Exposure to lead and psychophysiological development in students from Lviv region

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Abstract. Among young people investigated enhanceable maintenance of biomarkers of aminolevulinic acid and coproporphyrine in urines which represent the degree of development of leaden intoxication. The psychophysiological indexes (increase of anxiety degrees, depression, neurosis and aggressiveness levels) are conditioned the development of lead intoxication and closely correlates with the increase of heme destruction products in urine. By the unique sign not depending on the level of lead intoxication appeared rigidity, that, obviously, it is related in a greater degree to the type of temperament, which, as known, is the innate feature of character of every personality.

Keywords*: lead intoxication, δ-aminolevulinic acid, coproporphyrine, psychophysiological indexes.*

Introduction. In recent years the problem of environmental pollution with heavy metals, including lead, belongs to the category of global ecopatological problems [1, 15]. Environmentally caused, relatively low levels of lead in soil, water and food products of mass consumption that were previously considered safe, in fact, cause many neurotoxic disorders affecting primarily on cognitive function [1, 6, 13]. Chronic lead intoxication poses a threat primarily noosphere, increases the risk of mental retardation and maturation of the younger generation, and therefore threatens the future of humanity [3, 7, 12, 14, 17]. Current epidemiological data strongly suggest that inorganic lead in environmentally caused doses has adverse effects on the health of children, manifested a violation of mental and physical development, physiological disorders, decreased intensity of synthesis of heme, the development of anemia, increased threshold of auditory perception and a reduction in vitamin D levels [7, 14, 17]. The effects of lead on the development of the nervous system establish the basis for cognitive impairments in lead-exposed children, even after reducing it concentration in blood [3].

Analysis of recent research and publications. Lead exposure remains nevertheless an important public health issue for three primary reasons: first, many populations continue to be exposed to substantial quantities of lead; second, the blood lead levels recognized to be associated with potential toxicity have been revised downward in recent years based on expanding recognition of the biologic hazards of this metal, even with very low tissue exposure; and third, certain groups of individuals in the population continue to be at exceptional risk from lead exposure, including children and teenagers [8].

Lead is toxic, even at trace levels, and cause profound biochemical changes in the body. Chronic exposure to this metal can result in its gradual accumulation in the body; children and teenagers are more sensitive, and are hence more at risk than others [4]. Negative effects on the behavior and intelligence of children are found at even lower levels of lead exposure than those commonly associated with lead poisoning [11].

Numerous investigations focusing on the mechanism of lead neurotoxicity have found a wide array of effects, including apoptosis, excitotoxicity, interference with neurotransmitter storage and release mechanisms, alterations in second messengers, and damage to mitochondria [8]. Although there is no unifying mechanism, lead's ability to substitute for calcium, and possibly zinc, is a factor common to many of its toxic actions. The disruption of dopaminergic functioning, which is involved in motor control and attention, as well as memory and executive functioning, can produce a host of behavioral problems, including attention deficit hyperactivity disorder and alterations in cognition [4]. Also, lead has effects on glutamatergic transmission, which is a major player in both development and neuronal plasticity and is related to learning and memory impairments [16].

Goal. In contrast to studies noted above, results of psychophysiological investigations in students from an endemic goiter area are limited. Considering the demonstrated effects of lead toxicity it seemed conceivable that this additive effect would be manifested in cognitive defects such as learning and memory. Thus, the current investigation is designed to test this hypothesis. The aim of the present work is to study the lead's effects on cognitive and behavioral features in students from an endemic goiter area.

Materials and methods. The study is included above 600 students of Ivan Franko Lviv National University (males and females) between 18 and 24 years of age living in endemic goiter area (Lviv region).

Experimental studies included the following main stages.

