BLOOD BIOCHEMICAL PARAMETERS IN ATHLETES OF DIFFERENT TYPES OF SPORTS

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Abstract. The study was performed at the Gomel Regional Clinic of Sports Medicine (Belarus). Two hundred thirty-six healthy athletes (134 men and 102 women) were examined. The mean age of the examined athletes was 20 years. Features of blood biochemical parameters in athletes of cyclic sports, strength sports, and team game sports have been evaluated.

Keywords: athletes, blood biochemical parameters, team games sports, strength sports, cyclic sports, blood enzymes.

List of Abbreviations

ALP – alkaline phosphatase
HDL – high density lipoproteins
LDL – low density lipoproteins
AST – aspartate aminotransferase
ALT – alanine aminotransferase

Introduction

The general state of health of professional athletes practicing regular strenuous exercise during trainings and competitions is currently an urgent problem in medicine and sports. The human organism as a system responds to any impact, including physical activity, by the complex of changes of its parameters. Regular physical exercises expand a person's adaptive capabilities. Adaptation of the organism to strenuous muscle activity is accompanied by deep biochemical restructuring in the cells of skeletal muscles, the heart, the nervous system and other internal organs. (Witek *et al*., 2017). Blood represents an available biological object for monitoring of the health state. Blood chemical composition at rest corresponds to average physiological reference ranges and is characterized by constancy of its biochemical parameters, necessary for optimal vital activity (Lopatina, 2014).

During training and competition processes, physical activity leads to a change in blood electrolyte levels, protein metabolism, and energy metabolism. This affects the work of all systems of the organism, and may lead to alterations in the levels of many metabolic biochemical markers including the parameters of protein metabolism (such as urea and creatinine) and blood serum levels of calcium, which plays an important role in the process of muscle contraction and transmission of the nerve impulse. At high intensity of physical activity muscle destruction can be observed, reflected in the increase of the levels of some muscular enzymes (Milić *et al*., 2011).

Exercises of different duration and intensity can affect various routine biochemical parameters. The aim of the present study was to compare blood biochemical parameters in athletes of various sports types, which have different specificity of the sports training process. Cyclic types of sports are characterized by the motor activity involving repetitive movements and by dominating of endurance training. In strength sports the training process is basically directed on developing maximum force to improve performance and includes high intensity, but short-duration exercises. Team game sports require the capacity to perceive external stimuli and to act quickly under changing contest circumstances and include mixed types of physical exercises (Vodičar *et al*., 2018).

The revealing of the features of changes of biochemical blood parameters depending on the types of sports disciplines can help to get more insight in the physiological characteristics of

adaptation processes to physical exercises and can provide coaches and sports doctors with useful indicators for the evaluation of athletes' health state and the state of metabolic recovery from the training session (Rybina, 2012; Rybina, 2013).

Materials and Methods

The study was performed in Gomel Regional Clinic of Sports Medicine. 236 healthy athletes (134 men, 102 women) were examined. The mean age of the examined athletes was 20 years (with a range of 18 to 22 years). Athletes were divided into three groups according to the sports disciplines with different level and specifics of daily physical activity: the first group – cyclic sports (rowing, kayaking and canoeing), the second group – strength sports (combat sports – judo, Greco-Roman wrestling, freestyle wrestling), the third group – team games sports (hockey, football, handball). Examination of the athletes was performed during the recovery period of the training cycle, which was characterized by the low intensity physical exercises directed on increasing of aerobic capacity. Blood samples were taken at the beginning of the week (on Monday) in the morning (from 8.00 to 10.00 a.m.) after overnight fasting and before physical exercises. Biochemical parameters were measured in the blood serum using an automatic biochemical analyzer ErbaXL-200 (Czech Republic).

The blood serum samples of athletes were analyzed for the following biochemical parameters (the reference ranges of each parameter are given in parentheses according to the used analyzer and reagents): total protein (65–80 g/l), uric acid (males 210–432 mmol/l, females 150–360 mmol/l), total bilirubin (8,55–20,52 mcmol/l), urea (2,5–8,3 mmol/l), AST (males up to 37 units/l, females up to 31 units/l), ALT (males up to 42 units/l, females up to 32 units/l), creatinine (males 53–115 mmol/l, females 44–97 mmol/l), HDL (0,95–2,05 mmol/l), LDL (males 0,50–2,60 mmol/l, females 0,41–2,50 mmol/l), ALP (males up to 128 units/l, females up to 98 units/l), glucose (3,5–6,2 mmol/l), cholesterol (3,1–5,2 mmol/l), Ca^{2+} (2,1–2,6 mmol/l), creatine kinase (males 25–200 units/l, females 25–175 units/l) (Rajabkadiev, 2019). The study was carried out in compliance with the Helsinki Declaration (2013) and approved by Gomel Regional Clinic of Sports Medicine. All the examined athletes gave written informed consent to participate in the study.

