

BIOLOGY AND MEDICAL BIOLOGY

RATIO OF PERIPHERAL BLOOD LEUKOCYTES IN YOUNG WOMEN OF THE ARCTIC ZONE OF THE RUSSIAN FEDERATION

**Shashkova E.Yu.,
Kabbani M.S.,
Sergeeva T.B.,
Dedyukhina (Filippova) O.E.,
Shchegoleva L.S.**

N. Laverov Federal Center for Integrated
Arctic Research of the Ural Branch of the
Russian Academy of Sciences
(Nikolsky Avenue, 20, Arkhangelsk
163020, Russian Federation)

Corresponding author:
Elizaveta Yu. Shashkova,
e-mail: eli1255@ya.ru

RESUME

Seven subjects of the Arkhangelsk Region, and also the Northern Administrative District and the Yamalo-Nenets Autonomous District are part of the AZRF, where climatic and ecological conditions are characterized as extreme (the industry of the Central Industrial Complex, the military industrial complex, the cosmodrome, and the Neftegazprom). Part of the territory of the Arkhangelsk region and the NAO are adjacent to the nuclear test zone (NPS) at the Northern Test site from 1955 to 1990. Nuclear weapons have never been produced in Western Siberia (Yamalo-Nenets Autonomous District). The relevance of the study is determined by the lack of information about the immune status of young northern women who were born and permanently reside in the Arctic zone of the Russian Federation.

The aim. To identify the ratio of peripheral blood leukocyte levels in young women from different northern regions.

Materials and methods. Sixty two women were examined: 47 people from the Nenets Autonomous Okrug and the Arkhangelsk Region (22–35 years old) and 15 people aged 22–40 years (Yamalo-Nenets Autonomous Okrug). Leukocytes, NLR, CD8⁺, and CD16⁺ cells were determined. An indirect immunoperoxidase reaction with monoclonal antibodies was used. Microsoft Excel 2010 and SPSS 20.0 for Windows were used.

Results. Residents of the adjacent area had elevated concentrations of monocytes (20.0; 12.5; 43.7 %), eosinophils (20.0; 25.0; 12.5 %), CD8⁺ lymphocytes (73.3; 31.2; 75.0 %), and CD16⁺ lymphocytes (33.3; 62.5; 43.7 %). Deficiency of the total number of lymphocytes was 2.5 times more common than lymphocytosis: 20.0, 43.7, 12.5 %. Increased concentrations of monocytes 46.7 %, eosinophils 26.7 %, neutrophils 20.0 %, leukocytes 13.3 %, CD8⁺ (80.0 %) and CD16⁺ (66.7 %) lymphocytes were recorded in residents of the non-adjacent zone.

Conclusion. The ratio of lymphocyte subpopulations in young women living in the Arctic zone of the Russian Federation is characterized by a high concentration of monocytes, eosinophils, and lymphocytes (CD8⁺, CD16⁺) against the background of a pronounced deficiency of the total lymphocyte population.

Keywords: leukocytes, lymphocytes, NLR, CD8⁺, CD16⁺ lymphocyte phenotypes, Immune Imbalance in Women of the Russian Arctic Zone

Received: 15.04.2025
Accepted: 26.11.2025
Published: 25.12.2025

For citation: Shashkova E.Yu., Kabbani M.S., Sergeeva T.B., Dedyukhina (Filippova) O.E., Shchegoleva L.S. Ratio of peripheral blood leukocytes in young women of the arctic zone of the Russian Federation. *Acta biomedica scientifica*. 2025; 10(6): 28-36. doi: 10.29413/ABS.2025-10.6.4

СООТНОШЕНИЕ ЛЕЙКОЦИТОВ ПЕРИФЕРИЧЕСКОЙ КРОВИ МОЛОДЫХ ЖЕНЩИН АРКТИЧЕСКОЙ ЗОНЫ РФ

**Шашкова Е.Ю.,
Каббани М.С.,
Сергеева Т.Б.,
Дедюхина (Филиппова) О.Е.,
Щёголева Л.С.**

ФГБУН Федеральный
исследовательский центр комплексного
изучения Арктики имени академика
Н.П. Лаверова Уральского Отделения
Российской академии наук (163020
г. Архангельск, проспект Никольский, 20,
Россия)

Автор, ответственный за переписку:
Шашкова Елизавета Юрьевна,
e-mail: eli1255@ya.ru

РЕЗЮМЕ

Семь субъектов Архангельской области, а также Ненецкий автономный округ (НАО) и Ямало-Ненецкий автономный округ (ЯНАО) входят в состав АЗРФ, где климатозоологические условия характеризуются как экстремальные (промышленность целлюлозно-бумажный комбинат, военно-промышленный комплекс, космодром, Нефтегазпром). Часть территории Архангельской области и НАО являются прилегающими к зоне ядерных испытаний (ЯИ) на Северном полигоне с 1955 по 1990 гг. В Западной Сибири (ЯНАО) никогда не производились ЯИ. Актуальность исследования определяется отсутствием на данный момент сведений о состоянии иммунного статуса молодых северянок, родившихся и оседло проживающих в АЗРФ.

Цель исследования. Выявить соотношение уровней содержания лейкоцитов периферической крови у молодых женщин разных северных зон проживания.

