Chapter

Outdoor Recreation: Physiological Effects and Prevention of Socially Important Diseases

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Abstract

Physical activity improves the condition of the cardiovascular system, respiration, muscles, and metabolism and increases physical working capacity. This review of physiological effects and adaptation mechanisms of the outdoor recreation and its health benefits provides accessible information from a scientific point of view and research practice. Increased frequency of many socially important diseases such as diabetes mellitus type 2, metabolic syndrome and obesity, cardiovascular diseases, and others is associated with dramatically decreased physical activity in the last decades. Outdoor recreation for children, adolescents, adults, and older population is important for the prevention of these conditions. In this chapter, the authors describe in detail the physiological effects of different kinds of outdoor recreation physical activity with different intensities (such as walking, cycling, skiing, rowing, climbing, practicing some outdoor sports, etc.) and assess their benefits in the prevention of socially important diseases.

Keywords: outdoor recreation, adaptation, working capacity, physical activity, functional systems, socially important diseases

1. Physiological adaptation to outdoor recreation physical activity

Outdoor recreation physical activity includes a wide range of physical exercises that vary in structure, volume, and intensity. The structure is determined by whether the muscles perform static or dynamic work, the volume depends on the work (measured in kgm or J), and the intensity relates to the power (work done per unit time—W).

The changes that occur in the body (in muscles, cardiovascular, respiratory, and endocrine systems, blood, etc.) as a result of recreational physical exercises can be momentary or permanent. The momentary ones provide the immediate needs of the body during the performance of the exercise itself, and the permanent ones occur mostly as a result of systematic practice of recreational physical activity and are defined as adaptive.

The latter vary significantly depending on the type of recreational activity, as a result of which they occur and affect almost all functional systems of the body, such as cardiovascular, respiratory, endocrine, nervous, and blood systems, with significant changes occurring in both the muscles and the ability to adjust the thermoregulatory mechanisms, those which maintain the water and electrolyte balance, and acid–base balance of the body. Even the mechanisms involved in the individual's immune response are affected.

From a physiological point of view, it is important to answer questions, such as how the body responds to incidental recreational physical exercise, how it adapts to systematic outdoor recreation accompanied by physical activity, what are the mechanisms of the process of maladaptation, etc. On the other hand, it is important to differentiate the changes that occur with the different types of recreational exercise, with those of predominant aerobic energy supply (walking, running, cycling, swimming, and cross-country skiing), or of predominant anaerobic exercise (canoeing, rock climbing, rafting, etc.). Depending on the intensity, duration, nature, and structure of movements, physical exercises trigger different energy mechanisms. It is accepted that physical exercises are divided into cyclic and acyclic, according to the structure of movements. The cyclic ones involve uniform movements that are repeated (walking, running, and swimming). The acyclic exercises include sets of movements of varying complexity (in the exercise of surfing and rock climbing), and there may be combinations of cyclic and acyclic ones, as for example, in sports games.

According to the type of muscular activity, recreational physical exercises are divided into dynamic and static ones. The dynamic ones include successive phases of muscle contraction and relaxation, while with static exercises, muscles remain contracted for some time (concentric or isometric) [1].

1.1 Adaptation of the cardiovascular system to systematic outdoor recreation physical activity

The main task of the cardiovascular (performed in conjunction with the respiratory) system is to provide tissues with oxygen and nutrients, to eliminate carbon dioxide and end products of metabolism, to maintain body temperature, and to carry hormones from the endocrine glands to the target organs. To effectively perform these functions, the cardiovascular system must respond adequately to the enhanced (to a greater or lesser extent) muscular activity when carrying out outdoor recreation physical activity.

Almost without exception, the response is directly proportional to the oxygen needs of the muscles for each level of such exercise, as the consumption of oxygen in them increases linearly with the increase of its intensity [2].

1.1.1 Cardiac output

Cardiac output is a function of stroke volume and heart rate. And maximum oxygen consumption (VO_{2max}), in its turn, is a function of the cardiac output multiplied by the difference in the oxygen content of arterial and mixed venous blood. The cardiac output plays a key role in meeting the oxygen needs during outdoor recreational physical activity. As intensity increases, the cardiac output also goes almost linearly up to the point where the maximum capacity of the heart to pump blood is reached (Q_{max}). Under normal conditions, with the gradual increase of workload, the cardiac output and heart rate also increase progressively while the stroke volume increases only up to the so-called individual "critical frequency" of heart activity, which varies depending on the age and training of the individual. Studies conducted with people regularly practicing outdoor recreational sports show that their stroke volume continues to rise almost until the maximum load is reached [1].

1.1.2 Blood flow

The picture of the distribution of blood flow changes substantially at the very beginning of the recreational exercise. At rest, the skin and skeletal muscles receive about 20% of cardiac output. During physical work, the blood is forwarded to the active muscles, and when the body temperature rises, more blood flows to the skin. This process is mediated by the increased cardiac output and redistribution of the blood which "withdraws" from the deficient (mainly splanchnic) areas to satisfy those areas with increased needs (muscle and skin) of oxygen and nutrients. The mechanism allows, at high intensity of work, about 80% of the cardiac output to be forwarded exactly to the muscles and skin. In case of prolonged exercises performed at high temperature and humidity, most of the blood is flown to the skin to carry out effective thermoregulation, what restricts the flow to the muscles, and hence—endurance.

