METABOLIC CHANGES REGISTERED AT THE TIME OF PHYSICAL LONG TIME EFFECTED IN CLIMATE CONDITIONS WITH HIGH-TEMPERATURES

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Abstract

The long-term effort in high-temperature climates leads to a significant increase in internal temperature (above 41°C), but also to a strong dehydration through sweating. The combination of these two factors has a significant role in the fatigue process, even leading to disturbances that may affect sports performance. The present paper explains the main mechanisms of diminishing the sports efficiency due to hyperthermia and dehydration, describing the phenomena of alteration of the regulation, as well as the pathological pathologies associated with them. Practical recommendations on measures to prevent the negative effects of heat during physical exercise are also provided.

Keywords: *metabolic changes, physical exercise, sport, high-temperature.*

JEL classification*: I1, I12*

Introduction

Of the chemical energy used by the human body to perform muscle work, only a percentage equal to no more than 30% can actually be exploited, resulting in at least 70% of this energy being converted to heat (thermal yield). There are no "cold" energy transformations that is without heat. The amount of thermal energy produced (heat lost heat, "thermal residue") is proportional to the intensity of metabolism. Strong long-lasting sports carries a change in the balance between heat production and dispersion.

The demand to which the body undergoes during physical resistance efforts is the maximum internal heat load that the body has to deal with (the body "overheats" in the true sense of the word). Under such conditions, the temperature may increase net above 40ºC. Such high values can already be reached after 15 minutes (about 5 km of running).

The effect of the huge accumulation of heat inside the body can be considered in three aspects: it contributes to the fatigue, involves the

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implementation of compensatory mechanisms that have consequences on the maintenance of the physical effort, causes the occurrence of pathological disorders.

Therefore, in a long-term competition, especially in warm or hot weather, it is necessary to activate all possible measures to prevent the occurrence of heat-induced syndromes in the body.

1. Consequences of the strong increase in body temperature

A strong increase in body temperature (above 40°C) worsens the general working conditions of the body, especially the muscles. It is well known that when the prolonged physical effort is performed at high ambient temperatures, relatively slow working times are recorded.

Mechanisms that can affect the sportive performance of resistance are multiple:

- enzymatic sub-activation: important enzymes for performance no longer have the optimal temperature level for their activity;
- circumferential variation of blood irrigation: Increases blood irrigation of the skin, to the detriment of muscle in the muscle;
- inhibition of ATP synthesis: the release of directly available energy for muscle work is limited;
- decoupling the oxidative phosphor reactions: the oxidative metabolic efficiency is reduced and the heat production equals the consumption of oxygen;
- worsening of neuromuscular behavior: coordination disorder occurs;
- external hypoventilation ("short breath") and higher respiratory CO2 elimination: temperate rise, increased respiratory muscular metabolism, respiratory alkalosis, low blood pressure, tendency for cramps to develop;
- increasing or decreasing muscle tone;
- increasing the degree of dilatability of the venous vessels: subsequent dysfunction of the thematic return from the periphery to the heart occurs;
- blood lactate elimination: inferior to the norm;
- reduction of liver perfusion: slowing of liver function;
- dehydration of body tissues;
- increased hematic concentration: worsening of blood circulation characteristics in the vessels;
- reduction of anabolic processes;
- multiple hormonal changes: reactions to the specific stress of long-distance resistance efforts.

The set of thermal reactions recorded in the body of the athlete, affecting its performance, is called hyperthermia syndrome, and the subjective feeling of suffering derives from overheating and its consequences.

The body has four strategies for dispersing the heat produced: conduction, convection, irradiation, and sweat. Of these, the latter (the "wet" yield of heat through evaporation) is the most important in efforts characterized by extensive tasks.

Liquid loss due to sweat glands secretion

Among the conditions that cause negative effects and which are responsible for the deterioration of the internal environment during the long-term effort are the following two: hyperthermia and dehydration (starting with 1.5l of liquid removed).

The body of the trained individual reacts by adapting the repeated sweating drops due to sweating. It is able to double the amount of sweat secreted in the time unit by a major activation of the sweat glands. It's sweating also has a relatively low mineral concentration. Athletes required in long-term resistance tests showed a loss of body weight (even body weight), even greater than 5 l. By the nature of the conditions described here, the importance of fluid loss is superior to the requirements of thermoregulation: only the sweating that evaporates causes the body temperature to decrease. The drop, on the other hand, does not produce thermoregulation effects.

Hyperthermia and despair, as well as effort and fatigue, have a persistent influence on mental functions. It is possible that a behavior becomes aggressive or hysterical, but also apathetic. The threshold beyond which unpredictable and uncontrollable reactions are lowing, self-control becomes increasingly difficult, the average-reality ratio deteriorates, becomes confused, and the thinking and judgment capacity decreases, with deviant behavioral reactions.

