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Analysis of aluminum, minerals and trace elements in the milk samples from lactating mothers in Hamadan, Iran

Masoumeh Taravati Javad[a], Aliasghar Vahidinia[b], Fateme Samiee[c], Jomana Elaridi[d], Mostafa Leili[e,*], Javad Faradmal[f], Alireza Rahmani[g]

[a] Department of Midwifery, Faculty of Nursing and Midwifery, Hamadan University of Medical Sciences, Hamadan, Iran
[b] Department of Nutrition Sciences, Nutrition Health Research Center, School of Medicine, Hamadan University of Medical Sciences, Hamadan, Iran
[c] Department of Environmental Health Engineering, Research Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran
[d] Department of Natural Sciences, School of Arts and Sciences, Lebanese American University, Beirut, Lebanon
[e] Department of Environmental Health Engineering, Research Center for Health Sciences, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran
[f] Department of Biostatistics and Epidemiology, Modeling of Noncommunicable Diseases Research Center, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran
[g] Department of Environmental Health Engineering, Research Center for Health Sciences, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran

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ABSTRACT

The present cross-sectional study is aimed at analyzing the breast milk of lactating mothers in Hamadan, Iran for aluminum and several minerals and trace elements. Ten governmental health care centers were utilized to facilitate collection of breast milk samples. The breast milk samples were collected at 1, 2, 6, 7, and 12 months postpartum from one hundred healthy lactating women, who delivered full-term newborns. Detection of sodium (Na), zinc (Zn), calcium (Ca), iron (Fe), copper (Cu), magnesium (Mg) and aluminum (Al) levels was conducted with the use of Inductively Coupled Plasma Mass Spectrometry (ICP-MS). This method has shown high accuracy, precision, sensitivity, and linearity for the wide range of concentrations. The accumulated data were not normally distributed; thus, the non-parametric Mann-Whitney U test was used in the statistical analysis of the results. Mean concentrations of Fe, Zn, Cu, Ca, Mg, and Na were 0.75, 1.38, 0.35, 255, 34.58, and 155.72 μg/mL, respectively. The mean level of Al, a well-known neurotoxic metal, was determined to be an alarming 0.191 μg/mL. Moreover, 95% of participants contained very harmful concentrations of Al in their milk. This study also revealed Zn deficiency in about 50% of milk samples. Further investigation is needed to elucidate sources of exposure and factors that may influence maternal and fetal exposure to aluminum.

1. Introduction

Breast milk is the best source of nutrition for infants during the first six months of life [1]. Minerals are very important elements for the growth and development of healthy tissues. Literature reports indicate that nutrient deficiencies in the mother's milk are a public health concern and can lead to slowed growth rate in childhood, caloric reduction, osteoporosis, fractures and delay of bone organization [2,3]. Microelements are found in human milk in variable concentrations that depend on social, economic, climatological factors, as well as stages of lactation [3,4]. These microelements include iron (Fe), sodium (Na), calcium (Ca), potassium (K), zinc (Zn), copper (Cu), magnesium (Mg), etc. However, excessive amounts of these elements pose a significant health risk.

Iron is a component of hemoglobin in the blood and has an essential role in biological oxidation [5]. Iron deficiency anemia is the most common nutritional disorder in the world [6]. Its deficiency in infants and young children is widespread and has serious consequences like impairment of mental and psychomotor development. Prevention of iron deficiency should, therefore, be given high priority [7]. It should also be noted that a high iron intake my lead to iron overload, which may cause harmful effects including an increased risk of cardiovascular disease, noninsulin dependent diabetes and cancer [8]. Zinc is involved in many biochemical processes that are necessary for proper physiological function, growth and development. Low zinc levels are linked to damaged immune function and substantially increased infectious morbidity and mortality, and growth stoppage [4,5,9,10]. On the other hand, elevated zinc levels can cause nausea, vomiting, headaches and

* Corresponding author at: School of Public Health, Hamadan University of Medical Sciences, Shaheed Fahmideh Ave., 6517838695, Hamadan, Iran.
E-mail addresses: taravati.masoome@gmail.com (M. Taravati Javad), vahidinia@umsha.ac.ir (A. Vahidinia), samiee_fateme@yahoo.com (F. Samiee), jomana.aridi@lau.edu.lb (J. Elaridi), m.leili@umsha.ac.ir (M. Leili), javad.faradmal@umsha.ac.ir (J. Faradmal), rahmani@umsha.ac.ir (A. Rahmani).

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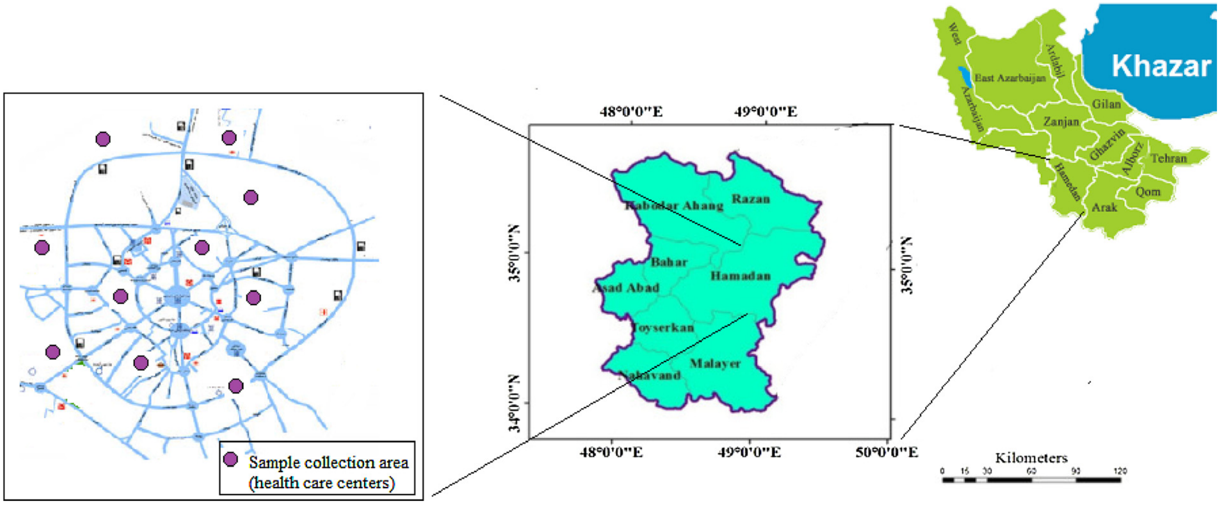

