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Research Article
Essential Trace Element Status in Foreign First-Year Students Attending RUDN University

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Abstract

Background and Objective: Micronutrient deficiency is characterized by strong geographic patterns. The objective of the present study was to perform comparative analysis of essential trace elements levels in hair and urine of Russian and foreign first-year students attending the Peoples' Friendship University of Russia (RUDN University, Moscow). **Materials and Methods:** The study involved 65 first-year RUDN University students from Russia as well as 207 foreign first-year students from Asia, Middle East, Africa and Latin America. Evaluation of hair and urinary copper (Cu), iron (Fe), iodine (I), selenium (Se) and zinc (Zn) content was performed using inductively-coupled plasma mass-spectrometry. **Results:** Hair Cu content in Russian students was found to be higher than that in examinees from Asia and Middle East by 25 and 32%, respectively. Hair Fe content in students from Asia, Middle East and Latin America were 30, 66 and 29% lower when compared to the control values. The hair iodine levels in the students from Middle East were lower than those of Russia, Asia, Africa and Latin America by a factor of 3.4, 3.6, 5.5 and 4.7 respectively. The highest hair Se levels were observed in Asian students. Hair Zn content in African students was found to be lower than that in Russian, Asian, Middle East and Latin American counterparts by 30, 30, 26 and 16%, respectively. Urinary metal levels partially corresponded to the observed patterns in hair. Zn excretion tended to be higher in all foreign students when compared to the Russian values. However, no significant group difference in urinary iodine levels were observed. **Conclusion:** The results correspond to the geographic patterns of the prevalence of micronutrient deficiency. Monitoring and modulation of nutritional trace element status may improve health and educational performance in students.

Key words: Foreign students, micronutrient deficiency, iodine, iron, zinc

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Essential trace elements are required for a lot of physiological processes, whereas its deficiency is associated with a variety of diseases[1]. Therefore, micronutrient deficiency is considered a significant public health concern[2]. Particularly, iron deficiency affects up to 1.2 billion people[3] contributing to more than 800,000 deaths worldwide[4]. Approximately 1.1 billion people worldwide face the risk of zinc deficiency[5], whereas iodine deficiency affects more than 1.5 billion people[6]. Copper play a significant role of in human health but epidemiological data on copper deficiency are lacking[7].

Micronutrient deficiency is characterized by strong geographic patterns. The prevalence of iron and zinc deficiency is shown to be highest in Africa and Asia[4,5]. Selenium status is also determined by geochemical factors depicting the deficiency or overload of selenium[8]. Naturally low iodine contents were found in soils of Asia, Africa, Europe and South America[6].

The prevalence of anemia in pregnant women was found to be higher in immigrant populations from Middle East, Africa, Asia, when compared to Danish women[9]. It is also notable that newcomers are characterized by inadequate zinc, calcium, vitamin D and iron intake[10]. These differences may have a significant impact on morbidity of immigrant population[11].

Foreign students are considered as a population at high risk of health problems[12]. Monitoring of micronutrient status of foreign students may provide a significant tool for prevention of essential trace element deficiency and associated adverse health effects[13]. However, the particular patterns of trace element status in students originating from different geographic regions are not estimated to date. The objective of the present study was to perform comparative analysis of hair and urinary levels of essential trace elements in Russian and foreign first-year students attending the Peoples' Friendship University of Russia (RUDN University, Moscow).

MATERIALS AND METHODS

The protocol of the present study was approved by the Institutional Ethics Committee (RUDN University, Moscow, Russia). All procedures including sampling and examining were performed according to the Declaration of Helsinki and its later amendments[14]. All students were invited to participate in the study. Participation was on a voluntary basis.

The study involved 65 first-year RUDN University students from Russia as well as 207 foreign first-year students from Asia (n = 57, China>40%), Middle East (n = 84, Iran>60%), Africa (n = 40; Angola, Zambia, Mauritania, Sao Tame and Principe>10%) and Latin America (n = 28; Dominican Republic, Ecuador >25%, Cuba>15%). The mean age of the students was 22.4±4.3 years. The overall male-to-female ratio was 40/60%, although significant group difference was observed. In view of high variability in age and gender, group comparison was adjusted for these parameters. Hair and urine sample was collected during the first medical examination on admission at the university.