Материалы и методы. Обследовано 62 женщины: 47 человек 22–35 лет (НАО и Архангельская область) и 15 человек 22–40 лет (ЯНАО). Определяли лейкоциты, NLR, клетки CD8⁺, CD16⁺. Использован метод непрямой иммунопероксидазной реакции с моноклональными антителами. Пакет прикладных программ Microsoft Excel 2010 и SPSS 20.0 для Windows.

Результаты. У жительниц прилегающей зоны выявлены повышенные концентрации моноцитов (20,0; 12,5; 43,7 %), эозинофилов (20,0; 25,0; 12,5 %), лимфоцитов CD8⁺ (73,3; 31,2; 75,0 %) и CD16⁺ (33,3; 62,5; 43,7 %). Дефицит общего количества лимфоцитов встречался в 2,5 раза чаще, чем лимфоцитоз: в 20,0; 43,7; 12,5 %. У жительниц не прилегающей зоны регистрировались повышенные концентрации моноцитов (46,7 %), эозинофилов (26,7 %), нейтрофилов (20,0 %), лейкоцитов (13,3 %), лимфоцитов CD8⁺ (80,0 %) и CD16⁺ (66,7 %).

Заключение. Соотношение субпопуляций лимфоцитов молодых жительниц АЗРФ характеризуется высокой концентрацией моноцитов, эозинофилов и лимфоцитов (CD8⁺, CD16⁺) на фоне выраженного дефицита общей популяции лимфоцитов.

Ключевые слова: лейкоциты, лимфоциты, NLR, фенотипы CD8⁺, CD16⁺, иммунный дисбаланс женщин Арктической зоны РФ

Статья поступила: 15.04.2025
Статья принята: 26.11.2025
Статья опубликована: 25.12.2025

Для цитирования: Шашкова Е.Ю., Каббани М.С., Сергеева Т.Б., Дедюхина (Филиппова) О.Е., Щёголева Л.С. Соотношение лейкоцитов периферической крови молодых женщин арктической зоны РФ. *Acta biomedica scientifica*. 2025; 10(6): 28-36. doi: 10.29413/ABS.2025-10.6.4

INTRODUCTION

The Arctic zone of the Russian Federation (AZRF) covers an area of 4.9 million km² [1]. This region includes the territories of several constituent entities of Russia, including seven municipalities of the Arkhangelsk Region, the Nenets Autonomous Okrug, the Yamalo-Nenets Autonomous Okrug, the Murmansk Region, and others [1].

In addition to its extreme climatic and geographic conditions, the Arctic is home to a number of large industrial facilities, including pulp and paper mills (Novodvinsk, Arkhangelsk Region), military-industrial complexes (Severodvinsk), a cosmodrome (Plesetsk, Arkhangelsk Region), and oil and gas companies (NAO, YNAO) [2, 3]. The high-latitude regions of this area are characterized by low temperatures, sharp changes in atmospheric pressure, and unique photoperiodisms, such as polar night, polar day, and “white nights”. These factors, combined with a low ultraviolet radiation index, create a unique environment in the region [4, 5].

It is important to note that the individuals under review (Soyana village, Sovpolye village in the Arkhangelsk Region, and Nes village in the NAO) were born and reside permanently in an area adjacent to the nuclear testing zone at the Northern Test Site during the period between September 1, 1955 and October 25, 1990 (up until the declaration of the current moratorium on October 26, 1991 No. 67-rp “On cessation of nuclear weapons testing at the Novaya Zemlya test site”). It is known that from 1955 to 1990, 130 nuclear tests were conducted at the Northern Test Site for the purposes of developing and enhancing nuclear weapons, as well as fundamental and applied research into extreme physical conditions affecting the environment, and others [6]. The climate in Nadym in the Yamalo-Nenets Autonomous Okrug (YNAO) of Western Siberia (AZRF) is subarctic continental with severe conditions and an average annual temperature of -6.6°C. Nuclear tests have never been conducted in this area [7].

The harsh climatic conditions in the AZRF place increased demands on the human body and leave a particular impact on the functioning of its physiological systems. This can lead to early onset of health problems and hinder the body's ability to regulate itself, thus leading to the activation and stress of cellular and humoral immunity components, and ultimately reducing the body's overall capacity for resilience [8-10].

Most researchers acknowledge the northern regions as a challenging living environment, in which humans are exposed to a range of adverse natural and climatic conditions. A distinct feature of human physiology in the north is the development of “polar stress syndrome”, which, according to Krivoshechekov S.G. et al., is the primary pathogenic mechanism for disease development in the northern regions [11, 12]. Northern pathology researchers believe that the effects of specific northern factors are hardly compensated for by social protective measures [13]. Cold exposure causes temperature stress and impacts the resilience of the human body in northern conditions. Cold-induced constriction of peripheral

blood vessels may be followed by vasodilation. Based on the combination of climatic factors, the climatic-ecological conditions, and the severity level, the polar regions of the European North can be generally classified as a region with uncomfortable natural and climatic living conditions, with some pronounced extremes in several parameters that place increased demands on human bodies and their systems, including the immune system. High morbidity rates and early mortality among the population, as well as the low socio-economic status of small indigenous populations and environmental pollution, are significant challenges in the Far North [14].

