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# ГІПЕРГОМОЦИСТЕЇНЕМІЯ У ДІТЕЙ – ІНДИКАТОР ЕКОЛОГІЧНОГО НЕБЛАГОПОЛУЧЧЯ, ПОВ'ЯЗАНОГО З ЧОРНОБИЛЬСЬКОЮ ЗОНОЮ ВІДЧУЖЕННЯ

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# HYPERHOMOCYSTEINEMIA IN CHILDREN IS AN INDICATOR OF ENVIRONMENTAL PROBLEMS ASSOCIATED WITH THE CHORNOBYL EXCLUSION ZONE

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The physical development of a person depends on his genetic potential and environmental influences.

Relevant, from a scientific and practical point of view, is the determination of markers of violations of the physiological interaction of endogenous and exogenous factors, leading to the development of severe pathological processes. The sooner it is possible to find a manifestation of a future disease, the more effective will be preventive and therapeutic measures.

The Chornobyl Exclusion Zone (ChEZ) is the territory most contaminated with radioactive elements after the accident at the 4-th power unit of the Chornobyl Nuclear Power Plant (ChNPP) in 1986. Soils and forest trees growing on them contain a huge amount of long-lived radionuclides, of which $^{137}$Cs, $^{90}$Sr, and $^{241}$Am are the most common [1]. Forest fires that constantly occur in the ChEZ contribute to the fact that these radionuclides and their decay products spread with air currents to other areas [2].

Some conventionality of the ChEZ should be noted, since, in the soils and trees, in the territories adjacent to it, the indicated radioactive elements are also determined in large quantities [3]. The population that lives in these ter-

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***Мета дослідження:** визначення участі генетичного фактора (поліморфізм MTHFR:C677T), що впливає на активність основного фермента фолатного циклу – метилентетрагідрофолатредуктази та зовнішньосередовищного впливу, що включає радіаційний чинник, у виникненні стану гіпергомоцистеїнемії у дітей, які проживають поблизу Чорнобильської зони відчуження (ЧЗВ).*

***Методи дослідження:** імунохімічний, математико-статистичний.*

***Результати**. У рамках міжнародних проєктів визначено рівні гомоцистеїну ($H_{cy}$) та алельних варіантів генетичного поліморфізму MTHFR:C677T у 624 дітей віком 13-17 років із Іванківського та Поліського районів Київської області. Встановлено, що підвищення рівня $H_{cy}$ у крові та збільшення кількості випадків гіпергомоцистеїнемії в обстежених групах дітей пов'язані з лісовими пожежами у ЧЗВ у 2015 та 2020 роках. В умовах вираженого впливу радіоактивних агентів та продуктів горіння лісових дерев питома вага випадків гіпергомоцистеїнемії у групах дітей з алеллю Т поліморфізму MTHFR:677 у геномі і без неї не мала статистичних відмінностей. Індикатором екологічного неблагополуччя у ЧЗВ та прилеглих до неї районах є підвищення понад фізіологічний рівень концентрації $H_{cy}$ у крові дітей підліткового віку з відсутністю у геномі алелі Т поліморфізму MTHFR:677. У районах, які постраждали від аварії на Чорнобильській атомній електростанції, необхідне регулярне проведення моніторингових досліджень стану здоров'я дітей з використанням тестів на вміст $H_{cy}$ у крові та визначення генів фолатного циклу.*

***Ключові слова: гомоцистеїн, гіпергомоцистеїнемія, підлітки, Чорнобильська зона відчуження.***



ritories is forced to conduct economic activities, being exposed to the danger of constant radiation exposure.

In many cases, no link can be established between this exposure and severe illness resulting in death or disability.

In our opinion, this is due to a very poor study of the real situation in the territory affected by the Chornobyl accident, when internal organs and the brain are simultaneously incorporated by long-lived radionuclides [4].

At the same time, even relatively small concentrations of radionuclides in the body can cause pronounced metabolic disorders, as well as structural and functional changes at the cellular and organ levels [5]. The children's organism is especially sensitive to this influence.

In this regard, the problem of preventive medicine in the areas affected by the Chornobyl accident, in our opinion, is the early diagnosis of these conditions, and hence the selection of markers illustrating the initial stages of the pathological process.

Homocysteine ($H_{cy}$), a sulfur-containing amino acid, a product of methionine metabolism, should be considered as one of these markers.

It was revealed that an increase in the content of this metabolite in the blood is accompanied by serious disorders in the cardiovascular system, leading to impaired circulation of vital organs [6, 7]. Hyperhomocysteinemia has been associated with oncological diseases, pathology of the nervous system, congenital malformations and impaired pregnancy [8-10].

Mostly hyperhomocysteinemia was recorded in adults, especially the elderly. At the same time, the relationship of this condition with the development of a particular pathological process was assessed.

