EXPERIMENTAL METHODS FOR CLINICAL PRACTICE

Correlation between Serum Content of Trace Elements and Interhemispheric Relationships in Children

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In 6-7 year-old children, the serum content of Fe correlated with activity of the right-hemispheric cognitive structures, the content of Zn correlated with the verbal-semantic type of information encoding typical of the left-hemisphere, and the content of Cu with adaptive brain functions.

Key Words: *trace elements; cognitive processes; interhemispheric relationships*

There is accumulating evidence that turnover of trace elements correlates with higher nervous activity under normal and pathological conditions. Specific relationships between the disturbance of trace element metabolism and various psychoneurological symptoms, as well as nonspecific effects of hypoxia, neurotoxins, and shifts in redox balance have been widely discussed [1,3,4].

The content of trace elements in the human body depends on age, gender, daytime, nutrition and geographic conditions, race, *etc.* [1]. High individual variability in the content of many elements [4] is determined by specific genetic and phenotypical personal characteristics. However, the relationships between the neuropsychological individuality and content of trace elements remain unclear.

We measured the content of trace elements in the blood of 6-7-year-old children with different organization of cognitive structures. Regulation of the trace element metabolism in children is imperfect and sensitive to age-related rearrangements in the nervous system [1]. This period is characterized by intense formation of neuropsychic individuality and close correlations of this process with changes in the autonomic regulation of somatic functions [2]. These correlations are weakened in adolescence, that is why our attention was focused on children of 6-7 years of age.

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MATERIALS AND METHODS

The study included 15 boys and 10 girls aged 6-7 years. All children lived in Irkutsk since birth, had no chronic diseases, had normal physical development, and were educated by similar programs.

Blood samples (3-5 ml) were collected from the cubital vein in the morning on an empty stomach. Samples were centrifuged for 3-5 min at 5.5*g*. The contents of Ca, K, Na, Fe, Mg, Cu, and Zn were determined on an AAS atomic absorption spectrometer (Karl Zeiss Jena) [5].

The type of information processing was assessed in two classification tests: in a design-test and a quantitative test of two-digit numbers [2]. The predominant mode of information encoding was evaluated by M. A. Kholodnaya's tests and by an associative test. The latter also provided information about the minimal time for verbal associations. Interhemispheric transfer of visual information was assessed by the corresponding test from the Luria-90 battery of tests. Emotional sensitivity was measured by a quantitative test [2]. The leading eye and ear were determined by neurophysiological tests. Mann—Whitney *U* test was applied to assess the difference between the data samples [4].

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RESULTS

The concentrations of trace elements in the serum and their relations corresponded to normal (Gaussian) distribution. We suggest that this phenomenon is due to individual characteristics of children with different interhemispheric relationships.

To test this hypothesis we analyzed the correlations between the serum content of trace elements and the gradient of interhemispheric relationships. The following criteria were used to classify these relationships: the type of information encoding and processing, the lateral profile of peripheral asymmetries, and the rate of associative test performance.