At present, there is no publicly available information regarding the concentration of cesium radioisotopes in the environment in the areas previously adjacent to the Northern Test Site. Furthermore, the existing literature on the immune status of residents in these areas is extremely fragmented and limited [15-18], or it pertains to the aftermath of man-made incidents and the health of individuals who have been exposed to radiation. It has been deemed necessary to investigate the levels of peripheral blood leukocytes among young women in the Arctic region, who were born after 1990 and reside permanently in an area adjacent to the nuclear testing zone of the Northern Test Site between September 1, 1955 and October 25, 1990 (until the declaration of a current moratorium on nuclear testing on October 26, 1991 No. 67-rp “On the cessation of nuclear weapons testing at the Novaya Zemlya test site”).

THE AIM OF THE STUDY

To identify the ratio of peripheral blood leukocyte levels in young women residing in different northern regions.

MATERIALS AND METHODS

The study was conducted at the Laboratory of Physiology of Immune Competent Cells, Institute of Physiology of Natural Adaptations, N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences in collaboration with BIOLAM LLC in Arkhangelsk, Russia. A total of 62 female participants, aged 22 to 40 years, with no history of chronic diseases and residing in the AZRF, volunteered for the study. Of these, 32 women, aged 22 to 35 years, were from the Arkhangelsk Region (16 from Soyana village and 16 from Sovpolye village) and 15 women were from the NAO (Nes village), born after 1990 and residing in an area adjacent to the nuclear test zone at the Northern Test Site from September 1, 1955 to October 25, 1990. The remaining 15 women were from YNAO (Nadym) and were aged 22 to 40 years, with no nuclear testing history in their area of residence.

The study was conducted in strict adherence to the ethical guidelines set forth in the Declaration

of Helsinki of the World Medical Association (1964, amended and updated in 2013). Approval for the study was granted by the Ethics Committee of the N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences (Protocol No. 001-20/01 dated January 20, 2025) under state assignment No. 125021902582-1 "Physiological significance of adaptive and innate immune responses in the formation of immune homeostasis reserves in Arctic residents depending on age, sex, and professional status".

The immunological examination involved the determination of peripheral blood leukocyte, monocyte, eosinophil, neutrophil, lymphocyte levels, the neutrophil-to-lymphocyte ratio (NLR), and lymphocyte phenotypes (CD8⁺ and CD16⁺). The content of neutrophils and lymphocytes was determined using a Pentra 60 ABX hematology analyzer. NLR was calculated based on the number of leukocytes counted in a Goryaev chamber and the percentage of neutrophils and lymphocytes stained on blood smears using Romanowsky – Giemsa staining. Lymphocyte phenotyping (CD8⁺ and CD16⁺) was performed using indirect immunoperoxidase staining with monoclonal antibodies on "dried drop" lymphocyte preparations using a peroxidase conjugate and chromogen solution for analysis under a Nikon Eclipse 50i immersion microscope. Primary analysis of peripheral venous blood samples was conducted under expedited conditions.

Statistical analysis was conducted using Microsoft Excel 2010 and SPSS 20.0 for Windows. Due to the absence of a normal distribution in the data, the median (Me) and interquartile range (Q1; Q3) were used to describe the content of the parameters under study. The 95% confidence interval (95% CI) (lower and upper bounds) was used to illustrate the range of the parameter distribution. Comparative analysis between all study groups was performed using the Kruskal – Wallis test. Pairwise comparisons were conducted using the Mann – Whitney U-test. To investigate the structure of relationships among the variables, Spearman's rank correlation coefficient was applied. Differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

It was of interest to examine in detail the average content of immune-competent cells in the leukocyte series among the indigenous population of the Arctic region who were born after 1990 and are still residing there.

The analysis revealed (Table 1) that the average leukocyte counts in the examined women from Sovpolye village, Soyana village, and Arkhangelsk Region were within the normal physiological range: 5.80 (3.98; 7.05) and 4.90 (4.60; 6.60) $\times 10^9$ cells/L, with a 95% CI (4.59–6.30) and (4.86–6.02) $\times 10^9$ cells/L, respectively. In contrast, the leukocyte counts among residents of Nes village (NAO) and Nadym (YNAO) were significantly higher ($p < 0.05$), averaging 6.68 (5.87; 7.25) and 6.63 (5.64;

8.50) $\times 10^9$ cells/L with a 95% CI (5.91–8.10) and (5.73–8.28) $\times 10^9$ cells/L, respectively.

The frequency of immune imbalances among the individuals under examination is presented in Table 2. During our study, no leukocyte deficiency was observed among residents of Nes village (NAO), Soyana village (Arkhangelsk Region), and Nadym (YNAO). However, leukopenia was detected in 25 % of cases among residents of Sovpolye village (Arkhangelsk Region). Leukocytosis was found in 6.7 % and 13.3 % of residents of Nes village (NAO) and Nadym (YNAO), respectively.

