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Mini-Review

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Some Features of Human Thermoregulation

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Abstract

Human thermoregulation is the most studied physiological process. The organs and systems responsible for maintaining a relatively constant temperature (temperature homeostasis) at the organism level are known. In this regard, humans do not possess any anatomical structures that are absent in other mammals in one form or another. Nevertheless, it is known that humans have the most developed thermoregulation among animals. This feature of human thermoregulation is evidenced by the fact that only Homo sapiens has managed to master all existing climatic and geographic conditions on Earth. This phenomenon does not yet have a complete scientific explanation. Thermoregulation is traditionally studied at the whole organism level. It has been established that the mechanisms of physiological thermoregulation are the same for all humans. However, there is evidence that some features of humans are related to their thermoregulation at the cellular level (cell thermoregulation). In particular, it has been shown that individuals in the population differ from each other in the level of their cell thermoregulation. This type of variability has allowed humans, not as individual beings, but as a population, to adapt to all climatic conditions, including the extreme conditions of the Far North and high altitudes.

Keywords: human thermoregulation; cell thermoregulation; chromosomal Q-heterochromatin; condensed chromatin; human body heat conductivity; human adaptation

Introduction

The study of human thermoregulation is one of the most developed areas of modern physiology and medicine. This is due to the important role of temperature in normal and pathological conditions. Directly or indirectly almost all systems and organs are involved in maintaining of relatively constant temperature in the body (temperature homeostasis).

It is generally accepted that among homeothermic animals, humans have the most advanced thermoregulation system, followed by higher primates and other mammals. However, it is still not fully known how humans manage to maintain thermal homeostasis in such diverse, including extreme environmental conditions, including the Far North and high altitudes.

The organs and mechanisms of the neurohumoral system of thermoregulation (physiological thermoregulation) are well studied. It is commonly believed that the main mechanisms for maintaining temperature homeostasis in mammals and humans are the same and are provided by the physiological thermoregulation. However, it remains not completely understood: a) how exactly humans have managed to master practically all existing climatic and geographical zones while remaining a single tropical biological species? b) why humans have the most developed thermoregulation without having the anatomical structures that are absent in other homeothermic organisms?

We believe that in addition to the well-known organ-based physiological thermoregulation (the hypothalamus, the sweat glands, the skin, and the circulation system), there are mechanisms for maintaining temperature homeostasis at the level of individual cells (cell thermoregulation) [1-3,7]. Moreover, it is the cell thermoregulation in humans that can explain their unique ability to adapt to different, including extreme, climatic and geographical conditions [3,4].

Cell thermoregulation in a broad sense is a continuous process aimed at eliminating the temperature difference between different domains of cells. Cell thermoregulation in a narrow sense is the removal of excess heat from the nucleus to avoid the harmful effects of high temperatures on the complex metabolic processes occurring within the cell. Therefore, by cell thermoregulation, we mean the process of equalizing the temperature difference between the nucleus and the cytoplasm when, for one reason or another, the temperature of the nucleus in the interphase cell begins to exceed the temperature of the cytoplasm. In this case, the heat transfer from the nucleus to the cytoplasm occurs through a dense layer of condensed chromatin located around the nuclear envelope. As is known, condensed chromatin consists of chromosome heterochromatin regions (HRs), which have been found to be capable of forming structures with the highest heat conductivity in interphase cells (for details see [1,2,7]).

There is no evidence in the literature that there is hereditary variability in the functioning of the physiological thermoregulation at the organism level (long distance transfer of heat energy). Whereas short distance transfer of heat energy (cell thermoregulation), the material basis of which is condensed chromatin, is subject to quantitative variability [1,2,7]. The fact is that condensed chromatin, which is the highest form of organization of the chromosomal HRs in the interphase nucleus, consists of non-coding, highly repetitive sequences of nucleotides subject to wide variability. Two types of chromosomal HRs are known: C- and Q-HRs. Chromosomal C-HRs invariably exist in the genome of all eukaryotes, whereas Q-HRs are present in the karyotype of only three higher primates (Homo sapiens, Pan troglodytes and Gorilla gorilla). It is very important to emphasize that among these three primates, only human populations have a wide quantitative variability of chromosomal Q-HRs [5,6]. This circumstance very important for us in understanding the reasons why humans and other higher primates were the owners of the most developed thermoregulation system [3,7].