Urine (second portion) samples were collected in the morning after overnight fasting using Vacuette® Urine Collection Cups (Greiner Bio-One International AG, Austria) and stored in freezer until analysis. Occipital hair samples were collected using precleaned stainless-steel scissors from three different sites. Usage of trace element (zinc, selenium)-enriched shampoos or other hair care agents was considered as exclusion criterion.

Hair samples were washed with acetone, rinsed thrice times with distilled water and dried to a stable weight on air in a fume hood. Microwave digestion was performed using Bergh of Speed Wave-4 DAP-40 (2.46 GHz, 1450 W) microwave system (Bergh of Products+Instruments GmbH, Eningen, Germany). Preparation of urine samples included dilution (1:15, v/v) with a solution containing 1% 1-Butanol (Merck KGaA, Germany), 0.1% Triton X-100 (Sigma-Aldrich, Co., USA) and 0.07% HNO3 (Sigma-Aldrich, Co., USA) in distilled deionized water (Labconco Corp., USA).

Evaluation of hair and urinary copper (Cu), iron (Fe), iodine (I), selenium (Se) and zinc (Zn) content was performed using ICP-MS technique at NexION 300D (PerkinElmer Inc., Shelton, CT, USA) equipped with 7-port FAST valve and ESI SC-2 DX4 autosampler (Elemental Scientific Inc., Omaha, NE, USA). Standard solutions of the respective elements (Universal Data Acquisition Standards Kit, PerkinElmer Inc., Shelton, CT, USA) were used for system calibration. On-line standardization was performed using 10 μg mL^{-1} solutions of yttrium-89 (^{89}Y) and rhodium-103 (^{103}Rh) prepared from Pure Single-Element Standard (PerkinElmer Inc. Shelton, CT, USA).

Laboratory quality assessment was performed using the certified reference materials of human hair (GBW09101, Shanghai Institute of Nuclear Research, Shanghai, China) and urine (ClinChek® Urine Control, Levels I, II, Lot 1227, Recipe, Munich, Germany).

The obtained data were analyzed using Statistica 10.0 software for Windows (Statsoft, OK, USA). Due to skewed distribution the values were expressed as median and the respective boundaries of interquartile range (IQR). Due to high group variability of demographic parameters, group comparisons were performed using analysis of covariance

(ANCOVA) with adjustment for age and gender values followed by Fisher's LSD post-hoc test. Group difference was considered significant at $p<0.05$.

RESULTS

The obtained data demonstrate high variability of hair metal content in the students of different geographic origin (Table 1). Hair copper content in Russian students was found to be higher than that in students from Asia and Middle East by 25 and 32%, respectively. Copper levels in African and Latin American students also exceeded the respective values in subjects originating from Middle East by 44 and 24%. Hair Fe content in students from Asia, Middle East and Latin America were found to be 30, 66 and 29% lower when compared to the Russian values. Hair iron levels in African students was higher than those of Asian and Middle East counterparts by 63 and 158% respectively. The hair iodine levels in the students from Middle East were lower than those of Russia, Asia, Africa and Latin America by a factor of 3.4, 3.6, 5.5 and 4.7 respectively. Hair iodine level in African students was higher than those of Russian and Asian students by 62 and 51% respectively. The hair Se levels in Asian students were higher than those in Russian, Middle East and African counterparts by 15, 13 and 23% respectively. Hair Zn content in African students was lower than those in Russian, Asian, Middle East and Latin American counterparts by 30, 30, 26 and 16%, respectively.

Table 2 shows the levels of urinary essential trace element in students of different geographic origin. Students originating from Middle East and Africa were characterized by significantly higher urinary Cu levels as compared to Russian counterparts by 40 and 41%, respectively. Urinary iron excretion in students from Latin America was nearly twofold higher than that in students from Russia, Asia and Middle East. Urinary Se excretion in subjects originating from Latin America significantly exceeded the control values (Russia) by 34%. It is notable that zinc excretion tended to be higher in all foreign students when compared to the Russian values. No significant difference in urinary iodine levels were observed.