Dysfunction of regulatory processes and pathological cases

Cases of pathological alteration are recorded due to the hyperthermia-dehydration complex (we are talking about a complex since it is not possible to define proportionally the extent to which each of these three causes to determine a particular disorder).

a. Cramp heat

Both losses of water and hyperthermia predispose the person to muscle cramps. The affected musculature is the one required in the work. Mechanical irritations, such as contusions, favor the occurrence of muscle cramps. The risk of their appearance becomes considerably higher if the skin covering the muscles is immediately cooled. Against the cramps, it is necessary to intervene promptly by stretching the affected muscles, because the affected muscles are a significant source of heat.

b. The collapse of thermal shock

Thermal shock may occur due to a long-lasting physical effort in a high-temperature environment. In sports, the heat shock condition is explained by important liquid losses associated with the significant loss of mineral salts in the case of prolonged hyperthermia. The complete symptomatology of the thermal shock condition is characterized by a profound physical weakness, tachycardia, hypotension, oliguria, and venous fill deficiency in the hypostatic subject due to massive extracellular water losses. Cardiac frequency and blood pressure decrease,

and this dysfunction of the circulatory system, mediated by the vagus nerve, often represents the stage preceding the heat collapse. Typical behavioral changes such as phobia, aggression, apathy, and diminution of control and judgment capabilities occur. (Table 1)

c. Hyperthermal coma (caloric shock)

It is related to the collapse of the thermoregulation system. In a stress-induced hyperthermal coma, the acceleration of metabolic processes related to exercise coincides with extreme climatic conditions. The main reason for the occurrence of hyperthermic seizures in athletes is the excessive increase in central temperature (above 41.5°C), followed by central nervous system damage and circulatory system collapse. The physical stress caused by heat inevitably exceeds the limits of the compensation mechanisms and leads to the collapse of the thermoregulation. The danger is vital.

The pathological case is initially manifested by emotional instability, strong coordination dysfunction, disorientation, decreased consciousness; the patient is more easily subjected to the cramps, his pulse is faster and more flat. The peak of heat shock is manifested through loss of consciousness and coma. The main notions of first aid can be synthesized by saying: "stretched", "wet", "cold". the patient must be transported urgently to the hospital for specific intensive care.

The onset of hyperthermic sequelae is characterized by emotional instability, excitability, and aggression or total apathy; sometimes the patient is confused, has disturbances of balance and disorientation. There may also be a headache, vertigo, vomiting, nausea. If the clinical picture of the hyperthermic seizures is complete, the circulatory collapse will occur very rapidly.

Mortality is closely correlated with the delay in first-aid delivery, as early hospitalization is indicated and absolutely necessary. The treatment will be directed towards:

- correction of exercise-induced hyperthermic dehydration, metabolic acidosis and renal vascular insufficiency, typical of hyperthermic coma;
- normalization of cardiovascular parameters (Table 2).

There are individual types of heat tolerance because there are innate differences in how to react to the body. Athletes, who know by experience that they have limited heat tolerance, often have a state of anxiety about it, representing an additional psychological burden that further worsens them, the general situation, and so negative in itself. In this case, careful consideration should be given to all possible means of preventing heat-induced disturbances and activating psychological adjustment interventions.

Heat tolerance is also subject to individual variations. If the athlete is not in a good physical form, he has a weaker tolerance to heat; thirst threshold is lower and sweating hypersecretion. If, however, his physical form is optimal, the thirst is not very oppressive, and the athlete carries high levels of internal body temperature and dehydration, showing relatively limited reactions. In this case, intentional

moderation of internal heat and water damage is strongly recommended, as otherwise exhaustion and a series of accidents can occur without any preliminary symptoms being recognized. Also, the restoration phase after the effort is prolonged too long.

2. Absorption of liquids

There is much talk and writing about the need to consume liquids in adequate quantities, but it is almost impossible to have an overall view of what is suggested in connection with the administration of energy substrates and additional substances in beverages. In this regard, it is important to bear in mind that normally the main objective is water consumption. The higher the concentration of additives in the sports drink, the slower the absorption of water into the digestive tract.

Therefore, with regard to the addition of energy and mineral substances in beverages, the minimum necessary principle is valid, but the absolute necessity of consuming liquids is indisputable. Instead, with regard to the consumption of energy and mineral substrates, each athlete has to build his own bag of experiences based on generally valid principles (especially in cycling it is known that there are a number of "secret" recipes ").

There are three aspects to be considered in relation to the fluids consumed in stress situations: volume, temperature, and osmotic pressure.

Thus, fluid consumption compensates for the loss of liquids. It is good to drink often and in small quantities. It also does not have to wait until thirst is felt (thus reducing mental stress or insufficient salivation).

