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K.I. Lyzohub, D.V. Morozenko, M.V. Lyzohub, I.F. Fedotova, F.S. Leontieva
Sytenko Institute of Spine and Joint Pathology of NAMSU, Kharkiv, Ukraine

Clinical assessment of the adaptation of military personnel with shoulder injuries depending on the degree of stress response

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Abstract. ***Background.*** *The degree of adaptation of the body depends on many factors, including its ability to adapt to certain factors that cause damage. After all, it is soldiers who are constantly exposed to physical and metabolic stress. Purpose: to perform a clinical assessment of the adaptation of the body in military personnel with shoulder injuries based on leukocyte index, blood biochemical indicators, and hemostasis system markers.* ***Materials and methods.*** *A survey of 34 military personnel was conducted, all of whom were male patients diagnosed with shoulder injuries. The average age of patients was 47.52 ± 12.25 years. All of them were divided into 4 groups according to the leukocyte index: group I — patients who showed a stress reaction (n = 5); group II — patients with a training reaction (n = 8); group III — patients who showed a calm activation reaction (n = 12); group IV — patients with an increased activation (n = 9). Stress was assessed according to the Mississippi scale, pain — according to the visual analogue scale. The following were examined in the patients' blood: leukocytes — by counting in a Goryaev chamber, leukogram — in smears stained according to Romanowsky-Giemsa, erythrocyte sedimentation rate — by the Westergren method. The following biochemical markers were determined in blood serum: total protein — using the biuret method, glucose — using the enzymatic method, and a thymol test was performed. The content of fibrinogen, active partial thromboplastin time (APTT), prothrombin time (PT) and soluble fibrin-monomer complexes in blood plasma was determined using ready-made reagent Renam kits.* ***Results.*** *The most pronounced changes in the integral leukogram indicators, markers of coagulation, and liver enzyme activity were observed in patients with a stress response; less pronounced disturbances were detected in patients with a training response. The indicators for calm adaptation and increased activation reactions were the least altered, which is associated with compensatory mechanisms in the patients' bodies. The most diagnostically significant in the study groups of patients with varying degrees of adaptation were leukocyte index of intoxication, fibrinogen level, APTT and PT, and in patients with acute stress reaction — alanine aminotransferase, aspartate aminotransferase and glucose activity.* ***Conclusions.*** *The laboratory results help us figure out what stage of stress response the patient is at and check out their ability to adapt based on the clinical assessment of biochemical tests and hemostasis markers.*

Keywords: *military personnel; shoulder injury; post-traumatic stress disorder; adaptation; leukocyte index; biochemical markers; hemostasis*

Introduction

The level of human's body adaptation, particularly among servicemen, which suffer from multiple injuries, depends on numerous factors, including the body's ability to adapt to the effects of certain factors that cause damage. Eventually, it is the military personnel who are constantly exposed to physical and metabolic stress [1]. Nowadays, leukocyte indices are often used in clinical practice to assess the condition of patients in clinical oncology, for example, to assess systemic inflammation and prognosis in colorectal cancer [2]. Leukocyte indices, including neutrophil-lymphocyte ratio, monocyte-lymphocyte ratio, can be used as biomarkers of systemic inflammation in patients with heart failure [3]. Changes in the leukocyte distribution can also be

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For correspondence: Kseniia I. Lyzohub, PhD in Medicine, Head of the Department of Pathophysiology, Anesthesiology and Functional Diagnostics, Sytenko Institute of Spine and Joint Pathology of NAMSU, Hryhoriya Skovorody st., 80, Kharkiv, 61024, Ukraine; e-mail: kslizogub@gmail.com; phone: +380 (66) 304-55-80
Full list of authors information is available at the end of the article.

a consequence of emotional stress via physical activity [4] and psycho-emotional disorder [5].

