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It contains information on the protection of the health of people living in the territories affected by the Chernobyl nuclear power plant. The collection is intended for health professionals and the population living in radioactive contaminated territories after accident at a nuclear power plant.

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AGE-SPECIFIC FEATURES OF ^{137}CS CONCENTRATIONS IN CHILDREN FROM IVANKOVSKY AND POLESSKY DISTRICTS IN KIEV REGION, UKRAINE, 30 YEARS AFTER THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Bandazhevsky Yu.I., Dubova N.F., Kadun O.N.

30 years after the accident at the Chernobyl nuclear power plant, soils of affected areas have remained contaminated with radioactive substances [1, 2]. This poses a danger to health of the population consuming locally produced farm products, forest berries, mushrooms and meat of wild animals [3, 4]. In this regard, an important element of preventive medicine is monitoring of levels of radioactive agents in the population of different age groups living in conditions of constant radiation risk in areas affected by the Chernobyl nuclear power plant accident. This will certainly help to establish cause-effect mechanisms of diseases prevailing in areas contaminated with radioactive substances.

The aim of this study was to measure ^{137}Cs levels in children of different ages living in Ivankovsky and Polessky districts, Kiev region, Ukraine, 30 years after the Chernobyl nuclear power plant accident.

Material and methods. The study was carried out within a project of the European Commission in Ukraine "Health and ecological programmes around the Chernobyl Exclusion Zone: Development, training and coordination of health-related projects" in 2013-2017.

^{137}Cs radionuclides were measured in 3752 children living in Ivankovsky and Polessky districts, Kiev region, located near the Chernobyl nuclear power plant (having the ^{137}Cs soil contamination density of 0.17 up to 1.9 Cu/km^2 [5]).

^{137}Cs specific activity was measured in the children using a SICH-AKP-3 three-detector spectrometer (OOO NPP ATOMKOMPLEKSPRIBOR, Ukraine), during 10 minuties, with the written consent of the parents.

Spectra were processed automatically, specific activities of radioactive elements were calculated and the information obtained was saved with the help of the AKWin software.

The children examined were divided into three groups according to their age at the time of examination: younger (group 1) – 2.0-5.11 years (n = 323), middle (group 2) – 6.0 -11.11 years (n = 1888), older (group 3) – 12.0-18.0 years (n = 1541).

During the study, we aimed to identify an association between ^{137}Cs incorporation and age of children using methods of statistical and correlation analyses.

The statistical processing of the results obtained was performed using the IBM SPSS Statistics 22 software (USA). The arithmetic mean (M) ± 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 ^{137}Cs specific activity and age of children were identified with the help of the Spearman's rank correlation coefficient (r_{xy}). The strength of correlation 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. In the total group of children (n = 3752), the average value of ^{137}Cs specific activity was 3.48 Bq/kg, the median was 2.12; and the interquartile range was 1.66-2.62. ^{137}Cs specific activity was statistically significantly higher in the children of the younger group than in those from the middle and older groups. In its turn, ^{137}Cs specific activity was higher in the children of the middle group than in those of the older group (Tables 1, 2).

Table 1

Statistical characteristics of ^{137}Cs specific activity (Bq/kg) in children examined by age groups

Variables	Younger group		Middle group		Older group	
	Me	IR	Me	IR	Me	IR
^{137}Cs specific activity, Bq/kg	3.00	2.79-3.31	2.41	2.06-2.62	1.63	1.51–1.85

Table 2

Results of statistically significant differences in ^{137}Cs specific activity in groups of children

Variables	Comparison groups	Comparison group size	Average rank	Mann–Whitney U test value, significance level, p
^{137}Cs specific activity, Bq/kg	1	323	1834.23	U = 69693.0; p = 0.0001
	2	1888	981.41	
	1	323	1521.07	U = 58765.0; p = 0.0001
	3	1541	809.13	
	2	1888	2220.05	U = 501170.0; p = 0.0001
	3	1541	1096.22	

An inverse association was observed between ^{137}Cs specific activity in the children and their age both in the total group and in separate age groups. At the same time, the strength of the association was minimal in the older group (Table 3).

Thus, during the studies, the age factor in ^{137}Cs incorporation in the children living in the districts located near the Chernobyl nuclear power plant was identified. The smaller the child the higher concentration of ^{137}Cs radionuclides was detected in the body (Fig.).

The findings show that there is a necessity to study in a detailed manner causes of ^{137}Cs incorporation in the population living in areas affected by the Chernobyl nuclear power plant accident.

Table 3

Results of correlation analysis between age and ^{137}Cs specific activity in children examined

Groups of children	Correlation coefficient	Parameters	
		Age, years	^{137}Cs specific activity, Bq/kg
Total group	Spearman's, r_{xy}	-0.658**	
	Sign. (2-tailed), p	0.0001	
	N	3752	
Younger group	Spearman's, r_{xy}	-0.472**	
	Sign. (2-tailed), p	0.0001	
	N	323	
Middle group	Spearman's, r_{xy}	-0.576**	
	Sign. (2-tailed), p	0.0001	
	N	1888	
Older group	Spearman's, r_{xy}	-0.241**	
	Sign. (2-tailed), p	0.0001	
	N	1541	

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

Thus, during the studies, the age factor in ^{137}Cs incorporation in the children living in the raions located near the Chernobyl nuclear power plant was identified. The smaller the child the higher concentration of ^{137}Cs radionuclides was detected in the body (Fig.).

The findings show that there is a necessity to study in a detailed manner causes of ^{137}Cs incorporation in the population living in areas affected by the Chernobyl nuclear power plant accident.

At the same time, it is necessary to pay attention to the fact that radionuclides can enter the human body through ingestion, take into account the anatomical and physiological features of children of different ages and determine the role of a genetic component.

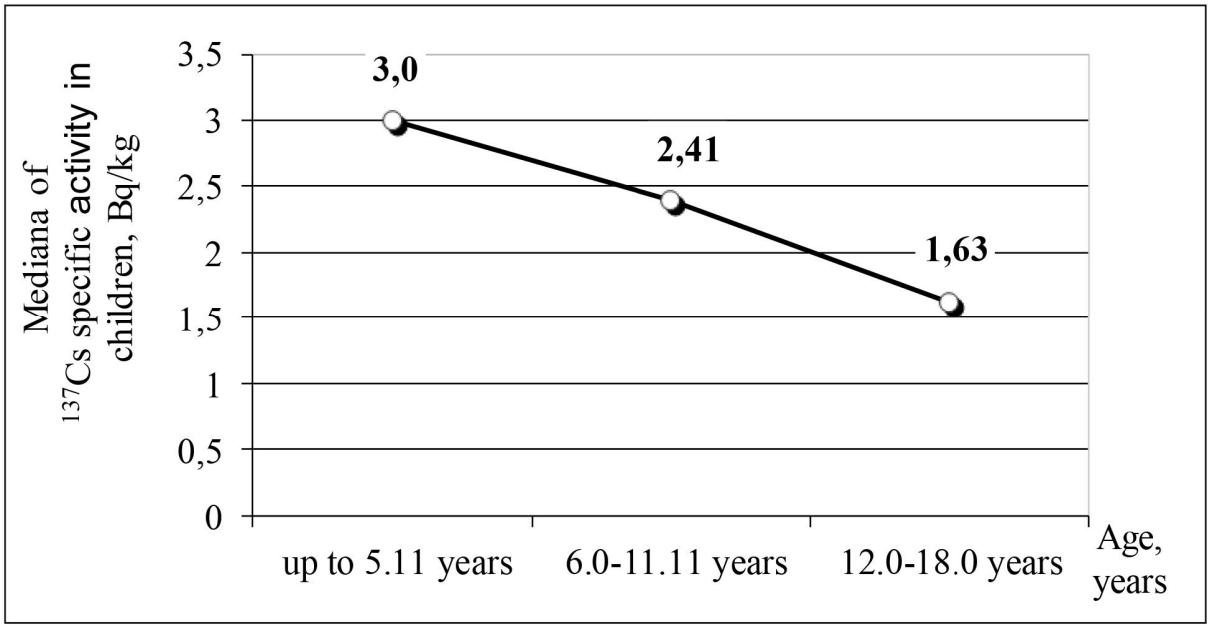

Figure. Age dependence of ^{137}Cs specific activity in a group of children from Ivankovsky and Polessky districts, Kiev region, Ukraine.

Conclusions. 1. We have identified an association between ^{137}Cs incorporation and age of children living in Ivankovsky and Polessky districts, Kiev region, 30 years after the Chernobyl nuclear power plant accident.

2. Children of primary school age are exposed to more radiation compared to those of older school age.

3. When identifying causes of ^{137}Cs incorporation in the population living in areas affected by the Chernobyl nuclear power plant accident, it is necessary to pay attention to the fact that radionuclides can enter the human body through ingestion, take into account the anatomical and physiological characteristics of children of different ages and determine the role of a genetic component.

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ВОЗРАСТНЫЕ ОСОБЕННОСТИ СОДЕРЖАНИЯ РАДИОНУКЛИДОВ ^{137}CS В ОРГАНИЗМЕ ДЕТЕЙ ИВАНКОВСКОГО И ПОЛЕССКОГО РАЙОНОВ КИЕВСКОЙ ОБЛАСТИ УКРАИНЫ СПУСТЯ 30 ЛЕТПОСЛЕ АВАРИИ НА ЧЕРНОБЫЛЬСКОЙ АТОМНОЙ ЭЛЕКТРОСТАНЦИИ

Бандажевский Ю.И., Дубовая Н.Ф., Кадун О.Н.

Контроль за содержанием радиоактивных агентов в организме людей разных возрастных групп, проживающих в условиях постоянного радиационного риска, на территории, пострадавшей от аварии на Чернобыльской атомной электростанции, является важным элементом профилактической медицины.
Целью настоящего исследования явилось определение содержания радионуклидов ^{137}Cs в организме детей разного возраста, проживающих в Иванковском и Полесском районах Киевской области Украины спустя 30 лет после аварии на Чернобыльской атомной электростанции.
Методы исследования. Радиометрический, антропометрический, математико-статистический.
Результаты. Определена связь между инкорпорацией радионуклидов ^{137}Cs и возрастом детей, проживающих в Иванковском и Полесском районах Киевской области Украины спустя 30 лет после аварии на Чернобыльской атомной электростанции.
Дети младшего школьного возраста подвергаются большему радиоактивному воздействию, по сравнению с детьми старшего школьного возраста. При выявлении причин инкорпорации радионуклидов ^{137}Cs в организм людей, проживающих в районах, пострадавших от аварии на Чернобыльской атомной электростанции, необходимо обратить внимание на алиментарный путь поступления радионуклидов в организм, учесть анатомические и физиологические особенности организма детей разного возраста, определить роль генетической компоненты.
Ключевые слова. Возраст детей, корреляционная связь, радионуклиды ^{137}Cs, радиоактивно загрязненная территория.

AGE-SPECIFIC FEATURES OF ^{137}CS CONCENTRATIONS IN CHILDREN FROM IVANKOVSKY AND POLESSKY DISTRICTS IN KIEV REGION, UKRAINE, 30 YEARS AFTER THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Bandazhevsky Yu.I., Dubova N.F., Kadun O.N.

An important element of preventive medicine is monitoring of levels of radioactive agents in the population of different age groups living in conditions of constant radiation risk in areas affected by the Chernobyl nuclear power plant accident.
The aim of this study was to measure ^{137}Cs levels in children of different ages living in Ivankovsky and Polessky districts, Kiev region, Ukraine, 30 years after the Chernobyl nuclear power plant accident.
Research methods. Radiometric, anthropometric, mathematical and statistical.
Results. We have identified an association between ^{137}Cs incorporation and age of children living in Ivankovsky and Polessky districts, Kiev region, 30 years after the Chernobyl nuclear power plant accident.
Children of primary school age are exposed to more radiation compared to those of older school age. When identifying causes of ^{137}Cs incorporation in the population living in areas affected by the Chernobyl nuclear power plant accident, it is necessary to pay attention to the fact that radionuclides can enter the human body through ingestion, take into account the anatomical and physiological characteristics of children of different ages and determine the role of a genetic component.
Keywords. Age of children, association, ^{137}Cs radionuclides, radiation-contaminated areas.

ASSOCIATIONS BETWEEN PROCESSES OF ^{137}CS INCORPORATION INTO HUMAN BODY, MTHFR:C677T GENETIC POLYMORPHISM AND PHYSICAL GROWTH IN CHILDREN LIVING IN DISTRICTS AFFECTED BY THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Bandazhevsky Yu.I., Dubova N.F.

30 years after the accident at the Chernobyl nuclear power plant, the problem of radiation exposure remains acute for the population of Ukraine and the Republic of Belarus [1, 2].

Studies conducted in Ukraine during 2013-2017 within the projects of the European Commission and the Rhône-Alpes Regional Council (France) in Ivankovsky and Polessky districts, Kiev region, located near the Chernobyl nuclear power plant, showed a large number of children with elevated blood levels of homocysteine, a product of metabolism of an essential amino acid methionine [3, 4]. In view of this, it is important to identify associations between ^{137}Cs concentrations in the body, state of genome responsible for the synthesis of folate metabolism (FM) enzymes and physical growth in children.

The purpose of the paper was to determine associations between ^{137}Cs levels in the body and the MTHFR:C677T genetic polymorphism responsible for the synthesis of methylenetetrahydrofolate reductase – one of the key folate metabolism enzymes, as well as physical growth in children of different age living in districts affected by the Chernobyl nuclear power plant accident.

Material and methods. The study was carried out in Ukraine with the support of the Children of Chernobyl Association (France).

67 children (26 boys and 41 girls) from Polessky and Ivankovsky districts, Kiev region, located near the Chernobyl nuclear power plant, were subjected to laboratory and instrumental examination. According to data of dosimetry certification of settlements, the territory of the districts has remained contaminated with radioactive substances after the Chernobyl accident until the present day (having the ^{137}Cs soil contamination density of 0.17 up to 1.9 Cu/km^2) [5].

The children examined were divided according to their age at the time of examination into two groups: younger - 8.0 - 11.11 years, and older- 12.0 - 17.0 years. The younger group included 33 children, and the older group included 34 children.

The children's average age at the time of examination was 11.7 ± 0.33 years (95 % CI 11.02-12.35 years).

All the children considered to be healthy had blood drawn from the ulnar vein after fasting in the morning. The blood samples were analysed at a laboratory certified under quality standards with the agreement of parents.

The following allelic variants were identified during genetic analysis of folate metabolism: C677T and A1298C of the MTHFR gene (synthesis of the methylenetetrahydrofolate reductase enzyme), A2756G of the MTR gene (synthesis of the B_{12}-dependent methionine synthase enzyme) and A66G of the MTRR gene (synthesis of the methionine synthase reductase enzyme). A real-time PCR method was used. Analyser and test kit: DT-96 detecting thermocycler, DNA-Technology (Russia).

