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## PHYSICAL DEVELOPMENT AND CALCIUM-PHOSPHORUS METABOLISM IN THE CHILDREN FROM THE REGIONS AFFECTED THE CHORNOBYL NUCLEAR POWER PLANT ACCIDENT

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*The **purpose of the study** was to determine the association between the physical development and calcium, phosphorus and <sup>137</sup>Cs radionuclides in the organisms of the children living in the regions affected the Chernobyl nuclear power plant accident.*

***Material and methods.** 520 children, living in Ivankiv and Polissya regions of the Kyiv oblast, were examined. The average age of the schoolchildren was 14.0±0.07 years. The Rohrer index was used as a criterion for the assessment of the state of physical development (PD) of the child. Radiometric, anthropometric, spectrometric, mathematical and statistical methods were used for the study.*

***Results.** Among the examined children, living in the regions affected the Chernobyl nuclear power plant accident, the cases of harmonious PD made up 66.9 %. The cases of disharmonious high PD were detected in 63.95 % of the children in the group with disharmonious PD.*

*There was no association between the PD of the examined children and the content of general calcium in blood. At the same time, the association was observed between the PD of those children and content of phosphorus in blood. The proportion of hypophosphatemia cases in the groups of the children with harmonious and disharmonious high PD development was statistically higher than the proportion of cases where the content of phosphorus in blood was within the reference range. The content of <sup>137</sup>Cs radionuclides and phosphorus in blood was reliably higher in the children with disharmonious low PD than in the children with harmonious and disharmonious high PD. The results of the statistical studies confirm the inverse correlative relationships between the indicators of <sup>137</sup>Cs, phosphorus values and PD.*

*The body weight decrease in the adolescents, living in the areas affected the Chernobyl nuclear power plant accident, is associated with an increase of the content of <sup>137</sup>Cs radionuclides in the organism and phosphorus in blood.*

***Conclusions.** The obtained results indicate the negative effect of incorporated <sup>137</sup>Cs radionuclides on the PD of child's organism.*

***Keywords:** the Rohrer's index, physical development, Cs-137 radionuclides, hypophosphatemia, correlative relationship, radiation-contaminated territory.*

## ФІЗИЧНИЙ РОЗВИТОК І КАЛЬЦІЙ-ФОСФОРНИЙ ОБМІН У ДІТЕЙ З РАЙОНІВ, ПОСТРАЖДАЛИХ ВІД АВАРІЇ НА ЧОРНОБИЛЬСЬКІЙ АТОМНІЙ ЕЛЕКТРОСТАНЦІЇ

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**Метою дослідження** було визначення у дітей, які проживають в районі, постраждалому від аварії на Чорнобильській атомній електростанції, зв'язку між фізичним розвитком дітей і кальцієм, фосфором, а також радіонуклідами <sup>137</sup>Cs, що містяться в організмі.

**Матеріали та методи.** Досліджено 520 дітей, які мешкають в Іванківському і Поліському районах Київської області. Середній вік школярів склав 14,0±0,07 років. В якості критерію оцінки стану фізичного розвитку (ФР) дитини застосований індекс Рорера. Для дослідження використані радіометричний, антропометричні, спектрометричний, математико-статистичний методи.

**Результати.** Серед обстежених дітей, які проживають в районах, постраждалих від аварії на Чорнобильській атомній електростанції, випадки гармонійного ФР становили 66,9 %. У групі дітей з дисгармонійним ФР випадки дисгармонічного високого ФР зустрілися у 63,95 %.

Не виявлено зв'язку між ФР обстежених дітей і вмістом загального кальцію в крові. У той же час виявлено зв'язок між ФР цих дітей і вмістом фосфору в крові.

Питома вага випадків гіпофосфатемії у групах дітей з гармонійним і дисгармонійним високим ФР була статистично більше, ніж питома вага випадків вмісту фосфору в крові в межах референтного інтервалу.

У дітей з дисгармонійним низьким ФР, вміст радіонуклідів <sup>137</sup>Cs в організмі і фосфору в крові, достовірно більше, ніж у дітей з гармонійним і дисгармонійним високим ФР.

