Position statement

BIOCHEMICAL SCREENING OF ATHLETES –

USEFULNESS AND EVALUATION

ΕΛΛΗΝΙΚΗ
ΕΤΑΙΡΕΙΑ ΒΙΟΧΗΜΕΙΑΣ ΚΑΙ
ΦΥΣΙΟΛΟΓΙΑΣ ΤΗΣ ΑΣΚΗΣΗΣ

Introduction

Athletes undergo biochemical tests in order to check their health and assess physical fitness. With this position statement, the Hellenic Society of Biochemistry and Physiology of Exercise aims to inform athletes, coaches and other interested parties as to which biochemical tests are useful in evaluating athletes and what information these tests yield.

The biochemical parameters presented will be limited to those measured in the blood (either whole blood or serum, i.e., the liquid obtained by centrifugation after coagulation of blood, or plasma, i.e., the liquid obtained by centrifugation after blood clotting has been prevented) under fasting and resting conditions (i.e., at least 12 hours after a meal and exercise). For the sake of completeness, hematological parameters of the so-called complete blood count will also be presented.

Reference ranges (also known as normal values) for each parameter will not be presented, as these depend on the measurement method and the demographic characteristics of the subject (such as age and gender). Therefore, athlete's test results should be compared with the reference ranges of the laboratory that performed the analysis. Also, there will be no particular reference to pathological conditions that may affect the described parameters, as this edition is addressed to presumably healthy individuals.

Parameters are presented in alphabetical order.

Cholesterol

What it is: Cholesterol is a lipid used by the cells to build their membranes and synthesize steroid hormones. It circulates in the blood as part of the lipoproteins (i.e., aggregates of lipids and proteins), LDL and HDL, which are the main cholesterol carriers.

What it shows: The total (i.e., regardless of which lipoproteins cholesterol is embedded in) serum cholesterol concentration (usually expressed in mg/dl) relates positively to the risk of atherosclerosis (or arteriosclerosis), which is the main cause of cardiovascular disease. Thus, a low cholesterol concentration is desirable. To assess the risk of atherosclerosis, the concentrations of LDL cholesterol, HDL cholesterol, and triglycerides are also taken into account, collectively making up the so-called lipidemic profile.

What it is affected by: The serum cholesterol concentration tends to rise with age. It is affected by hereditary factors and relates positively to body fat.

Importance of measurement in athletes: Because the serum cholesterol concentration relates to cardiovascular disease, its measurement is important to monitor the athletes' health.

Cortisol

What it is: Cortisol is a steroid hormone that belongs to the class of corticosteroids. It is synthesized in the adrenal cortex.

What it shows: The serum cortisol concentration (usually expressed in μg/l) rises in response to mental or physical stress. At high concentrations it causes proteolysis in the muscle and immune suppression, so low levels are desirable.

What it is affected by: The serum cortisol concentration presents diurnal variation, with higher values in the morning and lower values in the afternoon. It increases under stress and after intense exercise. Athletes (especially athletes of sprint and power sports) are likely to have higher values than non-athletes. Cortisol also increases in the presence of hypoglycemia or obesity.

Importance of measurement in athletes: The cortisol concentration serves as an index of mental or physical stress. Its ratio to the testosterone concentration serves as an indicator of the balance between catabolic and anabolic processes, respectively, in muscle tissue, of the athlete's response to training load and, possibly, of the overtraining syndrome.

Creatine kinase

What it is: Creatine kinase is the enzyme that catalyzes the resynthesis of adenosine triphosphate (ATP) from phosphocreatine during vigorous exercise and, conversely, the resynthesis of phosphocreatine from ATP during recovery from exercise. Creatine kinase (CK, also known as CPK from creatine phosphokinase) abounds in muscle tissues (skeletal muscle, myocardium, and smooth muscle).

What it shows: The catalytic concentration of CK in the serum (usually expressed in U/l at 37° C) is a marker of muscle damage and, in fact, destruction of muscle fibers. It is believed that, when muscle fibers are destroyed, their content leaks into the blood, resulting in a rising in the concentration of one of their most abundant components, CK. Thus, CK is a marker of myocardial infarction and muscle strain after exercise, particularly eccentric exercise.