The monocyte count was significantly higher in residents of Soyana village and Nadym compared to women from Sovpolye ($p < 0.01$): 0.60 (0.46; 1.12) and 0.60 (0.45; 0.68) $\times 10^9$ cells/L, respectively, with 43.7 % and 46.7 % of cases showing high monocyte levels. In contrast, only 20 % of women from Nes village had monocyte counts above the normal range, and their median value was 0.44 (0.28; 0.62) $\times 10^9$ cells/L, which is significantly higher (approximately 3-fold) than in women from Sovpolye village ($p < 0.01$) and approximately 1.4-fold lower than in residents of Soyana village and Nadym ($p < 0.05$).

The median eosinophil counts were within the normal range in all groups, although 12.5–26.7 % of the women had elevated levels.

The median lymphocyte counts in women from Nes and Soyana villages were 2.37 (1.55; 2.85), 1.64 (1.42; 2.30), 2.71 (1.57; 3.04) $\times 10^9$ cells/L, respectively. These values are within the physiological range and do not differ significantly from the Nadym group: 2.05 (1.56; 2.65) $\times 10^9$ cells/L. However, a decrease in lymphocyte concentration was observed in residents of Sovpolye village, with a significant difference compared to the Soyana group ($p < 0.05$). The frequency of lymphopenia among young women from Sovpolye village (43.7 %) was 2-fold higher than among residents of Nes village and Nadym (20.0 %), and 3.5-fold higher compared to residents of Soyana village (12.5 %).

The median neutrophil counts in the subjects from Nes village, Sovpolye village, and Soyana village were 3.55 (2.68; 4.58), 3.19 (2.90; 4.54), and 3.17 (2.47; 4.48) $\times 10^9$ cells/L, respectively, and did not exceed the reference values. There was no significant difference compared to the Nadym group: 3.37 (2.85; 5.25) $\times 10^9$ cells/L. Neutrophilia was observed in 6.7 % of residents from Nes village, 12.5 % from Soyana village, and 20.0 % from Nadym.

The neutrophil-to-lymphocyte ratio (NLR) is a biomarker that reflects the balance between the innate and adaptive immune systems. It is calculated by dividing the number of neutrophils by the number of lymphocytes. The NLR is used as an indicator of immune system function and inflammation [19]. We found that the median NLR was 1.52 (1.01; 2.49), 1.99 (1.50; 2.31), and 1.47 (0.98; 1.84) in residents of Nes village (NAO), Sovpolye village, and Soyana village, respectively, which was within the generally accepted normal range of 1–2 and did not differ from the Nadym group (1.84 (1.42; 2.01)). However, there was a significant difference

TABLE 1

MEDIAN AND 95% CONFIDENCE INTERVAL OF CONTENT OF IMMUNE INDICATORS IN PERIPHERAL BLOOD OF WOMEN LIVING IN THE ARCTIC ZONE OF THE RUSSIAN FEDERATION

Parameter	Median and percentiles Me (Q1; Q3) 95% confidence interval (lower-upper)				Reference range	Significance level (Kruskal-Wallis test)
	Nes n=15	Sovpolye n=16	Soyana n=16	Nadym n=15		
Leukocytes, ×10 ⁹ cells/L	6.68 (5.87:7.25) (5.91–8.10)	5.80 ^{*,a} (3.98:7.05) (4.59–6.30)	4.90 ^{*,a} (4.60:6.60) (4.86–6.02)	6.63 (5.64:8.50) (5.73–8.28)	4.0–8.8	0.030
Monocytes, ×10 ⁹ cells/L	0.44 [*] (0.28:0.61) (0.31–0.63)	0.22 ^{*,a,b} (0.14:0.28) (0.16–0.37)	0.60 ^a (0.46:1.12) (0.41–1.04)	0.60 (0.45:0.68) (0.48–0.71)	0.09–0.6	0.0002
Eosinophils, ×10 ⁹ cells/L	0.17 (0.07:0.30) (0.12–0.26)	0.19 (0.12:0.42) (0.15–0.34)	0.21 (0.13:0.28) (0.15–0.25)	0.14 (0.08:0.30) (0.10–0.41)	0.02–0.3	0.316
Lymphocytes, ×10 ⁹ cells/L	2.37 (1.55:2.85) (1.89–2.81)	1.64 ^b (1.42:2.30) (1.33–2.4 ^b)	2.71 (1.57:3.04) (1.64–3.38)	2.05 (1.56:2.65) (1.77–2.80)	1.5–3.5	0.190
Neutrophils, ×10 ⁹ cells/L	3.55 (2.68:4.58) (2.95–4.50)	3.19 (2.90:4.54) (2.98–4.04)	3.17 (2.47:4.48) (2.75–4.67)	3.37 (2.85:5.25) (3.12–4.61)	2.0–6.0	0.891
NLR	1.52 (1.01:2.49) (1.26–2.33)	1.99 ^b (1.50:2.31) (1.68–2.18)	1.47 (0.98:1.84) (1.08–2.28)	1.84 (1.42:2.01) (1.45–2.04)	1.0–2.0	0.195
CD8 ⁺ , ×10 ⁹ cells/L	0.55 (0.33:0.76) (0.40–0.78)	0.34 [*] (0.30:0.55) (0.29–0.56)	0.48 (0.34:0.55) (0.36–0.57)	0.58 (0.46:0.69) (0.43–0.70)	0.2–0.4	0.167
CD16 ⁺ , ×10 ⁹ cells/L	0.40 (0.30:0.62) (0.35–0.60)	0.64 ^a (0.45:0.69) (0.54–0.65)	0.46 (0.30:0.67) (0.38–0.68)	0.56 (0.37:0.58) (0.43–0.65)	0.03–0.5	0.096

Notes. * – significant difference compared with the Nadym group, $p < 0.05$; a – significant difference compared with the Nes village group, $p < 0.05$; b – significant difference compared with the Soyana village group, $p < 0.05$; Statistically significant differences compared with reference values are indicated.

between the NLRs of residents from Sovpolye and Soyana villages ($p < 0.05$), suggesting a possible difference in immune function between these two groups. Additionally, we found that 25–50 % of women in each village had an NLR that was considered “stress” levels (2–3).

