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EFFICACY OF MEDICAL PREVENTIVE MEASURES FOR SKIN LESIONS IN MINING INDUSTRY WORKERS

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Introduction. In miners, skin lesions are associated with dysfunction of various morphofunctional skin structures: epidermis; microvasculature; nerves of the dermis and hypodermis. In order to preserve the health of the skin as an independent anatomical unit, a complex of medical preventive measures has been developed, which includes topical and systemic therapy.

Objective. To evaluate the efficacy of a complex of medical preventive measures for skin lesions in vibration-exposed miners.

Materials and methods. A prospective, single-center, open-label, randomized controlled trial was conducted before and after the implementation of medical preventive measures for skin lesions in miners. The study included vibration-exposed miners ($n = 77$) divided into a main group and a control group. Their skin condition dynamics were analyzed through clinical examination and polarized dermoscopy, as well as assessment of skin microcirculation and oxidative metabolism by means of a device combining laser Doppler flowmetry with fluorescence spectroscopy. Statistical processing was performed via generally accepted statistical methods, employing Microsoft Excel 2018 and StatTech v. 4.9.5 software (StatTech, Russia).

Results. In the entire cohort of examined patients, a total of 57 (74%) individuals were diagnosed with the following skin diseases: other epidermal thickening, skin appendage diseases, allergic dermatoses, infectious skin diseases, papulosquamous dermatoses, photosensitive dermatoses, and pigmentation disorders. An analysis of clinical and dermoscopic manifestations revealed a significant positive dynamics of the pathological process in the main group ($p < 0.001$). Of all subjects, skin microcirculation dysfunction was detected in 55 (71.5%) miners. The main group exhibited a statistically significant increase in the microcirculation parameter ($p = 0.004$), a decrease in the fluorescence amplitude of reduced nicotinamide adenine dinucleotide ($p = 0.002$), and an increase in the oxidative metabolism index ($p < 0.001$).

Conclusions. The obtained results prove the efficacy of the developed complex of medical preventive measures. These measures can be implemented in addition to traditional methods of secondary prevention and rehabilitation of mining industry workers.

Keywords: miners; work-related diseases; occupational diseases; skin diseases; microcirculation; prevention

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ОЦЕНКА ЭФФЕКТИВНОСТИ МЕДИКО-ПРОФИЛАКТИЧЕСКИХ МЕРОПРИЯТИЙ ПРИ ПОРАЖЕНИЯХ КОЖИ У РАБОЧИХ ГОРНОДОБЫВАЮЩЕЙ ПРОМЫШЛЕННОСТИ

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Введение. Поражения кожи горнорабочих связаны с дисфункцией различных морфофункциональных структур кожи: эпидермиса, микроциркуляторного русла и нервов дермы и гиподермы. Для сохранения здоровья кожи как самостоятельной анатомической единицы разработан комплекс медико-профилактических мероприятий, включающий наружную и системную терапию.

Цель. Оценить эффективность комплекса медико-профилактических мероприятий при поражениях кожи у горнорабочих виброопасных профессий.

Материалы и методы. Проведено проспективное одноцентровое открытое рандомизированное контролируемое исследование до и после медико-профилактических мероприятий при поражениях кожи у горнорабочих. В исследование включены горнорабочие виброопасных профессий ($n = 77$), из них выделены основная и контрольная группы. Анализ динамики состояния кожи осуществляли при проведении клинического осмотра, поляризованной дерматоскопии, оценке кожного микрокровотока и окислительного метаболизма на аппарате лазерной доплеровской флоуметрии (ЛДФ) с флуоресцентной спектроскопией. Статистическая обработка выполнена с применением общепринятых статистических методов при использовании программных пакетов Microsoft Excel 2018 и StatTech v. 4.9.5 (ООО «Статтех», Россия).