Monitoring studies were carried out in a number of countries to determine the level of $H_{cy}$ in the blood of physiologically healthy children [11, 12]. However, at the same time, no assessment was made of the influence of internal and external factors on the exchange of this agent.

On the territory bordering the ChEZ, the results of monitoring studies of the child (adolescent) contingent with an assessment of the level of $H_{cy}$ in the blood and the state of the genetic system are very valuable, controlling the main enzymes of the folate cycle (FC), in particular, methylenetetrahydrofolate reductase. A significant decrease in the activity of this enzyme is recorded if the genome contains the risk allele T of the MTHFR:C677T polymorphism [13, 14].

***The aim of this study*** was to determine the involvement of a genetic factor (polymorphism MTHFR:C677T), which affects the activity of the main FC enzyme, methylenetetrahydrofolate reductase, and environmental exposure, including a radiation factor, in the occurrence of a state of hyperhomocysteinemia in children living near the ChEZ.

**Material and research methods.** The paper analyzes the results of studies conducted in 2015 in Ukraine within the framework of the projects of the European Commission «Health and Ecological Programmes around the Chornobyl Exclusion Zone: Development, training and coordination of health-related projects» and the Regional Council of Rhone-Alpes (France), and also, in January 2022, with the financial support of the public organization «Children of Chornobyl» (France).

624 children from Ivankivskyi and Polesskyi districts of the Kyiv region, located near the ChEZ, were subjected to laboratory examination. After the Chornobyl accident in 1986, the territory of these districts was contaminated with radioactive elements [15]. In particular, studies conducted in 2014 within the framework of the European Union project confirmed the high density of contamination of the territory of the Ivankivskyi district with $^{137}Cs$ and $^{90}Sr$ radionuclides [3].

In the examined children aged 13-17 years old who attended school, in the morning on an empty stomach, blood was taken from the cubital vein.

The 1-st group included children whose blood sam-

*Table 1*

**Number of examined children in age groups**

| Age, years old | Number of children in groups, persons | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 13 | 16 | 49 | 55 |
| 14 | 54 | 73 | 51 |
| 15 | 61 | 56 | 34 |
| 16 | 47 | 72 | 19 |
| 17 | 22 | 11 | 4 |
| 13-17 | 200 | 261 | 163 |

pling was carried out on 04/02/2015, the 2-nd group – 12/18/2015, the 3-rd group – 01/19/2022.

In the course of the ongoing mathematical and statistical analysis, age groups of children were identified (table 1).

The blood samples were analyzed in a laboratory certified according to international quality standards and were agreed with the parents. The content of $H_{cy}$ in the blood was assessed and allelic variants of the MTHFR:C677T genetic polymorphism were determined.

The determination of Hcy in the blood was carried out using the immunochemical method with chemiluminescent detection (ECLIA). Analyzer and test system: Architect 1000 (ABBOT Diagnostics (USA).

The level of $H_{cy}$ in the blood of children over 10 μmol/l was defined as a state of hyperhomocysteinemia.

During the determination of allelic variants of the genetic polymorphism MTHFR:C677T, the following method was used: Real-time PCR. Analyzer and test system DT-96 detecting cycler; «DNA-Technology» (Russia).

Statistical processing of the obtained results was carried out using the IBM SPSS Statistics 22 program (USA). For the analyzed indicators were calculated the arithmetic mean (M), standard error of the mean (±m), confidence interval of the mean value (95% CI), median (Me), interquartile range (IR), minimum and maximum values of the parameters, percentiles. The hypothesis about the type of distributions was tested (Kolmogorov-Smirnov criterion). All the studied parameters did not correspond to the normal distribution law, and therefore, the non-parametric Mann-Whitney U-test was used to compare the values.

The statistical significance of the indicators was assessed by determining the significance level p using a statistical program.

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

*Table 2*

**The number and proportion of cases of hyperhomocysteinemia ($H_{cy}$ > 10.0 μmol/l) in the age groups of children from Ivankivskyi and Poliskyi districts**

| Age, years old | Group 1 | | Group 2 | | Group 3 | |
|---|---|---|---|---|---|---|
| | Absolute number (n) | Percentage, % | Absolute number (n) | Percentage, % | Absolute number (n) | Percentage, % |
| 13 | 6 | 37.50 | 32 | 65.31 | 32 | 58.18 |
| 14 | 27 | 50.00 | 57 | 78.08 | 35 | 68.63 |
| 15 | 32 | 52.46 | 42 | 75.00 | 24 | 70.59 |
| 16 | 25 | 53.19 | 56 | 77.78 | 15 | 78.95 |
| 17 | 8 | 36.36 | 11 | 100.0 | 4 | 100.0 |
| 13-17 | 98 | 49.00 | 198 | 75.86 | 110 | 67.48 |

**Results and its discussion.** In the 1-st group of children (13-17 years old), the proportion of cases of hyperhomocysteinemia was significantly less than in the 2-nd and 3-rd groups. There were no statistical differences between groups 2 and 3 (tables 2, 3).

