SPORTS ADAPTOLOGY

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Summary

Sports adaptology is a new scientific discipline studying the holistic behavior of systems and organs of an athlete in the form of instant and long-term adaptive processes. As a result of sports exercises, instant and long-term adaptive processes take place. For description and prognostication of these processes, it is necessary to use logical and mathematical simulation modeling. That is why sports adaptology contains information about structure of systems and organs, special features of their functioning at performance of competitive and training exercises, description of processes of morphological reconstruction, as a result of long application of training exercises on the basis of mathematical simulation modeling and experimental analysis.

1. Introduction

Sports adaptology is a new scientific discipline of research of morphological, biochemical, physiological and biomechanical changes in the body of an athlete that take place in the course of training and competitive motor actions, and also long-term consequences of sport activity. The area of scientific research of sports adaptology comprises studying the holistic behavior of systems and organs of an athlete while performing physical exercises and in the course of restoration. The basic method of research is simulation (logical and mathematical) modeling of instant and long-term adaptive processes in the body of an athlete. Models of systems and organs of an athlete are developed based on experimental data about their structure and interconnections using established knowledge in the field of human biology.

Logical and mathematical models are used for description of phenomena taking place in sport practice. Description of instant and long-term processes in the course of sport exercises pertains to the theory of sports activity.

Plausible and adequate models of the physical body of an athlete can be used in pedagogic practice, within the framework of a new methodical discipline – sports educational pedagogy. By means of simulation modeling, it is possible to develop and verify experimentally the validity of theoretical calculations in the course of development of new methods of control of physical fitness, means and methods of physical training, and corresponding programs for a training process.

2. Methodology of Sports Adaptology

It is seen historically that the development any scientific discipline originates in myths, authoritative convictions, and empirical studies and culminates into a theoretical field as a subject of research. Theoretical cognition of a subject of research implies development of a model of the subject, initially, at the level of a logical narrative, which by the use of suitable methods, reaches a mathematical level, capable of reflecting both the material part of the subject and special features of its behavior in different internal conditions and external environment.

A model of the subject of study is developed considering state-of-the-art of scientific knowledge about structure of the subject and interconnections between its structural components (elements) and also its bonds with the external environment. Thus, modeling is a means of systematization and synthesis of the whole set of factual (sensual) data about a subject of study.

The mathematical tool for modeling the dynamics of a system is differential calculus. Differential equations are used to describe the dynamics not only of a physical system but also its internal processes. Such mathematical descriptions of a system provide deep and detailed understanding of the subject.

Sports 'adaptology' is a science that deals with the holistic behavior of the organism of an athlete in training and competitive conditions. Sports 'physiology' cannot study holistic behavior of the organism of an athlete, since its focus is mainly on individual components of a human organism, it does not use methods of mathematical modeling of holistic behavior of the organism of an athlete. Therefore sports adaptology must be considered as an independent scientific discipline. Development and application of generalized mathematical models of muscular fibers, muscles, nervous, cardiovascular, respiratory, immune systems is a subject of research of sports adaptology. The basis of such models must include all up-to-date knowledge, obtained by biologists till now.

Sports educational adaptology, unlike the fundamental science - sports adaptology which is about the study of an athlete for an understanding of fundamental laws of functioning and adaptation to loads, is a methodical science. Within its framework, a great number of rational variants of training – a sequence of control commands for selection of the best solution of sports problems – is developed. The sequence of actions (a method, a technology) is not a subject of a fundamental science. Such search for the best approach is similar to engineering design, to search of variants of solution to problems, taking into account corresponding environment, the state of the subject and possibility of implementation of a appropriate training program.

The process of scientific search as a methodical activity includes the following stages:

- choice of a conceptual and mathematical model of an athlete, according to a certain purpose of training,
- analysis of methods of training and choice of rational variants by means of simulation modeling,
- development of microcycles of training and their analysis in the course of simulation modeling,
- planning of training,
- experimental analysis of efficiency of an innovative program of training.

The training method is a description of the sequence of actions of an athlete (sometimes under the direction of the trainer). The sequence of actions implies observance of several principles. Search of rational variants of choice of these parameters is a subject of research of sports-pedagogic adaptology.

The plan of training (a corresponding technology) must define distribution within the framework of a microcycle of different methods of training and nutrition for achievement of desired goals of sports training, taking into account processes of long-term adaptation of systems and organs of an athlete.