Результаты. Среди всей когорты обследованных у 57 (74%) пациентов выявлены следующие заболевания кожи: другие эпидермальные утолщения, болезни придатков кожи, алергодерматозы, инфекционные болезни кожи, папуло-сквамозные дерматозы, фоточувствительные дерматозы, нарушения пигментации. В результате проведенных исследований в основной группе отмечали

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выраженную положительную динамику со стороны кожного патологического процесса при анализе клинико-дерматоскопических проявлений ($p < 0,001$). Среди всех испытуемых у 55 (71,5%) горнорабочих выявлена дисфункция микроциркуляции кожи. У пациентов из основной группы отмечали статистически значимое увеличение показателя микроциркуляции ($p = 0,004$), снижение амплитуды флуоресценции восстановленного никотинамидадениндинуклеотида ($p = 0,002$), рост показателя окислительного метаболизма ($p < 0,001$).

Заключение. Полученные результаты доказывают эффективность разработанного комплекса медико-профилактических мероприятий. Комплекс может быть реализован в дополнение к традиционным методам при вторичной профилактике и реабилитации рабочих горнодобывающей промышленности.

Ключевые слова: горнорабочие; профессионально обусловленные болезни; профессиональные болезни; болезни кожи; микроциркуляция; профилактика

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INTRODUCTION

In the mining industry, workers are at the greatest risk of developing occupational diseases as a result of exposure to industrial factors affecting various organs and tissues¹ [1].

Occupationally related dermatoses with predominant epidermal involvement are associated with exposure to chemical agents, adverse microclimatic conditions, and the physical demands of labor. These conditions manifest as skin xerosis, irritant and allergic contact dermatitis, and eczema. In miners, impaired skin barrier function plays a key role in the pathogenesis of epidermal lesions. Miners interact with chemical agents of mild potency, which, with regular exposure, irritate the skin. Such agents include weak acids and alkalis, organic solvents, heavy metal salts, and petroleum products found in cement, cutting fluids, industrial oils, etc. An additional destructive effect on the epidermis is caused by adverse microclimatic factors, such as excessively high or low temperatures and increased humidity. Regular manual lifting and movement of heavy loads also contribute to epidermal damage, as well as constant pressure on skin areas due to forced working postures² [1–5].

Exposure to occupational whole-body and local vibration, as well as adverse microclimatic conditions, causes lesions affecting the deep layers of the skin and subcutaneous tissue, which can be attributed to microcirculatory dysfunction and damage to receptors, nerve endings, and peripheral nerve

fibers. These changes represent the clinical manifestations of peripheral angiodystonic syndrome (including Raynaud's phenomenon) and vegetative-sensory polyneuropathy in vibration disease. Visually, these lesions may manifest on the skin of the distal extremities as marbling and pastiness, episodes of whitening and cyanosis, hyperhidrosis, impaired hair growth, and trophic changes³ [6].

Damage to the vessels and nerves of the dermis and hypodermis in vibration-induced conditions influences the course of occupational, work-related, and non-occupational skin diseases. The relevance and necessity of a comprehensive approach to scientifically supporting medical preventive measures for skin lesions in the vibration-exposed mining industry workers is confirmed by numerous publications on the subject. However, despite a large number of scientific studies on the impact of occupational factors in the mining industry on the human body, no studies have been conducted to examine their effect on skin lesions, with skin viewed as an anatomical unit.

One of the mechanisms for the development of skin lesions in miners is the disruption of the antioxidant system. Oxidative stress in miners as a result of their occupational activity has been described in the works of both Russian and foreign authors [7–9]. The association of oxidative stress with the onset and progression of a number of neurodegenerative diseases and inflammatory processes in various organs and tissues, as well as with microcirculatory dysfunction and premature aging, was confirmed [10, 11].

¹ On the state of sanitary and epidemiological welfare of the population in the Russian Federation in 2024: State Report. Moscow: Federal Service for the Oversight of Consumer Protection and Welfare; 2025.

