's hair were measured as 216.19 ±16.50 ppm. The Zn values of six different station's soil samples in the Pendik District were measured to compare with the hair Zn values. According to the results of our study, hair is a good biomonitor for Zn and can be used for diagnostic purposes, as indices body status in humans as well as for detecting certain diseases. Increasing Zn levels in hair could be a monitor for high traffic density while decreasing could be a monitor for industrial pollution. Additionally, higher or lower Zn in human hair could reflect firstly dietary habits, then sex, age, financial status, smoking habits and environmental status.

Keywords: Mineral elements, contaminants, intake, hair levels, biomonitor, zinc

Introduction

Scientists have been using many different living organisms or some of their tissues and organs as biomonitors to estimate contamination levels of metallic and non-metallic pollutants for a long time. For this purpose, vegetal (cyanobacteria, lichens, mosses and trees) [1-4] and animal (mollusks, fishes, birds and small mammalians) [5-8] samples have been extensively used as biomonitors of heavy metal pollution in terrestrial environments. Human is one of the most important biomonitor organisms in the world and is also an important tool in environmental medicine to assess and evaluate the level of internal exposure of the general population and individuals to environmental pollutants [9].

Human biomonitoring has been used in occupational medicine since the early 1930s, and the main matrices used are blood and urine [10]. Blood is an ideal matrix for most chemicals because the plasma is in contact with tissues and organs where chemicals are deposited [11]. After blood, urine is the second most common matrix for human biomonitoring, particularly for water-soluble chemicals and it can be collected as spot or 24-h samples [10]. Other mostly used matrices are hair, nails, breast milk, saliva, meconium, teeth, bones, semen and faeces [10, 11].

Human hair, has gained considerable ground in recent years for use as a biomonitor of trace elements to estimate environmental exposure levels [11]. Nevertheless, it is not only a

stable matrix for biomonitoring studies but also a potentially additional tool for the public health surveillance [10, 12]. Hair analysis is rather advantageous, because it can reflect the total body intake of certain elements better than biological fluids, even though careful evaluation of exogenous contamination is mandatory [13]. Moreover, it provides a non-invasive sampling with additional values, such as stable matrix, easy collection, short and long-term exposure tracings and so forth [12].

Since hair is an important biopsy material, like living organisms, non-living materials even the mummy samples can be analyzed by using hair [14]. Simply, blood analyses indicate what is happening; urine what has happened; by the way hair reflects what has happened at the cellular level for a period of about longer times prior to the sampling [15].

In 1980, human hair selected as one of the important monitoring materials for worldwide biological monitoring in the Global Environmental Monitoring Systems (GEMS) of the United Nations Environmental Program [15]. Today, when searched as "human hair" in Isi Web of Science, it can be found that there are over more than 8000 cited scientific studies by using human hair and this result expresses the importance and availability of this material in current science.

In spite of many advantages of using hair in biomonitoring studies, there are also some disadvantages. One of the major disadvantage in the application of hair as a biomonitor is the problem of contamination, and the poorly understood mechanisms of uptake, incorporation and binding of trace elements in the hair matrix, and hence the discrimination of endogenous and exogenous contributions [16]. Furthermore, many factors, such as age, sex, smoking habit, hair color and hair treatment affect the incorporation of contaminants into the hair. Some of them have already been clarified, but some not. It limits the evaluated reference values for hair analysis to a certain extent [17].

Zinc is one of the trace elements that are present in all living structures, both in plants and animals. It is a mineral essential to normal function of human body due to its role in both activating enzyme systems and as a cofactor of several metalloenzymes such as carbonic anhydrase, carboxypeptidase A and B, dipeptidase, pyruvate carboxylase, superoxide dismutase, alkaline phosphatase and DNA-RNA polymerase [18-20].

Many epidemiologic studies suggested that Zn deficiency may be associated with increased risk of some disorders and diseases [19-26]. In addition, profound Zn deficiency is quite rare in humans, but mild to moderate Zn deficiency may be relatively common thorough the world in both less developed and industrialized countries [20, 27].

In this research, we studied 70 healthy student's hair as experiment materials and determined the Zn values in hair in the Pendik District, Istanbul-Turkey. We also measured Zn values of 6 different station's soil samples in Pendik to compare the hair Zn values.

Materials and Methods

1. General Information

1. 1. Location

The Pendik District is located on the Anatolian (Asia) side of Istanbul (40°52'39 N, 29°15'05 E), on the North coast of the Marmara Sea (7.5 km). Total land area is 203 km^2, which includes some countryside areas inland (Figure 1).

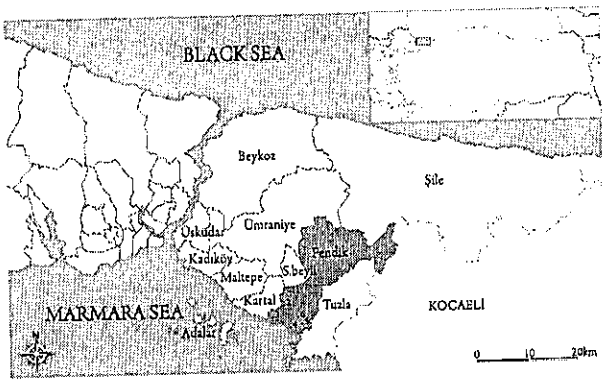

Figure 1: The study area (the Pendik District) and the stations (1-6) that soil samples were collected

1. 2. Geographical Characteristics

Pendik has a rough territory and the land area turns into the hills (Ballıca, Ağılbayırı and Karabayır Hills) through the north side while it is flat at the seacoasts. There are three brooks (Riva, Ballıca and Büyükdere) and there is a big dam (Ömerli) in the district. The climate of research area is typical four-season continental climate of the northern hemisphere and is mostly affected by the Mediterranean climate. The Mediterranean character is associated with the annual distribution of precipitation, being high during the winter months and having a drought period of 3 or 4 months in summer.

The most part of the study area consisted of brownish forest soil without lime (generally formed under the forests) and the remaining parts are alluvial soil, and brownish soil without lime. Furthermore, seacoast has partially sandy and clay soils, and there are limestone and quartz on the Hills [28, 29].

1. 3. Population

The population of Pendik increased rapidly over the last 25 years. While in 1935, the population was 3.514 in 1980, it reached 48.219. After 1980, the population increased fast and in 2009, the population is 520.486. Pendik was always a retreat from the city and by the 20th century it was peppered with holiday and weekend homes of Istanbul's wealthy. Today, Pendik is a heavily populated district, although located far from the city center [28, 30].

1. 4. Economy

There is a total of 5.658 both large and small business firms in the Pendik District and 2.022 of them are showing activity in production sectors while 1.242 of them are building societies. Additionally, Ömerli Dam, Sabiha Gökcen Airport and Formula 1 Area (Istanbul Park) affect the economy of Pendik. Today, Pendik is one of the most important industrial areas of Istanbul and it is projected to be a major urban and industrial area in the future [28].

2. Sample Collection and Treatment

Totally, 70 young high school student's hair samples whose ages are between 16-20 were collected from the Pendik District Istanbul Turkey. Each subject filled in a form to provide personal data such as age, sex, location, location time, general state of health, diet habits, possible use of pharmaceuticals, alcohol, coffee and tobacco, etc. Hair samples weighing approximately 1g were taken from the occipital region of the head, using a stainless steel scissors, and stored in poly-ethylene bags. Dry and clean hair samples were preferred, while gelled, sprayed or dyed were not collected. Hair samples were placed in 100ml beakers, washed with acetone + hexane mixture (1:1 v/v) for a period of 12 hours and then rinsed with

distilled water. After being washed, the hair samples were dried at 70°C for 16 hours followed by cooling to room temperature and finally reweighed on an analytical balance. After drying, approximately 0.5g of hair from each sample was weighed and transferred into polytetrafluoroethylene (PTFE) vessels (HP-500) and then 6 ml 65% HNO_3 and 1ml 30% H_2O_2 (Merck) were added. Samples were mineralized in microwave oven (CEM MARS5) as follows: 5min at 1200W maximum power, 115°C and 15min stand by. After cooling, the samples were filtered by Whattman filters and made up to 50ml with double distilled water in volumetric flasks and then stored in clean self-sealing plastic bags in silica gel.

Standard calibration techniques were used and Zn measurements were done by atomic absorption spectrometry (AAS), using a Varian AA200 model. The Zn hollow cathode lamp current was 5mA and the wave length was 213.9nm, slit width 0.5nm. Results were expressed in parts per million (ppm). Mean ± standard errors of mean values of Zn of both groups in hair were calculated for each group. The statistical analyses of the results were calculated in SPSS.

The statistical values (Table 1) and histogram (Figure 2) are given in result and discussion section.

Results and Discussion

In this study, we preferred healthy student's hair as experiment materials and average Zn value was measured as 216.19 ±16.50 ppm (Table 1). The normal limits of Zn in human hair are between 100-280 ppm. In our study 58 student's (83 %) Zn levels were within normal limits while 12 students (17 %) Zn levels were higher, and there were not any Zn values under normal limits (Figure 2).

Statistical Data

Zn hair

N	Valid	70
	Missing	0
Mean		216.1879
Std. Error of Mean		8.47727
Std. Deviation		70.92591
Variance		5030.484
Range		283.61
Minimum		126.77
Maximum		410.38
Percentiles	10	145.5750
	20	158.4960
	30	167.6510
	40	180.7060
	50	194.5700
	60	208.2260
	70	239.8750
	80	275.0980
	90	341.6240
	95	373.0645

Table 1. The statistical data of hair Zn levels.