Statistical analysis of the obtained results was carried out using "STATISTICA 10.0." software package. Since the received data were not subjected to the law of normal distribution according to Kolmogorov-Smirnov criterion, they were presented as Me (25%; 75%) format, where Me is the median, 25% is the lower percentile, 75% is the upper percentile. The non-parametric method – Mann-Whitney U-criterion was used when comparing two groups of athletes. Differences were considered statistically significant at $p < 0.05$.

Results

As a result of the study, it was found that all the examined biochemical parameters were within the reference ranges in both men and women, except for the level of ALP in the male athletes. However, significant differences for several blood biochemical parameters were revealed between the groups of the athletes of various sports types. The obtained results are presented in Table 1 and Table 2.

The analysis of the received results of serum biochemical parameters revealed, that the level of total protein in female athletes of game sports was significantly lower 63.80 (61.20 ÷ 69.90) g/l, compared to female athletes of both cyclic sports 69.50 (67.60 ÷ 71.40) g/l ($p < 0.001$) and strength sports 69.60 (66.20 ÷ 72.00) g/l ($p < < 0.01$). Differences of protein levels in blood serum in male athletes of all examined sports types were statistically insignificant.

According to the results of the study, the amount of urea was significantly increased in female athletes of game sports 6.01 (4.63 ÷ ÷ 7.49) mmol/l, in comparison with female athletes of cyclic sports 4.33 (3.59 ÷ 5.77) mmol/l ($p < 0.001$) and strength sports 4.20 (3.48 ÷ ÷ 4.55) mmol/l ($p < 0.01$). No statistically significant differences were found in men of all the examined groups.

Table 1

Blood biochemical parameters in female athletes of various types of sports

Parameter	Game sports	Strength sports	Cyclic sports
Number of athletes	23	29	50
Total protein (g/l)	63.80 (61.20 ÷ 69.90) **	69.60 (66.20 ÷ 72.00)#	69.50 (67.60 ÷ 71.40)
Urea (mmol/l)	6.01 (4.63 ÷ 7.49) **	4.20 (3.48 ÷ 4.55)#	4,33 (3.59 ÷ 5.77)
Uric acid (mmol/l)	253.20 (215.90 ÷ 311.20)	279.50 (248.60 ÷ 308.80)	277.80 (226.30 ÷ 344.30)
Creatinine (mmol/l)	78.74 (71.65 ÷ 89.52)	86.29 (73.66 ÷ 92.85)	79.79 (7364 ÷ 87.28)
Total bilirubin (mcmol/l)	9.67 (7.14 ÷ 12.50) **	12.10 (9.01 ÷ 14.22)	10.83 (8.86 ÷ 17.72)
Cholesterol (mmol/l)	4.71 (4.33 ÷ 5.31)	4.73 (4.18 ÷ 5.19)	4.30 (3.74 ÷ 5.11)
HDL (mmol/l)	1.94 (1.77 ÷ 2.30)	1.76 (1.50 ÷ 1.99)#	1.82 (1.62 ÷ 2.12)
Glucose (mmol/l)	5.25 (5.14 ÷ 5.63)	5.93 (5.70 ÷ 6.11)#	5.54 (5.25 ÷ 5.82) *
Ca^{2+}(mmol/l)	2.35 (2.27 ÷ 2.42) **	2.37 (2.28 ÷ 2.45)	2.42 (2.34 ÷ 2.64) *
ALT (u/l)	10.90 (9.00 ÷ 13.40) **	13.00 (11.30 ÷ 15.00)#	15.00 (12.10 ÷ 19.10) *
AST (u/l)	18.40 (15.90 ÷ 21.80) **	19.40 (16.90 ÷ 21.80)	20.80 (19.20 ÷ 27.50) *
ALP (u/l)	36.00 (33.00 ÷ 59.00) **	69.00 (53.00 ÷ 99.00)#	71.00 (46.00 ÷ 88.00)
LDL (mmol/l)	2.55 (2.01 ÷ 2.76)	2.33 (1.90 ÷ 2.94)	2.28 (1.89 ÷ 2.73)
Creatine kinase (u/l)	128.00 (107.20 ÷ 187.60)	186.30 (86.95 ÷ 239.65)	191.15 (129.20 ÷ 231.65)

Note:
* – cyclic and strength sports, $p < 0.05$;
** – cyclic and game sports, $p < 0.05$;
# – strength and game sports, $p < 0.05$.