Результати статистичних досліджень підтверджують зворотні кореляційні зв'язки між значеннями показників <sup>137</sup>Cs, фосфору і ФР.

Зниження маси тіла у дітей підліткового віку, які проживають на території, що постраждала від аварії на Чорнобильській атомній електростанції, пов'язане з підвищенням вмісту радіонуклідів <sup>137</sup>Cs в організмі і фосфору в крові.

**Висновки.** Отримані результати свідчать про негативний вплив на ФР дитячого організму інкорпорованих в організм радіонуклідів <sup>137</sup>Cs.

**Ключові слова:** індекс Рорера, фізичний розвиток, радіонукліди Cs-137, гіпофосфатемія, кореляційний зв'язок, радіоактивно забруднена територія.

**Relevance of the problem.** Projects of the European Commission and the Rhône-Alpes Regional Council (France) conducted in Ukraine in 2013-2017 allow to obtain objective information on the health of children from raions located near the Chernobyl Exclusion Zone [1-7].

At the same time, it is important to identify the cause of metabolic disorders leading to irreversible changes in the skeleton, juvenile osteoporosis and scoliosis [8], having studied the relationship between the physical growth of children and vital macro- and microelements and radionuclides present in their bodies.

The **purpose of this study** was to determine associations between the physical growth and calcium, phosphorus and <sup>137</sup>Cs levels in children living in a districts affected by the Chernobyl nuclear power plant accident.

**Material and methods.** During the work carried out within the European Commission's project "Health and ecological programmes around the Chernobyl Exclusion Zone: Development, training and coordination of health-related projects", 520 children living in Ivankovsky and Polesky districts, Kyiv region, having the <sup>137</sup>Cs soil contamination density of 0.17 to 1.9 curie/km<sup>2</sup> were subjected to laboratory, instrumental and radiological studies [9].

The examined children's average age was  $14.00 \pm 0.07$  years (95 % CI 13.9 – 14.2 years).

All examinations of the children were conducted in compliance with the rules of bioethics and informed consents were signed by the parents of each subject.

In order to determine serum total calcium (Ca) and inorganic phosphorus (P) levels, all the examined children had blood drawn from the ulnar vein after fasting in the morning.

Ca levels were measured by the spectrometric method using a Flexor E automated biochemical analyzer (Vital Scientific, The Netherlands) using reagents from Point Scientific, Inc. (USA). The wavelength is 650 nm.

Inorganic P concentrations were determined by the spectrometric method using a Flexor E automated biochemical analyzer (Vital Scientific, The Netherlands) using reagents from Point Scientific, Inc. (USA). The wavelength is 340 nm.

The children's anatomical measures were studied in compliance with standard conditions using standardized anthropometric measuring techniques [10].

The Rohrer's weight/height index (RI) being an indicator for physical growth (PG) and metabolism was used in this study.

RI is a measure that allows to assess the degree of conformity of one's weight to height calculated by dividing weight in kilograms by the cubic of height in meters.

Normal or average PG of children was found at RI values of 10.7 to 13.7  $\text{kg}/\text{m}^3$ , abnormal (low) PG was defined at RI values of less than 10.7  $\text{kg}/\text{m}^3$ , and abnormal (high) PG of children was defined at RI values of more than 13.7  $\text{kg}/\text{m}^3$  [11].

Systolic and diastolic blood pressure (SBP, DBP) were measured automatically using a patient monitor system (PM 9000, Penton Ltd). Pulse pressure (PP, the difference between the systolic and diastolic blood pressure) was also calculated.

$^{137}\text{Cs}$  specific activity in a child's body was measured using a SICH-AKP-3 three-detector spectrometer (OOO NPP ATOMKOMPLEKSPRIBOR, Ukraine) during 10 minutes. Spectra were processed automatically, specific activities of radioactive elements were calculated and the obtained information was saved with the help of the AKWin software.