3. Models of Systems and Organs of the Organism of an Athlete

Advances in science give rise to models of a subject of research helping to reveal new properties or to develop innovative technologies, to create a certain theory. For purely scientific explanation of functioning mechanisms of the organism of an athlete, it is necessary to develop a model of an ideal cell, a muscular fiber, a muscle, neuromuscular apparatus, cardiovascular system, respiratory system, endocrine, immune, digestive systems, etc. Details of models must be sufficient to provide solutions to the practical problems - explanation of phenomena of adaptation of an organism of an athlete to applied training and competitive loads.

3.1. Ideal Cell (Muscular Fiber)

At the first sight, all animal cells have the same structure. The cell, for example, a muscular fiber (MF), has a membrane (sarcolemma). In sarcoplasm, there are all common organellas and numerous kernels (MF is a multinucleate cell). Specific organellas are myofibrils.

Structural components of a cell are the following:

- plasma, transparent fluid with protein inclusions – enzymes for metabolism of carbohydrates, amino acids, fats (lipids) and other materials, and also tRNA. New organelles are created in plasma with the help of ribosomes and polyribosomes;
- membranes of a cell, consisting of lipids (40%) and proteins (60%). Protein inclusions perform functions of proteins-carriers, proteins-enzymes, receptors and a structural basis;
- mitochondria - power stations of a cell, they are engaged in resynthesis of molecules of ATP by means of oxidative phosphorylation. They consume oxygen,

carbohydrates, fats and release carbon dioxide, water and resynthesized molecules of ATP. Metabolism products also can inpour through membranes of mitochondria into cytoplasm;
- endoplasmic reticulum (ER) is a set of membranes, tubules, vacuoles. Specialists distinguish granular and agranular ER. In granular ER synthesis of membrane proteins and other cell components takes place. Agranular (smooth) ER participates in synthesis of lipids, it is well developed in cells of endocrine system; sometimes it participates also in glycogen synthesis;
- Golgi complex (apparatus) - a set of membranes performing secretory function;
- lysosomes - ball-shaped structures keeping inside hydrolytic enzymes (proteinases, glucosidases, phosphatases, nucleases, lipases). Lysosomes participate in processes of intracellular digestion. Lysosomes are especially active at cells acidulation, increase of concentration of hydrogen ions;
- ribosomes - elementary apparatuses of proteins synthesis;
- microtubules - fibrillar formations playing the role of frame structures;
- glycogen globules - reserve of carbohydrates in a cell;
- fat droplets – reserve of fat in a cell;
- nucleus – a system of genetic determination of protein synthesis. Includes chromatin, nucleoli, karyoplasm and a nuclear envelope. Chromatin contains DNA, mRNA is created here, and rRNA is created in nucleoli.

After revealing cell structure, it is possible to consider corresponding physiological processes in a cell. From the point of view of problems of physical training, it is interesting to study the processes of catabolism and anabolism.

Anabolism is provided by DNA and polyribosomes; this process is activated by steroid hormones. For physical development of a human organism, somatotropin (growth hormone) and testosterone are especially important. Steroid hormones inpour only into active cells.

Catabolism in cells is provided by lysosomes. They become especially active at cells acidulation – when hydrogen ions appear in them. In this case, pores in membranes expand and the processes of diffusion and active transportation are accelerated.

Thus, physical development of active cells is provided by growth of concentration of steroid hormones in blood, along with minimization of catabolism (blood acidulation). Thus, the main principles guiding a qualified coach in formulating the training process are the following:
- *control of activity of central nervous system (CNS) and muscles is provided by management of endocrine system (concentration of steroid hormones - somatotropin and testosterone in the organism of an athlete);*
- *control of concentration of hormones in blood leads to adaptive reconstruction in active MF (hyperplasia of myofibrils and mitochondria).*

3.2. Endocrine System

The endocrine system includes some glands: hypophysis, pineal body, adrenals, gonads, pancreas, etc. Performance of physical exercises induces mental tension (stress) in the cerebral cortex, and this process activates hypothalamus and secretion by hypophysis. The anterior lobe of hypophysis secretes into blood somatotropin, thyrotropin, adrenocorticotropic hormone (ACTH), follicle-stimulating hormones (FSH) and luteinizing hormones (LH).

Somatotropin (growth hormone) flowing into MF stimulates synthesis of myofibrils, activates synthesis in tendons and bone tissues.

FSH, LH activate gonads, this process leads to secretion of testosterone into blood, and testosterone activates in MF synthesis of myofibrils.

It is well known that concentration of somatotropin and testosterone grows at performance of power, speed-power and high-speed exercises, and also at sufficient mass of active muscles. Therefore development of MF is maximum intensive at performance of exercises with limiting and near-limiting mental tension at minimum acidulation (catabolism) of MF.

