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The Nickel Concentration in Breast Milk during the First Month of Lactation in Yazd, Center of Iran

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Abstract Breastfeeding plays an important role in the growth and development of breastfed infants, especially in the first 6 months of their lives. The present study was conducted to determine the nickel concentrations in breast milk of lactating women in Yazd, Iran. One hundred fifty volunteers were selected among nursing mothers referring to health centers in Yazd. In the first month of lactation, milk samples were collected three times, on days 3 to 5 (first), 16 (Second), and 30 (third) after delivery. Nickel concentration of the samples was measured by atomic absorption spectrophotometer. Demographic variables were collected through a questionnaire which was completed by mothers. The mean age of the study group was 27.40 ± 4.66 years. The mean nickel concentrations in breast milk at the first, second, and third samples were 47.3 ± 7.40, 49.9 ± 8.05, and 54.8 ± 7.38 μg/l, respectively. The concentration of nickel in the breast milk of more than 86 % of mothers was higher than the permissible range for it. There was no significant relationship between the mean value of nickel in breast milk and education, age, and job of mothers. High level of nickel in breast milk may be attributed to consumed food and drinking water containing nickel. Monitoring the nickel level in breast milk regularly is recommended.

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Introduction

Breastfeeding is the best natural method of nutrition for infants because this food contains an adequate amount of fat, protein, carbohydrate, and other essential components for infants' growth and immunity [1, 2]. The maternal nutrition is very important during lactation, and it is at the forefront of priorities in health programs [3]. The components of the breast milk promote infants' protection against infectious diseases, increasing the intelligence quotient (IQ) as well as the emotional and psychological development of the infants [4]. Lack of exclusive breastfeeding, mostly during the first 6 months, leads to more than one million preventable deaths annually [5, 6]. The World Health Organization (WHO) supported breastfeeding as the preferred nutrition for infants [7].

It is worth noting that in the first month of their lives, babies consume more than 400–500 ml of milk and at 2–6 months old, they consume more than 760 ml per day [8]. Despite the fact that breastfeeding is recommended for infants' growth and development all around the world, breast milk can be one way for the elimination of toxic elements from the body of mothers. Maternal nutrition is important during pregnancy and lactation, because the placenta and human milk act as intermediates for the transfer of heavy metals [8]. Pregnancy is considered as the most dangerous period of exposure to some pollutants like heavy metals [9]. The special susceptibility of infants to toxic substances, especially metals, is owing to their body building formation, high intestinal absorption, and energy consumption in the first year. Several authors reported that infants are widely vulnerable in contact to heavy metals; the reason is their lack of renal evolution and low tolerance level [10, 11]. Heavy metals can enter the food chain in different ways among contaminated water and crops grown on polluted soil through environmental contamination. So, human activity is the most common culprit in contamination of food with heavy metals. [12].

Increasing exposure to heavy metals causes several clinical disorders such as cancer of respiratory system, skin disorders, anemia, depression, reproductive disorders, heart failure, gastro-intestinal disorders, fatigue, immunity reduction, and even death [13]. Nickel, a heavy metal, and its compounds are present by 1–200 mg/Kg in the earth's crust and are widely used in industry due to their physical and chemical properties. Abundant use of products containing nickel leads to environmental pollution [14]. A little amount of nickel in food is necessary for the body, but when it exceeds the permissible limit, several harmful effects such as risk of lung, nasal, laryngeal, and prostate cancer will appear [15].

In 1990, the International Agency for Research on Cancer (IARC) evaluated the epidemiological and experimental studies on 169 work forces for cancer associated with nickel and its compounds and reported that these are carcinogenic for men [16]. Nickel toxicity studies on animals revealed the lipid peroxidation in the kidney, liver, and lung [17]. The data from human studies indicate that symptoms of acute exposure to nickel consist of gastro-intestinal disorders (nausea, vomiting, abdominal pain, and diarrhea), visual disturbance, headache, vertigo, and cough. In addition, chronic inhalation of nickel and its compounds is associated with high risk of lung cancer and cardiovascular, skin, and kidney diseases [18]. Therefore, it is essential that the breast milk be monitored in terms of contaminants such as heavy metals during breastfeeding. This study was conducted to determine nickel concentration in the breast milk of lactating mothers and to associate it with mothers' demographic parameters.

