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РАДИОНУКЛИДЫ ^{137}CS, ФОЛАТНЫЙ ЦИКЛ И ФИЗИЧЕСКОЕ РАЗВИТИЕ ДЕТЕЙ, ПРОЖИВАЮЩИХ ВБЛИЗИ ЧЕРНОБЫЛЬСКОЙ ЗОНЫ ОТЧУЖДЕНИЯ

Бандажевский Ю.И., Дубовая Н.Ф.

^{137}CS RADIONUCLIDES, FOLATE CYCLE AND PHYSICAL DEVELOPMENT OF CHILDREN LIVING NEAR THE CHERNOBYL EXCLUSION ZONE

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Assessment of the physical development of the child's body is an important section of preventive medicine. Especially if it concerns a situation where radiation exposure occurs.

In areas affected by the accident at the Chornobyl nuclear power plant, soils and trees growing on them currently contain significant amounts of ^{137}Cs, ^{90}Sr, ^{241}Am [1].

With locally produced food, forest products, air currents, these long-lived radioactive elements enter the body of local residents. Children especially suffer, since their vital organs incorporate, in comparison with adults, a much larger amount of radionuclides [2].

To prevent the development of these children in the future, serious diseases, it is important to assess their physical development.

In connection with the registration of a large number of cases of hyperhomocysteinemia in a group of children from the Chornobyl regions [3], it is important to determine the role of genes that affect the metabolism of homocysteine (H_{cy}) in the processes of ^{137}Cs incorporation into the body.

In particular, this concerns the MTHFR:C677T genetic polymorphism associated with methylenetetrahydrofolate reductase, the main enzyme of the folate cycle that provides the formation of the active form of vitamin B_9, 5-methyltetrahydrofolate.

The aim of the study was to evaluate the effect of incorporated ^{137}Cs radionuclides on the physical development of boys and girls living near the Chornobyl Exclusion Zone (ChEZ), taking into account the state of the folate

РАДІОНУКЛІДИ ^{137}CS, ФОЛАТНИЙ ЦИКЛ І ФІЗИЧНИЙ РОЗВИТОК ДІТЕЙ, ЩО ПРОЖИВАЮТЬ ПОБЛИЗУ ЧОРНОБИЛЬСЬКОЇ ЗОНИ ВІДЧУЖЕННЯ

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***Мета дослідження:** оцінка впливу інкорпорованих радіонуклідів ^{137}Cs на фізичний розвиток хлопчиків та дівчаток, які мешкають поблизу Чорнобильської зони відчуження, з урахуванням стану фолатного циклу та генетичного поліморфізму MTHFR:C677T.*

***Методи дослідження:** інструментальний, лабораторний, математично-статистичний.*

***Результати.** У рамках міжнародних проєктів проведено оцінку фізичного розвитку дітей за індексом Рорера (IP), визначено рівні та взаємозв'язок інкорпорованого ^{137}Cs, вітамінів B_6, B_9, B_{12}, гомоцистеїну (H_{cy}), алельних варіантів генетичного поліморфізму MTHFR:C677T у 260 дітей віком 13-17 років із Іванківського та Поліського районів Київської області, прилеглих до Чорнобильської зони відчуження. Встановлено, що серед обстежених дітей найбільшу питому вагу становить підгрупа підлітків з гармонійним фізичним розвитком (для хлопчиків – 70,40%, для дівчаток – 65,93%). Показано, що хлопчики та дівчатка з дисгармонійним високим фізичним розвитком (відповідно 15,20% та 25,19%) містили у своєму організмі вірогідно менше радіонуклідів ^{137}Cs порівняно з дітьми із підгруп гармонійного та дисгармонійно низького фізичного розвитку. В аналізованих групах хлопчиків та дівчаток реєструвався зворотний кореляційний зв'язок між питомою активністю ^{137}Cs та значеннями антропометричних показників. Найбільш виражений зворотний зв'язок між питомою активністю ^{137}Cs та значеннями маси, а також довжини тіла та IP, виявлено у підгрупі гармонійно розвинених*

cycle and the MTHFR:C677T genetic polymorphism.

Material and research methods. During the implementation of the projects of the European Commission «Health and Ecological Programs around the Chornobyl Exclusion Zone: Development, training and coordination of health-related projects» and the Rhone-Alpes Regional Council (France) in Ukraine, 260 children (125 boys and 135 girls) aged 13-17 living in the settlements of Ivankivskyi and Polisskyi districts bordering the ChEZ, the soils and trees of which contain significant amounts of long-lived radioactive elements [1].

Blood sampling from the cubital vein was performed in children attending school in the morning on an empty stomach.