In subgroups of children aged 14, 15, 16 and 17 years old from group 2, the proportion of cases of hyperhomocysteinemia was statistically higher than in similar subgroups from 1-st group. The proportion of cases of hyperhomocysteinemia in subgroups of children aged 16 and 17 years old was 3-rd group, also, was more than in similar subgroups that made up the 1-st group. Between similar age subgroups of the 2-nd and 3-rd groups, significant statistical differences in the proportion of cases of hyperhomocysteinemia were not recorded (tables 2, 3).

The distribution frequency of CC and TT genotypes, CT polymorphism MTHFR:677, in the studied groups of children, as well as between groups, within age subgroups, had no statistical differences (table 4).

The proportion of cases of hyperhomocysteinemia in subgroups of children with and without the T allele from the 2-nd group is statistically more than in similar subgroups from the 1-st group.

In the 3-rd group, in the subgroup of children who do not have the T allele in their genome, the proportion of cases of hyperhomocysteinemia is also significantly more than in the similar sub-

*Table 3*

**Group comparison results by Student's t-test for unrelated populations**

| Age, years old | Comparison groups | | |
|---|---|---|---|
| | [1-2] | [1-3] | [2-3] |
| 13 | t = 2.00; p = 0.052900 | t = 1.50; p = 0.143152 | t = 0.75; p =0.456350 |
| 14 | t = 3.36; p = 0.001175 | t = 1.98; p = 0.052311 | t = 1.17; p=0.246696 |
| 15 | t = 2.61; p = 0.010921 | t = 1.80; p = 0.078091 | t = 0.45; p=0.651498 |
| 16 | t = 2.80; p = 0.006400 | t = 2.17; p = 0.036188 | t = 0.11; p=0.912073 |
| 17 | t = 6.20; p = 0.000013 | t = 6.20; p = 0.000013 | - |
| 13-17 | t = 6.09; p = 0.000001 | t = 3.63; p = 0.000359 | t = 1.85; p =0.065104 |

*HYPERHOMOCYSTEINEMIA IN CHILDREN IS AN INDICATOR OF ENVIRONMENTAL PROBLEMS ASSOCIATED WITH THE CHORNOBYL EXCLUSION ZONE*

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***The aim of study:*** *determination of the genetic factor's involvement (MTHFR:C677T polymorphism), which affects the activity of the main enzyme of the folate cycle, methylenetetrahydrofolate reductase, and environmental exposure, including the radiation factor, in the occurrence of hyperhomocysteinemia in children which living near the Chornobyl Exclusion Zone (ChEZ).*
***Research methods.*** *Immunochemical, mathematical and statistical.*
***Results****. Within the framework of international projects, the levels of homocysteine (Hcy) and allelic variants of the genetic polymorphism MTHFR:C677T were determined in 624 children aged 13-17 years old from Ivankivskyi and Poliskyi districts of the Kyiv region. It has been established that an increase in the level of Hcy in the blood and an increase in the number of cases of hyperhomocysteinemia in the examined groups of children are associated with forest fires in the ChEZ in 2015 and 2020. Under conditions of pronounced exposure to radioactive agents and combustion products of forest trees, the proportion of cases of hyperhomocysteinemia in groups of children with and without the T allele of the MTHFR:677 polymorphism in the genome did not have statistical differences. An indicator of ecological trouble in the ChEZ and adjacent areas is an increase, above the physiological level, in the concentration of Hcy in the blood of adolescent children with the absence of the T allele of the MTHFR:677 polymorphism in the genome.*
***Conclusion****. In areas affected by the accident at the Chornobyl nuclear power plant, it is necessary to constantly conduct regular monitoring studies of the health of children, using tests for the content of $H_{cy}$ in the blood and the state of the folate cycle genes.*

***Keywords: homocysteine, hyperhomocysteinemia, folate cycle genes, adolescent children, Chornobyl exclusion zone.***

group from the 1-st group (tables 5, 6). Between the 2-nd and 3-rd groups, statistical differences in these parameters were not found.

Only in the 1-st group, the proportion of cases of hyperhomocysteinemia in the subgroup of children with the T allele in the genome is significantly more than in the subgroup without the T allele. No statistical differences were found in the 2-nd and 3-rd groups (tables 5, 6).

The proportion of cases of hyperhomocysteinemia in subgroups of children aged 15 and 17 years old with the T allele from group 2 was statistically greater than in similar subgroups of group 1.

The proportion of cases of hyperhomocysteinemia in the subgroup of children with the T allele at the age of 16 from the 3-rd group was significantly more than in the same subgroup from the 1-st and 2-nd groups (tables 5, 6).