² Clinical Guidelines "Contact Dermatitis", 2024. URL: https://cr.minzdrav.gov.ru/preview-cr/213_3

³ Зыков КА, Попкова АМ, Сметнева NS, Игонина NP, Самойлова NV, Goloborodova IV, et al. Vibration disease: a textbook for students. Moscow: RIO MGMSU; 2022.

Using a dermoscope to examine the skin under magnification is a non-invasive way to assess the epidermis condition. Dermoscopy is widely used in the daily practice of a dermatologist/venereologist, facilitating the differential diagnosis of various skin diseases, as well as enabling the effectiveness evaluation of administered therapy [12].

Laser Doppler flowmetry (LDF) combined with fluorescence spectroscopy is an accessible, non-invasive method for diagnosing skin microcirculatory dysfunction and oxidative metabolism *in vivo*. This method relies on the Doppler shift of light scattered by blood cells [13].

In order to prevent skin lesions, initial and periodic medical examinations are conducted by a dermatologist/venereologist⁴. Mining industry enterprises also use dermatological personal protective products of cleansing, protective, and regenerative types^{5,6}. Due to the disruption of various morphofunctional skin structures in miners, it is necessary to develop a complex of medical preventive measures aimed at preserving the health of skin and subcutaneous tissue.

Moisturizers and emollients, as well as keratolytic agents, are used externally to restore the normal structure and function of the skin, epidermal barrier, and hydro-lipid mantle [14, 15].

For the correction of oxidative metabolism, several studies suggest the use of systemic and topical ozone therapy. Ozone therapy stabilizes the imbalance of pro- and antioxidants, improves microcirculation, and has an immunomodulatory effect [7–11]. As a complex of medical preventive measures for skin lesions in miners, it has been proposed to administer systemic ozone therapy along with external therapy using emollients and keratolytic agents.

The study aims to evaluate the efficacy of a complex of medical preventive measures for skin lesions in vibration-exposed miners.

MATERIALS AND METHODS

A prospective, single-center, open-label, comparative study was conducted before and after the implementation of medical preventive measures for skin lesions in miners.

The study included vibration-exposed miners ($n = 77$). All subjects were males aged 34 to 60 years ($Me = 51$), with work experience of 10–37 years ($Me = 21$) at enterprises engaged in underground mining of copper-nickel ores ($n = 48$), underground ($n = 6$) and open-pit ($n = 7$) mining of ferruginous quartzites, and underground coal mining ($n = 16$). The study

participants consisted of machine operators ($n = 30$), drift miners ($n = 21$), stoper operators ($n = 11$), drillers ($n = 10$), roof bolters ($n = 2$), shotfirers ($n = 2$), and a fitter ($n = 1$).

In order to evaluate the efficacy of the complex of medical preventive measures, the subjects ($n = 77$) were divided into the following groups:

- Group 1 — main group in which the developed complex of medical preventive measures was implemented along with standard treatment ($n = 28$);
- Group 2 — control group comprising patients who received standard treatment according to clinical guidelines for the relevant nosologies ($n = 28$).

The remaining patients ($n = 21$) withdrew from the study due to contraindications to ozone therapy identified based on peripheral microcirculation indicators (hyperemic perfusion type). The developed complex of medical preventive measures included: external moisturizers (for all subjects), keratolytic agents (for patients with Grade II–III xerosis according to the dermoscopic criteria), and ozone therapy (for patients with normal and spastic perfusion).

The therapy for skin xerosis depended on its severity. Moisturizers and emollients were prescribed for external use to all subjects to be applied twice daily to the skin of the hands, shins, and feet. Additionally, moderate-to-severe xerosis patients used keratolytic agents containing 10% urea, 2% salicylic acid, and 1% lactic acid, applied twice a day externally to the skin of the hands, shins, and feet. In the absence of contraindications, intravenous administration of 500 mL ozonated saline with an ozone concentration of 1–4 mg/L was performed on alternate days in three courses using a UOTA-60-01 device (Medozon, Russia).