The statistical processing of the results obtained was performed using the IBM SPSS Statistics 22 software (USA). The arithmetic mean (M),  $\pm$ standard error of mean (m), confidence interval for the mean value (95% CI), median (Me), interquartile range (IR), minimum and maximum parameter values and percentiles were calculated for the variables analysed. The distribution hypothesis was tested (a Kolmogorov-Smirnov test). All the parameters under study did not conform to the normal distribution law, thus, a non-parametric Mann-Whitney U test was used to compare values. The statistical significance of variables was assessed by determining a significance level for p with the help of the statistical software programme.

Associations between the analysed variables were identified with the help of the Spearman's rank correlation coefficient ( $r_{xy}$ ). The strength of an association was assessed according to a typical scale: weak – 0 to 0.299; moderate – 0.3 to 0.699; strong – 0.7 to 1.0.

**Results and discussion.** The group of children with normal PG comprised the largest proportion among the children examined (table 1). Abnormal high PG was found in 110 children (63.95 %) among 172 children with abnormal PG.

Blood total calcium levels fell within the reference range in the majority of children examined (table 2).

Table 1. Examined children distribution into groups according to the PG level based on Rohrer's mass/height index (RI).

Group No.	RI values	Number of children in a group	
		Abs.	% $\pm$ m
1	< 10.7	62	11.9 $\pm$ 1.4
2	10.7-13.7	348	66.9 $\pm$ 2.1
3	> 13.7	110	21.2 $\pm$ 1.8

Table 2. Blood Ca values in children with different PG levels.

Group No.	RI values	Number of children in a group	Number of cases					
			Subgroup A Ca > 2.6 mmol/L		Subgroup B Ca=2.13-2.6 mol/L		Subgroup C Ca < 2.13 mmol/L	
			Abs.	%±m	Abs.	%±m	Abs.	%±m
1	< 10.7	62	1	1.6±1.6*	59	95.2±2.7	2	3.2±2.3
2	10.7-13.7	348	0	-	339	97.4±0.9	9	2.6±0.9
3	> 13.7	110	0	-	109	99.1±0.9	1	0.9±0.9

Note. Statistical differences between subgroups A and B in the Group 1:  $t=29.82$ ;  $p=0.00001$ .

The proportion of cases of hypophosphataemia (blood P levels < 1.29 mmol/L) was statistically significantly higher than the proportion of cases with P levels within the reference range – P=1.29-2.26 mmol/L in the groups 2 and 3 of children.

The proportion of cases of hyperphosphataemia (blood P levels > 2.26 mmol/L) was insignificant in all groups (tables 3, 4).

Table 3. Blood P values in children with different PG levels.

Group No.	RI values	Number of children in a group	Number of cases					
			Subgroup A P < 1.29 mmol/L		Subgroup B P=1.29-2.26 mol/L		Subgroup C P > 2.26 mmol/L	
			Abs.	%±m	Abs.	%±m	Abs.	%±m
1	< 10.7	62	34	54.8±6.3	26	41.9±6.3	2	3.2±2.3
2	10.7-13.7	348	217	62.4±2.6	128	36.8±2.6	3	0.9±0.5
3	> 13.7	110	72	65.5±4.5	38	34.6±4.5	0	-

$^{137}\text{Cs}$  levels were statistically significantly higher in the Group 1 of children (RI < 13.7) than in the Groups 2 and 3, and was higher in the Group 2 than in the Group 3 (tables 5, 6).

Table 4. Statistical differences in blood P values in children with different PG levels (RI).

Comparison groups	Test of differences, significance level p	Comparison groups	Test of differences, significance level p	Comparison groups	Test of differences, significance level p
1A and 1B	$t=1.45$ ; $p=0.153127$	1A and 1C	$t=7.69$ ; $p=0.00001$	1B and 1C	$t=5.77$ ; $p=0.00001$
2A and 2B	$t=6.96$ ; $p=0.00001$	2A and 2C	$t=23.23$ ; $p=0.00001$	2B and 2C	$t=13.56$ ; $p=0.00001$
3A and 3B	$t=4.86$ ; $p=0.00001$	3A and 3C	-	3B and 3C	-
1A and 2A	$t=1.12$ ; $p=0.265879$	1B and 2B	$t=0.75$ ; $p=0.455442$	1C and 2C	$t=0.18$ ; $p=0.86125$
1A and 3A	$t=1.38$ ; $p=0.169945$	1B and 3B	$t=1.76$ ; $p=0.082452$	1C and 3C	-
2A and 3A	$t=0.60$ ; $p=0.551323$	2B and 3B	$t=0.94$ ; $p=0.349453$	2C and 3C	-