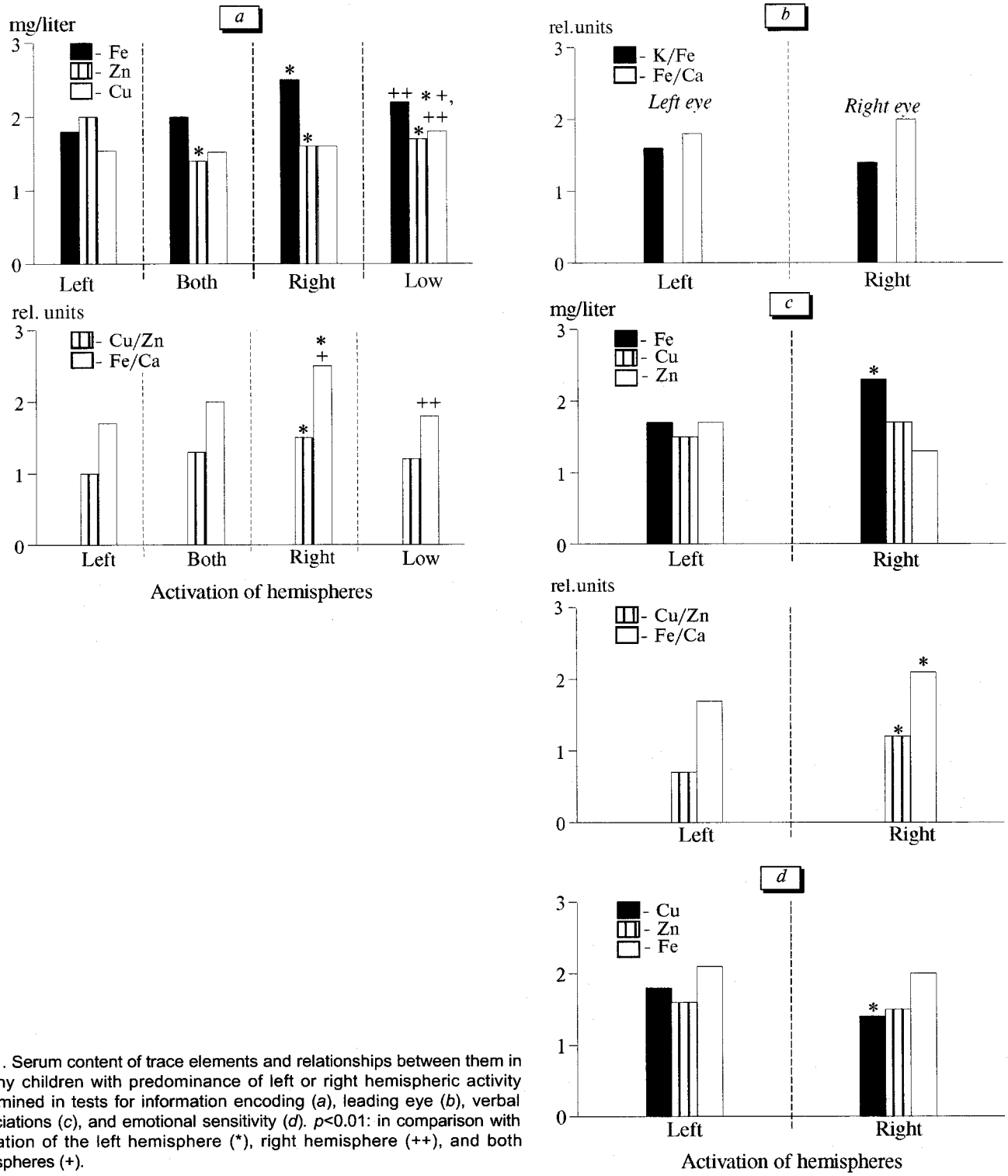

Fig. 1. Serum content of trace elements and relationships between them in healthy children with predominance of left or right hemispheric activity determined in tests for information encoding (*a*), leading eye (*b*), verbal associations (*c*), and emotional sensitivity (*d*). $p<0.01$: in comparison with activation of the left hemisphere (*), right hemisphere (++), and both hemispheres (+).

Along with the axis of the left-hemispheric dominance the distribution of Fe, Ca, and Zn and the ratios Cu/Zn, K/Mg, Zn/Ca, K/Fe, and Fe/Ca tended to be different and the differences for Fe, Zn, Cu/Zn, and Fe/Ca distributions were significant (Fig. 1, *a*). In subjects with the right-hemispheric information encoding, the serum content of Fe was higher than in subjects of the left-hemispheric (verbal-semantic) type. This finding is in line with the data on high energy expenditure for right-hemispheric cognitive activity, which is reduced during hypoxia in parallel with a decrease in the serum content of Fe [1].

Children with the left leading eye (which is primarily addressed to the right hemisphere) were characterized by a high content of Fe and their K/Fe ratio was lower, while the Fe/Ca ratio was higher than the corresponding indices in children with the right leading eye (Fig. 1, *b*). The information processing in the right hemisphere process is a synthetic, simultaneous, and impulsive process in contrast to a successive, reflexive, and analytic type of information processing in the left hemisphere. Hence, rapid performance of associative tests could imply a high level of right-hemispheric activity in children. At the same time, the serum content of Fe was not affected by emotional lability and changes in the mood (Fig. 1, *d*). Taken together, these results indicate that the serum content of Fe strictly correlates with cognitive activity of the right hemisphere. The same correlation was revealed for the Fe/Ca ratio which was significantly higher in children with the synthetic type of information processing. This finding is in line with published data on a correlation between the reduced concentration of Fe and low resistance to infection, apathy, and weakening of the immune system, which are indicative of reduced activity of natural adaptation centers in the right hemisphere [6].

We found a significantly higher concentration of Cu in the inherently right-hemispheric children who had to acquire the left-hemispheric way of information processing under the pressure of school environment (so-called "re-learned" left-handers; Fig. 1, *a*). These children are characterized by low learning abilities and low cognitive activity of both hemispheres, they often suffer from psychogenic disorders [2]. Cu content was reported to increase under stress conditions and in psychoneurological disorders [1,3]. Interestingly, we found no correlation between Cu content and the gradient of left- or right-hemispheric encoding, the mode of information processing (analytic or synthetic), and disturbances in interhemispheric transfer. However, activation of right-hemispheric structures associated with school adaptation and manifested itself in increased emotional sensitivity led to a significant reduction of the Cu content in the serum (Fig. 1, *d*). We suggest that Cu content correlates with the adaptive brain functions rather than with cognitive activity. Association between the Cu content and stress-limiting mechanisms was noted also in other studies [1,3].

Unlike Cu, serum content of Zn increased and the Cu/Zn ratio decreased with the increasing activity of left-hemispheric structures. "Re-learned" children showed a significantly lower content of Zn (Fig. 1, *a*). However, neither disturbances in the interhemispheric transfer, nor changes in the emotional resistance and sensitivity affected the serum content of Zn. At the same time, the Cu/Zn ratio was significantly lower in children with fast (< 2 sec) verbal operations. These data indicate that Zn content correlates with the left-hemispheric verbal-semantic mode of information encoding. This conclusion is in line with the data on positive relationships between the level of Zn and learning abilities in rats [3]. It is supported by the data on synergistic relationships between Cu and Fe and antagonistic relations between these two elements and Zn [6].

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