1.1.3 Arterial blood pressure

The average blood pressure increases in response to dynamic physical exercise, mainly at the expense of the systolic one, as the diastolic pressure remains in most cases close to that at rest. As the intensity of exercise increases, the values of the systolic blood pressure increase linearly, and they can reach up to 200–240 mmHg in normotensive people. The average blood pressure does not change dramatically, as the increase of cardiac output (affecting mainly the systolic pressure) is accompanied by a decrease of peripheral vascular resistance (which determines to a greater extent the diastolic pressure). The increase of this pressure is a positive result and is associated with "resetting" the baroreceptor reflexes and triggering them at higher average pressure. Without such a reset phenomenon, severe arterial hypotension would occur during physical exercise. Hypertensive patients show significantly higher values of systolic pressure at a given intensity of performed exercise than normotensive ones, and they have increase of diastolic pressure as well. This leads to significantly higher values of the average blood pressure, and it is associated with a smaller degree of decrease of the peripheral vascular resistance in this group. In the first 2–3 hours following exercise, the blood pressure has values lower than before, a phenomenon described as *postexercise hypotension.* Its mechanisms are not clear.

1.1.4 Oxygen utilization in tissues

The arteriovenous oxygen difference (A-vO_2) increases with the increased intensity of the performed exercise and is explained by the increased transfer of oxygen from the arterial blood to the muscles. At rest, A-vO_2 is 4–5 ml O_2 on the average for each 100 ml blood (ml/100 ml). When the performed exercise acquires maximum intensity, the arteriovenous oxygen difference reaches values of 15–16 ml/100 ml blood.

1.1.5 Coronary circulation

The heart is supplied with oxygen and nutrients through the coronary arteries. The left and right coronary arteries are located on its surface. They branch out and penetrate deeply into the muscle fibers, forming a dense capillary network that is intended to supply every single muscle fiber, on the principle of one capillary for one muscle fiber. Both at rest and during physical exercise, the coronary blood flow is closely related to the myocardial oxygen demand. This coupling is necessary because the work of the heart depends almost entirely on the aerobic metabolism and therefore requires a constant supply of oxygen. Even at rest, the myocardial oxygen utilization corresponding to the blood flow is extremely high. About 70–80% of the oxygen stored in each unit volume of blood which passed through the myocardial capillary bed is transmitted to the myocardium. For comparison, at rest, this percentage in skeletal muscles is only 25. With a healthy heart, there is a linear correlation between the value of the myocardial oxygen demand, the coronary blood flow, and the oxygen consumption, as synchronization is carried out at each cardiac contraction. The three main determinants of the myocardial oxygen consumption include heart rate, myocardial contractility, and blood pressure on the ventricular wall. A sudden rise in arterial blood pressure increases the pressure on the ventricular wall, which in turn increases the level of myocardial metabolism, and hence—the coronary blood flow. The increase in coronary circulation results from the increased perfusion pressure in the coronary arteries and from the coronary vasodilatation following the sympathicotonia and the increased concentration of catecholamines.

1.1.6 Muscular circulation

Blood flow through the muscles increases substantially during physical activity. This is explained by the task of the cardiovascular system to provide them with an adequate supply of oxygen and nutrients. Muscle blood flow of the calf, for example, at a 6-minute moderate rhythmic contraction, increases more than 10 times during muscle relaxation but decreases rhythmically during each contraction, as a result of the compression of blood vessels by the contraction. Therefore, strong, prolonged, tonic contractions of muscles cause fast occurrence of fatigue coming from oxygen deficiency and depletion of nutrients therein.

During intense exercise, blood flow can increase about 25 times: from 3.6 up to 90 ml/100 g muscle tissue/minute. The main reason for this is the increased muscle metabolism. Increased arterial blood pressure during physical activity causes stretching of the walls of the arterioles and a decrease in the peripheral vascular resistance, which also increases muscle blood flow.

1.2 Adaptation of the respiratory system to systematic outdoor recreation physical activity

1.2.1 Changes in pulmonary ventilation and oxygen consumption during exercise

Oxygen consumption at rest is 250 ml/minute on the average. In recreation physical activity, it can increase substantially: up to 3500 ml/minute with an untrained individual and up to above 5000 ml/minute, for example, with a well-trained long-distance runner.

The relationship between pulmonary ventilation and oxygen consumption in intensity ascending physical activity is linear, as with a trained individual, at the end of the exercise (where maximum intensity is reached), an increase of nearly 20 times of ventilation is available as compared to the values at rest.

At maximum intensity of physical activity, pulmonary ventilation can reach up to 100–110 l/minute, which is about 50% lower than the maximum respiratory capacity. This provides an additional reserve to the body, which can be added in the case of physical exercise at high altitudes or at high temperature.

The increased tissue production of CO_2, the increased temperature as a result of muscle contractions, and the reduced pH in the muscles, shift the location of the oxyhemoglobin dissociation curve to the right in the coordinate system. This is also facilitated by the increase of 2,3-diphosphoglycerate in erythrocytes as they pass through the capillaries in tissues with low pO_2 and in muscles with intense anaerobic glycolysis. Thus, the release of O_2 from the blood into tissues with increased metabolism, including in the muscles, is facilitated. As a result of the above, the arteriovenous difference in blood oxygen content can increase from 5 to 15 ml/100 ml.

It could be expected that during prolonged exercise of moderate intensity where the oxygen utilization and carbon dioxide production in the muscles are significant, the oxygen pressure in arterial blood decreases, and that of carbon dioxide in venous blood increases. This does not occur due to the large ventilation capacity of the respiratory system, which provides adequate aeration of the blood even during strenuous physical exercise. When carrying out physical activity, it is not so much the changes in blood-gas tension as the neural factors that are the incentive for increasing the pulmonary ventilation. Such is the impact of the motor cortex and the sensory signals, which reach the respiratory center. These regulatory effects are sufficient to maintain normal blood-gas tension even during strenuous physical exercise.