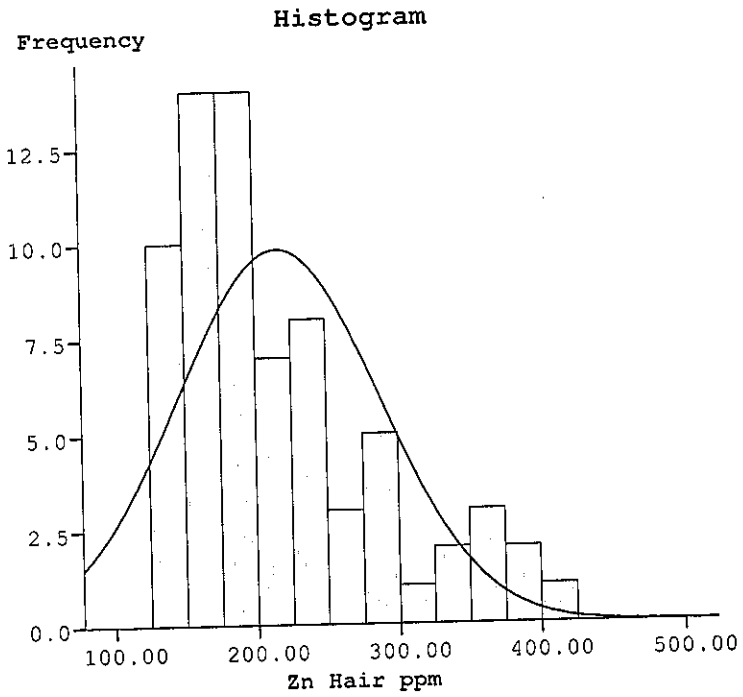

Figure 2: The histogram of hair Zn levels of students living in the Pendik District Istanbul-Turkey.

There are many studies by using human hair and blood for Zn detection in many disorders and diseases and most of them showed decreased hair Zn levels in patients compared with control (healthy) groups. According to the literature, similar to our study, healthy people's Zn values are usually within normal limits in many countries. By the way, in breast and ovarian cancers [20], some types of skin-diseases [26], epilepsy [22] and Down syndrome [19] reduced hair and plasma Zn levels were observed. In addition, a reduction was also observed in plasma Zn and Cu levels of boys with both attention deficit hyperactivity and oppositional defiant disorders [24, 25]. Furthermore, changes in blood Zn have been found in lymphoproliferative disorders as well as in lung and gastrointestinal tumors [20, 31-33]. Low Zn is related to poor wound healing, slow growth rate, low taste perception, slow hair growth and loss, night blindness, dermatitis, acne, strong body odor and an increased risk of dental cavities [23, 34]. It was also reported by other researchers, the decrease in plasma Zn concentration had been observed after stress, trauma, and in several malignancies [20, 33, 35]. In our study, all students were healthy and we did not obtain any lower Zn values.

Station Number	Station Type	Soil Zn value (ppm)
1	Rural	20.91
2	Urban Roadside	34.87
3	Urban	33.47
4	Urban	22.00
5	Motorway (D-100) Near Navy Yard	130.94
6	Urban Park	26.56

Table2. Stations and soil Zn values in the Pendik District Istanbul-Turkey

In our study, in addition to hair Zn concentrations, we also measured the soil levels in 6 stations. As it was seen in table 2, there was no Zn pollution in soil although Pendik is a fast-growing (urbanized and industrialized) district. By the way, soil Zn values were lower than we had imagined before the study. Although one station's (Motorway D-100 - Near Navy Yard) Zn value was higher 130.94 then others, it was within normal soil Zn limits. Other station's values were between 20.91-34.87 ppm (under normal soil Zn values). As known, in urban areas, there is traffic density and abrasion of the tires of the vehicles that contain ZnO and wastes of the oils from diesel engines cause Zn pollution in roadside [36]. This moderate higher result in Motorway D-100 could be a reflection of high traffic density.

There are some studies, which were performed in other industrialized cities measuring Zn values in hair samples. In one such study, Cd, Cu and Zn values of some tissues of deceased copper smelter workers were measured and an increased Cd and decreased Zn in hair were observed [37]. In another study, the highest Zn values were observed in businessmen (212.3 ppm) while the lowest in workers (98.4 ppm). By the way, workers' Cd values were the highest (1.3 ppm) and the businessmen's Cd values were the lowest (0.4 ppm) [21]. This could be an explanatory result relation between hair Zn levels and the wealth status of people related with other features such as age, job, dietary habits, smoking and alcohol usage etc. In another study, lower Zn levels were measured from the hair samples of industrialized area inhabitants while their Cd values were higher [38]. In addition to the detractive effects of increasing Cd levels in industrialized and polluted areas, the literature also indicated that increased Pb concentrations caused lower Zn and Cu levels in nails in industrialized areas [39].

Previous studies claimed that industrialization and urbanization had detractive effects for Zn concentrations in human hair related with increasing Cd and Pb. Nevertheless, in our study, the Zn levels of healthy students were within normal limits excluding some students higher Zn levels that were mostly living near motorways, which have naturally high traffic density. In a similar study, Al-Nasser and Hasbem (1997) observed increased levels of Zn in gas station workers which had the highest increases; 1.5 times in hair, 1.3 times in nails and 1.7 times in whole blood and in traffic polices 1.4 times in hair, 1.3 times in nails and 1.6 times in whole blood compared to control group [40]. This could also be the result of high traffic density to the increased Zn levels. By the way, Zn can be toxic if exposure is excessive. Although uncommon, high hair Zn might be indicative of Zn overload that could result from Zn contaminated water (galvanized pipes), welding or gross, chronic over supplementation (100 mg/day). Other sources of Zn exposure include: manufacture of brass, bronze, white paint, pesticide production, galvanization of steel and iron products, dry cell batteries, rubber, textile and ceramic industries [41].

It is clearly known that Zn deficiency is a critical nutritional problem for both plant and human in Turkey and soil Zn values are under normal limits [27]. Eyupoglu et al. (1994) analyzed 1511 soil samples that collected from all provinces of Turkey and they showed that 50 % of the cultivated soils in Turkey are Zn-deficient. These Zn-deficient areas are equivalent to 14 Mha of cultivated land in Turkey [42]. In our study, the soil Zn levels were under normal limits but its reflection was not deficit Zn levels in young student's hair in the Pendik District. Nevertheless, 41% of the children who lived in Southeastern Anatolia had very low concentration of Zn (<100 mg kg^{-1}) in their hair. Although soil Zn levels are low in both area, socioeconomic parameters are very different and the deficit Zn levels could be the result of low socioeconomic attributions related with nutritional differences in Southeastern Anatolia. Another study carried out in Chile with Chilean infants who are at risk for isolated Zn and Fe deficiencies because of a low consumption of animal products in low

socioeconomic sectors. An observed negative correlation between socioeconomic status and the concentration of Zn in the hair samples was concordant with the fact that a large part of ingested Zn and its availability originated from animal products, which were more expensive. It was also observed that poorer families have a higher risk of infections such as respiratory infections and gastrointestinal infections, which were important causes of the loss of ingested Zn [43]. In our study, although the Pendik District is a fast-growing, urbanized and industrialized district, urbanization and industrialization did not reflect negatively on our students' hair Zn levels. This could be the result of their age groups (16-20), their health and wealth status, dietary habits, non-smoking habits etc. or planned urbanization industrialization in the Pendik District.

According to the results of our study and the previous studies, hair is a good biomonitor for Zn and can be used for diagnostic purposes, as indices body status in humans as well as for detecting certain diseases. It was also seen that in many districts, urbanization and industrialization has detractive effects to the hair Zn levels related with increasing Cd and Pb levels. However, increasing Zn levels in hair could be a monitor for high traffic density while decreasing could be a monitor for industrial pollution. In addition, higher or lower Zn in human hair could reflect firstly dietary habits, age, financial status, smoking habits and environmental status (food, air, water, soil).

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Serum and Hair Levels of Zinc, Selenium, Iron, and Copper in Children with Iron-Deficiency Anemia

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ABSTRACT

In the present study, the serum and hair levels of zinc, selenium, and copper were determined in children with iron-deficiency anemia (IDA). A total of 52 anemic children aged 1–4 yr constituted the study group. Forty-six healthy children acted as controls. The copper and zinc levels were measured with an atomic absorption spectrophometer. Serum and hair selenium was determined by a spectroflourometric method. The serum zinc and selenium concentrations in the IDA group were found to be significantly lower and serum copper significantly higher than those in the controls ($p < 0.05$). Lower iron, zinc, and selenium concentrations ($p < 0.001$) but not copper were found in hair ($p > 0.05$).

Index Entries: Iron deficiency anemia; zinc; selenium; copper; hair.

INTRODUCTION

Iron, zinc, selenium, and copper are some of the inorganic elements that are necessary for normal growth and sustained biological activities *(1)*. Iron deficiency is probably the most common deficiency in children both in developing and industrialized nations *(2–6)*.

Prasad et al. first reported zinc deficiency in humans in 1963 *(7)*. The combined deficiencies of zinc and iron cause mental lethargy, hepatosplenomegaly, and growth retardation in geophagous children are referred

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to as "Prasad syndrome" in the literature. Other studies have shown that the serum zinc and copper levels were significantly altered in children with iron deficiency, in which zinc protoporfirin is produced instead of heme and is consequently increased in erythrocytes. Measuring zinc protoporfirin along with ferritin and hemoglobin can be used to assess the degree of iron deficiency *(8–10)*.

Copper deficiency can also impair the absorption of iron because ceruloplasmin is involved in the oxidation of Fe(II) to Fe(III) *(11)*. Selenium is an essential trace element that works as a cell membrane protector against lipid peroxidation *(12,13)*. It is central to enzymes such as glutathione peroxidase (GSH-Px), an enzyme that converts hydrogen peroxide into water, thus preventing formation of the oxidized form of hemoglobin *(14,15)*.

The purpose of this study was to determine the serum and hair zinc, selenium, and copper levels and its relation to hematological parameters in children with iron-deficiency anemia (IDA).

METHODS

Fifty-two anemic and 46 healthy children, all between 1 and 4 yr of age participated in this study. They were under medical care at a Health Policlinic in Elazığ, Turkey. All had been nursed by their mothers for at least 4 mo after birth. Children having hemoglobin concentrations under two standard deviations of the mean hemoglobin levels and ferritin values below 10 ng/mL and/or transferrin saturation below 12% were considered as anemic. Children who were malnourished or had chronic diarrhea or intestinal parasites were excluded from the study. Also excluded were children who had an infectious disease as recent as 2 wk before the study. Fasting blood samples were collected from all subjects between 8:00 and 10:00 AM. The serum was separated by centrifugation and stored at –30°C until needed for trace element analysis.