The proportion of cases of hyperhomocysteinemia in the subgroups of children aged 14, 16 and 17 years old, with the C/C MTHFR:677 genotype from the 2-nd group was statistically more than in similar subgroups of the 1-st group. In the subgroups of children aged 14 and 17 years old from the 3-rd group, who also did not contain the T allele in the genome, the proportion of cases of hyperhomocysteinemia was more than in similar subgroups of the 1-st group (tables 5, 6).

In group 1, in the subgroup of 14-years-old children with the T allele, the proportion of cases of hyperhomocysteinemia was statistically more than in the subgroup of children of the same age with

*Table 4*

**Number and distribution frequency of MTHFR:C677T genotypes in groups and age subgroups of children from Ivankivskyi and Poliskyi districts depending on FC genotypes**

| Age, years old | TT+CT MTHFR:677 | | | | | | CC MTHFR:677 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group 1 | | Group 2 | | Group 3 | | Group 1 | | Group 2 | | Group 3 | |
| | Abs. | % | Abs. | % | Abs. | % | Abs. | % | Abs. | % | Abs. | % |
| 13 | 6 | 37.50 | 28 | 57.14 | 31 | 56.36 | 10 | 62.50 | 21 | 42.86 | 24 | 43.64 |
| 14 | 26 | 48.15 | 39 | 53.42 | 28 | 54.90 | 28 | 51.85 | 34 | 46.58 | 23 | 45.10 |
| 15 | 27 | 44. 26 | 25 | 44.64 | 20 | 58.82 | 34 | 55.74 | 31 | 55.36 | 14 | 41.18 |
| 16 | 28 | 59.57 | 40 | 55.56 | 7 | 36.84 | 19 | 40.43 | 32 | 44.44 | 12 | 63.16 |
| 17 | 11 | 50.00 | 5 | 45.45 | 0 | 0.0 | 11 | 50.00 | 6 | 54.55 | 4 | 100.0 |
| 13-17 | 98 | 49.00 | 137 | 52.49 | 86 | 52.76 | 102 | 51.00 | 124 | 47.51 | 77 | 47.24 |

the absence of this allele in the genome.

A similar situation was revealed in the 3-rd group in the subgroup of children of 16 years of age (tables 5, 6).

In group 2, there were no statistical differences between subgroups of children of the same age, with and without the T allele in the genome.

The level of $H_{cy}$ in the blood of children from the 1-st group was significantly lower than in the blood of children from the 2-nd and 3-rd groups (tables 7, 8). At the same time, there were no differences between the 2-nd and 3-rd groups.

*Table 5*

**The number and proportion of cases of hyperhomocysteinemia ($H_{cy}$>10 μmol/l) in groups and age subgroups of children from Ivankivskyi and Poliskyi districts, depending on the genotypes of FC**

| Age, years old | TT+CT MTHFR:677 | | | | | | CC MTHFR:677 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group 1 | | Group 2 | | Group 3 | | Group 1 | | Group 2 | | Group 3 | |
| | Abs. | % | Abs. | % | Abs. | % | Abs. | % | Abs. | % | Abs. | % |
| 13 | 3 | 50.00 | 19 | 67.86 | 21 | 67.74 | 3 | 30.00 | 13 | 61.90 | 11 | 45.83 |
| 14 | 18 | 69.23 | 31 | 79.49 | 20 | 71.43 | 9 | 32.14 | 26 | 76.47 | 15 | 65.22 |
| 15 | 15 | 55.56 | 21 | 84.00 | 13 | 65.00 | 17 | 50.00 | 21 | 67.74 | 11 | 78.57 |
| 16 | 18 | 64.29 | 34 | 85.00 | 7 | 100.0 | 7 | 36.84 | 22 | 68.75 | 8 | 66.67 |
| 17 | 4 | 36.36 | 5 | 100.0 | - | - | 4 | 36.36 | 6 | 100.0 | 4 | 100.0 |
| 13-17 | 58 | 59.18 | 110 | 80.29 | 61 | 70.93 | 40 | 39.22 | 88 | 70.97 | 49 | 63.64 |

*Table 6*

**The results of statistically significant differences when comparing the proportion of hyperhomocysteinemia in the analyzed groups in children with genetic polymorphisms MTHFR:677 (CT, TT) and MTHFR:677**