It should be noted that the functional capacity of the respiratory system is not limited to the oxygen supply to the muscles. In the state of intensive aerobic metabolism, as is common in most cases of outdoor recreation physical activity, the ability of the heart to pump blood to the muscles is limited, which is adequate to their needs in the regime of aerobic exercise [3, 4].

The systematic practice of outdoor recreation physical activity of aerobic type increases the diffusion capacity of oxygen through the respiratory barrier, i.e. the amount of oxygen that diffuses through it in 1 minute, with a difference between the partial pressure of oxygen in the alveoli and its tension in the alveolar capillaries of 1 mmHg. While people without physical activity have a diffusion oxygen capacity at rest of about 24 mlO_2/minute, in individuals who practice outdoor sports, this figure can reach values up to 80 mlO_2/minute during exercise. The reason is that the pulmonary circulation increases (all pulmonary capillaries are perfused to the maximum extent), which also provides a maximum diffusion surface through which oxygen passes into the capillary blood.

1.3 Adaptation of muscles to systematic outdoor recreation physical activity

Muscles are significantly affected by the way they are used in everyday life. If the motoneurons that innervate the muscle fibers are disrupted, or destroyed for some reason, the so-called *denervation atrophy* occurs. It is distinguished by a reduction in the size of the denervated muscle fibers and of the amount of contractile proteins therein. The muscle can atrophy even with normal innervation, however, when not used for a long time, i.e. in case of prolonged immobilization (for example, as in a limb fracture). With enhanced physical activity, accompanied by increased contraction of certain muscles, the opposite state is reached—*muscle hypertrophy*. The size of the fibers gets larger and their chemical composition changes. It is assumed that the number of muscle fibers remains constant in elderly people, and the changes that occur with atrophy and hypertrophy affect only a change in their size and metabolic capacity [5, 6]. However, a number of studies recently conducted on humans and animals evidence that physical exercise can stimulate satellite cells (monopotent myogenic stem cells) in skeletal muscles to myoblast proliferation and the emergence of new muscle fibers in the process of adaptation to enhanced activity [7].

Human skeletal muscles are made of three main types of fibers. Depending on their rate of contraction, metabolic characteristics, and fatiguability, they are divided into type I (SO—slow oxidative)—slow-twitch, with high oxidative capacity, resistant to fatigue; type IIa (FOG—fast oxidative-glycolytic)—fast-twitch, oxidative-glycolytic, relatively resistant to fatigue, and type IIb (FG—fast glycolytic)—fast-twitch, with high glycolytic capacity, fatigable [8]. Their ratio and cross-section in the various muscles largely determine the differences in their contractile and metabolic characteristics.

The aerobic physical exercise, which is characterized by low intensity and longer duration (such as long-distance running and swimming) causes an increase in the number of mitochondria in type I and type IIa muscle fibers, which are most actively involved in this kind of physical work. The activity of oxidative enzymes in them increases. The amount of capillaries around these fibers increases. All this strengthens their endurance. Interestingly, the diameter of the muscle fibers decreases slightly what also leads to a lesser strength of the muscle fibers at the background of their enhanced endurance. In addition to muscles, exercises of this kind cause changes in all systems involved in the supply of oxygen thereto (respiratory, blood, and cardiovascular system) what provides a more efficient supply of oxygen to muscles for the oxidative energy production. This, combined with the enhanced capillarization of myofibers, shortens the diffusion distance of oxygen, metabolites, and heat and may increase the endurance [9, 10].

On the other hand, anaerobic physical exercises that are characterized by high intensity and short duration (weightlifting) mainly affect the fast-twitch, glycolytic muscle fibers (type IIb). These fibers increase in diameter due to the increased synthesis of contractile proteins. The synthesis and activity of glycolytic enzymes in them increase. Eventually, muscle strength increases, but endurance capacity is negligible and such muscles get tired easily.

Insofar as the different types of physical activity of the muscles cause different changes in their strength and endurance, each person can individually choose his/her way of training for the development of one or other quality. For example, weightlifting training causes muscle hypertrophy, and systematic long-distance running or cycling increases endurance. Practicing some physical exercises affects both qualities of the muscles.

It takes 6–8 weeks and sometimes months of recurring training sessions for the above changes to occur. After their cessation, however, there is a slow return to the initial condition [11].

Aging process is associated with changes in muscle mass and muscle strength with decline of maximal muscle strength after the 30th life year [12]. The reason is related to the decrease of the diameter of the muscle fibers, which in turn comes from the reduced physical activity. Systematic muscle training in adult life can prevent this process. It should be taken into account that with age, the adaptive capacity of the muscles decreases, e.g. the same intensity and duration of training sessions in older individuals do not cause such apparent changes as observed in younger ones. This can be explained by the disruption of the mechanisms that drive the transcription and translation of information from genes into muscle proteins. Regardless of aging, both systematic endurance exercises due to their beneficial effect on muscles and cardiovascular system and moderate exercises for strength to prevent atrophic changes in the striated muscles are recommended as recreational.

Intense strain of the muscles of an individual who has not adapted thereto causes reduced working capacity the next day. It is due to microlesions in the muscle tissue, which are the cause of moderate aseptic inflammation in it (DOMS = Delayed Onset Muscle Soreness). A more significant inflammatory reaction can be observed after muscle contractions while lifting a serious weight, in which case they get elongated, and this leads to more expressed damage to muscle cells as compared to those observed in isotonic and isometric contractions.