1. Psychophysiological investigations. We used the following tests for evaluating cognitive and behavioral function of students. Coefficient of intellectual abilities is used for estimation of mental retardation of students. The general health questionnaire is used to estimate the students' mental health. Test Aisenk's is used for diagnostics of self-appraisal of mental conditions (anxiety, aggression, frustration, mobility). The level of anxiety is estimated by a Teylor test [9]. The state of depression is diagnosed following the test of Zhmurov [5]. For estimation of neurosis is used the method of Hake and Hess [18]. Level of aggression estimated by the method of Assinger [13]. Determination of formal and dynamic properties of individuality is carried out by the method of Rusalov [6]. Force of nervous processes is estimated by a tapping-test [2]. Mobility of nervous processes is estimated by the method of plasticity investigation [20]. The operative estimation of feel, activity and mood is carried out by the method of Raygorodskiy [13]. The attention is estimated

by the proof-reading test of Anfimov [5]. Volume of attention and mobility of basic nervous processes is carried out by the tables of Shul'te [19].

2. Biochemical estimation of urinary δ-aminolevulinic acid and coproporphyrine concentrations. Measurement of urinary δ-aminolevulinic acid (δ-ALA) level continues to be a useful method for determination of extent of cut-off point of lead toxicity. The level of urine δ-aminolevulinic acid is estimated following the method with Ehrlich's reagent. Coproporphyrine concentration in urine is measured using iodine as a substrate after suitable dilution following the method by Kamyshnikov [10].

3. Statistical analysis. The results is expressed as mean ±S.D. Significant differences among the means measured using a multiple range test at min. $p<0.05$. Data not having a normal distribution is log transformed. Student t-tests with 95% confidence intervals ($\alpha=0.05$) is applied to determine the significance of differences between groups. The individual treatment difference between two groups is assessed by computation of the least significant difference by taking at value for error at the level of 5% significance. Statistical processing included descriptive summarizing data, Student's t-test, and correlation analysis. These results are expressed with the use of procedure of one-factor analysis of variance due to the program SPSS 11.5.

Results. Our results showed an increase in levels of δ-aminolevulinic acid (δ-ALA) and coproporphyrine concentration indicating of lead-induced oxidative stress. Measurement of urinary δ-ALA level and coproporphyrine concentration continues to be a useful method for determination of extent of cut-off point of lead toxicity. After estimation of levels of δ-ALA and coproporphyrine concentration in urine we divided the students into control and experimental groups. Such correlation of students in control and experimental groups is 35.96 ± 2.45 and 64.04 ± 3.82% accordingly. We studied that the greater of students' inherent middle levels of δ-ALA and coproporphyrine in urine. Comparing the concentrations of δ-ALA and coproporphyrine, the high levels of lead intoxication are observed only in 1-9% students. The increase of lead intoxication level for students substantially influences on the level of their psychophysiological development (Fig.1).

