Criteria for assessing the adaptive changes in MMA athletes of strike fighting style in different training load regimes

Andrii Chernozub [1] , **Veaceslav Manolachi** [Corresp., 2, 3] , **Georgiy Korobeynikov** [4] , **Vladimir Potop** [3, 5] , **Liudmyla Sherstiuk** [1] , **Victor Manolachi** [2, 3] , **Ion Mihaila** [5]

[1] Petro Mohyla Black Sea National University, Mykolaiv, Ukraine

[2] "Dunarea de Jos" University of Galati, Galati, Romania

[3] State University of Physical Education and Sport, Chisinau, Republic of Moldova

[4] National University of Physical Education and Sport, Kyiv, Ukraine

[5] Department of Physical Education and Sport, University of Pitesti, Pitesti, Romania

Corresponding Author: Veaceslav Manolachi
Email address: manolachivsciences@yahoo.com

Background. To study the peculiarities of changes in functional indicators and body composition parameters of MMA athletes of strike fighting style and a number of biochemical blood indicators during two months of using different intensity training load regimes, and to determine the most informative criteria for assessing adaptive body changes in these training conditions. **Methods.** We examined 40 MMA athletes (men) aged 20-22, who used mainly strike fighting style in their competitive activity, and divided them into 2 research groups (A and B), 20 athletes in each group. Group A athletes used medium intensity (R_a = 0.64), and group B - high intensity (R_a = 0.72) training load regime. To assess the adaptive body changes we applied methods of control testing of maximum muscle strength growth (1 RM), special training (the number of accurate kicks on the mannequin for 30 s), and bioimpedansometry. By monitoring biochemical parameters (testosterone, cortisol, creatinine, phosphorus, calcium, cholesterol, LDH) in the blood serum of athletes we determined the peculiarities of adaptive-compensatory body reactions in response to training loads. **Results.** The obtained results of special training increased during the study period by an average of 10.5% in group B athletes, but group A participants' results had no significant changes compared to basal data. The largest increase in the development of maximum muscle strength growth by an average of 44.4% was recorded after 2 months of research in group B. Group B athletes also had positive changes in body fat and fat-free mass indicators during the study which were 2 times higher than the results of group A. The laboratory studies and correlation analysis showed informative biochemical markers (cortisol, testosterone and creatinine) for assessing the condition of athletes in both groups before using high and medium training load regimes. The biochemical markers for assessing the adaptive-compensatory reactions of athletes in

response to high-intensity physical stimuli at the beginning of the study were indicators of LDH and cholesterol, and in conditions of medium intensity it was LDH, testosterone and cortisol. After 2 months of study the set of biochemical markers assessing the adaptation processes before the load completely changed only in group B athletes and consisted of LDH, phosphorus, cholesterol, and calcium. At the same time, the set of biochemical criteria for assessing adaptive-compensatory reactions after training in group B athletes was completely changed compared with the data recorded at the beginning of the study. **Conclusion.** Defining the optimal set of criteria for assessing the adaptive-compensatory changes in MMA athletes of strike fighting style will allow in the shortest possible time to correct the parameters of the training load regime for accelerating the body functionality in the process of special power training.

Criteria for assessing the adaptive changes in MMA athletes of strike fighting style in different training load regimes

6 Andrii Chernozub[1], Veaceslav Manolachi[2,3], Georgiy Korobeynikov[4], Vladimir Potop[3,5],
7 Liudmyla Sherstiuk[1], Victor Manolachi[2,3], Ion Mihaila[5]

9 [1] Petro Mohyla Black Sea National University, Mykolaiv, Ukraine
10 [2] "Dunarea de Jos" University of Galati, Romania
11 [3] State University of Physical Education and Sport, Republic of Moldova
12 [4] National University of Physical Education and Sport, Kyiv, Ukraine
13 [5] Department of Physical Education and Sport, University of Pitesti, Pitesti, Romania

15 Corresponding Author:
16 Veaceslav Manolachi
17 Str. Domneasca no. 47, Galati, 800008, Romania
18 Email address: manolachivsciences@yahoo.com

Abstract

21 **Background.** To study the peculiarities of changes in functional indicators and body
22 composition parameters of MMA athletes of strike fighting style and a number of biochemical
23 blood indicators during two months of using different intensity training load regimes, and to
24 determine the most informative criteria for assessing adaptive body changes in these training
25 conditions.
26 **Methods.** We examined 40 MMA athletes (men) aged 20-22, who used mainly strike fighting
27 style in their competitive activity, and divided them into 2 research groups (A and B), 20 athletes
28 in each group. Group A athletes used medium intensity ($R_a = 0.64$), and group B - high intensity
29 ($R_a = 0.72$) training load regime. To assess the adaptive body changes we applied methods of
30 control testing of maximum muscle strength growth (1 RM), special training (the number of
31 accurate kicks on the mannequin for 30 s), and bioimpedansometry. By monitoring biochemical
32 parameters (testosterone, cortisol, creatinine, phosphorus, calcium, cholesterol, LDH) in the
33 blood serum of athletes we determined the peculiarities of adaptive-compensatory body reactions
34 in response to training loads.
35 **Results.** The obtained results of special training increased during the study period by an average
36 of 10.5% in group B athletes, but group A participants' results had no significant changes
37 compared to basal data. The largest increase in the development of maximum muscle strength
38 growth by an average of 44.4% was recorded after 2 months of research in group B. Group B

39   athletes also had positive changes in body fat and fat-free mass indicators during the study which
40   were 2 times higher than the results of group A. The laboratory studies and correlation analysis
41   showed informative biochemical markers (cortisol, testosterone and creatinine) for assessing the
42   condition of athletes in both groups before using high and medium training load regimes. The
43   biochemical markers for assessing the adaptive-compensatory reactions of athletes in response to
44   high-intensity physical stimuli at the beginning of the study were indicators of LDH and
45   cholesterol, and in conditions of medium intensity it was LDH, testosterone and cortisol. After 2
46   months of study the set of biochemical markers assessing the adaptation processes before the
47   load completely changed only in group B athletes and consisted of LDH, phosphorus,
48   cholesterol, and calcium. At the same time, the set of biochemical criteria for assessing adaptive-
49   compensatory reactions after training in group B athletes was completely changed compared
50   with the data recorded at the beginning of the study.
51   **Conclusion.** Defining the optimal set of criteria for assessing the adaptive-compensatory
52   changes in MMA athletes of strike fighting style will allow in the shortest possible time to
53   correct the parameters of the training load regime for accelerating the body functionality in the
54   process of special power training.