According to Zahorec (2021) [20], normal NLR values range from 0.7 to 3.0, with optimal values between 1.0 and 2.0. Stress levels between 0.7 and 1.0 or 2.0 and 3.0 serve as early warnings of possible pathological conditions or maladaptation [20, 21].

The number of cytotoxic T-lymphocytes (CD8⁺ cells) in the peripheral blood exceeded the physiological norm. The median count in Nes village and Soyana village was 0.55 (0.33; 0.76) and 0.48 (0.34; 0.55) × 10⁹ cells/L, respectively. In Sovpolye village, it was 0.34 (0.30; 0.55) × 10⁹ cells/L. There was no statistically significant difference between the villages. High concentrations of cytotoxic lymphocytes were found in 73.3 to 75 % of the women examined from Nes village and Soyana village, which was 2.5-fold higher than in the women from Sovpolye village (31.2 %).

In residents of Nadym (YNAO), the median CD8⁺ cell count was 0.58 (0.46; 0.69) × 10⁹ cells/L, and the median CD16⁺ cell count was 0.56 (0.37; 0.58) × 10⁹ cells/L. These values were significantly higher in 80 % of women

from Nadym compared to the median values observed in residents from territories adjacent to the Northern Nuclear Test Site before 1990, with a 1.1–2.7-fold increase, depending on the specific location (30–75 % of women examined).

The median natural killer cell (CD16⁺) count was 0.40 (0.30; 0.62) and 0.46 (0.30; 0.67) × 10⁹ cells/L in Nes village and Soyana village, respectively, within the physiological range, with 33.3–43.7 % of women showing elevated CD16⁺ cell concentrations. In contrast, natural killer cell (CD16⁺) levels exceeded the normal range in 62.5 % of women from Sovpolye village, with a median value of 0.64 (0.45; 0.69) × 10⁹ cells/L. No significant differences between groups were observed. In Nadym residents, the median CD16⁺ cell count was 0.56 (0.37; 0.58) × 10⁹ cells/L, seen in 66.7 % of women, which was 1.1–2.0-fold more frequent than in other groups.

It should be noted that the levels of lymphoid cells expressing CD8⁺ and CD16⁺ markers indirectly reflect the level of cell-mediated cytotoxicity, and elevated levels in northern populations are common [22].

Correlation analysis (Table 3) revealed significant strong correlations between neutrophil and monocyte counts ($r = 0.86$ and 0.58 , respectively) in women from Soyana village and Nadym. Strong inverse

TABLE 2

FREQUENCY OF IMMUNE IMBALANCES IN YOUNG WOMEN OF THE ARCTIC REGION, %

	Nes village (NAO), n = 15	Sovpolye village (Arkhangelsk Region), n = 16	Soyana village (Arkhangelsk Region), n = 16	Nadym (YNAO), n = 15
Leukocytes, $\times 10^9$ cells/L < 4.0	–	25.0%	–	–
Leukocytes, $\times 10^9$ cells/L > 8.8	6.7%	–	–	13.3%
Lymphocytes, $\times 10^9$ cells/L < 1.5	20.0%	43.7%	12.5%	20.0%
Lymphocytes, $\times 10^9$ cells/L > 3.5	6.7%	–	12.5%	13.3%
Monocytes, $\times 10^9$ cells/L > 0.6	20.0%	12.5%	43.7%	46.7%
Eosinophils, $\times 10^9$ cells/L > 0.3	20.0%	25.0%	12.5%	26.7%
Neutrophils, $\times 10^9$ cells/L > 5.5	6.7%	–	12.5%	20.0%
CD8 ⁺ , $\times 10^9$ cells/L < 0.2	6.7%	–	12.5%	–
CD8 ⁺ , $\times 10^9$ cells/L > 0.4	73.3%	31.2%	75.0%	80.0%
CD16 ⁺ , $\times 10^9$ cells/L > 0.5	33.3%	62.5%	43.7%	66.7%
NLR > 2.0	40.0%	50.0%	25.0%	26.7%

TABLE 3

CORRELATION ANALYSIS OF IMMUNOLOGIC INDICES IN YOUNG WOMEN OF THE ARCTIC REGION
(BY SPEARMAN)

		Nes village	Sovpolye village	Soyana village	Nadym
Neutrophils and monocytes	r	0.35	0.11	0.86	0.58
	p	0.225	0.715	0.000	0.025
NLR and eosinophils	r	0.55	0.09	-0.09	0.72
	p	0.040	0.762	0.758	0.002
NLR and neutrophils	r	0.78	0.04	0.75	0.15
	p	0.001	0.896	0.002	0.585
NLR and lymphocytes	r	0.78	0.71	-0.43	0.64
	p	0.001	0.004	0.126	0.01
NLR and CD8 ⁺	r	-0.40	0.86	-0.11	-0.11
	p	0.154	0.000	0.707	0.970
CD8 ⁺ and CD16 ⁺	r	0.67	0.55	0.96	0.41
	p	0.009	0.038	0.000	0.130

Note. r – correlation coefficient; p – level of statistical significance.

relationships were observed between NLR and eosinophil counts ($r = -0.72$ and -0.55 , respectively) among women from Nadym and Nes village.