A remarkable feature of the human genome is that: a) chromosomal C-HRs are present without exception on all its chromosomes, whereas Q-HRs can be found only on seven autosomes and the Y chromosome; b) unlike chimpanzees and gorillas, which also have chromosomal Q-heterochromatin, in the human karyotype Q-HRs may be completely absent without visible phenotypic or other manifestations; c) in the population, the number of Q-HRs in the human karyotype ranges from 0 to 10, whereas in chimpanzees and gorillas it varies within very narrow limits (from 5 to 7). We have shown that the number of chromosomal Q-HRs affects the variability of the heat conductivity of the human body [3,19]. The fact is the total number of chromosomal C-HRs human populations do not differ significantly from each other [10,11].

From our point of view, human still has a feature that distinguishes him from other mammals, including higher primates. By this statement, we mean the features of its genome. Therefore, to the question: why does man have the most developed thermoregulation system among mammals, we would answer like this: a) among the higher primates, man has the highest body heat conductivity (BHC) due to the presence of all types of chromosomal HRs in his genome; b) individuals in the population differ in BHC due to the wide variability of the amount of chromosomal Q-HRs in the genome; c) the wide variability of human BHC in the population allowed him to master almost all climatic and geographic zones.

What consequences could these features of the human genome lead to? The presence of the largest number of chromosomal HRs in the human karyotype allows maintaining a very high level of cellular metabolism among all mammals. In addition, this is possible if excess metabolic heat from the cell nucleus is efficiently removed and this depends on the total amount of chromosomal HRs in the condensed chromatin around the nucleus. In fact, it was this circumstance that made possible the emergence of homeothermic animals in general up to the presence of intelligence in humans in particular [12,20].

The existence of individuals in a population with different BHC allowed for a human to adapt to different temperature conditions because: a) people with high BHC tolerate heat better due to their ability to effectively dissipate excess thermal energy into the environment; b) individuals with low BHC are better cope with the cold because of their ability to better retain heat in the body. Therefore, there are no humans who are able to adapt to different extreme temperatures equally well because they differ in the number of chromosomal Q-HRs in the genome. In other words, a human managed to master all climatic and geographic zones not as the owner of the most perfect organ-based thermoregulation system among mammals, but because there are individuals in the population who differ from each other in the level of heat conductivity of their bodies, which is a phenotypic manifestation of cell thermoregulation.

Finally, why is it necessary to study the features of human thermoregulation? From our point of view, they are important:

1) in understanding the mustering of climatic and geographical territories beyond East Africa, including the Far North and high-altitude regions. Due to the presence of individuals with varying BHC in the population, humans have managed to inhabit all the land on Earth while remaining a single tropical biological species. Individuals with high BHC were relatively better able to adapt to hot climates, while those with low BHC adapted to cold climates and high altitudes. At the same time, the same person cannot be well adapted to all climatic and geographical conditions [2-4];

2) in the development of purely human forms of pathologies: atherosclerosis, alimentary obesity, alcoholism, drug addiction, and high-altitude pulmonary edema [14-18];

3) in the prevention of childhood morbidity and mortality [3];

4) 4) in the choice of sports related to thermoregulation (the removal of excess heat from the body or, conversely, the danger of hypothermia): long-distance running, including marathon running, football, professional boxing or mountaineering, water and winter sports [17-19];

5) in the choice of professions related to extreme cold, heat, or hypoxia: physical work outdoors in the conditions of the Far North (oil workers, drillers, drivers, etc.) or in the highlands, deep underground mines, and cotton plantations [22,23];

6) in evolution, particularly in the origin of cold-blooded and warm-blooded animals [20,21].

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