Table 2

Blood biochemical parameters in male athletes of various types of sports

Parameter	Game sports	Strength sports	Cyclic sports
Number of athletes	30	42	62
Total protein (g/l)	70.65 (68.40 ÷ 73.70)	71.75 (68.90 ÷ 75.80)	71.20 (69.10 ÷ 73.40)
Urea (mmol/l)	4.62 (3.98 ÷ 4.95)	4.79 (4.03 ÷ 5.29)	4.97 (4.25 ÷ 6.06)
Uric acid (mmol/l)	353.10 (322.00 ÷ 408.70) **	370.50 (315.15 ÷ 416.45)	334.80 (301.80 ÷ 390.30)
Creatinine (mmol/l)	69.34 (61.25 ÷ 87.06) **	86.26 (77.66 ÷ 100.16)#	82.44 (74.97 ÷ 94.17)
Total bilirubin (mcmol/l)	13.01 (10.12 ÷ 16.71)	11.74 (8.66 ÷ 18.88)	15.09 (10.93 ÷ 21.31)
Cholesterol (mmol/l)	3.87 (3.32 ÷ 4.66) #	4.57 (3.72 ÷ 4.85)	4.05 (3.62 ÷ 4.46) *
HDL (mmol/l)	1.44 (1.25 ÷ 1.60) **	1.60 (1.42 ÷ 1.99)#	1.66 (1.52 ÷ 1.82) *
Glucose (mmol/l)	5.77 (4.99 ÷ 6.07)	5.93 (5.72 ÷ 6.18)#	5.76 (5.47 ÷ 6.06)
Ca^{2+}(mmol/l)	2.26 (2.18 ÷ 2.34) **	2.41 (2.33 ÷ 2.48)#	2.43 (2.36 ÷ 2.55)
ALT (u/l)	14.20 (10.51 ÷ 17.90)	16.70 (13.00 ÷ 20.60)	16.40 (13.20 ÷ 19.70)
AST (u/l)	22.80 (17.30 ÷ 27.30)	23.50 (20.20 ÷ 26.90)	22.20 (19.60 ÷ 29.20)
ALP (u/l)	84.00 (59.00 ÷ 114.00) **	155.00 (96.00 ÷ 277.00)#	125.00 (75.50 ÷ 206.50) *
LDL (mmol/l)	2.07 (1.66 ÷ 3.17)	2.44 (1.93 ÷ 2.79)	2.14 (1.87 ÷ 2.47)
Creatine kinase (u/l)	183.40 (133.40 ÷ 302.50)	204.80 (160.80 ÷ 332.30)	215.60 (138.20 ÷ 402.50)

Note:
* – cyclic and strength sports, $p < 0.05$;
** – cyclic and game sports, $p < 0.05$;
# – strength and game sports, $p < 0.05$.

When analyzing the uric acid amount in the blood, it was noted that women of the all the examined groups did not have significant differences in this parameter. Nevertheless, in male athletes of game sports the amount of uric acid was significantly higher 353.10 (322.00 ÷ 408.70) mmol/l, compared to male athletes of cyclic sports 334.80 (301.80 ÷ 390.30) mmol/l ($p = 0.02$).

The differences in creatinine level in female athletes of all examined types of sports were statistically insignificant. However, in male

athletes of game sports this parameter was significantly lower 69.34 (61.25 ÷ 87.06) mmol/l, compared to male athletes of cyclic sports 82.44 (74.97 ÷ 94.17) mmol/l ($p < 0.01$) and strength sports 86.26 (77.66 ÷ 100.16) mmol/l ($p < < 0.01$).