Anthropometric measuring techniques standardised in Ukraine [6] were used to assess physical growth (PG) in the children. Rules of bioethics were also observed and informed consents were signed by the parents of each subject [7, 8]. The Rohrer's weight/height index (RI), being independent of age and sex and calculated by dividing weight in kilograms by the cubic of height in meters, was chosen as a criterion for assessment of PG and metabolism in a child.

The RI allows to estimate the degree of weight and height conformity of an individual. Normal PG is defined at RI values of 10.7 to 13.7 kg/m^3, abnormal PG in children with insufficient body weight is defined at RI values of less than 10.7 kg/m^3, and abnormal PG in children with excessive body weight is defined at RI values of 13.7 kg/m^3. Three subgroups were identified in the group of children from Polessky and Ivankovsky raions according to RI values:

«1» – abnormal (low) PG, RI values are < 10.7;

«2» – normal PG, RI values lie within the range ≤ 13.7 and ≥ 10.7;

«3» – abnormal (high) PG, RI values are > 13.7.

Among all the children examined (n=67), RI values in the range of ≤ 13.7 and ≥ 10.7 were observed in 47 cases (70.15 %), in 24 cases (72.72 %) in the subgroup of children under 12 years, and in 23 cases (67.65 %) in the subgroup of children aged 12.0-17.0 years.

^{137}Cs specific activity in the children was measured on the date of blood collection using a SICH-AKP-3 three-detector spectrometer (OOO NPP ATOMKOMPLEK-SPRIBOR, Ukraine), during 10 minutes. Spectra were processed automatically, specific activities of radioactive elements were calculated and the information obtained was saved with the help of the AKWin software.

The results of statistical analysis of individual incorporated ^{137}Cs levels in the children from Ivankovsky and Polessky districts, Kiev region, are presented in Table 1.

During the study, we performed a comparative assessment of associations between PG and ^{137}Cs levels in children who were carriers of different FM genotypes, taking into account their age.

The statistical processing of the results obtained was performed using the IBM SPSS Statistics 22 software (USA). The arithmetic mean (M) ± 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.

Table 1

Results of statistical analysis of specific content of incorporated ^{137}Cs in children from Ivankovsky and Polessky districts, Kiev region

Group name	Specific content of incorporated ^{137}Cs, Bq/kg			
	Average value	Median	IR*	Maximum value
Whole group (n = 67)	4.15 ± 0.76	2.35	1.98 – 3.0	37.21
^{137}Cs > 5.0 Bq/kg^{-} (n = 6)	21.99 ± 4.0	17.7	15.1 – 32.3	37.21

Note. *IR - interquartile range (the range of values, containing the central 50 % of sample observations, i.e. the interval between the 25th and 75th percentiles).

The Student's t-test was used to compare relative values. The critical level of significance for the null hypothesis (p) was set at 0.05. Associations between ^{137}Cs specific activity, RI and age of children were identified with the help of Spearman's rank correlation coefficient (r_{xy}). The strength of correlation 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. When comparing levels of ^{137}Cs specific activity in the children, the median of the variable was 2.82 Bq/kg (IR 2.44-3.25; n=33) in the group of younger school children (age: 8.0 - 11.11 years), and 2.07 Bq/kg (IR 1.88-2.21; n=34) – in the group of older school children (age: 12.0 - 17.0 years). The non-parametric Mann-Whitney U test value was 175.0. Differences between the variables were statistically significant (p = 0.0001). The average rank of the variable was higher in the first group than in the second one, which showed that there were higher measured levels of ^{137}Cs specific activity in the children aged 6.0 - 11.11 years (Tables 2, 3).

Table 2

Statistical characteristics of variables analysed in children examined

Variables	Group of children aged 8.0-11.11 years			Group of children aged 12.0-18.0 years		
	n	Me	IR	n	Me	IR
Age, years	33	9.1	8.1-10.1	34	14.1	12.8-15.1
^{137}Cs specific activity, Bq/kg	33	2.8	2.4-3.3	34	2.1	1.9-2.21
RI	33	12.4	11.7-13.5	34	12.5	11.3-13.9

PG according to RI had no statistical differences in the younger and older groups (Table 3).

A moderate inverse association was found between age of children and their ^{137}Cs concentrations (Table 4).

Thus, the studies conducted show that children of primary school age are more exposed to radiation effects than those of older school age. Why does this happen?

Taking into account dietary habits of rural population in Polessky and Ivankovsky raions, this can be explained by a larger consumption of milk and dairy products produced in radiation contaminated areas by children of primary school age compared to older children. Nevertheless, one should not exclude the effect of a genetic factor on the activity of enzymes, which also determines the level of metabolic processes in a developing body. In this regard, first of all, it is necessary to study FM enzymes that regulate the main metabolic processes in the body.

Table 3

Results of statistically significant differences when comparing ^{137}Cs specific activity by age in children examined

Variables	Comparison groups	Number of subjects	Average rank	Mann–Whitney U test, significance level, p
Age, years	1[1]	33	17.00	U = 0.0001; p = 0.0001
	2[2]	34	50.50	
^{137}Cs specific activity, Bq/kg	1[1]	33	45.70	U = 175.00; p = 0.0001
	2[2]	34	22.65	
RI	1[1]	33	34.00	U = 561.00; p = 1.00
	2[2]	34	34.00	

Note. [1] - group 1 (age: 6.0-11.11 years); [2] - group 2 (age: 12.0-17.0 years).

Table 4

Results of correlation analysis between age and ^{137}Cs specific activity measurements in children examined

Parameter	Correlation coefficient	Parameter	
		Age, years	^{137}Cs specific activity, Bq/kg
Age, years	Spearman's, r_{xy}	1.000	-0.617**
	Sign. (2-tailed), p	.	0.0001
	N	67	67
^{137}Cs specific activity, Bq/kg	Spearman's, r_{xy}	-0.617**	1.000
	Sign. (2-tailed), p	0.0001	.
	N	67	67

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

Carriership of the T allele of the MTHFR:C677T polymorphism responsible for the synthesis of methylenetetrahydrofolate reductase involved in folate metabolism was observed in 36 cases (53.7 % of the children examined) in the total group of children. At the same time, a moderate inverse association was reported between ^{137}Cs specific activity and age of children both in this subgroup and in the subgroup of children who were not carriers of this allele (Table 5).

Table 5

Results of correlation analysis between ^{137}Cs specific activity and age in groups of children with different polymorphisms

Genotype	Correlation coefficient	Parameters
		^{137}Cs specific activity, Bq/kg and age, years
MTHFR:677 C/T + T/T	Spearman's	-0.545**
	Sign. (2-tailed), p	0.001
	N	36
MTHFR:677 C/C	Spearman's	-0.699**
	Sign. (2-tailed), p	.0001
	N	31

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

There were no statistical differences between ^{137}Cs specific activity and RI in the subgroups with the MTHFR:677 C/C and MTHFR:677 C/T+T/T genotypes. A similar situation was detected in the subgroup of children aged 12.0 – 17.0 years, while carriership of the allele was seen in 17 cases (50.0 % of the number of children in the subgroup).

Carriership of the T allele was reported in 19 cases (57.6 % of children in the subgroup) in the younger subgroup of children. Elevated ^{137}Cs levels and decreased PG (RI) index were found in the subgroup of children with the MTHFR:677 C/T+T/T genotypes compared to the subgroup of children with the MTHFR:677 C/C genotype (Tables 6, 7).

Table 6

Statistical characteristics of metabolic and physical growth variables in examined children from a younger group

Variables	Group of children with MTHFR:677 C/C genotype			Group of children with MTHFR:677 C/T + T/T genotypes		
	n	Me	IR	n	Me	IR
^{137}Cs specific activity, Bq/kg	14	2.52	2.39-2.83	19	3.07	2.75-3.29
RI	14	13.3	12.38-14.23	19	11.90	11.50-13.30

Table 7

Results of statistically significant differences when comparing metabolic and physical growth variables in examined children from a younger group

Variables	Comparison groups	Comparison group size	Average rank	Mann–Whitney U test, significance level, p
^{137}Cs specific activity, Bq/kg	1	14	13.14	U = 79.0; p = 0.05
	2	19	19.84	
RI	1	14	21.43	U = 71.0; p = 0.024
	2	19	13.74	

Note: Group «1» - a group of children with MTHFR:677 C/C genotype; «2» - a group of children with MTHFR:677 C/T+T/T genotypes.

Thus, in the children who were carriers of the T allele of the MTHFR:677 polymorphism, elevated ^{137}Cs levels in the body were accompanied by a decrease in weight in relation to body length. This is confirmed by results of correlation analysis.

There was a moderate inverse association between ^{137}Cs specific activity and RI values not only in the subgroup where the representation of the T allele was 100 per cent, but also in the MTHFR:1298 A/A genetic subgroup where there was the largest proportion of carriers of the T allele among all the other genetic subgroups analysed (Tables 8, 9).

So carriership of the T allele of the MTHFR:677 polymorphism predetermines a larger ^{137}Cs accumulation in the body.

The studies carried out show that ^{137}Cs incorporation processes are closely connected with the genome of FM. The 677 point mutation in the MTHFR gene which affects the activity of methylenetetrahydrofolate reductase, contributes to the increase in ^{137}Cs concentrations in children living in districts affected by the Chernobyl nuclear power plant accident.

However, this ability is manifested when large amounts of radionuclides are entered into the human body.

In this case, we are talking about the younger group of children aged 8.0 - 11.11 years who consume locally produced foods, especially milk and dairy products, which according to recent studies, contain high levels of radioactive elements [10].

At the same time, an inverse association is found between ^{137}Cs specific activity and PG in children which shows that incorporated ^{137}Cs radionuclides suppress metabolic processes.

The presence of ^{137}Cs in the children examined shows that foods produced in Ivankovsky and Polessky districts, Kiev region, contain ^{137}Cs radionuclides. It is possible to reduce levels of internal contamination with ^{137}Cs in the population in these areas, firstly, provided foods are carefully selected and processed.

It should be prohibited to consume forest berries, mushrooms and locally pro-

duced foods without prior radiation monitoring. It should be prohibited to burn wood from radiation-contaminated areas in stoves in people's homes, and it should also be prohibited to use wood ashes from stoves as a fertiliser in fields where agricultural plants are grown. In this regard, it is important to carry out regular outreach activities with the population to raise awareness of the importance of following radiation safety rules in areas affected by the Chernobyl nuclear power plant accident.

Table 8

Results of correlation analysis between ^{137}Cs and RI values in groups of children with different polymorphisms

Genotype	Correlation coefficient	Parameters
		^{137}Cs and RI
MTR:2756 A/G + MTR:2756 G/G	Spearman's	-0.242
	Sign. (2-tailed), p	p = 0.215
	N	28
MTR:2756 A/A	Spearman's	-0.202
	Sign. (2-tailed), p	p = 0.217
	N	39
MTHFR:1298 A/C+ MTHFR:1298 C/C	Spearman's	-0.035
	Sign. (2-tailed), p	p = 0.826
	N	43
MTHFR:1298 A/A	Spearman's	-0.435*
	Sign. (2-tailed), p	p = 0.033
	N	24
MTHFR:677 C/T + MTHFR:677 T/T	Spearman's	-0.330*
	Sign. (2-tailed), p	p = 0.049
	N	36
MTHFR:677 C/C	Spearman's	0.114
	Sign. (2-tailed), p	p = 0.541
	N	31
MTRR:66 A/G + MTRR:66 G/G	Spearman's	-0.233
	Sign. (2-tailed), p	p = 0.084
	N	56
MTRR:66 A/A	Spearman's	0.094
	Sign. (2-tailed), p	p = 0.784
	N	11

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

Table 9

Proportion of cases with T allele of MTHFR:C677T polymorphism among the genetic groups under study

Genotype	Number of cases	Number of cases of carriership of T allele of MTHFR:C677T polymorphism	
		Absolute number	%
MTR:2756 A/G + MTR:2756 G/G	28	16	57.1
MTR:2756 A/A	39	20	51.3
MTHFR:1298 A/C + MTHFR:1298 C/C	43	20	46.5
MTHFR:1298 A/A	24	16	66.7
MTHFR:677 C/T + MTHFR:677 T/T	36	36	100
MTHFR:677 C/C	31	0	0
MTRR:66 A/G + MTRR:66 G/G	56	31	55.4
MTRR:66 A/A	11	5	45.5

Conclusions. 1. ^{137}Cs specific activity levels are higher in the children from the districts of Kiev region, Ukraine, affected by the Chernobyl nuclear power plant accident that comprise the younger age group (8.0 - 11.11 years) than in the children from the older age group (12.0 – 17.0 years). There is an inverse association between the age of children and their ^{137}Cs levels.

2. ^{137}Cs concentrations are higher and physical growth index is lower in the children from the younger group who have the MTHFR:677 C/T + T/T genotypes than in those from the same group who have the MTHFR:677 C/C genotype.

3. The 677 point mutation in the MTHFR gene which reduces the activity of methylenetetrahydrofolate reductase involved in folate metabolism contributes to the increase in ^{137}Cs levels and suppression of metabolic processes in the children from the younger age group living in districts affected by the Chernobyl nuclear power plant accident.

4. The children who are carriers of the T allele of the MTHFR:C677T genetic polymorphism comprise a risk group with respect to incorporation of ^{137}Cs radionuclides entering the human body through the digestive system, as well as by inhalation.

5. The findings can be used in the implementation of initiatives aimed at reducing the degree of radiation effect on various population groups living in districts affected by the Chernobyl nuclear power plant accident.

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СВЯЗЬ ПРОЦЕССОВ ИНКОРПОРАЦИИ В ОРГАНИЗМ РАДИОНУКЛИДОВ ^{137}CS С ГЕНЕТИЧЕСКИМ ПОЛИМОРФИЗМОМ MTHFR:C677T И ФИЗИЧЕСКИМ РАЗВИТИЕМ У ДЕТЕЙ, ПРОЖИВАЮЩИХ В РАЙОНАХ, ПОСТРАДАВШИХ ОТ АВАРИИ НА ЧЕРНОБЫЛЬСКОЙ АТОМНОЙ ЭЛЕКТРОСТАНЦИИ

Бандажевский Ю.И., Дубовая Н.Ф.

В районах, расположенных вблизи Чернобыльской атомной электростанции, выявлено большое число детей с повышенным содержанием в крови гомоцистеина – продукта незаменимой аминокислоты метионина. Важно определить связь между содержанием радиоактивных элементов в организме, состоянием фолатного цикла и физическим развитием детей.

Целью работы явилось определение связей между уровнем радионуклидов ^{137}Cs в организме и генетическим полиморфизмом MTHFR:C677T, ответственным за синтез метилентетрагидрофолатредуктазы – одного из основных ферментов фолатного цикла, а также, физическим развитием у детей разного возраста, проживающих в районах, пострадавших от аварии на Чернобыльской атомной электростанции.