There are criteria for adaptative reaction of human's body that are based on the ratio of the percentage of lymphocytes to segmented neutrophils in the peripheral blood, which is known as a criterion of adaptive reactions [6, 7]. For instance, the leukocyte index = lymphocytes / segmented neutrophils — reflects the relationship between the humoral and cellular parts of the immune system and is the main criterion for the body's adaptive reactions. Leukocyte shift index (LSI) = (myelocytes + metamyelocytes + band neutrophils + segmented neutrophils + eosinophils + basophils) / (lymphocytes + monocytes). An increase in LSI means an active inflammatory process and impaired body reactivity in the acute course of the disease. Leukocyte index of intoxication (LII) = (myelocytes + metamyelocytes + band neutrophils + segmented neutrophils + plasma cells) / (lymphocytes + monocytes + eosinophils + basophils). An increase in LII indicates an increase in endogenous intoxication and activation of tissue breakdown processes. Leukocyte to erythrocyte sedimentation rate (ESR) ratio (IRWESR) = (lymphocytes × ESR) / 100. Changes in this indicator can be used to judge the presence of intoxication associated with infectious (decreased) or autoimmune (increased) processes. Lymphocyte to monocyte ratio (LMR) = lymphocytes / monocytes. It reflects the ratio of the affective and effector links in the reactive process. In general, researchers have recently paid much attention to the clinical assessment of leukocyte indices in surgical, oncological and infectious diseases, and these tests are considered perspective [8, 9]. There are several degrees of adaptation according to the value of this criterion (leukocyte index = % lymphocytes / % segmented neutrophils): a) stress response: lymphocytes less than 20 %, adaptation index less than 0.30; b) training reaction: lymphocytes — 21–27 %, adaptation index — 0.31–0.50; c) reaction of calm activation: lymphocytes — 28–33 %, adaptation index — 0.51–0.70; d) reaction of increased activation: lymphocytes — 34–42 %, adaptation index — 0.71–0.90; e) reaction of overactivation: lymphocytes above 43 %, adaptation index above 0.90; f) reaction of incomplete adaptation: peripheral blood leukocytes — 4.0–10^9/l and less. Therefore, changes in the number of leukocytes as criteria of adaptation are quite important in clinical practice for assessing the condition of individuals with stress disorders, in particular, against the background of trauma in orthopedic patients [10].

Objective of the study was to conduct a clinical assessment of the body's adaptation in military personnel with shoulder injuries based on leukocyte indices, blood biochemical parameters and markers of the hemostatic system.

Materials and methods

The study was conducted at the Department of Pathophysiology, Anesthesiology and Functional Diagnostics, Department of Laboratory Diagnostics and Immunology of the Sytenko Institute of Spine and Joint Pathology of the National Academy of Medical Sciences of Ukraine in 2024. We examined 34 servicemen, all of whom were male and were diagnosed with shoulder injuries (S40-S49). The mean age of the patients was 47.52 ± 12.25 years. All of them were divided into 4 groups according to the leukocyte index: group I — patients with a stress response (n = 5); group II — patients with a training response (n = 8); group III — patients with a calm activation response (n = 12); group IV — patients with increased activation (n = 9). At the planning stage of the study, in accordance with the World Medical Association's Declaration of Helsinki for Ethical Principles for Medical Research Involving Human Subjects (2008), the military personnel were informed about the purpose, methods and design of the study. Patients voluntarily confirmed in writing their consent to participate in the study: clinical examination, collection of material for laboratory tests, filling out questionnaires. Blood sampling was carried out on an empty stomach. This study was reviewed and approved for implementation at the meeting of the Committee on Bioethics and Deontology, Minutes No. 254 of August 15, 2025.

Exclusion criteria were complicated allergic history; refusal to participate in the study; inability to support the study; stage II-b heart failure or ejection fraction of 45 % or lower; diabetes mellitus; cancer; congenital or acquired coagulopathy; renal or hepatic failure.