What it is affected by: Serum CK rises slowly after exercise and remains elevated for several days. The greater the muscle strain and the less familiar with the particular exercise the person is, the greater the increase in CK. Repetition of the same exercise, even weeks after the initial exercise, causes a smaller increase in CK. Because of regular training, athletes have higher values than non-athletes, which usually exceed the upper reference limit (i.e., the upper limit of normal values) for the general population. CK returns to baseline values after a few days' rest.

Importance of measurement in athletes: CK measurements are used to assess the training load and avoid possible excesses or other problems (such as dehydration and side effects of drugs that elevate CK).

Creatinine

What it is: Creatinine is the substance into which part of the creatine and phosphocreatine in tissues (particularly muscle tissue) and food is converted. It is transported through the blood to the kidneys and excreted through urine.

What it shows: The serum creatinine concentration (usually expressed in mg/dl) is a key indicator of renal function, because when there is a kidney malfunction creatinine removal is obstructed and its concentration rises in the blood.

What it is affected by: As mentioned above, the serum creatinine concentration is affected by renal function. Athletes may have higher values because of typically greater muscle

mass than the general population (thereby having more creatine and phosphocreatine), intense training (causing muscle damage that can increase the release of creatinine in the blood), high intake of meat (which is rich in creatine) or, finally, consumption of creatine supplements.

Importance of measurement in athletes: To assess renal function and creatine intake.

Erythrocyte count

What it is: Erythrocyte count is the number of erythrocytes (also known as red blood cells, the oxygen-carrying cells) in a specific volume of blood.

What it shows: Usually expressed in millions per microliter of blood, erythrocyte count shows the ability of the blood to carry oxygen. Values lower than the lower reference limit (i.e., lower than the lowest normal value) indicate anemia.

What it is affected by: Erythrocyte count increases from childhood to adolescence to adult life. This increase is greater in males, resulting in males having higher erythrocyte count values than females from adolescence and on. Erythrocyte count increases by living at high altitude. It also increases with erythropoietin administration and can increase with administration of anabolic androgenic steroids. (The latter means of increasing erythrocyte count are prohibited by WADA.) Lastly, erythrocyte count can be found slightly reduced within a few hours to a few days after exercise (or permanently in those exercising regularly) due to the increase in blood water as a result of body water shifts observed during and after exercise. Such decrease does not affect the oxygen-carrying capacity of the blood, since there is no change in the number of erythrocytes. Athletes do not seem to have higher rates of anemia compared to the general population.

Importance of measurement in athletes: Erythrocyte count correlates positively with aerobic capacity.

Ferritin

What it is: Ferritin is the protein that stores iron in organs such as the spleen, bone marrow and liver. The tissue iron content is one of the factors that determine aerobic capacity.

What it shows: The serum ferritin concentration (usually expressed in ng/ml or mg/l) serves as an index of the iron stores in the body. Thus, a high ferritin concentration (within the reference intervals) is desirable.

What it is affected by: The serum ferritin concentration relates positively to long-term iron intake through diet or dietary supplements.

Importance of measurement in athletes: The measurement of ferritin is used to assess the adequacy of long-term iron intake.

gamma-Glutamyl transferase

What it is: gamma-Glutamyltransferase is an enzyme participating in the metabolism of glutathione, an important antioxidant of the body, among other functions. Located in the liver and other tissues, it is better known by the abbreviation γ-GT.

What it shows: Since γ-GT abounds in the liver, its catalytic concentration in the serum (usually expressed as U/l at 37° C) is increased in liver disease and after alcohol overconsumption. Thus, γ-GT serves as an indicator of the integrity and proper functioning of the liver.

What it is affected by: γ-GT is affected by liver disease, alcohol consumption and use of drugs that cause hepatotoxicity.

Importance of measurement in athletes: Since, unlike the [transaminases](#) (also indicators of liver injury), γ-GT is not affected by exercise, it is considered to be a more accurate indicator of liver damage for athletes.

Glucose

What it is: Glucose is a simple carbohydrate and serves as an energy source for all cells in the body. In biochemical tests it is often referred to as blood sugar.

What it shows: The serum glucose concentration (usually expressed in mg/dl) shows the balance between the mechanisms that increase it (including the activity of the hormones glucagon and epinephrine) and mechanisms that reduce it (including the activity of the hormone insulin).

What it is affected by: The serum glucose concentration (under fasting and resting conditions) is influenced by the adequacy of carbohydrates in the body. Insufficient intake of carbohydrates can lead to low glucose concentration (hypoglycemia). In contrast, in pathological situations, the lack of insulin or resistance to its action leads to high glucose concentration (hyperglycemia).