From this point of view, we deduce the third pedagogic principle of sports training:

- *the most efficient (stress) are those physical exercises, which are performed with limiting or near-limiting mental stress.*

3.3. Immune System

Immune system includes bone marrow, thymus, lymph nodes, etc. Bone marrow participates in creation of blood corpuscles. The major factors of normalization of functioning of bone marrow are testosterone and vitamin B_{12}. Therefore, stress loads stimulate activity and development of bone marrow and the whole immune system.

3.4. Muscles

Muscles consist of MF. All MF are classified as FMF (fast MF) and SMF (Slow MF). Biopsy allows defining the composition of any muscle. Biopsy of lateral head of quadriceps muscle of thigh is a typical operation for corresponding analysis. A sample of a muscular tissue undergoes a process of fast freezing, after that specialists slice it and treat it chemically according to a specified technology. Usually, scientists study the activity of myosin ATPase – an enzyme destroying the molecules of ATP. Then, they analyze cross sections of MF and observe corresponding coloration - black, grey and white MF. After that specialists count corresponding proportions on a certain surface or in 200 units of MF of the same color. This muscular composition is inherited. It is impossible to change significantly ATPase activity of MF. In experiments with muscle electro-stimulation, it is possible to temporarily vary ATPase activity, but these experiments yet have no practical value.

It is important to note that each muscle has its own inherited muscular composition; therefore, biopsy from one muscle cannot give a full picture of endowments of an athlete. Pedagogic supervision and testing can give fuller information about the talent of a certain athlete in comparison with common laboratory analysis. For example, for track and field athletes, these tests must include standing jumping, multi-jumping from one foot to another, shot put (forward and backward), grenade throwing. Such exercises allow estimating work of different muscular groups of an athlete in comparison with standards. For example, if in a group the majority of boys of 11-12 years old cover in standing jumping a distance equal to 180-200 cm, and the result of one of them is equal to 250 cm, then there is no doubt that this boy has high percentage of fast MF in muscles-extensors of corresponding joints of legs.

There is a special method of classification of MF according to the content of other enzymes. Classification of MF by activity of enzymes of mitochondria is of special interest. In this case specialists consider oxidative, mediate and glycolytic MF (OMF, MMF and GMF, accordingly). This muscular composition is not inherited, since OMF easily turns into GMF at termination of trainings. Mitochondria disintegrate, deteriorate and in 20 days only 50% of their full number remains. Good sports form is lost without training very quickly.

MF has specific organellas - myofibrils. Myofibrils have the same structure in all animals; they differ only by their length (by a number of sarcomeres). Cross-section of all myofibrils is identical. Therefore, force of contraction of MF depends on a number of myofibrils in it.

Sarcomere is a consecutive component of a myofibril; it consists of actin and myosin fibers. Myosin fibers have branches with heads. The myosin head is at the same time a special enzyme for destruction of molecules of ATP and phosphocreatine (PCr). Decomposition of ATP molecules results in the appearance of ADP, inorganic phosphate (P_i), H and release of corresponding energy. For resynthesis of molecules of ATP certain amount of energy is required; it comes from the molecules of PCr, and at decomposition it is transformed into free Cr, P_i and energy.

Contraction of sarcomere and myofibril takes place when calcium from corresponding cisterns is released. Calcium leaves these cisterns when MF activation takes place. It attaches itself to active centers of actin and releases them for creation of bridges between actin and myosin. Myosin heads, fastened to actin, turn through an angle of 45 degrees, enabling fibers to slide relative to one another. Disconnection of heads of myosin requires certain energy, which comes from a process of decomposition of ATP molecules by a special enzyme – myosin ATPase. After this process, creatine phosphokinase destroys PCr, and energy of this molecule is consumed for resynthesis of ATP. Free creatine and inorganic phosphate flow through myofibril to mitochondria or enzymes of glycolysis and this induces initiation of glycolysis and oxidative phosphorylation in mitochondria.

The release of calcium from corresponding cisterns takes place during MF activation. After termination of electrical stimulation of MF, pores in cisterns are closed, and calcium pumps continue to pump atoms of calcium into the cisterns. In 50-100 ms, the main part of ions of calcium is pumped back into cisterns. This process is called relaxation of muscles.

Since the molecules of ATP are considerably large, they are very slowly transported through MF, and molecules of PCr serve as a mediator between myofibrils and mitochondria delivering energy. These molecules are small and easily move through MF. Russian scientists refer to this mechanism as PCr-shuttle.

Thus, intake of creatine with common food allows increasing its concentration in MF. As a result, metabolic processes in MF are significantly accelerated.