DISCUSSION

The obtained data demonstrate that students from Asia, Middle East and Latin America are characterized by low levels of iron, cobalt, copper and manganese whereas students from Africa were characterized only by low level of hair Zn content. It is also notable that all foreign students tended to have increased urinary Zn losses. Hypothetically, the observed difference may be due to prior environmental exposure as well as national dietary patterns.

The obtained values of hair trace element content in Russian students generally correspond to the reference values. However, hair Cu content was found to be on the lower border of the reference range (11.8-29.2 μg g^{-1})[15]. The existing data demonstrate that deficiency of Fe, Cu, Se and Zn in different regions of Russia varies significantly with the mean prevalence of 20, 33, 31 and 34%, respectively[16]. The estimated hair levels of Cu and Zn in students originating from Asia generally correspond to the earlier obtained values in Chinese (Jinzhou) college students, although the reported hair Fe levels were far higher (up to 104.97 μg g^{-1})[17]. A study in Iran demonstrated significantly higher hair Cu (9.74 μg g^{-1}) and Mn (0.69 μg g^{-1}) content, whereas hair Zn levels were found to be lower (170 μg g^{-1}) when compared to a recent study conducted on the students of Middle East[18].

Table 1: Hair essential element levels (μg g^{-1}) in Russian and foreign first-year RUDN University students

Elements	Russia	Asia	Middle East	Africa	Latin America
Cu	11.33 (8.75-15.09)	9.05[1] (8.15-11.25)	8.59[1] (7.58-10.03)	12.38[3] (9.55-14.24)	10.68[2,3] (9.44-13.61)
Fe	21.87 (14.2-34.04)	15.41[1] (9.28-23.23)	9.73[1] (7.71-15.72)	25.09[2,3] (20.53-35.27)	15.69[1,4] (11.87-20.94)
I	0.341 (0.158-0.654)	0.364 (0.197-0.653)	0.102[1,2] (0.071-0.262)	0.551[1,2,3] (0.333-0.814)	0.470[3] (0.279-1.294)
Se	0.446 (0.343-0.494)	0.514[1] (0.429-0.591)	0.449[2] (0.399-0.523)	0.394[2] (0.355-0.444)	0.524 (0.451-0.594)
Zn	201.4 (166.8-244.9)	199.1 (162.5-330.6)	189.3 (164.3-258.5)	140.7[1,2,3] (113.8-174.7)	166.4[4] (148.1-227)

Data are expressed as Median (IQR), [1,2,3]Significant group difference as compared to the respective values in Russia, Asia and Middle East at $p<0.05$, respectively (age-and gender-adjusted ANCOVA with Fisher's LSD post-hoc)

Table 2: Urinary essential trace element (μg L^{-1}) levels in first-year RUDN University students of different geographic origin

Elements	Russia	Asia	Middle East	Africa	Latin America
Cu	12.79 (6.54-16.95)	14.69 (10.30-17.79)	17.88[1] (13.60-23.17)	18.02[1] (12.79-22.33)	16.64 (11.56-20.49)
Fe	22.02 (14.94-32.58)	22.49 (15.44-37.50)	25.55 (16.88-39.15)	33.06 (20.17-49.18)	47.99[3] (21.74-207.85)
I	113.0 (52.5-182.6)	124.2 (81.4-195.9)	99.4 (69.2-154.2)	120.1 (93.7-175.5)	167.7 (93.1-211.6)
Se	29.19 (13.96-43.22)	30.14 (21.56-48.88)	35.36 (25.75-58.31)	32.97 (23.41-51.62)	39.07[1] (25.64-56.11)
Zn	328.7 (218.9-832.4)	557.9 (400.3-782.3)	680.9[1,2] (406.2-1140.9)	792.5[1] (479.7-1051.7)	804.4 (538.5-1145.0)

Data are expressed as Median (IQR), [1,2,3]significant group difference as compared to the respective values in Russia, Asia and Middle East at $p<0.05$, respectively (age-and gender-adjusted ANCOVA with Fisher's LSD post-hoc)

Although earlier findings stated the highest prevalence of iron deficiency anemia (IDA) in Africa and Asia[4], the more recent estimates demonstrated high rate of iron deficiency in Asia[8]. A decline in the prevalence of IDA in African populations was achieved through implementation of iron fortification strategies, although further efforts are also required[19]. A systematic analysis of data (2005-2015) on micronutrient deficiencies in Ethiopia, Kenya, Nigeria and South Africa demonstrated that the rate of iron deficiency ranged from 9-16%[20]. At the same time, studies performed in the last two decades demonstrated that dietary intake of iron and zinc is lower and higher than RDA, respectively[21]. Analysis of Nigerian foods and dietary patterns demonstrated that the intake of copper and zinc corresponds to the recommended values[22].

