Energy exchange in age physiology: regulation of metabolism and adaptive reactions

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Abstract: In this article we consider the characteristics of energy exchange at different stages of human life with emphasis on physiological changes occurring with age. Special attention is paid to hormone regulation, mitochondrial role, mechanisms of stress adaptation, as well as prevention of age-related metabolic disorders. Present modern scientific views on the relationship of metabolism and aging processes, substantiated directions of maintenance of metabolic health in old age. The analysis takes into account biological, clinical and behavioral factors.

Keywords: energy exchange, age physiology, metabolism, hormone regulation, mitochondria, aging, adaptation, metabolic disorders

Modern age physiology is a complex area of knowledge that studies how the functions of the human body change in the process of its development, growth and aging. One of the key physiological processes that undergo significant changes with age is energy exchange. Energy exchange (or metabolism) is the basis of life in the body, as it ensures the conversion of nutrients into energy necessary for the functioning of cells, tissues and organs.

The relevance of studying energy exchange in different age periods is due not only to the need to understand basic life processes, but also to practical tasks: prevention of age-related diseases, development of individual nutrition strategies, Treatment and maintenance of health. With the rapid ageing of the population globally, knowledge of patterns of metabolic changes with age becomes particularly important for health care, gerontology, sports medicine and nutrition.

The term metabolism refers to the totality of all chemical reactions that take place in the body, aimed at obtaining, transforming and using energy. Age physiology studies how body functions change throughout life - from the embryonic period to deep old age. Homeostasis is the ability of an organism to maintain stability of internal environment despite changes in external. All three concepts are closely interrelated:

with age, the homeostatic mechanisms and the structure of metabolism change, which entails the need for adaptation of the organism.

Common Energy Exchange Framework

Energy exchange is a basic physiological process that provides the organism with the energy needed for growth, movement, body temperature maintenance, molecule synthesis and other vital functions. Metabolism is divided into two interrelated components - catabolism and anabolism.

Catabolism involves the processes of degradation of organic substances (glucose, fatty acids, amino acids), during which energy is released. The main source of this energy is the cleavage of macronutrients, especially glucose in the process of glycolysis and further oxidative phosphorylation in mitochondria. These processes result in the production of adenosine triphosphate (ATP) molecules - a universal energy substrate that provides cells with energy. Catabolic processes also include β-oxidation of fatty acids and demineralization of amino acids with the subsequent involvement of their metabolites in the Crebs cycle.

Anabolism, in contrast to catabolism, involves the synthesis of complex molecules - proteins, nucleic acids, polysaccharides and lipids - from simpler compounds. These processes require the energy that the organism receives from ATP synthesized in catabolic reactions. Anabolism is especially active in childhood, during the period of growth, tissue recovery, as well as when adapting to physical exertion.

ATP plays a key role in providing all forms of cellular activity. This molecule is able to rapidly release the phosphate group, releasing energy. ATP is not available in the cells and must be constantly resynthesized, especially under high load or stress conditions. Most of the energy in the body is produced in mitochondria - cellular organelles, often called "cell power stations".

Regulation of energy exchange is carried out by a number of organs and systems. The endocrine system plays a central role in the coordination of metabolic processes. The thyroid (tyrosine), pancreas (insulin and glucagon), adrenal glands (adrenaline and cortisol), pituitary gland (somatotropin) and genitals (estrogen and testosterone) produce hormones that affect the rate of metabolism. For example, thyroxine enhances the basic exchange and insulin promotes glucose uptake and glycogen synthesis.

The nervous system, especially the hypothalamus, controls metabolism through sympathetic and parasympathetic regulation. When the sympathetic nervous system is activated (for example, under stress), catabolic processes are intensified, the mobilization of energy reserves - lipolysis, glycogenolysis, gluconeogenesis is accelerated.

Also important role in metabolism is played by liver (center of metabolism of carbohydrates, proteins and fats), muscles (main depot of proteins and energy consumer), fat tissue (reservoir of energy in the form of triglycerides), kidneys

(involved in acid-alkali balance and metabolyl production) and skin (thermoregulation). All these organs work together and ensure the adaptation of metabolism to different conditions - from rest to physical exertion, from hunger to overeating.