Note. Group 1 – RI < 10.7; 2 – RI=10.7-13.7; 3 – RI > 13.7. Subgroups: «A» – P < 1.29 mmol/L; «B» – P=1.29-2.26 mmol/L. «C» – P > 2.26 mmol/L.

Table 5. Statistical characteristics of the analysed variables in groups of children with different physical growth.

Variables	Groups					
	1 – RI < 10.7		2 – RI 10.7-13.7		3 – RI > 13.7	
	Me	IR	Me	IR	Me	IR
<sup>137</sup> Cs, Bq/kg	1.81	1.65-2.07	1.69	1.57-1.92	1.51	1.45-1.61
Ca, mmol/L	2.35	2.28-2.4	2.34	2.28-2.39	2.33	2.27-2.39
P, mmol/L	1.27	0.95-1.55	1.14	0.75-1.41	1.13	0.78-1.41

Blood calcium levels in the children from the analysed groups had no statistical differences (tables 5, 7).

Blood P levels in the children from the Group 1 were statistically significantly higher than in the Groups 2 and 3 (tables 5, 8).

Table 6. Statistical differences in <sup>137</sup>Cs specific activity values in examined children.

Comparison groups	Comparison group size	Average rank	U test value, significance level, p
1-2	62	239.69	U=8668.0; p=0.014
	348	199.41	
2-3	348	256.14	U=9871.0; p=0.00001
	110	145.24	
1-3	62	118.25	U=1441.5; p=0.00001
	110	68.60	

Table 7. Statistical differences in Ca values in groups of children examined.

Comparison groups	Comparison group size	Average rank	U test value, significance level, p
1-2	62	209.15	U=10562.0; p=0.792
	348	204.85	
2-3	348	231.47	U=18453.5; p=0.570
	110	223.26	
1-3	62	89.75	U=3208.5; p=0.520
	110	84.67	

Table 8. Statistical differences in P values in groups of children examined.

Comparison groups	Comparison group size	Average rank	U test value, significance level, p
1-2	62	244.80	U=8351.5; p=0.005
	348	198.50	
2-3	348	229.10	U=18999.5; p=0.908
	110	230.78	
1-3	62	98.46	U=2668.5; p=0.018
	110	79.76	

A correlation analysis of values of analysed variables of all the children examined showed an inverse association between RI and  $^{137}\text{Cs}$ , RI and P. There was no association between RI and Ca (table 9).

Table 9. Results of correlation analysis between RI values and analysed variables among the children examined.

Parameters	Correlation coefficient	Parameter
		RI c.u.
Cs-137, Bq/kg	Spearman's	-0.397**
	Sign. (2-tailed), p	0.00001
	N	520
Ca, mmol/L	Spearman's	-0.011
	Sign. (2-tailed), p	0.807
	N	520
P, mmol/L	Spearman's	-0.130**
	Sign. (2-tailed), p	0.003
	N	520

Note. \* – Correlation is significant at the 0.05 level (2-tailed). \*\* – Correlation is significant at the 0.01 level (2-tailed).

Thus, the study showed that the majority of adolescent children living in the raion affected by the Chernobyl nuclear power plant accident had a normal PG – 66.9%.

Cases of abnormal high physical growth (63.95%) prevailed among the children with abnormal PG.

The study showed no association between physical growth and blood total calcium levels. Blood Ca levels were within the reference range in the vast majority of children.

An association was identified between the physical growth of the children and blood P levels.

