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The Content of Essential and Toxic Metals in the Hair of Children with Autistic Spectrum Disorders

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Abstract: The aim of this study was to assess the possible relationship between the content of essential and toxic metals in the hair samples with the etiology of autism spectrum disorder (ASD) in children from Bosnia and Herzegovina. Taking into account the age and gender of the child, in the study and control group, the samples were divided into three subgroups (1-5 years; 6-9 years; 10-14 years). Altered profiles of the values of the Cu, Fe, Mn, Zn, Cd, Co, Cr, Ni, Pb in the study group were observed in comparison with the control group children with typical neuromotor development. Higher values of toxic metal concentrations (Co, Ni, Cd, Pb) were found in boys, compared to the girls in the study group. The content of Pb in the study group was higher in all three ages compared to their controls, with the difference being especially pronounced in the age group 1-5 years (6.64 mg/kg; 1.89 mg/kg). A strong correlation between the content of Pb and Cd (0.93) was confirmed. Lower values of Cr concentration and higher of Ni, Cu and Fe were recorded in the study group. Statistically significant differences ($p<0.05$) were found in Zn concentrations (6-9 years; 10 -14 years) between the control and study groups. The findings help highlight the role of heavy metals as environmental factors in the etiology of ASD.

INTRODUCTION

Autism spectrum disorder (ASD) is a heterogeneous class of neurodevelopmental disorders characterized by deficits in social interaction, interests, and repetitive behaviors (Bishop, Havdahl, Huerta, *et al*., 2016). ASD is often associated with other mental and physical disorders such as: anxiety, ADHD (Attention Deficit Hyperactivity Disorder), intellectual disorders, epilepsy and motor coordination imbalance (Fiore, Barone, Copat, *et al*., 2020). There is currently no known cause for most ASD cases, and there are no psychological diagnostic tools or biomarkers for ASD to be reliably diagnosed.

Over 25% of people diagnosed with ASD have genetic disorders that are associated with the development of the nervous system (Wegiel, Kuchna, Nowicki, *et al*., 2010). In addition, mutations in genes closely related to metabolism, chromatin remodeling, mRNA regulation, protein synthesis, and synaptic function have been detected in individuals with ASD. Regardless of all the potentially detected factors associated with ASD, 80-90% of the entire autistic population remains without an identified cause (Kaushik and Zarbalis, 2016).

Many studies that follow the perinatal and neonatal periods list several risk factors that may be associated with ASD. The main risk factors are gestational diabetes in mothers, bleeding during pregnancy, intrauterine infections, gestational viral infections as well as the use of medications. Premature birth, trauma, low birth weight, neonatal anemia, incompatibility of ABO or Rh blood groups are also associated with an increased risk of autism. An increased risk of ASD in first-born children has also been reported (Modabbernia, Velthorst and Reichenberg, 2017).

Toxic metals are among the environmental factors associated with the development of ASD (Yassa, 2014; Mohamed, Zaky, El-Sayed, *et al*., 2015; Mostafa, Bjørklund, Urbina, *et al*., 2016; Saghazadeh, Ahangari, Hendi, *et al*., 2017a). Toxic metals can cause epigenetic changes and thus play a role in neurodevelopmental disorders (Jakovcevski and Akbarian, 2012). Environmental pollutants act as neurotoxins of the central nervous system and adversely affect prenatal development. Essential minerals are crucial for the proper functioning of biological systems, thereforethe dysregulation of their content and the retention of toxic elements in the body can contribute to the genesis of ASD (Da Silva, Vellas, Elemans, *et al.*, 2014; Saghazadeh, Mahmoudi, Dehghani Ashkezari, *et al.*, 2017b).

Intensive global research in this field indicates that there are significant differences in the concentration of toxic and essential elements in children with autism spectrum disorders compared to the group of healthy children (Lakshmi Priya and Geetha, 2011; Li, Yang, Wang, *et al*., 2011; Blaurock-Busch, Amin, Dessoki, *et al*., 2012; De Palma, Catalani, Franco, *et al*., 2012; Adams, Audhya, McDonough-Means, *et al*., 2013; Tabatadze, Zhorzholiani, Kherkheulidze, *et al*., 2015; Fiore *et al*., 2020).

