Publication date: 01.12.2021
DOI: 10.51871/2588-0500_2021_05_04_11
UDC 796.96:616.728.3-089.85:616-08:612.014.423

# THE BIOFEEDBACK METHOD AS A WAY TO IMPROVE THE ANTIOXIDANT AND IMMUNOMODULATORY POTENTIAL OF REHABILITATION OF ATHLETES AFTER ARTHROSCOPIC MENISCECTOMY

E.V. Titskaya, I.I. Antipova, N.G. Abdulkina, I.N. Smirnova
Federal State Budgetary Institution «Siberian Federal Scientific and Clinical Center of the Federal Medical and Biological Agency»,
closed city Seversk, Russia

**Key words**: elite athletes, arthroscopic meniscectomy, medical rehabilitation, biofeedback method, system of lipid peroxidation and antioxidant protection, immune system.

**Annotation**. The aim of the study is to scientifically substantiate the feasibility of using the biofeedback training to improve the antioxidant and immunomodulatory potential of complex rehabilitation of athletes after arthroscopic meniscectomy. The conducted study proved that the inclusion of the biofeedback training in the rehabilitation complex contributes to statistically significant reduction of reactive inflammation, increases efficiency of the antiradical and anti-peroxide protection system, optimizes the activity of the cellular link of the systemic immunity, stimulates the absorption and digesting functions of neutrophils.

**Introduction.** Among reasons for elite athletes to stop their professional activity, the most frequent ones are injuries in anatomical structures of knee joints [1-4]. At present time, surgical treatment of this pathological state in most cases is carried out using a minimally invasive method – arthroscopy that ensures minimizing a severity of surgical trauma and reduce rehabilitation terms [5]. Moreover, after arthroscopic surgical intervention in the injured knee joint, an acute reactive inflammatory process develops. Enhanced lipid peroxidation processes, decreased activity of antioxidant enzymes and concentration of bio-antioxidants, suppression of functional activity of the cellular link of the systemic immunity play a significant role in the occurrence of the reactive inflammatory process [6].

To restrict processes of free radical oxidation and inflammation, prevent a formation of secondary immunodeficiency after conducted arthroscopic treatment of the meniscus in the knee joints, rehabilitation therapists more often use non-drug technologies of restoring disturbed functions of the organism, including the biofeedback method (BF-training). It was earlier proven that using the

BF-training for individuals with diagnosed psychoemotional stress allows minimizing a degree of its severity through reducing excessive activity of neurons in the brain cortex, recovery of the balance between sympathetic and parasympathetic divisions of the vegetative nervous system, decrease in permeability of the blood-brain barrier for peripheral neurotransmitters of stress, suppression of processes of disturbance in tissue metabolism initiated by an excessive production of catecholamines and corticosteroids by the adrenal glands [7-9]. At the same time, an issue of the BF-training's influence on the character of processes of antiradical and anti-peroxide protection and inflammation, functioning of cellular and humoral links of immunity, absorbing and digesting functions of neutrophils, remains open, which makes relevant continuing scientific research in this field.

The study's purpose: to scientifically substantiate the feasibility of using the BF-training to improve the antioxidant and immunomodulatory potential of complex rehabilitation of athletes after arthroscopic meniscectomy.

**Methods and organization.** The clinical study (CS) included 20 athletes of precise, game and cyclic sports: 14 (70,0%) men and 6 (30,0%) women with the average age of 25,50±8,41 years. 20,0% (n=4) of participants were Candidates Masters of Sports, 70,0% (n=14) – Masters of Sports, 10% (n=2) – Masters of Sports of International Class. All athletes had acute or chronic injury of the medial meniscus of one of the knee joints, due to which arthroscopic meniscectomy was carried out 10-14 days ago.

The CS participants were divided into 2 groups that corresponded by gender, age, sports qualification and features of the pathological process. The rehabilitation complex of athletes of the main group (I, n=6) included individual therapeutic exercises, massage, exposure to low-frequency alternating magnetic fields, low-intensity infrared band laser radiation, cold-temperature sapropel clay applications (34-36ºC) and the BF-training. The BF-training was carried out using the software and hardware complex of psychological and psychophysiological diagnostics and biocontrol "BF-PULSE" (registration certificate № FSR 2011/11235 from 12.08.2011, manufactured by the LLC "Biocontrol computer systems", Novosibirsk, Russia), including a set of computer games. An athlete was assigned to achieve maximally possible relaxation during the game. In the course of the training, three game sessions were suggested. A duration of each session was 20-25 minutes. An effectiveness of controlling one's own psychophysiological state was supported through an identification of heart rate using a pulse detector with a simultaneous presentation of results on a monitor screen.