55   ## Introduction

56   Leading experts in sports and physical training (*James et al., 2017; Kirk et al., 2021; Tota &*
57   *Wiecha, 2022*) have recently showed great interest in optimizing the system of integrated control
58   of athletes' adaptation processes in Mixed Martial Arts to increase the body functional reserves,
59   to improve the mechanisms of training activity correction, and to maximize performance in the
60   shortest possible time. The complexity of the process of developing an optimal set of criteria for
61   assessing adaptive body changes of MMA athletes is connected with taking into account their
62   individual characteristics, level of training, the style of fighting, and parameters of training load
63   regimes used during training (*Matthews & Nicholas, 2017; Slimani et al., 2017; Chernozub, et*
64   *al.,2019*).
65   The wide and diverse range of techniques, methods, and principles of training activities
66   used by athletes, depending on the style of fighting in Mixed Martial Arts, raises a number of
67   controversial issues among experts on determining effective training load parameters and
68   correction mechanisms (*Del Vecchio & Franchini, 2011; Chernozub, et al.,2019; Kirk et al.,*
69   *2021*). The search for new ways to improve the training of athletes of strike fighting style
70   requires the development of explosive strength and endurance, and a constant increase in
71   adaptive reserves due to intra-muscular and intermuscular coordination and energy efficiency of
72   muscle activity in anaerobic training load regime (*James et al., 2016; Futorniy et al., 2017*).
73   Several researchers (*Manolachi, 2015; Korobeynikov et al., 2017; Titova et al., 2018;*
74   *Chernozub, et al., 2020*) considering speed and power training of athletes to be the key factor of
75   adaptive changes effectiveness, noted that the main criteria for assessing the effectiveness of
76   different intensity training load on the body's functional reserves and the level of athletes' fitness
77   are the following indicators: morpho-functional parameters, assessment of special training and
78   changes in biochemical components of blood. At the same time, the problem of searching the

79 effective training load regimes in the process of special strength training of MMA athletes of
80 strike fighting style has not been studied yet and the ways of determining the optimal set of
81 informative criteria for assessing adaptive body changes for further correction of the training
82 process have not been described in scientific literature.
83 Extensive use of biochemical control indicators (hormones, enzymes, microelements, etc.) to
84 assess the adaptive-compensatory reaction of athletes in training and competitive activities is an
85 integral part of the training system in martial arts and fitness (*Marques et al., 2017; Philippou et*
86 *al., 2017; Wochyński et al., 2017; Titova et al., 2018; Kılıc et al., 2019; Tota & Wiecha, 2022*) in
87 recent decades. At the same time there is no clear definition which indicators of biochemical
88 blood control reliably reflect the course of adaptive changes depending on the structure of special
89 strength training and the peculiarities of the training load regime for MMA athletes of strike
90 fighting style.
91 One of the priority issues of improving the training system in MMA is the development of
92 mechanisms for operational control of the functional state of athletes using the minimum number
93 of indicators but the most informative set of biochemical blood markers. Appropriate ways to
94 optimize the diagnosis of athletes will reduce the time to determine the necessary mechanisms
95 for correcting the value of the training load regime and decrease the cost of research.
96 The purpose of the study is to review the peculiarities of changes in functional indicators and
97 body composition parameters of MMA athletes of strike fighting style and a number of
98 biochemical blood indicators during two months of using different intensity training load
99 regimes, and to determine the most informative criteria for assessing adaptive body changes in
100 these training conditions.

101 **Materials & Methods**

102 **Participants**
103 We examined 40 MMA athletes (men) aged 20-22 with an average training experience is $2.5 \pm$
104 0.32 years. The research took place at the stage of specialized basic training of athletes. These
105 athletes were divided them into 2 research groups (A and B), 20 athletes in each group. Thus,
106 group A athletes used medium intensity training load regime ($R_a = 0.64$), and group B
107 representatives used high intensity training load regime ($R_a = 0.72$).
108 For the validity of study, we selected participants without significant differences in the initial
109 parameters of the studied indicators.
110 The experimental study was approved by Petro Mohyla Black Sea National University Ethics
111 Committee for Biomedical Research in accordance with the Ethical Standards of the Helsinki
112 Declaration (ecbr10-02-2022). The participants gave written consent to the study in accordance
113 with the recommendations of the Biomedical Research Ethics Committees (*World Health*
114 *Organization, 2000*).
115 We used diagnostic equipment of the medical center of the university for medical
116 examination, assessment of morpho-functional parameters, and biochemical control of blood
117 serum in athletes during the study.
118 **Measurements**
119 **Maximal muscle strength**

120 Control testing of the maximum muscle strength growth (1 RM) in athletes of both groups took
121 place at the beginning and after 2 months of special strength training using the specified training
122 load regimes. Control testing consisted of the following control exercises: bench press on the
123 Smith simulator, block thrust behind the head, legs press in the simulator lying. Measurements of
124 1 RM were performed during control exercises on simulators to reduce the level of injuries of
125 study participants. During the control testing and throughout the training period, strength
126 exercises were performed in accordance with generally accepted techniques and methods (*James*
127 *et al., 2017; Loturco et al., 2021*).
128 **Special training**
129 The special training development of group participants was determined using the method of
130 control testing of the training level in MMA athletes of the strike fighting style. The proposed
131 method is based on determining the maximum number of kicks on the mannequin during the
132 control exercises (front kick, side kick, reverse side kick, roundhouse kick) for 30 seconds
133 following the appropriate technique. We chose such control exercises because of their frequent
134 usage in the competitive activity of Mixed Martial Arts.
135 **Body composition**
136 A non-invasive biophysical method of bioimpedansometry was used to determine the body
137 composition of athletes during the study (initial data, after the first and second months of
138 training). This method is based on measuring the electrical resistance of biological tissues of the
139 body. Determination of the body composition parameters occurs in the process of computer
140 processing of the obtained data. The method of bioimpedansometry allows to determine the
141 following indicators: body fat (BF, %), fat-free mass (FFM, kg), body cell mass (BCM, %), body
142 mass index (BMI, cond. units), dry cell weight (DCW, kg). To evaluate the studied parameters,
143 we used a bioimpedance analyzer (body composition analyzer) consisting of diagnostic
144 computerized hardware-software complex KM-AP-01 (Diamond-AST configuration) (VYUSK.
145 941118.001 PE) (*Martyrosov, Nikolayev & Rudnev, 2006*).
146 **Biochemical parameters**
147 The activity of lactate dehydrogenase (LDH) and the concentration of creatinine in the blood
148 serum of athletes were determined by kinetic method on the equipment of the company "High
149 Technology Inc" (USA) with a set of reagents PRESTIGE 24i LQ LDH (Poland). Testosterone
150 and cortisol concentration in the blood serum was determined by enzyme-linked immunosorbent
151 analysis, using a set of reagents SteroidIFA-testosterone on the equipment of the company
152 "Alcor Bio". The concentration of calcium and phosphorus in the blood was determined using a
153 photometric method by measuring the optical density on a spectrophotometer StatFax 4700 using
154 a set of reagents "Medical Analysis" for determining calcium, and a set of reagents Liquick Cor-
155 PHOSPHORUS (Poland) for determining the concentration of phosphorus. The concentration of
156 total cholesterol was determined by colorimetric and enzymatic methods with esterase and
157 cholesterol oxidase using Liquick Cor-CNOL diagnostic kit (Poland). The blood sampling was
158 performed according to the general requirements of biomedical research (*Tietz, 1995*). Venous
159 blood sampling was performed by a paramedic before and after training at the beginning and end
160 of the second month of the study in compliance with all requirements and norms.