Biomonitoring, as a method that assesses the impact on living organisms of chemical elements present in the environment, is approved by mandatory legislation (The EU Water Framework Directive (2000/60/WE), US EPA-600 / 4-79-049. August 1979), (Mikulewicz, Chojnacka, Gedrangec, *et al*., 2013). In the case of human biomonitoring, non-invasive matrices (hair, urine, saliva) were approved. Interest in human hair as a clinical sample has recently increased due to the advantages of hair as a sample over blood or urine: sampling is relatively easy and non-invasive, the sample is stable, easy to store and transport in the laboratory, it is inert and chemically homogeneous (De Palma *et al*., 2012). Hair, as well as adipose tissue, is a place that can store substances from the body exposure, including heavy metals whose concentrations are up to 10 times higher than the concentrations determined in the blood or urine (Bader, Dietz, Ihrig, *et al*., 1999; Moreda-Piñeiro, Alonso-Rodríguez, López Mahía, *et al*., 2007). Hair grows about 10 mm per month, which allows long-term monitoring of past and recent exposure to metals, and an analysis of 2 cm of hair from the scalp gives a picture of the state of the organism in the last two months (Gil and Pla, 2001). Furthermore, there is not enough information to define heavy metal reference values, because the metal content in hair varies depending on age, gender, hair color, care, smoking habits, ethnic factors, geographical location of the population.

The analysis of metal content in hair has become an interesting diagnostic tool for biomonitoring exposure to toxic elements, in order to assess the health and nutritional status of the population of a particular geographical area. Research in this field is intensive and goes in the direction of highlighting the role of metals as environmental factors in the etiology of ASD. Given the number of factors that can affect the final results, the obtained values of metal content in one population may not correlate to that of another population.

Therefore, the aim of this study was to assess the possible relation between the content of essential and toxic metals with the etiology of ASD in children from Bosnia and Herzegovina.

MATERIALS AND METHODS

Materials

The study was conducted with the consent of the parents/guardians, whose children are the members of the "Support center for families of children/members with developmental difficulties - Colibri". Hair samples were collected during the year 2019. A total of 31 hair samples were analyzed from children in the age group of 1-14. From the total number of samples, 55% were taken from males and 45% from females. Hair samples were divided into two groups: a control group and a study group. The control group included children who, according to their parents, had a normal psychomotor development. The study group included children who, according to their parents, and according to their previous medical history, had elements or a disorder from the autism spectrum (ASD). All the hair samples were collected from children whose birthplace and place of residence were in the Sarajevo Canton. Table 1 provides an overview of samples based on their division into groups and gender.

Table 1: Review of the analyzed samples based on groups and gender

Total number of samples			
Gender	♀	♂	Total
Control group	9	6	15
Study group	5	11	16[1,2,3,4]
Total (N)	14	17	31

[1]Autism; [2]Pervasive Developmental Disorder With Elements Of Autism; [3]Disharmonious Development With Elements Of Autism; [4] Slowed Disharmonious Psychomotor Development

Out of the 15 samples in the control group, 60% were collected from females and 40% from males. In the examined group, there were more male samples 69%, while female hair samples accounted for 31% of the total number of examined samples. The percentage of samples in the study group is explained by the fact that gender is one of the risk factors when it comes to ASD (De Palma *et al*., 2012).

The metal content in hair varies depending on a number of factors, primarily the age structure of the observed population (Chojnacka *et al*., 2006; Mikulewicz *et al*., 2013). In order to achieve consistency in the interpretation of the results in the study and control groups, the samples were divided into three subgroups, taking into account the age (1-5 years; 6-9 years; 10-14 years). The percentual representation of the samples in the control and study groups by age is presented in Figures 1 and 2.