Although the NLR is the ratio of neutrophils to lymphocytes, our data indicate that their influence on the NLR may not be uniform. In women from Nes village, we found that changes in neutrophil and lymphocyte counts had a balanced effect on the NLR. However, in subjects from Sovpolye and Nadym villages, the lymphocyte count, particularly CD8⁺ cytotoxic lymphocytes in the Sovpolye group, seemed to have a more significant impact on NLR regulation compared to the neutrophil count. The relationship between cells reflecting innate cellular response via natural killer cells

(CD16⁺) and cell-mediated cytotoxic activity via T-lymphocytes (CD8⁺) was heterogeneous: in Soyana village and Nes village, the relationship was direct and strong, while in Sovpolye village, it was inverse and moderate. No significant correlation could be found for residents of Nadym.

An attempt was made to compare the health outcomes of women residing in an AZRF territory that was adjacent to the nuclear test site 35 years ago, with those of women residing in another AZRF territory, in Western Siberia and YNAO, where nuclear tests had never taken place.

It is noteworthy that the residents of Nes village (NAO) exhibited a relatively balanced profile of innate

immunity, with 40 % and 33.3 % of cases exhibiting elevated NLR and natural killer (CD16⁺) cell counts, respectively. This was against a background of hyperactivated adaptive cytotoxic activity of CD8⁺ T-lymphocytes.

Residents of Sovpolye village (Arkhangelsk Region) exhibited suppressed adaptive immune responses, likely due to lymphopenia in 43.7 % of women, against a background of increased stress-inflammatory tension (as indicated by NLR) and an unusual negative correlation between cytotoxic innate (CD16⁺) and adaptive (CD8⁺) functions. This can be interpreted as a compensation mechanism involving suppression of adaptive functions.

In residents of Soyana village (Arkhangelsk Region), hyperactivation of the phagocytic function was revealed due to an increase in the frequency of monocytes, as well as the cytotoxic innate (CD16⁺) and adaptive (CD8⁺) functions against the background of optimal NLR levels.

Residents of Nadym (YNAO) exhibited a typical "Arctic" type of adaptation, which is characterized by an increased monocyte count, relatively high NLR levels, and the activation of both innate (CD16⁺) and adaptive (CD8⁺) cytotoxic functions. Studies have shown that for populations living in areas with high ecological stress, pre-nosological diagnosis of diseases is the basis for implementing health-preserving activities [23]. This necessitates the continuation of scientific research into the impact of environmental factors on the health of the Far North population.

CONCLUSION

Young women residing in the AZRF exhibit a state of chronic functional stress on the immune system. This stress is manifested in two ways: an overactivation of innate phagocytic and inflammatory functions, and an overactivation of both cytotoxic adaptive (CD8⁺) and innate (CD16⁺) functions. These findings may indirectly suggest a reduced reserve capacity for immune homeostasis and a possible development of secondary environmental-dependent immunodeficiency.

Among all immune imbalances identified in the individuals examined, the highest prevalence was observed for elevated levels of lymphocytes with CD8⁺ and CD16⁺ phenotypes. An increased cell-mediated cytotoxicity (CD8⁺, CD16⁺) in all women examined was associated with the activation of the monocytic and phagocytic systems. Heterogeneity was revealed in the leukocyte ratio and the level of immune system activation among the individuals examined. Thus, among women residing in an area previously adjacent to the Northern Nuclear Test Site, an imbalance in cell concentrations was observed: elevated CD8⁺ levels were more frequently recorded in Nes village and Soyana village, while increased CD16⁺ levels were more commonly recorded in Sovpolye village. In individuals residing in the AZRF where nuclear tests have never taken place, the leukocyte balance was maintained, and increases in CD8⁺ and CD16⁺ concentrations were unidirectional. The findings of subtle,

although insignificant, differences emphasize the importance of considering the microregional characteristics of immune homeostasis in assessing the health status of the AZRF population and in developing preventive measures. These findings also require careful monitoring.

Funding

The study was conducted as part of the state-funded research project "Physiological significance of the features of adaptive and innate immune responses in the formation of reserve capacities of immune homeostasis among residents of the Arctic region, depending on age, sex and professional status". The state registration number is 125021902582-1.

Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

1. Arctic Zone of the Russian Federation (AZRF). [Арктическая зона Российской Федерации (АЗРФ)]. URL: <https://neftegaz.ru/tech-library/transportirovka-i-khraneniye/668885-arkticheskaya-zona-rossiyskoy-federatsii-azrf/> [date of access: September 29, 2025].
2. Staroded AS, Maidan VA, Tsvetkov SV. Influence of medico-geographical features of the Far North on the processes of adaptation. *Proceedings of the Russian Military Medical Academy*. 2020; 39(3-5): 160-163. (In Russ.). [Стародед А.С., Майдан В.А., Цветков С.В. Влияние медико-географических особенностей Крайнего Севера на процессы адаптации. *Известия Российской военно-медицинской академии*. 2020; 39(3-5): 160-163.].
3. Pashinskaya KO, Samodova AV, Dobrodeeva LK. Features of the immune system and levels of blood transport components in residents of the arctic of the Russian Federation. *Am J Hum Biol*. 2024; 36(10): e24136. doi: 10.1002/ajhb.24136
4. Lushnov AM, Lushnov MS. *Medical information systems: multivariate analysis of medical and environmental data*. St. Petersburg. "Helicon Plus. 2013; 460. (In Russ.). [Лушнов А.М., Лушнов М.С. *Медицинские информационные системы: многомерный анализ медицинских и экологических данных*. Санкт-Петербург. «Геликон Плюс». 2013; 460.].
5. Gmoshinsky IV, Nikityuk DB. Polar stress: mechanisms and modeling in the experiment. *Bulletin of the Russian Academy of Medical Sciences*. 2022; 77(6): 447-457. (In Russ.). [Гмошинский И.В., Никитюк Д.Б. Полярный стресс: механизмы и моделирование в эксперименте. *Вестник Российской академии медицинских наук*. 2022; 77(6): 447-457.]. doi: 10.15690/vramn2209
6. Ivanov AB, Krasilov GA, Logachev VA, Matushchenko AM, Safronov VG. *Northern Novaya Zemlya test site, radiological consequences of nuclear tests*. Moscow. 1997; 83. (In Russ.). [Иванов А.Б., Красилов Г.А., Логачев В.А., Матушченко А.М., Сафронов В.Г. *Северный полигон Новая Зем-*

ля, радиологические последствия ядерных испытаний. Москва. 1997; 83.].

7. Korchin VI, Korchina TYa, Ternikova EM, Bikbulatova LN, Lapenko VV. Influence of climatic and geographical factors of the Yamalo-Nenets Autonomous District on public health (review). *J. Med.-biol. Res.* 2021; 9(1): 77–88. (In Russ.). [Корчин В.И., Корчина Т.Я., Терникова Е.М., Бикбулатова Л.Н., Лапенко В.В. Влияние климатогеографических факторов Ямало-Ненецкого автономного округа на здоровье населения (обзор). *Журн. мед.-биол. исследований.* 2021; 9(1): 77–88.]. doi: 10.37482/2687-1491-Z046

8. Donaldson S, Adlard B, Odland JØ. Overview of Human Health in the Arctic: Conclusions and Recommendations. Arctic Monitoring and Assessment Program. *International Journal of Circumpolar Health.* 2016; 75: 33807. doi: 10.3402/ijch.v75.33807

9. Kurzanov AN, Zabolotskikh NV, Kovalev DV. *Functional reserves of the organism.* – Moscow: Publishing House of the Academy of Natural Science. 2016; 96. (In Russ.). [Курзанов А.Н., Заболотских Н.В., Ковалев Д.В. *Функциональные резервы организма.* – М.: Издательский дом Академии Естествознания. 2016; 96.].

10. Verster JC, Kraneveld AD, Garssen J. The Assessment of Immune Fitness. *Journal of Clinical Medicine.* 2023; 12(1): 22. doi: 10.3390/jcm12010022

11. Krivoshechekov SG. Labor and human health in the Arctic. *Vestn. Sev. (Arctic) feder. Uni. Ser.: Med.-biol. sciences.* 2016; 4: 84–93. (In Russ.). [Кривошечков С.Г. Труд и здоровье человека в Арктике. *Вестн. Сев. (Арктич.) федер. ун-та. Сер.: Мед.-биол. науки.* 2016; 4: 84–93.].

12. Malikova EL. *Mapping of Aeolian relief forms of the Nadym Ob region. Geographical studies of Siberia and adjacent territories.* Mat. International geographical conf. Irkutsk: Publishing House of the V.B. Sochava Institute of Geography SB RAS. 2019; 510–513. (In Russ.). [Маликова Е.Л. *Картографирование эоловых форм рельефа Надымского Приобья. Географические исследования Сибири и сопредельных территорий.* Мат. Междунар. геогр. конф. Иркутск: Изд-во Инст. геогр. им. В.Б. Сочавы СО РАН. 2019; 510–513.].

13. Gorbachev AL. Biogeochemical characteristics of the northern regions of Russia. Man in the North: systemic mechanisms of adaptation: collected works dedicated to the 90th anniversary of the founding of Magadan / ed. Academician NN Besetnova. Magadan: Express polygraphy. 2019; 3: 68–79. (In Russ.). [Горбачев А.Л. Биогеохимическая характеристика северных регионов России. Человек на Севере: системные механизмы адаптации: сб. тр., посвященный 90-летию основания Магадана / под ред. акад. Н.Н. Беседновой. Магадан: Экспресс-полиграфия. 2019; 3: 68–79.].

