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Dietary intake of metals by the young adult population of Eastern Poland: Results from a market basket study

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ABSTRACT

Dietary intake of macro-, trace and toxic elements was determined among the young adult population of Eastern Poland. The study was performed in 2011–2013 and involved 583 participants living in Lublin and its province. Dietary intakes of metals were determined using a 24 h dietary recall technique and a market basket method. The analytical quantification of As, Ca, Cd, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Se and Zn was performed using ICP-MS technique, whereas the content of mercury was determined using the Mercury Analyzer. Performed investigations revealed that daily dietary intakes of the majority of the study elements (macro- and trace) and toxic elements such as As, Pb or Hg are within the range of reference values. However, high consumption of Na and improper Na/K ratio combined with low intake of Mg may be harmful to the health of the population. Moreover, obtained data suggest that the risk of developing diseases among population in Eastern Poland related to high exposure to Ni and Cd absorbed from foodstuffs was high.

1. Introduction

One of the most important determinants affecting human health is food consumption. The individual's body size, weight and all vital functions are strongly influenced by food habits, which determine the intake of all essential components, including macro- and microelements. Metals are widely distributed in the earth's crust. While many of them are essential for the normal functioning of the human body, others do not posses any known positive function being even toxic at relatively low concentrations. For instance, chronic exposure to heavy metals, such as cadmium (Cd), lead (Pb), mercury (Hg), or metalloids, such as arsenic (As), at relatively low levels, can cause adverse effects on individuals or some populations. Although some workers are exposed to toxic elements via inhalation or dermal absorption in the workplace, the main route of exposure to metals (toxic and essential) for most people is through the diet [1]. Excess or insufficient intakes of some essential elements also affect human health. Calcium (Ca), magnesium (Mg) and phosphorus (P) are the main components of the bones and skeletal system. Iron (Fe) is the major component of blood and many important enzymes. Minerals like zinc (Zn), copper (Cu), manganese (Mn), selenium (Se) and Mg are either a structural part of or activate a number of enzyme systems. Sodium (Na) and potassium (K) are present in body fluids and help in maintaining water and acid–base balance [2,3]. Moreover, some elements play ambivalent roles in human organisms, e.g., nickel (Ni) is an essential nutrient for several animal species but can be toxic at higher levels of exposure [4]. The role of molybdenum (Mo) in humans has not been fully elucidated. Therefore, in Poland the recommended dietary intake (RDI) as well as the upper level of consumption for this element have not yet been established.

The Food and Agriculture Organization/World Health Organization (FAO/WHO) recommends three basic approaches to assess the intake of nutrients and other food contaminants: total diet study/market basket study, duplicate diet study and diary study. Total diet study/market basket study combines the data of the

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Table 1
Average daily intakes of foods by food group in the present study. Values are presented according to the year of study and gender.

Food group	Food intake (g/day)								
	2011		2012		2013		Mean	SD	Range
	Women	Men	Women	Men	Women	Men			
1. Milk and dairy	196.1	283.5	241.9	347.3	246.6	279.8	265.9	80.3	156–412
2. Eggs	22.5	47.6	13.8	26.7	15.3	62.1	31.3	20.3	9.9–72.4
3. Meat and meat products	118.6	125.8	109.1	214.8	116.3	156.1	140.1	55.7	88.5–292
4. Fish	45.8	77.5	8.6	12.3	12.2	26.8	30.5	28.5	3.4–105
5. Cereals	268.4	323.9	221.4	388.1	212.1	300.9	285.8	65.8	177–425
6. Vegetables	225.1	258.7	188.0	220	149.8	165.4	201.2	44.4	126–283
7. Fruits	159.5	161.3	141.0	86.3	115.8	121.7	130.9	41.0	67.4–202
8. Potatoes	134.2	126.3	101.7	142.8	69.5	101.3	112.6	37.6	48.4–187
9. Fats and oils	12.5	15.4	20.1	23.7	14.5	37.8	20.7	12.9	6.7–55.1
10. Sugar and sweets	32.7	32.6	36.0	43.1	47.9	50.7	40.5	22.2	15.4–110
11. Water and beverages	843.6	832.3	860.7	1026.2	758.7	524.7	807.7	256.5	318–1354
12. Other foods	2.3	6.5	2.8	8.8	1.5	12.9	5.8	4.48	1.1–18.4
Total	2061.3	2291.4	1945.1	2540.1	1760.2	1840.2	2073	377.5	1461–2912