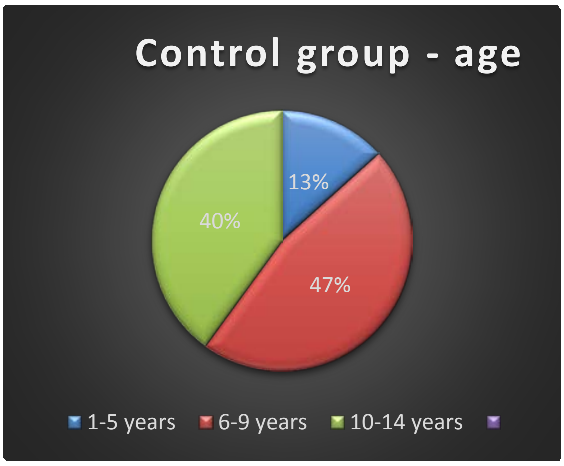

Figure 1: Representation of samples by age in the control group

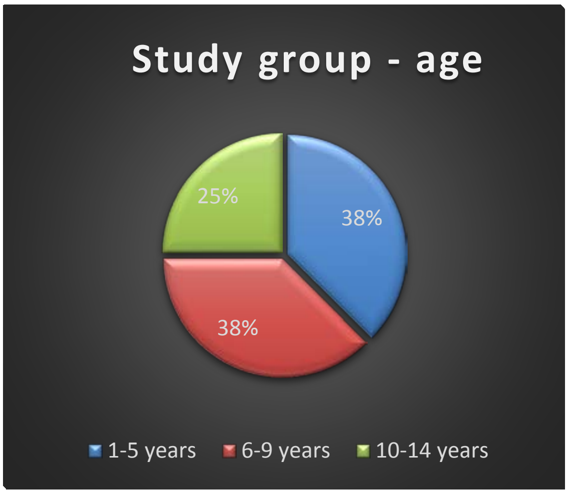

Figure 2: Representation of samples by age in the study group

Methods

Sample preparation and analysis

Determination of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn content in the hair samples was performed using atomic absorption spectrometry (AAS), flame technique (Varian AA240FS) in the Laboratory for Analytical Chemistry, Department of Chemistry, Faculty of Natural Science, University of Sarajevo. Before dissolution the hair samples were cut into 0.5 cm long hair pieces. Hair washing, in order to remove grease and surface impurities, was carried out according to the IAEA (International Atomic Energy Agency) procedure with ethanol and distilled water, upon which the hair samples were dried in an oven at 80°C for 2 hours. and dried sections of hair were subjected to wet digestion. The volume of 10 mL of concentrated nitric acid was added to the defined weight – of approximately 0.5 g with the precision of 0.1 mg – of previously prepared samples and gradually heated until brown nitrogen oxide vapors separated. Heating continued further with the addition of 1-2 mL of 30% hydrogen peroxide. After cooling, the samples were filtered through Whatman No.42 filter paper into 25 mL flasks and diluted with distilled water. In the obtained filtrates, the metal levels were determined using the method of calibration curve, constructed by measuring the absorbance value for a series of standard solutions (1000 mg/L, Merck) of the tested metals. A comparative analysis by groups and subgroups between the monitored categories was used for the interpretation of the results.

Analytical quality control

All used reagents had the analytical grade of purity (Merck, Germany). Precision of the method was checked by performing two or three indenpendent determination (depending on the available sample mass) for each sample and calculating the value of repeatability standard deviation. The traceability of the measurement results was established using standard metal solutions traceable to NIST (National Institute of Standards and Technology, USA). Method blanks are prepared and analyzed along with the samples in order to correct results for systematic errors.

Statistical data analysis

All statistical analyses were performed using Statistics 12 software (Copyright © StatSoft, Inc. 1984-2014). Descriptive statistics of the content of essential and toxic metals in hair included mean, standard deviation (SD), minimum (MIN) and maximum values (MAX). One-way ANOVA was usedfor comparative analysis by groups, followed by the Post-hoc LSD test and the Newman-Keuls test. The Pearson product-moment correlation coefficient was used to examine the correlations between groups and variables. A statistical significance level of $p<0.05$ was applied to all analyses. ORIGIN version 8.1 software (originLab Corporation, USA) was used to graphically display the results.