As an adaptive phenomenon, muscle strength can only increase when the contraction occurs against a certain resistance, i.e. muscles to be "forced" to develop more than 50% of their maximum strength. If an untrained individual is subject to such exercises, he/she can increase the maximum power of contraction of a muscle or a group of muscles by nearly 20% for about 4 weeks. However, the maximum effect is achieved for a period of 6–8 weeks, at the end of which the power of contraction may further increase by another 10% of the initial values.

Each skeletal muscle has a different distribution of fast- and slow-twitch fibers. M. gastrocnemius, for example, has predominantly fast-twitch fibers what determines its purpose—to allow for fast and powerful contractions when jumping.

On the other hand, m. soleus consists almost entirely of slow-twitch fibers what makes it particularly effective in prolonged contractions of the muscles of the lower limbs. The fast-twitch fibers allow the muscles to perform powerful contractions of short duration—from a few seconds to a minute. The slow-twitch fibers provide for endurance in prolonged contractions of less power. The distribution of fiber types is genetically determined and varies considerably for one and the same muscle in different people what makes some people more suitable to practice sprinting, others long-distance running, and still others climbing.

Skeletal muscles have the property of *plasticity*, and partial transformation of muscle fibers from one type into another can be observed in them, as a result of systematic training or following modulation of motoneuron activity [9, 13]. This transformation is interceded by calcium-mediated pathways that are associated with the involvement of calcineurin, calmodulin-dependent kinase, and the transcription cofactor PGC-1α. The transcription factors directly responsible for the reprogramming of the genes that regulate the specificity of metabolism and contractility of muscle fibers are the subject of intensive research. *Calcineurin,* for example, is a cyclosporine-sensitive and calcium-dependent protein phosphatase. It is necessary for the differentiation of myocytes and the formation of the slow-twitch muscle fibers. Its activation leads to up-regulation of the gene promoters responsible for the synthesis of the isoforms of the heavy chains of the myosin molecule, specific thereof.

There is ample evidence to suggest that the key to muscle plasticity is held by the family of genes responsible for the myosin molecule. Seven different gene variants exist, which allows a great variety of muscle composition. In theory, the contractile ability of muscle fibers is modified depending on the expression of various genes responsible for the heavy myosin chains. Most genes can be switched on and off by the indirect action of signaling molecules, such as hormones or growth factors. The adaptive changes in muscles as a response to training depend on the type of muscles applied during physical activity. It is considered that muscle genes are regulated primarily by mechanical and/or metabolic stimuli [8].

Stretching muscle fibers during outdoor recreation physical activity is one of the possible stimuli for adaptation. Passive stretching increases hypertrophy even in the absence of innervation, hormone action, and adequate nutrition [1]. The transmission of mechanical forces to nuclei and ribosomes can occur directly (via the cytoskeleton) or indirectly (via stretch-activated ion channels or stretch-activated adenylate cyclase).

The destruction of muscle cells as a result of strenuous physical exercise may also play a role in stimulating muscle hypertrophy. This occurs under the impact of released muscle-specific growth factors.

It is also suggested that the increased concentration of cAMP and the increased entry of metabolites into muscle cells stimulate the development of mitochondria as a result of training for endurance [14].

1.4 Endocrine adaptation in outdoor recreation physical activity

Together with the nervous system, the endocrine system integrates the physiological response in incidental physical exercise and plays an essential role in maintaining homeostasis. During physical activity, the plasma level of some hormones changes. This occurs as a result of the secretion of endocrine glands, the accelerated blood flow, the increased loss of water, and the subsequent hemoconcentration and also as a result of the reduced metabolism of the hormones in liver and the clearance of the end metabolites by the kidneys. The established changes are summarized in **Table 1**.

Growth hormone (hGH) increases its levels in the blood as a result of physical exercise and can reach levels 20–40 times higher than those at rest. The increase is more significant in untrained than in trained people [1]. In athletes, the increased concentration returns to initial values significantly faster than in untrained individuals. The importance of increased levels of the growth hormone in physical activity is explained by the subsequent facilitated entry of amino acids into cells and

Hormone	Response	Features	Importance
Catecholamines (adrenaline, noradrenaline)	Their plasma concentrations increase	Noradrenaline increases more than adrenaline	Blood glucose is increased; glycogenolysis in skeletal muscles and liver is increased; lipolysis is increased
Growth hormone (hGH)	Increased production	Increases substantially in untrained; drops more rapidly in trained individuals	It raises the level of anabolic processes in cells, including in muscles
Adrenocortico-tropic hormone (ACTH) → cortisol	Increased production	More significant increase in intense exercise; in submaximal exercise, they increase to a smaller extent	Gluconeogenesis in liver increases; mobilization of fatty acids increases
Thyroid stimulating hormone (TSH) → thyroxine	Increased production	Intensity of thyroxine transformation increases, with no toxic effect	Enhanced intensity of lipolysis
Insulin	Decreases the hormone production, due to increased glucose utilization	Drops the level of hormone after physical exercise (training)	Blood sugar level is regulated
Glucagon	Increases	Plasma level increases immediately after training	Increases blood glucose through glycogenolysis and gluconeogenesis
Renin-angiotensin-aldosterone (system)	Increases	With enhanced capacity after training	Retention of Na to keep the plasma volume
Antidiuretic hormone (ADH)	Increases		Retention of water to keep the plasma volume
Testosterone	Increases		Raises the levels of cellular protein anabolism and stimulates erythropoiesis

Table 1.
Endocrine response after single-bout of physical exercise.

their use in the process of protein anabolism (especially in muscles), as well as by hyperglycemia, which improves the conditions of energy supply.