The obtained data demonstrate higher risk of iodine deficiency in students of Middle East and improved iodine status in African and Latin American students. No significant difference in urinary iodine concentration was observed in students of different geographic origin. These findings generally correspond to the high rate of salt iodization in Africa (78-81%), Asia (87-91%) and South America (>80%)[23], whereas certain countries of the Eastern Mediterranean region are characterized by lack of iodine supplementation program. At the same time, many countries of the region have significantly improved iodine nutrition through universal salt iodization[24]. A higher risk of iodine deficiency is also prevalent in Russian population[25]. The obtained data on urinary iodine concentrations in Russian students correspond to the respective value of 78 μg L^{-1} observed in pregnant women[26] The highest hair iodine levels in African and Latin American students are in agreement with a previous study conducted by UNICEF[23] on household salt iodization in these regions.

High prevalence of micronutrient deficiencies in Middle East region may be related to insufficient use of food fortification and inadequate consumption of dietary supplements[27]. Particularly, the results of meta-analysis demonstrated that the prevalence of iron deficiency in the region is considered as moderate-to-severe[28]. A recent study in Iran demonstrated that despite optimal daily intake of zinc, dietary products did not provide enough Cu and Fe to reach RDA[29]. It has been demonstrated that the incidence of copper deficiency in Iran was found to be 24%[30]. Moreover, the prevalence of copper deficiency (21.1%) was more widespread when compared to zinc deficiency (6.9%) in Iranian girls[31].

Despite a significant improvement in nutrition in Latin America, a high prevalence of zinc and iron deficiency is still observed in children and women of childbearing age[32]. Particularly, the highest rate of iron deficiency anemia in Latin America was observed in Panama (40%) and Haiti (45%)[33]. A recent survey demonstrated that insufficient intake of iron was observed in 46-89% of the Mexican adults[34].

Hair Zn levels as well as patterns of urinary Zn excretion clearly demonstrate the lowest Zn status in African students and this is in agreement with a previous study[35] which showed the highest prevalence of Zn deficiency in this region. However, recent study indicated a significant reduction in the risk of Zn deficiency in Africa[5]. Despite the earlier study demonstrated high prevalence of insufficient Zn intake in Asian populations[36], the results of the present study revealed no significant difference in hair or urinary Zn levels in students from Asia and Russia.

Increased hair Se levels in Asian students may be associated with high prevalence of seleniferous soils in China (Enshi, Hubei Province) and India (Punjab Nawanshahr-Hoshiarpur), although the majority of provinces of China were considered to be selenium-deficient[37]. Certain estimates demonstrated high prevalence of Se deficiency in Middle East countries, as well as Central Europe[38]. At the same time, the particular data on Se deficiency in Middle East and Northern Africa are scarce and insufficient[39]. Low soil Se content is the predominant problem in tropical areas[8]. However, it is estimated that the geographic patterns of Se deficiency in soil may be changed due to climate-associated changes at the end of the century[40]. Hypothetically, higher incidence of trace element deficiency may contribute to impaired adaptive response[41] and higher morbidity[1], especially in the first years after arrival.

CONCLUSION

Generally, foreign RUDN University students are characterized by low level of essential metals in hair and at the same time showed the tendency to increased urinary metal excretion. Taken together, these findings are indicative of higher risk of essential trace element deficiency. Therefore, monitoring and modulation of nutritional trace element status may significantly improve health and educational performance of students.

SIGNIFICANCE STATEMENT

This study discovered essential trace element status of students originating from different geographical regions (Asia, Africa, America, Russia) that can be beneficial for comparative assessment of nutritional status in different countries. This study will help the researcher to uncover geographic patterns of dietary essential trace element intake in a healthy population of young adults.

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