It was detected that the total bilirubin level in blood serum was significantly lower in female athletes of game sports 9.67 (7.14 ÷ 12.50) mmol/l compared to the female athletes of cyclic sports 10.83 (8.86 ÷ 17.72) mmol/l ($p = = 0.03$). The level of total bilirubin in all examined male athletes was not significantly different.

According to the results of the study of blood cholesterol levels, no significant differences were found for this parameter in female athletes of all examined sports types. However, male athletes of cyclic sports had a significantly lower level of cholesterol 4.05 (3.62 ÷ 4.46) mmol/l, than the male athletes of strength sports 4.57 (3.72 ÷ ÷ 4.85) mmol/l ($p = 0.02$). Also, in the group of male athletes of game sports the level of cholesterol was significantly lower 3.87 (3.32 ÷ ÷ 4.66) mmol/l, than the male athletes of strength sports 4.57 (3.72 ÷ 4.85) mmol/l ($p < < 0.05$).

When analyzing HDL level in the blood it was noted that in female athletes of strength sports this parameter was significantly lower 1.76 (1.50 ÷ 1.99) mmol/l than in women of game sports 1.82 (1.62 ÷ 2.12) mmol/l ($p = = 0.02$). The results of HDL levels analysis in male athletes showed a different trend. So, in male athletes of game sports HDL level was much lower 1.44 (1.25 ÷ 1.60) mmol/l compared to male athletes of both strength sports 1.60 (1.42 ÷ 1.99) mmol/l ($p = 0.02$) and cyclic sports 1.66 (1.52 ÷ 1.82) mmol/l ($p < 0.01$).

As a result of the blood biochemical analysis, it was found that glucose level, in both female 5.93 (5.70 ÷ 6.11) mmol/l and male athletes of strength sports 5.93 (5.72 ÷ 6.18) mmol/l, was much higher in comparison with other examined groups of athletes ($p < 0.05$).

The amount of Ca^{2+} in the blood of female athletes of cyclic sports was significantly higher 2.42 (2.34 ÷ 2.64) mmol/l, than in female athletes of strength sports 2.37 (2.28 ÷ 2.45) mmol/l ($p = = 0.02$) and game sports 2.35 (2.27 ÷ 2.42) mmol/l ($p < 0.01$). In male athletes of game sports, the amount of Ca2+ was significantly lower 2.26 (2.18 ÷ 2.34) mmol/l, in comparison with the values of this parameter in the blood at male athletes of cyclic 2.43 (2.36 ÷ 2.55) mmol/l ($p < 0.0001$) and strength sports 2.41 (2.33 ÷ ÷ 2.48) mmol/l ($p < 0.0001$).

Examination of biochemical blood test parameters revealed that the level of ALT in female athletes of cyclic sports was the highest 15.00 (12.10 ÷ 19.10) u/l, and it was significantly increased in comparison with the level of this parameter in female athletes of strength sports 13.00 (11.30 ÷ 15.00) u/l ($p = 0.02$) and game sports 10.90 (9.00 ÷ 13.40) u/l ($p < 0001$). No statistically significant differences of ALT level were detected in men of all the examined groups.

Similar differences were observed in the study of AST level. So, the highest level of this parameter was noted at female athletes of cyclic sports 20.80 (19.20 ÷ 27.50) u/l, compared to female athletes of strength sports 19.40 (16.90 ÷ 21.80) u/l ($p = 0.02$) and game sports 18.40 (15.90 ÷ 21.80) u/l ($p < 0.01$). The differences of the serum AST levels in male athletes of all examined sports were statistically insignificant.

In female athletes of game sports ALP level was 36.00 (33.00 ÷ 59.00) u/l, and that was much lower in comparison with female athletes of strength sports 69.00 (53.00 ÷ 99.00) u/l ($p < < 0.001$), as well as female athletes of cyclic sports 71.00 (46.00 ÷ 88.00) u/l ($p < 0.01$). However, in male athletes of strength sports ALP level exceeded normal values and was equal to 155.00 (96.00 ÷ 277.00) u/l, and it was significantly higher compared to the level of this parameter in the groups of male athletes of cyclic sports 125.00 (75.50 ÷ 206.50) u/l ($p = = 0.04$) and game sports 84.00 (59.00 ÷ 114.00) u/l ($p < 0.01$), where ALP level was within the reference ranges.

Discussion

In the present study significant differences were revealed for the most of the examined biochemical parameters between the groups of the athletes of cyclic, strength and team game sports.