All hospitalized patients were military personnel with shoulder injuries (rotation cuff rupture) who underwent stress level assessment. Time after trauma — 6.2 ± 2.1 months. Indications for surgery were pain and impaired function regardless conservative treatment. Upon admission to the clinic, patients underwent collection of anamnestic data, physical examination, and anthropometric measurement. The Mississippi Stress Scale was used to determine posttraumatic stress disorder (PTSD) by the number of points: PTSD — more than 130, mental disorders — 86 ± 26, well-adapted — 76 ± 18 points. According to the PSM-25 questionnaire, > 155 points indicated high level of stress, 100–154 — medium level of stress, < 100 — low level of stress. According to the visual analogue scale (VAS), the following criteria were used: 0 to 1 cm — extremely mild pain, 2 to 4 cm — mild pain, 4 to 6 cm — moderate pain, 6 to 8 cm — very severe pain, 8 to 10 cm — unbearable pain.

The following indicators were examined in the patients' blood: leukocytes — by counting in the Goryaev chamber, leukogram — in Romanowsky-Giemsa stained smears, ESR — by the Westergren method. The following biochemical markers were determined in the blood serum: total protein — by the biuret method, glucose — by the enzymatic method, and a thymol test was performed. The fibrinogen content, active partial thromboplastin time (APTT), prothrombin time (PT) and soluble fibrin monomer complexes (SFMC) in blood plasma were determined using reagent kits from Renam (Ukraine).

The data were statistically analyzed using Microsoft Excel XP and Statsoft Statistica 6.0 software packages. Comparison of groups in dynamics was performed by the nonparametric Wilcoxon test with the determination of the median (Me) and percentiles (25–75 %).

Results

During the clinical assessment of the degree of stress and pain in servicemen with shoulder injuries, there were no differences in the relevant scales, which indicates the need to assess adaptive capacity and stress response in patients who were injured and hospitalized after 6–8 months using laboratory markers (Table 1).

Within group I of patients who showed a stress response, the leukocyte index was reduced by 43.9 % compared to that of clinically healthy individuals. At the same time, LII was increased by 3.1 times, and LMR was reduced by 3.8 times compared to clinically healthy individuals (Table 2). In patients with a stress response, an increase in blood glucose, alanine aminotransferase (ALT), aspartate aminotransferase (AST) activity, as well as an increase in plasma fibrinogen, SFMC and a decrease in PT were found. These changes indicate the development of significant metabolic disorders and require further consideration when prescribing treatment (Table 3).

In group II of patients who showed a training response, an increase in the leukocyte index by 46.5 % was detected compared to group I, and it did not differ from that of clinically healthy individuals. The LII was 2.7 times higher than in clinically healthy individuals. The patients also showed an increase in LSI compared to group III. There was also an increase in total protein, fibrinogen, SFMC and a decrease in PT compared to clinically healthy individuals. No changes were found in glucose and enzyme activity compared to clinically healthy individuals, but ALT and AST activity were lower than in group I. Obviously, an increase in fibrinolysis is a consequence of inflammation because of trauma, but the integral leukogram parameters did not change significantly. This corresponds to the significant adaptive capacity of the patient's body.

In group III of patients who showed a calm activation reaction, there was an increase in the leukocyte index compared to clinically healthy patients by 29.3 %, to group I — by 60.3 %, group II — by 25.9 %. LII was 2.1 times higher than in clinically healthy individuals, and decreased by 32.5 % compared to group I, by 23.0 % compared to group II. IRWESR in group III was higher than in group I. ALT activity in group III was lower than in group I, fibrinogen and SFMC levels remained increased, and PT was decreased compared to that of clinically healthy patients.