The mean age ($M \pm SD$) of workers in the main group was 51 years (50.68 ± 5.22 ; 95% CI 48.65–52.70), with a work experience of 22 years (22.21 ± 6.06 ; 95% CI 19.87–24.56); the mean age of workers in the control group was 53 years (52.64 ± 4.24 ; 95% CI 51.00–54.29), with a work experience of 21 years (21.14 ± 5.22 ; 95% CI 19.12–23.17). In the main and control groups, the subjects were comparable in terms of age and work experience.

All subjects had an established diagnosis of an occupational disease and underwent examination and treatment in the neurological department of the Institute of General and Occupational Pathology named after Academician of the Russian Academy of Medical Sciences A.I. Potapov (F.F. Erisman Federal Scientific Center of Hygiene, Rospotrebnadzor) in 2024–2025. According to medical records, the subjects were diagnosed with the following pathologies of occupational

⁴ Order of the Ministry of Health of the Russian Federation No. 29N dated January 28, 2021 “On Approval of the Procedure for Conducting Mandatory Preliminary and Periodic Medical Examinations of Employees, as Provided for in Part Four of Article 213 of the Labor Code of the Russian Federation, the List of Medical Contraindications to Work with Harmful and (or) Dangerous Occupational Factors, as well as to Work for which Mandatory Preliminary and Periodic Medical Examinations are Conducted.”

⁵ Order of the Ministry of Labor and Social Protection of the Russian Federation No. 767n dated October 29, 2021 “On Approval of the Unified Standard Norms for the Issuance of Personal Protective Equipment and Flushing Agents.”

⁶ GOST R 12.4.301-2018 “Occupational safety standards system. Dermatological personal protective products. General specifications.”

etiology: dorsopathy in 72 (93.5%) patients, limb polyneuropathy in 52 (67.5%), vibration disease in 42 (54.5%), lung diseases in 1 (1.3%), and sensorineural hearing loss in 1 (1.3%).

The study excluded subjects with the following decompensated diseases: diabetes mellitus, Grade 3 obesity, Grade 3 hypertension, ischemic heart disease, cardiac arrhythmias, history of acute cerebrovascular accident, blood coagulation disorders, systemic autoimmune processes, chronic kidney disease, malignant neoplasms, and other somatic diseases. Additional exclusion criteria included legume intolerance (glucose-6-phosphate dehydrogenase deficiency), allergy to ozone or components of the topical preparations used in the study, and exposure to medications capable of distorting the results.

The therapy lasted ten days, before and after which the patient underwent a clinical examination, polarized dermoscopy with a Heine Delta 30 dermoscope (Heine Optotechnik GmbH & Co. KG, Germany), and LDF with fluorescence spectroscopy with the use of a Lazma PF device (LAZMA, Russia).

When assessing the clinical picture of diagnosed skin diseases using the developed methodology, we considered the degree of erythema, the intensity of scaling, and the presence of fissures accompanied by complaints of itching, discomfort, or pain. Points were assigned to the assessed signs depending on the intensity of manifestation: from 0 (absence) to 3 (pronounced manifestations). Subsequently, the total number of points was calculated, and the degree of skin involvement was determined using a 15-point scale:

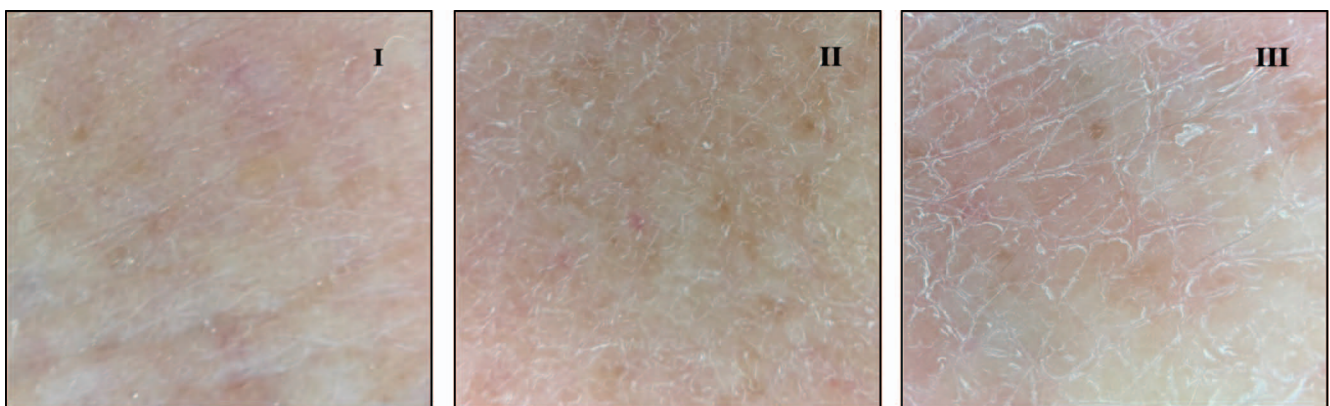
- 0–3 points: minimal changes; good condition of the skin;
- 4–6 points: moderate changes;
- 7–9 points: significant skin changes;
- 10–15 points: severe skin lesions.

The dynamics of lesion severity in skin appendage diseases and pigmentation disorders were not considered due to the impossibility of their identification according to the selected clinical diagnostic criteria (erythema, scaling, fissures, pain, discomfort, and itching).

Other epidermal thickenings, including skin xerosis of the hands, were most common among the subjects and could be occupationally related. Therefore, the efficacy of medical preventive measures was assessed by analyzing the dermoscopic signs indicating the degree of hand xerosis.

Polarized dermoscopy was performed on all subjects to assess the dynamics of xerosis severity before and after the implementation of medical preventive measures. The assessment was conducted on the dorsal hand surface at five randomly selected points, with a subsequent determination of the intermediate result. Dermoscopic criteria for assessing the severity of xerosis (Grades I–III) included the presence of scales (intensity of scaling: slight, moderate, and severe), confinement of scaling to skin furrows (within the furrows; extending beyond them), and the presence of erythema (Fig. 1) [16].

Laser Doppler flowmetry was performed on all subjects in the morning (30 min after waking; on an empty stomach and in a resting state) at an ambient temperature of 21–24 °C. In order to avoid distortions of the recorded signals, patients were asked to refrain from smoking and drinking coffee/tea for 3 h before the study. Laser Doppler flowmetry was carried out with normal blood pressure levels (from 101/61 to 139/89 mmHg), measured on the left arm with a mechanical tonometer (Korotkoff method) 15 min before the study. The patients had not taken antihypertensive or other medications for 12 h prior to the study. During the procedure, the subjects were seated, with the right forearm resting on a table at heart level. The



Dermoscopic image by the authors

Fig. 1. Dermoscopic signs indicating the degree of skin xerosis: Grade I — slight scaling confined to the skin furrows; Grade II — moderate scaling extending beyond the skin furrows; Grade III — pronounced lamellar scaling extending beyond the skin furrows, with erythema ranging from light pink to pink

analyzer was freely attached with a strap to the palmar distal phalanx of the third right-hand finger. The LDF signal was recorded for 10 min, during which time the patients were asked not to speak or make active movements.

The primary result of flowmetry is the microcirculation index, expressed in relative perfusion units (PU). Mathematically, it can be expressed as follows:

$$MI = Pc \times N_{rbc} \times V_m, \quad (1)$$

MI — microcirculation index; Pc — proportionality coefficient; N_{rbc} — number of red blood cells; V_m — mean erythrocyte velocity in the interrogated tissue volume.