| Comparison groups | Age, years old | Genotypes | Student's t-test | Significance level, p |
|---|---|---|---|---|
| 1-2 | 13-17 | TT+CT<br>TT+CT | 3.68 | 0.000319 |
| 1-2 | 13-17 | CC<br>CC | 5.02 | 0.000002 |
| 1-3 | 13-17 | CC<br>CC | 3.34 | 0.001229 |
| 1-1 | 13-17 | CC<br>TT+CT | 2.74 | 0.007368 |
| 1-2 | 15 | TT+CT<br>TT+CT | 2.36 | 0.024295 |
| 1-2 | 17 | TT+CT<br>TT+CT | 4.39 | 0.004623 |
| 1-3 | 16 | TT+CT<br>TT+CT | 3.95 | 0.000688 |
| 2-3 | 16 | TT+CT<br>TT+CT | 2.65 | 0.011526 |
| 1-2 | 14 | CC<br>CC | 3.88 | 0.000496 |
| 1-2 | 16 | CC<br>CC | 2.32 | 0.028624 |
| 1-2 | 17 | CC<br>CC | 4.39 | 0.003199 |
| 1-3 | 14 | CC<br>CC | 2.49 | 0.021257 |
| 1-3 | 17 | CC<br>CC | 4.39 | 0.007095 |
| 1-1 | 14 | CC<br>TT+CT | 2.93 | 0.007266 |
| 3-3 | 16 | CC<br>TT+CT | 2.45 | 0.030653 |

The level of $H_{cy}$ in the blood of children aged 14, 15, 16 and 17 years old from the 2-nd group was statistically higher than in the blood of children from subgroups of the same age included in the 1-st group.

The level of $H_{cy}$ in the blood of children aged 14 and 15 from the 3-rd group was also higher than in the blood of children of the same age from the 1-st group (tables 7, 8).

Among children aged 15 years old with the T allele in the genome, the level of $H_{cy}$ in the blood was higher in children of the 2-nd group compared to the 1-st group.

Children aged 14, 15 and 16 years old who are not carriers of the T allele, included in 1-st group, had a lower level of $H_{cy}$ in the blood, compared with children of the same age from 2-nd group. At the same time, children aged 14 and 15 years old from the 1-st group had a lower level of $H_{cy}$ in the blood in comparison with children of the same age from the 3-rd group.

In children with the T allele in the genome, at the age of 14 from the 1-st group, as well as in children at the age of 16 from the 2-nd group,

the level of $H_{cy}$ in the blood was higher than in the blood of children with the CC genotype (tables 9-12).

The obtained results indicate that the indicators of the content of $H_{cy}$ in the blood and the proportion of cases of hyperhomocysteinemia in children had different values depending on the time of the study.

The 1-st group of children was examined on 04/02/2015 – before the fires in the ChEZ forest, the 2-nd group of children was examined on 12/18/2015 – after the forest fires in the ChEZ in spring and summer 2015 [1], the 3-rd group of children was examined on January 19, 2022, after forest fires in a large area of the ChEZ in the spring of 2020 [16].

In the analyzed groups and their age subgroups, there were no statistical differences in the frequency of distribution of CC and TT genotypes, CT polymorphism MTHFR:677.

The proportion of cases of hyperhomocysteinemia and the level of $H_{cy}$ in the blood in the 2-nd and 3-rd groups were more pronounced, in comparison with the 1st group. There were no statistical differences between groups 2 and 3.

In most of the individual age subgroups that made up these groups, a similar relationship was found. The most informative in this regard was the subgroup of children aged 14 years old.

The largest number of statistical differences were found in the age subgroups of children with the absence of the T allele in the genome.

It should be noted that if the values of the proportion of cases of hyperhomocysteinemia in the 1-st group in the subgroup of children with the T allele are statistically more significant than in the subgroup of children without the T allele, then in the 2-nd and 3-rd groups there were no statistical differences between these subgroups.

The same applies to most age subgroups with these genotypes.

Thus, in the groups of children from the 2-nd and 3-rd groups, compared with the 1-st group, the proportion of cases of hyperhomocysteinemia, to a greater extent, is due to the presence in the genome of the homozygous variant of the neutral allele C of the MTHFR:677 polymorphism. If in the 1-st group the state of hyperhomocysteinemia associated with the C/C MTHFR:677 genotype was registered in 40 cases, or in 20.0% of the number of children in the group, then in the 2-nd group – in 88 cases, or in 33.72% of the number of children in the group, which is significantly more (t=3.37; p=0.001007), in the 3-rd group – in 49 cases, or 30.06% of the number of children in the group, which, also, significantly more than in the 1st group (t=2.20; p=0.030439).

We are inclined to believe that the increase in the level of homocysteine in the blood of children in the Ivankivskyi and Poliskyi districts, who made up the 2-nd and 3-rd groups of the survey, registered during the ongoing research, is a consequence forest fires in the ChEZ in the spring and summer of 2015 year [1], as well as in the summer of 2020 [16].