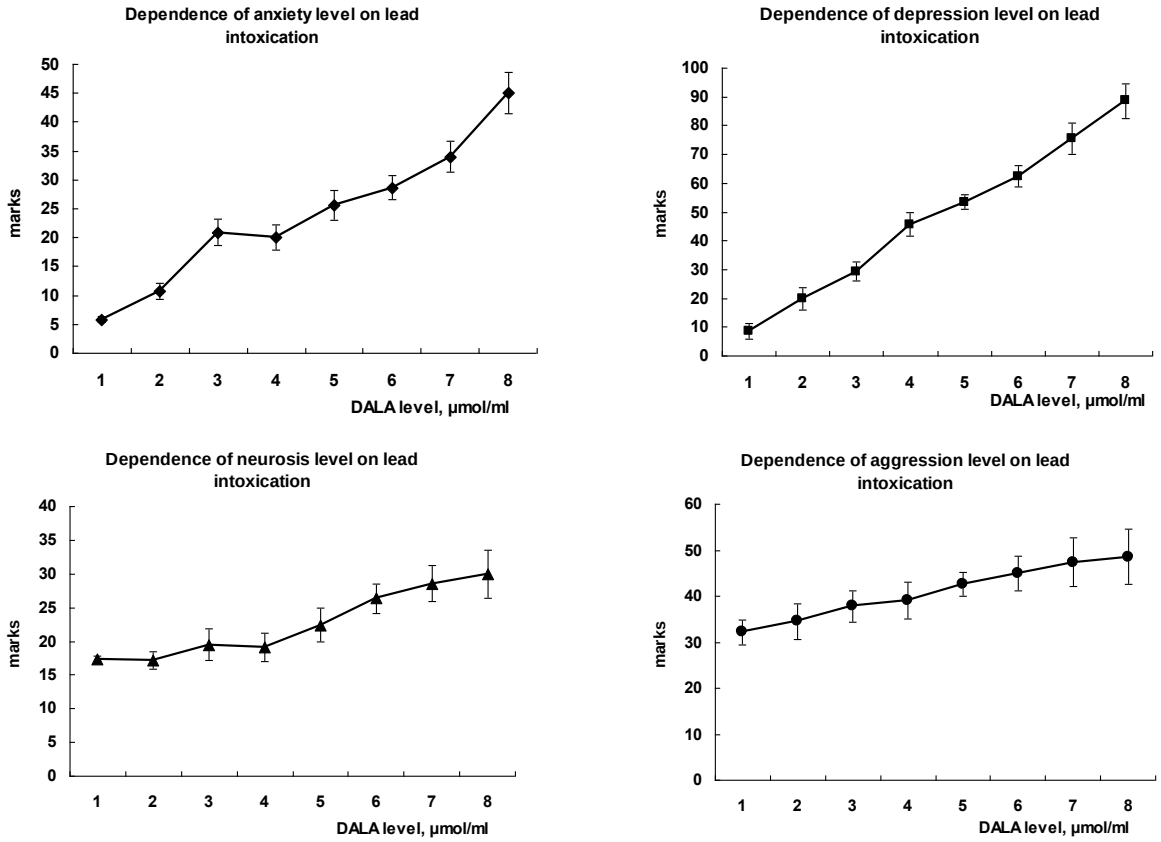

Fig. 1. Dependence of psychophysiological indexes on urinary level.
In x-axis is δ-ALA concentration, μmol/ml; in y-axis is psychophysiological indexes in marks.

In particular, the increase of δ-ALA level in urine results in substantial growth of anxiety among young people. In particular, maintenance of δ-ALA level in urine over 5 μmol/ml suggests that level of anxiety arrives at high (25-40 marks) and ever-higher levels (over 41 marks).

We investigated that the level of depression is considerably worsened for young people with the increase of lead intoxication level. The level of moderate depression was registered for students in which found out maintenance of urinary δ-ALA concentration over 4 μmol/ml, and expressed and the deep depression was registered at δ-ALA level within the limits of 7-8 μmol/ml. Similar results were investigated in relation to the degrees of neurosis and aggressiveness. It is suggest that probability of neurosis grows with the increase of lead intoxication level. Analogical dependence is observed in the case of aggressiveness. In particular, a surplus aggressiveness is

inherent for students with the concentration of δ-ALA in urine over 7-8 μmol/ml.

Due to the method of one-factor analysis of psychophysiological indexes we studied the empiric shortchanged Fisher coefficient exceeding the critical value which testifies about significance of our results (tables 1, 2). The analysis of variance allowed also investigating that the degree of lead intoxication not influence on rigidity of personality. In this case this index is an independent and, probably, determined the innate type of temperament.

Table 1 An analysis of variance among influence of δ-aminolevulinic acid level on the degree of psychophysiological indexes of young people

Psychophysiological indexes	Disspersion	Sum of Squares	df	Mean Square	F	Sig.	F_{st}
Level of anxiety by Teylor	Between Groups	4592,639	118	59,645	18,39	0,0075	4,60
	Within Groups	8853,940	124	71,403			
	Total	13446,579	242				
Level of depression by Zhmurov	Between Groups	12892,650	118	167,437	19,65	0,0057	4,60
	Within Groups	17095,726	124	137,869			
	Total	29988,376	242				
Level of rigidity	Between Groups	1029,260	118	13,367	1,71	0,951	4,60
	Within Groups	2350,027	124	18,952			
	Total	3379,287	242				
Level of neurosis by Hake and Hess	Between Groups	4356,580	118	56,579	80,76	0,00034	4,60
	Within Groups	6974,687	124	56,247			
	Total	11331,267	242				
Level of aggression by Assinger	Between Groups	1005,764	118	13,062	253,65	0,00023	4,60
	Within Groups	1365,845	124	11,015			
	Total	2371,609	242				

These results are expressed with the use of procedure of one-factor analysis of variance due to the program SPSS 11.5.