RESULTS AND DISCUSSION

The content of essential and toxic metals in the control and study groups by gender

Table 2 shows the values of concentrations of essential and toxic metals in the control and study groups by gender. Preforming a comparative analysis of the obtained results by gender, we can observe that the mean values of metal concentrations in the control group are quite equal, except for the content of Cu, Co and Zn, whose values are slightly higher in females, while Cr is higher in males. In the examined group, a higher value of the content of the essential metal Cu was observed in females compared to its values in males. With regard to the values of toxic metals between the genders in the examined group, higher values of Cr were found in females, compared to males. If we compare the values of Cr in the control and study groups in females, we can conclude that they do not differ significantly. Higher values of concentrations of toxic metals Co, Ni, Cd, Pb were found in males, compared to the same values in females in the study group. Observing the results by gender, we notice that the values of Cd in the study group males were statistically significantly higher than in the control group males. In the control and study groups, a statistically significant correlation was found between Pb and Cd contents (0.90; 0.89). On the other hand, a negative correlation in the control group males was found between Fe and Zn (-0.85). This result was recorded in a meta-analysis by De Palma *et al.* (2012).

Table 2: Elements content (mg/kg)±standard deviation in hair samples of males and females in the control and study groups

Gender	Control group				Study group			
Group	Male		Female		Male		Female	
Data	Mean±SD	(MIN, MAX)	Mean±SD	(MIN, MAX)	Mean±SD	(MIN, MAX)	Mean±SD	(MIN, MAX)
Cu (mg/kg)	9.89±2.15	7.5, 12.32	11.65±6.14	7.08, 27.05	11.63±1.76	8.13, 14.29	14.07±3.23	10.26, 18.91
Fe (mg/kg)	52.52±18.42*	37.7, 80.31	41.69±7.37	33.69, 55.04	57.48±16.99	35.28, 79.38	57.76±5.04	52.50, 64.39
Mn (mg/kg)	2.04±0.44	1.35, 2.52	1.71±0.71	0.43, 2.57	1.90±0.78	0.22, 2.92	1.69±0.67	1.28, 2.86
Zn (mg/kg)	110.24±34.36*	53.94, 156.33	139.67±82.64	33.94, 279.10	123.64±43.90	49.36, 198.81	110.28±34.71	67.75, 144.28
Cd (mg/kg)	0.15±0.05[a*]	0.09, 0.19	0.26±0.24	0.08, 0.74	0.48±0.32[a*]	0.15, 1.34	0.33±0.07	0.26, 0.42
Co (mg/kg)	0.26±0.18	0.13, 0.39	1.74±1.97	0.34, 3.13	1.28±1.41	0.22, 3.81	0.62±0.49	0.27, 0.96
Cr (mg/kg)	3.56±0.87	2.64, 5.11	2.50±1.70	0.13, 5.82	1.88±1.04	0.30, 4.30	2.89±2.27	0.96, 6.14
Ni (mg/kg)	2.32±0.67	0.98, 2.75	2.50±1.01	1.03, 4.83	3.15±1.14	1.98, 5.89	2.34±0.77	1.75, 3.67
Pb (mg/kg)	2.59±1.84*	0.33, 5.51	2.96±3.21	0.68, 11.30	4.68±4.82*	2.21, 19.05	4.43±1.73	2.98, 7.31

Values sharing the same letter differ statistically significantly within one parameter at a significance level of $p<0.05$ after Post-hoc analysis of variance by the LSD test and the Newman-Keuls test

*correlations are statistically significant at the level of $p<0.05$

Content of essential and toxic metals in the control and study groups by age

The metal content in hair varies according to age (Chojnacka *et al*., 2006; Mikulewicz et *al*., 2013). Table 3 shows the values of essential metals in the samples of the control and study groups by age (1-5 years; 6-9 years; 10-14 years).