The temperature of the beverage has only a limited influence, the internal body temperature: 250ml of a beverage, having a temperature of 17ºC stealing the body 5kcal, while the same amount at a temperature of 42ºC brings to the body 2 Kcal. In any case, cold drinks should be preferred for their refreshing and toning effect; In addition, passing through the stomach is relatively fast.

Every athlete has to adjust his condition, and based on his own experiences. However, cold or icy drinks should be avoided, their consumption in a hurry or greed, causing stomach cramps or other short-term digestive disorders or even shock conditions.

If the sweat of a trained subject is hypotonic and lower osmotic pressure, when subjected to a workload that stimulates sweating secretion, fluid loss is proportionately higher than the salt loss. This seems incredible if we think of the salt crusts that sometimes appear on the face of a very sweaty athlete.

Therefore, for those who practice a sport, it is advisable to drink low-volume electrolyte fluids so as to limit osmotic pressure determined during an effort.

3. About sports equipment

When considering thermoregulatory issues, there are some aspects that should be highlighted: Preferably, open colors (due to external radiant reflection),

with non-repellent fiber fabrics (modern sweeping synthetic fibers are in compliance with these requirements). It may be useful to moisten the clothing with cold water.

A special situation is where sporting equipment must also play a protective role, such as American football. Under these circumstances, heat disturbances have been observed and described repeatedly, up to the caloric shock. also in the case of physical exercise in direct solar irradiation, it is advisable to wear a white cap, moistened even without exerting pressure on the head.

4. Behavioral thermoregulation

If the weather is sunny and warm, the shadow (the shadowy side of the street, the shade of the trees, etc.) must be sought. Also, the wind should not be totally avoided, even if the wind is contrary to the direction of travel: the refractive effect, in sport performance conditions, can outweigh the negative mechanical braking effect.

5. About adapting to warm training

The human body has the ability to acclimate to the heat. The multiple adaptation processes make it possible for the very high external temperatures to be better supported. Systematic training under conditions that cause a stagnation of heat is a stimulus for the body, which improves resistance to heat stress. Indeed, if stress has an exciting effect on thermoregulation, so true is that it does not lead to the sufficient development of other systems that are equally decisive for sports performance.

A high external temperature is already a task in itself, generally requiring an athlete practicing resistance disciplines to reduce training, primarily because recovery times become longer. Extreme physical exertion requires somewhat of a great deal of sensitivity from the athlete since the effort-recovery cycle seems to be changing. Thus, the training has a reduced efficacy.

6. Ambient temperature

If let's say, the marathon athlete could choose the climate for competition, he would like it to be + 14ºC and rain small. For the skier in the background, however, temperatures above 0°C are already "very high". The latter achieves an internal body temperature above 40°C, even when the external temperature is below 0°C, and can have a considerable loss of sweat liquids.

For all resistance efforts, noting that the external temperature is favorable or high, the same basic principles apply. In the first case, however, the likelihood of accidents is very low, as the high temperature between the body and the environment does not allow extreme accumulation of heat in the body.

From thermoregulation point of view, in order to achieve the maximum sporting form, the reduction of body temperature and water balance have priority. However, training involves changes in temperature and internal body fluids that cause adaptation. However, if the body's thermal and hydrological balance is

repeatedly caused strong and long-lasting alterations, the training loses its effectiveness and therefore the training for the competition is compromised. Continuous alterations of homeostasis, with strong significance, lead to the risk of chronic fatigue, which causes negative psychological sensations.

7. Indications

Excessive thermal energy is ceded to the exterior almost exclusively through the body surface. In particular, hands have a high surface area (relative to their volume); when the athlete is subjected to a thermal load, he must not close his fist (and hence reduce the surface of his hand), but open and close his fingers, thus exploiting the entire surface, to eliminate the heat; "Vasodilation (...) effects changes in blood flow and associated metabolic functions through physiological mechanisms, including those of thermoregulation." (Stan, E. A., 2013).

Also, the question is whether it is recommended or not to quickly wash the salt film formed on the skin as a result of prolonged sweating. This salt layer increases the ionic concentration of sweat subsequently secreted, preventing evaporation. It is, therefore, necessary to remove it as soon as possible.

If, however, the athlete, like the cyclist, has only a limited amount of water, then he should drink it instead of pouring it on his head (as is often the case).

Often, the question arises as to whether, at high outdoor temperatures, it is recommended that the athlete, in a 1000m racing course, runs - if tactile - runs the entire distance at a steady speed or better to adopt a rhythm initial or final race with variations in speed. From the thermoregulation point of view, the answer is positive if the load is reduced at the beginning of the race. At a high tread speed, internal body temperature may reach 40°C already only after 5 km, and then gradually increase exponentially. Such a temperature causes disturbances in the body. An internal body temperature of approx. 39ºC can be achieved by limiting the initial speed and can cause a more advantageous internal situation as a whole. It is good to note that any unnecessary movement increases the body's overheating.