Thus, energy exchange is a dynamic and highly organized system, vital for the functioning of an organism. Against the background of age changes, regulation of these processes becomes especially important: with age there are not only quantitative but also qualitative shifts in metabolism, affecting all levels - from molecular to systemic.

Characteristics of metabolism in different age periods

The metabolism of a human being changes continuously throughout life. These changes depend on both the physiological characteristics of the body at each stage of development, and external factors - level of physical activity, nutrition, hormonal background, environmental impact. Each age period is characterized by specific metabolic mechanisms and needs.

The period of newborns and infancy is considered to be one of the most intensive in terms of energy exchange rate. In the first few hours of life, a newborn organism must adapt to an extra-uterine environment where it is necessary to maintain body temperature, breathing, digestion and other functions previously provided by the placenta. The basic exchange in this period is higher than in any other age, because the organism actively grows, all organs and systems develop, especially the brain.

Infants spend a significant amount of energy on thermoregulation processes, which is especially important given their immature skin and underdevelopment of the subcutaneous fatty tissue.

Childhood and adolescence are also accompanied by high metabolic activity, especially in the periods of so-called «growth jumps». At this time, active formation of bone, muscle and fat tissue occurs, the volume of circulating blood increases, secondary sexual signs develop. The secretion of hormones - insulin, thyroid hormones, sex steroids - becomes more pronounced and affects the regulation of the energy balance.

Maturity is the period of relative stabilization of all physiological processes. The basic exchange is usually balanced, provided that there is a healthy lifestyle and no endocrine disturbances. However, at this time the preconditions for age-related changes are beginning to form, especially if a person leads a sedentary lifestyle, eats improperly or experiences chronic stress.

Old age is characterized by a pronounced decline in the basic exchange. The body’s energy needs are reduced, but appetite regulation is often disrupted, which can lead to nutrient deficiencies. One of the key age changes is sarcopenia - a progressive loss of muscle mass and strength associated with decreased protein synthesis and reduced physical activity.

At the cellular level there is a suppression of mitochondrial activity, which leads to a decrease in ATP synthesis and accumulation of damaged organelles. Age-related decline in anabolic hormones (testosterone, estrogen, growth hormone) aggravates catabolic processes, and fat accumulation - especially in the abdominal area - increases the risk of insulin resistance and metabolic syndrome. In addition, age-related decline of thermogenesis and coping mechanisms makes older persons more vulnerable to temperature changes, infections and stress.

In general, metabolism in old age becomes less flexible, adaptive mechanisms are weakened and the response to physical exertion and diet change is slowed. This requires a special approach to nutrition, physical activity and medical care for older persons.

Adaptive mechanisms of the organism allow to maintain vitality and homeostasis in conditions of changing external and internal environment. As we age, our ability to adapt decreases, but it is normally maintained into old age due to the flexibility of metabolic processes and plasticity of metabolic regulation.

One of the most striking adaptive reactions is the response to physical exertion. In a healthy person, physical activity stimulates oxygen consumption and accelerates the oxidation of carbohydrates and fats. In response, ATP production increases, lipolysis is activated, insulin sensitivity is increased. In older people, these reactions are slowed down, but regular exercise can significantly improve metabolic adaptation, promote mythochondrial synthesis and reduce the risk of age-related diseases.

Age-related changes in energy exchange are a complex, multi-layered process based on changes in hormone regulation, mitochondrial activity, tissue sensitivity to insulin and adaptive capabilities of the body. The decrease in metabolic activity with age is accompanied by an increased risk of developing chronic diseases, deterioration of quality of life and loss of functional independence. However, modern science provides effective tools for the prevention of metabolic disorders - from lifestyle and nutrition to pharmacological and nutritional interventions. Understanding the mechanisms of age metabolism allows not only to delay the onset of pathological conditions, but also to actively shape the strategy of healthy aging. In the face of a rapidly ageing population, this knowledge is particularly important for both medicine and public health.

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