Table 2. An analysis of variance among influence of coproporphyrine concentration on the degree of psychophysiological indexes of young people

Psychophysiological indexes	Disspersion	Sum of Squares	df	Mean Square	F	Sig.	F_{st}
1	2	3	4	5	6	7	8
Level of anxiety by Teylor	Between Groups	3414,751	78	60,98	13,42	0,0075	2,72
	Within Groups	5217,557	124	71,47			
	Total	8632,308	202				
Level of depression by Zhmurov	Between Groups	10664,352	78	190,44	16,82	0,0057	2,72
	Within Groups	9973,679	124	136,63			
	Total	20638,031	202				
Level of rigidity	Between Groups	789,412	78	14,09	0,85	0,951	2,72
	Within Groups	1550,095	124	21,23			
	Total	2339,508	202				
Level of neurosis by Hake and Hess	Between Groups	2902,950	78	51,84	35,67	0,00034	2,72
	Within Groups	4445,173	124	60,89			
	Total	7348,123	202				
Level of aggression by Assinger	Between Groups	664,679	78	11,87	125,37	0,00023	2,72
	Within Groups	681,198	124	9,33			
	Total	1345,877	202	60,98			

These results are expressed with the use of procedure of one-factor analysis of variance due to the program SPSS 11.5.

We compared influence of different concentrations of δ-ALA and coproporphyrine on psychophysiological data in the control and experimental groups of students, in particular on the level of anxiety, depression, neurosis and aggressiveness. Our results are presented on Fig. 2.