The blood samples were tested in a quality-certified laboratory and agreed with the parents.

The determination of H_{cy} in the blood was carried out using the immunochemical method with chemiluminescent detection (ECLIA). Analyzer and test system: Architect 1000 (ABBOT Diagnostics (USA)). The level of homocysteine in the blood of children over 10 μmol/l was defined as a state of hyperhomocysteinemia.

Determination of vitamin B_6 (HPLC) was carried out using the method of high performance liquid chromatography. Analyzer and test system: HPLC-System 1100, Agilent with fluoressence detection; Recipe complete kit (Germany).

Determination of vitamin B_9 – (folacin) was carried out using an immunochemical method with electrochemiluminescent detection (ECLIA). Analyzer and test system: Cobas e411; Roche Diagnostics (Switzerland). The laboratory has set a reference interval for vitamin B_9 in the range of 4.6-18.7 ng/mL.

Determination of vitamin B_{12} – holotranscobalamin (active vitamin B_{12}) was carried out using an immunochemical method with chemiluminescent detection (CLIA). Analyzer and test system: Architect 1000 (Abbott Diagnostics), USA.

The reference interval of extreme values for vitamin B_6 in the blood, indicated by the laboratory in which the analysis was carried out, was 8.7-27.2 μg/l, for folic acid (vitamin B_9) – 4.6-18.7 ng/ml, for vitamin B_{12} – 191.0-663.0 pg/ml.

Allelic variants of the MTHFR:C677T genetic polymorphism were determined using the Real-time PCR method. Analyzer and test system DT-96 detecting cycler; «DNA-Technology» (Russia).

Determination of ^{137}Cs radionuclides in the body was carried out using a three-detector counter of human gamma radiation (HGR), manufactured by AtomComplexPribor (Ukraine).

To measure the weight and length of the body of the examined children, unified anthropometric methods were used [4], in compliance with the rules of bioethics and the signing of protocols of informed consent of the parents for each subject.

To assess the physical development (PD) of the examined children, the results of measuring the mass and length of their body were used, with the calculation of the mass-height Rohrer index (IR) – a quotient from dividing body weight in kilograms by body length in meters, cubed. The value of IR allows assessing the degree of correspondence between a person's mass and his height, and therefore, is a criterion for assessing the state of PD and metabolism.

It is generally accepted to consider harmonious PD, with an IR value from 10.7 kg/m^3 to 13.7 kg/m^3, disharmonious low PD with an IR value of less than 10.7 kg/m^3, disharmonious high PD with an IR value of more than 13.7 kg/m^3 [5, 6].

During the statistical analysis of the research results,

дівчаток. Підгрупа гармонійно розвинених хлопчиків відрізнялася від підгрупи гармонійно розвинених дівчаток вищою питомою активністю ^{137}Cs в організмі та вищим рівнем H_{cy} у крові. Зниження рівня H_{cy} у крові гармонійно розвинених дівчаток, порівняно з гармонійно розвиненими хлопчиками, може бути пов'язане з вищим рівнем вітаміну B_{12} у крові, а також з більш інтенсивним функціонуванням циклу транссульфурації.

Порівняльний аналіз показав, що у підгрупі дівчаток з надмірною масою тіла питома вага випадків носійства генотипів, складених з нейтральних алелів C/C поліморфізму MTHFR:677, є більшою, ніж у підгрупі гармонійно розвинених дівчаток. При цьому зареєстровано меншу питому активність ^{137}Cs в їхньому організмі.

***Висновок:** інкорпоровані радіонукліди ^{137}Cs викликають зменшення маси тіла у дітей, які мешкають на території, що постраждала від аварії на Чорнобильській атомній електростанції. При цьому відбувається порушення обміну речовин у вигляді збільшення вмісту у крові H_{cy}, яке більш виражене у хлопчиків. Процес інкорпорації радіонуклідів ^{137}Cs в організм дітей, можливо, пов'язаний з алелею T поліморфізму MTHFR:C677, що впливає на активність метилентетрагідрофолатредуктази.*

Ключові слова: цезій-137, фізичний розвиток, гомоцистеїн, фолатний цикл, підлітки, Чорнобильська зона відчуження.

groups of boys and girls were identified. Children with IR <10.7 made up the 1-st subgroup, with IR 10.7-13.7 – the 2-nd subgroup, with IR >13.7 – the 3-rd subgroup.

Statistical processing of the obtained results was carried out using the IBM SPSS Statistics 22 program (USA). For the analyzed indicators, the arithmetic mean (M), standard error of the mean (m), confidence interval of the mean value (95% CI), median (Me), interquartile range (IQR), minimum and maximum values of the parameters, percentiles were calculated.