Materials and Methods

Study Design and Participants

A cross-sectional study was conducted for considering the nickel pollution of breast milk. The participants included lactating mothers referring to the health center on the first month after delivery in Yazd, Iran. In coordination with Yazd health centers, 150 mothers volunteered for sampling in a convenience method after explanation of the research aims. The participants were called on the 3–5, 16, and 30 days after delivery for sampling of breast milk. A questionnaire was given to breastfeeding mothers for collecting the personal information. To measure the nickel levels, 10- to 20-ml breast milk samples were manually taken by individual mothers with sterilized breast pumps in the mornings before infant feeding. The samples were collected in sterile plastic containers and were immediately transferred to the research laboratory of the School of Public Health and were stored at a temperature of −20 °C until analysis. All chemicals in this study were of analytical grade to prevent the effect of impurities on the results. Double distillated water was used for the preparation of the solution and washing the Labware.

Samples Preparation and Measurements

The milk samples were removed from the freezer and were thawed at laboratory temperature. After complete melting, each sample was stirred for a few times for mixing and 3 ml of it was transferred into the test tube with sterile pipette. Then, 1 ml of 1 M acetic acid was added to each sample and the mixtures were centrifuged at 3200 revolutions per minute (RPM). Supernatant was discarded and lower liquid was extracted. The samples were followed by 0.2 ml of 1 M acetic acid and centrifuged again, at 3200 RPM for 15 min to get completely clear solutions. Again, the supernatant was discarded and finally, the lower liquid was extracted.

The nickel concentration was measured by atomic absorption spectrophotometer model 20AA (Varian, Australia) at a wavelength of 232 nm by standard addition methods. The absorption of each sample was read three times, and the mean concentration was calculated.

Data Analysis

The output of AAS and questionnaires were analyzed using descriptive statistics and linear regression model procedure of the SPSS18. All data were expressed as mean ± standard deviation. Statistical significance was set at the level of $P < 0.05$. The limit of detection (LOD) and limit of quantification (LOQ) for nickel were calculated under LOD = $3 \times s.m.^{-1}$ and LOQ = $10 \times s.m.^{-1}$, respectively, where s is the standard deviation of blanks and m is the slope of the calibration curve. The LOD and LOQ were 0.15 and 45 $\mu g.L^{-1}$, respectively.

Ethical Considerations

This study was approved by the Ethical Committee of Shahid Sadoughi University of Medical Science. Volunteers provided an informed written consent, agreed to sampling, and no payment was done in the experiment.

Results

The results indicated that 34 % of mothers were under the age of 25 years, 42 % aged between 25 and 30 years, and 24 % aged over 30 years. The age range of volunteers was 18 to 43 years with a mean age 27.40 ± 4.66 years. The studied samples consisted of housewives, 94 % (141 subjects) and working women, 6 % (9 subjects). In terms of educational level, 23.3 % (35 subjects) of mothers were under high school, 52 % (78 subjects) had high school, and 24.7 % (37 subjects) had university education. The mean and standard deviation of nickel concentration in breast milk during the first month of lactation via demographic profiles are given in Table 1.

Likewise, the nickel pollution in breast milk samples was analyzed in three stages of sampling. The frequency distributions of nickel pollution of mother's milk status in three stages of sampling are presented in Table 2.

The results of nickel concentration in three stages of sampling were correlated with some characteristics of mothers such as length, weight, age, and number of deliveries in the first month of breastfeeding. Table 3 depicts the correlation between nickel concentrations with mother's demographic parameters in the first month of lactation.

Discussion

Nickel is a heavy metal that is known as a hematotoxic, immunotoxic, neurotoxic, nephrotoxic, hepatotoxic, and carcinogenic agent. It is also toxic to the respiratory and reproductive systems [19]. The WHO has reported 11 μg/kg b. wt. to be acceptable as daily nickel intake in baby food and infant formula [20]. The tolerable weekly nickel intake in breast milk has been declared 35 μg/week/kg b. wt. which has been based on daily intake of 5 μg/day/kg b. wt. [21]. Hence, it is necessary that the amount of this element is monitored and controlled in the population and foods, especially in human milk. In the present study, the nickel levels in breast milk were monitored in the first month of breastfeeding, which was detected to be in the range value of 46.0–56.7 μg/l with a mean nickel of 51.0 ± 7.6 μg/l in breast milk samples.