Another principle is to keep calm – there are no objections to the application of refreshing compresses around the first joints since in this area there are relatively large superficial vein vessels useful for heat exchanges with the outside.

It is also necessary to take into account the psychological effect resulting here, as well as the differentiated role of the brain in the regulation processes, which is very sensitive to temperature variations. By refraining the head and neck, there are selectively obtained positive effects on the "brain term dispersion" system, thus preventing a series of negative reactions originating from the brain.

Recovery

If we take into account the requirements of thermoregulation, it is possible to maintain the temperature and dehydration within certain limits, it is proved that the effects on the recovery processes following the effort are positive. If the

importance and duration of the alterations were not exorbitant, the internal balance can be restored with relative speed. In this context, we refer to the rapid restoration of fluid homeostasis and internal temperature. At the end of the physical exercise, complete hydration should be restored, but without consuming beverages containing CO2, alcohol or ice.

It's impressive how much sometimes dehydrated sportsmen drink, but we must take into account that the stomach cannot stand more than 500ml. of liquids ingested once. Of the various drinks that can be consumed for hydration (especially in the long-term exercise: decathlon, marathon), even the soup is recommended ... The amount of urine eliminated daily by the person practicing a sport, used as an index to assess whether liquid consumption is sufficient, must be no less than 1,5l.

The athlete has to consume carbohydrates for rapid glycogen synthesis, and the return to basal temperature, heavily elevated in the effort, can be accelerated by using somewhat cooler water in the shower, then alternating with warm water and always clinging to cold water.

The general resistance of the body and, in particular, of the immune system, is considerably weakened in the state of exhaustion caused by high-performance sports activity. Therefore, in addition to sustaining recovery processes, it is advisable to avoid situations that may predispose the body to disease states (air currents).

It is necessary to control body weight vs. consumption of liquids. Even if the temperature has undergone severe alterations, within 2-3 hours of the end of the epoch, it returns in an abnormal fashion. This normalization process can be actively accelerated; also applying the above recommendations can reduce the body's reactivity to subsequent temperature variations during the rest period.

Conclusions

Often, even specialist authors, do not know that at the end of a marathon or a cycling race, cases of internal body temperature over 42ºC have been recorded, without symptoms of caloric shock.

Ambient temperatures have a considerable influence on thermoregulation. As we have already shown, for indoor skiers whose competitions are below 0°C, internal temperatures of 40°C have been recorded. In winter sports, no serious pathologies due to thermoregulation have yet been described; even in the case of very strong sweating, the body faces the rise in temperature without any strong subjective difficulty. Thus, "the body intensifies the removal of heat through the skin and breath to maintain the constant of temperature." (Stan, E.A., 2014).

An increased percentage of humidity in the air is always an additional load for the body. If the physical load is intense and prolonged, and the physical behavior of the athlete is not appropriate to these weather conditions, it can cause a hot-shock with vital danger even at ambient temperatures of the only 20ºC.

Successive dehydration through sweat and hyperthermia are factors limiting performance and preventing subsequent thermoregulatory processes.

Children, the elderly, women, and generally non-trained people have a lower tolerance to heat; there are also ethnic differences regarding this aspect. At the same time, the consumption of certain drugs limits the potential for thermoregulation. Alcoholic beverages should be avoided, knowing too well that alcohol greatly stimulates kidney hydration, thus having a dehydrating effect and limiting the functionality of sweating processes.

The huge losses of sweat fluids trigger feedback processes in the body: in other words, hydronic retention mechanisms are activated. Given that these mechanisms are prolonged beyond normal normalization, it may be possible to temporarily record an excessive water retention in the next 2-3 days, causing an increase in body weight by 2-3 kg.

Additional intense physical loads trigger the production of endogenous opioids, and endorphins are particularly marked by a euphoric and analgesic effect. This implies that negative feelings due to hyperthermia, dehydration, and fatigue are no longer perceived in their true size, and therefore there is no proper behavioral reaction. This phenomenon refers to the need to consciously overcome the conditions mentioned here in order to prevent the pathologies we have discussed and, whenever their symptoms arise, be mentally confronted in a concrete manner and also to engage in behavior suitable.

Those who train or practice long-standing resistance disciplines need to know the possible disorders and, in particular, the mechanisms, signs, and symptoms of hyperthermia and dehydration, as well as the decrease in their associated performance.

The analysis of successes and failures, the exchange of experiences, training from training to training, information and self-education constitute a basis for minimizing the negative effects of hyperthermia-dehydration- fatigue.

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