Based on the microcirculation index (MI), the perfusion type was determined: normal, spastic, or hyperemic⁷ [13]. Spectroscopy was implemented using low-intensity laser radiation, enabling the fluorescence assessment of a coenzyme, reduced nicotinamide adenine dinucleotide (NADH), followed by the calculation of the oxidative metabolism index (OMI). An increase in NADH fluorescence amplitude (A_{NADH}) in tissue occurs with a decrease in antioxidant defense and mitochondrial respiration. The OMI is inversely proportional to A_{NADH} and directly proportional to nutritive microcirculation (M_{nutr}). In turn, M_{nutr} depends on the arithmetic mean value of the microcirculation index (M_{MI}) and is determined by passive (Ac, Ad) and active (Am, An) microcirculation factors [17]:

$$M_{nutr} = \frac{M_{MI} \times Am}{An + Ac}.$$

Passive regulatory factors implementing longitudinal blood flow oscillations originate outside the microcirculation system: the pulse wave from the arteries (cardiac spectrum, Ac) and the suction effect of the “respiratory pump” from the veins (respiratory spectrum, Ad). Active mechanisms of microcirculation regulation underlie transverse oscillations and are determined by endothelial (Ae), myogenic (Am), and neurogenic (An) mechanisms of vascular tone regulation⁸.

Statistical processing was performed via generally accepted statistical methods employing Microsoft Excel 2018 and StatTech v. 4.9.5 (StatTech, Russia) software. Categorical data were described in absolute numbers and percentages. Confidence intervals for percentages were calculated using the Clopper-Pearson method. Quantitative variables that follow a normal distribution were described using arithmetic means (M) and standard deviations (SD). The boundaries of the 95% confidence interval (95% CI) were indicated as a measure of representativeness for the mean values. For the correct comparison of the same indicators from groups with normal and non-normal data

distribution, quantitative parameters were described with the median (Me) and the lower and upper quartiles [$Q1$; $Q3$] using the Wilcoxon test. In the comparison of normally distributed quantitative indicators calculated for two related samples, the paired Student's t -test was used. Binary indicators characterizing two related populations were compared using McNemar's test. Differences were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

All subjects ($n = 77$) underwent clinical examination, dermoscopy, and LDF with fluorescence spectroscopy. The performed clinical examination found skin diseases in 57 (74%) of all examined miners: other epidermal thickening in 33 (42.9%) workers, skin appendage diseases in 29 (37.7%), allergic dermatoses in 9 (11.7%), infectious skin diseases in 5 (6.5%), papulosquamous dermatoses in 5 (6.5%), photosensitive dermatoses in 2 (2.6%), and pigmentation disorders in 1 (1.3%).

In the main group of patients (in which the developed medical preventive measures were implemented along with standard treatment), positive dynamics were observed: a decrease in the intensity of erythema, the degree of scaling, partial epithelialization of fissures and excoriations; patients noted a reduction or regression of pain, itching, and discomfort. The examination of control group patients, who received standard treatment, also showed positive dynamics; however, in some cases, these were less significant, or a slight worsening of the skin pathology was noted. Considering the minimal skin changes, this may be due to the absence of emollients in the prescriptions of attending physicians. Noteworthy is that severe skin lesions were not diagnosed in the miners participating in the study.

The severity of skin lesions in diagnosed diseases was assessed on a scale from 0 to 15 for the convenience of analyzing dynamics. In the main group, skin diseases (excluding skin appendage diseases and pigmentation disorders) were identified in 16 subjects, with a skin lesion severity score of 5.94 ± 1.73 (95% CI [5.02; 6.86]) before therapy and 2.62 ± 1.36 (95% CI [1.90; 3.35]) after the implementation of therapeutic measures ($p < 0.001$). In the control group, skin diseases were diagnosed in 15 individuals, with a severity score of 4.60 ± 1.64 (95% CI [3.69; 5.51]) before treatment and 3.20 ± 1.86 (95% CI [2.17; 4.23]) after therapy ($p = 0.004$) (Fig. 2).

Polarized dermoscopy was performed on patients from the main and control groups ($n = 56$) (Table 1). The dynamics of dermoscopic manifestations in xerosis, which was analyzed using the Wilcoxon test, revealed a statistically significant reduction in its degree in the main group ($p < 0.001$) (Table 1).