The hypothesis about the type of distributions was tested (Kolmogorov-Smirnov criterion). All the studied parameters did not correspond to the normal distribution law, and therefore, the non-parametric Mann-Whitney U-test was used to compare the values. The statistical significance of the indicators was assessed by determining the significance level p using a statistical program.

Student's t-test was used to compare relative scores. The critical confidence level of the null hypothesis (p) was taken as 0.05.

The relationship between the analyzed indicators was determined using the Spearman rank correlation coefficient (r^{xy}). The strength of the correlation was assessed according to the traditional scale: weak – from 0 to 0.299; medium – from 0.3 to 0.699; strong – from 0.7 to 1.0.

Results and its discussion. The results of anthropometric studies indicate that the majority of boys and girls had a harmonious physical development (IR values in the range of 10.7-13.7). There were significantly fewer children with IR >13.7 and IR <10.7 (table 1).

In the 3-rd subgroup, the relative number of boys was statistically less, and more girls, compared with the 1-st subgroup. In the 3-rd subgroup, the number of girls was significantly higher than boys (table 2).

There were no age differences between the subgroups of boys and girls. Also there were no differences in age between the same-named subgroups of boys and girls (tables 3, 4).

In the group of boys in the 1-st and 2-nd subgroups, the specific activity of ^{137}Cs in the body of children was significantly more, and the body weight was less than in the 3-rd subgroup (tables 3, 5).

In the group of girls, the specific activity of ^{137}Cs in the body of children of the 1-st subgroup was significantly

Table 1

Distribution of boys and girls according to the index of physical development

Groups	N	Subgroups					
		«1» – IR –<10.7		«2» – IR – 10.7-13.7		«3» – IR >13.7	
		Abs.	%	Abs.	%	Abs.	%
Boys	125	18	14.40	88	70.40	19	15.20
Girls	135	12	8.89	89	65.93	34	25.19
Both sexes	260	30	11.54	177	68.08	53	20.38

Table 2

Distribution of boys and girls in subgroups with different index of physical development

Groups	Subgroups					
	«1» – IR <10.7		«2» – IR – 10.7-13.7		«3» – IR >13.7	
	Abs.	%	Abs.	%	Abs.	%
Boys	18	60.002	88	49.72	19	35.85
Girls	12	40.003	89	50.28	34	64.151

Notes: 1 – statistical differences between the subgroups of boys and girls in the 3-rd subgroup: t = 3.04. p = 0.003795;
2 – statistical differences between the 1-st and 3-rd subgroups among boys: t = 2.17; p = 0.036726.
3 – statistical differences between the 1-st and 3-rd subgroups among girls: t = 2.17; p = 0.035222.

Table 3

Statistical characteristics of the specific activity of ^{137}Cs, body length and weight, vitamins B_6, B_9, B_{12} and H_{cy} in the blood of examined boys from Ivankivskyi and Polisskyi districts in groups with different levels of IR

Parameters	1-st subgroup IR <10.7 (n = 18)		2-nd subgroup IR = 10.7-13.7 (n = 88)		3-rd subgroup IR >13.7 (n = 19)	
	Me	IQR	Me	IQR	Me	IQR
Age, years	14.58	14.04-15.33	15.01	14.04-16.05	14.07	13.10-16.01
Length body, cm	169.50	156.75-172.75	162.50	154.0-171.00	163.00	160.00-170.00
Weight body, kg	48.50	38.75-51.25	51.00	42.00-58.50	68.00	60.00-74.00
^{137}Cs, Bq/kg	1.86	1.57-4.23	1.76	1.57-5.92	1.47	1.28-1.54
B_6, µg/l	20.20	14.40-24.35	19.50	16.25-24.00	19.50	14.90-23.50
B_9, ng/ml	6.24	5.46-8.22	6.52	4.60-7.86	6.02	4.55-7.08
B_{12}, pg/ml	282.80	232.58-389.73	296.45	234.53-373.50	306.60	236.60-358.00
H_{cy}, µmol/l	12.76	10.05-17.47	12.53	11.02-15.41	12.96	11.31-18.39
IR	10.10	9.75-10.43	11.80	11.30-12.30	15.00	14.30-16.80