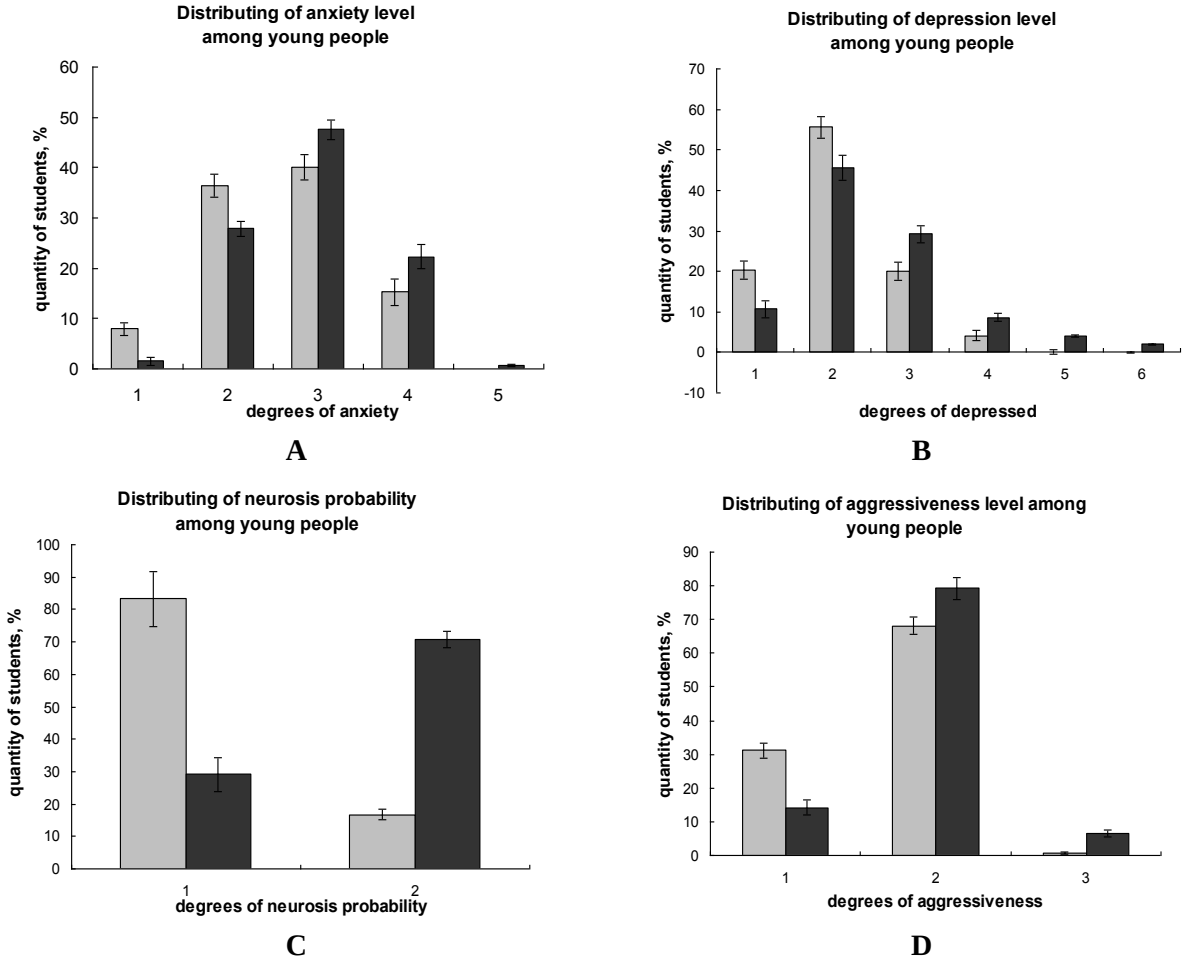

Fig. 2. Distributing of psychophysiological indexes among young people from control and experimental groups. **A.** Degrees of anxiety: 1 – low; 2 – middle with a tendency to low; 3 – middle with a tendency to high; 4 – high; 5 – ever higher; **B.** Degrees of depressed: 1 – absence of depression; 2 – depression is minimum; 3 – depression is easy; 4 – depression is moderate; 5 – the depressed is expressed; 6 – depression is deep; **C.** Degrees of neurosis probability: 1 – low; 2 – high; **D.** Degrees of aggressiveness: 1 – a peaceful type; 2 – a moderate aggressiveness; 3 – a surplus aggressiveness.

Our results show that in the control group of young people a tendency to the low anxiety is observed in 8-39%, in that time as in an experimental group these degrees are considerably below and expressed accordingly from 2 to 28%. It is showed also, that high level of anxiety in an experimental group considerably prevails comparatively with control group. It was also noted that the ever-higher degree of anxiety is inherent only students from the experimental group. It testifies to considerable development of anxiety for young people with lead intoxication in relation to the indexes from control group of students with low anxiety level. Similar results were investigated in relation to depression level. It is noted in particular, that the signs of depression are more expressly shown in the experimental group of the young people. In particular, for people with lead intoxication the insignificant percent of young people noted with expressed and deep depressed unlike a control group with absence of such people.

Confronting different probability of neurosis from two groups of students we suggest that in an experimental group high probability of neurosis considerably prevail low probability. An opposite tendency in a control group is observed. Our results allow assuming that high probability of neurosis is dependent of lead intoxication level. Similar results were noted in the case of comparison of display of certain aggressiveness degrees on condition of lead intoxication and its absence. Thus, it is possible to suggest, that worsening of psychophysiological properties depends on development of lead intoxication level.

It was expressed the non-parametric analysis of correlation of Spirmen grades with the purpose of finding out of connection between the level of lead intoxication due to measurement of δ-ALA and coproporphyrine level and by the indexes of psychophysiological properties (Table 3).

The degree of the lead exposure closely correlates with the degrees of anxiety, depressed and neurosis. The loosely-coupled positive interface of degree of lead intoxication with the level of aggressiveness is also established. However one of psychophysiological features, rigidity, is characterized the negative and very low correlative coefficient with the degree of lead intoxication confirming an idea about independence of this property from the level of lead intoxication. It was established also the close cross-correlation links of psychophysiological features between itself. Our results testify that increase of anxiety degrees, depression, and neurosis and aggressiveness level is related to the increase of δ-ALA and coproporphyrine levels in urines representing the development of lead intoxication.