⁷ Krupatkin AI, Sidorov VV. Functional diagnostics of the state of microcirculatory-tissue systems: Oscillations, information, nonlinearity. A guide for physicians. Stereotyped edition. Moscow: LENAND; 2022.

⁸ Ibid.

Laser Doppler flowmetry found spastic perfusion in 34 (44.2%) of all examined subjects ($n = 77$); normal, in 22 (28.6%) individuals; hyperemic, in 21 (27.3%) individuals. Due to the vasodilating effect of ozone therapy, patients with hyperemic microcirculation were excluded from the study. In order to analyze the efficacy of the complex of medical preventive measures, the microcirculation index (MI), the fluorescence amplitude of reduced nicotinamide adenine dinucleotide (A_{NADH}), and the oxidative metabolism index (OMI) were estimated.

In the main group, statistically significant changes were noted over time in MI ($p = 0.004$), A_{NADH} ($p < 0.002$) (Wilcoxon test), and OMI ($p < 0.001$) (paired Student's t -test). The main group (in which the complex of medical preventive measures was implemented) exhibited an increase in the median values of MI (15.23 and 18.33), a decrease in A_{NADH} (0.86 and 0.67), and an increase in the mean values of OMI (5.16 ± 2.19 and 6.36 ± 1.98). In the control group, the analysis of MI ($p = 0.614$), A_{NADH} ($p = 0.210$), and OMI ($p = 0.081$) over time revealed no statistically significant changes (Table 2).

According to the performed LDF, the MI dynamics noted in the main group after ozone therapy administration are associated with improved microcirculation resulting from the vasodilating effect of ozone, which is also confirmed by other studies in animals and for other pathologies [18–20]. The statistically significant OMI increase in the main group after systemic ozone therapy as compared to the control group, as well as a decrease in A_{NADH} (resulting from enhanced NADH oxidation during oxidative phosphorylation), can be attributed to the restored antioxidant system and mitochondrial respiration, as revealed by fluorescence spectroscopy [17].

This study may be limited by the uncontrolled influence of the patient's psycho-emotional state on the results obtained via the LDF method. The variability of indicators associated with the psycho-emotional state of the subjects, the patient's body position, ambient temperature, and equipment characteristics was

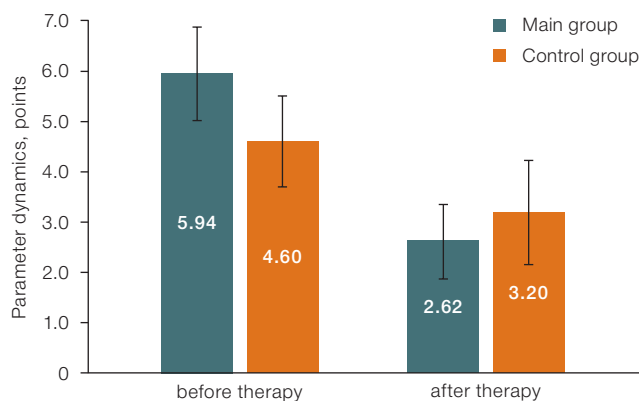


Figure prepared by the authors based on their own data

Fig. 2. Intensity of diagnosed skin lesions (on a 15-point scale) before and after the implementation of medical preventive measures in the main and control groups

reduced by establishing uniform study conditions and sample size.

The efficacy of topical therapy with emollients and keratolytic agents for skin xerosis was confirmed by foreign and Russian authors, with moisturizers also noted to be effective in other skin diseases [1, 14–16]. Numerous domestic publications examine the efficacy of topical use of ozone-oxygen gas mixture, ozonated distilled water, and various methods of systemic ozone application in infectious and autoimmune skin lesions, as well as allergic and other dermatoses [21–23]. The efficacy of ozone therapy in the treatment and prevention of vibration disease in miners was verified by laboratory and functional studies; however, these works do not assess skin condition [24, 25]. Foreign authors note the efficacy of ozone therapy in treating skin and musculoskeletal diseases while highlighting the insufficient number of studies on this topic. The available publications contain scattered information on the methods of ozone application, dosages, long-term efficacy, and safety [26, 27].