The comparison group (II, n=14) included athletes with the same pathological state. The rehabilitation events complex for the II group athletes was presented as

same therapeutic physical agents with equal parameters of procedure prescription, excluding BF-procedures.

In order to achieve the set task, we determined following laboratory indicators: superoxide dismutase (SOD), glutathione peroxidase (GPx) in whole blood and red blood cells, total antioxidant status (TAS) in blood serum, malondialdehyde (MDA), high-sensitivity C-reactive protein (hs-CRP), fibrinogen, CD3+, CD4+, CD8+, CD16+ peripheral blood lymphocytes, class A, M and G immunoglobulins (Ig A, Ig M, Ig G), interleukins (IL) 1β, 4, 6, tumor necrosis factor α (TNF-α), circulating immune complexes (CIC), spontaneous (PhAspont) and stimulated (PhAstim) phagocytic activity, spontaneous (PhNspont) and stimulated (PhNstim) phagocytic number.

Critical level of significance when checking on statistical hypotheses in the study was equal to 0,05. The data was presented in the form of "sample mean±standard derivation" (M±SD).

**Results and discussion.** Before carrying out complex rehabilitation of athletes, there were no pathological derivations of studied clinical and biochemical blood indicators, except for an increase of GPx in whole blood (11856±4584 u/l, reference values are 4171-10881 u/l) and in red blood cells (79,98±31,47 u/g, reference values are 27,5-74,6 u/g Hb), which is a logical response of the organism aimed at suppression of the process of excessive formation of lipid peroxidation in injured tissues of the knee joints due to trauma and a subsequent surgical intervention contributing to a formation of pathological structural changes of various biosubstrates with a subsequent injury of biomembranes, inactivation of enzymes, deformation of macromolecules, integrity damage of cells and intercellular structures and, consequently, earlier apoptosis.

The initial state of the cellular link of the systemic immunity was characterized by an increase of the absolute number of CD16+ effector cells (3,16±0,73 g/l, reference values are 0,06-0,3 g/l). Moreover, a relative number of CD+16 lymphocytes was within limits of physiological norm, which is possible in case of having the chronic inflammatory process in the proliferation or reparation phase.

It is also important to note an increase of the absolute number of CD8+ lymphocytes (28,80±9,09 g/l, reference values are 0,3-0,8 g/l) after arthroscopic meniscectomy, which is explained by a necessity to hold production of autoantibodies by CD19+ lymphocytes and a support of full-fledged eradication of pathologically changed cells during the convalescence period.

The aforementioned features of the functioning cellular link of the systemic immunity of athletes after the surgical intervention defined a small decrease of the CD4+/CD8+ immunoregulatory index (1,58±1,09 c.u., reference values are 1,6-2,2

c.u.), which in combination with a revealed worsening of spontaneous (28,74±8,79%, reference values are 40-60%) and stimulated (37,40±11,39%, reference values are 40-80%) absorbing ability of neutrophils and negative changes of their digesting ability (PhAspont– 3,16±0,73 pcs, reference values are 4-9 pcs; PhAstim – 3,38±0,50 pcs, reference values are 4-9 pcs) can be considered as an evidence of potential risk of forming the secondary immunodeficiency in conditions of no rehabilitation that is appropriate to an athlete's state and preservation of a long-term persistence of the inflammatory process.

Aside from described pathological changes of the cellular link of the systemic immunity, we also registered an increase in the absolute number of CD19+ lymphocytes (2,18±0,65 g/l, reference values are 0,09-0,6 g/l). This event is possibly connected to an increase of Ig A (2,99[1,80;4,50] g/l, reference values are 1,25-2,8 g/l) in blood serum, which is produced mainly by plasma cells that are a result of a transformation of CD19+ lymphocytes in case of their contact with an antigen or stimulation by CD3+ lymphocytes. The revealed fact deserves special attention due to a high risk of forming severe immunopathological reactions that occur in case of participating high concentrations of Ig A. One should not also forget about an ability of Ig A to affect processes of the cartilage and subchondral bone remodeling due to disturbance of appropriate interaction between extracellular matrix components: collagen, elastin, adhesive proteins of fibronectin and laminin and a main substance produced by proteoglycans. It leads to a gradual development of such joint diseases as osteoarthritis [10].