The toxic metals in the breast milk may depend on various factors such as the time of sampling, the time of lactation, as well as environmental factors. Despite numerous studies on breast milk heavy metal levels, there are no data on the nickel levels of breast milk in the first month of breastfeeding in Iran. Generally, the studies on nickel levels in breast milk in the other countries are as follows: The study by Gürbay et al. (2012) in Turkey revealed that the range of nickel in milk samples of women was 6.2–111.5 μg/day with an average value of 43.9 ± 33.8 μg/L. The results of this study indicated that levels of the breast milk nickel exceeded partly the recommended limit [22]. Casey et al. (1987) reported the nickel value of 1.2 ± 0.4 μg/L in breast milk samples during the first lactation with an average daily nickel intake of 0.8 μg [23]. The study by Turan et al. (2001) on 30 samples of maternal colostrum indicated that the nickel contents were about 27.8 μg/L [24]. Comparing our results with reported values revealed the high nickel values in mother's milk samples. Rica et al. (1982) found that nickel contents in the 179 human milk samples of different countries and different sociological groups were in the ranges of 3–50 μg/L [25]. The maximum nickel concentration in breast milk was reported to be 50 μg/L, which is close to the maximum value determined in the present study. In line with the finding of the current study, the results of previous study that were conducted by Almedia et al. (2008) on 44 healthy lactating Portuguese women that investigated no significant trend for a decrease in concentration of Co, Pb, and Ni in milk during the first month of lactation [26].

The obtained *P* values illustrated that there was no significant relationship between demographic parameters of mothers and the nickel value in breast milk. The results in Table 1 indicate that the amount of nickel in breast milk is not associated with age (*P* value ≥0.27). Mother's age is a factor affecting the amount of nutrients in breast milk. However, not many studies have been conducted on the effects of mother's age on metal concentration in breast milk. A study showed that with increasing age, metal uptake decreases in the intestine. Eventual changes in the expression of transporter proteins gene and the increase in cholesterol level were mentioned as the reasons for a decrease in metal absorption [27].

Table 1 Mean ± SD concentration (μg/L) of nickel in the breast milk during the first month of lactation

		First sampling		Second sampling		Third sampling	
	Groups	Mean ± SD	*P* value	Mean ± SD	*P* value	Mean ± SD	*P* value
Education level	Under high school	49.1 ± 6.57	0.24	50.4 ± 7.85	0.89	55.0 ± 6.28	0.87
	High school	46.6 ± 7.91		49.8 ± 8.52		54.5 ± 7.94	
	University	47.1 ± 6.92		49.5 ± 7.39		55.2 ± 7.26	
Age (years)	<25	46.0 ± 6.69	0.27	50.3 ± 8.5	0.31	54.8 ± 7.70	0.65
	25–30	48.1 ± 6.51		50.5 ± 8.06		54.3 ± 7.31	
	>30	47.6 ± 9.38		48.1 ± 8.23		55.7 ± 7.12	
Job	Housewife	47.0 ± 7.33	0.06	49.9 ± 8.06	0.09	54.7 ± 7.51	0.43
	Employee	51.7 ± 7.68		50.0 ± 8.47		56.7 ± 3.85	
	Total	49.7 ± 7.51		49.9 ± 8.26		55.7 ± 5.67	

Table 2 Frequency distribution of nickel pollution of mother's milk status in three stages of sampling

	>The permissible limit	In the permissible limit	<The permissible limit
First sampling	132 (88)[a]	11 (7.34)	7 (4.66)
Second sampling	141 (94)	2 (1.34)	7 (4.66)
Third sampling	129 (86)	14 (9.34)	7 (4.66)

[a] Number (percent)

The statistical results presented in Table 1 demonstrated no significant relationship between nickel concentration of breast milk and mothers' job. Considering that 94 % of the women participating in the present study were housewives and that they were not employed in factories and industrial centers, so no significant relationship was observed between the amount of nickel in the milk samples and job. A study with more samples probably can offer clear results about the relationship between job and heavy metal pollution.

The frequency distribution results (Table 2) showed that 88 % of the samples in the first round had the nickel concentration above the permissible limit value, but it was less than in the second round (94 %). It is likely that breastfeeding mothers may have more consumption of nickel-rich foods after delivery. Also, it was observed that 86 % of the samples in the third round had the nickel concentration above the permissible limit, but it was less than the first and second rounds. It can be argued that nickel concentration in breast milk diluted with increasing of milk volume during the breastfeeding. Of course, this argument requires a more detailed study.

A positive correlation between nickel concentration in breast milk and weight of mothers (Table 3) was found in the three stages of sampling in the first month of lactation, contradicting the nickel pollution regulation of breast milk.