The female athletes of team game sports were found to have significantly decreased

level of total protein, total bilirubin, calcium ions, glucose; ALT, AST, ALP and increased urea levels in comparison with other groups of female athletes. Female athletes of strength sports had significantly reduced levels of HDL and increased glucose levels. In female athletes of cyclic sports, the amount of calcium ions, ALT, AST and ALP were significantly increased. Male athletes of team game sports had significantly decreased levels of creatinine, cholesterol, HDL, calcium ions, ALP, while biochemical parameters of male athletes of strength sports were characterized by the increased levels of creatinine, cholesterol, glucose, ALP.

According to the obtained data it is possible to assume that the deceased total protein amount and increased urea level in blood plasma in female athletes of game sports compared to other types of sports may be a sign of the increased catabolism of proteins (Marqués-Jiménez *et al*., 2016). At the same time in male athletes the type of sports and training process does not cause any significant differences in protein metabolism which can be partially explained by the anabolic effects of androgens. Significantly higher levels of creatinine in male athletes of strength sports can be explained by the fact that creatinine is a metabolic product of creatine breakdown and its blood levels depend basically on the muscle mass of athletes.

Significantly high glucose levels in both male and female athletes of strength sports compared to other sport types can reflect the adaptive features of metabolism to the specificity of training processes. (Makarova *et al*., 2017). During high-intensity exercises blood glucose and muscle glycogen are the primary sources to produce adenosine triphosphate required for muscular contraction and therefore metabolic recovery processes after training are adapted for quick restoration of glycogen depot and blood glucose level. At the same time endurance training may reduce vulnerability to low glucose levels in athletes of cyclic and game sports because of the shift in substrate metabolism towards the increased fats oxidation (Lee *et al*., 2017).

The revealed differences in blood cholesterol levels in male athletes can be explained by the fact that the adaptation of lipid metabolic processes for endurance training is basically characterized by the increased fats oxidation. Fats are used as a primary energy source in endurance sports, and fat utilization during exercise impacts lipid profiles by reducing resting levels of total cholesterol and triglycerides (Lee *et al*., 2017).

The literature data on the influence of sports training on LDH and HDL levels in male and female athletes are controversial. The results obtained in the present study revealed decreased levels of HDL in female athletes of strength sports and male athletes of game sports. It may be associated with the gender differences of lipoprotein metabolism in athletes and with the influence of estrogens on the levels of HDL (Banfi *et al*., 2012). The decreased levels of HDL in female athletes of strength sports can be connected with the decreased levels of estrogens due to intensive physical exercises and relative energy deficiency, which, according to the literature data, can affect the secretion of gonadotropin-releasing factor by hypothalamus (Dipla *et al*., 2021). The decreased levels of HDL in male athletes of game sports can be explained by the significantly low blood cholesterol levels in this group of athletes in comparison of other groups of male athletes.

The highest levels of calcium ions in blood plasma were revealed in both male and female athletes of cyclic sports in comparison with other groups of athletes. Plasma calcium levels can be increased in response to physical exercise due to metabolic acidosis or decreased albumin concentration because a part of serum calcium is bound to albumin (Fragala *et al*., 2017).

In the present study significant differences in levels of some blood enzymes were revealed between the groups of the examined athletes. The significantly increased levels of AST and ALT in female athletes of cyclic sport can basically reflect the increased amino acid metabolism in this group of athletes compared to other types of sports (Inman *et al*., 2018).

ALP is an enzyme found primarily in bone tissue and the liver and involved in bone metabolism and inflammatory processes. According

to the literature data, ALP blood levels in athletes usually can be increased at strength and weight-bearing exercises (Fragala *et al*., 2017; Rudberg *et al*., 2000) and this can be a possible reason for the revealed increase of levels of ALP in male athletes of strength sports.

Creatine kinase is reliable biomarker of the functional state of the muscle tissue. No significant differences in levels of creatine kinase in the examined groups of athletes were detected which can be a sigh of sufficient recovery and absence of muscular damage (Makarova *et al*., 2020).

Conclusion

As a result of the study the features of blood biochemical parameters in athletes of various sports were revealed, expressed in decreasing of the levels of total protein, total bilirubin, calcium ions, glucose; alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase and increasing of urea levels in female athletes of team game sports; in female athletes of strength sports – in reducing of high-density lipoproteins amount and increasing of glucose levels, and in female athletes of cyclic sports – in increasing of the levels of calcium ions, alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase.