Importance of measurement in athletes: Since exercise reduces the carbohydrates stored in the body, athletes that do not compensate for these losses by adequate intake of carbohydrates are at risk for hypoglycemia. Thus, the measurement of serum glucose is used to estimate whether an athlete has a sufficient carbohydrate intake through food and food supplements or not.

HDL cholesterol

What it is: It is the cholesterol that circulates in the blood embedded in the high-density lipoproteins (HDL).

What it shows: The HDL cholesterol concentration (usually expressed in mg/dl) relates negatively to the risk of atherosclerosis. Thus, it is considered that HDL play a cardioprotective role. HDL cholesterol is known as good cholesterol and high values of it are desirable.

What it is affected by: The HDL cholesterol concentration is higher in women than men. Regular endurance exercise that includes considerable energy expenditure increases HDL cholesterol.

Importance of measurement in athletes: As regular exercise can increase HDL cholesterol, which reduces the risk of atherosclerosis, the measurement of HDL cholesterol contributes to monitoring the athletes' health and helps to assess the effectiveness of training programs in improving the lipidemic profile.

Hematocrit

What it is: The hematocrit is the volume of the erythrocytes (or red blood cells) as a percentage of the blood volume.

What it shows: Since erythrocytes carry oxygen in the blood, the hematocrit shows the oxygen-carrying capacity of the blood. A hematocrit value below the lower reference limit (i.e., lower than the lowest normal value) indicates anemia.

What it is affected by: Hematocrit is affected by the same parameters that affect the [erythrocyte count](#).

Importance of measurement in athletes: Hematocrit correlates positively with aerobic capacity.

Hemoglobin

What it is: Hemoglobin is the protein that carries oxygen in the blood. Located within the erythrocytes (red blood cells), it is responsible for the red color of both themselves and of blood as a whole.

What it shows: The blood hemoglobin concentration (usually expressed in g/dl) shows the body's ability to absorb atmospheric oxygen in the lungs and transfer it to the tissues. Values lower than the lower reference limit (i.e., lower than the lowest normal value) indicate anemia.

What it is affected by: The blood hemoglobin concentration is influenced by the same factors that affect the [erythrocyte count](#).

Importance of measurement in athletes: The blood hemoglobin concentration correlates positively with aerobic capacity.

Iron

What it is: Iron is a chemical element used in the synthesis of hemoglobin and other proteins in the body. Iron circulates in the plasma bound to proteins, mainly to transferrin.

What it shows: The serum iron concentration (usually expressed in µg/dl) indicates the amount of iron available for absorption by the tissues and for incorporation in the proteins they synthesize. Thus, a high iron concentration (within the reference interval) is desirable.

What it is affected by: The serum iron concentration relates positively to the iron content of food and iron supplementation.

Importance of measurement in athletes: As many athletes often follow particular dietary regimens (such as weight-loss diets), which contain insufficient amounts of iron, its measurement in serum is important to determine adequate iron intake. It should be noted, however, that serum iron shows short-term iron intake and it can be easily changed within a few hours depending on the preceding meal. Therefore, the measurement of iron alone is not as useful as when combined with the measurement of [total iron binding capacity](#) to calculate [transferrin saturation](#).

Lactate dehydrogenase

What it is: Lactate (or lactic) dehydrogenase is the enzyme that catalyzes the interconversion of lactate and pyruvate. It is known by the initials LD or LDH. It is present in abundance in the muscles and liver.

What it shows: The catalytic concentration of serum LD (usually expressed as U/l at 37° C) is an indicator of muscular damage. The same are true for LD as for [creatine kinase](#), but LD is not as sensitive an index of muscle strain as creatine kinase, since its increase after exercise is smaller.

LDL cholesterol

What it is: LDL cholesterol is the cholesterol that circulates in the blood embedded in low-density lipoproteins (LDL). It is a parameter that is not usually measured directly; instead, it is calculated from total cholesterol, HDL cholesterol and triglycerides.

What it shows: The LDL cholesterol concentration (usually expressed in mg/dl) relates positively to the risk of atherosclerosis. The LDL are the main atherogenic lipoproteins. LDL cholesterol is known as bad cholesterol and low values of it are desirable.