Hemoglobin, hematocrit, white blood cells, and red cell morphology (MCV, MCH, MCHC, and RDW, respectively), were determined with an automatic cell counter following standard clinical protocols. Serum ferritin levels were determined by the ACS 180 automated immunuassay method. The ratio of serum iron and total-iron-binding capacity (TIBC) or transferrin saturation (serum iron level/TIBC × 100) was also determined.

For the determination of iron, copper, zinc, and selenium in hair the samples were digested in acid using a domestic microwave oven in low-pressure Teflon bombs. The hair samples were washed twice with 1% Triton X-100 and deionized, doubly-distilled water (dd-water) and then dried at 60°C for 24 h. The dry samples were homogenized using an agate homogenizer and stored in polyethylene bottles until analysis. All plastic and glass containers were cleaned by overnight soaking in a 10% nitric acid solution and then rinsed with dd-water.

Table 1
Results of Hematologic Parameters in the Two Groups

	Iron deficiency anemia group	Control group	p
Hb (gr/dl)	9.6±1.1*	12.6±0.9	<0.05
Hct (%)	30.9±2.7	37.0±3.0	<0.05
MCV (μm^3)	63.3±7.2	78.2±5.0	<0.05
Ferritin (ng /ml)	5.8±3.0	33.5±20.0	<0.001
Transferrin saturation (%)	7.3±6.2	19.8±10.8	<0.001

* Mean ± standard deviation.

A sample portion weighing approx 0.5 g was placed into the Teflon vessel and treated with 2 mL concentrated HNO_3, 2 mL $HClO_4$, and 1 mL H_2O_2. The vessel was placed into the microwave oven and twice subjected to radiation for 2 min each at 10%, 25%, and 40% power followed by 5 min at 50% power. After cooling, the solution was transferred into a Teflon beaker, made up to 5 mL with dd-water and kept at 4°C until analysis *(16)*.

Hair and serum concentrations of iron, copper, and zinc were determined in an ATI UNICAM 929 atomic absorption spectrophotometer using an air–acetylene flame with deuterium background correction *(17)*. Serum and hair selenium was analyzed by Lalonde's flourimetric method using a Perkin-Elmer Model 100 spectrofluorometer *(18)*.

The results are given as mean ± SD with 95% confidence intervals. The commercially available SPSS software was used for the statistical evaluation of the data using Student's *t*-test and correlation tests.

RESULTS

Among the 52 children with IDA, 31 (59%) were boys and 21 (41%) were girls. In the control group, there were 46 children, of whom 28 (60%) were boys and 18 (40%) girls. The ages of all children ranged from 1 to 4 yr. The mean age was 1.96 ± 0.76 yr in the IDA group and 2.32 ± 1.07 yr in the controls.

The hematological parameters of both groups are given in Table 1. Children with IDA had a statistically significant lower mean hemoglobin level (9.6 ± 1.1 g/dL) than those in the control group (12.6 ± 0.9 g/dL, $p < 0.05$). Also, serum iron, TIBC, and ferritin values in the anemic children were significantly lower than the healthy controls ($p < 0.001$).

The serum iron concentration was 5.9 ± 3.9 μmol/L in the IDA group and 12.9 ± 5.1 μmol/L in the control group ($p < 0.001$). Serum zinc was 16.0

Table 2
Serum Levels of Trace Elements

Trace element	Iron deficiency anemia group (n=52)	Control group (n=46)	p
Iron (μmol/L)			
Mean ±SD	5.9±3.9	12.9±5.1	<0.001
95% Confidence interval	(4.8-6.9)	(11.9-13.9)	
Zinc (μmol/L)			
Mean ±SD	16.0±5.2	19.1±5.9	<0.05
95% Confidence interval	(16.0-17.4)	(18.0-19.7)	
Copper (μmol/L)			
Mean ±SD	25.1±5.8	21.9±3.8	<0.05
95% Confidence interval	(24.8-26.4)	(21.9-23.1)	
Serum selenium (μmol/L)			
Mean ± SD	0.44±0.10	0.73±0.22	<0.001
95% Confidence interval	(0.42-0.45)	(0.70-0.76)	

± 5.2 μmol/L and 19.1 ± 5.9 μmol/L, respectively ($p < 0.05$). The mean serum copper in the IDA and control groups was 25.1 ± 5.8 μmol/L and 21.9 ± 3.8 μmol/L, respectively ($p < 0.05$). The mean serum selenium concentrations were also significantly lower in the IDA group (0.44 ± 0.10 μmol/L vs 0.73 ± 0.22 μmol/L in the controls; $p < 0.001$). The serum iron, zinc, selenium, and copper levels are shown in Table 2.

The iron, zinc, selenium, and copper levels in hair are shown in Table 3. In hair, the mean iron, zinc, copper, and selenium concentrations were also lower in the IDA group. The difference was significant for Fe, Zn, and Se ($p < 0.001$) but not for Cu ($p > 0.05$).

A statistically significant correlation between the mean serum copper, selenium, and zinc concentrations could not be found; nor could it be found between the measured hematological parameters and the mean serum element concentrations.

DISCUSSION

Iron deficiency is the most common nutritional deficiency among children in the world and it is also the most common reason for childhood anemia *(5,20,21)*. IDA is most common between 6 and 24 mo of age *(20)*. The children included in this study were within this age group. The sex and mean age of both groups were well matched, with no significant difference of their ages ($p > 0.05$).

The mean serum zinc concentration was significantly lower in the IDA group than in the controls ($p < 0.05$). This might indicate that in addi-

Table 3
Hair Levels of Trace Elements

Trace element	Iron deficiency anemia group (n=52)	Control group (n=46)	p
Iron (microg/g)	17.76 ± 3.45*	43.49 ± 6.23	<0.001
Zinc (microg/g)	59.24 ± 9.67	104.14 ± 8.59	<0.001
Selenium (microg/g)	0.61 ± 0.12	1.02 ± 0.14	<0.001
Copper (microg/g)	9.37 ± 1.83	11.59 ± 2.30	NS**

* Mean±standard deviation.
** Not significant.

tion to the iron deficiency, a nutritional deficiency of zinc is possible in IDA. Alternatively, in iron deficiency, zinc protoporfirin production is increased, resulting in a replacement of iron by zinc, leading to lower serum Zn values *(10,22,23)*. Similar results have been reported in Russian adult subjects *(24)* and in children from Manisa, Turkey *(9)*.

The mean serum copper concentration was higher in the IDA group than in the control group, and the difference was statistically significant ($p < 0.05$). This might be the result of the fact that copper is used insufficiently and accumulates excessively in tissues during iron deficiency. In experimental studies with iron deficiency, changes of some trace elements levels in tissue and increases of the level of some trace elements like copper have been observed *(25,26)*. Results of a study conducted by Ece et al. among children were also similar *(9)*. On the contrary, in humans with severe copper deficiency, little or no copper-binding ceruloplasmin was found in serum and tissues because of the absence of active ferroxidase, leading to iron accumulation in the liver *(11)*.

The mean serum selenium concentration was significantly lower in the IDA group ($p < 0.001$). In another study from Turkey, Yetgin et al. *(27)* found a mean serum selenium concentration of 0.80 ± 0.14 μmol/L in IDA children aged 6 mo to 16 yr vs age-matched controls having 0.95 ± 0.16 μmol/L ($p < 0.001$). McAnulty et al., however, reported that the serum selenium concentration of a low iron stores group were not significantly different from those of the controls *(28)*. Results of previous studies on IDA showed decreased levels of GSH-Px activity, which might be useful for evaluating the nutritional selenium status *(27,29,30)*. Although GSH-Px is not an iron-containing metalloprotein, its activity has been found decreased in erythrocytes of patients with IDA, suggesting that selenium deficiency might accompany iron deficiency. Moriarty et al. found that serum selenium and GSH-Px levels are decreased in rats with IDA *(31)*.

The mean iron, zinc, copper, and selenium concentrations in hair were lower in the IDA cases. Previous studies showed that the concentrations of

zinc and copper in hair were lower in persons with iron deficiency (*32,33*). Hac et al. (*34*) found that low serum selenium might accompany low selenium in hair. There was a direct relationship between the serum and hair concentrations of iron, selenium, and zinc, but no relationship was found between the increased serum and decreased hair copper concentrations. This observation is consistent with previous studies that also showed no relationship between the serum and hair copper levels (*35,36*).

Our results show that the serum and hair zinc, copper, and selenium concentrations were altered in children with IDA. The differences observed might be attributed to relations between iron and different elements at the absorption, transportation, and storage areas (*26*). We suggest that the zinc, selenium, and copper status of children with IDA should be taken into account before and after iron supplementation therapy.

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ORIGINAL ARTICLE

Low hair selenium and plasma glutathione peroxidase in children with chronic renal failure

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Abstract Selenium (Se) is a trace element that incorporates into the selenoenzyme glutathione peroxidase (GSH-Px). There are conflicting results regarding the Se levels and activity of GSH-Px in adult uremic patients. The aim of this study was to determine (1) the hair Se status, (2) the possible relation between the hair Se status and the antioxidant enzyme, GSH-Px, and (3) the influence of different treatment procedures on hair Se status and GSH-Px activity in children with CRI, those treated conservatively and those on HD and on CAPD. Ninety-three patients, including 32 patients with CRI, treated conservatively, 42 PD patients, 19 HD patients and 34 healthy children were enrolled in the study. The hair Se level was measured by the atomic absorption spectrophotometer method. Plasma GSH-Px activity was determined using a Randox test combination (RANSEL). Hair Se levels were significantly lower in the CRI, CAPD, and HD groups when compared to the control group (P=0.001, P=0.001, and P=0.001, respectively). Plasma GSH-Px activity was significantly lower in the CRI, CAPD, and HD groups when compared to the control group (P=0.001, P=0.001, and P=0.001, respectively). Plasma GSH-Px activity correlated with the GFR in patients with CRI and the control group (P=0.000; r^2=0.60). There was no correlation between plasma GSH-Px and hair Se levels in the patient and control groups. These results revealed a decreased hair Se level and impaired antioxidative capacity in children with CRI on CAPD and HD. The lack of any relation between plasma GSH-Px and hair Se suggests that plasma GSH-Px is not a good marker of Se stores.