In patients in group IV who showed increased activation, significant changes were observed: the leukocyte index was the highest, LII and LSI were the lowest compared to other groups of patients, and IRWESR was the highest compared

Table 1. Assessment of stress and pain in servicemen with shoulder injuries (Me, 25–75 %)

Indicators	Groups of patients, n = 34			
	Group I, n = 5	Group II, n = 8	Group III, n = 12	Group IV, n = 9
Mississippi Scale, points	77 75–79	81 64–96	78 64–97	80 66–100
PSM-25, points	57 56–80	89 73–141	83 54–91	98 70–124
VAS, cm	5 4–6	5 3–6	6 4–6	6 4–7

Table 2. Integral indicators of the leukogram in servicemen with shoulder injuries depending on the degree of stress response (Me, 25–75 %)

Indicators	Clinically healthy, n = 20	Groups of patients, n = 34			
		Group I, n = 5	Group II, n = 8	Group III, n = 12	Group IV, n = 9
Leukocytes, g/l	6.20 5.63–7.68	6.71 6.10–6.83	8.10 5.60–8.80	6.20 5.40–6.90	5.60 5.36–6.46
Leukocyte index	0.41 0.30–0.52	0.23* 0.10–0.26	0.43◊ 0.39–0.46	0.58*◊○ 0.55–0.66	0.87*◊○△ 0.78–0.82
LII	0.65 0.41–1.17	2.03* 1.90–7.33	1.78* 1.70–1.90	1.37*◊○ 1.23–1.56	1.04△ 0.98–1.13
IRWESR	1.22 0.64–1.92	0.54 0.45–0.81	1.04 0.80–3.14	1.65◊ 0.98–2.58	1.84◊ 1.22–3.43
LSI	2.28 1.96–2.96	2.85 2.45–7.33	1.99◊ 1.80–2.18	1.44◊○ 1.38–1.70	1.13*△ 1.02–1.20
LMR	6.29 5.10–7.25	1.64* 1.22–3.00	3.19 2.49–6.44	6.80 3.69–8.25	8.20◊ 6.39–10.75

Notes: * — $p < 0.05$ compared to clinically healthy subjects; ◊ — $p < 0.05$ compared to group I; ○ — $p < 0.05$ compared to group II; △ — $p < 0.05$ compared to group III.

to clinically healthy individuals, groups I, II and III. LMR was higher than in group III. Also, in group IV, a decrease in blood glucose was observed compared to group I. Fibrinogen and SFMC levels remained increased, and PT — decreased compared to those of clinically healthy individuals.

Discussion

Clinical assessment of the adaptive capabilities of the body of military personnel with shoulder injuries was performed according to the leukocyte index using criteria determined in four research groups. The findings from the pain assessment utilizing the VAS, in conjunction with the evaluation of emotional stress and PTSD, demonstrated no discernible differences among the patient groups. This underscores the necessity and potential for the implementation of laboratory adaptation criteria, which are calculated and pathogenetically substantiated based on leukocyte indices and markers of metabolic disorders [12]. In group I of patients (acute stress response), significant metabolic disorders are evident, indicative of a pronounced stress response, characterized by the highest LII index and a decrease in LMR. This suggests the development of endogenous intoxication and a disturbance in the effector link of the immune response. Group I patients also had increased fibrinolysis (SFMC and fibrinogen) and decreased PT, indicating activation of systemic inflammation and impaired prothrombin synthesis in the liver. This correlates with an increase in the activity of ALT and AST enzymes, which is associated with a violation of metabolic processes in hepatocytes. After all, it is known that aminotransferases can be used to assess the degree of adaptation during exercise and potential damage [13].

Group II patients (training response) showed a lower LII, an increase in total protein, as well as an increase in SFMC, fibrinogen, and a decrease in PT. However, in contrast to group I, there were no corresponding changes in liver enzyme activity and hyperglycemia. This indicates the possibility of more active adaptation in military personnel with higher leukocyte index and, accordingly, a more pronounced potential for adaptation. It is known that the adaptive potential can be directly related to the severity of the injury and can lead to dysregulation of the systemic inflammatory response [14].