Adrenocorticotropic hormone (ACTH) increases its levels as a result of physical work. This increases the activity of the adrenal cortex and results in glucose storage (glucocorticoids stimulate gluconeogenesis, the formation of glucose from noncarbohydrate sources, such as amino acids, lactate, and pyruvate), which is especially important during prolonged exercises. During physical work with a very long duration, both morphological and functional depletion of the adrenal cortex occur.

The increased tone of the sympathetic part of the autonomic nervous system during physical exercises causes an increase of the level of catecholamines in the blood. This is a result of both their increased secretion from the sympathetic endings and the stimulated adrenal medulla. The changes are of great functional importance associated with the body's adaptation to physical stress—cardiac output increases, as well as blood pressure, blood sugar levels, activity of lipolytic enzymes, and as a result, fats are mobilized from depots. The induced bronchodilation helps to increase pulmonary ventilation.

Androgens (testosterone) have an expressed anabolic effect on skeletal muscles. They increase bone density and stimulate erythropoiesis. Serum testosterone and the amount and binding capacity of androgen receptors in skeletal muscles transiently increase with physical exercises, and therefore they have a beneficial effect on the body's adaptation to physical exercise [15].

1.5 Thermoregulation in systematic outdoor recreation physical activity

Almost all the energy released during catabolic processes in the body is converted into heat. During exercise, 75–80% of the energy released from intracellular chemical reactions is transformed into such, ensuring the production of ATP necessary for muscle contractions. Much of the remaining energy, eventually, is also converted into heat (muscle contraction, friction of blood in the vessel walls, friction on joint surfaces, etc.). During physical work, the amount of heat produced by the muscles can be up to 60 higher than that at rest. To not overheat the body, in these cases, it is necessary to provide adequate heat loss, which under conditions of the most heat production can reach 1 kJ per second. The efficiency of heat transfer during physical work depends on the weather conditions under which it is performed. Radiation is the main mechanism for heat loss when the ambient temperature is lower than the body one. In sports practiced outdoors (running, cycling, rowing), convection has a bigger share in heat loss than that at rest. The share of evaporation depends on both the ambient temperature and the humidity. Physical activity is also accompanied by increased perspiration. At high temperature in environment and moist air, the mechanism of heat loss is greatly impeded.

Sweating is an essential thermoregulatory mechanism when performing physical work, the main one—at ambient temperature above 31°C, and the only one— at temperature above 34°C. The maximum amount of sweat released for 1 hour is 1.8 l. Such a discharge can be kept for 3–4 hours, after which it decreases in ongoing physical effort.

Overheating of the body occurs at high temperature and air humidity and low speed of wind. When working in an environment with the above characteristics, body temperature can rise up to 41–42°C, values to which brain cells are particularly sensitive. Weakening, headache, nausea, profuse sweating, confusion, and sometimes loss of consciousness occur. The combination of the above symptoms gives a picture of *heat stroke*. Even if physical work is stopped immediately, the temperature does not return to normal at once, because it itself accelerates the chemical processes in the cells and disrupts the precision of thermoregulation.

Systematic training provides better adaptation of thermoregulatory mechanisms and maintenance of stable isothermy, which is extremely important for high working capacity in the performance of muscle work, especially in conditions of overheating microclimate [16].

1.6 Electrolyte balance and acid-base balance in systematic outdoor recreation physical activity

The loss of body water during physical work can be significant. It is performed through sweating and *perspiratio insensibilis* (mainly because of the increased pulmonary ventilation). As mentioned, evaporation and sweating are thermoregulatory mechanisms that adapt the body to the increased heat production. However, with prolonged and intensive work, they can also have adverse effects on the body.

At high temperatures and humidity, 2–5 kg of body weight can be lost per hour (primarily at the expense of the released sweat). When sweating is so abundant that decrease of body weight becomes greater than 3%, there is a deterioration in performance indicators. In the case of rapid weight loss of 5–10%, muscle cramps, nausea, and vomiting occur, which requires medical intervention aimed at restoring the discharged fluids by infusion of replacement solutions [17].

Performing physical activity is accompanied by decreased urine production due to the decreased renal blood flow, the increased sympathetic tone, the increased secretion of antidiuretic hormone (ADH), and aldosterone. Meanwhile, the breakdown of muscle and liver glycogen produces metabolic water, the amount of which can reach up to 1–1.2 l in intense exercises where a complete depletion of glycogen stores occurs.

Due to the lower osmolarity of the discharged sweat in comparison with the plasma one, profuse sweating may cause *hyperosmolar dehydration*. Plasma amount decreases due to the total loss of water and the movement of water from the bloodstream to the interstitium, as a result of the increased concentration of osmotically active substances therein. This causes a significant hemoconcentration aggravated by the emptying of the blood depots. The hematocrit increases, and with it the internal resistance of the blood, which further impedes the work of the heart.

Increased sweating during physical activity is associated with a significant loss of electrolytes, including also of sodium. The intake of sodium chloride solutions during exercise at high temperature and humidity has an adverse effect on the body. The addition of salts to the water increases the osmolarity of the stomach contents, which slows down the emptying of the stomach and further aggravates the dehydration. The intake of hypertonic solutions suppresses sweating, which disrupts thermoregulation and thus encumbers the process of acclimatization to heat. Therefore, it is customary to give hypotonic fluids with little or no sodium to people who perform a prolonged physical work with profuse sweating. However, taking too much hypotonic fluids also has an adverse effect due to the developing hyponatremia and water intoxication.