Методы исследования. Радиометрический, иммунохимический, антропометрический, математико-статистический

Результаты. Удельная активность радионуклидов ^{137}Cs в организме детей из районов Киевской области Украины, пострадавших от аварии на Чернобыльской атомной электростанции, входящих в младшую возрастную группу (8,0 - 11,11 лет) выше, чем в организме детей, составивших старшую возрастную группу (12,0 – 17,0 лет). Между возрастом детей и содержанием радионуклидов ^{137}Cs в их организме существует обратная корреляционная связь.

Точечная мутация 677 гена MTHFR, снижающая активность метилентетрагидрофолатредуктазы фолатного цикла, способствует увеличению содержания радионуклидов ^{137}Cs и подавлению процессов обмена веществ в организме детей младшей возрастной группы, проживающих в районах, пострадавших от аварии на Чернобыльской атомной электростанции.

Дети, являющиеся носителями аллели Т генетического полиморфизма MTHFR:C677T, составляют группу риска в отношении инкорпорации радионуклидов ^{137}Cs, поступающих в организм алиментарным или воздушным путем.

Полученные результаты могут быть использованы при осуществлении мероприятий, направленных на снижение степени радиационного воздействия на различные группы населения, проживающих в районах, пострадавших от аварии на Чернобыльской атомной электростанции.

Ключевые слова. Корреляционная связь, радионуклиды ^{137}Cs, фолатный цикл, метилентетрагидрофолатредуктаза, аллель Т, генетический полиморфизмы, физическое развитие, радиоактивно загрязненная территория.

ASSOCIATIONS BETWEEN PROCESSES OF ^{137}CS INCORPORATION INTO HUMAN BODY, MTHFR:C677T GENETIC POLYMORPHISM AND PHYSICAL GROWTH IN CHILDREN LIVING IN RAIONS AFFECTED BY THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Бандажевский Ю.И., Дубовая Н.Ф.

A large number of children have been found to have elevated blood levels of homocysteine, a product of metabolism of an essential amino acid methionine, in districts located near the Chernobyl nuclear power plant. It is important to identify associations between concentrations of radioactive elements, state of folate metabolism and physical growth in children.

The purpose of the paper was to determine associations between ^{137}Cs levels in the body and the MTHFR:C677T genetic polymorphism responsible for the synthesis of methylenetetrahydrofolate reductase – one of the key folate metabolism enzymes, as well as physical growth in children of different age living in districts affected by the Chernobyl nuclear power plant accident.

Research methods. Radiometric, immunochemical, anthropometric, mathematical and statistical.

Results. ^{137}Cs specific activity levels are higher in children from districts of Kiev region, Ukraine, affected by the Chernobyl nuclear power plant accident that comprise the younger age group (8.0-11.11 years) than in the children from the older age group (12.0 – 17.0 years). There is an inverse association between the age of children and their ^{137}Cs levels.

The 677 point mutation in the MTHFR gene which decreases the activity of methylenetetrahydrofolate reductase involved in folate metabolism contributes to the increase in ^{137}Cs levels and suppression of metabolic processes in children from the younger age group living in districts affected by the Chernobyl nuclear power plant accident.

The children who are carriers of the T allele of the MTHFR:C677T genetic polymorphism comprise a risk group with respect to incorporation of ^{137}Cs radionuclides entering the human body through the digestive system, as well as by inhalation.

The results obtained can be used in the implementation of initiatives aimed at reducing the degree of radiation effect on various population groups living in districts affected by the Chernobyl nuclear power plant accident.

Keywords. Association, ^{137}Cs radionuclides, folate metabolism, methylenetetrahydrofolate reductase, T allele, genetic polymorphisms, physical growth, radiation-contaminated areas.

PECULIARITIES OF HOME DIETS OF RURAL CHILDREN LIVING IN RADIATION-CONTAMINATED AREAS IN THE POST-CHERNOBYL PERIOD

Dubovaya N.F., Bandazhevsky Yu.I.

The consumption of locally produced foods as a main food source by rural children living in radiation-contaminated areas (RCAs) still leads to increased intake of radionuclides and an increase in the internal radiation dose, causing significant morphofunctional disorders of many organs and body systems, and also physical growth, which to a certain extent reflects the level of their health [1-7].

"Forest gifts" also play an important role among foods that contain ^{137}Cs and ^{90}Sr – the main dose-forming radionuclides in the remote period after the Chernobyl accident. The ^{137}Cs specific activity in samples of the mushrooms and berries studied picked in radiation- contaminated forests often exceeds maximum permissible levels (PL-2006) and cases of samples with high specific activity have been still reported [8, 9].

When living in RCAs it is important not only that foods do not contain radioactive agents. A diet should be nutritious, balanced, diverse and safe, and help to keep and maintain health.

Until recently, children living in areas affected by the Chernobyl nuclear power plant accident received approximately 75-80 % of the daily ration having three meals a day in preschool and school institutions. At present, school children are forced to receive most of the daily ration at home, since the state has completely or partially stopped financing school meals.

A questionnaire survey of 346 residents of rural localities in Ivankovsky and Polessky districts of Kiev region was conducted to study peculiarities of home diets of children living in RCAs. The survey involved 109 parents having children of younger age (5.0-11.11 years) and 237 school children aged 12.0–17.0 years. During the survey, special attention was paid to clarifying issues on the frequency of consumption and the origin of basic foods due to which the internal radiation dose is formed in RCAs in the remote period after the accident.

Milk and dairy products are the main source of vital nutrients for the developing human body, including animal proteins, essential amino acids, vitamins and microelements [10]. In particular, in order to cover a child's daily requirement for calcium, it is necessary to consume at least 500 ml of cow's milk or fermented milk products. Failure to meet the norms of consumption of milk and farmer cheese leads to insufficient levels of this macronutrient in the body, and as a result, to the abnormal formation of bone system and other vital systems [11].

Calcium is also an antagonist to ^{90}Sr. Calcium inclusion into the diet in the amount of 1.5-2 times exceeding the physiological needs significantly reduces the absorption of ^{90}Sr in the gastrointestinal tract (up to 15 % of its content in food) [12].

According to the survey results, 91.6 % of all the children analysed consume milk and dairy products (Fig.). At the same time, this figure was 95.4 % in the younger age group and 89.9 % in the older age group.

The mentioned food product was present in the home diet of children with a different frequency. Thus, 158 children - 45.7 % of all respondents (57 or 52.3 % of children aged 5.0-11.11 years and 101 subjects or 42.6 % of the older age group) said they consumed milk on a daily basis; 87 (subjects) - 25.1 % of respondents (34 children from the younger age group (31.2 %) and 53 subjects of older age (22.4 %) included milk in the home diet 3-4 times a week; 20.8 % of respondents (72 out of 346 rural children): 11.9 % of younger children (13 subjects) and 24.9 % of older children (59 subjects) consumed milk and meals containing milk 1-2 times per week. 29 children or $^{1}/_{12}$ of the total number of respondents answered that they did not consume this product for various reasons.

We carried out a comparative analysis of the frequency of distribution of affirmative answers, taking into account the age. It was found that the children aged 5.0–11.11 years consumed milk every day statistically significantly more often ($t=1.96$; $p<0.05$) than children aged 12.0–17.0 years and among them there are fewer individuals who do not consume milk, but this difference was not statistically significant ($t=1.96$, $p=0.0603$).

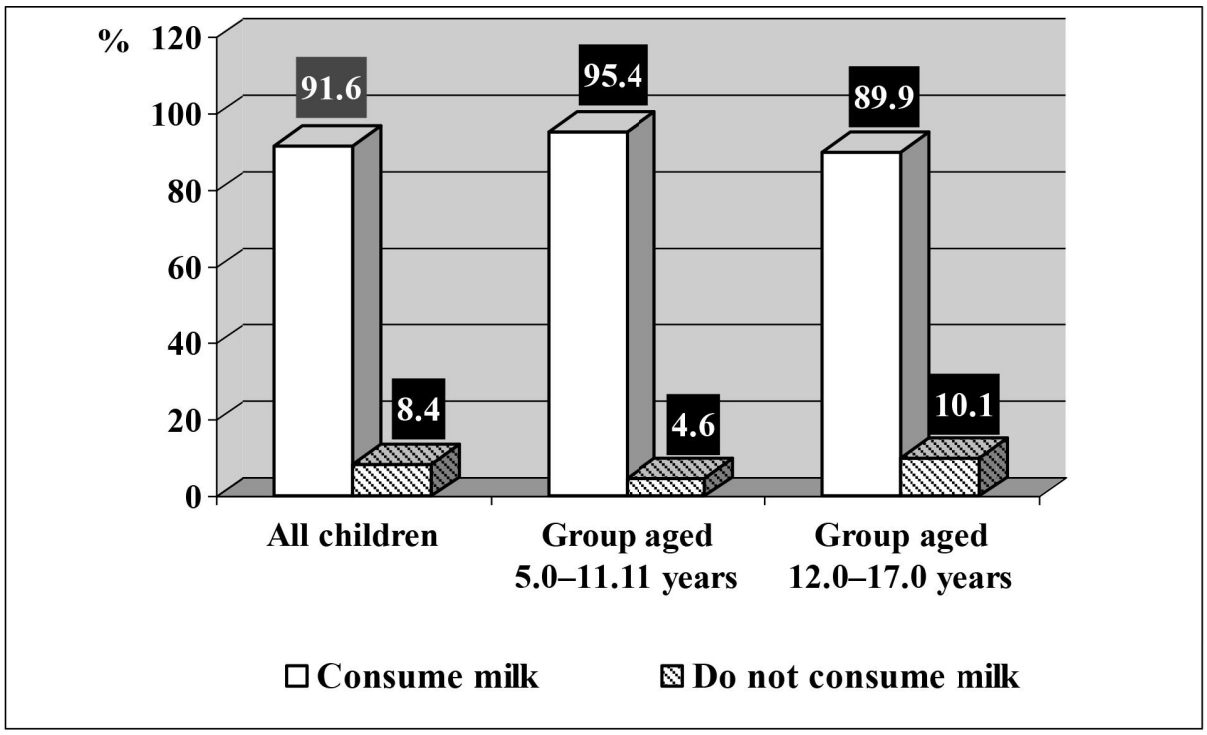

Fig. Distribution of affirmative answers of respondents to a question on the consumption of locally produced milk within each age group of children.

Meat also contains nutrients that are very important for the human body - phosphorus, magnesium, iron, potassium, vitamins. However, it should be kept in mind that meat and internal organs (heart, liver, kidneys, lungs) of farm animals raised in private farms in RCAs without complying with the rules of animal management and nutrition, as well as meat of hunted wild animals may contain elevated radionuclide concentrations [13].

An analysis of affirmative answers to the question on the inclusion of meat into the home diet of children showed that 93.7 % (324 respondents) consumed this type of food with a different frequency (103 children of the younger age group (94.5 %) and 221 school children of the older age group (93.2 %)). 42.2 % of respondents consumed meat with a frequency of 3 times per week or more, 40.2 % (139 children) - 1-2 times per week and 11.3 % (39 children) consumed meat rarely. 2.6 % of school children (9 subjects) said they had no meat in their home diet, 3.8 % or 13 children chose «Other» among the answer options, which may suggest they consume meat or meat products occasionally.

Interest was generated by the answers to the question on what kind of meat was used most often in the diet of the children. 113 respondents (32.7 %) answered that it was pork, and and this product was more common in the home diet of younger school children (41.3 %) compared with the older children (28.7 %). The second place in terms of frequency of consumption was taken by poultry meat (26.6 %) and the third place belonged to beef (9.3 %). Only 2.0 % of respondents reported that they mainly consumed rabbit meat. The home ration of 3.8 % of school children included meat of wild animals and birds, and about 22.0 % of respondents said they consumed 2 or 3 types of meat with the same frequency. In addition, 1.2 % of children could not answer the question categorically and chose the answer option «Other».

In the current critical economic situation in RCAs, forest gifts are the important food sources for the majority of rural residents. It has been established that the contribution of natural food to the internal radiation dose increases every year and may reach 70 % [14].

The results of the survey showed that forest mushrooms and berries were constantly present in the home diet of 8.1 % of respondents, and they were consumed by more than half of respondents (62.1 %) in their season. 15.9 % of children consumed forest gifts rarely, and 13.0 % did not consume at all. 3 out of 346 (0.9 %) respondents found it difficult to say how frequently they use wild mushrooms or berries in their diet.

A comparative analysis of consumption of wild foods showed that the children of younger age consumed mushrooms and berries in their season statistically significantly more often than older children ($t=3.59$; $p=0.0004$). The proportion of individuals who denied the consumption of this type of products was 6.4% in the younger age group of children and was statistically significantly ($p<0.05$) smaller compared with the children aged 12.0-17.0 years (16.03 %).

Thus, the findings suggest that rural residents of RCAs use local agricultural and natural foods in their home diet. In this regard, radioactive elements enter the body of children every day and adversely impact the metabolic processes and the functioning of vital organs.

Conclusions. 1. The diet of children from families living in rural areas contaminated with radioactive elements as a result of the Chernobyl nuclear power plant accident mainly consists of locally produced foods, as well as wild mushrooms and berries.

2. A higher frequency of consumption of dairy products, as well as wild berries and mushrooms was reported in the group of children aged 5.0–11.11 years compared to the group of children aged 12.0–17.0 years.

3. A small number of rural children consume meat of wild animals. However, taking into account the high levels of radioactive contamination of the meat, this part of the population should be viewed, first of all, as a critical group along with the residents who consume wild foods more actively.

4. The findings indicate that there is a need to provide children living in rural areas affected by the accident at the Chernobyl nuclear power plant with safe and healthy food products.

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ОСОБЕННОСТИ ДОМАШНЕГО ПИТАНИЯ СЕЛЬСКИХ ДЕТЕЙ, ПРОЖИВАЮЩИХ НА РАДИОАКТИВНО ЗАГРЯЗНЕННЫХ ТЕРРИТОРИЯХ, В ПОСТЧЕРНОБЫЛЬСКИЙ ПЕРИОД

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Изменения в организации питания сельских школьников, проживающих на радиоактивно загрязненных территориях (РЗТ), привело к увеличению вклада домашнего питания в суточном рационе детей. Неконтролируемые продукты питания приводят к повышенному поступлению радионуклидов в организм и увеличению дозы внутреннего облучения, что обуславливает существенные морфофункциональные нарушения многих органов и систем организма, а также физического развития.

Целью работы было изучение особенностей домашнего питания детей, проживающих на РЗТ, в отдаленный период после Чернобыльской аварии.

Методы исследования. Анкетный, математико-статистический.