In group III patients (reaction of calm adaptation), a less pronounced increase in LII was observed compared to patients in groups I and II. No changes in blood biochemical parameters were observed, but the level of fibrinolysis markers (SFMC and fibrinogen) remained elevated. Against this background, patients at the stage of calm adaptation also have changes in hemostatic markers, which may indicate an insufficient level of adaptation associated with systemic inflammation after trauma [15].

In group IV (increased activation), against the background of the highest leukocyte index, there was an increase in LII and a decrease in LSI, which was similar to group III. However, this group had the lowest SFMC across all study groups. After all, there is evidence of a possible effect of oxidative stress in leukocyte cells on fibrinogen proteolysis and, as a result, the development of coagulopathy during hypercoagulation [16].

Thus, each degree of adaptation according to the value of the leukocyte index is characterized by specific metabolic disorders. These disorders are reflected in the mechanisms of further development of the posttraumatic inflammatory process and possible complications.

Table 3. Blood biochemical parameters and hemostatic markers in servicemen with shoulder injuries depending on the degree of stress response (Me, 25–75 %)

Indicators	Clinically healthy, n = 20	Groups of patients, n = 34			
		Group I, n = 5	Group II, n = 8	Group III, n = 12	Group IV, n = 9
Total protein, g/l	70.10 68.40–72.80	70.30 70.10–75.40	76.50* 73.10–82.30	75.95 71.90–76.98	68.60 67.90–82.25
ALT, U/L	21.0 19.0–31.0	40.0* 39.0–90.5	24.0◊ 21.5–38.0	30.0◊ 23.5–35.8	39.0 21.3–54.3
AST, U/L	20.0 14.0–26.0	31.0* 31.0–56.0	25.0◊ 20.3–25.0	28.50 22.00–36.50	27.5 24.0–35.0
Thymol test, U/L	3.0 2.5–4.0	2.0 0.5–3.5	1.8 0.8–2.9	2.0 1.0–2.9	1.5 1.3–5.0
Glucose, mmol/l	4.70 4.40–5.25	6.70* 6.00–7.00	5.60 5.30–5.70	5.20 4.70–5.90	5.30◊ 4.95–6.00
Fibrinogen, g/l	2.20 1.90–2.88	4.80* 4.20–5.40	4.60* 3.00–6.80	4.30* 4.13–4.60	4.30* 4.00–4.90
SFMC, mg%	3.20 3.10–3.38	11.00* 4.00–16.00	10.30* 6.10–17.80	6.50* 6.00–10.00	4.25* 4.00–11.50
PT, s	16.00 15.50–17.75	12.00* 10.10–13.90	10.50* 9.88–11.95	13.00*° 12.10–13.80	11.75* 10.95–13.10
APTT, s	29.20 24.13–31.95	22.80 22.00–27.00	25.60 23.18–29.28	24.60 23.40–28.90	26.70 25.05–27.25

Notes: * — $p < 0.05$ for the indicator in clinically healthy subjects; ◊ — $p < 0.05$ for deterioration from group I; ° — $p < 0.05$ for deterioration from group II.

Conclusions

The most pronounced changes in the integral leukogram parameters, markers of coagulation and liver enzyme activity were observed in patients with a stress response; less pronounced disorders were observed in patients with training reaction. Indicators for the reactions of calm adaptation and increased activation were the least changed compared to those of clinically healthy individuals, which is associated with compensatory mechanisms in the patients' body. The most diagnostically significant parameters in the study groups with different degrees of adaptation were LII, fibrinogen level, APTT and PT, and in patients with acute stress response — ALT, AST and glucose activity. The dynamics of leukocyte indices, markers of coagulation and metabolic disorders allow us to clearly track the degree of pathogenetic changes at different stages of adaptation. It also makes it possible to objectify the assessment of patients who have no differences in the results of examinations and clinical studies. Among the laboratory indicators we studied to assess the condition of patients, leukocyte index and LSI can be recommended. Leukocyte index in group I with a stress response decreased compared to clinically healthy individuals, which is justified by a decrease in the ability to adapt, but in other groups, it gradually increased — from patients with training reaction to those with reaction of increased adaptation. LSI can be recommended as a second marker for assessing the condition of patients: its increase in patients of group I with a stress response indicates an active inflammatory process and impaired reactivity of the body, but a significant decrease was found in patients of groups II–IV.