Table 1. Results of polarized dermoscopy of the skin before and after the implementation of medical preventive measures

Grade of xerosis	Main group*		Control group*	
	Before therapy	After therapy	Before therapy	After therapy
0	42.9 (24.5–62.8)	71.4 (51.3–86.8)	53.6 (33.9–72.5)	53.6 (33.9–72.5)
I	25.0 (10.7–44.9)	21.4 (8.3–41.0)	17.9 (6.1–36.9)	28.6 (13.2–48.7)
II	28.6 (13.2–48.7)	7.1 (0.9–23.5)	25.0 (10.7–44.9)	14.3 (4.0–32.7)
III	3.6 (0.1–18.3)	0	3.6 (0.1–18.3)	3.6 (0.1–18.3)

Table compiled by the authors based on their own data

Note: Data are presented as relative values and 95% confidence intervals; * — $p < 0.001$ for the main group and $p = 0.317$ for the control group in the Wilcoxon test.

Table 2. Results of laser Doppler flowmetry combined with fluorescence spectroscopy before and after the implementation of medical preventive measures

Parameters	Main group (n = 28)			Control group (n = 28)		
	Before therapy	After therapy	Statistical significance level, p	Before therapy	After therapy	Statistical significance level, p
MI, PU ¹	15.23 [13.28; 20.94]	18.33 [14.29; 21.96]	0.004	15.88 [13.56; 20.44]	14.73 [13.49; 20.36]	0.614
A _{NADH} , a.u. ¹	0.86 [0.71; 0.99]	0.67 [0.58; 0.88]	0.002	0.93 [0.82; 1.01]	0.98 [0.89; 1.04]	0.210
OMI, a.u. ²	5.16 ± 2.19 (4.31–6.01)	6.36 ± 1.98 (5.60–7.13)	< 0.001	4.94 ± 1.20 (4.48–5.41)	4.40 ± 1.22 (3.93–4.88)	0.081

Table compiled by the authors based on their own data

Note: ¹ — data are presented as median and interquartile range (Me [Q1; Q3]), p-value in the Wilcoxon test; ² — data are presented as arithmetic means and standard deviations with a 95% confidence interval ($M \pm SD$ (95% CI)), p-value in the paired Student's t-test; MI — microcirculation index; A_{NADH} — NADH fluorescence amplitude; OMI — oxidative metabolism index; a.u. — arbitrary units; PU — perfusion units

The published data on the application of ozone in skin diseases and in vibration disease indicate the relevance of ozone therapy for skin lesions in vibration-exposed miners. The obtained data do not contradict the results of previous studies, complementing them within the field of occupational medicine.

CONCLUSION

The developed complex of medical preventive measures was found to be effective in skin and subcutaneous tissue lesions caused by occupational factors affecting vibration-exposed miners. The obtained results show their positive impact on the morphofunctional structures of skin and subcutaneous tissue. The objective and subjective manifestations of skin lesions diagnosed during the study improved on average by 55.89% in the main group and by 30.43% in the control group; the microcirculation index increased by 20.35% in the main group, while in the control group it

decreased slightly (by 7.24%). These figures indicate a more significant reduction in the clinical manifestations of skin lesions in the main group compared to the control group, as well as a microcirculation improvement in the main group.

In the early stages of development, epidermal lesions are easily diagnosable and potentially reversible, unlike vascular-neurogenic dermal lesions. The obtained data confirm the need for timely diagnosis of skin xerosis and the use of topical agents for the treatment and prevention of epidermal lesions in miners in order to prevent more severe skin diseases and improve the quality of life. Also, reducing dryness is important in the treatment of most skin diseases, which also ensures the efficacy of measures concerning other skin conditions.

The developed complex of medical preventive measures can be implemented in addition to traditional methods in the treatment and prevention of skin lesions in mining industry workers.

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