161 **Experimental design**

162 The research took place in several stages:

163   - in the first stage we determined the characteristics of adaptive-compensatory reactions in

164 MMA athletes of strike fighting style who used different intensity of training load regimes

165 (Table 1), which were effective in power fitness (e.g., *Chernozub et al., 2020*), promoted

166 accelerated growth of maximum muscle strength, and stimulated pronounced adaptive body

167 changes. Thus, group A participants used medium intensity training load regime ($R_a = 0.64$), and

168 group B athletes used high intensity training load regime ($R_a = 0.72$) for 2 months of research

169 with a frequency of 3 sessions per week. During each workout, no more than 3-4 muscle groups

170 were loaded with 2 exercises (basic and isolated) for each. Training exercises were performed on

171 simulators following the techniques that we defined in order to prevent injuries.

172   - in the second stage, we studied the nature of adaptive body changes to the stress stimulus

173 (power loads in a training regime), we also determined peculiarities of changes in maximum

174 muscle strength and the level of special training. We studied changes in the concentration of

175 cortisol, testosterone, phosphorus, calcium, cholesterol, creatinine, and lactate dehydrogenase

176 activity in the blood serum of both group athletes in conditions of different intensity training load

177 regimes. We compared the results of the studied indicators to determine the optimal training load

178 regime for MMA athletes of strike fighting style, which could maximally promote the processes

179 of adaptation in the shortest possible time.

180   - in the third stage we compared the results of the correlation between the biochemical

181 parameters of blood serum before and after training in the given conditions of muscular activity

182 at the beginning and end of 2-month study. The obtained results allowed to determine which of

183 the studied biochemical indicators of blood serum had multiple strong correlations at different

184 phases of control in each group. This analysis revealed the optimal set of informative criteria for

185 assessing short-term and long-term adaptation for MMA athletes using strike fighting style.

186 **Insert here Table 1**

187 **Statistical analysis**

188 Statistical analysis of the study results was performed using the software package IBM * SPSS *

189 Statistics 23 (StatSoftInc., USA). Descriptive statistics methods were used to calculate the

190 arithmetic mean and the error of the mean. The non-parametric Wilcoxon test was used to assess

191 the reliability of paired differences, and Friedman's ANOVA was used to analyze repeated

192 measurements. The relationship between certain variables and individual-typological

193 characteristics of the subjects was established using Spearman's rank correlation coefficients

194 (e.g., *Nasledov, 2013*).

195 # Results

196 Table 2 presents the results of the dynamics of maximum muscle strength development (1 RM)

197 in both group participants during 2 months of research using different intensity training load

198 regimes.

199   The results analysis showed that both group athletes demonstrated positive dynamics of

200 maximum muscle strength growth performing the control exercises during the research. Thus,

201 using high intensity training load regime ($R_a = 0.72$) by group B athletes increased the studied
202 indicator fixed in control exercises by 44.4% ($p < 0.05$) on average for 2 months of training
203 compared to initial data. Group A athletes who used medium intensity training load regime ($R_a =$
204 0.64) also showed positive changes of the investigated indicator (1 RM) for the similar period of
205 time which made up 34.3% ($p < 0.05$).
206 **Insert here Table 2**
207   The peculiarities of the change in the indicators of special training in Mixed Martial Arts (the
208 number of accurate kicks on the mannequin for 30 s) for 2 months of research are presented in
209 table 3.
210   We observed that both group representatives had no significant differences in control
211 indicators at the beginning of research, which allowed to determine the degree of impact of the
212 proposed training load regimes on their level of special training.
213 **Insert here Table 3**
214 The parameters of special training (the number of accurate kicks on the mannequin for 30 s)
215 during control exercises increased by an average of 10.5 % ($p < 0.05$) during the study period in
216 group B athletes, who used high intensity training load regime ($R_a = 0.72$), compared to baseline
217 data. At the same time, the studied indicators in group A athletes showed only a positive
218 unreliable tendency to change by an average of 2.2% ($p > 0.05$) for the same period of training in
219 conditions of medium intensity training load regime ($R_a = 0.64$).
220   Table 4 shows the peculiarities of changes in body composition of athletes of both groups in
221 the given conditions of muscular activity during 2 months of research.
222   The bioimpedansometry results analysis showed that the body fat parameter positively
223 decreased by 13.5% ($p < 0.05$) for 2 months in group B athletes. Group A representatives also
224 decreased the studied indicator, but it was by almost 4 times less than group B.
225   During the study, the fat-free mass parameter increased by 3.2% ($p < 0.05$) in athletes of
226 group B compared with baseline data. Representatives of group A showed no significant changes
227 in the studied indicator.
228 **Insert here Table 4**
229 Table 5 presents the results of changes in biochemical inadicators of the blood serum in the
230 participants of both groups in terms of muscular activity, taking into account the peculiarities of
231 training load regimes during all stages of the research.
232   The concentration of cortisol in the blood serum of group A athletes in response to medium
233 intensity training load regime ($R_a = 0.64$) remained almost unchanged at all stages of control.
234 Group B athletes demonstrated increase in the concentration of this hormone by 57.9% ($p <$
235 0.05) at the beginning and 32.9% ($p < 0.05$) after 2 months of study in response to high intensity
236 training load regime ($R_a = 0.72$).
237 **Insert here Table 5**
238 The control results of testosterone concentration in the blood serum showed that the basal level
239 of this hormone increased by 30.4% ($p < 0.05$) in athletes of group A, and by 20.0% ($p < 0.05$) in
240 participants of group B.