As a result of conducted rehabilitation events, we registered a decrease of an absolute GPx activity in whole blood (p=0,036) in athletes of the II group. It serves as an evidence of deceleration in free radical reactions, accompanied by an appearance of oxidation-prone lipid fractions and an increase in speed of their peroxidation and an effective expenditure of endogenic antioxidants that define restoration of balance of the lipid peroxidation (LPO) and antioxidant protection (AOP) systems (table 1).

The fact of normalization of the initially reduced SOD activity in 14,3% participants of the II group contributes to this estimation. A tendency of an increase of MDA in 64,3% of athletes (p=0,009) of the II group also shows a positive influence on the LPO-AOP system of medical rehabilitation with therapeutic physical agents (table 1).

Table 1

Dynamics of mean values of blood biochemical indicators of athletes within the process of complex rehabilitation with therapeutic physical agents (M±SD)

| Indicators | I group (n=6) | | II group (n=14) | |
|---|---|---|---|---|
| | Before rehabilitation | After rehabilitation | Before rehabilitation | After rehabilitation |
| Antioxidant activity, mmol/l (standard values: 0,5-2,55) | 1,84±0,13 | 1,71±0,12 | 1,74±0,32 | 1,80±0,30 |
| Extracellular catalase, μkat/l (standard values: <30) | 17,84±5,96 | 10,98±2,65* p=0,042 | 15,55±4,67 | 15,58±4,91 |
| Ceruloplasmin, mg/l (standard values: 280-400) | 303,44±62,93 | 302,38±51,94 | 301,53±27,08 | 300,00±38,55 |
| Malondialdehyde, mmol/l (standard values: <3,8) | 2,76±0,73 | 2,69±0,84 | 3,09±4,10 | 2,66±0,54 |
| Superoxide dismutase of red blood cells, u/ml (standard values: 164-240) | 207,19±40,75 | 217,99±17,04 | 222,94±54,11 | 236,33±59,97 |
| Superoxide dismutase of red blood cells, u/ml Hb (standard values: 1102-1601) | 1471,67±280,19 | 1578,22±195,47 | 1496,58±279,34 | 1612,80±378,13 |
| Glutathione peroxidase, u/g (standard values: 4171-10881) | 10821,00± 2178,55 | 8420,00± 2694,32* p=0,047 | 10791± 2268,04 | 8588,57± 1704,38* p=0,036 |
| Glutathione peroxidase, u/g Hb (standard values: 27,5-73,6) | 80,05±20,33 | 60,92±18,97 p=0,045 | 72,66±13,04 | 64,03±9,59 |
| Fibrinogen, g/l (standard values: 2-4) | 2,73±1,16 | 2,58±0,29* p=0,021 | 2,73±0,17 | 2,62±0,48 |
| High-sensitivity C-reactive protein, g/l (standard values: <3) | 2,67±0,13 | 2,40±0,24* p=0,005 | 2,73±0,17 | 2,62±0,48 |

Note: * – p – criterion of significance of differences between groups

Positive changes in the LPO and AOP systems and the immune system of athletes of the I group were proven by a decrease of an absolute GPx activity in whole blood (p=0,047) and red blood cells (p=0,045), a decrease of extracellular catalase (p=0,042) and Ig M (p=0,028) in blood serum, increase in a relative number of CD4+ lymphocytes (p=0,050), normalization of values of the CD4+/CD8+ immunoregulatory index (p=0,048), absorbing (PhAspont, p=0,049) and digesting functions of phagocytes (PhNspont p=0,012, PhNstim, p=0,018). This serves as an evidence of increasing resistance to an influence of biological, chemical and physical stress factors (tables 1, 2).

Analysis of dynamics of indicators of the systemic immunity of the II group participants did not reveal significant positive dynamics (table 2).

Table 2

Dynamics of mean values of immunological blood indicators in athletes within the process of complex rehabilitation with therapeutic physical agents (M±SD)