Результаты. Проанкетировано 346 жителей сельских населенных пунктов Иванковского и Полесского районов Киевской области, из них - 109 родителей, имеющих детей младшего возраста (5,0-11,11 лет), и 237 учеников в возрасте 12,0-17,0 лет. В ходе анкетирования выяснялся вопрос о частоте употребления и происхождении продуктов питания, которые вносят основной вклад в формирование дозы внутреннего облучения на РЗТ в настоящее время. Установлено, что рацион домашнего питания семей в сельской местности преимущественно составляют продукты местного производства, а также дикорастущие грибы и ягоды. При этом дети в возрасте 5,0-11,11 лет статистически достоверно ($p<0,05$) чаще употребляют местное молоко и «дары леса» в сравнении с возрастной группой 12,0-17,0 лет. 3,8 % респондентов указали на употребление мяса диких животных. Принимая во внимание высокие уровни радиоактивного загрязнения дичи, эта часть населения должна рассматриваться как критическая группа наряду с жителями, активно потребляющими в пищу дикорастущую продукцию. Полученные результаты свидетельствуют о необходимости обеспечения питания сельских детей, проживающих на РЗТ, экологически чистыми и полезными для здоровья продуктами.

Ключевые слова. Дети, домашнее питание, сельская местность, радиоактивно загрязненная территория.

PECULIARITIES OF HOME DIETS OF RURAL CHILDREN LIVING IN RADIATION-CONTAMINATED AREAS IN THE POST-CHERNOBYL PERIOD

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Changes in the organisation of school nutrition for rural school children living in radiation-contaminated areas (RCAs) have led to an increase in the contribution of home meals to the daily ration of children. Uncontrolled foods lead to increased intake of radionuclides and an increase in the internal radiation dose, causing significant morphofunctional disorders of many organs and body systems, as well as physical growth.

The purpose of this work was to study the peculiarities of home diets of children living in RCAs in the remote period after the Chernobyl accident.

Research methods. Questionnaire, mathematical and statistical.

Results. 346 residents of rural localities in Ivankovsky and Polessky raions of Kiev oblast filled questionnaires. Among them there were 109 parents who had children of younger age (5.0-11.11 years) and 237 school children aged 12.0–17.0 years. During the survey, we tried to clarify issues on the frequency of consumption and the origin of foods which contribute to the formation of the internal radiation dose in RCAs in the present time. It was found that the home diet of families living in rural areas mainly consisted of locally produced foods, as well as wild mushrooms and berries. At the same time, the children aged 5.0–11.11 years consumed milk and “forest gifts” statistically significantly ($p<0.05$) more often compared to the age group of 12.0–17.0 years. 3.8 % of respondents said that they consumed meat of wild animals. Taking into account high levels of radioactive contamination of the meat, this part of the population should be viewed, first of all, as a critical group along with the residents who consume wild foods more actively. The findings indicate that there is a need to provide children living in RCAs with safe and healthy food products.

Keywords. Children, home diet, rural areas, radiation-contaminated areas.

PHYSICAL GROWTH OF CHILDREN IN THE PRESENCE OF ^{137}CS INCORPORATION 30 YEARS AFTER THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

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A significant part of the population of the former USSR countries, including Ukraine, the Republic of Belarus and the Russian Federation, has been under constant radiation exposure due to the testing of nuclear weapons and Chernobyl nuclear power plant accident for more than half a century [1-3].

This is mainly due to ^{137}Cs and ^{90}Sr radionuclides which can enter the body with air or as a part of food [1, 4].

Taking into account negative trends in morbidity and mortality, as well as the demographic situation as a whole, during the observed period, it is important to conduct a comprehensive assessment of the effect of the radiation factor on vital processes of the human body, and this, first of all, relates to children.

In this regard, it is reasonable to determine whether there are associations between radionuclides incorporated into the child's body and its physical growth, which is a combination of morphological and functional markers characterising the processes of growth and biological maturation.

The purpose of this study was to identify associations between ^{137}Cs radionuclides incorporated into the body and physical growth in children 30 years after the Chernobyl nuclear power plant accident.

Material and methods. The study was carried out within a project of the European Commission in Ukraine "Health and ecological programmes around the Chernobyl Exclusion Zone: Development, training and coordination of health-related projects", bioethics rules were also followed and informed consents were signed by parents of each subject.

1656 children (838 boys and 818 girls) from Polessky and Ivankovsky districts of Kiev region located near the Chernobyl nuclear power plant were examined. According to data of dosimetry certification of settlements, the territory of the raions has remained contaminated with radioactive substances after the Chernobyl accident until the present day (^{137}Cs soil contamination density in some localities varied from 0.17 to 1.9 Cu/km^2) [5].

The children were divided into three groups according to their age at the time of examination: younger – 2.0-5.11 years (n = 150), middle – 6.0 -11.11 years (n = 782), older – 12.0-18.0 years (n = 724).

Physical growth (PG) in children was assessed with the help of anthropometric measuring techniques standardised in Ukraine [6, 7, 8]. The Rohrer's weight/height index (RI), calculated by dividing weight in kilograms by the cubic of height in meters, was chosen as a criterion for assessment of PG and metabolism in a child [9].

The RI allows to estimate the degree of weight and height conformity of an individual. Normal PG is defined at RI values of 10.7 to 13.7 kg/m^3, abnormal PG in children with insufficient body weight is defined at RI values of less than 10.7 kg/m^3, and abnormal PG in children with excessive body weight is defined at RI values of more than 13.7 kg/m^3. Three subgroups were identified in the group of children from Polessky and Ivankovsky districts according to RI values: «1» – abnormal (low) PG, RI is ≤ 10.7; «2» – normal PG, RI is in the range of ≤ 13.7 and ≥ 10.7; «3» – abnormal (high) PG, RI is > 13.7.

Blood erythrocyte and haemoglobin concentrations in children were determined using a Pentra XL80&ACCESS&454086 (25x1200 pcs) (France&Germany) haematology analyser.

^{137}Cs specific activity in children was measured on the date of anthropometric measurements and blood collection 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 information obtained was saved with the help of the AKWin software.

During the studies conducted, a comparative assessment of statistical values of ^{137}Cs concentrations in different age groups was carried out. The assessment also took into account physical growth index values, associations between ^{137}Cs levels and physical growth, erythrocyte and haemoglobin levels in children and the age parameter.

The statistical processing of the results obtained was performed using the IBM SPSS Statistics 22 software (USA). The arithmetic mean (M), ± 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.

The Student's t-test was used to compare relative values. The critical level of significance for the null hypothesis (p) was set at 0.05. Associations between ^{137}Cs specific activity, RI, age of children, haemoglobin and erythrocyte values were identified with the help of the Spearman's rank correlation coefficient (r_{xy}). The strength of correlation 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 measurements conducted showed that ^{137}Cs specific activity in the children examined was 4,36±0,27 Bq/kg.

An inverse association was found between the age of children and their ^{137}Cs specific activity (Table 1).

The ^{137}Cs specific activity and RI values were statistically significantly higher in children from the younger group than in those from the middle and older groups (Tables 2, 3, 4). There was a weak direct association between these values in the total group, there was no association in the younger group, while in the older group there was a moderate inverse association (Table 5), with no link between age and RI (Table 6). The ^{137}Cs specific activity values of children from the older group were higher in the subgroup with RI ≤ 10.7 than in the subgroups of children with RI > 10.7 and ≤ 13.7, and with RI > 13.7 (Tables 7, 8).

Table 1

Results of correlation analysis between age and ^{137}Cs specific activity in children examined

Groups of children	Correlation coefficient	Parameters	
		Age, years	^{137}Cs specific activity, Bq/kg
Total group	Spearman's	-0.603**	
	Sign. (2-tailed), p	0.0001	
	N	1656	
Younger group	Spearman's	-0.513**	
	Sign. (2-tailed), p	0.0001	
	N	150	
Middle group	Spearman's	-0.573**	
	Sign. (2-tailed), p	0.0001	
	N	782	
Older group	Spearman's	-0.224**	
	Sign. (2-tailed), p	0.0001	
	N	724	

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

Thus, in the absence of the effect of the age factor, the association is observed between RI and ^{137}Cs concentrations in children of the older group. Higher ^{137}Cs specific activity is accompanied by a decrease in RI (Fig. 1).

The analyses carried out showed that a body mass to length ratio as RI was higher in the children of younger age in the group under study than in those from the older age group (Fig. 2), i.e. there are more cellular and intercellular elements per unit of body length.

Table 2

Statistical characteristics of analysed variables of children examined

Variable	Younger group (n = 150)		Middle group (n = 782)		Older group (n = 724)	
	Me	IR	Me	IR	Me	IR
^{137}Cs specific activity, Bq/kg	3.01	2.79-3.27	2.48	2.15-2.68	1.68	1.54-1.96
RI	15.08	13.74-16.02	12.73	11.82-13.66	12.17	11.19-13.44

Table 3

Results of statistically significant differences in ^{137}Cs specific activity between groups of children

Variable	Comparison groups	Comparison group size	Average rank	Mann-Whitney U test value, significance level, p
^{137}Cs specific activity, Bq/kg	1	150	739.01	U =17773.000; p = 0.0001
	2	782	414.23	
	1	150	691.51	U=16198.000; p=0.0001
	3	724	384.87	
	2	782	976.12	U=108996.000; p=0.0001
	3	724	513.05	

Note. Group 1 – younger group; 2 – middle group; 3 – older group.

This logically goes together with higher ^{137}Cs specific activity (Fig. 3). However, no positive association was observed between ^{137}Cs specific activity and RI in separate age groups, there was a weak link only in the total group. Thus, the increased accumulation of ^{137}Cs radionuclides in children of the younger group in comparison with those from the older group cannot be associated only with physiological age peculiarities. It can be explained by the fact that younger children consume more dairy products (cow's and goat's milk) produced in areas contaminated with radionuclides than children of older age. Even relatively small amounts of ^{137}Cs radionuclides contained in food can cause abnormal functioning of vital organs in the developing body of a child [10, 11].

The absence of an association between age and RI in the older group of children allows to determine the effect of incorporated ^{137}Cs radionuclides on metabolic processes. The negative association between ^{137}Cs specific activity and RI values, as well as statistical differences in ^{137}Cs levels between the groups with different RI show that there is a suppression of cell metabolism under conditions of internal radiation expansion.

Table 4

Results of statistically significant differences in the physical growth index (Rohrer's index) between groups of children

Variable	Comparison groups	Comparison group size	Average rank	Mann–Whitney U test value, significance level, p
RI	1	150	717.02	U =21072.500; p = 0.0001
	2	782	418.45	
	1	150	689.89	U=16442.000; p=0.0001
	3	724	385.21	
	2	782	814.80	U=235143.500; p=0.0001
	3	724	687.28	

Note. Group 1 – younger group; 2 – middle group; 3 – older group; RI – Rohrer's index.

^{137}Cs specific activity and RI values were the highest in children from the age group of 2.0 – 5.11 years compared to other groups, the inverse association between age and RI was of moderate strength, and there was no association between ^{137}Cs specific activity and RI values.

Table 5

Results of correlation analysis between RI and ^{137}Cs specific activity in children examined

Groups of children	Correlation coefficient	Parameters	
		RI	^{137}Cs specific activity, Bq/kg
Total group	Spearman's	0.070**	
	Sign. (2-tailed), p	0.005	
	N	1656	
Younger group	Spearman's	0.120	
	Sign. (2-tailed), p	0.144	
	N	150	
Middle group	Spearman's	-0.094*	
	Sign. (2-tailed), p	0.009	
	N	782	
Older group	Spearman's	-0.326**	
	Sign. (2-tailed), p	0.0001	
	N	724	

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

The moderate inverse association was found between ^{137}Cs specific activity and RI values in the group of children aged 12.0 – 18.0 years, and there was no link between age and RI.

The age dynamics of ^{137}Cs incorporation values is associated not so much with specific aspects of physical growth of children as with the alimentary factor. Children of younger age consume cow's and goat's milk produced in areas contaminated with radionuclides in larger quantities compared with children of older age.

A child's PG is closely associated with the state of vital systems of the human body, including the hematopoietic system. Peripheral blood erythrocyte and haemoglobin concentrations increase with a child's age, as evidenced by a positive association (Table 9).

Table 6

Results of correlation analysis between age and RI in groups of children examined

Groups of children	Correlation coefficient	Parameters	
		Age, years	RI
Total group	Spearman's	-0.325**	
	Sign. (2-tailed), p	0.0001	
	N	1656	
Younger group	Spearman's	-0.511**	
	Sign. (2-tailed), p	0.0001	
	N	150	
Middle group	Spearman's	-0.320**	
	Sign. (2-tailed), p	0.0001	
	N	782	
Older group	Spearman's	0.023	
	Sign. (2-tailed), p	0.532	
	N	724	

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

Table 7

^{137}Cs specific activity (Bq/kg) in children from the older group (12-17 years) with different RI values.

Variable	Subgroups of children with different RI values					
	Subgroup 1 (n =102)		Subgroup 2 (n =474)		Subgroup 3 (n =148)	
	Me	IR	Me	IR	Me	IR
^{137}Cs (Bq/kg)	1.80	1.65-2.08	1.70	1.56-1.97	1.53	1.43-1.70

Note. Subgroup number: Subgroup 1 – RI is ≤ 10.7; Subgroup 2 – RI is in the range of ≤ 13.7 and > 10.7; Subgroup 3 – RI is > 13.7.

Table 8

Results of quantitative comparison of variables (non-parametric analysis) in children from the older group (12-17 years) with different RI values.

Variable	Subgroup number	Ivankovsky raion		
		Number of cases	Average rank	Mann–Whitney U test, significance level, p
^{137}Cs (Bq/kg)	1	102	326.29	U=20319.500; P=0.011
	2	474	280.37	
	1	102	161.35	U= 3891.000; P=0.0001
	3	148	100.79	
	2	474	339.95	U= 21588.500; P=0.0001
	3	148	220.37	

Note. Subgroup number: Subgroup 1 – RI is ≤ 10.7; Subgroup 2 – RI is in the range of ≤ 13.7 and > 10.7; Subgroup 3 – RI is > 13.7.

An inverse association between ^{137}Cs specific activity and blood erythrocyte and haemoglobin concentrations found in the total group reflects the inhibition of cell proliferation processes under the influence of incorporated ^{137}Cs radionuclides (Table 9). This statement finds confirmation in children aged 12.0–18.0 years, when there is no pronounced effect of the age factor on hematopoiesis processes (Table 10). The studies conducted show that a child's body is sensitive towards even relatively small amounts of ^{137}Cs radionuclides.

Conclusions. As a result of the studies conducted, the dependence of ^{137}Cs specific activity, physical growth index and their associations on the age of children living in districts affected by the Chernobyl nuclear power plant accident has been found.

The inverse association was observed between ^{137}Cs specific activity values and blood erythrocyte and hemoglobin concentrations in the children examined.

The results obtained show that there is a negative effect of incorporated ^{137}Cs radionuclides on metabolic processes in the child's body.