^{137}CS RADIONUCLIDES, FOLATE CYCLE AND PHYSICAL DEVELOPMENT OF CHILDREN LIVING NEAR THE CHORNOBYL EXCLUSION ZONE

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The purpose of the study: *to assess the impact of incorporated ^{137}Cs radionuclides on the physical development of boys and girls living near the Chornobyl Exclusion Zone, taking into account the state of the folate cycle and the MTHFR:C677T genetic polymorphism.*
Research methods: *instrumental, laboratory, mathematical and statistical.*
Results: *Within the framework of international projects, an assessment of physical development was carried out according to the Rohrer index (IR), the levels and relationship of incorporated ^{137}Cs, vitamins B_6, B_9, B_{12}, homocysteine (H_{cy}), allelic variants of the MTHFR:C677T genetic polymorphism were determined in 260 children aged 13-17 years old from Ivankivskyi and Polisskyi districts of the Kyiv region, bordering the Chornobyl Exclusion Zone.*
It has been established that among the surveyed, the more proportion is the subgroup of adolescents with harmonious physical development (respectively, for boys – 70.40%, for girls – 65.93%). It was shown that boys and girls with disharmonious high physical development (respectively 15.20% and 25.19%) contained significantly less ^{137}Cs radionuclides in their bodies, compared with children from the subgroups of harmonious and disharmonious low physical development.
In the analyzed groups of boys and girls, an inverse correlation was recorded between the specific activity of ^{137}Cs and the values of anthropometric indicators. The most pronounced inverse relationship between the specific activity of ^{137}Cs and the values of mass, as well as body length and IR, was found in the subgroup of harmoniously developed girls.
The subgroup of harmoniously developed boys differed from the subgroup of harmoniously developed girls by a higher specific activity of ^{137}Cs in the body and a higher level of H_{cy} in the blood. The decrease in the level of H_{cy} in the blood of harmoniously developed girls, compared with harmoniously developed boys, may be associated with a higher level of vitamin B_{12} in the blood, as well as with a more intense functioning of the trans-sulfurization cycle.
Comparative analysis showed that in the subgroup of girls with overweight, the proportion of cases of carriage of genotypes composed of neutral alleles of the C/C polymorphism MTHFR:677 is greater than in the subgroup of harmoniously developed girls. At the same time, a lower specific activity of ^{137}Cs in their body was registered.
It is concluded that incorporated ^{137}Cs radionuclides cause a decrease in body weight in children living in the area affected by the accident at the Chornobyl nuclear power plant. At the same time, there is a metabolic disorder, in the form of an increase in the content of H_{cy} in the blood, more pronounced in boys. The process of incorporation of ^{137}Cs radionuclides into the body of children may be associated with the T allele of the MTHFR:C677 polymorphism, which affects the activity of methylenetetrahydrofolate reductase.

Keywords: cesium-137, physical development, homocysteine, folate cycle, adolescents, Chornobyl Exclusion Zone.

Table 4

Statistical characteristics of the specific activity of ^{137}Cs, body length and weight, vitamins B_6, B_9, B_{12} and H_{cy} in the blood of examined girls from Ivankivskyi and Polisskyi districts in groups with different levels of IR

Parameters	1-st subgroup IR <10.7 (n = 12)		2-nd subgroup IR = 10.7-13.7 (n = 89)		3-rd subgroup IR >13.7 (n = 34)	
	Me	IQR	Me	IQR	Me	IQR
Age, years	14.58	14.07-15.11	14.10	13.56-16.03	15.08	14.08-16.04
Length body, cm	158.00	156.50-164.75	159.00	155.00-162.00	158.50	152.00-163.25
Weight body, kg	42.50	37.00-43.75	49.00	45.50-53.00	57.50	52.75-62.25
^{137}Cs, Bq/kg	1.83	1.75-1.97	1.65	1.57-1.82	1.54	1.46-1.65
B_6, µg/l	21.15	19.15-28.55	18.20	15.35-21.85	20.00	15.65-23.20
B_9, ng/ml	5.50	4.80-7.64	6.33	5.11-7.75	5.47	4.69-6.84
B_{12}, pg/ml	341.70	272.20-424.88	338.90	269.10-463.40	379.25	284.65-492.80
H_{cy}, µmol/l	11.49	9.77-15.93	10.76	9.27-12.48	11.94	10.26-13.19
IR	10.25	9.43-10.58	12.20	11.20-13.20	14.50	14.20-15.25

more, and body weight, less than in the 2-nd subgroup. At the same time, the blood of children from the 1-st group contained more vitamin B_6 in the blood of tables 4, 5).

In the group of girls in the 3-rd subgroup, the specific activity of ^{137}Cs in the body of children was significantly less, and body weight, more than in the 1-st and 2-nd subgroups (tables 4, 5).

When comparing the analyzed indicators of boys and girls who made up the 1-st subgroup, no statistical differences were found.

