SECTION 7. BIOLOGICAL TECHNOLOGIES AND BIOENGINEERING

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ENERGY CONSERVATION LAW IN BIOMECHANICAL SYSTEMS

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Energy is a scalar physical quantity, which is a single measure of various forms of motion and interaction of matter, a measure of the transition of matter from one form to another. One of the reasons that energy is so difficult to describe is that it can take many forms, and not all of them are easy to understand. In any of these cases, there are exact formulas that describe the energy stored in the system and well-defined ways to measure it.

Energy is a special quantity of great importance to physics. The reason for this importance is that it is "preserved." Why is the energy saved? Because of the mathematical principle, correlating the fact that the laws of nature do not change over time, with the existence of a conserved quantity, which we by definition call "energy".

The general formulation of the law of conservation and transformation of energy: in all phenomena occurring in nature, energy does not arise and does not disappear, it only turns from one species to another, while its value is preserved. For each type of energy, the conservation law can have its formulation, which differs from the universal one.

The law of conservation of mechanical energy for the system – the total mechanical energy when the system moves in a stationary potential force field of external and internal forces is a constant.

When walking at a constant speed on level ground, a person also does the work, although his kinetic energy does not change. In this case, the energy is spent mainly on periodically raising the center of mass of the body and on accelerating or slowing down the legs. Part of this energy goes to the heating of the body due to the "resistance" of its parts and the heating of the environment. For example, a person weighing 70 kg when walking at a speed of 5 km/h develops a power of about 60 watts. With increasing speed, this power rapidly increases, reaching 200 watts at a speed of 7 km/h. When riding a bicycle, the position of the center of mass of a person changes much less than when walking, and the acceleration of the legs is also less. Therefore, the power spent when riding a bicycle is much less: 30 W at a speed of 9 km/h, 120 W at 18 km/h [1].

The work done by the muscles when performing active movements is called dynamic. This work involves moving parts of the body. In the case when a person keeps his posture unchanged, such movements are absent, and in the absence of movement, the work of all forces is zero. Therefore, it may seem that a person standing motion-less does not spend energy. However, experience shows that maintaining a fixed posture for a long time causes significant fatigue. Even more tired is a person holding a dumbbell in his outstretched arm. A seated person also feels tired muscles of the back and lumbar region if a load is placed on his shoulders. The cause of fatigue (and hence energy consumption) under static loads is that peace, in this case, is apparent. Due to the biological activity of muscles in humans, physiological tremor is always observed (Latin tremor – trembling). In this case, very small and very frequent contractions and relaxation of muscles occur that are invisible to the eye. Consequently, the muscles are constantly doing work (such work is called static) and spend energy. Muscle strength decreases and a break is required to restore it. This explains the fact that a standing person from time to time transfers the weight of the body from one leg to another [2].

Ergometers. To measure the work of a person, instruments called ergometers are used. For example, a bicycle ergometer is designed to measure useful work and power when riding a bicycle. To do this, a steel tape is thrown over the rim of the wheel that the subject rotates. The frictional force between the belt and the wheel rim is measured by a dynamometer. All the work of the subject is spent on overcoming friction. Multiplying the circumference of the wheel by the force of friction, they find work that is perfect for each revolution. Knowing the number of revolutions and the test time, they determine the total work and average power [3].

Running energy. Suppose a runner moves at a constant speed on a horizontal sur-face. The work that is being accomplished comes down to overcoming friction and air resistance. When running, the effect of friction is small, but running at a constant speed is associated with significant energy costs. Energy is spent on moving the run-ner's body up and down and pushing it off the ground with his feet. Also, the runner's body turns energy into heat. An additional reason for the loss of energy is that the legs of the runner, whose mass is about 40% of body weight, are constantly accelerated and braked during the run. Therefore, the work performed by the leg muscles to maintain the body moving forward at a constant speed is great.