Table 9

Results of correlation analysis between age, haemoglobin concentration, erythrocyte count and ^{137}Cs specific activity in children from the total group

Parameters	Correlation coefficient	Parameters			
		Erythrocyte count, 10^{12}/L	Hb, g/L	^{137}Cs specific activity, Bq/kg	Age, years
Age, years	Spearman's	0.196**	0.364**	-0.599**	1.000
	Sign. (2-tailed), p	0.0001	0.0001	0.0001	.
	N	1606	1606	1601	1607

Continuation of the table number 9

Parameters	Correlation coefficient	Parameters			
		Erythrocyte count, 10^{12}/L	Hb, g/L	^{137}Cs specific activity, Bq/kg	Age, years
^{137}Cs specific activity, Bq/kg	Spearman's	-0.170**	-0.312**	1.000	-0.599**
	Sign. (2-tailed), p	0.0001	0.0001	.	0.0001
	N	1600	1600	1601	1601
Hb, g/L	Spearman's	0.715**	1.000	-0.312**	0.364**
	Sign. (2-tailed), p	0.0001	.	0.0001	0.0001
	N	1605	1606	1600	1606
Erythrocyte count, 10^{12}/L	Spearman's	1.000	0.715**	-0.170**	0.196**
	Sign. (2-tailed), p	.	0.0001	0.0001	0.0001
	N	1604	1605	1600	1606

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

Table 10

Results of correlation analysis between age, haemoglobin concentration, erythrocyte count and ^{137}Cs specific activity in children aged 12,0-18,0 years

Parameters	Correlation coefficient	Parameters		
		Erythrocyte count, 10^{12}/L	Hb, g/L	^{137}Cs specific activity, Bq/kg
^{137}Cs specific activity, Bq/kg	Spearman's	-0.075*	-0.174**	1.000
	Sign. (2-tailed), p	0.044	0.0001	.
	N	721	721	721
Hb, g/L	Spearman's	0.739**	1.000	-0.174**
	Sign. (2-tailed), p	0.0001	.	0.0001
	N	721	721	721
Erythrocyte count, 10^{12}/L	Spearman's	1.000	0.739**	-0.725**
	Sign. (2-tailed), p	.	0.0001	0.044
	N	721	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.

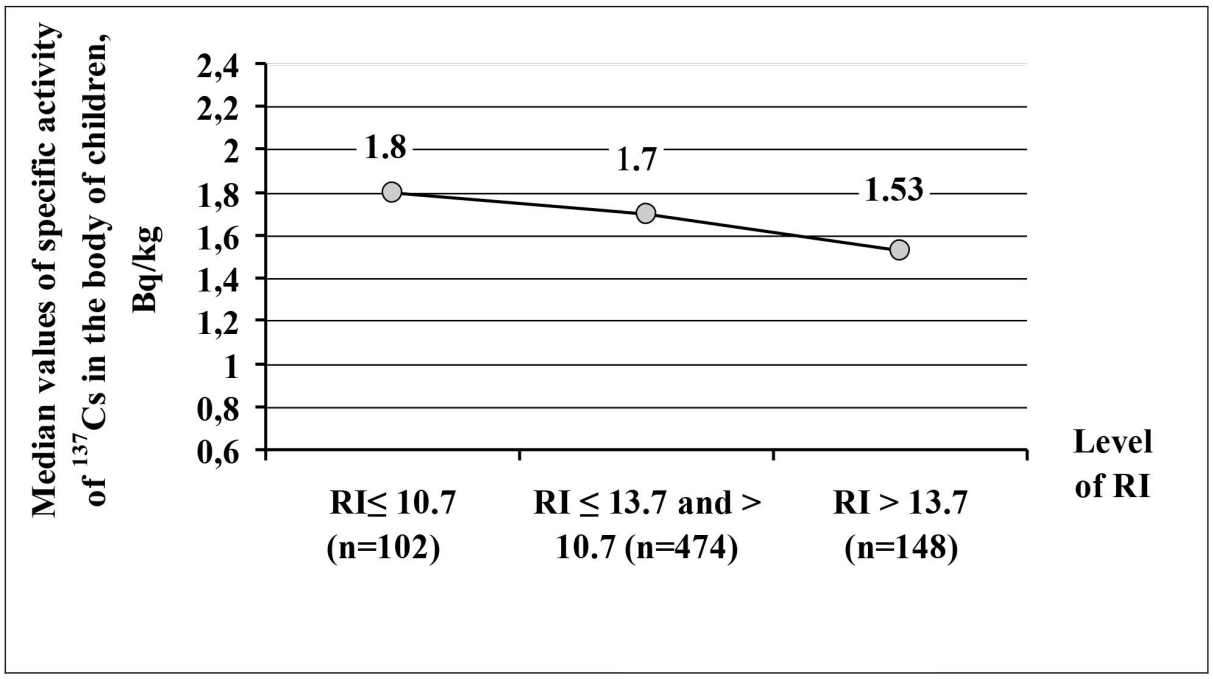

Figure. 1. Distribution of medians of ^{137}Cs specific activity values in the body of children of the older group with different levels of physical development (Rohrer index).

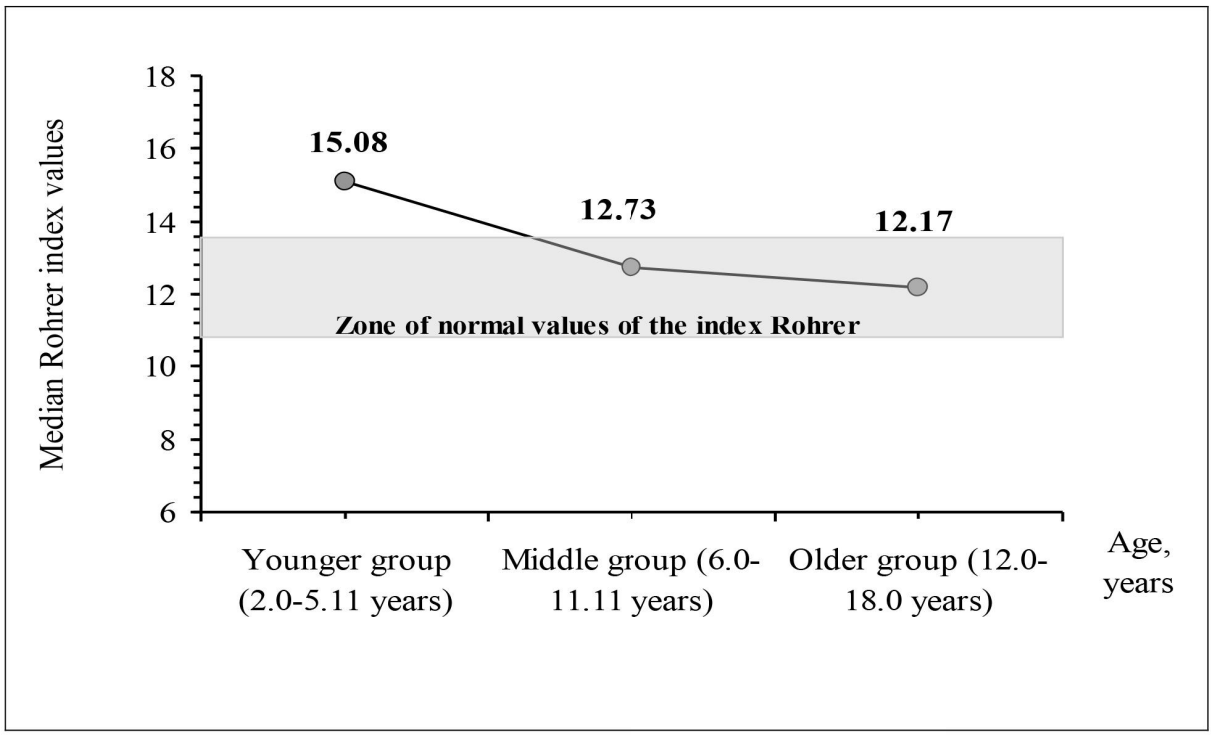

Figure. 2. The distribution of the medians of the values of the Rohrer index in children of different ages.

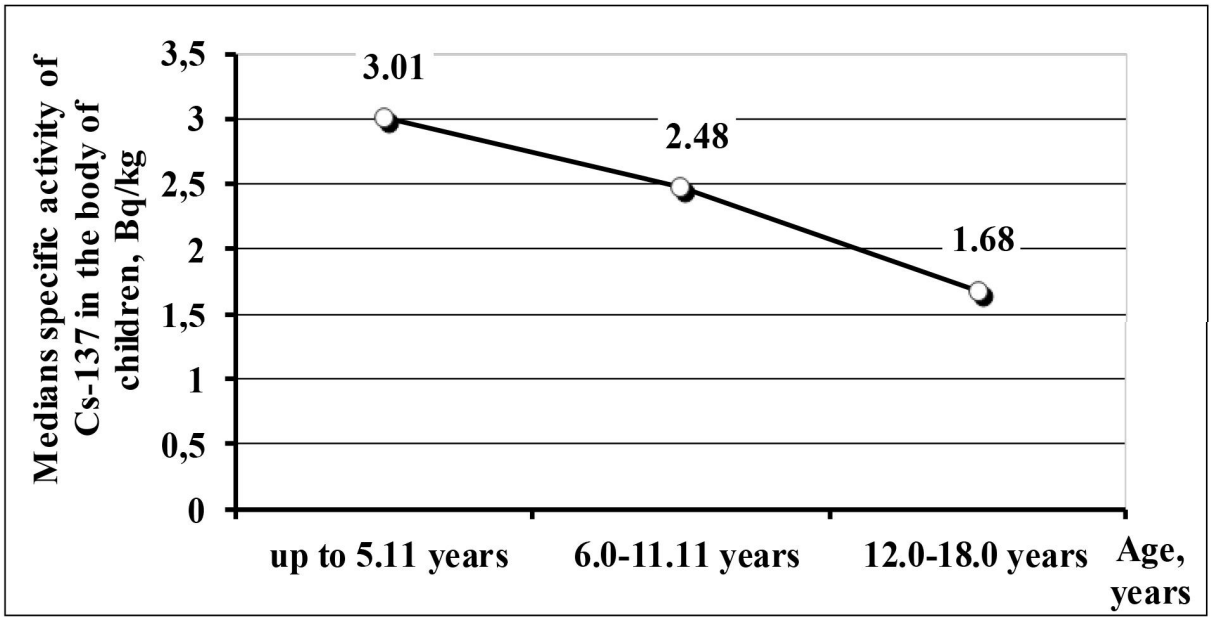

Figure. 3. The distribution of the median values of the specific activity of ^{137}Cs in the body of children of different age groups.

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ФИЗИЧЕСКОЕ РАЗВИТИЕ ДЕТЕЙ ПРИ ИНКОРПОРАЦИИ РАДИОНУКЛИДОВ ^{137}CS СПУСТЯ 30 ЛЕТ ПОСЛЕ АВАРИИ НА ЧЕРНОБЫЛЬСКОЙ АТОМНОЙ ЭЛЕКТРОСТАНЦИИ

Бандажевский Ю.И., Дубовая Н.Ф.

Учитывая негативную тенденцию заболеваемости и смертности, и в целом, демографической ситуации на территории, пострадавшей от аварии на Чернобыльской атомной электростанции, важным является оценка влияния радиационного фактора на процессы жизнеспособности организма, прежде всего детского.

Целью настоящего исследования явилось определение связи между инкорпорированными в организм радионуклидами ^{137}Cs и физическим развитием детей, спустя 30 лет после аварии на Чернобыльской атомной электростанции.

Методы исследования. Радиометрический, антропометрический, гематологический, математико-статистический.

Результаты. Выявлена зависимость показателей удельной активности ^{137}Cs и физического развития, и их корреляционных связей, от возраста детей, проживающих в районах, пострадавших от аварии на Чернобыльской атомной электростанции.

У детей из возрастной группы 2,0 - 5,11 лет значения удельной активности ^{137}Cs и индекса Ропера (ИР) были наибольшими, в сравнении с другими группами, обратная корреляционная связь между возрастом и ИР была средней силы, а связь между значениями удельной активности ^{137}Cs и ИР не определялась.

В группе детей в возрасте 12,0 - 18,0 лет между значениями удельной активности ^{137}Cs и ИР установлена обратная корреляционная связь средней силы, связь между возрастом и ИР отсутствовала.

Возрастная динамика показателей инкорпорации радионуклидов ^{137}Cs, связана не столько с особенностями физического развития детей, сколько с алиментарным фактором. Дети младшего возраста потребляют в больших количествах, по сравнению с детьми старшего возраста, коровье и козье молоко, получаемое на территории, загрязненной радионуклидами.

Между значениями удельной активности ^{137}Cs и количеством эритроцитов и гемоглобина в крови обследуемых детей установлена обратная корреляционная связь.

Полученные результаты свидетельствуют о негативном влиянии инкорпорированных радионуклидов ^{137}Cs на процессы обмена веществ детского организма.

Ключевые слова. Возраст детей, корреляционная связь, индекс Ропера, радионуклиды ^{137}Cs, радиоактивно загрязненная территория.

PHYSICAL GROWTH OF CHILDREN IN THE PRESENCE OF ^{137}CS INCORPORATION 30 YEARS AFTER THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Bandazhevsky Yu.I., Dubova N.F.

Taking into account negative trends in morbidity and mortality, as well as the demographic situation as a whole in areas affected by the Chernobyl nuclear power plant accident, it is important to carry out an assessment of the effect of the radiation factor on vital processes of the human body, and this, first of all, relates to children.

The purpose of this study was to identify associations between ^{137}Cs radionuclides incorporated into the body and physical growth in children 30 years after the Chernobyl nuclear power plant accident.

Research methods. Radiometric, anthropometric, haematological, mathematical and statistical.

Results. The dependence of ^{137}Cs specific activity, physical growth index and their associations on the age of children living in districts affected by the Chernobyl nuclear power plant accident has been found.

Children from the age group of 2.0 – 5.11 years had the highest values of ^{137}Cs specific activity and RI compared to other groups, an inverse association between age and RI was of moderate strength, and there was no association between ^{137}Cs specific activity and RI values.

A moderate inverse association was found between ^{137}Cs specific activity and RI values in the group of children aged 12.0 – 18.0 years, and there was no link between age and RI.

The age dynamics of ^{137}Cs incorporation values is associated not so much with specific aspects of physical growth in children as with the alimentary factor. Children of younger age consume cow's and goat's milk produced in areas contaminated with radionuclides in larger quantities compared with children of older age.

An inverse association was observed between ^{137}Cs specific activity values and blood erythrocyte and haemoglobin concentrations in the children examined.

The results obtained show that there is a negative effect of incorporated ^{137}Cs radionuclides on metabolic processes in the child's body.

Keywords. Age of children, association, physical growth index, ^{137}Cs radionuclides, radiation-contaminated areas.

ASSOCIATIONS BETWEEN ^{137}CS RADIONUCLIDES INCORPORATED INTO THE HUMAN BODY AND BLOOD PRESSUREIN CHILDREN LIVING IN DISTRICTS AFFECTED BY THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Bandazhevsky Yu.I., Dubova N.F.

Living in the constant presence of the radiation factor in areas affected by the Chernobyl nuclear power plant accident adversely impacts the health of the child and adult population [1].