The values of the specific activity of ^{137}Cs in the body, body length, Hcy content in the blood, in the 2-nd subgroup of boys were significantly more, and the values of IR and vitamin B_{12} content were less than in the same subgroup of girls (tables 3-5).

The weight and body length of boys from the 3-rd subgroup were more, and the content of vitamin B_{12} in the blood was less than that of girls from the same subgroup (tables 3-5).

Between the values of the specific activity of ^{137}Cs in the body of children and anthropometric indicators in the groups of boys and girls, an inverse correlation was recorded, most pronounced in subgroups with an IR of 10.7-13.7.

At the same time, in the subgroup of girls, in contrast to the subgroup of boys, this relationship was represented not only by the values of body weight and length, but also by the values of IR (tables 6, 7).

In the subgroup of boys with IR 10.7-13.7, the inverse correlation between Hcy and vitamins B_9, B_{12} was more pronounced than in the same-named subgroup of girls. The same applies to the direct relationship between vitamins B_9 and B_{12} (tables 8, 9). However, in the subgroup of girls there was an inverse relationship between vitamins B_6 and B_{12} (table 9).

In the subgroup of girls with IR 10.7-13.7, the proportion of cases with the T allele of the MTHFR:677 polymorphism was statistically more, and the proportion of cases with the C/C genotype of the same polymorphism, respectively, was lower, compared with the subgroup of girls with IR >13.7 (tables 10, 11).

The conducted studies testify to the negative impact of incorporated ^{137}Cs radionuclides on the physical development of children living near the ChEZ.

This is based on the penetration of ^{137}Cs into the cells

Table 5

Statistically significant differences when comparing the analyzed indicators in subgroups of boys and girls with different levels of physical development

Subgroups comparisons	Parameter	Groups comparisons	Number of cases	Average rank	Mann-Whitney U test value, significance level, p
1	^{137}Cs	B[1]	18	25.50	U = 54.00; p = 0.0001
3		B	19	12.84	
1	Weight body	B	18	10.72	U = 22.00; p = 0.0001
3		B	19	26.84	
2	^{137}Cs	B	88	60.19	U = 291.00; p = 0.0001
3		B	19	25.32	
2	Weight body	B	88	47.53	U =266.50; p = 0.0001
3		B	19	83.97	
1	^{137}Cs	G[2]	12	70.67	U = 298.00; p = 0.013
2		G	89	48.35	
1	Weight body	G	12	25.04	U = 222.50; p = 0.001
2		G	89	54.50	
1	B_6	G	12	69.00	U =318.00; p = 0.023
2		G	89	48.57	
1	^{137}Cs	G	12	34.25	U= 75.00; p = 0.001
3		G	34	19.71	
1	Weight body	G	12	7.83	U= 16.00; p = 0.0001
3		G	34	29.03	
2	^{137}Cs	G	89	69.10	U = 881.00; p = 0.0001
3		G	34	43.41	
2	Weight body	G	89	51.79	U = 604.00; p = 0.0001.
3		G	34	88.74	
2	^{137}Cs	B	88	98.18	U = 3108.00; p = 0.018
2		G	89	79.92	
2	Length body	B	88	99.14	U = 3023.50; p = 0.009
2		G	89	78.97	
2	IR	B	88	81.26	U = 3234.50; p= 0.045
2		G	89	96.66	
2	H_{cy}	B	88	107.56	U = 2282.50; p = 0.0001
2		G	89	70.65	
2	B_{12}	B	88	78.18	U = 2963.50; p = 0.005
2		G	89	99.70	
3	Weight body	B	19	35.89	U = 154.00; p = 0.002
3		G	34	22.03	
3	Length body	B	19	34.50	U = 180.50; p = 0.008
3		G	34	22.81	
3	B_{12}	B	19	20.37	U = 197.00; p = 0.019
3		G	34	30.71	

Note: 1 – boys, 2 – girls.

of internal organs and skeletal muscles [2] and disruption of the energy supply of synthetic processes [7].

Statistical differences were revealed between subgroups of children with different levels of PD and the content of ^{137}Cs radionuclides in their bodies. The more radionuclides in the body, the less the body weight of the child. This was most pronounced in the group of girls.

Correlation analysis confirmed the statistical data, revealing inverse relationships between the values of the specific activity of ^{137}Cs in the body of children and their body weight.

Subgroups of children with harmonious PD made it possible to determine statistical differences between boys and girls. Harmoniously developed boys had a higher specific activity of ^{137}Cs in the body compared to harmoniously developed girls. At the same time, they recorded lower IR values due to higher values of body length.