| Indicators | I group (n=6) | | II group (n=14) | |
|---|---|---|---|---|
| | Before rehabilitation | After rehabilitation | Before rehabilitation | After rehabilitation |
| $CD_{3+}$ lymphocytes, % (standard values: 40-69) | 68,89±5,62 | 68,13±5,11 | 68,00±66,50 | 4,42±5,98 |
| $CD_{4+}$ lymphocytes, % (standard values: 23-45) | 38,56±4,88 | 46,88±8,04* p=0,050 | 43,33±7,44 | 39,83±5,32 |
| $CD_{8+}$ lymphocytes, % (standard values: 22-28) | 26,78±4,38 | 23,00±2,14 | 26,87±4,17 | 27,00±3,41 |
| $CD_{16+}$ lymphocytes, % (standard values: 10-20) | 16,33±3,64 | 12,25±5,23* p=0,049 | 15,00±2,98 | 15,42±2,97 |
| $CD_{19+}$ lymphocytes, % (standard values: 9-29) | 10,11±2,31 | 10,50±4,44 | 10,13±2,26 | 9,75±2,14 |
| Immunoregulatory index $CD_4$+/$CD_8$+, c.u. (standard values: 1,6-2,2) | 1,51±0,26 | 2,16±0,42* p=0,048 | 1,68±0,59 | 1,52±0,38 |
| Class A immunoglobulins, g/l (standard values: 1,25-2,9) | 2,55±0,81 | 2,48±0,89 | 1,98±0,91 | 2,07±1,14 |
| Class G immunoglobulins, g/l (standard values: 8,4-17,0) | 14,51±2,31 | 12,65±2,39 | 12,30±2,03 | 12,75±1,58 |
| Class M immunoglobulins, g/l (standard values: 1,03-2,2) | 1,47±0,49 | 1,19±0,29* p=0,028 | 1,30±0,54 | 1,16±0,71 |
| Spontaneous phagocytic activity, % (standard values: 40-60) | 34,67±5,29 | 44,50±7,04* p=0,049 | 35,07±11,45 | 42,75±9,81 |
| Stimulated phagocytic activity, % (standard values: 40-80) | 41,80±12,10 | 51,08±8,39 | 43,67±10,34 | 40,75±14,19 |

Table 2 (continued)

| | | | | |
|---|---|---|---|---|
| Spontaneous phagocytic number, pcs (standard values: 4-9) | 3,27±0,67 | 4,62±0,94* p=0,012 | 3,35±0,59 | 3,87±0,80 |
| Stimulated phagocytic number, pcs (standard values: 4-9) | 3,35±0,45 | 4,48±0,98* p=0,018 | 3,55±0,62 | 4,06±0,93 |
| Circulating immune complexes, c.u. (standard values: 45-90) | 45,63±10,50 | 46,75±10,8 | 63,47±33,11 | 64,92±31,8 |
| Tumor necrosis factor α, pg/ml (standard values: 0-6) | 4,78±1,59 | 4,02±0,93 | 2,59±1,53 | 3,09±2,14 |
| Interleukin 1β , pg/ml (standard values: 0-11) | 4,20±0,49 | 4,06±0,25 | 3,20±1,12 | 3,02±1,03 |
| Interleukin 6, pg/ml (standard values: 0-10) | 2,62±1,07 | 2,38±0,63 | 3,09±2,14 | 3,92±3,20 |
| Interleukin 4, pg/ml (standard values: 0-13) | 1,45±0,29 | 1,50±0,12 | 1,96±0,87 | 1,65±0,18 |

Note: * – p – criterion of significance of differences between groups

Another argument for including the BF-training into the complex of rehabilitation events is a decrease of fibrinogen (p=0,021) and hs-CRP (p=0,005) in comparison with dynamics of similar blood biochemical indicators of participants of the II group.

Therefore, explaining presented results obtained from the CS lies at the basis of BF-training's approved ability to effectively influence on main pathogenetic mechanisms of stress disorder, caused in this case by trauma, and its surgical treatment. It is made through balancing relationships between sympathetic and parasympathetic divisions of the vegetative nervous system, suppression of an excessive activity of the hypothalamic-hypophysial-adrenocortical system, decrease of an excessive production of catecholamines and corticosteroids by the adrenal glands, decrease of the LPO's excessive activity and a subsequent occurrence of active products of the thiobarbituric acid (TBA-active products). These products are able to affect tissues directly, activate or intensify the inflammatory reaction with a consecutive degradation of cellular elements and structures of the extracellular matrix in the pathological focus and a formation of dysfunction of the cellular and humoral links of the non-specific immunity [11].

**Conclusion.** While reviewing the aforementioned data, it is important to note that as a result of the CS, we received facts that evidence the reason to include the BF-training into the complex of rehabilitation events of elite athletes after the arthroscopic meniscectomy in order to support statistically more significant anti-inflammatory, antioxidant and immunomodulatory effects of medical rehabilitation with therapeutic physical agents.