In male athlete of team game sports, the decrease in the amount of creatinine, cholesterol, high-density lipoproteins, calcium ions, alkaline phosphatase in blood serum were detected, while in male athletes of strength sports there was an increase in the level of creatinine, cholesterol, glucose, alkaline phosphatase. In male athletes engaged in cyclic sports, no patterns in blood biochemical parameters were observed.

References

BANFI G., COLOMBINI A., LOMBARDI G. & LUBKOWSKA A. (2012): Metabolic markers in sports medicine. *Advances in clinical chemistry* **56**, 1–54.

DIPLA K., KRAEMER R., CONSTANTIN N. & HACKNEY A. (2021): Relative energy deficiency in sports (RED-S): elucidation of endocrine changes affecting the health of males and females. *Hormones (Athens)* **20**(1), 35–47.

FRAGALA M.S., BI C., CHAUMP M., KAUFMAN H.W. & KROLL M.H. (2017): Associations of aerobic and strength exercise with clinical laboratory test values. *PLos One* 1–22.

INMAN L.A., RENNIE M.J., WATSFORD M.L., GIBBS N.J., GREEN J. & SPURRS R.W. (2018): Reference values for the creatine kinase response to professional Australian football match-play. *J Sci Med Sport* **21**(8), 852–857.

LEE E.C., FRAGALA M.S., KAVOURAS S.A., QUEEN R.M., PRYOR J.L., & CASA D.J. (2017): Biomarkers in sports and exercise: tracking health, performance, and recovery in athletes. *Journal of Strength and Conditioning Research* **31**(10), 2920–2937.

LOPATINA A.B. (2014): Theoretical aspects of changes in biochemical parameters of athletes' blood as an indicator of adaptation processes. *Pedagogical-psychological and medico-biological problems of physical culture and sports* **2**(31), 117–122.

MAKAROVA G.A., ACHKASOV E.E. & BARANOVSKAYA I.B. (2017): Biochemical control in sports: the main directions of efficiency improvement. *Sports Medicine: Science and Practice* **7**(1), 46–52.

MAKAROVA G.A., KOLESNIKOVA N.V., SKIBITSKY V.V. & BARANOVSKAYA I.B. (2020): *Diagnostic potential of the blood picture in athletes.* Moscow: Sport, 256 pp.

MARQUÉS-JIMÉNEZ D., CALLEJA-GONZÁLEZ J., ARRATIBEL I. & TERRADOS N. (2016): Relevant biochemical markers of recovery process in soccer. *Arch Med Deporte* **33**(6), 404–412.

MILIĆ R., BANFI G., DEL FABBRO M. & DOPSAJ M. (2011): Serum creatinine concentrations in male and female elite swimmers. Correlation with body mass index and evaluation of estimated glomerular filtration rate. *Clinical Chemistry and Laboratory Medicine* **49**.

RAJABKADIEV R.M. (2019): Biochemical markers of adaptation of highly qualified athletes to various physical activities. *Science and Sport: Modern Trends* **2**(7), 81–91.

RUDBERG A., MAGNUSSON P., LARSSON L. & JOBORN H. (2000): Serum isoforms of bone alkaline phosphatase increase during physical exercise in women. *Calcif Tissue Int.* **66**, 342–347.

RYBINA I.L. (2012): Taking into account the influence of factors of the preanalytical stage is a necessary condition for ensuring the quality of sports medicine. *Bulletin of Sports Medicine* 61–63.

RYBINA I.L. (2013): Determination of diagnostic informativeness of biochemical indicators that are most relevant for sports practice. The Center for Scientific Cooperation "Interactive plus". *Bulletin of Sports Medicine* 31–34.

VODIČAR J., PAJEK J., HADŽIĆ V. & BUČAR M. (2018): Relation of Lean Body Mass and Muscle Performance to Serum Creatinine Concentration in Hemodialysis Patients. *BioMed Research International* 1–7.

WITEK K., ŚCISŁOWSKA J., TUROWSKI D., LERCZAK K., LEWANDOWSKA-PACHECKA S. & POKRYWKA A. (2017): Total bilirubin in athletes, determination of reference range. *Biol Sport* **34**(1), 45–48.