Higher levels of ^{137}Cs in the body of boys, compared with girls, were accompanied by higher levels of the sulfur-containing amino acid H_{cy} in the blood. One of the reasons for this phenomenon could be a lower concentration of vitamin B_{12} in the blood of boys.

In the general group of examined children (n = 260), the proportion of cases of hyperhomocysteinemia (H_{cy} >10 μmol/l) is significantly more than the proportion of cases of vitamins B_9 and B_{12} deficiency according to their reference values (table 12).

Thus, in children living under conditions of constant radiation exposure, there is a functional deficiency of vitamins B_9 and B_{12} [8], as evidenced also by the inverse correlations H_{cy}-B_9 and H_{cy}-B_{12}, which are more pronounced in the subgroup of boys.

Table 6

Correlations between anthropometric parameters and ^{137}Cs specific activity in the subgroup of boys with IR 10.7-13.7

Parameter	Correlation coefficient	Parameter			
		Length body	Weight body	IR	^{137}Cs
Length body	Spearman's	1.000	0.961**	0.110	- 0.276**
	Sign. (two-sided), p	.	0.000	0.308	0.009
	N	88	88	88	88
Weight body	Spearman's	0.961**	1.000	0.347**	- 0.302**
	Sign. (two-sided), p	0.000	.	0.001	0.004
	N	88	88	88	88
IR	Spearman's	0.110	0.347**	1.000	- 0.168
	Sign. (two-sided), p	0.308	0.001	.	0.117
	N	88	88	88	88
^{137}Cs	Spearman's	- 0.276**	- 0.302**	- 0.168	1.000
	Sign. (two-sided), p	0.009	0.004	0.117	.
	N	88	88	88	88

Table 7

Correlations between anthropometric parameters and ^{137}Cs specific activity in the subgroup of girls with IR 10.7-13.7

Parameter	Correlation coefficient	Parameter			
		Length body	Weight body	IR	^{137}Cs
Length body	Spearman's	1.000	0.742**	0.019	- 0.478**
	Sign. (two-sided), p	.	0.000	0.861	0.000
	N	89	89	89	89
Weight body	Spearman's	0.742**	1.000	0.620**	- 0.689**
	Sign. (two-sided), p	0.000	.	0.000	0.000
	N	89	89	89	89
IR	Spearman's	0.019	0.620**	1.000	- 0.467**
	Sign. (two-sided), p	0.861	0.000	.	0.000
	N	89	89	89	89
^{137}Cs	Spearman's	- 0.478**	- 0.689**	- 0.467**	1.000
	Sign. (two-sided), p	0.000	0.000	0.000	.
	N	89	89	89	89

Table 8

Correlations between H_{cy} and vitamins B_6, B_9, B_{12} in the subgroup of boys with IR 10.7-13.7

Parameter	Correlation coefficient	Parameter			
		H_{cy}	B_6	B_9	B_{12}
H_{cy}	Spearman's	1.000	- 0.031	- 0.542**	- 0.418**
	Sign. (two-sided), p	.	0.773	0.000	0.000
	N	88	88	88	88
B_6	Spearman's	- 0.031	1.000	0.159	- 0.005
	Sign. (two-sided), p	0.773	.	0.138	0.964
	N	88	88	88	88
B_9	Spearman's	- 0.542**	0.159	1.000	0.352**
	Sign. (two-sided), p	0.000	0.138	.	0.001
	N	88	88	88	88
B_{12}	Spearman's	- 0.418**	- 0.005	0.352**	1.000
	Sign. (two-sided), p	0.000	0.964	0.001	.
	N	88	88	88	88

Note (tabl. 6-9):
** – correlation is significant at the 0.05 level (2-tailed).*
*** – correlation is significant at the 0.01 level (2-tailed).*

The inverse correlation between the values of vitamins B_{12} and B_6 in the group of harmoniously developed girls indicates the utilization of H_{cy} in trans-sulfurization reactions, as a result of which its concentration in the blood is lower than in harmoniously developed boys.

In the subgroup of overweight girls, the proportion of cases of carriage of genotypes composed of neutral C/C alleles is greater, and the proportion of cases of carriage of genotypes with the T allele is less than in the subgroup of harmoniously developed girls.

Given that the specific activity of ^{137}Cs in the body of overweight children is less than in the body of harmoniously developed children, it can be assumed that the process of incorporation of ^{137}Cs radionuclides into the body is associated with the risk allele T of the MTHFR: C677T genetic polymorphism. Children with the C/C genotype have great opportunities in the formation of the active form of vitamin B_9 - 5 methyltetrahydrofolate, which promotes synthetic processes in the body.