241   Using high intensity training load regime ($R_a = 0.72$) for 2 months stimulated an increase of
242   the basal level of creatinine in the blood serum by 17.4% ($p < 0.05$) in group B participants. At
243   the same time the level of creatinine in group A participants remained unchanged.
244   Calcium concentration was observed only in athletes of group A in response to stress stimuli
245   at the beginning of the study (by 5.2% compared to rest) and after 2 months (by 2.5%) while
246   using medium intensity training load regime ($R_a = 0.64$). At the same time, the results of this
247   biochemical indicator did not change significantly in group B representatives.
248   We recorded increased concentration of cholesterol in the blood serum of group A athletes in
249   response to physical stimuli at the beginning of the study by 9.2% ($p < 0.05$). On the contrary,
250   group B athletes demonstrated decrease in cholesterol concentration at all stages of control by
251   3.9% ($p < 0.05$). After 2 months of training, group B had changes in the studied indicator, but the
252   results were not reliable.
253   Table 5 provides the results of changes in the activity of LDH in the blood serum of MMA
254   athletes. Using medium intensity training load regime ($R_a = 0.64$) required almost twice the
255   energy expenditure in response to stress stimuli at the beginning of the study compared with the
256   results found in conditions of using the regime of high intensity training load ($R_a = 0.72$). There
257   were significant adaptive body changes in group B athletes, who used the regime of high
258   intensity training load, on the background of lowering the basal level of LDH in their blood
259   serum.
260   Based on laboratory monitoring of blood biochemical indicators in athletes of both groups,
261   samples were taken at rest and after training at the beginning and end of the study, we obtained
262   the corresponding results of correlations using Spearman's rank correlation coefficient. The
263   obtained data allow to determine which of the studied biochemical parameters of blood have the
264   greatest number of strong correlations and can be used as a set of informative markers for
265   assessing adaptive-compensatory reactions in MMA athletes of strike fighting style (Fig. 1 - 2).
266   **Insert here Figures 1 and 2**
267   The obtained results analysis showed that before long-term use of different intensity regimes of
268   training load ($R_a = 0.64$ and $R_a = 0.72$) the informative biochemical markers for assessing the
269   condition of athletes before training were cortisol, testosterone, and creatinine in both groups.
270   Our study proved that at the beginning of the research the biochemical criteria for assessing
271   adaptive-compensatory responses to physical stimuli were LDH and cholesterol in athletes of
272   group A, and LDH, testosterone and cortisol in group B athletes.
273   The laboratory tests and correlation analysis after 2 months of training established that the set
274   of biochemical markers indicating adaptation completely changed in athletes of group B and
275   consisted of LDH, phosphorus, cholesterol, and calcium. Moreover, the set of biochemical
276   criteria for assessing adaptive-compensatory reactions (after training) also changed in group B
277   athletes in response to high intensity training load ($R_a = 0.72$), compared with the data recorded
278   at the beginning of the study.
279   Figures 1 and 2 show that the concentration of cortisol, testosterone, creatinine and LDH
280   activity are informative biochemical markers of group A athletes recorded before training. The
281   results fixed after training indicated that the biochemical parameters of LDH, cholesterol and
282   calcium, cortisol in serum were indicators of assessing adaptive-compensatory reactions of group
283   A participants.

Discussion

284
285 The lack of a clear understanding of the overall strategy for optimizing the comprehensive
286 control system in Mixed Martial Arts is one of the controversial issues for scientists in physical
287 education and sports physiology (*James et al., 2017; Kirk et al., 2021; Chernozub et al., 2019;*
288 *Tota & Wiecha, 2022*). One of the directions of this problem is related to the need to identify the
289 most informative criteria for assessing the adaptive body changes in MMA athletes of strike
290 fighting style and to find effective regimes of power training in the process of special training.
291 Despite the generally accepted system of performance control in world practice, mainly by
292 assessing the dynamics of morphometric parameters, changes in maximum muscle strength
293 parameters (1RM) and special training (*Del Vecchio & Franchini, 2011; Schoenfeld et al., 2016;*
294 *James et al., 2017; Loturco et al., 2021*), in recent years scientists (*Marques et al., 2017;*
295 *Crewther, Obmiński & Cook, 2018; Stajer, Vranes & Ostojic, 2020; Sarin et al., 2019*) have paid
296 attention to the use of biochemical blood markers to determine the course of adaptive changes.
297   The bioimpedansometry results proved that using the most effective for power fitness regime
298 (Ra = 0.72) contributed to a significant reduction in body fat on the background of increasing fat-
299 free mass. Changes in these indicators of body composition point at a pronounced process of
300 adaptation of the organism (e.g., *Chernozub, et al., 2019*).
301   On the background of increasing maximum muscle strength and reducing the level of body fat
302 in group B athletes, the parameters of special training increased 4 times compared with group A
303 results. We assume that these changes are connected with increased adaptation reserves due to
304 intra-muscular and intermuscular coordination and energy efficiency of muscular activity in
305 anaerobic exercise regime (*James et al., 2016; Futorniy et al., 2017*).
306   The peculiarities of changes in the steroid hormones cortisol and testosterone in the serum of
307 MMA athletes with a strike fighting style in response to training loads of different intensity,
308 confirmed the research results in boxing and weightlifting where eccentric exercises were used
309 during training (*Philippou et al., 2017; Crewther et al., 2018; Kılıc et al., 2019*). However, the
310 results of our research contradict the research results in athletics (Wahl et al., 2013) which stated
311 that prolonged use of high intensity training load regime helped to reduce basal testosterone level
312 in the blood serum. In addition, the increase in basal testosterone and LDH in the blood serum
313 after training load of medium and low intensity in conditions of predominantly aerobic energy
314 supply, indicates the activation of compensatory mechanisms in athletes (e.g., *Wochyński &*
315 *Sobiech, 2017*). That is why, the use of basal testosterone as a marker for assessing adaptive
316 changes during high intensity training load regime requires further research.
317   We found out that the nature of changes in creatinine in the blood serum of both group
318 participants before and after training load of different intensity during 2 months of research,
319 confirmed the results of experimental studies in power fitness (*Titova et al., 2018; Chernozub et*
320 *al., 2020*). At the same time, the increase in basal creatinine level, which indicates growing
321 resources for creatine phosphokinase response on the background of increasing fat-free mass and
322 decreasing body fat, confirm the research results of a number of scientists (*Clarkson et al., 2006;*
323 *Papassotiriou & Nifli, 2018; Stajer, Vranes & Ostojic, 2018*). These researchers recorded an
324 increase in the concentration of creatinine in the serum during anaerobic lactate regime of energy
325 supply of muscular activity in athletics and wrestling training in the process of eccentric
326 exercises of high intensity.