## References


1. Valeev N.M. The issue of rehabilitation of sports performance of soccer players after traumatic injuries / N.M. Valeev // Theory and Practice of Soccer. – 2002. – № 1(13). – P. 23.

2. Sokrut V.N. Rehabilitation approach to sports medicine / V.N. Sokrut, I.R. Shvirenko, E.S. Povazhnaya // Physiatrist. – 2011. – № 3. – P. 6-7.

3. Kochergin V.V. Features of rehabilitation for knee joint injuries of athletes / V.V. Kochergin // Innovational Science. – 2015. – № 10. – P. 123-125.

4. Lyadov K.V. Comprehensive rehabilitation of athletes after knee joint surgery / K.V. Lyadov, V.I. Dubrovskij, A.V. Dubrovskaya // Physical Therapy, Balneology and Rehabilitation. – 2008. – № 6. – P. 4-10.

5. Zubi Yu. Kh. Arthroscopy of the knee joint in case of injuries / Yu. Kh. Zubi, D.M. Sajdalin, M.D. Kurbansupiev, M.S. Sajdalina, S.S. Alkhodzhaev // Bulletin of the KazNMU. – 2015. – № 2. – P. 305-308.

6. Zakhvatov A.N. Substantiation of intraarticular use of ozone in correction of free radical processes in traumatic knee joint injury (experimental study) / A.N. Zakhvatov, S.I. Kuznetsov, S.A. Kozlov // Bulletin of New Medical Technologies. – 2015. – Vol. 22. – № 1. – P. 19-22.

7. Titskaya E.V. Biofeedback training as a factor of optimization of the functioning of mechanisms of psychophysiological rehabilitation of elite athletes after arthroscopic meniscectomy / E.V. Titskaya, I.I. Antipova, T.E. Levitskaya, N.G. Abdulkina // Multidisciplinary Medical Associations in the System of Medical Rehabilitation: materials of the All-Russian Scientific and Practical Conference within the framework of the I Congress «Healthcare of Russia. Technologies of Advanced Development». – 2015. – P. 84-85.

8. Kunelskaya N.L. The biofeedback method in clinical practice / N.L. Kunelskaya, N.V. Rezakova, A.A. Gudkova, A.B. Geht // Journal of Neurology and Psychiatry. – 2014. – № 8. – P. 46-50.

9. Bykov A.T. The biofeedback methods in the correction of psychophysiological maladjustment in conditions of a sanatorium / A.T. Bykov, Ya.A. Piterskaya, R.Yu. Poddubnaya, L.D. Chernousova // General Questions of Using the Biofeedback Method: collection of articles. – Saint Petersburg: CJSC «Biosvyaz». – 2008. – 100 p.

10. Dmitrieva L.A. Immunopathological manifestations in patients with severe forms of coxarthrosis / L.A. Dmitrieva, E.Yu. Korshunova, V.E. Lebedev // Medical Immunology. – 2009. – Vol. 11. – № 2-3. – P. 161-168.

11. Piterskaya E.A. Free radical processes in the blood and saliva of patients with cholelithiasis / E.A. Piterskaya, V.V. Vnukov // Journal of Higher Education Institutions. North Caucasian Region. Natural Sciences (Rostov-on-Don). – 2007. – № 4. – P. 88-92.

**Information about the authors: Elena Vasil'evna Titskaya** – Doctor of Medical Sciences, Leading Researcher of the Therapeutic Division of the Department of Prevention and Restorative Treatment of Occupational Diseases of the Branch of the TSRIBiP FSBI SibFSCC of FMBA of Russia, Seversk, e-mail: doctor.tizkaya@gmail.com; **Inna Ivanovna Antipova** – Candidate of Medical Sciences, Leading Researcher of the therapeutic division of the Department of Prevention and restorative treatment of occupational diseases of the Branch of the TSRIBiP FSBI SibFSCC of FMBA of Russia, Seversk, e-mail: doctor.antipova@gmail.com; **Natal'ya Gennad'evna Abdulkina** – Doctor of Medical Sciences, Deputy General Director for Scientific and Clinical Work of the FSBI SibFSCC of FMBA of Russia, Seversk, e-mail: nauka@med.tomsk.ru; **Irina Nikolaevna Smirnova** – Doctor of Medical Sciences, Head of the Therapeutic Division of the Department of Prevention and Restorative Treatment of Occupational Diseases of the Branch of the TSRIBiP FSBI SibFSCC of FMBA of Russia, Seversk, e-mail: irin-smirnova@yandex.ru.