Keywords Hair · Selenium · Glutathione peroxidase · Chronic renal failure · Children

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Introduction

Altered blood levels of various trace elements have been demonstrated in uremic patients on hemodialysis (HD) and continuous ambulatory peritoneal dialysis (CAPD). Selenium (Se) is a trace element that plays an important role in humans, and its deficiency has been implicated as a contributing factor in some cases of congestive cardiomyopathy, skeletal muscle myopathy, increased cancer risk, deranged immune function, anemia, and increased cardiovascular complications [1–3]. The best known biological

role of Se is attributed to its presence in glutathione peroxidase (GSH-Px), which is one of the enzymes protecting membrane lipids and other cellular and extracellular components from oxidative damage [4].

Oxidative stress has been reported in children and adults with chronic renal failure (CRF) treated by HD and CAPD [5–12]. An impaired GSH-Px activity was shown in both erythrocytes and the plasma of dialysis and pre-dialysis patients with advanced CRF [6–8, 13]. One of the factors contributing to this reduction of antioxidative capacity is reported to be Se deficiency [6, 14, 15]. Selenium is a trace element essential for the activity of GSH-Px, which catalyses the breakdown of toxic hydrogen peroxide and lipid hydroperoxides. Several authors reported decreased levels of plasma and erythrocyte Se and decreased plasma GSH-Px activity in dialysis patients and in pre-dialysis patients with advanced CRF [5, 6, 14, 15]. In most of the studies, the recommendation for Se supplementation in adult patients on CAPD or HD treatment has been suggested [14, 16].

Various body fluids and tissues, such as the blood, urine, hair, nails, lens, etc., have been widely used in monitoring the concentrations of trace elements [17–19]. Among these, hair is unique in that it remains isolated from human metabolic activities and indicates the concentrations of elements at a particular time period. The assessment of Se status is complicated since no single measurement provides a reliable indication of body Se reserves in all circumstances [20]. Plasma Se concentrations are commonly used, however, and they respond rapidly to deficiency states induced by a low dietary intake of the element [20, 21]. Furthermore, abnormalities of hair Se levels have been reported in various diseases in the past [18, 22, 23].

The aim of this study was to determine (1) the hair Se status, (2) the possible relation between hair Se status and the antioxidant enzyme, GSH-Px, and (3) the influence of different treatment procedures on hair Se status and GSH-Px activity in children with CRI treated conservatively and those on HD and CAPD.

Materials and methods

Patients

Ninety-three patients including 32 with CRI treated conservatively, 42 on CAPD, and 19 on HD were enrolled in the study. Thirty-four healthy children (19 males and 15 females) with a mean age of 10.2±4.6 years served as the control group. The criteria for recruitment were as follows: (1) being between 5 and 18 years old, (2) a glomerular filtration rate (GFR) of 20 to 75 ml/min/1.73 m^2 for pre-dialysis patients, and (3) at least 3 months of dialysis therapy (HD/PD) for dialysis patients. Patients were excluded from the study in the presence of one of the following conditions: (1) severe infections such as peritonitis, sepsis, and exit-site infection for PD patients, (2) any chronic diseases or medications leading to anorexia and/or growth retardation except for CRF, and (3) any disease that may affect liver function and/or the lipid profile. Families were asked to keep dietary records, but most families did not comply with this request. Therefore, the direct dietary intake of protein and Se could not be quantitated for our patients. Schwartz's formula was used to estimate the glomerular filtration rate in patients with CRI and controls [24]. None of the patients were exposed to Se-containing shampoos. The present study was conducted under written informed consent and approved by the Ethics Committee.

Blood and hair sampling measurements

Venous blood was obtained from the patients and the controls in the morning at 8.00 a.m. after an overnight fast. Blood samples in HD patients were obtained immediately before the start of HD. Blood samples were collected from the antecubital vein, carefully avoiding external metal contamination and hemolysis. Plasma samples were stored at −70°C until analyzed.

All hair samples were collected by hair clippings from the back of the head and near the scalp with stainless-steel scissors and stored in separate clean plastic bags. To avoid contamination, the handling, cutting, and transfer of hair samples were minimized and carried out using plastic disposable forceps, fresh stainless-steel scissors, and disposable vinyl examination gloves. Hair samples were prepared for the graphite furnace atomic absorption (GFAA) as follows [25]: All chemicals used were of super-pure grade unless stated otherwise; aqueous reagents were prepared in double-distilled deionized water. The working solution was prepared daily from 1,000 mg/l stock. For the standard solutions, serial dilutions were made with double-distilled deionized water. Distilled and deionized water was supplied through Barnstead Easypure-RF compact-ultra water system. A normal human scalp hair sample was used to optimize the experimental conditions. Hair samples of about 100 mg were cut into pieces 3 to 5 cm long and were washed first with deionized water then dried at 30°C overnight. The next day, hair samples were digested before analysis using nitric acid to free and bind the metals present in the matrix. Then, 100 mg of hair samples was transferred into a deionized glass tube, and 2 ml of ultra-pure concentrated nitric acid was added into each deionized glass tubes. Glass tubes were then placed on a hot plate, and air samples were digested at 80°C for 2 h. After cooling, samples were diluted, and the final volume

of each of the solutions adjusted to 15 ml with deionized water. Ten microliters of the solution was injected into the graphite furnace, and the Se concentration was determined by GFAA. A deuterium arc background corrector was used to minimize interference. Sensitivity, linearity, within-run coefficients of variation (CVs), and relative recovery values were determined (sensitivity: 10 ng/g; linearity: 0.1–2.5 μg/g; CVs: 2.5–4.8%; relative recovery: 90–97%). Samples were estimated with a polarized atomic absorption spectrophometer (Hitachi Z-8000 Zeeman) using a graphite furnace at 196 nm, 12.5 mA lamp current and a slit width of 1.3 nm. Palladium modifier and vitamin C as an antioxidant were used. The standard addition method was used, and 10 μl of sample was estimated at each time. All determinations were made in duplicate. The total levels of hair Se were determined by regression analysis of the sample absorption data on a standard curve. Hair Se levels are expressed as ng per gram weight. Plasma GSH-Px activity was determined using a Randox test combination (RANSEL). GSH-Px catalyses the oxidation of glutathione (at a concentration of 5 μmol) using cumene hydroperoxide according to the method of Paglia and Valentine [26]. In the presence of glutathione reductase (at a concentration of >0.75, 10–3 U) and 0.35 μmol of NADPH, the oxidized glutathione is immediately converted to the reduced form with concomitant oxidation of NADPH to NAD^+. The decrease in absorbance was recorded at 340 nm and 37°C. The necessary enzyme activity to convert 1 μmol of NADPH to NADP in 1 min was defined as 1 unit of GSH-Px, and the results were expressed as GSH-PxU/l. The intra-assay coefficient of variation was below 3%.

Statistical methods

All values are reported as mean±SD. Differences between groups were tested by one-way ANOVA and the post hoc Bonferroni test when the variables were in normal distribution. In case of non-normal distribution, Kruskal-Wallis analysis and Mann-Whitney-U test were used. Multiple regression analysis was used to determine the relationships between GSH-Px activity and hair Se concentration, and between GFR. Differences were considered significant at $P<0.05$.

Results

Clinical characteristics and laboratory data of the patient groups are summarized in Table 1. There was no difference in the age and gender between the patient groups and the controls. The mean GFRs in patients with CRI and controls were 27.3±16.3 ml/m^2/min and 84±8.2 ml/m^2/min, respectively.

Table 1 Clinical and laboratory findings of patients (CRI: chronic renal impairment; HD:hemodialysis; CAPD: continuous ambulatory peritoneal dialysis)

	CRI (n:32)	SAPD (n:42)	HD (n:19)
Age (year)	11.1±4.4	11.9±4.5	11.3±2.7
Gender (M/F)	13/19	15/27	11/8
Hemoglobin (g/dl)	10.03±1.32	9.93±2.15	9.85±1.52
Hematocrit (%g)	28.87±3.46	29.75±5.65	28.52±4.24
BUN (mg/dl)	71.10±36.41	88.36±38.24	114.47±51.46
Creatinine (mg/dl)	3.47±2.33	7.32±2.55	8.25±1.82
Albumin (g/dl)	3.95±0.50	3.55±0.56	4.01±0.71
T. protein (g/dl)	6.82±0.77	6.41±0.86	6.89±0.20

Hair Se levels were significantly lower in the CRI (527.7±261 ng/g), CAPD (547±288.9 ng/g), and HD (485.4±256.2 ng/g) groups when compared to the control group (1,025.5±345.8 ng/g) (P=0.001, P=0.001, and P=0.001, respectively) (Fig. 1). Although the hair Se level tended to be lower in the HD group than in the CAPD and CRI groups, there was no statistically significant difference in hair Se levels among the three groups. There was no significant difference in the hair Se levels between girls and boys in the patient groups or control group (P>0.05).

Plasma GSH-Px activity was significantly lower in the CRI (30.4±16.1 U/l), CAPD (18.9±8 U/l), and HD (22.9±11 U/l) groups when compared to the control group (58.8±16.8 U/l) (P=0.001, P=0.001, and P=0.001, respectively) (Fig. 2). There was no significant difference in plasma GSH-Px levels among the CRI, CAPD, and HD groups. Multiple regression analysis revealed that not hair Se, but rather GFR is an independent factor for GSH-Px activity (P=0.000; r^2=0.60) (Fig. 3). No correlation was found between the hair Se levels and serum albumin level.