levels of specific contaminants with individual (or household) consumption records. Although their costs may be high, market basket studies are considered the most effective means for assuring that people are not exposed to unsafe levels of toxic chemicals through the diet [5,6]. In contrast, duplicate diet studies may be a more affordable option, which was successfully used in the past to evaluate the dietary intake of environmental pollutants in a number of surveys [6–9]. Each method has its advantages and disadvantages, but some studies on dietary intakes of essential and toxic elements have revealed a reasonably good agreement between the results obtained by using market basket study and those obtained by using duplicate diet study [10].

In Lublin and its province with a population of over 2 million, there have been no reports on the dietary intake of essential trace elements by the population. During the last 10 years only 2 studies were carried out concerning dietary intake of some essential (Se, Cr) and toxic elements (Cd, Pb, Ni, Hg) by the local population [11,12]. The aim of the present study was to assess, the dietary exposure of population to ten essential macro- and trace elements (Ca, Cu, Fe, K, Mg, Mn, Mo, Na, Se and Zn) and five toxic elements (As, Cd, Hg, Ni and Pb) using the market basket approach. The second aim was to compare the dietary intake of particular elements according to sex and year of study (2011–2013). In our study, we did not identify which food groups are the main dietary sources of contaminants or nutrients, but focused on the total dietary intake of particular elements. The obtained exposure estimates were compared with the appropriate nutritional and toxicological reference values and with the data from similar investigations performed in other countries. The study findings may shed a new light on the link between the deficiency and excess of macro- and trace elements in the diet and the disease risk in Poland. Since the food is the major marker of environmental pollution with chemicals, our results may also be of significance for estimation of human exposure to toxic elements in this part of Europe.

2. Materials and methods

2.1. Chemicals

All reagents were of electrochemical grade (EL). High purity deionized water (resistivity 18.2 MΩ cm) obtained using a Milli-Q water purification system (Millipore, Bedford, MA, USA) was used throughout. Teflon vials and polypropylene recipients were used for digestion and storage of digests, respectively.

Table 2
The programs of microwave digestion system for the decomposition of food samples.

Step	Temperature (°C)	Power (W)	Time (min)
All elements (except mercury)			
1	0–180	1000	0–15
2	180	1000	15–25
3	180–0	0	25–30
Mercury			
1	0–170	700	0–20
2	170	700	20–30
3	170–0	0	30–40

2.2. Selection and food sampling

Healthy adults aged 19–30 years who are not occupationally exposed to the metals were recruited into this study. The study was performed in 2011–2013 and involved 583 participants (359 women and 224 men), living in the eastern part of Poland (Lublin and its province). All the participants were students of the Medical University in Lublin, their lifestyle was characterized by moderate physical activity. The average ages and the ranges of age for male and female participants were 24 ± 4 (19–30) and 23 ± 3 (19–27), respectively. Pregnant and lactating mothers were excluded from the study. Dietary intakes of metals were determined using a 24 h dietary recall technique and a market basket method. For this reason, participants completed special questionnaires containing qualitative and quantitative parameters of the consumed diets. In total, 583 questionnaires were returned (271 in the year 2011, 162 in 2012 and 150 in 2013). Dietary questionnaires were collected from January to March and the composite diets were prepared in April each year.

The composite diets were prepared in duplicate using the information provided by the respondents. All the products used to prepare food rations were from the retail market of the Lublin region. Since the region is agricultural, over 90% of the most important products – cereal products, milk and its products, meat and its products, eggs, vegetables and fruits – were of local origin. Six groups of composite diets were prepared for both sexes and three years (2011, 2012, and 2013) of collection. For each group, six market baskets were prepared (in total 36 composite diets in duplicates). From each composite diet 6 samples were taken for further analysis. In total 216 samples were investigated.

The book of Nadolna et al. [13] was consulted for the preparation of composite diets and food items were prepared and cooked in the laboratory in a manner similar to local cooking practices. In compliance with the international WHO/GEMS/Food recommendations, foods were prepared using drinking water from the city