Table 3. A non-parametric cross-correlation analysis of psychophysiological indexes of young people and level of lead intoxication

Indexes		Level of anxiety by Teylor	Level of depression by Zhmurov	Level of rigidity	Level of neurosis by Hake and Hess	Level of aggression by Assinger	δ-ALA level	Coproporphyrine level
Level of anxiety by Teylor	Correlation Coefficient	1,000	0,661(**)	-0,004	0,801(**)	0,976(**)	0,976(**)	0,952(**)
	N	12	12	12	12	12	12	10
Level of depression by Zhmurov	Correlation Coefficient	0,661(*)	1,000	-0,059	0,697(*)	0,952(**)	0,976(**)	0,801(**)
	N	12	12	12	12	12	12	10
Level of rigidity	Correlation Coefficient	-0,004	-0,059	1,000	-0,081	-0,099	-0,030	-0,081
	N	12	12	12	12	12	12	10
Level of neurosis by Hake and Hess	Correlation Coefficient	0,801(**)	0,697(*)	-0,081	1,000	0,952(**)	0,952(**)	0,976(**)
	N	12	12	12	12	12	12	10
Level of aggression by Assinger	Correlation Coefficient	0,976(**)	0,952(**)	-0,099	0,952(**)	1,000	0,976(**)	0,697(*)
	N	12	12	12	12	12	12	10
δ-ALA level	Correlation Coefficient	0,976(**)	0,976(**)	-0,030	0,952(**)	0,976(**)	1,000	0,976(**)
	N	12	12	12	12	12	12	10
Coproporphyrine level	Correlation Coefficient	0,952(**)	0,801(**)	-0,081	0,976(**)	0,697(*)	0,976(**)	1,000
	N	10	10	10	10	10	10	10

** – Significance of Spirmen coefficient (0.01); * – Significance of Spirmen coefficient (0.05).

Conclusions. Our results showed an increase in levels of urinary δ-aminolevulinic acid and coproporphyrine concentration indicating of lead intoxication among young people. In students investigated enhanceable maintenance of biomarkers of aminolevulinic acid and coproporphyrine in urines which represent the degree of development of leaden intoxication. The psychophysiological indexes (increase of anxiety degrees, depression, neurosis and aggressiveness levels) are conditioned the development of lead intoxication and closely correlates with the increase of heme destruction products in urine. By the unique sign not depending on the level of lead intoxication appeared rigidity, that, obviously, it is related in a greater degree to the type of temperament, which, as known, is the innate feature of character of every personality.

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Свинцовая интоксикация и психофизиологическое развитие студентов Львовской области

Н. В. Налывайко, Г.М. Ткаченко

Аннотация. Среди молодежи исследовали повышенное содержание биомаркеров δ-аминолевулиновой кислоты и копропорфиррина в моче, которые представляют степень развития свинцовой интоксикации. Психофизиологические показатели (увеличение уровней тревожности, депрессии, невроза и агрессивности) обусловлено развитием свинцовой интоксикации и тесно коррелирует с увеличением продуктов разрушения гема в моче. Единственным признаком, независимым от уровня развития свинцовой интоксикации оказалась ригидность, что, очевидно, связано в большей степени с типом темперамента, который, как известно, является врожденной чертой характера каждой личности.

Ключевые слова: *свинцовая интоксикация, δ-аминолевулиновая кислота, копропорфиррин, психофизиологические показатели*

Свинцева інтоксикація та психофізіологічний розвиток студентів Львівської області

Н. В. Наливайко, Г. М. Ткаченко

Анотація. Серед молоді виявлено підвищений вміст біомаркерів δ-амінолевулінової кислоти та копропорфірину у сечі, які відображають ступінь розвитку свинцевої інтоксикації. Психофізіологічні показники організму (зростання ступенів тривожності, депресивності, неврозу та агресивності) обумовлено рівнем розвитку свинцевої інтоксикації і тісно корелює із збільшенням вмісту у сечі продуктів розпаду гему. Єдиною ознакою, яка не залежить від рівня розвитку свинцевої інтоксикації виявилась ригідність, що, очевидно, пов'язано більшою мірою із типом темпераменту, який, як відомо, є вродженою особливістю характеру кожної особистості.

Ключові слова: *свинцева інтоксикація, δ-амінолевулінова кислота, копропорфірин, психофізіологічні показники*