Exposure to warm and humid climate while performing physical activity causes acclimatization of the sweat glands within 1–2 weeks due to the increased aldosterone secretion as a result of the increased activity of adrenal cortex. Aldosterone stimulates the reabsorption of sodium in the tubules of the sweat glands whereby its loss together with the sweat decreases. By contrast, the potassium excretion with urine and sweat increases.

The changes in the acid-base balance that occur while performing physical activity depend on its intensity and duration. A reduction of pH is observed, which is due to an increase in the plasma concentration of lactate and fatty acids. The normal plasma concentration of lactate at rest is within 0.7–1.6 mmol/l. During exercises of high intensity and duration, it can reach values above 15 mmol/l. To the extent that the plasma lactate is of metabolic origin, this condition is defined as *metabolic acidosis*.

The systematic practicing of outdoor recreation physical activity increases the adaptive capabilities of the mechanisms that maintain the electrolyte and acid-base balance in the body.

1.7 Immune and hemocoagulation response in systematic outdoor recreation physical activity

It is well-known that physical activity affects the body immune system. It is believed that submaximal exercise stimulates both nonspecific immunity and specific immunity, which reduces the risk of inflammatory diseases [18]. However, there are studies that evidence immunodepression induced by intense training and accompanied by increased infectious morbidity, especially by acute respiratory infections [19, 20].

It is predominantly thought that the *single-bout* exercise causes a decrease in immune reactivity, while the systematic, repeated submaximal exercise has a different effect on the indicators of immunity and of the systematic inflammatory response, respectively.

We conducted a study on 143 youngsters actively practicing rowing (14.01 ± 0.06 years; 56.35 ± 0.49 kg; 3.44 ± 0.06 years of sports experience, training twice, 5 days a week) and 61 untrained controls (14.12 ± 0.09 years; 57.01 ± 0.23 kg). We found that the average level of serum IgA in training individuals is by 47.5% higher ($P < 0.001$), that of IgM is by 22.0% lower ($P < 0.001$), and of IgG—by 10.7% higher ($P < 0.05$) than that of not training people [21].

In healthy people, physical activity and training also cause changes in hemostatic indicators. A single-bout exercise usually results in transient activation of the coagulation system, which is demonstrated by a shortening of the *activated partial thromboplastin time* (APTT) [22–24] or by activation of the fibrinolytic mechanisms [25]. There are few studies intended to explore the effect of long-term practicing of different types of physical exercise on coagulation. From our study conducted on 37 actively practicing submaximal exercise people (age—15.49 ± 2.02 years; 4.83 ± 2.20 years of physical activity) and compared to 67 controls of the same age (15.81 ± 2.73 years), no difference was found in the basal values of the main hemocoagulation indicators: *number of thrombocytes* (PLT), *fibrinogen* (FGN), *prothrombin time* (pT), *activated partial thromboplastin time* (APTT), and *thromboplastin time* (TT). By contrast, in people practicing anaerobic exercises for a longer time, these indicators evidence persisting, to a largely greater extent, activation of the hemocoagulation mechanisms, a thing which is typical of extreme exercise in untrained individuals [26].

1.8 Adaptation of oxygen transport in blood in systematic outdoor recreation physical activity

While practicing systematic and intensive exercises, changes occur, which affect the variables associated with the red blood cells. Many researchers even describe the so-called" *sports anemia*" in both athletes and experimental animals [27–29].

With our large-scale study conducted on 876 (559 boys and 317 girls) from sports schools, we aimed to analyze the variables of the red blood cells by sex and practiced sport discipline, as well as to compare them with the same indicators in 357 untrained youngsters (171 boys and 186 girls) [30]. The sporting students carried out training five times a week, 90 minute twice a day. The untrained students had a moderate physical activity performed in two training sessions, of 45 minute each week. It was found that the trained group has a significantly lower number of erythrocytes, hematocrit, and hemoglobin as compared to the control, untrained group.

The applied factor analysis showed that "sports practicing" has a strong impact on the values of these indicators ($P < 0.001$). The average values in the trained group were below the lower reference limit for the population of the same age [31, 32]. It turned out that active sports do not affect the average amount of erythrocytes.

Specific gender differences in performance were found between trained and untrained boys and girls. Trained boys had significantly lower values of the red blood cell count (by 6.14%), hematocrit (by 6.78%), and hemoglobin (by 7.21%) compared to the same indicators in untrained students, as the average values were lower than the reference for the same age. Similar results were obtained for the girls actively practicing sports. No differences in the mean corpuscular volume (MCV) between trained and untrained boys and girls were found.

A statistically significant effect of the type of practiced sports discipline by boys on the studied indicators was observed. For example, swimmers had a lower red blood cell count by 10.4% than that of the controls, rowers—by 7.5%, weight lifters—by 6.6%, practicing team sports—by 5%, wrestlers—by 4.4%, and track and field athletes—by 3.5%. In respect of hemoglobin concentration, swimmers had lower values by 13% than those of untrained students, wrestlers—by 7.8%, rowers—by 7.3%, weightlifters—by 4.2%, and practicing team sports—by 4.1%. In swimmers, lower hematocrit by 10.1% than that of the controls was found, in wrestlers—by 7.3%, in play sports—by 7%, and in rowers—by 6.2%.

In girls, the lowest values of the erythrocyte count were found with the rowers (by 4.4% below those of the untrained). The lowest value of hemoglobin was found with the rowers, practicing team sports, and swimmers.

Correlation analysis showed that in athletes, there is a relationship between sports experience and the reduction of the studied hematologic parameters. The highest degree of correlation in boys was found between the length of sports experience and the reduction in swimmers and rowers. In girls, such a high correlation was found in those practicing judo.