Table 3: Content of essential metals in the control and study group presented by age of the sample

Age	Group	Data	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
1-5 years	Control group	Mean±SD	9.70±3.71	54.68±22.92	1.93±0.10	123.0±27.44
		(MIN, MAX)	7.08,12.32	38.47, 70.89	1.86, 2.00	103.63, 142.44
	Study group	Mean±SD	12.46±1.79	62.40±14.96	1.92±1.02	122.4±55.08
		(MIN, MAX)	10.26, 14.92	37.44, 77.95	0.22, 2.87	49.36, 198.81
6-9 years	Control group	Mean±SD	9.90±1.41	48.39±15.62	1.87±0.59	76.29±34.49a
		(MIN, MAX)	7.68, 12.11	33.69, 80.31	0.9, 2.52	33.94, 123.69
	Study group	Mean±SD	11.51±8.13	51.35±15.74	1.90±0.64	124.5±25.79a
		(MIN, MAX)	8.13, 14.29	35.28, 79.38	1.20, 2.92	77.85, 154.26
10-14 years	Control group	Mean±SD	12.57±7.54	40.37±6.06	1.78±0.81	189.7±53.17b
		(MIN, MAX)	7.5, 27.05	34.22, 48.51	0.43, 2.57	125.68, 279.10
	Study group	Mean±SD	13.62±3.86	59.66±71.50	1.60±0.43	107.6±41.56b
		(MIN, MAX)	10.09, 18.91	52.50, 71.50	1.28, 2.22	67.8, 155.36

Values that share the same letter differ statistically significantly with in one parameter at a significance level of $p<0.05$ after Post-hoc analysis of variance by the Newman-Keuls test.

* correlations are statistically significant at the level of $p <0.05$

Analyzing the results of Cu, Fe, Zn and Mn levels in children's hair, it can be concluded that the levels of essential metals in the control and study groups, for all three age groups, follows the pattern: Zn> Fe> Cu> Mn (Table 3). The highest Zn level was found in the control group of the age 10-14 in the amount of 189.7 mg/kg. In the same age study group, the Zn level was 107.6 mg/kg, which also represents the lowest Zn concentration recorded in the work. In the age group of 6-9, the study group had a higher Zn level (124.5 mg/kg), compared to the control group (76.29 mg/kg). Statistically significant differences ($p<0.05$) were found in the Zn content between the control and study groups in the age group of 6-9 as well as in the group of 10-14. Lower concentrations of trace elements such as zinc are significantly associated with autism spectrum disorders (De Palma *et al*., 2012; Tabatadze *et al*., 2015). However, there are results in which zinc levels in hair were inversely related to age, and a negative significant association was found between zinc levels in hair and the severity of autistic symptoms (De Palma *et al*., 1012; Fiore *et al*., 2020). However, the mean values of Zn

levels for the age of 1-5, in the control and study groups, were almost identical: 123.0 mg/kg and 122.4 mg/kg.
The Cu content in the study group, for all three age groups, was higher compared to the same age groups of the control group, which is in line with research conducted by Lakshmi Priya and Geeth (2011). In literature, this trend of higher Cu levels in the hair of children with ASD is associated with increased oxidative stress and increased "cytokine" levels (Bjørklund, 2013). Since Cu and Zn are metabolic antagonists, there are many results in this field confirming that the Cu/Zn ratio in the blood is increased in children from the autism spectrum. Higher values of Cu concentration and less Zn in the blood were recorded by Saghazadeh *et al*. (2017). By analyzing the obtained results in our study, it can be seen that the Cu/Zn ratio is higher in the study group aged 1-5 as well as the group 10-14 compared to the control groups of the same age.
The Fe content in the control group decreases with the age of the sample, while in the study group the highest Fe content was recorded in the youngest children (age group 1-5). A comparative analysis of the Fe content by age structure of samples in the study groups found a higher concentration compared to the control groups. These results are in line with other studies that report a higher Fe content in children with autism spectrum disorders (Yasuda,Yonashiro, Yoshida,*et al*., 2005).
The smallest differences between the control and study groups were confirmed for the Mn levels. In the control group, there was a decreasing trend of the Mn concentration with age (from 1.93 to 1.78 mg/kg). The same trend was observed in the study group with a tendency to increase with age (from 1.92 to 1.60 mg/kg). This trend is in line with the results of a 2012 study that found a deficit and negative correlation of manganese with age (De Palma *et al*., 2012).
The content of toxic metals in the control group aged 1-5 follows the pattern: Cr> Ni> Pb> Cd, while at the age of 6-9 and 10-14 this pattern is different: Pb ~ Cr ~ Ni >> Cd. For all three age groups of the study group the content of toxic metals follows the pattern: Pb> Ni> Cr> Cd (Table 4).