Discussion

In this study, we assessed the hair Se levels and their relation to the antioxidant status in children with CRI on HD and CAPD. To our knowledge, this is the first study investigating the hair Se status of children with CRI and on dialysis. Different factors such as diet, circadian variations, and acute illnesses can influence plasma levels of trace elements, whereas hair is a highly stable material and has a potential for revealing and reconstructing past episodes relevant to health even after their action has ceased [23, 27]. Plasma and serum element levels show wide diurnal variations in a day, even in an hour depending on food intake, and reflect the short-term index of nutritional status. Furthermore, it has been demonstrated that hair reflects the total body burden of certain elements better than blood, and the accumulation over extended periods of time leads to

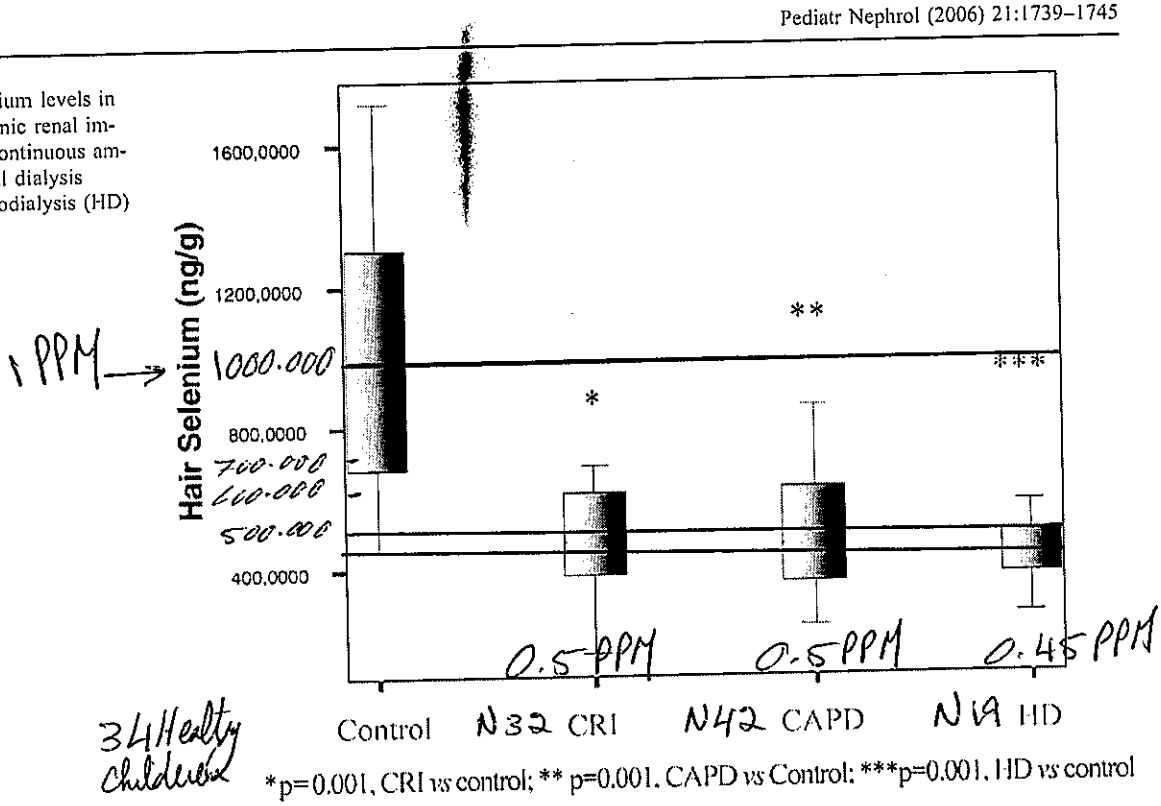

Fig. 1 Hair selenium levels in patients with chronic renal impairment (CRI), continuous ambulatory peritoneal dialysis (CAPD) and hemodialysis (HD)

*p=0.001, CRI *vs* control; ** p=0.001, CAPD *vs* Control; ***p=0.001, HD *vs* control

metal concentrations much higher than those in biological fluids [27]. Hair Se was used to asses the Se status in many studies [18, 23, 28–32]. Selenium in the hair of people was correlated with selenium in the kidney [33] and in the kidney cortex, liver, and lung [34]. Therefore, we preferred to measure hair Se, which has been shown to correlate with both Se in the kidney and in plasma.

It is well known that there are geographical variations in Se concentrations depending on the soil and diet. Somarriba et al. [35] reported that the mean hair selenium of citizens of Managua was higher than that of citizens of Moscow. The authors found significant differences between groups of citizens with different social statuses: those with low incomes had hair selenium values lower (598±46 mg/kg)

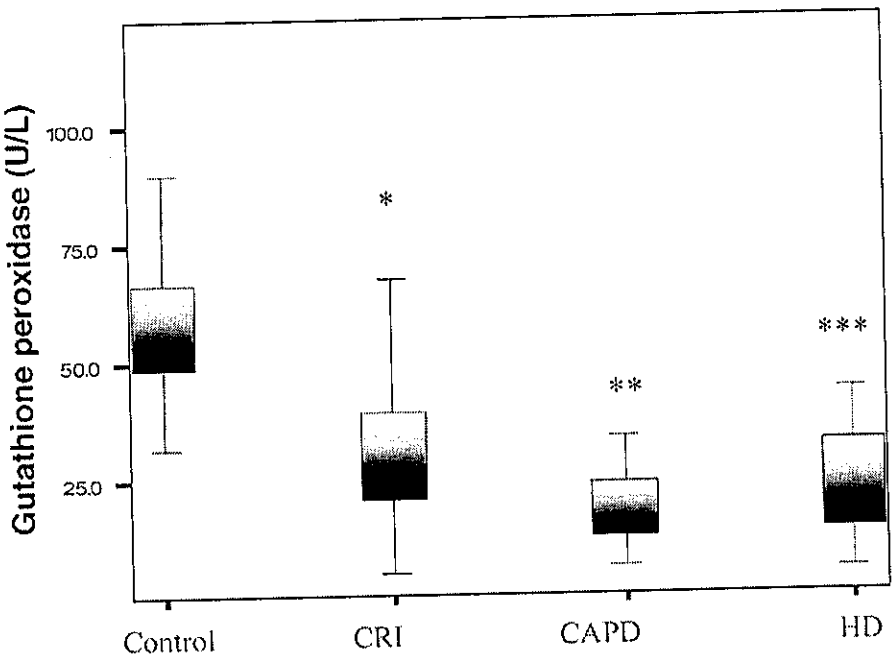

Fig. 2 Plasma glutathione peroxidase activity in patients with chronic renal impairment (CRI), continuous ambulatory peritoneal dialysis (CAPD), and hemodialysis (HD)

*p=0.001, CRI *vs* control; ** p=0.001, CAPD *vs* Control; ***p=0.001, HD *vs* control

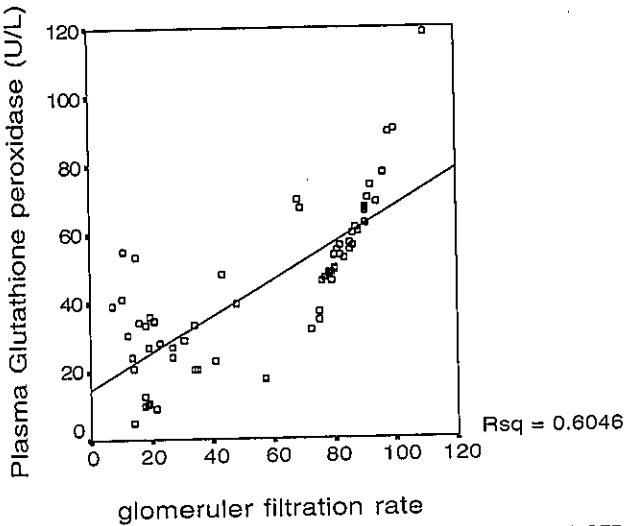

Fig. 3 Correlation between plasma glutathione peroxidase and GFR in patients with chronic renal impairment (CRI) and control group

than those with relatively high incomes (713±40 mg/kg). Selenium was found to be the highest (898±60 mg/kg) in recent country emigrants with extremely low social statuses and who consumed exclusively corn and beans. All the patients and healthy children in our study were recruited from three different regions of Turkey. Both the patients and control groups consisted of children with similar proportions of regions of residence. Hair Se levels in healthy controls in our study were slightly higher than those of Senofente et al.'s [28] findings. The mean hair Se levels of healthy controls in our study were 1,025.5±345.8 ng/g. Senofente et al. [28] found a mean hair Se concentration of 0.7 mg/kg (700 ng/g) in children from several urban areas of Rome. This difference can be attributed to the geographical and social variations between two countries.

In the present study, a significant decrease was found in hair Se levels of children with CRI on HD and CAPD compared to that of controls irrespective of the mode of treatment. Contradictory results were observed in Se levels in blood components of adult patients with chronic renal failure and on dialysis. Decreased [36–38], normal [7, 39], or even increased levels [40] of Se were reported in serum. Likewise, erythrocyte Se levels also have been found to be normal [36] or decreased [41, 42]. In most of the studies, plasma Se levels were found to be decreased [15, 43]. Several reasons have been proposed to explain decreased Se levels in uremic adult patients [44–47]. Since proteins in the diet are the main source of Se, nutritional factors such as protein restriction might contribute to the Se depletion in uremic patients [47]. In our study, all the children were advised to follow a diet according to the K/DOQI pediatric guideline [48]. However, direct dietary intake of protein and Se could not be quantitated for our patients due to the non-compliance of the parents and children. Furthermore, intestinal absorption of Se was shown to be adequate in uremic patients [45]. In dialyzed patients, the loss of Se during dialysis was shown to be an additional reason for low Se levels [14, 45, 46], and Kallistratos et al. [46] suggested that the lower Se levels may be due to the loss of Se across the dialysis membranes. Moreover, Se in effluent peritoneal fluid was shown by Dworkin [47]. This indicates that the peritoneal membrane is an additional potential site of Se loss. Since this study was not designed to determine the underlying mechanisms for the low Se levels in uremic patients, we cannot draw a certain conclusion regarding the causes of decreased hair Se levels.