327   Lowering blood cholesterol levels in athletes of group B in response to high intensity training
328   load (Ra = 0.72) confirm the results of studies concerning strength training (*Costa et al, 2019;*
329   *Sarin et al, 2019*). However, these studies were not focused on the parameters of the volume and
330   intensity of strength training, but only assessed the overall impact on training with weights on
331   certain biochemical markers of blood. The concentration of cholesterol in the blood of group A
332   athletes increased, which may be due to compensatory reactions of the body in response to this
333   stress stimulus.

334   Increases in blood calcium were observed only in response to high intensity training load,
335   regardless the stage of the study. However, our data differ from the results of research in power
336   sports (e.g., *Pullinger et al, 2019*), which show a decrease in the concentration of calcium ions in
337   response to medium and low intensity exercise. Such changes in this biochemical indicator slow
338   down the transmission of nerve impulses, which negatively affects the speed of muscle
339   contraction.

340   Investigating the structure of complex control in martial arts, a number of researchers
341   (*Chernozub, et al., 2019; Kirk et al., 2021; Tota & Wiecha, 2022*) found out that changes in
342   biochemical indicators of blood were the most informative markers of adaptation compensatory
343   reactions of athletes to stressful physical stimuli. Taking into account the complexity and high
344   cost of conducting comprehensive biochemical blood tests to study adaptation processes in
345   different training load regimes, most leading experts in biology and sports (*Marques et al., 2017;*
346   *Philippou et al., 2017; Wochyński et al., 2017*) used only a small number of markers (2-4).
347   However, even with a clear record of changes in the activity of certain physiological processes in
348   response to stress stimuli, it is almost impossible to establish the nature of adaptive or
349   compensatory reactions using a standard set of biochemical blood markers in such studies.

350   In this study we obtained the results and the peculiarities of changes in the biochemical blood
351   parameters during special training in MMA and determined the correlation between them, which
352   allowed to establish a minimum set of criteria for assessing adaptation to different training load
353   regimes. A similar direction of research concerning adaptive-compensatory body reactions to
354   power loads of different intensity was conducted with the intention to optimize the training
355   system of MMA athletes and in other sports (*James et al. 2017; Crewther, Obmiński & Cook,*
356   *2018; Chernozub, et al., 2019, 2020*).

Conclusions

358 Using high intensity training load regime by MMA athletes with strike fighting style in the
359 process of special strength training allows to increase the parameters of muscular strength and
360 the number of accurate kicks in the shortest possible time. The implementation of this study
361 results in competitive activity of MMA athletes will increase the effectiveness of attacking and
362 counterattacking actions of athletes by increasing the power, speed and number of accurate
363 kicks.

364   A wide range of biochemical blood indicators, which are used as criteria for assessing
365 adaptive-compensatory reactions in the conditions of special strength training of MMA athletes,
366 shows different tendencies to change depending on the intensity of the load. The results of
367 laboratory tests and correlation analysis allows to clearly determine the optimal set of
368 biochemical blood markers to assess the processes of short-term and long-term adaptation of
369 athletes using medium and high intensity training loads.

370 A clear definition of the optimal set of criteria for assessing the adaptive-compensatory
371 changes in MMA athletes of strike fighting style in the process of special strength training will
372 allow quickly adjust the parameters of the load mode to accelerate the body's functionality.

Limitations and future studies

374 The number of participants in the research groups was limited by the peculiarity of the training
375 stage and the selection of the subjects. In the future it will be necessary to involve in research
376 more athletes of different levels of training with the aim of using the obtained results in the
377 process of long-term training. In further studies it is recommended to control samples every 20-
378 30 days regardless of the possible long-term (up to 6-9 months) examination period for obtaining
379 detailed determination of the course of adaptive and compensatory reactions to a physical
380 stimulus at the expense of biochemical blood markers. Using indicators of athletes' heart rate
381 variability in conditions of intense muscle activity will allow to improve the system of control
382 over training loads and to upgrade the mechanisms of the training system correction.

Acknowledgements

384 The article is a part of the planned scientific work "Development and implementation of
385 innovative technologies and correction of the functional state of a person during physical activity
386 in sports and physical therapy", (state registration number 0117U007145) and Ministry of
387 Education and Science of Ukraine project number 0118U000809.

References

389 Chernozub A, Danylchenko S, Imas Y, Kochina M, Ieremenko N, Korobeynikov G,
390   Korobeynikova L, Potop V, Cynarski WJ, Gorashchenco A. 2019. Peculiarities of
391   correcting load parameters in power training of mixed martial arts athletes. *Journal of*
392   *Physical Education and Sport* 19(Suppl. 2):481–488 DOI: 10.7752/jpes.2019.s2070.

393 Chernozub A, Potop V, Korobeynikov G, Timnea OC, Dubachinskiy O, Ikkert O, Briskin Y,
394   Boretsky Y, Korobeynikova L. 2020. Creatinine is a biochemical marker for assessing how
395   untrained people adapt to fitness training loads. *PeerJ* 8:e9137 DOI:10.7717/peerj.9137.

396 Kirk C, Langan-Evans C, Clark D, Morton J. 2021. Quantification of training load distribution in
397   mixed martial arts athletes: A lack of periodisation and load management. *PLoS One*
398   16(5):e0251266 DOI:10.1371/journal.pone.0251266.

399 Clarkson PM, Kearns AK, Rouzier P, Rubin R, Thompson PD. Serum creatine kinase levels and
400   renal function measures in exertional muscle damage. Medicine & Science in Sports &
401   Exercise 38(4):623-627 DOI: 10.1249/01.mss.0000210192.49210.fc.

402 Costa RR, Buttelli ACK, Vieira AF, Coconcelli L, Magalhães RL, Delevatti RS, Kruel LFM.
403   2019. Effect of Strength Training on Lipid and Inflammatory Outcomes: Systematic
404   Review With Meta-Analysis and Meta-Regression. *Journal of Physical Activity and Health*
405   16(6):477-491 DOI:10.1123/jpah.2018-0317.

406 Crewther BT, Obmiński Z, Cook CJ. 2018. Serum cortisol as a moderator of the relationship
407   between serum testosterone and Olympic weightlifting performance in real and simulated
408   competitions. *Biology of Sport* 35(3):215-221 DOI:10.5114/biolsport.2018.74632.