Given the obtained values of laboratory parameters, we can make appropriate calculations and determine the stage of the patients' stress response, as well as assess their adaptive potential based on the results of biochemical studies and clinical evaluation of markers of the hemostatic system.

Prospects for further research. Metabolic disorders make it possible to assess the stage of adaptive disorders in a patient. These changes cannot be faked, even non-verbally. Further research will allow us to combine PTSD scales and laboratory changes.

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Information about authors

Kseniia I. Lyzohub, PhD in Medicine, Head of the Department of Pathophysiology, Anesthesiology and Functional Diagnostics, Sytenko Institute of Spine and Joint Pathology of NAMSU, Kharkiv, Ukraine; e-mail: kslizogub@gmail.com; phone: +380 (66) 304-55-80; https://orcid.org/0000-0001-9149-7208

Dmytro V. Morozenko, Doctor of Veterinary Sciences, Leading Research Fellow, Senior Researcher, Department of Laboratory Diagnostics and Immunology, Sytenko Institute of Spine and Joint Pathology of NAMSU, Kharkiv, Ukraine; e-mail: d.moroz.vet@gmail.com; phone: +380 (67) 722-57-48; https://orcid.org/0000-0001-6505-5326

Mykola V. Lyzohub, MD, DSc, PhD, Professor, Medical Director, Sytenko Institute of Spine and Joint Pathology of NAMSU, Kharkiv, Ukraine; e-mail: nlizogub@gmail.com; phone: +380 (95) 198-32-83; https://orcid.org/0000-0003-4776-1635

Inga F. Fedotova, MD, DSc, PhD, Professor, Deputy Director for Science, Sytenko Institute of Spine and Joint Pathology of NAMSU, Kharkiv, Ukraine; e-mail: ibolokadze@ukr.net; phone: +380 (50) 651-71-79; https://orcid.org/0000-0003-2069-7020

Fryda S. Leontieva, PhD in Biological Sciences, Senior Research Fellow, Head of the Department of Laboratory Diagnostics and Immunology, Sytenko Institute of Spine and Joint Pathology of NAMSU, Kharkiv, Ukraine; e-mail: frida@farfora.com; phone: +380 (96) 570-04-26; https://orcid.org/0000-0001-9801-7908

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Data availability. The authors affirm that this manuscript is based on their own clinical research, which was systematically collected, organized, and analyzed by the research team. The primary data include aggregated patient metrics, laboratory results, clinical protocols, and derived quantitative measures.

Ethical norms. The authors of the manuscript explicitly declare that the study was conducted using primary medical records and included clinical observations of patients. The study was performed in accordance with the ethical standards of the World Medical Association's Declaration of Helsinki for Ethical Principles for Medical Research Involving Human Subjects, the European Society Directive 86/609 on the participation of humans in biomedical research, and the Order of the Ministry of Health of Ukraine No. 690 dated September 23, 2009. Informed consent was obtained from all participants after providing clear, complete, and accessible information about the purpose, design, and methodology of the study, its potential risks, expected benefits, and possible alternatives. All patients confirmed their voluntary participation by signing an informed consent form. The study was approved by the Ethics and Bioethics Committee of Sytenko Institute of Spine and Join Pathology of the National Academy of Medical Sciences of Ukraine (Protocol No. 254 dated August 15, 2025).