Selenium has a highly specific metabolism centered around its incorporation as selenocysteine into selenoproteins. Sources of Se-cys include the metabolism of selenomethionine (Se-met) via the transsulfuration pathway and catabolism of endogenous and ingested proteins. A unique tRNA, designated tRNA, $^{[Ser]Sec}$, is charged with L-serine, which is then converted through at least two steps to selenocysteine. With the aid of a unique translation factor, the selenocysteinyl-tRNA, $^{[Ser]Sec}$ recognizes specific UGA codons in mRNA to insert selenocysteine into the primary structure of selenoproteins such as GSH-Px [49, 50]. In this study, the plasma GSH-Px activity of patients with CRI and on dialysis was found to be significantly lower than that of the controls. Conflicting results have been reported in erythrocyte GSH-Px activity in uremic patients. Erythrocyte GSH-Px activity was reported to be normal [7, 8, 43, 51] or decreased [13, 15,16, 41]. In most of the studies, plasma GSH-Px activity was found to be decreased in patients with renal disease and on dialysis [7, 13, 16, 42, 43]. Low Se levels are known to affect the activity of GSH-Px. Reduced GSH-Px activity in HD patients was attributed partly to Se deficiency [14, 15]. Ceballos-Picot [13] also observed impaired GSH-Px activity in CAPD patients. Furthermore, the serum Se level in these patients was positively correlated with GSH-Px activity. Several authors have reported a positive effect of Se supplementation on plasma GSH-Px activity in CRF patients [14, 16], whereas the others did not confirm this [43, 52]. Koenig et al. [16] observed that intravenous Se supplementation of 400 μg thrice weekly after each HD session increased Se levels in plasma and erythrocytes and enhanced GSH-Px activity. On the other hand, Zachara et al. [52] indicated that in patients at the advanced stage of CRF, Se supplementation has only a weak or no effect on plasma GSH-Px activity. We did not find an association between hair Se levels and GSH-Px activity in either patients or controls. The lack of any link between hair Se levels and GSH-Px activity even in the controls might indicate that hair Se is not a good marker of body Se stores and that plasma GSH-Px is not very sensitive to body Se stores. Another explanation for the

lack of association between hair Se and GSH-Px activity might be related to the fact that hair contains non-specific, unregulated, Met-Se incorporation via the same codon as "regular" (sulfur-containing) Met during translation. This is quite different from selenoproteins like GSH-Px. Our findings indicated that the lower activity of GSH-Px in uremic patients was not related to the Se deficiency as previously suggested by Zachara et al. [8, 52].

Since plasma GSH-Px is mainly synthesized in proximal tubules [53], we preferred to assess plasma GSH-Px. It has been shown that the degree of the reduction in plasma GSH-Px activity depends on the stage of the impairment of the renal function, reaching in the end-stage 20% to 30% of the activity of healthy patients [7, 8]. Similarly, we observed a positive correlation between GSH-Px levels and GFR ($P=0.000$, $r^2=0.60$), suggesting the important role of the kidney in the maintenance of GSH-Px concentration in plasma. Furthermore, the kidney is a major site of the trans-selenation/trans-sulfuration pathway [49, 50]. This could also be a potential factor leading to decreased incorporation of Cys-Se into GSH-Px in uremic patients.

In summary, the present study revealed low hair Se and plasma GSH-Px levels not only in children on dialysis, but also in children with CRI as well. The lower GSH-Px activity was related to kidney impairment, not Se deficiency. The lack of any relation between plasma GSH-Px activity and hair Se suggested that plasma GSH-Px was not a good assay for Se deficiency in renal patients. Further studies using different methods are needed to clarify the relationship between Se and GSH-Px and the clinical significance of low hair Se levels in children with CRI and undergoing dialysis.

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ترکیا - اروپا

Turkey 1984

Hair manganese concentrations in newborns and their mothers[1,2]

18 mother (G1 Group 1)
12 newborn (G2 Group 2)

Günay Saner, Türkan Dağoğlu, and Tülin Özden

ABSTRACT The study was designed to investigate the manganese (Mn) status of mothers and their offspring at delivery. Hair Mn concentrations in 31 full-term, 18 preterm and 12 newborn infants with congenital malformations and their mothers were determined by the flameless atomic absorption technique. Both in infants with congenital malformations and their mothers, hair Mn levels were significantly lower than the full-term and preterm infant-mother pairs. With the exception of mothers of infants with congenital malformations, hair Mn concentrations in mothers were significantly higher as compared with their infants. Low hair Mn concentrations of infants with congenital malformations and their mothers may possibly reflect a state of Mn deficiency in these women. These results imply that *1*) Mn deficiency may play a role as one potential factor in intrauterine malformations, *2*) Mn is supplied to the fetus by a homeostatic mechanism which is mainly dependent on the Mn status of the mother, *3*) prenatal Mn analysis in maternal hair may prove to be a reliable indicator for the risk of intrauterine malformations. *Am J Clin Nutr* 1985;41:1042–1044.

KEY WORDS Hair, manganese, newborn, mother, trace element, full-term, preterm, congenital malformations

Introduction

Manganese (Mn) is one of the essential trace elements in animal nutrition and has a role in several enzyme systems. Mn deficiency in different species is characterized by defective growth, bone abnormalities, impaired reproductive functions, neonatal ataxia and various congenital malformations. Abnormalities of glucose tolerance and lipid metabolism have also been reported in manganese-deficient animals (1–4). These findings point to the importance of an adequate maternal Mn nutritional state during pregnancy for normal fetal development.

To date, Mn deficiency has not been described in man, except for the case reported by Doisy (5) in association with vitamin K deficiency and the case reported by Rubenstein et al (6, 7). The latter author described a fall in blood sugar following infusions of alfalfa (noted to be a manganese rich plant) in a diabetic patient. However, present knowledge on Mn deficiency is still far from being adequate and the clinical and biochemical signs of Mn deficiency in man are essentially unknown.

Reliable and sensitive laboratory indices for the diagnosis of Mn status have not yet been developed. Despite the difficulties in the interpretation of hair analyses (8, 9), this method may prove to be valuable in assessing Mn status.

This study was designed to investigate the Mn status of mothers and their offspring at delivery by the determination of hair Mn concentrations.

Materials and methods

The study was carried out on 31 full-term (Group 1), 18 preterm (Group 2), and 12 newborn infants with

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Alfalfa very high in Mn also Pinaffle and Cinnamon

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Good Mn level in Hair
≃ 0.75 PPM

TABLE 1
Hair Mn concentrations in newborns and their mothers and in control subjects

	Hair Mn concentration (μg/g)	Students *t* test	One tail probability
Group 1 (31)			
Full-term infants	0.75 ± 0.46*	t_{dep} = 5.17	p < 0.001
Mothers	2.54 ± 2.00		
Group 2 (18)			
Preterm infants	0.80 ± 0.40	t_{dep} = 3.90	p < 0.001
Mothers	2.37 ± 1.55		
Group 3 (12)			
Infants with congenital malformations	0.45 ± 0.25	t_{dep} = 1.04	NS
Mothers	0.56 ± 0.23		
Group 4			
Control subjects	2.42 ± 1.22		

* Means ± SD.
† Infants: Group 1 vs Group 3, t_{ind} = 2.14, p < 0.025; Group 2 vs Group 3, t_{ind} = 2.59, p < 0.01; Group 1 vs Group 2, NS.
‡ Mothers: Group 1 vs Group 3, t_{ind} = 3.40, p < 0.001; Group 2 vs Group 3, t_{ind} = 3.99, p < 0.001; Group 3 vs Group 4, t_{ind} = 4.86, p < 0.001; there is no significant difference between Groups 1, 2 and 4.

congenital malformations (Group 3) and their mothers and 11 nulliparous women of comparable ages (Group 4—controls). Ages of the mothers ranged from 17 to 42 yr, and parity of the group ranged from one to seven. None of the mothers showed clinical evidence of nutritional deficiency. No subject had received iron or vitamin supplements during pregnancy. The study was approved by the Dean of Istanbul Faculty of Medicine. Informed consent was obtained from parents and/or subjects.

Gestational ages of the full-term infants ranged from 37 to 42 weeks and birth weights ranged from 2.7 to 4.4 kg. In preterm infants, gestational ages ranged from 28 to 32 weeks and birth weights ranged from 1.2 to 2.4 kg. In newborn infants with congenital malformations, gestational ages ranged from 30 to 40 weeks and birth weights ranged from 1.5 to 3.2 kg. Six of 12 babies with congenital malformations had developmental defects of the central nervous system (1 anencephaly, 5 meningomyelocele cases, one with spina bifida occulta and one with hydrocephalus). Three cases had double cleft lip and cleft palate, 1 case had hermaphroditism, 1 case with digital aplasia of both hands and 1 case with digital aplasia of the left foot.

Hair samples in the mothers were collected from the suboccipital area of the head in immediate proximity to the scalp and stored in plastic bags. Before the collection of hair samples, it was established that the subject was not using any hair shampoo or coloring substance. As hair was generally scarce in newborn babies, collections were not limited to the occipital area only.

The concentration of Mn in hair was determined by the flameless atomic absorption technique using a Perkin-Elmer 503 double-beam atomic absorption spectrometer equipped with both a HGA-2100 graphite furnace and a model 56 recorder.

Duplicate hair samples of approximately 50 to 100 mg were washed sequentially in hexane, analytical grade ethanol and deionized distilled water (3 times). They were dried at 110°C in a vacuum oven overnight, weighed and then placed in a muffle furnace, heated to 250°C for two hours and then ashed at 430°C for 12 h or until the ash was completely white. The ashed samples were then dissolved in 1 ml of 1 N HCl and 20 μl aliquots injected into the graphite furnace directly or after appropriate dilution for determination of Mn content.

The instrumental parameters used for the analysis of the hair samples were: drying for 20 s at 120°C, charring for 30 s at 1100°C and atomization for 6 s at 2500°C. The sample response was compared to that of inorganic Mn (Fisher Scientific Co,). Bovine Liver, Standard Reference Material No 1577, National Bureau of Standards (NBS) Washington DC was used in testing the validity of analytical methods. Mean Mn concentration obtained for the reference standard was 10.39 ± 1.08 μg/g (with individual values ranging from 8.8 to 11.9 μg/g), compared with the certified values of 10.3 ± 1.0 μg/g.