Table 4: Values of toxic metal content in the control and study group presented by the age of the sample

Age	Group	Data	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
1-5 years	Control group	Mean±SD	0.16±0.02[a]	0.13±0 (<LOD)	3.47±0.42	2.69±0.08	1.90±1.40
		(MIN, MAX)	0.14, 0.17	0.13, 0.13	3.17, 3.77	2.63, 2.75	0.91, 2.88
	Study group	Mean±SD	0.59±0.38[a*]	1.81±1.81	2.80±2.11	2.81±1.53	6.64±6.28*
		(MIN, MAX)	0.27, 1.34	0.27, 3.81	0.3, 6.14	1.85, 5.89	3.05, 19.05
6-9 years	Control group	Mean±SD	0.18±0.06	0.37±0.04	2.72±1.52	2.35±0.25	2.81±1.39
		(MIN, MAX)	0.10, 0.27	0.34, 0.39	0.13, 5.11	1.95, 2.67	1.70, 5.51
	Study group	Mean±SD	0.34±0.16	0.76±0.91	1.73±0.61	3.31±0.76	3.51±1.07
		(MIN, MAX)	0.22, 0.65	0.22, 1.81	1.09, 2.77	2.14, 4.14	2.21, 4.73
10-14 years	Control group	Mean±SD	0.27±0.32	3.13±0 (<LOD)	2.98±1.79	2.43±1.41	3.13±4.10
		(MIN, MAX)	0.08, 0.74	3.13, 3.13	0.91, 5.82	0.98, 4.83	0.33, 11.30
	Study group	Mean±SD	0.34±0.50	0.59±0.52	2.01±1.54	2.41±0.58	3.19±0.65
		(MIN, MAX)	0.15, 0.50	0.22, 0.96	0.96, 4.30	1.75, 3.15	2.37, 3.76

Values that share the same letter differ statistically significantly within one parameter at a significance level of $p<0.05$ after Post-hoc analysis of LSD variance and the Newman-Keuls test.

*correlation is significant at $p<0.05$

There is an increase in the level of Ni compared to the content of Cr, whose level is declining in the study samples, especially in older children (6-9 years). The results of similar studies indicate that the content of Ni in the hair of children aged 3-9 with ASD was higher compared to the control group (Blaurock-Busch *et al*., 2012; Fiore *et al*., 2020). The level of Pb in the control group increases with age, while the case is opposite in the study group. The level of Pb in the study group is higher in all three age groups compared to the levels in the control groups, with this difference being especially highlighted in the age group 1-5 (study group - 6.64 mg/kg; control - 1.89 mg/kg). The increased lead concentration and its positive association with ASD have been confirmed in other studies (Lakshmi Priya and Geetha, 2011; De Palma *et al*., 2012; Fiore *et al*., 2020). Significantly increased lead levels in children with autism spectrum disorders compared to healthy children (78% and 16%) were observed at the age of 4 to 5 in a study conducted by Tabatadze et al. (2015) which corresponds with our results. The negative correlation of the Pb content with the age in the hair of children with ASD suggests that younger children are more susceptible to toxic metal retention compared to older children, as confirmed by the results of similar studies (Ballesteros, Serrano and Álvarez, 2017; Skalny, Skalnaya, Grabeklis *et al*., 2018; Fiore *et al*., 2020). The Cd content in the control group increased from 0.15 mg/kg (1-5 years) to 0.27 mg/kg (10-14 years). The highest Cd content (0.59 mg/kg) was recorded in the study group aged 1-5. The content of Cd in the study group aged 1-5 was statistically significantly higher ($p<0.05$) compared to the control group of the same age according to LSD and Newman-Keuls test. Significant correlations in this study group were found between Pb and Cd (0.926936), which is in agreement with the results of research conducted by De Palma et al. (2012). In the study group of 6-9 and 10-14 years of age, Cd has the same mean value (0.34 mg/kg), which is higher compared to the same age groups of the control group. The association and significant differences in cadmium values in children with ASD compared to healthy ones have previously been observed (De Palma *et al*., 2012; Tabatadze *et al*. 2015; Fiore *et al*., 2020). The Cr content in the study group for all three age groups was lower compared to the controls. The lowest level of Cr in the control group is 2.71 mg/kg for the age 6-9. In the same age of the study group the Cr level was 1.70 mg/kg. The highest Cr content in the control group was 3.47 mg/kg for the age of 1-5, while in the same age of the study group it was 2.80 mg/kg. Lower Cr concentrations in the hair of children with ASD compared to the control group were noted by Saghazadeh *et al*. (2017). Chromium is a component of the "glucose-tolerance" factor and playsa role in cellular sensitivity to insulin, so its deficiency may indicate a disorder of glucose metabolism, leading to disruption of cell activity (Yasuda *et al*., 2005). The Co content in the control groups was below the detection limit for 90% of the samples. Therefore, the obtained results were not interpreted. The literature states that the Co content is lower in ASD compared to the control group of children Saghazadeh *et al*. (2017).