A large number of cases of abnormal autonomic regulation manifesting itself both in an increase and a decrease in blood pressure were reported among children from Gomel and Mogilev regions of the Republic of Belarus during the first decade after the Chernobyl tragedy [2, 3].

However, the assessment of only absolute values of blood pressure when determining the effect of the radiation factor on the state of the cardiovascular system is not informative. The identification of associations between ^{137}Cs specific activity values and the main parameters of blood pressure in children within certain age groups is of greater importance.

The purpose of this work was to assess associations between ^{137}Cs specific activity and blood pressure values in children of separate age groups living in raions affected by the Chernobyl nuclear power plant accident.

Material and methods. This study was conducted within a project of the European Commission in Ukraine “Health and ecological programmes around the Chernobyl Exclusion Zone: Development, training and coordination of health-related projects”, implemented in Ukraine in districts adjacent to the Chernobyl nuclear power plant.

A total of 1474 children (742 boys and 732 girls) from Polessky and Ivankovsky districts of Kiev region, located near the Chernobyl nuclear power plant were examined. Bioethics rules were also followed and written parental consents were received for each subject. According to data of dosimetry certification of settlements, the territory of the districts has remained contaminated with radioactive substances after the Chernobyl accident until the present day (having a ^{137}Cs soil contamination density of 0.17 to 1.9 Cu/km^2) [4].

The children were divided into two groups according to their age at the time of examination: younger – 6.0 -11.11 years (n = 755), older – 12.0-18.0 years (n = 719).

Blood pressure was measured using the Cord (X) plore blood pressure monitor and ECG (Hungary).

^{137}Cs specific activity in the children was measured using a SICH-AKP-3 three-detector spectrometer (OOO NPP ATOMKOMPLEKSPRIBOR, Ukraine) during 10 minutes.

Before this, the children had their weight and height measured. Spectra were processed automatically, specific activities of radioactive elements were calculated and the information obtained 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), ± 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.
Associations between ^{137}Cs specific activity and blood pressure values 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. The critical level of significance for the null hypothesis (p) was set at 0.05.
Results and discussion. The mean age of the children was 8.6±0.06 years in the younger group and 13.9±0.05 in the older group. ^{137}Cs specific activity levels in the children varied from 1.1 to 199.0 Bq/kg. The absolute values of the variables determined are presented in Table 1.

Table 1

Statistical characteristics of analysed age variables of children examined

Variable	Younger group (6.0-11.11 years)		Older group (12.0-18.0 years)	
	Me	IR	Me	IR
^{137}Cs specific activity, Bq/kg	2.47	2.14-2.67	1.68	1.54-1.96
SBP mm Hg	114.0	107.0-121.0	126.0	118.0-133.0
DBP mm Hg	69.0	62.0-75.0	70.0	63.0-77.0
PP mm Hg	45.0	38.0-52.0	55.0	47.0-64.0
HR heart beats per 1 minute	90.0	81.0-100.0	81.0	72.0-91.0

Note. SBP – systolic blood pressure; DBP – diastolic blood pressure; PP – pulse pressure; HR - heart rate, the number of heart beats per 1 minute.

During the studies conducted, in the age groups of 6.0-11.11 and 12.0-18.0 years inverse associations were found between ^{137}Cs specific activity values in the range 1.1 to 199.0 Bq/kg and peripheral blood pressure, more pronounced with respect to systolic blood pressure values (Tables 2, 3).

A weak direct association was detected between ^{137}Cs specific activity and heart rate values in the younger age group (Table 2)

Table 2

Results of correlation analysis between ^{137}Cs specific activity, blood pressure and heart rate values of examined children aged 6.0-11.11 years from districts affected by the Chernobyl nuclear power plant accident

Parameter	Correlation coefficient, r_{xy}	Parameters			
		SBP mm Hg	DBP mm Hg	PP mm Hg	HR, heart beats per 1 minute
^{137}Cs specific activity, Bq/kg	Spearman's	-0.326**	-0.081*	-0.228**	0.126**
	p	0.0001	0.026	0.0001	0.001
	N	755	755	755	755

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

On this basis, it can be concluded that an increase in ^{137}Cs levels in the range of 1.1–199.0 Bq/kg in children is accompanied by a decrease in blood pressure and an elevation in heart rate.

These findings are in line with results of examination conducted by students of the Gomel State Medical Institute [5], as well as results of experimental studies conducted by the IRSN staff on laboratory animals [6].

At the same time, a high frequency of cases of borderline hypertension and hypertension was reported in a group of children from affected districts in Gomel region of the Republic of Belarus in the presence of pronounced incorporation of ^{137}Cs radionuclides into the body during the first ten years after the accident at the Chernobyl nuclear power plant [5].

Table 3

Results of correlation analysis between ^{137}Cs specific activity, blood pressure and heart rate values of examined children aged 12.0-18.0 years from districts affected by the Chernobyl nuclear power plant accident

Parameter	Correlation coefficient, r_{xy}	Parameters			
		SBP mm Hg	DBP mm Hg	PP mm Hg	HR, heart beats per 1 minute
^{137}Cs specific activity, Bq/kg	Spearman's	-0.318**	-0.098**	-0.228**	-.043
	p	0.0001	0.008	0.0001	0.249
	N	719	719	719	719

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

The results obtained suggest that under the effect of ^{137}Cs radionuclides incorporated into vital organs, including the brain, heart and endocrine organs [7], dysfunction of the autonomic nervous system connected to the endocrine system, including the hypothalamic-pituitary-thyroid axis, occurs in children and young people.

Conclusions. 1. Inverse associations were detected between ^{137}Cs specific activity, systolic and diastolic blood pressure values, as well as pulse pressure values in the groups of children aged 6.0-11.11 and 12.0-18.0 years from the districts affected by the Chernobyl nuclear power plant accident with ^{137}Cs levels in the range of 1.1-199.0 Bq/kg.

2. A weak direct association was identified between ^{137}Cs specific activity and heart rate values in the children from the younger age group.

3. The findings suggest that there is an abnormal autonomic regulation in children being under conditions of radiation risk associated with the ^{137}Cs incorporation into the body.

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СВЯЗЬ ИНКОРПОРИРОВАННЫХ В ОРГАНИЗМ РАДИОНУКЛИДОВ ^{137}CS С АРТЕРИАЛЬНЫМ ДАВЛЕНИЕМ У ДЕТЕЙ, ПРОЖИВАЮЩИХ В РАЙОНАХ, ПОСТРАДАВШИХ ОТ АВАРИИ НА ЧЕРНОБЫЛЬСКОЙ АТОМНОЙ ЭЛЕКТРОСТАНЦИИ

Бандажевский Ю.И., Дубовая Н.Ф.

При определении влияния радиационного фактора на состояние сердечно-сосудистой системы у детей, большое значение будет иметь определение корреляционных связей между показателями удельной активности ^{137}Cs и основными параметрами артериального давления.

Цель работы - оценка корреляционных связей между показателями удельной активности ^{137}Cs и артериального давления у детей отдельных возрастных групп, проживающих в районах, пострадавших от аварии на Чернобыльской атомной электростанции.

Методы исследования. Радиометрический, антропометрический, математико-статистический

Результаты. В группах детей в возрасте 6,0 - 11,11 и 12,0 - 18,0 лет из районов, пострадавших в результате аварии на Чернобыльской атомной электростанции, с содержанием в организме радионуклидов ^{137}Cs в диапазоне 1,1 - 199,0 Бк/кг, регистрируются обратные корреляционные связи между значениями удельной активности ^{137}Cs и систолического, диастолического артериального давления, а также показателями пульсового давления.

У детей младшей возрастной группы между значениями удельной активности ^{137}Cs и частотой сердечных сокращений определялась прямая корреляционная связь слабой силы.

Полученные результаты свидетельствуют о нарушении вегетативной регуляции у детей, пребывающих в условиях радиационного риска, связанного с инкорпорацией радионуклидов ^{137}Cs в организм

Ключевые слова. Возрастные группы детей, корреляционная связь, радионуклиды ^{137}Cs, систолическое и диастолическое артериальное давление, радиоактивно загрязненная территория.

ASSOCIATIONS BETWEEN ^{137}CS RADIONUCLIDES INCORPORATED INTO THE HUMAN BODY AND BLOOD PRESSURE IN CHILDREN LIVING IN DISTRICTS AFFECTED BY THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Bandazhevsky Yu.I., Dubovaya N.F.

The identification of associations between ^{137}Cs specific activity values and the main parameters of blood pressure will be of great importance when determining the effect of the radiation factor on the state of the cardiovascular system.

The purpose of this work was to assess associations between ^{137}Cs specific activity and blood pressure values in children of separate age groups living in districts affected by the Chernobyl nuclear power plant accident.

Research methods. Radiometric, anthropometric, mathematical and statistical.

Results. Inverse associations were detected between ^{137}Cs specific activity, systolic and diastolic blood pressure values, as well as pulse pressure values in the groups of children aged 6.0 - 11.11 and 12.0 - 18.0 years from districts affected by the Chernobyl nuclear power plant accident with ^{137}Cs levels in the range of 1.1 - 199.0 Bq/kg.

A weak direct association was identified between ^{137}Cs specific activity and heart rate values in the children from the younger age group.

The results obtained suggest that there is an abnormal autonomic regulation in children being under conditions of radiation risk associated with the ^{137}Cs incorporation into the body.

Keywords. Age groups of children, association, ^{137}Cs radionuclides, systolic and diastolic blood pressure, radiation-contaminated area.

^{137}CS CONCENTRATIONS AND ACTIVITY OF SERUM TRANSAMINASES IN CHILDREN FROM POLESSKY AND IVANKOVSKY DISTRICTS, KIEV REGION, UKRAINE, 30 YEARS AFTER THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

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The population residing in areas affected by the Chernobyl nuclear power plant accident has been living under conditions of constant radiation risk for the past 30 years [1, 2].

In this regard, it is important to determine the effect of radioactive substances incorporated into the human body on the state of vital organs and systems.

The activity of serum transaminases - aspartate aminotransferase (AST) and alanine aminotransferase (ALT), can serve as a marker of cell damage [3, 4].

The purpose of this study was to identify associations between the activity of serum transaminases and ^{137}Cs concentrations in the bodies of children living in districts affected by the Chernobyl nuclear power plant accident.

Material and methods. During a project of the European Commission in Ukraine "Health and ecological programmes around the Chernobyl Exclusion Zone: Development, training and coordination of health-related projects", 1320 children (666 boys and 654 girls) living in Polessky and Ivankovsky districts of Kiev region located near the Chernobyl nuclear power plant were studied. According to data of dosimetry certification of settlements, the territory of the raions has remained contaminated with radioactive substances after the Chernobyl accident until the present day (having the ^{137}Cs soil contamination density of 0.17 up to 1.9 Cu/km^2) [5].

Written parental consent was received for each child under study.

The children were divided into three groups according to their age at the time of examination: younger – 2.0-5.11 years (n = 91), middle – 6.0 -11.11 years (n = 580), older – 12.0-18.0 years (n = 649).

^{137}Cs specific activity in the children 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 information obtained was saved with the help of the AKWin software.

All the examined children considered to be healthy had blood drawn from the ulnar vein after fasting in the morning of the day of examination.

Serum AST and ALT activity levels were measured on the XL640 with ISE&PC spectrophotometer (Germany). The reference values for serum AST were 5.0–34.0 U/L, and for serum ALT – 4.0–36.0 U/L.

During the studies, we carried out a comparative assessment of values of ^{137}Cs specific activity, AST, ALT and AST/ALT ratio (De Ritis ratio) - the quotient of AST and ALT, for each child from different age groups, and associations between ^{137}Cs specific activity and AST, ALT and AST/ALT ratio values.

The statistical processing of the results obtained was performed using the IBM SPSS Statistics 22 software (USA). The arithmetic mean (M), ± 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.

The Student's t-test was used to compare relative values. The critical level of significance for the null hypothesis (p) was set at 0.05. Associations between ^{137}Cs specific activity and transaminase activity values in the age groups of children 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 analysis carried out showed that the proportion of cases when enzyme activity exceeded the reference values was 37.5 % for serum AST and 1.2 % for serum ALT in the total group of children examined (Table 1).

A dependence of the proportion of cases of increased serum AST activity on the age of children was reported. The proportion of cases of AST activity above 34.0 U/L was higher in the children from the younger group compared with those from the older group (Tables 1, 2).

The proportion of cases of serum ALT activity above 36.0 U/L had no statistically significant differences in separate age groups.

No cases of AST activity below 5.0 U/L were reported. A decrease in ALT activity below 4.0 U/L was found in 4 cases (0.3 % of the number of children examined).

Table 1

Proportion of cases of transaminase activity and AST/ALT ratio values above reference ranges in groups of children examined

Groups	Number of children	AST > 34.0 U/L		ALT > 36.0 U/L		AST > 34.0 U/L - AST/ALT > 2.0	
		Abs. number	%	Abs. number	%	Abs. number	%
Younger	91	48	52.8±5.2	3	3.30±1.9	43	47.25±5.2
Middle	580	271	46.7±2.1	6	1.03±0.4	181	31.21±1.9
Older	649	176	27.1±1.8	7	1.08±0.4	123	18.95±1.5
Total	1320	495	37.5±1.3	16	1.21±0.3	347	26.29±1.2

Table 2

Results of statistically significant differences in groups of children

Comparison groups	Parameter	T-test value, significance level, p	Parameter	T-test value, significance level, p
1 2	AST > 34.0 U/L	t = 1.09; p = 0.277545	AST > 34.0 U/L - AST/ALT > 2.0	t = 2.88; p = 0.004381
1 3	AST > 34.0 U/L	t = 4.67; p = 0.0001	AST > 34.0 U/L - AST/ALT > 2.0	t = 5.19; p = 0.0001
2 3	AST > 34.0 U/L	t = 7.09; p = 0.0001	AST > 34.0 U/L - AST/ALT > 2.0	t = 4.98; p = 0.0001

Note. Group 1 – younger group; 2 – middle group; 3 – older group.

ALT is a cytosolic enzyme, which is present mainly in the cytoplasm of liver cells [6]. Most of AST resides in the mitochondria of cells with a high level of energy metabolism, in particular, in cardiomyocytes and hepatocytes [3]. The activity of serum AST is normally low [7]. However, if cells are damaged and there is an oxidative stress, cell necrosis and mitochondrial decay occur resulting in AST being released into the blood. In view of this, the serum AST activity can serve as a marker of severe damage to high-energy cells [4]. Taking into account that most of adults and children have a large variability in serum AST and ALT activity levels, the AST/ALT ratio is used to assess the degree of cell damage. It can be used when carrying out a comparative analysis of cell damage in children of different age groups.

This ratio is a simple, fast and quite reliable predictor of outcomes in the presence of both liver [8, 9] and heart diseases [10]. However, if there is an increase in AST activity only, with no elevation in ALT activity, the AST/ALT ratio indicates that there is an extrahepatic source of AST.