What it is affected by: The LDL cholesterol concentration tends to rise with age. It is affected by hereditary factors and relates positively to body fat.

Importance of measurement in athletes: The measurement of LDL cholesterol contributes to monitoring the athletes' health.

Leukocyte count

What it is: Leukocyte count is the number of leukocytes (also known as white blood cells, cells of the immune system) in a specific volume of blood.

What it shows: Usually expressed in thousands per microliter of blood, leukocyte count indicates immune status. Values lower than the lower reference limit (i.e., lower than the lowest normal value) indicate immunosuppression. Infections raise the number of leukocytes over the upper reference limit.

What it is affected by: As mentioned above, leukocyte count is influenced by the presence of infection. Excessive training load is likely to reduce leukocyte count at rest.

Importance of measurement in athletes: As with the general population, measuring leukocyte count in athletes is used to detect or confirm the presence of infection. An additional utility to athletes is to identify possible immunosuppression due to excessive training load.

Platelet count

What it is: Platelet count is the number of platelets (also known as thrombocytes, the cells involved in blood clotting) in a specific volume of blood.

What it shows: Usually expressed in thousands per microliter of blood, platelet count is indicative of the state of the blood coagulation system. Values lower than the lower reference limit (i.e., lower than the lowest normal value) show difficulty in blood clotting (thus risk of bleeding), while values higher than the upper reference limit indicate a risk for thrombosis.

Importance of measurement in athletes: Since there is no documented effect of exercise on platelet count, its measurement is of no particular use to athletes, but this parameter is included anyway in the complete blood count, along with hematocrit, hemoglobin, erythrocyte count, and leukocyte count.

Testosterone

What it is: Testosterone is a steroid hormone that belongs to the group of androgens. It is synthesized primarily in the testes.

What it shows: The serum testosterone concentration (usually expressed in µg/l) is increased during the passage from childhood to adolescence and from adolescence to adulthood. This increase is greater in males, resulting in their having higher concentrations than females from adolescence and on. As testosterone exerts anabolic (protein-synthetic) action in muscles, high testosterone concentrations are desirable.

What it is affected by: As just mentioned, the serum testosterone concentration is influenced by sex and biological age. It increases after exercise in proportion to the total work produced. Endurance athletes often have lower concentrations than non-athletes, whereas weightlifters have higher.

Importance of measurement in athletes: The testosterone concentration is used to assess the anabolic environment in the athlete's body. The ratio of serum cortisol to testosterone is a possible indicator of the overtraining syndrome.

Total iron-binding capacity

What it is: Abbreviated as TIBC, total-iron binding capacity is the serum iron concentration in the case where all proteins that bind iron (especially transferrin) are fully saturated (which, however, never happens in reality).

What it shows: TIBC is negatively correlated to the adequacy of iron in the body. So, TIBC values above the upper reference limit (i.e., higher than the highest normal value) are a warning sign for iron depletion.

What it is affected by: Iron deficiency leads to an increase of transferrin in the plasma and, hence, an increase in TIBC.

Importance of measurement in athletes: The measurement of TIBC is used to assess the adequacy of iron in the body.

Transaminases

What they are: Transaminases are enzymes that catalyze the transfer of an amino group from an α-amino acid to an α-keto acid; this transfer is a part of amino acid metabolism. The commonly measured transaminases are glutamate-pyruvate transaminase (GPT) and glutamate-oxaloacetate transaminase (GOT). The letter, S, is sometimes added in front of the abbreviations to highlight that the enzymes are measured in serum. Alternatively, the two enzymes are referred to as ALT (i.e., alanine aminotransferase) and AST (i.e., aspartate aminotransferase) repsectively.

What they show: As transaminases abound in the liver, their catalytic concentrations in serum (expressed in U/l at 37°C) rise in the case of liver disease (such as cirrhosis and hepatitis) due to the leakage of the contents of the damaged liver cells into the blood. Thus, transaminases serve as indices of liver integrity.

What they are affected by: As just mentioned, the transaminase concentrations are affected by liver damage. Furthermore, as transaminases are present in muscle as well, their serum concentrations increase after hard exercise because of muscle fiber damage (although the rise is lower than the rise in CK). Of the two aforementioned transaminases, GOT (AST) increases more, as its muscle concentration is higher than that of GPT (ALT).

Importance of measurement in athletes: The fact that both transaminases increase after exercise limits their utility as indices of liver damage in athletes. To assess the intrgrity of liver in athletes, it is preferable to measue γ-GT.