Table 9

Correlations between H_{cy} and vitamins B_6, B_9, B_{12} in the subgroup of girls with IR 10.7-13.7

Parameter	Correlation coefficient	Parameter			
		H_{cy}	B_6	B_9	B_{12}
H_{cy}	Spearman's	1.000	0.133	- 0.407**	- 0.233*
	Sign. (two-sided), p	.	0.214	0.000	0.028
	N	89	89	89	89
B_6	Spearman's	0.133	1.000	- 0.042	- 0.215*
	Sign. (two-sided), p	0.214	.	0.696	0.043
	N	89	89	89	89
B_9	Spearman's	- 0.407**	- 0.042	1.000	0.211*
	Sign. (two-sided), p	0.000	0.696	.	0.047
	N	89	89	89	89
B_{12}	Spearman's	- 0.233*	- 0.215*	0.211*	1.000
	Sign. (two-sided), p	0.028	0.043	0.047	.
	N	89	89	89	89

Table 10

The proportion of MTHFR:C677T genotypes in subgroups of girls with different IR

Genotypes MTHFR: C677T	Subgroups					
	«1» – IR <10.7		«2» – IR – 10.7-13.7		«3» – IR >13.7	
	Abs.	%	Abs.	%	Abs.	%
T/T	2	16.67	11	12.36	5	14.71
C/T	4	33.33	45	45.56	8	23.53
T/T+C/T	6	50.00	56	62.92	13	38.24
C/C	6	50.00	33	37.08	21	61.76

Table 11

Statistical comparisons of the proportion of MTHFR:C677T genotypes in subgroups of girls with different IR

Comparison subgroups	Genotypes MTHFR:C677T	Student's t-test	Level significance, p
2 - 3	T/T+C/T	2.52	0.014013
	T/T+C/T		
2 - 3	C/C	2.52	0.014755
	C/C		

Table 12

The proportion of cases of H_{cy}, vitamins B_6, B_9, B_{12} levels in the blood that go beyond the reference values in the general group of children (n = 260)

Number of cases							
H_{cy} >10µmol/l		B_6 >27.2 µg/l		B_9 <4.6 ng/ml		B_{12} <191.0 pg/ml	
Abs. number	%	Abs. number	%	Abs. number	%	Abs. number	%
197	75.77	31	11.90	54	20.77	13	5.00

Given that the specific activity of ^{137}Cs in the body of overweight children is less than in the body of harmoniously developed children, it can be assumed that the process of incorporation of ^{137}Cs radionuclides into the body is associated with the risk allele T of the MTHFR: C677T genetic polymorphism. Children with the C/C genotype have great opportunities in the formation of the active form of vitamin B_9 - 5 methyltetrahydrofolate, which promotes synthetic processes in the body.

Conclusions

In the surveyed groups of boys and girls, aged 13-17 years old, from areas bordering the Chornobyl exclusion zone, the more number of cases fell on the subgroup of harmonious physical development – 70.40 and 65.93%, respectively.

Boys and girls with disharmonious high physical development (15.20 and 25.19%, respectively) contained significantly less ^{137}Cs radionuclides in their bodies, compared with children from subgroups of harmonious and disharmonious low physical development.

In the analyzed groups of boys and girls, an inverse correlation was recorded between the specific activity of ^{137}Cs and the values of anthropometric indicators.

The most pronounced inverse relationship between the specific activity of ^{137}Cs and the values of weight, as well as body length and IR, was in the subgroup of harmoniously developed girls.

The subgroup of harmoniously developed boys differed from the subgroup of harmoniously developed girls by a higher specific activity of ^{137}Cs in the body and a higher

level of Hcy in the blood.

The decrease in the level of Hcy in the blood of harmoniously developed girls, compared with harmoniously developed boys, may be associated with a higher level of vitamin B_{12} in the blood, as well as with a more intense functioning of the trans-sulfurization cycle.

In the subgroup of overweight girls, the proportion of cases of carriage of genotypes composed of neutral alleles of the C/C polymorphism MTHFR:677 is greater than in the subgroup of harmoniously developed girls. At the same time, the specific activity of ^{137}Cs in their body is less.

Incorporated ^{137}Cs radionuclides cause a decrease in body weight in children living in the area affected by the accident at the Chornobyl nuclear power plant. At the same time, there is a metabolic disorder, in the form of an increase in the content of Hcy in the blood, more pronounced in boys.

The process of incorporation of ^{137}Cs radionuclides into the body of children may be associated with the T allele of the MTHFR:C677 polymorphism, which affects the activity of methylenetetrahydrofolate reductase.