2. Outdoor recreation and prevention of socially important diseases

Socially important diseases include a large and diverse group of conditions that are characterized by high frequency, high cost of treatment, and rehabilitation and require specialized medical care. They affect a part of the population in active working age and lead to various complications and disability, and in addition, they have a high mortality rate and thus cause a serious economic damage to people. Psychological harm affects not only patients but also their loved ones. Some of the widely spread socially important diseases include some diseases of the cardiovascular system, metabolic diseases (obesity, metabolic syndrome, and diabetes), some mental illnesses, cancer, osteoporosis, etc. The increase in their frequency in recent decades is associated with a greatly neglected physical activity of the population, affecting increasingly younger groups of people. In this regard, given the above physiological adaptive effects of the increased outdoor recreation physical activity, the latter is a favorable preventive tool to reduce the risk of such diseases, and its practice would lead to significant medical and social benefits.

2.1 Cardiovascular diseases

Cardiovascular diseases are the leading cause of death in most countries around the world.

Arterial hypertension (AH) affects more than one billion people worldwide. It is a permanent increase in systolic and/or diastolic arterial blood pressure. Depending on the course and severity of AH, various complications develop, such as early atherosclerosis, ischemic heart disease, including myocardial infarction, renal disease, retinopathy, vascular disorders, etc.

A number of clinical and experimental studies evidence that the recreation physical exercise of the aerobic type can be used as a prevention or drug-free therapy for hypertension, as it has a hypotensive effect and favorably affects some of the cardiovascular risk factors (dyslipidemia, insulin resistance, obesity, etc.), resulting in a reduced risk of cardiovascular morbidity and mortality [33, 34]. One of the largest meta-analyses conducted so far shows that aerobic exercise in hypertensives reduces systolic pressure by about 5–10 mmHg but has almost no effect on diastolic arterial blood pressure [35]. Optimizing the duration, frequency, and intensity of the applied endurance exercise is of key importance for the effective reduction of high blood pressure. In patients, training with an intensity of 40–60% of VO_{2max}, 30–60 minute per day, 3–5 days a week, is recommended; however, the issue of exercise refinement is still not fully resolved [34–36].

Ischemic heart disease is due to the disparity between the volume of the coronary blood flow and the oxygen needs of the myocardium because of a change in the coronary blood flow. Some of the risk factors for the development of the disease include AH, dyslipidemia, smoking, diabetes, family history, increased body weight, mental stress, and last but not least—reduced physical activity.

A study of people with ischemic heart disease using coronary computed tomography angiography shows that regular, moderate to intense, exercises for endurance (three or more times a week, for 60 minutes or more) has a beneficial effect on the course of disease [37]. In US Preventive Services Task Force Recommendation Statement, 2017, it is recommended to maintain a healthy lifestyle and follow a balanced diet and appropriate physical activity for adults with cardiovascular risk factors and also for those without high cardiovascular risk [38]. The higher frequency of physical activity and aerobic training to increase the level of cardiorespiratory fitness leads to a reduction in the incidence and occurrence of complications of cardiovascular diseases [39].

2.2 Metabolic diseases

Obesity is most commonly defined as a condition with an increased body mass index over 30 (kg/m^2). Its frequency has been on the rise in recent decades. It is widespread in all countries and affects more and more children. Although it has a broad etiology (endocrine diseases, intake of medications due to other diseases, mental illnesses, genetic predisposition, etc.), the leading cause is an unbalanced diet and reduced physical activity. Obesity is associated with a high risk of developing type 2 diabetes, cardiovascular diseases, bronchial asthma, and cancer. It is perceived as a condition of chronic low-grade inflammation with all consequences thereof, and ultimately significantly deteriorates the lifestyle of those affected.

Type 2 diabetes is a metabolic disease, which is characterized by the development of insulin resistance. It occurs with disorders of the carbohydrate, protein, and fat metabolism. All systems and organs are affected, and the changes are mostly in the blood vessels and the nervous systems. It leads to serious, often irreversible complications.

Metabolic syndrome is defined as a combination of interrelated risk factors for the development of atherosclerotic cardiovascular diseases and type 2 diabetes. Its main components are abdominal obesity, atherogenic dyslipidemia, high blood pressure, and insulin resistance with/without impaired glucose tolerance. It is considered a proinflammatory and prothrombic condition. It is widely spread and has an increased mortality.

An integral part of the treatment of metabolic diseases is a change in lifestyle, including increased physical recreation activity. A study conducted on children shows that for just 12 weeks, the performance of one-hour outdoor physical activities, 3 or 2 times a week, reduces their body mass index and is a preventive measure against children's obesity. Physically active children in this study have increased their social–emotional wellness [40].

Research on the relationship between body mass index and total fat mass index, and some cardiometabolic parameters in young people—aged 10 and 18 years, evidences that higher total fat mass index and body mass index are associated with higher arterial blood pressure, higher plasma levels of very low-density lipoproteins, low-density lipoproteins, triglycerides, insulin, and lower levels of high-density lipoproteins. The same study also reported that body mass index and total fat mass index increased at the age of 18, which in turn was associated with higher values of glycoprotein acetyls [41].

2.3 Mental health

There is ample evidence that increased physical activity has a neuroprotective effect and can be used as a means to accelerate the recovery processes of both the peripheral and central nervous systems after nerve injuries, as well as to slow down neurodegenerative processes in the brain [42]. Outdoor recreational physical activity can induce endogenous neuroprotection by activating multiple mechanisms, such as promoting neurogenesis, improving the neurovascular unit integrity, decreasing apoptosis, and modulating inflammation.