Comparative analysis of the content of essential and toxic metals in the control and study groups based on gender and age

Analyzing the values of essential and toxic metals and taking into account the gender and age structures, altered profiles of the values of metals were observed between the study group and the control group of children (Figure 3). The content of Co, Cd and Pb in the hair of children aged 1-5 in the control group is lower than the values determined in the study group. The largest difference is recorded in the content of Pb, where the control group has values of 0.91 mg/kg in females and 2.88 in males, while in the study group these values are 5.37 mg/kg and 7.28 mg/kg, respectively. The values for Cr levels in the control group aged 1-5 are similar in both genders (mean value 3.47 mg/kg), but in the study group the Cr content in females is statistically significantly higher than in males. A strong positive correlation (0.99) was observed in the levels of Cd and Pb in the study group in males aged 1-5. It is also characteristic that the Fe level in the hair of the control group females increases with age, while in the study group it decreases. The Cr level in the hair of males aged 6-9 was statistically significantly different between the control and study groups. In male hair, the Pb levels in the control and study groups were similar, but in females of the same age it was about 2 times higher in the study group compared to the control group. The Zn levels in the hair of females of this age differed statistically significantly between the control and study groups.

In the hair of children aged 10-14, the Zn level was lower in the study group compared to the control group. In females of this age, the Zn levels differed statistically significantly in the control and study groups. The Pb level in the hair of the study group males was 3.3 times higher than that in the control group.