*Table 7*

**Statistical characteristics of $H_{cy}$ levels (μmol/l) in examined children from Ivankivskyi and Poliskyi districts by age**

| Age, years old | Group 1 | | Group 2 | | Group 3 | |
|---|---|---|---|---|---|---|
| | Me | IR | Me | IR | Me | IR |
| 13 | 9.43 | 7.96-11.46 | 10.88 | 9.31-12.37 | 10.80 | 9.10 – 12.00 |
| 14 | 9.92 | 8.20-11.94 | 12.12 | 10.12-16.24 | 11.80 | 9.20 – 15.50 |
| 15 | 10.18 | 7.88-12.21 | 11.96 | 9.87-13.51 | 12.10 | 9.05 – 14.07 |
| 16 | 10.20 | 9.03-13.50 | 11.65 | 10.40-14.29 | 12.30 | 10.10 – 15.00 |
| 17 | 9.38 | 8.32-13.36 | 13.20 | 12.58-17.44 | 13.40 | 11.43 – 15.23 |
| 13-17 | 9.90 | 8.24-12.51 | 11.80 | 10.12-13.80 | 11.40 | 9.20 – 13.70 |

*Table 8*

**The results of statistically significant differences when comparing the levels of $H_{cy}$ (μmol/l) in the blood of children in the analyzed groups**

| Comparison groups | Age, years old | Comparison group size | Average rank | Mann–Whitney U test value, significance level, p |
|---|---|---|---|---|
| 1 | 13-17 | 200 | 188.12 | U = 17524.0; p = 0.0001 |
| 2 | | 261 | 263.86 | |
| 1 | 13-17 | 200 | 162.59 | U = 12418.0; p = 0.0001 |
| 3 | | 163 | 205.82 | |
| 1 | 14 | 54 | 49.63 | U = 1195.0; p = 0.0001 |
| 2 | | 73 | 74.63 | |
| 1 | 14 | 54 | 45.59 | U = 977.0; p = 0.010 |
| 3 | | 51 | 60.84 | |
| 1 | 15 | 61 | 49.52 | U = 1129.5; p = 0.002 |
| 2 | | 56 | 69.33 | |
| 1 | 15 | 61 | 42.72 | U = 715.0; p = 0.012 |
| 3 | | 34 | 57.47 | |
| 1 | 16 | 47 | 50.26 | U = 1234.0; p = 0.013 |
| 2 | | 72 | 66.36 | |
| 1 | 17 | 22 | 13.93 | U = 53.5; p = 0.010 |
| 2 | | 11 | 23.14 | |

Radioactive elements and combustion products of trees, with air currents, spread from the fire sites to the territories adjacent to the ChEZ. As a result, the organism of the children living there was subjected to long-term radiation-toxic effects, which resulted in a violation of the functioning of the enzyme systems responsible for the exchange of sulfur-containing amino acids methionine and $H_{cy}$. Therefore, despite the fact that the genetic factor, in the form of the T allele of the MTHFR:677 polymorphism, played a significant role in increasing the number of cases of hyperhomocysteinemia, directly affecting the activity of methylenetetrahydrofolate reductase, an increase in the level of $H_{cy}$ in the blood occurred even in children without this mutation.

*Table 9*

**Statistical characteristics of $H_{cy}$ levels (μmol/l) in the examined children of the 1-st group, taking into account the genetic polymorphisms of FC**

| Age, years old | MTHFR:677 (CT + TT) | | | MTHFR:677 (CC) | | |
|---|---|---|---|---|---|---|
| | Number of cases | $H_{cy}$, μmol/l | | Number of cases | $H_{cy}$, μmol/l | |
| | | Me | IR | | Me | IR |
| 13 | 6 | 10.22 | 8.19-12.00 | 10 | 9.18 | 7.76-11.50 |
| 14 | 26 | 11.41 | 8.59-15.14 | 28 | 9.34 | 7.30-10.56 |
| 15 | 27 | 10.18 | 7.96-14.01 | 34 | 9.94 | 7.57-11.37 |
| 16 | 28 | 10.84 | 9.10-14.12 | 19 | 9.39 | 8.49-10.89 |
| 17 | 11 | 9.39 | 7.37-22.17 | 11 | 9.37 | 8.94-13.23 |
| 13-17 | 98 | 10.38 | 8.36-14.02 | 102 | 9.38 | 8.02-11.13 |

*Table 10*

**Statistical characteristics of $H_{cy}$ levels (μmol/l) in the examined children of the 2-nd group, taking into account the genetic polymorphisms of FC**

| Age, years old | MTHFR:677 (CT + TT) | | | MTHFR:677 (CC) | | |
|---|---|---|---|---|---|---|
| | Number of cases | $H_{cy}$, μmol/l | | Number of cases | $H_{cy}$, μmol/l | |
| | | Me | IR | | Me | IR |
| 13 | 27 | 11.21 | 9.42-12.31 | 22 | 10.86 | 8.98-12.46 |
| 14 | 39 | 11.84 | 10.10-17.00 | 34 | 12.13 | 10.00-14.40 |
| 15 | 25 | 12.10 | 10.84-14.52 | 31 | 11.45 | 9.25-13.28 |
| 16 | 40 | 12.60 | 10.90-17.71 | 32 | 11.06 | 9.78-12.26 |
| 17 | 5 | 13.23 | 13.00-27.44 | 6 | 12.83 | 12.01-15.97 |
| 13-17 | 136 | 12.04 | 10.53-15.0 | 125 | 11.41 | 9.56-13.08 |