Some studies have reported a correlation between the decreased neurotrophin production and diseases, such as depression, schizophrenia, and dementia [43]. Rodent models have shown that increased physical activity elevates the expression of the *brain-derived neurotrophic factor* (BDNF) in the hippocampal and cortical areas, and it has been related to the improvement of cognitive function, including memory [44]. Both acute, high-intensity activity and regular, moderate aerobic exercise have been reported to increase the levels of circulating neurotrophic factors and enhance neurotransmission, exerting beneficial effects on mood and cognitive functions in individuals of all ages. Additionally, increased physical activity promotes brain health by supporting the cerebrovasculature, sustaining the integrity of the blood-brain barrier, increasing glymphatic clearance and proteolytic degradation of amyloid beta species, and regulating microglia activation [45, 46].

In recent years, a number of data have been accumulated on the beneficial physiological and psychological effects of physical activity in epilepsy. Epilepsy is a socially important disease characterized by a persistent predisposition to generate epileptic seizures with neurobiological, cognitive, psychological, and social consequences. Systematic physical exercise, on one hand, reduces the severity and frequency of seizures, and on the other hand, raises the seizure threshold in both animal models with epilepsy [47, 48] and in clinical trials with epileptic patients [49]. Although the mechanisms are not fully explained, it is believed that due to its neuroprotective effect, physical exercise successfully counteracts harmful factors, such as distress, intoxication, degenerative changes, and circulatory disturbance, which can lead to seizures and impairment of cognitive functions in these patients [50]. Epilepsy itself and most of the antiepileptic medications impair the cognitive functions [51], which requires the search for methods that complement the basic therapy to reduce cognitive deficits. Our previous experimental studies have shown that the regular physical exercise reduces the cognitive deficit from the application of antiepileptic medications and suppresses depression and anxiety behavior in epilepsy [44, 51, 52].

The regular outdoor recreation physical activity improves the physical and mental condition of the individual, but data on the positive effect of physical exercise in epilepsy are still being clarified. This is one of the reasons for the health-care organizations to warn people with epilepsy to avoid certain types of physical exercise because of the potential risks of inducing seizures or injury [53]. Extreme sports are prohibited, such as some of the winter ones (snowboarding and extreme skiing), water sports (diving), freestyle (fencing and mountain biking), and in ball sports, head playing is not allowed.

A number of studies have noted a link between the level of physical activity and the severity of symptoms in depression and conditions of anxiety. A sedentary lifestyle is a prerequisite for deteriorating mental health, while physical exercise reduces the risk of developing these conditions [54–56]. Mental health prevention includes stimulating the population for increased physical activity, including outdoor recreation.

2.4 Others

Malignant diseases form a severe heterogenous group of diseases. The most commonly diagnosed are cancers of breast, colon and lungs. It is a worrying fact that in 2012 alone, 14 million new cases were registered worldwide [57, 58]. The frequency is expected to rise to 22 million newly registered annually over the next two decades [57]. This requires strengthening of preventive measures, such as visits to preventive examinations, avoidance of harmful habits, rational nutrition, maintaining optimal body weight, and increasing physical activity [58].

Osteoporosis is a disease characterized by deterioration of the microarchitecture of the bone tissue and a decrease in the mass of the bone stock, which leads to an increased risk of fractures. A number of factors determine bone mass: genetic, nutritional, bad habits, hormonal, intake of some medications, hypokinesia, immobilization, etc. There is strong evidence that physical activity in a "dose-dependent" manner slows down the loss of bone mass in postmenopausal women. The outdoor physical exercise in the form of recreation procedures can increase bone mineral density [59].

Timely and complex treatment of socially important diseases leads to their more favorable course delay or avoidance of the occurrence of complications, as well as to the better quality of life of patients. The prevention of these diseases would lead to an improvement in the health status of the population as well as a number of economic and social benefits. Undoubtedly, outdoor recreation physical activity is a part of the prevention of most noninfectious socially important diseases.

3. Take-home messages

Outdoor recreation physical activity is causing beneficial physiological changes in the body, which affect both the somatic and mental health. Adaptation changes concern cardiorespiratory, endocrine, nervous, and most of the other functional systems:

- It causes an increase of the activity of muscle oxidative enzymes in the pathway of carbohydrate, fat metabolism, and in the respiratory chain.

- Along with the increased muscle vascularization, the outdoor recreation physical activity is associated with partial muscle fiber transformation in submaximal trained muscle groups.

- A metabolic adaptation occurs due to the shift from carbohydrates to fats as a source of energy during exercise with a submaximal intensity with a following "glycogen-sparing" effect, which in turn delays the time to fatigue and increase physical endurance.

- Long-lasting changes in humoral immunity manifested by an increase of serum IgA and IgG levels occur as a result of outdoor recreation activity.

- Adaptation of the oxygen delivery system and of the mitochondrial oxygen utilization system is observed, which results in an increase of the maximal oxygen uptake (VO_{2max}) and economy of the oxygen utilization.

- The hormonal response to outdoor recreation physical activity is associated with better adaptation to physical stress and maintenance of homeostasis.

- Outdoor recreation physical activity is beneficial for prevention and treatment of socially important diseases, such as increased blood pressure, ischemic heart diseases, metabolic syndrome, diabetes type 2, etc.

- The increased outdoor physical activity has a neuroprotective effect. It can be used to accelerate the recovery process after nerve injuries, to slow down neurogenerative processes and have beneficial effects in epilepsy, depression, anxiety, and cognitive impairments.

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