Thus, we can assume that the speed that the runner can maintain does not depend on its size. People are unimportant runners. This is because the weight of a person's legs is about 40% of body weight and requires a significant amount of energy for each braking and acceleration. The fastest animals have thin legs, and the bulk is concentrated in the body. The large muscles of the legs in some animals (lion, tiger, big cats) are adapted for jumping, and not for fast running [1]. A person is limited in the amount of work performed by him, not only the energy required for this but also the speed of its use, that is, power. For example, a person can walk a long distance up the stairs before being forced to stop because too much energy has been used up. However, when climbing at a high pace, he may fall exhausted, having overcome only a small part of the path. In this case, the limitation is set by the amount of power expended, i.e., the speed with which a person, through biochemical processes, converts the chemical energy of food into mechanical work. The fact that an active body often functions to the point of its ultimate capabilities is confirmed by many cases when athletes tear muscles, ligaments, and tendons in competitions.

Bioenergy of the motor actions of the human body and its links is determined by the metabolic reactions of the body, supply and energy consumption. Sources of energy are chemical energy received by the muscles of the body as a result of chemical reactions, as a result of which contractile components are included in the work and their mechanical energy passes into the potential energy of deformation of sequential and elastic parallel components.

Another source of energy is the energy of the external environment, mechanically in contact with humans. All movements of the links and the human body are ac-companied by the conversion of the potential energy of the muscles into the kinetic energy of the links with which the muscles are connected. The accumulation of potential muscle energy occurs due to their stretching in inferior work. The links and the human body can accumulate potential energy in some cases due to their movement against gravity.

In the process of performing any holistic movement in the muscles, metabolic re-actions occur, i.e. chemical transformations of substances, energy production, and their metabolism both in the body and between the body and the environment. At the same time, in the preceding phases of any phase of the movement, deformation energy is accumulated in the elastic elements of the biomechanical model of muscles, which allows increasing the strength and speed of muscle contraction.

The energy spent on muscle work is divided into metabolic and non-metabolic. The energy that is released during metabolic reactions and goes into the mechanical work of muscles is called metabolic energy/

Muscles are capable of performing mechanical work, ensuring the movement of a person, the movement of air in the respiratory tract, the movement of blood and many other vital processes.

Coefficient of performance of the muscle. When the muscles do the work, the chemical energy accumulated during the metabolism is released in them; it is partially converted into mechanical work, and partially lost in the form of heat.

Energy metabolism is the result of the conversion of nutrients to energy. Energy is used to provide muscle function. The intensity of energy production by the body as a whole depends on the amount of energy released (external work, heat) and the amount of stored energy (nutrient deposition, structural transformation) per unit time: the total amount of energy generated is the sum of external work, heat loss, and stored energy.

The mechanical energy of a person's movement is determined by the power of his muscles and the power of external factors.

The work developed by the muscles in a certain period corresponds to a change in the mechanical energy of the body, which, in turn, consists of two components: kinetic and potential energy of the body. The kinetic and potential energy in the calculation is determined approximately by the kinematics of the body or by the movement of the general center of mass (G.C.M.) of the body. The calculation of the mechanical work of muscles during the locomotors cycle is carried out by direct and indirect calorimeter methods, or by the amount of oxygen consumed.

Any mechanical work of muscles (muscles) always requires energy, regardless of whether the muscle contracts (or lengthens) or is in isometric contraction.

References:

1. Курысь В.Н. Биомеханика. Познание телесно-двигательного упражнения. учебное пособие / М. : Советский спорт, 2013. – 368 с. : ил. – ISBN 978-5-9718-0629-5
2. Turpin, N.A.; Watier, B. Cycling Biomechanics and Its Relationship to Performance. Appl. Sci. 2020, 10, 4112.
3. Henry Vandewalle and Tarak Driss. Friction-loaded cycle ergometers: Past, present and fu-ture. Biomedical engineering | review article. Cogent Engineering (2015), 2: 1029237. P. 1-35.