Serum ALT and AST can be used as independent predictors of coronary heart disease [11].

In this study, the AST/ALT ratio exceeded 2.0 (the upper physiological limit for children) in 26.29 % of cases of the number of children whose AST levels were above 34.0 U/L (Table 1). In addition, the age dependence was established for this variable (Tables 1, 2).

Thus, it can be assumed that there is damage to high-energy cells in a significant number of children of the group under study. At the same time, the proportion of cases of such abnormalities is higher in the children of the younger group than in those of the older group.

^{137}Cs specific activity and serum AST activity values were also higher in the children of the younger group than in those from the middle and older groups, and were higher in the children of the middle group than in the children of the older

group (Tables 3–5). A similar dependence also refers to the AST/ALT ratio calculated for all the children examined, regardless of AST activity (Tables 3, 6).

Direct associations were found between ^{137}Cs specific activity and AST activity values, and between ^{137}Cs specific activity and AST/ALT ratio values in the total group of children. There was no association between ^{137}Cs specific activity and ALT activity (Table 7).

Table 3

Statistical characteristics of analysed variables of children examined

Parameters	Younger group (n = 91)		Middle group (n = 580)		Older group (n = 649)	
	Me	IR	Me	IR	Me	IR
^{137}Cs specific activity, Bq/kg	3.0	2.8-3.2	2.5	2.1-2.7	1.7	1.5-2.0
AST, U/L	34.5	31.4-39.3	33.3	28.1-39.4	28.5	22.3-34.5
ALT, U/L	12.8	10.4-16.1	15.3	12.2-18.8	14.2	11.3-17.2
AST/ALT	2.7	2.2-3.2	2.3	1.9-2.7	2.0	1.7-2.4

Table 4

Results of statistically significant differences in ^{137}Cs specific activity between groups of children

Parameter	Comparison groups	Comparison group size	Average rank	Mann–Whitney U test value, significance level, p
^{137}Cs specific activity, Bq/kg	1	91	540.7	U = 7762.5; p = 0.0001
	2	580	303.9	
^{137}Cs specific activity, Bq/kg	1	91	600.6	U = 8593.5; p = 0.0001
	3	649	338.2	
^{137}Cs specific activity, Bq/kg	2	580	816.3	U = 71467.5; p = 0.0001
	3	649	4354.1	

Note. Group 1 – younger group; 2 – middle group; 3 – older group.

The strength of the above associations was more pronounced in the younger group of children compared with the total group, as well as with the middle and older groups (Tables 7–9).

Table 5

Results of statistically significant differences in AST activity values between groups of children

Parameter	Comparison groups	Comparison group size	Average rank	Mann–Whitney U test value, significance level, p
AST, U/L	1	91	377.5	U = 22611.0; p = 0.028
	2	580	329.5	
	1	91	528.9	U = 15111.5; p = 0.0001
	3	649	348.3	
	2	580	717.9	U = 128552.5; p = 0.0001
	3	649	523.1	

Note. Group 1 – younger group; 2 – middle group; 3 – older group.

Table 6

Results of statistically significant differences in AST/ALT ratio values between groups of children

Parameters	Comparison groups	Comparison group size	Average rank	Mann–Whitney U test value, significance level, p
AST/ALT	1	91	450.6	U = 15960.5; p = 0.0001
	2	580	318.0	
	1	91	543.6	U = 13782.0; p = 0.0001
	3	649	346.2	
	2	580	672.0	U = 155166.5; p = 0.0001
	3	649	564.1	

Note. Group 1 – younger group; 2 – middle group; 3 – older group.

Table 7

Results of analysis of associations between values of ^{137}Cs specific activity (Bq/kg) and activity of serum transaminases in examined children of the total group (n = 1320)

Parameters	Correlation coefficient	Parameters			
		^{137}Cs	AST	ALT	AST/ALT
^{137}Cs	Spearman's	1.000	0.295**	- 0.027	0.285**
	Sign. (2-tailed), p	.	0.0001	0.328	0.0001
	N	1320	1320	1320	1320

Continuation of the table number 4

Parameters	Correlation coefficient	Parameters			
		^{137}Cs	AST	ALT	AST/ALT
AST, U/L	Spearman's	0.295**	1.000	0.412**	0.366**
	Sign. (2-tailed), p	0.0001	.	0.0001	0.0001
	N	1320	1320	1320	1320
ALT, U/L	Spearman's	- 0.027	0.412**	1.000	-0.606**
	Sign. (2-tailed), p	0.328	0.0001	.	0.0001
	N	1320	132	1320	1320
AST/ALT	Spearman's	0.285**	0.366**	-0.606**	1.000
	Sign. (2-tailed), p	0.0001	0.0001	0.0001	.
	N	1320	1320	1320	1320

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

The findings indicate that there is damage to high-energy cells in a significant number (26.29 %) of children living in the raions in Ukraine affected by the Chernobyl nuclear power plant accident. At the same time, there is a dependence of these abnormalities on the age of children. The frequency of manifestations and the enzyme activity values are higher in the children of the younger group than in the older groups.

A dependence of ^{137}Cs specific activity on the age of children was reported in the group of children under study. The activity level is higher in the children of the younger group than in the older children.

A direct association was observed between ^{137}Cs specific activity and AST activity values both in the total and in separate age groups of children

A similar association can be seen between ^{137}Cs specific activity and AST/ALT ratio values. There was no association between ^{137}Cs specific activity and ALT activity values.

The findings show that there is damage to mitochondria of heart cells with AST being released into the blood under the effect of incorporated ^{137}Cs radionuclides in the children living in the raions affected by the Chernobyl nuclear power plant accident.

This conclusion is confirmed by results of experimental studies with ^{137}Cs incorporation into the bodies of laboratory animals [12], as well as results of radiometric studies of internal organs of inhabitants of Gomel region performed during autopsies in 1996–1998 [13].

Table 8

Results of analysis of associations between ^{137}Cs specific activity and AST activity values in age groups

Groups of children	Correlation coefficient	Parameters	
		^{137}Cs specific activity, Bq/kg	AST, U/L
Younger group	Spearman's	0.306**	
	Sign. (2-tailed), p	0.003	
	N	91	
Middle group	Spearman's	0.101*	
	Sign. (2-tailed), p	0.015	
	N	580	
Older group	Spearman's	0.207**	
	Sign. (2-tailed), p	0.0001	
	N	649	

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

Table 9

Results of analysis of associations between ^{137}Cs specific activity and AST/ALT ratio values in age groups

Groups of children	Correlation coefficient	Parameters	
		^{137}Cs specific activity, Bq/kg	AST/ALT
Younger group	Spearman's	0.334**	
	Sign. (2-tailed), p	0.001	
	N	91	
Middle group	Spearman's	0.297**	
	Sign. (2-tailed), p	0.0001	
	N	580	
Older group	Spearman's	0.187**	
	Sign. (2-tailed), p	0.0001	
	N	649	

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

Since the 60s of the last century [14], ^{137}Cs radionuclides have been constantly entering the body of children living in areas where soil contains radioactive substances. As a result, mitochondrial structures of highly specialised cells are damaged, causing the death of the latter. In the absence of a possibility of the complete repair of cells of a damaged organ, there is a basis for the development of severe pathological processes. It is not always possible to identify them without the use of special research methods in childhood and adolescence.

In more mature age, diseases that cause death and disability may develop. These are, in particular, various cardiac arrhythmias, cerebrovascular disturbances, impaired myocardial and internal organ circulation, abnormal nervous and endocrine regulation.

Conclusions. 1. The proportion of cases when enzyme activity exceeded the reference values was 37.5 % for serum AST and 1.2 % for serum ALT.

2. The AST/ALT ratio values above 2.0 (the upper physiological limit for children) were detected in 26.29 % of cases in the group of children whose AST levels were above 34.0 U/L.

3. The relative and absolute values of serum AST activity, as well as AST/ALT ratio are higher in the children from the younger group than in those from the older groups.

4. ^{137}Cs activity levels are higher in the bodies of children from the younger group than in those from the older groups.

5. Direct associations were identified between ^{137}Cs specific activity and AST activity values, and between ^{137}Cs specific activity and AST/ALT ratio values. The strength of the above associations was more pronounced in the younger group of children compared with the total group, as well as with the middle and older groups. There was no association between ^{137}Cs specific activity and ALT activity values.

6. Relatively small amounts of incorporated ^{137}Cs radionuclides cause damage to mitochondria of heart cells, with AST being released into the blood, in the children living in raions affected by the Chernobyl nuclear power plant accident.

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СОДЕРЖАНИЕ РАДИОНУКЛИДОВ ^{137}CS И АКТИВНОСТЬ ТРАНСАМИНАЗ СЫВОРОТКИ КРОВИ У ДЕТЕЙ ИВАНКОВСКОГО И ПОЛЕССКОГО РАЙОНОВ КИЕВСКОЙ ОБЛАСТИ УКРАИНЫ СПУСТЯ 30 ЛЕТ ПОСЛЕ АВАРИИ НА ЧЕРНОБЫЛЬСКОЙ АТОМНОЙ ЭЛЕКТРОСТАНЦИИ

Бандажевский Ю.И., Дубовая Н.Ф.

На территории, пострадавшей от аварии на Чернобыльской атомной электростанции, важно определить связь между инкорпорированными в организм радиоактивными элементами и состоянием жизненно важных систем организма человека.

Индикатором клеточного повреждения может служить активность трансаминаз: АСТ и АЛТ в сыворотке крови.

Целью исследования явилось определение связи между активностью сывороточных трансаминаз и содержанием радионуклидов ^{137}Cs в организме детей, проживающих в районах, пострадавших от аварии на Чернобыльской атомной электростанции.

Методы исследования. Радиометрический, спектрофотометрический, математико-статистический.

Результаты. Удельный вес случаев, когда активность фермента превышала референтные значения, для сывороточной АСТ составил 37,5 %, для сывороточной АЛТ - 1,2 %.

Превышение значение коэффициента де Ритиса значений 2,0 (верхняя физиологическая граница для детей) в группе детей, у которой уровень АСТ был выше 34,0 U/л, регистрировалось в 26,29 % случаев.

У детей младшей группы относительные и абсолютные показатели активности сывороточной АСТ, а также коэффициента де Ритиса больше, чем у детей старших группах.

Уровень активности ^{137}Cs в организме детей младшей группы выше, чем в организме детей старших групп.

Между показателями удельной активности ^{137}Cs и активности АСТ, удельной активности ^{137}Cs и значениями коэффициента де Ритиса, определялась прямая корреляционные связь. Сила указанной связи в младшей возрастной группе детей была более выраженной, по сравнению с общей группой, а также со средней и старшей возрастными группами.

Между показателями удельной активности ^{137}Cs и активности АЛТ корреляционная связь отсутствовала.

У детей, проживающих в районах, пострадавших от аварии на Чернобыльской атомной электростанции, относительно небольшие количества инкорпорированных радионуклидов ^{137}Cs, вызывают повреждение митохондрий клеток сердца, с выходом в кровь АСТ.

Ключевые слова. Корреляционная связь, радионуклиды ^{137}Cs, АСТ, АЛТ, коэффициент де Ритиса, радиоактивно загрязненная территория.

^{137}CS CONCENTRATIONS AND ACTIVITY OF SERUM TRANSAMINASES IN CHILDREN FROM POLESSKY AND IVANKOVSKY DISTRICTS, KIEV REGION, UKRAINE, 30 YEARS AFTER THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Bandazhevsky Yu.I., N.F.Dubovaya

It is important to determine a relationship between the radioactive substances incorporated into the body and the state of vital systems of the human body in areas affected by the Chernobyl nuclear power plant accident.
The activity of serum transaminases – AST and ALT, can serve as a marker of cell damage.
The purpose of this study was to identify associations between the activity of serum transaminases and ^{137}Cs concentrations in the bodies of children living in districts affected by the Chernobyl nuclear power plant accident.
Research methods. Radiometric, spectrophotometric, mathematical and statistical.
Results. The proportion of cases when enzyme activity exceeded the reference values was 37.5% for serum AST and 1.2% for serum ALT.
The AST/ALT ratio values above 2.0 (the upper physiological limit for children) were detected in 26.29 % of cases in the group of children whose AST levels were above 34.0 U/L.
The relative and absolute values of serum AST activity, as well as AST/ALT ratio are higher in children from the younger group than in those from the older groups.
^{137}Cs activity levels are higher in the bodies of children from the younger group than in those from the older groups.
Direct associations were identified between ^{137}Cs specific activity and AST activity values, and between ^{137}Cs specific activity and AST/ALT ratio values. The strength of the above associations was more pronounced in the younger group of children compared with the total group, as well as with the middle and older groups.
There was no association between ^{137}Cs specific activity and ALT activity values.
Relatively small amounts of incorporated ^{137}Cs radionuclides cause damage to mitochondria of heart cells, with AST being released into the blood, in children living in districts affected by the Chernobyl nuclear power plant accident.
Keywords. Children, association, ^{137}Cs radionuclides, AST, ALT, AST/ALT ratio, radiation-contaminated areas.

THE RISK OF CARDIOVASCULAR DISEASES IN THE POPULATION LIVING IN THE TERRITORIES AFFECTED BY THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Bandazhevsky Yu.I.

The problem of cardiovascular diseases is one of the most significant in the health care system. A huge number of people around the world die annually due to heart and vascular diseases. Moreover, the highest mortality rates have been reported in areas contaminated with radioactive elements due to the Chernobyl nuclear power plant accident, including among men of working age [1, 2, 3].

The world community first faced radiation exposure 70 years ago. Since then, representatives of the nuclear power industry have done and continue to do everything in their power to hide the negative effect on humans of radioactive elements that have polluted the biosphere of the entire earth as a result of nuclear weapons testing and technogenic catastrophes. This, in particular, is confirmed by the following facts. The research monograph by A.N. Marey, R.M. Barkhudarov, N.Ya. Novikova "Global Cs-137 fallout and the human" published by the Atomizdat Moscow Publishing House in 1974 presents a map of contamination with radioactive caesium of the territory of the Belarusian and Ukrainian Polesie in the 60s of the 20th century long before the Chernobyl nuclear power plant accident occurred in 1986 [4]. However, this book currently does not exist officially in the Russian Federation. After the accident at the Chernobyl nuclear power plant, it disappeared from many libraries in the USSR. We managed to find it only in one small library in Gomel region of the Republic of Belarus.

After the Chernobyl accident, the degree of radioactive contamination of the territories of Ukraine, the Republic of Belarus and the Russian Federation was very high [5-8]. At the same time, this did not stop the leadership of the USSR from using the meat of farm animals containing huge amounts of radioactive elements (in particular, $1.1x10^{-7}$-$1.0x10^{-6}$ Cu/kg) for the production of sausage products, canned and partially prepared meat food items mixing it in a ratio of one to ten with the "normal" meat (From the text of the message delivered by the Chairman of the Agro-Industrial Committee of the USSR V.S. Murakhovskiy to the Politburo of the CPSU Central Committee).