Table 3 Correlation coefficient of nickel concentrations with mother's demographic parameters

Characteristics	Coeff.	SE	*ß*	SD	*P* value
First sampling					
Length	0.055	0.10	0.004	0.048	0.96
Weight	0.032	0.06	0.042	0.047	0.63
Age	−0.007	0.17	0.004	−0.038	0.97
No. of delivery	0.590	1.01	0.065	0.571	0.56
Second sampling					
Length	0.109	0.11	0.090	1.021	0.30
Weight	0.042	0.07	0.041	0.549	0.58
Age	−0.110	0.19	−0.059	−0.578	0.55
No. of delivery	−0.10	1.10	−0.011	−0.092	0.92
Third sampling					
Length	−0.182	0.10	−0.151	−1.728	0.086
Weight	0.085	0.06	0.112	1.270	0.203
Age	−0.011	0.17	0.060	−0.055	0.951
No. of delivery	0.253	1.02	0.028	0.251	0.802

The low variation on three stages of sampling nickel concentration in the breast milk indicated little influence of maternal intake or environmental exposure. It can be related to refusal of mothers to receive any allergic food for protection of their children. According to Table 3, a negative correlation between nickel concentration in breast milk and age of mothers was found in the three stages of sampling. It seems that increasing maternal age interacts with the transportation of Ni ions into the mammary gland. Also, the nickel cations may share toward common transporters with two-valent cations such as Fe, Ca, and Zn for transferring to breast milk [28].

A possible reason for high nickel contents in breast milk can be related to the consumption of foods containing nickel, drinking water, contact with nickel-containing particles, and use of nickel-containing products like nickel jewelry or even nickel cooking utensils [21]. Respiratory, oral, and dermal contact can be noted as sources of exposure to nickel. Inhalation of tobacco smoke can affect the nickel concentration in breast milk. Torjussen et al. (2003) indicated that nickel content is high in cigarettes, and it was in the range of 6.2–50.5 μg/L in the blood plasma of smokers [29]. Also, a study on US adult smokers (2009) reported that the mean value of nickel levels in cigarettes was 2.21 ± 0.54 μg per gram of tobacco [17]. Therefore, mothers' exposure to tobacco smoke can be one of the ways of entering nickel into the breast milk.

One way of nickel entry into the body is oral exposure. Common food items such as tea, coffee, chocolate, nuts, soya beans, oatmeal, cabbage, spinach, and potatoes which contain high amounts of nickel are a major source of exposure to this heavy metal [30]. A research conducted by Velayetzadeh et al. (2010) revealed high levels of nickel in tuna fish using the wet digestion method [31]. Also, in a study conducted by Shahriari et al. (2003), the nickel contents in 25 % of the cases of red snapper and otolithes rubber were 0.38 ppm that is more than the WHO standards [32]. The study by Amaro et al. (1998) on raw cow's, ewe's, and goat's milk indicated that the mean concentration of nickel was 15.0 ± 3.8, 18.6 ± 2.5, and 13.6 ± 2.5 $\mu g.kg^{-1}$, respectively [33]. Mortezavi et al. (2005) determined the Ni, V, Pb, and Cu concentrations in oysters and found that nickel average in oysters was 32.6 μg/kg, which was higher than the standard [14]. Thus, consuming food contaminated with heavy metals can be a reason for an increase in concentrations of these metals in breast milk. In general, plant food is a dietary source of Ni exposure, because plants can cause heavy metals such as nickel to enter into the human body by the food chain through soil. The normal amount of nickel in plants was reported as 1 mg/kg of dry matter and the toxicity limit was 50 mg/kg of dry matter [34]. Hoodaji and Jalalli (2004) investigated the distribution of nickel in soil and reported that the surface layer of soil (0–5 cm) contained a significant concentration of nickel [35]. Therefore, soil pollution can cause food contamination, and in alimentary turn, can be transmitted to the breast milk through consuming the contaminated foods by breastfeeding mothers.

Conclusion

This study confirmed the presence of nickel in breast milk, and our results showed that more than 86 % of breast milk samples contained a high value of nickel, a fact which has a great risk to the health of breastfed infants. Regarding the importance of breast milk in babies' health, growth, and development, further studies are necessary to screen the contents of toxic pollutant concentration in breast milk. Moreover, it is proposed to conduct large-scale studies with more numbers of volunteers for estimating the effects of parameters such as diet and smoking on the heavy metals concentration in breast milk.

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