*Table 11*

**Statistical characteristics of $H_{cy}$ levels (μmol/l) in the examined children of the 3-rd group, taking into account the genetic polymorphisms of FC**

| Age, years old | MTHFR:677 (CT + TT) | | | MTHFR:677 (CC) | | |
|---|---|---|---|---|---|---|
| | Number of cases | $H_{cy}$, μmol/l | | Number of cases | $H_{cy}$, μmol/l | |
| | | Me | IR | | Me | IR |
| 13 | 31 | 11.0 | 9.30-11.90 | 24 | 9.65 | 8.85-12.75 |
| 14 | 28 | 11.85 | 9.35-15.53 | 23 | 11.10 | 9.20-15.50 |
| 15 | 20 | 12.30 | 8.88-14.58 | 14 | 11.95 | 10.33-14.70 |
| 16 | 7 | 12.50 | 12.10-16.80 | 12 | 10.20 | 8.43-13.73 |
| 17 | 0 | 0.0 | 0.0 | 4 | 13.40 | 11.43-15.23 |
| 13-17 | 86 | 11.60 | 9.38-13.70 | 77 | 11.20 | 9.05-14.40 |

In recent years, the environmental situation around the ChEZ has deteriorated significantly. This is due to the increased frequency of forest fires affecting large areas of the ChEZ, and, beyond its borders, as well as the difficult economic situation, as a result of which the population is forced to use wood containing radioactive elements in economic activities, including for heating homes and cooking food.

Since the child's body is very sensitive to changes in the state of the environment, it is a sensitive indicator of the appearance of pathogenic factors in it.

In this regard, it is necessary to constantly conduct regular monitoring studies of the health status of children, using in-depth research methods that allow assessing the state of the vital metabolic systems of the body. Identification of unfavorable external environmental factors, and determination of markers of their pathogenic effects on the body, will allow organizing effective preventive measures and preventing the development of serious diseases.

An increased level of $H_{cy}$ in the blood of most adolescents indicates a violation of the development of their body, as well as serious environmental problems in areas bordering the ChEZ.

As a result of the conducted studies, it is possible to make a reasonable statement that an increase in the level of Hcy in a group of adolescent children from areas bordering the ChEZ, who do not have the risk allele T of the MTHFR:677 genetic polymorphism in their genome, may be an indicator of environmental distress associated with the spread of radioactive elements and wood combustion products.

Cases of carriage of the T allele of the MTHFR:677 polymorphism cannot be used to assess the state of

the environment near the ChEZ, since this genetic mutation, in itself, has a direct negative effect on the activity of methylenetetrahydrofolate reductase.

**Conclusions**

In groups of children aged 13-17 years old living in the Ivankivskyi and Poliskyi districts of the Kyiv region, an increase in the level of $H_{cy}$ in the blood and an increase in the number of cases of hyperhomocysteinemia is associated with forest fires in the ChEZ in 2015 and 2020.

Under conditions of pronounced exposure to radioactive agents and combustion products of forest trees, the proportion of cases of hyperhomocysteinemia in groups of children with and without the T allele of the MTHFR:677 polymorphism in the genome did not have statistical differences.

An indicator of ecological trouble in the ChEZ and adjacent areas is an increase, above the physiological level, in the concentration of $H_{cy}$ in the blood of adolescent children with the absence of the T allele of the MTHFR:677 polymorphism in the genome.

In the areas affected by the Chornobyl accident, it is necessary to constantly conduct regular monitoring studies of the health status of children, using tests for the content of $H_{cy}$ in the blood and the state of FC genes.

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*Table 12*

**Results of statistically significant differences when comparing $H_{cy}$ levels (μmol/l) in the blood in the analyzed groups of children with genetic polymorphisms MTHFR:677 (CT+TT) and MTHFR:677 (CC)**