Hypophosphataemia was present in most of the children from the groups with normal and abnormal high PG. This effect was absent in the group of children with abnormal low PG. Blood P levels in the children of this group were statistically significantly higher than in the other two analysed groups. The correlation analysis showed an inverse association between RI values and P.

Considering that the examined children have been constantly living in the territory contaminated with radioactive elements, it is very important to determine the severity of incorporation of the latter into the body and their link with PG.

$^{137}\text{Cs}$  concentrations were higher in the children with abnormal low PG compared to the children with normal and abnormal high PG.

This relationship is confirmed by the inverse association between RI and  $^{137}\text{Cs}$  contained in the body.

A progressive decrease in RI values with an increase in  $^{137}\text{Cs}$  levels in the children identified during the study indicates that there is suppression of proliferation of cells of the musculoskeletal system and vital organs. This effect of  $^{137}\text{Cs}$  was also recorded in the children with respect to blood cells (table 10) [12].

The findings can be used when carrying out medical preventive activities among children living under conditions of radiation exposure due to the Chernobyl nuclear power plant accident.

Table 10. Results of correlation analysis between age, haemoglobin level, red blood cell count and <sup>137</sup>Cs specific activity in children aged 12-18 years.

Parameter	Correlation coefficient	Parameters	
		Red blood cell count, 10 <sup>12</sup> /L	Hb, g/L
<sup>137</sup> Cs specific activity, Bq/kg	Spearman's	-0.075*	-0.174**
	Sign. (2-tailed), p	0.044	0.0001
	N	721	721

Note. \* – Correlation is significant at the 0.05 level (2-tailed). \*\* – Correlation is significant at the 0.01 level (2-tailed); Hb – haemoglobin.

### Conclusions

1. Among the examined children living in a districts affected by the Chernobyl nuclear power plant accident, cases of normal physical growth made up 66.9%. Cases of abnormal high physical growth were found in 63.95 % in the group of children with abnormal physical growth.

2. No association was found between the physical growth of the children examined and blood total calcium levels. At the same time, an association was observed between the physical growth of the children and blood phosphorus levels.

3. The proportion of cases of hypophosphataemia in the groups of children with normal and abnormal high physical growth was statistically higher than the proportion of cases where blood phosphorus levels were within the reference range.

4. Blood <sup>137</sup>Cs and phosphorus levels were statistically significantly higher in the children with abnormal low physical growth than in the children with normal and abnormal high physical growth.

5. The results of statistical studies confirm inverse associations between <sup>137</sup>Cs and phosphorus values, and physical growth measures.

6. The decrease in body weight in adolescent children living in areas affected by the Chernobyl nuclear power plant accident is associated with the increase in blood <sup>137</sup>Cs and phosphorus concentrations.

7. The findings indicate that <sup>137</sup>Cs radionuclides have a negative effect on the physical growth of a child's body.

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## **ОСОБЛИВОСТІ ПОКАЗНИКІВ СОЦІАЛЬНО-ПСИХОЛОГІЧНОЇ АДАПТАЦІЇ УЧНІВ І СТУДЕНТІВ СУЧАСНИХ ЗАКЛАДІВ ОСВІТИ РІЗНИХ ТИПІВ ЗА РЕЗУЛЬТАТАМИ ТЕСТУ ЛЮШЕРА**

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*Сучасний активний стиль життя та постійне підвищення рівня інтенсивності потоку інформаційного впливу у період навчання та у позанавчальний час суттєво впливає на рівень соціально-психологічної адаптації учнівської та студентської молоді, як певної особливої категорії, що характеризується особливими умовами протікання навчального процесу, специфічними особливостями функціонування молодого ростучого організму.*

*Метою дослідження було визначення особливості показників соціально-психологічної адаптації учнів і студентів сучасних закладів освіти різних типів за результатами тесту Люшера.*

*Організація та методи досліджень. Для визначення особливостей соціально-психологічної адаптації та пов'язаних з нею особистісних рис учнів та студентів, застосовували колірний тест Люшера, адаптованого Собчик.*

*Результати досліджень. Одержані в ході проведених досліджень результати відзначають той факт, що незалежно від особливостей організації навчального процесу*