409   Del Vecchio & Franchini (2011) Del Vecchio F.B., Franchini E. Specificity of high-intensity
410   intermittent action remains important to MMA athletes' physical conditioning: response to
411   Paillard. *Perceptual and motor skills* 116(1) DOI:10.2466/25.05.PMS.116.1.233-234.
412   Futorniy SM, Osadchaya OI, Shmatova EA, Maslova EV. 2016. Informational significance of
413   calculated hematological indices in prediction of overtraining development in professional
414   athletes. *Sports Medicine and Physical Rehabilitation* 2:13–19
415   DOI:10.32652/spmed.2016.2.13-19.
416   James LP, Haff GG, Kelly VG, Beckman EM. 2016. Towards a Determination of the
417   Physiological Characteristics Distinguishing Successful Mixed Martial Arts Athletes: A
418   Systematic Review of Combat Sport Literature. *Sports Medicine* 46(10):1525-1551
419   DOI:10.1007/s40279-016-0493-1.
420   James LP, Beckman EM, Kelly VG, Haff GG. 2016. The Neuromuscular Qualities of Higher-
421   and Lower-Level Mixed-Martial-Arts Competitors. *International Journal of Sports*
422   *Physiology and Performance* 12(5):612-620 DOI:10.1123/ijspp.2016-0373.
423   Kılıç Y, Cetin HN, Sumlu E, Pektas MB, Koca HB, Akar F. 2019. Effects of boxing matches on
424   metabolic, hormonal, and inflammatory parameters in male elite boxers. *Medicina*
425   55(6):288 DOI:10.3390/medicina55060288.
426   Korobeynikov G, Korobeinikova L, Mytskan B, Chernozub A, Cynarski WJ. 2017. Information
427   processing and emotional response in elite athletes. Ido movement for culture. *Journal of*
428   *Martial Arts Anthropology* 17(2):41–50 DOI:10.14589/ido.17.2.5.
429   Loturco I, Suchomel T, Kobal R, Arruda AS, Guerriero A, Pereira LA, Pai CN. 2021. Force-
430   Velocity Relationship in three Different Variations of Prone Row Exercises. *Journal of*
431   *Strength and Conditioning Research* 35(2):300-309 DOI:10.1519/JSC.0000000000002543.
432   Marques L., Franchini E., Drago G., Aoki M., Moreira A. 2017. Physiological and performance
433   changes in national and international judo athletes during block periodization training.
434   *Biology of Sport* 34(4):371-378 DOI:10.5114/biolsport.2017.69825.
435   Martyrosov EG, Nikolayev DV, Rudnev SG. 2006. Technologies and methods of defining body
436   composition. Nauka; Moscow.
437   Matthews JJ, Nicholas C. 2017. Extreme Rapid Weight Loss and Rapid Weight Gain Observed
438   in UK Mixed Martial Arts Athletes Preparing for Competition. *International Journal of*
439   *Sport Nutrition and Exercise Metabolism* 27(2):122-129 DOI:10.1123/ijsnem.2016-0174.
440   Nasledov AD. 2013. *IBM SPSS statistics 20 and AMOS: professional statistical data analysis*.
441   St. Petersburg: Piter.
442   Papassotiriou I, Nifli AP. 2018. Assessing performance in pre-season wrestling athletes using
443   biomarkers. *Biochemia Medica* 28(2):020706 DOI:10.11613/BM.2018.020706.
444   Pullinger S, Robertson CM, Oakley AJ, Hobbs R, Hughes M. 2019. Effects of an active warm-up
445   on variation in bench press and back squat (upper and lower body measures).
446   *Chronobiology International* 36(3):392-406 DOI:10.1080/07420528.2018.1552596
447   Philippou A, Maridaki M, Tenta R, Koutsilieris M. 2017. Hormonal responses following
448   eccentric exercise in humans. *Hormones* 16(4):405-413 DOI:10.14310/horm.2002.1761.

449 Sarin HV, Ahtiainen JP, Hulmi JJ, Ihalainen JK. 2019. Resistance Training Induces
450   Antiatherogenic Effects on Metabolomic Pathways. *Medicine and Science in Sports and*
451   *Exercise* 51(9):1866-1875 DOI:10.1249/mss.0000000000002003.

452 Shaner AA, Vingren JL, Hatfield DL, Budnar RG, Duplanty AA, Hill DW. 2014. The acute
453   hormonal response to free weight and machine weight resistance exercise. *Journal of*
454   *Strength and Conditioning Research* 28(4):1032-1040
455   DOI:10.1519/JSC.0000000000000317.

456 Schoenfeld BJ, Pope ZK, Benik FM, Hester GM, Sellers J. 2016. Longer Interset Rest Periods
457   Enhance Muscle Strength and Hypertrophy in Resistance-Trained Men. *Journal of*
458   *Strength and Conditioning Research* 30(7):1805-1812
459   DOI:10.1519/JSC.0000000000001272.

460 Slimani M, Davis P, Franchini E, Moalla W. 2017. Rating of Perceived Exertion for
461   Quantification of Training and Combat Loads During Combat Sport-Specific Activities: A
462   Short Review. *Journal of Strength and Conditioning Research* 31(10):2889-2902
463   DOI:10.1519/JSC.0000000000002047.

464 Shin KA, Park KD, Ahn J, Park Y, Kim YJ. 2016. Comparison of changes in biochemical
465   markers for skeletal muscles, hepatic metabolism, and renal function after three types of
466   long-distance running: observational study. *Medicine* 95(20):e3657
467   DOI:10.1097/MD.0000000000003657.

468 Spada TC, Silva JM, Francisco LS, Marçal LJ, Antonangelo L, Zanetta DM, Yu L, Burdmann
469   EA. 2018. High intensity resistance training causes muscle damage and increases
470   biomarkers of acute kidney injury in healthy individuals. *PLOS ONE* 13(11):e0205791.
471   DOI:10.1371/journal.pone.0205791.

472 Stajer V, Vranes M, Ostojic SM. 2020. Correlation between biomarkers of creatine metabolism
473   and serum indicators of peripheral muscle fatigue during exhaustive exercise in active men.
474   *Research in Sports Medicine* 20(1):147-154 DOI:10.1080/15438627.2018.1502185.

475 Tietz NW, Finley PR, Pruden EL. 1995. *Clinical guide to laboratory test*, 3rd edition.
476   Philadelphia: WB Saunders company.

477 Titova AV, Chorniy OG, Dolgov AA, Gladyr TA. 2018. Parameters of biochemical control as a
478   criterion of adaptive changes in the organism of athletes with various fitness levels
479   engaged in the conditions of power fitness. *Ukrainian Journal of Medicine, Biology and*
480   *Sports*. 2018;3(2):278–283 DOI:10.26693/jmbs03.02.278.