14. Dudarev AA, Dorofeyev VM, Dushkina EV, Allosyayarov PR, et al. Food and water security issues in Russia III: Food- and Waterborne Diseases in the Russian Arctic, Siberia and the Far East, 2000–2011. *Int. J. Circumpolar Health.* 2013; 72(1): 21856. doi: 10.3402/ijch.v72i0.21856

15. Shchegoleva LS, Shashkova EYu, Sergeeva TB. Cellular immunity in women aged 20–40 living in different

climatic and geographic regions. *Acta biomedica scientifica.* 2024; 9(2): 120–129. (In Russ.). [Щёголева Л.С., Шашкова Е.Ю., Сергеева Т.Б. Клеточный иммунитет у женщин 20–40 лет, проживающих в разных климатогеографических регионах. *Acta biomedica scientifica.* 2024; 9(2): 120–129.]. doi: 10.29413/ABS.2024-9.2.12

16. Sabirov JB, Namazbaeva ZI, Mukasheva MA. Assessment of peripheral blood parameters in the population living near the Semipalatinsk polygon. *Med. labor and industrial ecol.* 2019; 59(9). (In Russ.). [Сабиров Ж.Б., Намазбаева З.И., Мукашева М.А. Оценка показателей периферической крови у населения, проживающего вблизи Семипалатинского полигона. *Мед. труда и пром. экол.* 2019; 59(9).]. doi:10.31089/1026-9428-2019-599-738-739

17. Snigireva GP, Novitskaya NN. Possibilities of using cytogenetic methods in the examination of the population exposed to radiation as a result of nuclear explosions at the Semipalatinsk test site. *Bulletin of the Russian Scientific Research Center for Reconstruction and Research of the Ministry of Health of the Russian Federation.* 2011; 11. [Снигирева Г.П., Новицкая Н.Н. Возможности использования цитогенетических методов при обследовании населения, подвергшегося облучению в результате ядерных взрывов на Семипалатинском полигоне. *Вестник РНЦРР МЗ РФ.* 2011; 11.]. URL: http://vestnik.rncrr.ru/vestnik/v11/papers/snigir_v11.htm [date of access: February 02, 2025].

18. Tanaka K, Iida S, Takeichi N, Chaizhunusovaet NJ, Gusev BI, Apsalikov KN, et al. Unstable-type chromosome aberrations in lymphocytes from individuals living near Semipalatinsk nuclear test site. *Journal of Radiation Research (Tokyo).* 2006; 47(A): 159–164. doi: 10.1269/jrr.47.a159

19. Buonacera A, Stancanelli B, Colaci M, Malatino L. Neutrophil to Lymphocyte Ratio: An Emerging Marker of the Relationships between the Immune System and Diseases. *Int J Mol Sci.* 2022; 23(7): 3636. doi: 10.3390/ijms23073636

20. Zahorec R. Neutrophil-to-lymphocyte ratio, past, present and future perspectives. *Bratisl Lek Listy.* 2021; 122(7): 474–488. doi: 10.4149/BLL_2021_078

21. Song M, Graubard BI, Rabkin CS, Engels EA. Neutrophil-to-lymphocyte ratio and mortality in the United States general population. *Sci Rep.* 2021; 11(1): 464. doi: 10.1038/s41598-020-79431-7

22. Dobrodeeva LK, Samodova AV. *Adhesion and aggregation of peripheral venous blood cells in inhabitants of high latitudes.* Ekaterinburg: Uro RAS; 2024; 216. (In Russ.). [Добродеева Л.К., Самодова А.В. *Адгезия и агрегация клеток периферической венозной крови у жителей высоких широт.* Екатеринбург: Уро РАН; 2024; 216.].

23. Unguryanu T, Novikov S, Buzinov R, Gudkov A, Grjibovski A. Respiratory Diseases in a Town with Heavy Pulp and Paper Industry. *Epidemiologia e Prevenzione.* 2010; 34(5–6): 138.

Information about the authors

Elizaveta Yu. Shashkova – Cand. Sc. (Biol.), Senior Research Officer at the Laboratory of Physiology of Immune Competent Cell, N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences; e-mail: eli1255@ya.ru, <https://orcid.org/0000-0002-1735-6690>

Mohammad S. Kabbani – Cand. Sc. (Biol.), Senior Research Officer at the Laboratory of Physiology of Immune Competent Cell, N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences; e-mail: sohibmsk@hotmail.com, <https://orcid.org/0000-0002-2330-7123>

Tatyana B. Sergeeva – Cand. Sc. (Biol.), Senior Research Officer at the Laboratory of Physiology of Immune Competent Cell, N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences; e-mail: tanya-86@mail.ru, <https://orcid.org/0000-0003-0745-3099>

Oksana E. Dedyukhina (Filippova) – Cand. Sc. (Biol.), Senior Research Officer at the Laboratory of Physiology of Immune Competent Cell, N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences; e-mail: oxana_filippova_85@mail.ru, <https://orcid.org/0000-0001-6117-0562>

Lyubov S. Shchegoleva – Dr. Sc. (Biol.), Professor, Chief Research Officer, Head of the Laboratory of Physiology of Immune Competent Cells, N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences; e-mail: shchegoleva60@mail.ru, <https://orcid.org/0000-0003-4900-4021>