The model of bioenergetic processes in MF of different types. In GMF, there are reserves of molecules of ATP in myofibrils, near mitochondria, and in sarcoplasm. There is a reserve of molecules of PCr, globules of glycogen and fat droplets. The amount of mitochondria in GMF is at its low, since it is necessary only for maintenance of life of these cells at rest.

Activation of biochemical processes begins from the moment of transition of electrical impulses through membranes of MF. Pores in corresponding cisterns open, calcium is released into sarcoplasm, then it attaches to actin, and actin-myosin bridges are created, ATP and PCr are consumed for this process. Free creatine and inorganic phosphate leave myofibrils and use energy of sarcoplasmic molecules of ATP for resynthesis of PCr. Molecules of ATP resynthesize during anaerobic glycolysis. Glycolysis begins with decomposition of molecules of glucose or glycogen, and finishes with pyruvate creation. Pyruvate transforms into lactate due to absence of mitochondria. Binding of anions of lactate with protons (hydrogen ions) leads to formation of lactic acid, which can appear in this form in blood. In blood molecules of lactic acid are decomposed; therefore there is high correlation between concentration of hydrogen and lactate (R=0.99).

Hydrogen ions are formed at decomposition of sarcoplasmic and other molecules of ATP.

The activity of GMF leads to accumulation in sarcoplasm of products of metabolism (H, Cr, P_i, lactate, pyruvate, etc.).

The reserve of myofibrillar ATP is sufficient for 1-2 s of work, the reserve of PCr – for 5-20 s of work (depending on the regime of contraction and relaxation of MF). After that, glycolysis intensifies, but its power does not exceed 50% of maximum, and due to accumulation of hydrogen ions the process of formation of actin-myosin bridges is suppressed, and in 30 s this process almost completely stops. This phenomenon usually is determined as local muscular fatigue. GMF are defined as tired MF.

The structure of OMF is similar to that of GMF. The main difference is in the mass of mitochondria. In OMF, the mass of mitochondria corresponds to a marginal ratio with myofibrils, and that provides maximum oxygen consumption about 0.3 l/min by 1 kg of OMF.

Activation of OMF leads to formation of actin-myosin bridges and to energy consumption from molecules of ATP. Concentration of myofibrillar molecules of ATP is maintained by PCr. Maintenance of concentration of PCr is provided by the following ways:

- by molecules of ATP re-synthesized in mitochondria,

- by molecules of ATP re-synthesized in aerobic glycolysis.

This process develops in a period of 45-60 s. By this time, both glycolysis and oxidation of fats can take place. But in the process of functioning of mitochondria, citrate accumulates in sarcoplasm, therefore, inhibition of enzymes of glycolysis begins, and OMF completely switch over to lipolysis.

Lipolysis uses fat reserve in droplets; this reserve is sufficient for 30-50 min of work of normal people. Since fatty acids of blood are slowly transported to MF, they cannot provide fully for intensive muscle work.

Mitochondria consume ADP, P_i, oxygen, pyruvate, fatty acids, glycerol, hydrogen ions and extract resynthesized molecules of ATP, carbon dioxide and water. Therefore, OMF do not acidulate, do not get tired.

Oxidation of fats in OMF can be stopped, if lactate ions appear in sarcoplasm. In this case, oxidation of fats is inhibited, and lactate becomes an oxidation substrate. Lactate by means of heart isoenzyme of lactate dehydrogenase (LDH-1) is turned into pyruvate, which is transported into mitochondria through acetyl-coenzyme A. Pyruvate is also created in the course of glycolysis from glucose and glycogen.

Lactate can appear in OMF only in case of simultaneous functioning of GMF and OMF.

Biomechanical characteristics of MF are connected with the empirical laws relating the following:
- force - length,
- force - speed,
- force - activation time,
- force – relaxation time,
- force - energy of elastic deformation.

These laws must be considered when analyzing competitive activity.

Any coach must understand that OMF do not get tired, but GMF – can get tired; therefore, during the training process, it is necessary to work for increasing mass of mitochondria in GMF, and hence, transforming the latter into MMF and OMF.

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Biographical Sketch

Victor Nikolaevich Seluyanov (born in 1946), Ph. D., Professor, Honored Worker of Physical Culture. Since 1972, he has been working as a professor in the Department of Natural Sciences of the Russian State University of Physical Education, Sport, Youth and Tourism.

Prof. Seluyanov has authored more than 300 publications. His scientific interests are connected with solution of problems of sports biomechanics, sports anthropology, sports physiology, and theory of sport. He has developed new scientific directions: sports adaptology, technology of health improving physical training – “ISOTON”, methodology of intravital definition of mass-inertial characteristics of human body segments, the concept of biomechanical analysis of motor acts on the basis of the term “biomechanism”.