Differences between groups were analyzed using paired-sample *t* test (indicated in Table as t_{dep}) and two sample *t* test (indicated as t_{ind}).

Results

Table 1 shows hair Mn concentrations in the three groups of newborn infants and their mothers and in control subjects. Mean hair Mn concentration in control subjects was 2.42 ± 1.22 μg/g (mean ± SD). Hair Mn contents in mothers of full-term and preterm infants were not found different from control subjects. As seen in the table, in infants with congenital malformations and their mothers, hair Mn levels were found to be significantly

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lower than full-term and preterm infants and their mothers as well as compared with normal control subjects. With the exception of mothers of infants with congenital malformations, hair Mn concentrations in mothers were significantly higher as compared with their infants.

In the total group, the hair Mn concentrations of the newborns and their mothers did not show any correlation with the mother's age and birth rank.

Discussion

To our knowledge, available information on Mn concentrations of hair in man is limited (10), and there are no studies to date in newborn infants and their mothers. It is known from animal experiments that adequate maternal Mn nutritional state during pregnancy is important for normal fetal growth and development (1–4).

Mn deficiency would not be expected to arise in human adults because the element is widely distributed in foodstuffs. One exception may be the pregnancy state, when transfer of Mn to the fetus via the placenta may lead to some alterations in the mother.

In this study, hair Mn levels in mothers of full-term and preterm infants were found to be almost identical with those of control subjects, while mean hair Mn content in mothers of infants with congenital malformations was significantly lower. The low hair Mn concentrations found in mothers of infants with congenital malformations may possibly reflect a state of Mn deficiency in these women.

Hair Mn levels in full-term infants are in accord with the results on preterm infants. This finding indicates that transfer of Mn to the fetus occurs before the third trimester of pregnancy.

Low hair Mn levels in infants with congenital malformations and their mothers suggest that Mn deficiency may play a role as one potential factor in intrauterine malformations. Additionally, these results support the assumption that the interrelationship between hair Mn content in the newborn and that of its mother is regulated by a homeostatic mechanism which is mainly dependent on the Mn status of the mother. The results also indicate that prenatal Mn analysis in maternal hair may prove to be a reliable indicator for the risk of intrauterine malformations. Further research is needed to support and clarify these results.

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Samples Came from Turkey

Batch 31

Turkey Hair

بحث رائد
سعد
للتأكد من
نقص عنصر
السلينيوم
في شعر
الأطفال
وعلاقته
بالأمراض

Element		15	16	17	18	19	20
		HB1(Turky)	HB2(Turky)	HB3(Turky)	HB4(Turky)	7 Years HB5(Turky)	HB6(Turky)
Be	Be_9	-0.01278	-0.03266	0.02337	-0.01434	-0.00876	0.01476
Li	Key	-0.14303	-0.14628	-0.03567	-0.03448	-0.03563	0.00169
B	B_11	1.28193	-0.21766	2.87932	6.02583	1.17596	0.80825
		1.1389	**-0.36394**	**2.84365**	**5.99135**	**1.14033**	**0.80994**
Ag	Ag_109	0.07456	0.23194	0.11476	0.07821	0.03397	3.08466
Cd	Cd_114	0.00617	0.05805	0.11723	0.02424	0.0431	0.17265
In	In	ND	ND	ND	ND	0.01612	ND
Pd	Pd	0.01861	0.01482	0.01741	0.01084	0.08832	0.01695
Sn	Sn_118	0.29567	7.79592	1.10514	0.2197	0.68322	39.2362
Ba	Ba_137	0.36262	0.97409	1.17062	0.70217	0.81596	8.91925
Sb	Sb_121	0.06053	2.05243	0.40875	0.11772	0.02671	0.06745
Pr	Pr	ND	ND	ND	ND	ND	ND
La	La	ND	ND	ND	ND	ND	ND
Ce	Ce	ND	0.02324	0.05343	0.0593	0.01333	0.03809
Cs	Cs	ND	ND	0.01074	0.01035	ND	ND
Te	Te_125	ND	ND	ND	ND	ND	ND
		0.81816	**11.15049**	**2.99808**	**1.22253**	**1.72073**	**51.53525**
Cu	Cu	11.27219	31.98313	27.17326	9.36394	18.71251	48.8394
W	W_184	0.00647	0.05854	0.01156	0.00752	0.02388	0.01617
Co	Co_59	-0.00048	0.021	0.04414	0.01406	0.01481	0.09929
Zn	Zn	164.66133	205.58787	127.72781	85.97225	173.69235	210.69737
Ni	Ni_60	0.5487	1.00362	0.63987	0.56222	0.57223	6.58447
Os	Os_192	0.00377	ND	ND	ND	0.00649	ND
Fe	Fe	7.10798	22.40779	48.85227	14.74902	10.91945	13.6499
Ta	Ta	0.13476	0.13866	0.1047	ND	0.78023	0.18146
Re	Re_185	ND	ND	ND	ND	ND	ND
Yb	Yb_174	ND	ND	ND	ND	ND	ND
Hf	Hf_180	0.61516	0.59227	0.41641	0.30865	5.54286	0.75016
Lu	Lu	-0.00038	0.00017	-0.00018	-0.00004	0.00045	0.00025
Tm	Tm	ND	ND	ND	ND	ND	ND
Ho	Ho	ND	ND	ND	ND	ND	ND
Er	Er	ND	ND	ND	ND	ND	ND
Dy	Dy_164	ND	ND	ND	ND	ND	ND
Tb	Tb	ND	ND	ND	ND	ND	ND
Gd	Gd_158	ND	ND	ND	ND	ND	ND
		184.3495	**261.79305**	**204.96984**	**110.97762**	**210.26526**	**280.81847**
Na	Na	188.16918	142.3814	3250.5061	1062.60644	245.21101	207.68074
C	C	292414.7035	313123.9193	363827.413	349135.8795	318358.6877	273297.1526
		292602.8727	**313266.3007**	**367077.9191**	**350198.4859**	**318603.8987**	**273504.8333**
Rh	Rh	ND	ND	ND	ND	ND	ND
Mo	Mo_98	0.02577	0.04834	0.04057	0.04261	0.03216	0.01288
Ru	Ru	-0.00159	-0.00172	-0.00174	-0.00211	-0.00098	-0.00099
Nb	Nb	0.0316	0.03416	0.02685	0.01884	0.18989	0.03851
Zr	Zr_90	0.42262	0.45594	0.39682	0.32693	2.52185	0.43913
		0.4784	**0.53672**	**0.4625**	**0.38627**	**2.74292**	**0.48953**

		15	16	17	18	19	20
Ca	Ca	503.55432	709.58044	1416.7677	553.67315	636.09631	9446.94726
K	K	243.40893	250.7315	1281.458	1530.41015	53.82457	50.23252
Sc	Sc	0.13422	0.79182	1.54124	1.82216	3.27449	1.94536
Si	Si	12.95151	91.80982	29.88284	28.52	31.86545	219.06063
P	P	178.72349	135.86195	193.78765	214.80192	154.16664	127.6908
Cl	Cl_35	510.97195	436.43296	3494.69351	1293.52843	999.09225	-17.05109
S	S	43444.66406	46252.85546	39125.42968	37821.3789	43364.91796	35795.16796
		44894.40848	**47878.06395**	**45543.56062**	**41444.13471**	**45243.23767**	**45623.99344**
Cr	Cr_53	0.07266	0.36766	0.14497	0.00795	-0.10717	0.02636
V	V_51	-0.03782	0.02803	0.20672	0.01866	0.03758	0.07079
Ti	Ti_49	-0.14307	-0.19783	0.74363	0.1133	-0.02717	0.19176
Eu	Eu	ND	ND	ND	ND	ND	ND
Sm	Sm_149	ND	ND	ND	ND	ND	ND
Nd	Nd	ND	ND	0.02741	0.02262	ND	0.01492
Mn	Mn_55	0.22902	1.08079	1.76104	0.4927	0.17688	0.9554
		0.12079	**1.27865**	**2.88377**	**0.65523**	**0.08012**	**1.25923**
Al	Al	-8.36982	2.68344	19.86471	5.40516	0.21862	22.55184
Tl	Tl_205	-0.00022	-0.00085	0.00114	0.00093	0.00093	0.00002
Pb	Pb_208	1.11607	73.97342	4.10709	2.63898	0.40674	4.38087
U	U_238	-0.00881	0.01663	0.0017	0.10212	0.04435	0.11241
As	As_75	0.04127	0.03857	0.54319	0.1284	0.03032	0.00695
Hg	Hg	0.338	0.046	0.129	0.04	0.038	0.054
Bi	Bi_209	-0.00832	-0.00506	-0.0052	-0.00404	0.07104	0.01719
		-6.89183	**76.75215**	**24.64163**	**8.31155**	**0.81**	**27.12328**
Au	Au	0.05702	0.0495	0.08134	0.10608	0.17479	0.52513
Mg	Mg	51.28121	52.30457	142.65476	42.92577	214.10244	790.63244
Ir	Ir_193	ND	ND	ND	ND	0.01384	ND
Pt	Pt	0.00184	0.00381	0.00253	0	0.02866	0.00409
Rb	Rb	0.23168	0.20066	0.96947	1.22772	0.0342	0.04693
Sr	Sr	1.85581	3.44795	4.03033	2.5078	3.68531	46.14295
Ga	Ga	0.00379	0.02125	0.02821	0.01759	0.01714	0.19105
Th	Th_232	0.17033	0.24001	0.32679	0.34674	2.4687	0.93993
Y	Y	-0.00006	0.00508	0.01631	0.00423	0.0071	0.0111
Br	Br_79	-8.55367	-6.16777	-3.29569	-3.46832	5.03993	-1.34682
Ge	Ge	0.28495	0.37164	0.25289	0.21353	0.18206	0.1556
Se	Se_82	0.49633	0.85651	0.63191	0.74804	0.5705	0.08783
		45.82923	**51.33321**	**145.69885**	**44.62918**	**226.32467**	**837.39023**