481 Tota ŁM, Wiecha SS. 2022. Biochemical profile in mixed martial arts athletes. *PeerJ* 10:e12708.
482   DOI:10.7717/peerj.12708.

483 Walker S, Häkkinen K, Haff GG, Blazevich AJ, Newton RU. 2017. Acute elevations in serum
484   hormones are attenuated after chronic training with traditional isoinertial but not
485   accentuated eccentric loads in strength-trained men. *Physiological Reports* 5(7):e13241
486   DOI:10.14814/phy2.13241

487   World Health Organization 2000. Air quality guidelines for Europe, 2nd edition. Copenhagen:
488   WHO Regional Office for Europe Available at
489   https://apps.who.int/iris/handle/10665/107335
490   Wochyński Z, Sobiech K. 2017. Impact of special aviation gymnastics instruments training on
491   selected hormones in cadets' blood serum and plasma. *International Jornal Occupation*
492   *Medicineand Environmental Health* 30(4):655-664 DOI:10.13075/ijomeh.1896.00904.

Structure of training load regimes used by participants of research in the process of strength training in MMA

Training load indicators	Training load regimes	
	Medium intensity ($R_a = 0.64$)	High intensity ($R_a = 0.72$)
Amplitude of exercise, %:	maximum (100%)	partial (90% from maximum)
Conditional coefficient of movement amplitude (Q)	0.9	0.8
Duration of movement phases	concentric phase – 2 s; eccentric phase – 3 s	concentric phase – 3 s; eccentric phase – 6 s
Duration of one repetition (t, s)	5	9
Duration of rest between sets, p	60	40
Number of repetitions in a set	8	4
Maximum duration of work in a set (T_{max}, s)	40	36
Projectile working mass (m), % of maximum (1RM)	64-69	72-74
Training load index (R_a)	0.64	0.72
Training load intensity	medium intensity	high intensity
Duration of training session, min	30-32	30-32

Parameters of maximum muscle strength (1 RM) development in both group participants during the research, n = 40

* the difference in comparison with previous results is significant according to the Wilcoxon test (p < 0.05); df - the number of degrees of freedom; p - level of significance

Control exercises, 1RM, kg	Group	Observation period, months			χ^2, p df=2
		Initial data	After 1 month of training	After 2 months of training	
Bench press on the Smith simulator	A	62.47±1.72	73.62±1.17* Z=-3.8; p<0.000	85.00±2.21* Z=-3.9; p<0.000	χ^2=39.5 p<0.000
	B	61.50±1.74	74.62±1.89* Z=-3.9; p<0.000	85.75±1.89* Z=-3.9; p<0.000	χ^2=40.0 p<0.000
Block thrust behind the head	A	65.25±1.39	72.50±1.02* Z=-3.7; p<0.000	78.12±1.21* Z=-4.1; p<0.000	χ^2=39.1 p<0.000
	B	60.00±1.52	69.37±1.51* Z=-3.7; p<0.000	77.75±1.38* Z=-3.8; p<0.000	χ^2=38.5 p<0.000
Legs press in the simulator lying	A	115.25±3.68	143.52±5.01* Z=-3.9; p<0,000	169.62±6.27* Z=-3.9; p<0.000	χ^2=40.0 p<0.000
	B	122.20±4.58	167.00±5.21* Z=-3.9; p<0.000	201.25±4.98* Z=-3.9; p<0.000	χ^2=40.0 p<0.000

Parameters of the number of accurate kicks on the mannequin for 30 s in both group participants during the research, n = 40

* the difference in comparison with previous results is significant according to the Wilcoxon test (p < 0.05); df - the number of degrees of freedom; p - level of significance

Control exercises	Group	Observation period, months			χ^2, p df=2
		Initial data	After 1 month of training	After 2 months of training	
Front kick	A	14.25±0.23	14.40±0.21 Z=-1.0; p>0.05	14.45±0.19 Z=-0.4; p>0.05	χ^2=2.3 p>0.05
	B	14.10±0.17	14.65±0.19* Z=-2.4; p<0.05	15.75±0.27* Z=-3.3; p<0.001	χ^2=22.9 p<0.000
Side kick	A	18.60±0.19	18.90±0.19 Z=-1.5; p>0.05	18.95±0.18 Z=-0.4; p>0.05	χ^2=5.3 p>0.05
	B	18.45±0.16	19.05±0.18* Z=-2.1; p<0.05	19.80±0.25* Z=-2.8; p<0.005	χ^2=15.1 p<0.001
Reverse side kick	A	16.40±0.18	16.75±0.14 Z=-1.8; p>0.05	16.95±0.16 Z=-1.6; p>0.05	χ^2=9.4 p<0.009
	B	16.50±0.13	17.25±0.17* Z=-2.9; p<0.005	18.45±0.11* Z=-3.2; p<0.001	χ^2=27.3 p<0.000
Roundhouse kick	A	18.05±0.16	18.40±0.11 Z=-1.8; p>0.05	18.50±0.11 Z=-0.8; p>0.05	χ^2=6.4 p<0.04
	B	18.15±0.15	18.60±0.13* Z=-2.2; p<0.05	20.20±0.15* Z=-3.9; p<0.000	χ^2=31.8 p<0.000

Parameters of body composition of research participants during two months, n = 40

* the difference in comparison with previous results is significant according to the Wilcoxon test (p < 0.05); df - the number of degrees of freedom; p - level of significance

Parameters	Group	Observation period, months			χ^2, p df=2
		Initial data	After 1 month of training	After 2 months of training	
BF (body fat, %)	A	11.93±0.83	13.25±0.84* Z=-2.5; p<0.01	11.47±0.80* Z=-2.3; p<0.05	χ^2=6.1 p<0.05
	B	16.30±1.08	14.27±1.18* Z=-3.4; p<0.001	14.09±1.06 Z=-1.1; p>0.05	χ^2=13.6 p<0.001
FFM (fat-free mass, kg)	A	67.50±1.29	67.05±1.28 Z=-1.3; p>0.05	68.62±1.25 Z=-1.6; p>0.05	χ^2=2.1 p>0.05
	B	63.86±0.62	65.77±0.94* Z=-3.7; p<0.000	65.94±0.99 Z=-0.5; p>0.05	χ^2=28.2 p<0.000
BCM (body cell mass, %)	A	62.54±0.71	65.31±1.11* Z=-2.8; p<0.005	63.70±0.24 Z=-1.3; p>0.05	χ^2=6.2 p<0.05
	B	63.98±0.16	62.45±0.31* Z=-3.5; p<0.000	62.84±0.22 Z=-0.4; p>0.05	χ^2=12.9 p<0.005
BMI (body mass index, cond. units)	A	23.80±0.51	23.76±0.39 Z=-1.4; p>0.05	23.92±0.46 Z=-1.4; p>0.05	χ^2=6.8 p<0.05
	B	24.09±0.58	24.27±0.60* Z=-2.0; p<0.05	24.39±0.58 Z=-0.4; p>0.05	χ^2=6.1 p<0.05
DCW (dry cell weight, kg)	A	10.95±0.29	11.35±0.25* Z=-2.5; p<0.05	11.34±0.22 Z=-0.7; p>0.05	χ^2=13.4 p<0.001
	B	10.55±0.11	10.50±0.14* Z=-3,2; p<0.001	10.69±0.13* Z=-3.9; p<0.000	χ^2=38.1 p<0.000