Use of generative artificial intelligence. The authors explicitly declare that during the conduct of the study and the preparation of this manuscript, no generative artificial intelligence (AI) tools or services were used to perform any tasks listed in the Generative AI Task Delegation Taxonomy (GAIDeT, 2025). All stages of the work — from conceptualization to final editing — were completed without the involvement of generative AI, solely by the authors.

Authors' contribution. Lyzohub K.I. — study design, formulation of objectives; Morozenko D.V. — formulation of objectives, analysis of the data obtained and their statistical processing; Lyzohub M.V. — concept and design, collection and processing of data; Fedotova I.F. — determination of research directions, formulation of conclusions; Leontieva F.S. — justification of the feasibility of the study, development of its methodology, analysis of results.

Лизогуб К.І., Морозенко Д.В., Лизогуб М.В., Федотова І.Ф., Леонтьєва Ф.С.
ДУ «Інститут патології хребта та суглобів імені професора М.І. Ситенка НАМН України», м. Харків, Україна

Клінічна оцінка адаптації організму військовослужбовців із травмами плеча залежно від ступеня стресової реакції

Резюме. ***Актуальність.*** Ступінь адаптації організму залежить від багатьох факторів, включно з його здатністю адаптуватись до дії тих чи інших факторів, які спричиняють пошкодження. Адже саме військові постійно піддаються фізичному та метаболічному стресу. ***Мета:*** провести клінічну оцінку адаптації організму військових із травмами плеча на основі лейкоцитарних індексів, біохімічних показників крові та маркерів системи гемостазу. ***Матеріали та методи.*** Було обстежено 34 військовослужбовців, усі — пацієнти чоловічої статі, у яких діагностовано травми плеча. Час після травми 6,2 ± 2,1 міс. Середній вік хворих становив 47,52 ± 12,25 року. Усіх учасників (n = 34) розділено на 4 групи згідно з лейкоцитарним індексом: I група — особи, які проявляли стрес-реакцію (n = 5); II група — пацієнти з реакцією тренування (n = 8); III група — хворі, у яких відмічено реакцію спокійної активації (n = 12); IV стадія — особи, які проявляли підвищену активацію (n = 9). Оцінка стресу проводилась за Міссісіпською шкалою, оцінка рівня болю — за візуальною аналоговою шкалою. У крові пацієнтів було досліджено: лейкоцити — методом підрахунку в камері Горяєва, лейкограму — у мазках, фарбованих за Романовським — Гімзою, швидкість осідання еритроцитів — методом Вестергрена. У сироватці крові визначено наступні біохімічні маркери: загальний білок — біуретовим методом, глюкозу — ферментативним методом, також проводили тимолову пробу. Уміст фібриногену, активний частковий тромбопластиновий час (АЧТЧ), протромбіновий час (ПЧ) та розчинні фібрин-мономерні комплекси у плазмі крові визначали з використанням наборів готових реагентів фірми «Ренам». ***Результати.*** Найбільш виражені зміни інтегральних показників лейкограми, маркерів коагуляції та активності печінкових ферментів спостерігались у пацієнтів зі стрес-реакцією, менш виражені порушення — в осіб із реакцією тренування. Показники за реакції спокійної адаптації та підвищеної активації були найменш зміненими, що пов'язано з компенсаторними механізмами організму. Найбільш діагностично значущими в групах із різним ступенем адаптації виявилися лейкоцитарний індекс інтоксикації, рівень фібриногену, АЧТЧ та ПЧ, у хворих із гострою стрес-реакцією — активність аланінамінотрансферази, аспартатамінотрансферази й глюкози. ***Висновки.*** На основі одержаних лабораторних показників можна провести відповідні розрахунки і визначити, на якій стадії стресової реакції знаходиться пацієнт, а також оцінити його адаптаційний потенціал за результатами біохімічних досліджень та клінічної оцінки маркерів системи гемостазу.

Ключові слова: військові; травма плеча; посттравматичний стресовий розлад; адаптація; лейкоцитарний індекс; біохімічні маркери; гемостаз