	21	22	23	24
		11 Years		
	HB7(Turky)	HB8(Turky)	HB9(Turky)	HB10(Turky)
Be_9	-0.01023	-0.01641	0.01087	0.00603
Key	0.01207	0.02082	0.00043	-0.01716
B_11	1.07097	3.00773	1.60516	0.9977
	1.08304	**3.02855**	**1.60559**	**0.98054**
Ag_109	0.05159	0.24656	0.12556	0.13075
Cd_114	0.09129	0.10254	0.03731	0.10721
In	ND	ND	ND	ND
Pd	0.01821	0.01544	0.01263	0.00909
Sn_118	1.56623	0.8308	0.88356	0.80322
Ba_137	4.57935	0.78874	10.94267	3.0227
Sb_121	0.02668	0.05397	0.10366	0.16787
Pr	ND	ND	ND	ND
La	ND	ND	ND	ND
Ce	0.02156	0.02628	0.09606	0.02873
Cs	ND	ND	ND	ND
Te_125	ND	ND	ND	ND
	6.35491	**2.06433**	**12.20145**	**4.26957**
	Diabetic			
Cu	9.66241	33.47302	14.87756	14.68543
W_184	0.04773	0.00911	0.20989	0.00453
Co_59	0.01705	0.02251	0.05778	0.01908
Zn	166.46582	111.78536	288.7763	148.74691
Ni_60	1.25055	0.38828	1.25428	0.61071
Os_192	ND	ND	ND	ND
Fe	14.66213	14.49954	64.90731	15.70627
Ta	0.15466	0.1228	ND	ND
Re_185	ND	ND	ND	ND
Yb_174	ND	ND	ND	ND
Hf_180	0.65675	0.44795	0.31948	0.24416
Lu	0.00011	0.00008	0.00021	-0.00003
Tm	ND	ND	ND	ND
Ho	ND	ND	ND	ND
Er	ND	ND	ND	ND
Dy_164	ND	ND	ND	ND
Tb	ND	ND	ND	ND
Gd_158	ND	ND	ND	ND
	192.91721	**160.74865**	**370.40281**	**180.01706**
Na	447.67852	1003.69665	972.21502	341.53341
C	347208.6759	309321.3412	305486.9638	310509.9919
	347656.3544	**310325.0379**	**306459.1788**	**310851.5253**
Rh	ND	ND	ND	ND
Mo_98	0.03969	0.04378	0.10899	0.03984
Ru	-0.00187	0.0001	-0.00139	0.00004
Nb	0.03469	0.02367	0.02016	0.01533
Zr_90	0.44725	0.32073	0.32981	0.22997
	0.51976	**0.38828**	**0.45757**	**0.28518**

	21	22	23	24
Ca	614.79602	523.79669	3535.66894	4272.73388
K	237.89506	1925.27038	570.0285	161.42605
Sc	0.74487	0.88762	1.31829	1.52169
Si	61.45438	42.6686	43.07497	99.80564
P	127.82876	135.03117	234.59199	555.72949
Cl_35	284.2769	1930.43398	586.19646	14.016
S	41424.58593	41797.58203	39329.46875	40027.51953
	42751.58192	**46355.67047**	**44300.3479**	**45132.75228**
Cr_53	-0.2257	-0.17502	0.53967	-0.10031
V_51	0.10496	0.04356	0.0804	0.06502
Ti_49	0.11352	-0.06125	0.3173	0.02354
Eu	ND	ND	ND	ND
Sm_149	ND	ND	ND	ND
Nd	ND	0.01799	0.03077	ND
Mn_55	0.86687	0.56597	1.47624	0.4776
	0.85965	**0.39125**	**2.44438**	**0.46585**
Al	-2.78061	0.77719	15.77495	6.77059
Tl_205	-0.00037	0.00088	0.00022	-0.00006
Pb_208	0.72925	7.83879	3.81029	1.71095
U_238	0.01484	0.04066	0.01175	0.00115
As_75	0.07068	0.03362	0.0256	0.01491
Hg	0.02	0.021	0.032	0.04
Bi_209	-0.00008	-0.00043	0.0043	0.00165
	-1.94629	**8.71171**	**19.65911**	**8.53919**
Au	0.08839	0.10498	0.04294	0.04626
Mg	155.41021	86.5436	256.39645	473.58734
Ir_193	ND	ND	ND	ND
Pt	0.00184	0.00158	0.0009	0.00065
Rb	0.15474	1.3551	0.49696	0.12607
Sr	18.11508	2.84306	17.96324	22.11265
Ga	0.09204	0.01445	0.23381	0.06534
Th_232	0.34453	0.32499	0.36804	0.40185
Y	0.00707	0.00538	0.0194	0.00399
Br_79	-5.1285	67.29361	-2.36469	90.07933
Ge	0.22872	0.19331	0.18867	0.19371
Se_82	0.288	0.6346	0.12861	0.37876
	169.60212	**159.31466**	**273.47433**	**586.99595**

15	HB1(Turky)	Skin Cancer	Male 50 Years	Smoker
16	HB2(Turky)	Son of HB1	Male 15 Years	
17	HB3(Turky)	Prostate Cancer	Male 50 Years	
18	HB4(Turky)	Brother of HB3	Male 43 Years	No smoke
19	HB5(Turky)		Male 7 Years	
20	HB6(Turky)	Gouter	Female 43 Years	No smoke
21	HB7(Turky)	Heart attach-Diabetic	Male 75 Years	Smoker
22	HB8(Turky)		Male 11 Years	
23	HB9(Turky)			
24	HB10(Turky)			

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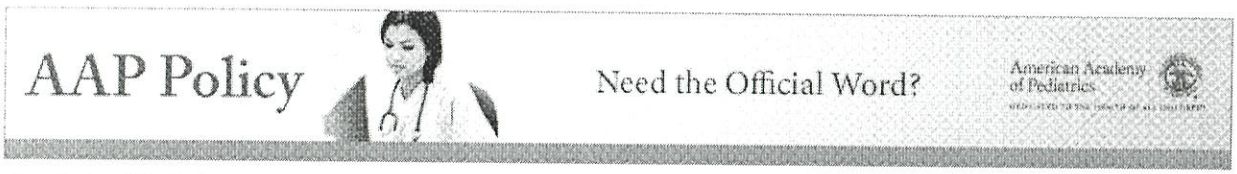
Subject: Low Levels of Selenium in Mothers and Their Newborns in Pregnancies With a Neural Tube Defect (Turky Study) Thanks



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Low Levels of Selenium in Mothers and Their Newborns in Pregnancies With a Neural Tube Defect

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What's this?

Objective. Very few data are presented in the literature about selenium (Se) in human fetal development. The aim of this paper was to study the relationship between maternal and neonatal Se status and neural tube defects (NTDs).

NTD = neural tube Defect

Patients and methods. Serum and hair samples were obtained from 20 nonpregnant women, 32 healthy mothers with normal newborns, and 28 mothers who had a newborn with NTD, and their newborns at delivery. Serum Se levels, as ng/mL, and hair Se levels, as µg/g, were determined on a Perkin-Elmer 1000 spectrophotometer (United Kingdom) by fluorometry.

Results. The mean maternal serum and hair Se concentrations in the NTD group (42.9 ± 1.75 ng/mL, 277 ± 7.73 ng/g, respectively) were significantly lower than those of the control healthy mothers (50.2 ± 2.35 ng/mL, 300 ± 6.10 ng/g, respectively) and the nonpregnant women (58.1 ± 3.12 ng/mL, 315 ± 7.64 ng/g, respectively). A significant decrease in concentrations of Se in serum and hair was observed in newborns with a NTD (26.0 ± 1.55 ng/mL, 181 ± 3.71 ng/g, respectively) compared with healthy newborns (32.6 ± 1.70 ng/mL, 204 ± 4.43 ng/g, respectively).

Conclusions. Maternal Se deficiency during pregnancy was thought to be one of the factors responsible for NTDs. However, the lowered serum and hair Se concentrations may be secondary manifestations of an abnormal pregnancy and did not contribute to its production. More studies on maternal Se status during the antenatal period, especially early gestation and neonatal Se status including normal newborns and NTD infants, are needed.

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Accepted on September 26, 1994

Hair Se ~~NTD Group 277~~
Control mother Healthy 0.30
Non Pregnat W 0.315
New Born with NTD. 181

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Original Paper

Concentrations of Toxic Metals and Trace Elements in the Meconium of Newborns from an Industrial City

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117 Newborn from industrial city
Pb 46.5 (1.399) µg/g dry weight
Cd 2.3
Zn 234
Cu 11.8
Fe 105

Key Words

- Cadmium
- Lead
- Toxic metal
- Trace elements
- Meconium

Abstract

Objective: To investigate fetal exposure to toxic metals [lead (Pb), cadmium (Cd)] and fetal levels of trace elements [zinc (Zn), copper (Cu), and iron (Fe)] in newborns from an industrial city. Relationships between meconium mineral contents and parental occupation and location of residence were also tested. *Method:* The meconium mineral contents of 117 healthy newborn infants were measured by flame atomic absorption spectrophotometer. *Results:* The median concentrations (interquartile range) of toxic metals and trace elements in the meconium were as follows: Pb: 46.5 (1,399) µg/g dry weight (wt), Cd: 2.3 (55.6) µg/g dry wt; Zn: 234 (3,049) µg/g dry wt; Cu: 11.8 (818.7) µg/g dry wt, and Fe 105 (2,980) µg/g dry wt. All the meconium samples contained both toxic metals and trace elements. The proportions of trace elements in the meconium samples with concentration higher than 100 µg/g dry wt of the substances tested were Zn 90%, Cu 64%, and Fe 53%. There were significantly positive correlations between the concentrations of toxic metals and trace elements. Also there were positive correlations between the levels of Zn, Fe, and parental occupations, and between the level of Fe and location of residence of the parents (proximity to the petroleum refinery or the dye industries). *Conclusion:* All the meconium samples were positive for toxic metals, and thus may reflect environmental pollution in the city. The occupation environments and the location of the family residence are linked with levels of trace elements in meconium.

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