Radioactive elements with food, water, and as part of air masses have spread, and continue to spread over great distances from the epicenter of the accident.

Thus, the entire life of many generations of people in the countries of the former USSR, and not only, has dealt, is dealing, and will deal with radioactive agents.

The tragedy of the current situation lies also in the fact that the physiological effects in humans and animals that have been discovered in the last half century are difficult to separate from the radiation component, since radioactive elements are present everywhere. It is improper to try to present this phenomenon as some natural background radiation, since a number of radionuclides, including ^{137}Cs, do not occur naturally.

After the Chernobyl nuclear power plant accident in 1986, the secret information about radiation was partially exposed. Due to the lack of medical personnel in the affected areas of Gomel and Mogilev regions, in 1990 it was decided to establish the Gomel State Medical Institute. And already in 1992, the Institute-based research studies began to establish an effect of the radiation factor due to the Chernobyl accident on vital systems of the human body, including the cardiovascular system in children living in Gomel and Gomel region, which according to official data is the territory with the highest contamination with radioactive elements [5-8]), as well as in other cities of the Republic of Belarus, in particular, in Grodno). Electrocardiography was chosen as a diagnostic test for the cardiac activity. All the children had their radioactive caesium levels measured. A non-selective study showed that ^{137}Cs concentrations in the children subjected to monitoring were tens and hundreds of Bq per kilogram of body mass.

In addition, metabolic variables were also measured in the children. At the same time, a series of experimental studies was conducted using a natural model of incorporation of radioactive elements as part of food products into the body of laboratory animals [9-12]. A very important component of the studies, which later received wide international public response was the determination of radioactive elements in the organs of deceased children and adults that had lived in areas affected by the accident at the Chernobyl nuclear power plant [11, 12, 13]. As a result of the studies conducted, a conclusion was made about the negative effect of radionuclides incorporated into the body on the state of vital systems, including the cardiovascular system of the developing body. A relationship between incorporated ^{137}Cs levels and frequency of electrocardiographic changes in children was also established. Pathomorphological studies of autopsy material of adults, children and experimental animals confirmed the relationship between incorporated ^{137}Cs and cardiovascular morpho-functional changes [9-14].

The greatest irritation among defenders of nuclear energy is created by the fact that these pathological effects are caused by relatively small, from their point of view, doses of radioactive exposure. The studies on the medical consequences of the Chernobyl nuclear power plant accident that had been conducted at the Gomel Medical Institute since 1990, were unexpectedly discontinued in July 1999.

And only many years later, in 2013-2017, it was possible to launch, thanks to the help of like-minded people from Europe, a large social project of the European Commission in Ukraine “Health and ecological programmes around the Chernobyl Exclusion Zone: Development, training and coordination of health-related projects”, within which new studies were performed.

During the project, we were able to improve a system of the regular medical check-up of children from Ivankovsky and Polessky raions of Kiev region directly adjacent to the Chernobyl nuclear power plant which allowed us to identify the initial stages of pathological processes in vital organs and systems in the children. At the same time, abnormalities detected during the monitoring were analysed in the context of the structural and functional integrity of the body.

The state of the cardiovascular system in the children was assessed with the help of modern diagnostic systems, that enabled us to determine accurately the heart rate, blood pressure level and electrocardiographic changes.

With the help of modern radiometric equipment, it was possible to establish a relationship between relatively small quantities of radionuclides and changes in the vital organs in the children examined, including the cardiovascular system [15].

In order to identify the pathogenetic mechanisms of the abnormalities found, we carried out genetic analyses of folate metabolism, one of the main metabolic cycles in the human body, and measured blood levels of homocysteine, a product of the essential amino acid methionine [15-26].

Taking into account the information received, it was concluded that the population living in areas contaminated with radioactive agents due to the Chernobyl nuclear power plant accident, was at high risk of developing cardiovascular diseases. In addition, the nature of these pathological processes may be different: it may either belong to stochastic effects or refer to deterministic states. We were able to show that pathological processes in the cardiovascular system, as in other vital organs and systems, began in childhood and were closely associated with metabolic abnormalities which occurred under the effect of radioactive elements incorporated into the body [27-30]. Thus, on the basis of results of long-term studies (1992-2018) we can draw a conclusion that under long-term chronic exposure radiocaesium causes cardiac effects.

The results obtained by us are inconsistent with the conclusion made participants of a cross-sectional population-based study conducted by an international group of researchers from France (IRSN, Department of Cardiology Bichat Hospital, Paris) and the Russian Federation (Department of Cardiology, Bryansk Diagnostic Center) in Bryansk region, Russian Federation in 2009-2013 [31].

According to a text of the officially published article, on the basis of an assessment of results of examination of 17697 children aged 2.0–18.0 years these researchers did not observe an association between cardiac arrhythmia and ^{137}Cs deposition levels in Bryansk region, Russian Federation, exposed to Chernobyl fallout. The suspected increase of cardiac arrhythmia in children exposed to Chernobyl fallout is not confirmed [31]. In this regard, on July 11, 2018, the Le Monde newspaper published an article «Les maladies cardiaques et Tchernobyl», where the main points and conclusions of the study were explained to the French readers. The conclusion of the article sounds categorically - “The study conducted allows to make a strong conclusion. Current contamination does not cause cardiac arrhythmias. And the previous opposite statements (I think it also refers to works by Yury Bandazhevsky and Galina Bandazhevskaya, as they were mentioned in the article – author’s note) were done on the basis of poorly performed observations. Thus, the main direct consequences of radioactive contamination due to the accident for children (under 18.0) remain almost 7000 cases of thyroid cancer observed in the late 1980s and early 1990s”.

Due to this conclusion, I had to review the article published by the team members from IRSN and Bryansk Diagnostic Center [31].

A methodological part is the main part of a scientific study. In this regard, a number of principal aspects should be noted:

$^2/_3$ of the children examined were urban children, so a selective study was conducted in Bryansk region, since children from rural areas who were in direct contact with radionuclides were not included in this study. This is understandable because it is much easier to organise the examination of urban children than to go to small localities. However, it is necessary to take into account that urban and rural residents have different socio-economic living conditions.

Currently, urban children in present conditions are less exposed to radiation even if they live in radiation-contaminated areas, since they have much more opportunities to consume "clean" food in terms of radiation compared to rural children. Due to poverty, rural children are constantly forced to consume locally produced food – cow's and goat's milk, vegetables grown on soils contaminated with radionuclides, meat of wild animals, fish from local water bodies, forest berries and mushrooms [15].

Due to the fact that forest trees are used for heating houses and cooking in rural areas, rural children have to constantly breathe air containing wood combustion products, including radioactive elements.

Therefore, high radionuclide levels in rural children are stable and consistent. A cross-sectional radiometric study among rural children will reflect more objectively the radiation expansion than among urban children, whose radionuclide levels can vary greatly depending on what food products are consumed. Therefore, even the selection of contaminated and control raions on the basis of ^{137}Cs soil deposition makes no sense.

Thus, the principal methodological mistake in the organisation of this study is a cross-sectional examination of mainly urban rather than rural child population.

As a counter-argument, I can say that within the project of the European Commission we focused on results of examinations of rural children, since they are exposed to more radiation through consuming locally produced food and really reflect the effects of radiation exposure 30 years after the Chernobyl nuclear power plant accident.

If we compare the work under analysis with the studies conducted at the Gomel Medical Institute in 1992-1997, one can note the following.

When conducting a study aimed at identifying effects of a particular environmental factor on a particular system, in this case, the cardiovascular system, it is necessary to carefully select the groups to be examined. In particular, a comparative analysis should be made between children of the same age both within a group and between groups, who constantly and for a long time (most of time of a day) are in the similar conditions and receive the same type of meals. Currently, this is difficult to implement in the post-Soviet space. We managed to conduct our studies in the Republic of Belarus in 1992-1993, when a similar system of social life existed, in particular, pre-school and school institutions. The population also lived in quite the same socio-economic conditions.

For our studies, we chose pre-school institutions which were similar in terms

of the number of children, buildings and diets in Gomel region and Grodno. The children aged 3.0-7.0 years, whom we examined were considered to be healthy and attended pre-school institutions. They had no bad habits, did not smoke, did not drink alcohol or use drugs, which is very important when conducting studies on the relationship between radiation exposure and the state of the cardiovascular system. Due to the socio-economic conditions existing at that time (total poverty of the post-Soviet period), during the day, children were given similar diets established by the state, and food products with the same ^{137}Cs and ^{90}Sr contamination levels according to the republican acceptable limits. Thus, we examined officially healthy children who were constantly in the same conditions of living and feeding and marked radiation exposure.

The authors of the study under review used for the determination of the relationship between the radiation factor and arrhythmias urban children of different ages, from families with different socio-economic opportunities, and these factors have a different impact on the state of the cardiovascular system. It is impossible to identify the true cause of cardiovascular conditions in this situation. A child may live in excellent conditions and not be exposed to radiation, but before a study he may eat foods containing radionuclides. As a result, an ECG examination will not identify any abnormalities, while a radiological examination will detect radioactive elements in the body.

It is very doubtful to conclude that with such a high level of drug addiction in Russia, the children aged 12.0-18.0 years from the group examined have never smoked or used drugs. A questionnaire survey of children in most cases will not provide objective information.

The next problem is that the study conducted detected ^{137}Cs radionuclides in several percents of cases of the total number of children examined. ^{137}Cs radionuclides were not detected in 78.6 % of children from contaminated territories and 86.3 % of children from control territories.

Thus, the children in whom ^{137}Cs radionuclides were detected comprise a small proportion of children examined.

The reason for this may lie in the fact that mainly urban children were examined. This is partly because the detection limit for children in this study was determined to be 1200 Bq per body. It was established that concentrations below the limit were not recorded. The authors ignored the detection of smaller quantities of radionuclides in the body of children and their relationship with abnormal metabolism and the state of the cardiovascular system. The studies that we conducted in 2013-2017, as part of the project of the European Commission found that there were associations between relatively small concentrations of radionuclides and a number of physiological variables [15].

All the children were united in groups according to the level of ^{137}Cs specific activity, without taking into accout the age. Thus, high radionuclide levels were taken into account and the age of the groups under comparison was not considered.

It is not correct from a methodological point of view to determine any phenomenon, including the presence of cardiac rhythm disorders, in this relatively small group in comparison with a total group. In the studies conducted at the Gomel Medical Institute during the first ten years after the Chernobyl nuclear power plant accident ^{137}Cs radionuclides were detected in all children examined, since the whole population of Gomel region, and the whole of Belarus was exposed to incorporated radioactive elements [9-12].

The policy of state structures on the distribution of food products contaminated with radionuclides among all the inhabitants of the country also added to contamination of the population.

The following remark concerns the material presented. Different types of cardiac abnormalities, including in separate age groups, were not presented in the article under review. I think that mixing all types of arrhythmias in one group is an illustration of a non-professional attitude towards the problem. The genesis of various types of cardiac arrhythmias can be different. There are some types of arrhythmias that can be evaluated as stochastic effects. At the same time, the radiation dose received by the human body determines only the probability of their occurrence, but not their severity. Incomplete right bundle branch block detected by us in a large number of children in Gomel region belongs to such arrhythmias. We established a dose-effect relationship with respect to this very type of arrhythmia [12]. It should be noted that the frequency of this type of arrhythmias is much higher in the Republic of Belarus than in Ukraine [32]. Unfortunately, the authors did not provide statistics on this type of arrhythmias, as well as on certain types that they identified among the children examined in Bryansk region.

There are arrhythmias that belong to the group of deterministic effects, which suggest the presence of a certain minimum limit, below which the radiation effect is completely absent, and above which the severity of the effect depends on the dose received. Such arrhythmias can include bradycardia and tachycardia, and also sinus bradycardia and sinus tachycardia. The authors of the study came across such arrhythmias, since they indicate their codes among the material analysed: abnormalities of heart beat, R00.0 - tachycardia, unspecified; R00.1 - bradycardia, unspecified. However, statistical data on this type of arrhythmia is also absent.

A single examination of children does not enable to identify accurately cases of tachycardia and bradycardia, taking into account that they may be caused by different pathological processes.

The article under analysis discussed the issue of an effective radiation dose of 1mSv per year, but this is not correct at the the present moment.

In recent years in Russia, a level of 0.1 mSv/year is applied to employees of enterprises with links to radiation exposure [33], this level should be even smaller for the population living in affected areas.

Thus, the publication under review reflects serious violations in conducting the cross-sectional population-based study carried out by the international group of researchers from France (IRSN, Department of Cardiology Bichat Hospital, Paris) and the Russian Federation (Department of Cardiology, Bryansk Diagnostic Cen-

ter) in Bryansk region, Russian Federation in 2009-2013 [31].

The data presented throws discredit upon their reliability and significance. One can only regret that the large-scale study has no scientific value because of the gross methodological mistakes.

Organisers of such studies should have been more responsible towards the problem of consequences of technogenic catastrophes, since the health and lives of many millions of people depend on it.

The analysis of the material published allows to state that the authors of the following article made a wrongful conclusion.

«Is exposure to ionising radiation associated with childhood cardiac arrhythmia in the Russian territories contaminated by the Chernobyl fallout? A cross-sectional populationbased study»

Jean-Rene Jourdain, Geraldine Landon, Enora Clero, Vladimir Doroshchenko, Aleksandr Silenok, Irina Kurnosova, Andrei Butsenin, Isabelle Denjoy, Didier Franck, Jean-Pierre Heuze, Patrick Gourmelon.

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РИСК ВОЗНИКНОВЕНИЯ СЕРДЕЧНО-СОСУДИСТЫХ ЗАБОЛЕВАНИЙ У НАСЕЛЕНИЯ, ПРОЖИВАЮЩЕГО НА ТЕРРИТОРИИ, ПОСТРАДАВШЕЙ ОТ АВАРИИ НА ЧЕРНОБЫЛЬСКОЙ АТОМНОЙ ЭЛЕКТРОСТАНЦИИ

Бандажевский Ю.И.

Статья посвящена анализу результатов исследований влияния инкорпорированных радионуклидов ^{137}Cs на состояние сердечно-сосудистой системы детей, проживающих на территории, пострадавшей от аварии на Чернобыльской атомной электростанции.

Ключевые слова: детский организм, сердечно-сосудистая система, аритмии, инкорпорированные радионуклиды ^{137}Cs.

THE RISK OF CARDIOVASCULAR DISEASES IN THE POPULATION LIVING IN THE TERRITORIES AFFECTED BY THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Bandazhevsky Yu.I.

The article is dedicated to the analysis of results of studies of the effect of incorporated ^{137}Cs radionuclides on the state of the cardiovascular system in children living in areas affected by the Chernobyl nuclear power plant accident.

Keywords: child's body, cardiovascular system, arrhythmias, incorporated ^{137}Cs radionuclides.

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