Sweating, dehydration and prevention of heatstroke

Sudoración, deshidratación y prevención del golpe de calor

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doi: 10.18176/archmeddeporte.00037

In the thermoregulatory system, the sweat glands respond to a complex physiological relationship between the central nervous system, the cardiovascular system and the skin. At rest, 80% of heat is dissipated by conduction, convection and radiation. When ambient temperature exceeds the temperature of the skin, ~32^{0}C, these mechanisms are no longer effective and the body starts to secrete sweat, taking over the evaporation of 80% of the dissipated heat. It is necessary to maintain a balanced body temperature for the organism to work correctly and, increasing the internal temperature by more than a couple of degrees has significant physiological consequences that might even be life-threatening.

To maintain a normal internal temperature (36.8 ± 0.5°C), the maximum temperature of the skin is required to be 35ºC, to thereby produce an appropriate temperature gradient from the core to the skin. In this mechanism, an increase in relative air humidity will progressively and significantly reduce evaporation by sweating. These effects can be compensated by the wind that facilitates evaporation and its radiating effect. In any case, and without considering environmental conditions, there are very few types of exercise that produce enough wind speed itself for this, such as cycling.

In any of the conditions observed above, hydration is fundamental. Almost 80 years ago, the effects of physical performance in a hot atmosphere had already been observed, demonstrating the need to ingest liquids to replace losses due to sweat.[1] It should also be considered that there are considerable differences in daily hydration (0.74 L/day to 2.70 L/day) among healthy young adults.[2] Furthermore, it has been observed that in sport, continuous exercise and intermittent exercise do not have the same effect on hydration efficiency, and the latter is more efficient.[3] Scientific entities update this knowledge cyclically leading to a considerable number of recommendations on hydration, euhydration and hydration with supplementation, even in special environments.[4] There are specific recommendations to avoid pathologies associated with heat caused by effort.[5]

In situations of heat stress, increased activity in the vasodilation system is responsible for 80% to 90% of the increase in blood flow to the skin. During exercise, blood supply to the active muscles and blood flow to the skin to dissipate heat come into conflict, both are important in thermal regulation, regulation of arterial pressure, to cover metabolic needs, and in cardiovascular homoeostasis. These conditions seem to be associated with dehydration when the water loss is greater than 2%, 2-3% or 4% of body mass. Consequently, exercising when dehydrated, particularly in a hot atmosphere, can increase the risk of heat-related illnesses, including heat stroke. However, working from studies performed on more than 5,000 soldiers, only 17% of cases were associated with dehydration.[6] Heatstroke seems to be more associated with other factors such as acclimatising to the heat, medicines, genetic predisposition and injuries.[4,6] It has also been observed that incidence of heatstroke has increased greatly since the 1980s. In the USA alone, more than 3,300 deaths were attributed to this cause between 2006 and 2010.

At rest, urination is the best way of eliminating liquid, followed by the skin, respiration, faecal matter and sweat. However, when exercising, in a hot atmosphere, or a combination of the two, the situation is completely reversed. There is a great interest in finding out about and pinpointing biomarkers that represent both hydration and dehydration. These biomarkers can be found by collecting urine samples (osmolality, specific severity, colour, volume; considered to be non-invasive measurements)[4] or plasma/saline solution (osmolality, vasopressin, etc.). Biomarkers are considered to be just as important as the actual measurement of difference in body mass[3,4].

Dehydration induced by sweating not only causes changes in these markers but a loss of electrolytes that must be recovered, such as sodium.[4,5] Consequently, sweating during exercise also makes it possible

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to eliminate significant quantities of ammonia, urea and lactate, among other metabolic residue.

Dehydration can endanger life and affect not only athletes but also vulnerable populations. The situation is worsening for these populations due to climate change. There is a progressive spread of geographic areas that reach dry-bulb temperatures above 33ºC or 35ºC[7].

The stability point for our supposed heat-regulating centre, on the anterior hypothalamus, seems to change its control point in some conditions (fever or heatstroke). It is important to mention that it remains unclear that our hypothalamus is the only integrative centre or controller that determines our temperature stability. It has been suggested that other independent centres might exist, including the hypothalamus that, with their own afferent and efferent branches, manage to coordinate around a common variable that is body temperature[8,9]. It is possible that the classic heat-regulating model[10] might change considerably over time.

During prolonged exercise in a hot atmosphere over a long period of time, sweat production will drop and body temperature will rise, with cutaneous vasodilation, decrease in blood volume, renal flow and the antidiuretic hormone; a phenomenon that has been called "Sweating fatigue" that will reduce the capacity to respond to exercise. The low blood volume will cause inefficient muscular irrigation, intense fatigue, with an increase in the HR, less sweating and a high risk of hyperthermia, cardiac syncope and risk of death. Although temperature modifies the heart's vagal response, using heart rate as a control variable does not help us identify sweating fatigue.

Biosensor technology has been developed over the last 30 years. The use of non-invasive biosensors directly on the skin, making the most of the electric surface characteristics and/or the actual composition of sweat, is not a new idea. It is worth remembering that, although it seems mundane, a heart rate monitor is also a biosensor. Over the last few years, studies on biosensors have really taken off. An average of over 60 articles have been published every year. Since the 1990s, one of the first papers on biosensors began by testing an inefficient biosensor for amino acids and another for L-lactate[11].

Many of the biosensors being developed are intended for diagnosis or screening of pathologies, such as the case of glucose sensitive patches. These biosensors can be built into products or fabric clothing, they can also be designed as different models of patches or encapsulated systems that cover the skin. Some studies on biosensors associated with physical activity deserve a mention, such as the system to record bipolar ECG. This uses a system similar to headphones for ears, also making it possible to record sweat rate, pH and lactate[12]. In another study, nanoparticles have been used, built into a normal filter base, that was designed to measure sweat rate, and sweat loss[13].

When these contraptions are small enough with sufficient autonomy, they can be used to control athletes during sport. Of course, there are protocols for treatments against heatstroke, but the key to the problem revolves around seeking detection measures to stop it happening.

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