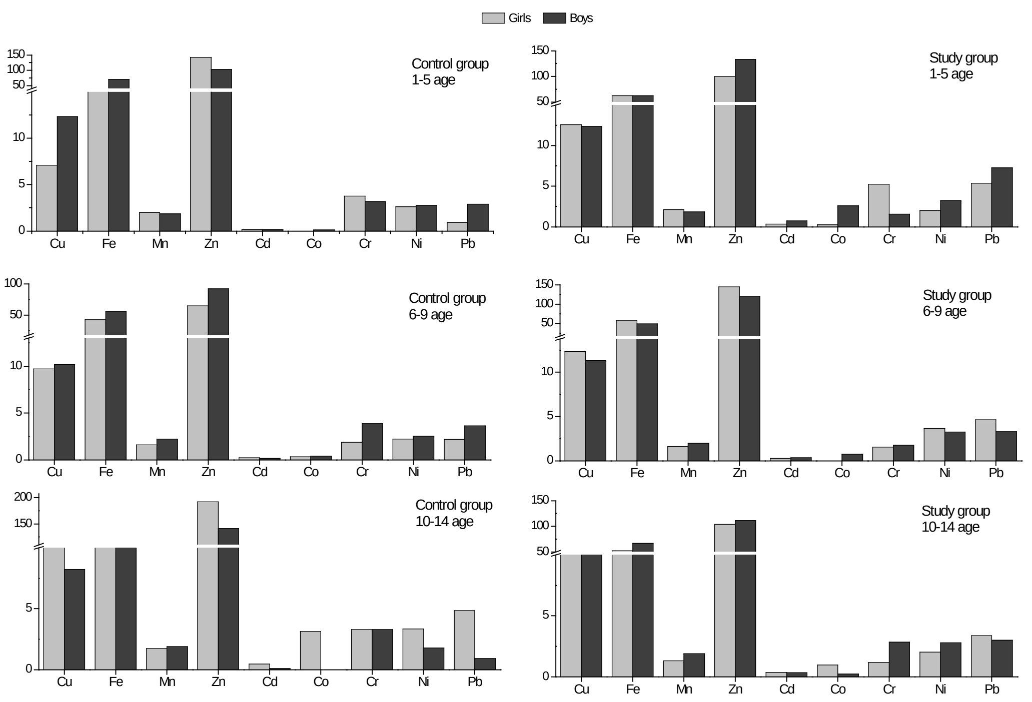

Figure 3: Comparative analysis of metal content by groups in relation to gender and age

CONCLUSION

Our research has shown different concentrations of essential and toxic metals in hair samples of children with autism spectrum disorders compared to healthy children. There is a higher content of toxic metals in the hair of children with ASD, primarily of Pb and Cd, but also a higher content of essential metals Cu and Fe, and a deficit of Zn compared to the control group of children. Strong correlations between Pb and Cd were observed in a large number of monitored groups.

Several factors may play a role in explaining the differences in the content of toxic and essential metals in children's hair. In our study, it was expected that children grew up in the same environment, i.e. that they had similar ways of exposure to pollutants, so that the observed differences are not only due to different exposure to toxic metals, but also due to a difference in retention or greater absorption. In addition, poor eating habits are often recorded in children with ASD, so that some of the results can be explained by inadequate intake of certain nutrients as well as their excess if children who have consumed some of the supplements.

Further research in this field is extremely important, primarily for establishing the reference values for cross-linked metals in a given population, possible positive correlations between elevated levels of heavy metals in hair and autism spectrum disorders, as well as biomonitoring, i.e. assessment of the effects on human health of chemical elements present in the environment. Such research helps to highlight the role of such elements as environmental factors in the etiology of ASD. The results of this research represent a significant scientific contribution given that this is the first research in Bosnia and Herzegovina.

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Summary/Sažetak

Cilj ovog istraživanja bio je procijeniti moguću povezanost sadržaja esencijalnih i toksičnih metala u uzorcima kose s etiologijom poremećaja autističnog spektra (ASD) kod djece iz Bosne i Hercegovine. Uzimajući u obzir spolnu i dobnu strukturu, u ispitivanoj i kontrolnoj skupini uzorci su podijeljeni u tri podskupine (1-5 godina; 6-9 godina; 10-14 godina). Uočeni su izmjenjeni profili vrijednosti Cu, Fe, Mn, Zn, Cd, Co, Cr, Ni, Pb u ispitivanoj skupini u poređenju sa djecom kontrolne skupine tipičnog neuromotorog razvoja. Kod dječaka utvrđene su veće vrijednosti koncentracija toksičnih metala (Co, Ni, Cd, Pb) u poređenju s djevojčicama u ispitivanoj skupini. Sadržaj Pb u ispitivanoj skupini bio je veći u sva tri uzrasta u poređenju s njihovom kontrolom, s tim da je razlika posebno izražena u dobnoj skupini 1-5 godina (6,64 mg/kg; 1,89 mg/kg). Potvrđena je snažna korelacija između sadržaja Pb i Cd (0,93). Niže vrijednosti koncentracije Cr i veće Ni, Cu i Fe zabilježene su u ispitivanoj skupini. Utvrđene su statistički značajne razlike ($p <0,05$) u koncentraciji Zn (6-9 godina; 10 -14 godina) između kontrolne i ispitivane skupine. Rezultatiovog istraživanja ukazuju na ulogu teških metala kao faktora okoliša u etiologiji ASD-a.