| Groups comparisons | Age, years old | Genotypes | Number of cases | Average rank | Mann-Whitney U test value, significance level, p |
|---|---|---|---|---|---|
| 1 | 13-17 | (CT, TT, CC) | 200 | 188.12 | U = 17524.0; p = 0.0001 |
| 2 | | (CT, TT, CC) | 261 | 263.86 | |
| 1 | 13-17 | (CT, TT, CC) | 200 | 162.59 | U = 12418.0; p = 0.0001 |
| 3 | | (CT, TT, CC) | 163 | 205.82 | |
| 1 | 13-17 | CC | 102 | 88.48 | U = 3771.5; p = 0.003 |
| 1 | | CT+TT | 98 | 113.02 | |
| 2 | 13-17 | CC | 125 | 118.37 | U= 6921.5; p = 0.010 |
| 2 | | CT+TT | 136 | 142.61 | |
| 1 | 13-17 | CC | 102 | 89.13 | U = 3838,0; p = 0.0001 |
| 2 | | CC | 125 | 134.30 | |
| 1 | 13-17 | CC | 102 | 76.87 | U = 2588.0; p = 0.0001 |
| 3 | | CC | 77 | 107.39 | |
| 1 | 13-17 | CT+TT | 98 | 100.80 | U = 5027.5; p = 0.001 |
| 2 | | CT+TT | 136 | 129.53 | |
| 1 | 15 | CT+TT | 27 | 21.93 | U = 214.0; p = 0.024 |
| 2 | | CT+TT | 25 | 31.44 | |
| 1 | 14 | CC | 28 | 21.38 | U = 192.5; p = 0.0001 |
| 2 | | CC | 34 | 39.84 | |
| 1 | 14 | CC | 28 | 20.32 | U =163.0; p = 0.003 |
| 3 | | CC | 23 | 31.00 | |
| 1 | 15 | CC | 34 | 27.96 | U = 355.5; p = 0.024 |
| 2 | | CC | 31 | 38.53 | |
| 1 | 15 | CC | 34 | 21.21 | U = 126.0; p = 0.011 |
| 3 | | CC | 14 | 32.50 | |
| 1 | 6 | CC | 19 | 20.00 | U = 190.0; p = 0.026 |
| 2 | | CC | 32 | 29.56 | |
| 1 | 14 | CC | 28 | 21.52 | U = 192.5; p = 0.0001 |
| 1 | | CT+TT | 26 | 33.94 | |
| 2 | 16 | CC | 32 | 29.56 | U = 418.0; p = 0.012 |
| 2 | | CT+TT | 40 | 42.05 | |

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# THE STATE OF DISABILITY IN THE ADULT POPULATION EVACUATED FROM THE 30-KM ZONE OF THE CHORNOBYL NUCLEAR POWER PLANT DUE TO DISEASES OF THE CIRCULATORY SYSTEM

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# СТАН ІНВАЛІДНОСТІ ВНАСЛІДОК ХВОРОБ СИСТЕМИ КРОВООБІГУ У ДОРОСЛОГО НАСЕЛЕННЯ, ЕВАКУЙОВАНОГО ІЗ 30-км ЗОНИ ЧОРНОБИЛЬСЬКОЇ АЕС

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Хвороби системи кровообігу (ХСК) призводять до високого рівня захворюваності, інвалідності, смертності та значною мірою впливають на збільшення витрат на охорону здоров'я, особливо з постарінням населення [1, 2]. Ключове місце в оцінці здоров'я належить інвалід-

*СТАН ІНВАЛІДНОСТІ ВНАСЛІДОК ХВОРОБ СИСТЕМИ КРОВООБІГУ У ДОРОСЛОГО НАСЕЛЕННЯ, ЕВАКУЙОВАНОГО ІЗ 30-км ЗОНИ ЧОРНОБИЛЬСЬКОЇ АЕС*
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*Ключове місце в оцінці здоров'я населення належить інвалідності з урахуванням її високої поширеності й різноманіття соціально значущих наслідків. Наукові дослідження в Україні і в усьому світі засвідчують глобальну поширеність хвороб системи кровообігу (ХСК) серед населення різних вікових груп. До найбільш несприятливих наслідків Чорнобильської катастрофи для здоров'я та соціального благополуччя належить інвалідизація постраждалого населення.*
***Мета дослідження:*** *проаналізувати динаміку показників інвалідності дорослого населення, евакуйованого після аварії на ЧАЕС, внаслідок провідних ХСК з акцентом на особливості їх розподілу за групами первинно визнаних інвалідами.*
***Матеріали та методи дослідження.*** *Проведено ретроспективний аналіз стану первинного виходу на інвалідність внаслідок ХСК серед дорослого евакуйованого населення за даними Державного реєстру України осіб, які постраждали внаслідок Чорнобильської катастрофи. Аналіз інвалідності проводили за даними осіб, первинно визнаних інвалідами, серед дорослого евакуйованого населення залежно від часу та віку на дату аварії, за класами, формами патології та групами. Період спостереження – 1988-2016 роки. Обробка отриманих даних потребувала формування комп'ютерної бази даних на основі Microsoft Excel.*
***Результати****. Згідно з проведеним аналізом ХСК продовжують, як і у попередні післяаварійні роки, посідати перше місце у структурі причин первинної інвалідності у дорослого евакуйованого населення. З часом, що минув після аварії, рівень інвалідності підвищувався порівняно з раннім періодом і досяг найвищих рівнів у пізньому періоді*