Biochemical blood indicators of group participants during the research, n = 40

* the difference in comparison with previous results is significant according to Wilcoxon's test (p < 0.05) ** the difference between basal parameters (before training load) in comparison with previous results is significant according to Wilcoxon's test (p < 0.05)

Indicator	Group	At the beginning of the study		After 2 months of training	
		Before training load	After training load	Before training load	After training load
Cortisol, nmol / l	A	320.53±14.72	351.62±27.85 Z=-0.5; p>0.05	416.50±26.70** Z=-2.5; p<0.01	506.85±42.06 Z=-0.7; p>0.05
	B	332.72±11.26	525.55±36.41* Z=-3.9; p<0.000	509.88±28.79** Z=-3.6; p<0.000	677.72±9.50* Z=-3.9; p<0.000
Testosterone, nmol / l	A	19.42±1.28	20.52±1.72 Z=-1.0; p>0.05	25.32±2.27** Z=-2.9; p<0.005	27.65±1.98* Z=-3.3; p<0.001
	B	28.85±1.53	29.15±1.63* Z=-2.1; p<0.05	34.62±0.62** Z=-3.3; p<0.001	35.72±0.75 Z=-1.8; p>0.05
Creatinine, µmol / l	A	85.50±0.83	83.95±0.86 Z=-1.7; p>0.05	86.00±1.27 Z=-0.5; p>0.05	94.85±1.25* Z=-3.9; p<0.000
	B	84,60±2.24	82.15±2.88 Z=-0.8; p>0.05	99.30±1.49** Z=-3.9; p<0.000	105.75±1.16* Z=-3.9; p<0.000
Calcium, mmol / l	A	2.48±0.01	2.61±0.11* Z=-3.9; p<0.000	2.36±0.01** Z=-3.9; p<0.000	2.42±0.01* Z=-3.9; p<0.000
	B	2.55±0.01	2.57±0.11 Z=-0.5; p>0.05	2.35±0.01** Z=-3.9; p<0.000	2.37±0.01 Z=-1.2; p>00.5
Phosphorus, mmol / l	A	1.10±0.01	1.23±0.01* Z=-3.6; p<0.000	0.94±0.03** Z=-3.2; p<0.001	0.97±0.02 Z=-1.0; p>0.05
	B	1.11±0.03	1.17±0.03* Z=-3.5; p<0.000	1.14±0.03 Z=-0.6; p>0.05	0.99±0.01* Z=-3.3; p<0.01
Cholesterol, mmol / l	A	4.32±0.13	4.72±0.08* Z=-3.9; p<0.000	4.10±0.12 Z=-0.2; p>0.05	4.15±0.09 Z=-1.0; p>0.05
	B	4.20±0.06	4.07±0.04* Z=-2.4; p<0.05	4.37±0.06** Z=-2.3; p<0.05	4,32±0,04 Z=-1.1; p>0.05
LDH, c. u.	A	371.50±7.42	502.55±7.44* Z=-3.9; p<0.000	434.55±16.84** Z=-2.4; p<0.05	447.75±7.98 Z=-0.9; p>0.05
	B	389.50±6.52	442.20±18.26* Z=-2.2; p<0.05	378.50±15.97 Z=-0.5; p>0.05	379.25±9.25 Z=-0.1; p>0.05

Figure 1

Correlation between biochemical parameters of blood in group A athletes during 2 months of research in the conditions of medium intensity training load regime (Ra = 0.64)

*A – the results recorded at the beginning of the study before training; B – the results recorded at the beginning of the study after training; C – the results recorded after 2 months of study before training, D – the results recorded after 2 months of study after training; ** - correlation at the level of 0.01; * - correlation at the level of 0.05.*
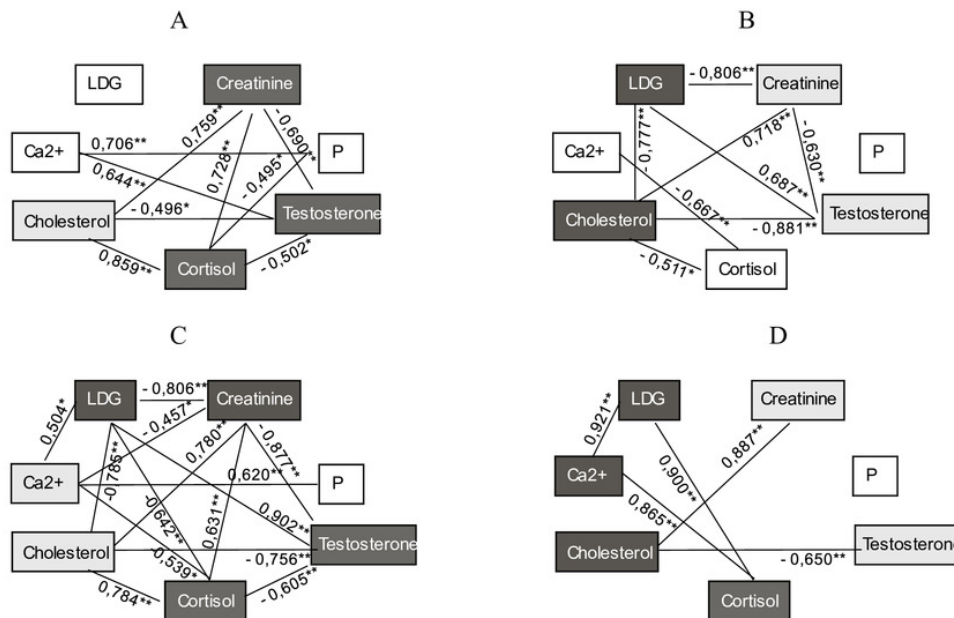
Figure 2

Correlation between biochemical parameters of blood in group B athletes during 2 months of research in the conditions of high intensity training load regime (Ra = 0.72)