ЛІТЕРАТУРА

1. Bandazhevskyi Yu.I., Dubova N.F. Forest fires in the Chornobyl exclusion zone and children's health. Ivankiv PI Coordination and Analytical Center «Ecology and Health». Kyiv : Aliant LLC, 2021. 44 p.

2. Bandazhevskyi Yu.I. Chronic Cs-137 incorporation in children's organs. Swiss Medical Weekly. 2003. Vol. 133. P. 488-490.

3. Bandazhevskyi Yu.I., Dubova N.F. Chornobyl catastrophe and childrens health. 35 years of world tragedy. Ivankiv PI Coordination and Analytical Center «Ecology and Health». Kyiv : Alyant LLC, 2022. 158 p.

4. Івахно О.П, Козярін І.П., Нємцева Ю.В. Методи оцінки фізичного розвитку і здоров'я дитячого населення : Навчальний посібник. К., 2012. 129 с.

5. Стандарти для оцінки фізичного розвитку школярів (випуск 3). За заг. ред. Сердюка А.М. К. : Казка, 2010. 60 с.

6. Кашкевич Е.И. Экологические особенности физического развития детей и подростков Красноярского края: монография. Красноярск, 2013. 188 с.

7. Бандажевский Ю.И., Дубовая Н.Ф., Бандажевская Г.С. и др. Чернобыль 25 лет: инкорпорированные радионуклиды Cs-137 и здоровье людей. Под ред. Ю.И. Бандажевского ; Координационный аналитический центр «Экология и здоровье». К., 2011. 156 с.

8. Бандажевский Ю.И., Дубовая Н.Ф. Гипергомоцистеинемия и B_{12}-фолиевый дефицит у детей, проживающих на территории, загрязненной радионуклидами в результате аварии на Чернобыльской атомной электростанции. *Педиатрия. Восточная Европа.* 2017. Т. 5. № 1. С. 25-32.

REFERENCES

1. Bandazhevskyi Yu.I. and Dubova N.F. Forest Fires in the Chornobyl Exclusion Zone and Children's Health. Ivankiv : PI Coordination and Analytical Center «Ecology and Health». Kyiv : Aliant LLC ; 2021 : 44 p.

2. Bandazhevskyi Yu.I. Chronic Cs-137 Incorporation in Children's Organs. Swiss Medical Weekly. 2003 ; 133 : 488-490.

3. Bandazhevskyi Yu.I. and Dubova N.F. Chornobyl Catastrophe and Children's Health. 35 Years of World Tragedy. Ivankiv PI Coordination and Analytical Center «Ecology and Health». Kyiv : Alyant LLC ; 2022 : 158 p.

4. Ivakhno O.P., Koziarin I.P. and Niemtseva Yu.V. Metody otsinky fizychnoho rozvytku i zdorovia dytiachoho naselennia : Navchalnyi posibnyk [Methods of Assessing the Physical Development and Health of the Children's Population: Study Guide]. Kyiv ; 2012 : 129 p. (in Ukrainian).

5. Serdiuk A.M. (ed.) Standarty dlia otsinky fizychnoho rozvytku shkoliariv (Vyp. 3) [Standards for Assessing the Physical Development of Schoolchildren (Issue 3)]. Kyiv : Kazka ; 2010 : 60 p. (in Ukrainian).

6. Kashkevich E.I. Ekologicheskiye osobennosti fizicheskogo razvitiya detey i podrostkov Krasnoyarskogo kraya: monografiya [Ecological Features of the Physical Development of Children and Adolescents in the Krasnoyarsk Territory: Monograph]. Krasnoyarsk, RF ; 2013 : 188 p. (in Russian).

7. Bandazhevskyi Yu.I., Dubovaya N.F., Bandazhevskaya G.S. et al. Chernobyl 25 let: inkorporirovannye radionuklidy Cs-137 i zdorove lyudei. Koordinatsionnyi analiticheskiy tsentr «Ekologiya i zdorove» [Chernobyl 25 Years: Incorporated Cs-137 Radionuclides and Human Health. Coordinating Center «Ecology and Health»]. Kiev ; 2011 : 156 p. (in Russian).

8. Bandazhevskyi Yu.I. and Dubovaya N.F. Gipergomotsisteinemiya i B_{12}-folievyi defitsit u detey, prozhivayushchikh na territorii, zagryaznennoy v rezultate avarii na Chernobylskoy atomnoy elektrostantsii [Hyperhomocysteinemia and B_{12}-Folic Deficiency Among Children Who Live on the Territory Contaminated with Radionuclides as a Result of the Accident at the Chernobyl Nuclear Power Plant]. *Pediatria. Vostochnaya Evropa*. 2017 ; 5 (1) : 25-32 (in Russian).

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