Fig. 1. Location of the desired governmental health care centers.

copper deficiencies [6]. Copper is an essential element involved in hemoglobin synthesis and in the formation of bone tissues and myelin sheaths in the nervous system [11], and is considered as an important cofactor in metalloenzymes [7]. Copper deficiency increases levels of free radicals, compromises defensive ability against oxidative stress, and adversely affects collagen and elastin reticulation. In excessive amounts, copper can cause diarrhea, nausea, vomiting, cirrhosis, anemia and bronchitis [6,9]. Sodium is important because of its characteristic role in the electrical activity of cells, adjustment of extracellular volume and acid-base balance, nerve conduction velocities as well as muscular function. In infants, high plasma sodium concentration (hypernatremia) is usually associated with excessive sodium intake and considered a cause of brain damage [7]. Calcium is another essential element for the structural integrity and mineralization of bones and teeth and plays an important role in many metabolic and intracellular regulatory processes and in the contraction of muscles and nerve transmission. Low calcium intake in infants or children may result in rickets, growth retardation and biochemical signs of hyperparathyroidism. Magnesium is essential for nerve and muscle activity and plays an important role in many enzymatic processes [7]. It is also a constituent of bones, teeth, and enzyme cofactors such as kinases. The symptoms of magnesium deficiency are similar to that of low-calcium tetany. A magnesium-deficient diet leads to poor growth, decreased muscle tone, ataxia, progressive incoordination and convulsions. An excess of magnesium, iron or aluminum interferes with phosphorus absorption through the formation of insoluble phosphates [12].

Aluminum is the most abundant metal in the earth's crust but has no essential biological function. Exposure to aluminum may originate from a variety of sources including diet [13] and personal care products. For example, recent evidence has linked breast cancer with aluminium-based antiperspirants [14]. Carcinogenicity of Al has also been proven in animal studies [15]. Moreover, Al is a neurotoxin whose toxicity for neuronal tissues is well-documented [16]. In this regard, Mirza et al. [17] showed that genetic predilection to Alzheimer's disease is accompanied by a higher tendency to accumulate and maintain aluminum in the brain. Furthermore, aluminum and cadmium interact with calcium in the skeletal system leading to osteodystrophies [18]. There is also some evidence for a metabolic relationship between aluminum and iron, calcium, magnesium, and manganese [19]. This relationship has been suggested as a factor in the occurrence of amyotrophic lateral sclerosis and Parkinsonian-dementia in the Western Pacific [20]. Infants and children are more vulnerable and sensitive to the adverse effects of toxic substances than adults [21]. Infant exposure to aluminum *via* breastfeeding depends primarily on dietary exposure of the lactating mother, however, this route of Al intake encounters several physiological barriers [22]. Blood–brain barrier (BBB), for example, considered as the main barrier for Al as it separates the brain microenvironment from the systemic circulation and keeps the central nervous system (CNS) in stable circumstances [23], especially at the early stage of life, but it's permeability to Al increases with age [24]. However, the results of Lorenzo et al. [25] study showed that the fat concentrate and lactose contribute to the high aluminum content of milk. In another study [26], it was also shown that the levels of aluminum are generally 50-fold higher in breast milk than in blood serum which suggests that breast milk is a sink for aluminum in the body [27].

The bioavailability of these elements to breastfed infants depends on the trace element content of the breast milk, length of breastfeeding and physiological factors [9]. Several studies have indicated that the concentration of nutrients and substances in breast milk may change, and particularly decrease, over the lactation period to reflect the infant's needs [28–31]. Nevertheless, breast milk should supply the growing needs of infants, which is especially important during the period of exclusive breastfeeding, i.e., the first 6 months postpartum.

Thus, it is necessary to measure trace element levels in breast milk to monitor changes in their concentration and to consider compensating for a specific deficiency with a supplement for the mother or infant. It is also important to assess for the presence of toxic metals that may have adverse health effects on the breastfed infant. To this effect, we aimed to measure the concentrations of Zn, Cu, Fe, Mg, Ca, and Na as the main minerals and trace elements and Al as the toxic metal in the human milk of Iranian mothers at specific periods over the lactation period. To our knowledge, no such study has been previously conducted on Western Iranian women and will provide essential information about the trace element composition of human milk and to evaluate the exposure of nursing infants to toxic elements such Al.

2. Materials and methods

2.1. Study population

This cross-sectional study was conducted in Hamadan, a Western Iranian city that is believed to be among the oldest Iranian cities [32]. The participants in this study were breastfeeding mothers who delivered term infants. Ten governmental health care centers were selected for sample collection. The location of the study area is shown in Fig. 1. In total, 100 women were randomly recruited and invited to participate in the study by providing breast milk samples.

The inclusion criteria were that the women could not be taking any nutrient supplements, and had infants who were full term and exclusively breastfed with normal birth weight, and with no chronic