Transferrin saturation

What it is: Transferrin saturation is the serum iron concentration as a percentage of TIBC, namely: transferrin saturation = iron / TIBC × 100.

What it shows: Transferrin saturation shows how saturated the iron transport system is.

What it is affected by: Transferrin saturation is positively correlated with iron adequacy in the body, since iron adequacy will create a high numerator and low denominator in the formula above. When there is iron deficiency, the numerator (i.e., the serum iron concentration) is reduced, while the denominator (i.e., TIBC) increases. So, transferrin saturation is altered proportionally more than each of the two other parameters. Transferrin saturation is therefore considered a more sensitive indicator of iron status than the other two.

Importance of measurement in athletes: The measurement of transferrin saturation is used to assess the adequacy of iron in the body.

Triglycerides

What they are: Triglycerides are the most abundant lipid category in the body. They are found mainly in adipose tissue, but they are present in appreciable amounts in the blood as well.

What they show: The serum triglyceride concentration (usually expressed in mg/dl) relates positively to the risk for atherosclerosis (or arteriosclerosis), which is the main cause of cardiovascular disease. Thus, a low concentration of triglycerides is desirable.

What they are affected by: The serum triglyceride concentration tends to increase with advancing age and it is generally higher among males than females. It is affected by hereditary factors and it is positively correlated with body fat (especially abdominal fat) and carbohydrate intake (especially the intake of simple carbohydrates like sugar). Finally, the serum triglyceride concentration decreases with regular aerobic exercise, so long as exercise has remarkable energy expenditure.

Importance of measurement in athletes: As regular aerobic exercise can decrease the serum triglyceride concentration, thus reducing the risk of atherosclerosis, the measurement of triglycerides contributes to the monitoring of athletes´ health and helps to assess the effectiveness of training programs in improving the lipidemic profile.

Urea

What it is: Urea is the substance used by the human body to remove the majority of the nitrogen that results from the breakdown of proteins and other nitrogenous substances. It is synthesized in the liver, extracted in the blood and excreted in the urine. Certain laboratories may report urea nitrogen instead of urea.

What it shows: The serum urea concentration (usually expressed in mg/dl) indicates protein intake through the diet and dietary supplements. It is also a marker of kidney function, as, when the kidneys do not work properly, the removal of urea is hindered; thus, its concentration in the blood rises.

What it is affected by: As just mentioned, the serum urea concentration is affected by protein intake and kidney function.

Importance of measurement in athletes: Athletes often consume unreasonably high amounts of protein; as a result, a large part of dietary protein is degraded, producing urea, since the body cannot utilize dietary protein beyond a limit to synthesize its own proteins. Hence, the serum urea measurement serves to protect athletes against dietary excesses.

Uric acid

What it is: Uric acid, or urate, is the product of the degradation of purines (constituents of DNA and RNA) contained in the tissues or diet. Uric acid has antioxidant properties.

What it shows: The serum uric acid concentration (usually expressed in mg/dl) partially indicates kidney function, because when the kidneys do not work properly its removal is hindered; thus, its concentration in the blood rises. High concentration of uric acid is associated with gout.

What it is affected by: A diet rich in purines (liver and other offals) raises the concentration of uric acid. Increased uric acid can be found after intense exercise, due to increased ATP breakdown, since adenine, a component of ATP, is a purine. It is believed that, as an endogenous antioxidant, uric acid reduces the oxidative stress caused by intense exercise.

Importance of measurement in athletes: On the basis of the factors affecting it, the serum uric acid concentration serves as an indicator of dietary consumption of purines and intense exercise.

Epilogue

In order to yield the maximum benefit possible, athletes' biochemical monitoring should be regular and scheduled (about every trimester to semester or at milestones of the training macrocycle). It should be noted that useful information for athletes can be obtained from biochemical analyses of other biological samples (such as urine, saliva and muscle biopsy), which are likely to be covered in future editions. Moreover, the Society intends to cover, future editions, the biochemical measurements that are important for the athletes' assessment during or after exercise (notably, lactate).

Finally, it is noted that the assessment of the results of biochemical tests should be performed by specialized scientists, namely, doctors, biochemists and (for indices of the nutritional status) nutritionists-dietitians.

August 2015

Hellenic Society of Biochemistry and Physiology of Exercise