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Review Article

Chromosomal Heterochromatin Regions, Cell Thermoregulation and Human Body Heat Conductivity. Mini Review

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Abstract:

New data on chromosomal heterochromatin regions, cell thermoregulation, and human body heat conductivity are presented. Their possible roles in evolution, development, norm, and pathology are determined. The significance of cell thermoregulation and body heat conductivity in maintaining human temperature homeostasis in its adaptation to different climatic and geographical conditions is highlighted. Attention is drawn to the fact that the concept of body temperature not only in humans, but also in homeothermic organisms in general needs to be rethought. We cannot find out the temperature inside cells because of the diversity of organelles in them. There is no method that allows measuring cell temperature as a whole, since the existing ones can only work with organelles (nucleus, mitochondria, ribosomes, or ER). In the same way, we cannot speak about human body temperature because of the heterogeneity of its constituent tissues and organs, since thermometers reflect the temperature of circulating blood. It is emphasized that the role of organ-based physiological thermoregulation is to maintain the structural and functional integrity of cell membranes, not body temperature.

Key words: chromosomal heterochromatin regions; cell thermoregulation; human body heat conductivity; human body temperature; cell temperature

Introduction

Chromosomal heterochromatin regions.

As is well known, DNA in the eukaryotic genome is represented in the form of coding (genes) and non-coding nucleotide sequences. The latter are short, repetitive nucleotide sequences that are incapable of encoding proteins or enzymes. They make up the vast majority of the DNA in the eukaryotic genome and are known collectively as “excess” DNA. In humans, such DNA accounts for almost 98% of the genome. The biological role(s) of “excess” DNA are still unclear. There are many hypotheses regarding their possible role in development, adaptation, and evolution. It is not our task to analyze them, as they are widely covered in the literature. Here, we will limit ourselves to the possible role of only part of this “excess” DNA, which forms the material basis of the so-called chromosomal heterochromatin regions (HRs). Chromosomal HRs are the highest form of organization of short, non-coding, highly repetitive nucleotide sequences. There are two types of chromosomal HRs: C- and Q-heterochromatin. C-heterochromatin is present in the karyotype of all eukaryotes, while Q-heterochromatin is found only in the three higher primates (humans, chimpanzees, and gorillas). In the human genome, about 15-20% of “excess” DNA is represented in the form of chromosomal HRs [1-6].

Cell thermoregulation and human body heat conductivity.

Cell thermoregulation (CT) refers to the process of dissipating excess metabolic heat outside the interphase cell. Since the temperature of the nucleus is higher than that of the cytoplasm, the cell uses a dense layer of condensed chromatin (CC) around the nucleus as a thermal conductor to release excess heat into the cytoplasm. The heat energy is then transferred to the intercellular fluid and further into the circulation system. In this sense, CT is a unidirectional flow of heat energy directed from the nucleus to the cytoplasm through the CC, which consists of chromosomal HRs. The layer of CC around the nucleus is the densest and, accordingly, the most heat conductive structure in the interphase cell [1,6,7]. CT refers to the cell's ability to effectively equalize the temperature difference between different areas, primarily between the nucleus and cytoplasm. This ability of cells is determined by the quantitative and qualitative composition of chromosomal HRs in CC. The thickness of the CC layer around the nucleus in an interphase cell depends entirely on the number

of chromosomal C-HRs. However, the packing density (compactness) of the CC increases if, in addition to chromosomal C-HRs, it also contains Q-HRs: the more Q-HRs, the faster the temperature differences are equalized between the nucleus and cytoplasm and the faster the heat is removed (dissipated) from the cell [8-10]. It has been established that, unlike gorillas and chimpanzees, individuals in the human population differ in the number of chromosomal Q-HRs [1-3]. At the same time, it has been shown that there is a direct relationship between the number of chromosomal Q-HRs and the level of the human body heat conductivity (BHC): the more Q-HR in the genome, the higher its BHC level. BHC is the cumulative effect of the CT process at the organism level. In other words, BHC is a phenotypic manifestation of CT, allowing an indirect assessment of the heat removal capacity of the cells of a given individual [6,11]. As is well known, heat conductivity (HC) is the transfer of energy from warmer parts of the body to cooler parts, which leads to the equalization of body temperature (the second law of thermodynamics). All substances have HC: gases, liquids, and solids. Unlike gases and liquids, convection is impossible in solids, so heat transfer occurs only through HC. The HC of the human body, as one of the types of physical characteristics of the human body, has never been purposefully studied by anyone. In fact, there is nothing new in the very idea that the human body must have some HC. It would appear that this is due to the known physical heterogeneity (in the sense of density) of the human body. In addition, direct HC (conduction) is of relatively little importance in the redistribution of heat in the human body, because most tissues do not conduct heat well [12,13]. However, the characteristics of human BHC, as a living body, differ from the rules generally accepted in thermophysics, which were established for homogeneous (in terms of density) non-living physical bodies. Therefore, human BHC mainly refers to the body's ability to remove (dissipate) excess heat from the body through CT mechanisms to the circulatory system. Human BHC is the cumulative effect of the vital activity of all cells in the body, aimed at equalizing the temperature difference between the nucleus and the cytoplasm. It should be noted that CT is not regulated by the known mechanisms of the organ-based physiological thermoregulation system (the hypothalamus, sweat glands, skin, and circulatory system), but is mainly governed by the second law of thermodynamics. The task of physiological thermoregulation is not to regulate body temperature, but to preserve the structural and functional integrity of cell membranes (for details see [12-14]).

What is the human body temperature?

Apparently, the concept of distinguishing people from each other by BHC is not perceived in connection with the well-known fact that in norm, all individuals in the population have almost the same body temperature (~36-37 ºC) and, perhaps, for this reason, it is considered unreasonable to expect a wide hereditary variability in this feature in humans. However, it turns out that the very concept of body temperature not only in humans, but also in homeothermic organisms in general, needs to be clarified, since body temperature does not really correspond to its name [14]. Therefore, the human body temperature measured by thermometers is not its important physical characteristics, as this value is relatively constant, adjustable and regulated by mechanisms of physiological thermoregulation. The general opinion of experts is as follows: "the analysis of thermal homeostasis in the human body and homeothermic animals. It is shown that the temperature in the internal tissues of the body (the nucleus of the body) is high and relatively consistent because it is maintained via heat transfer through the blood flow" [15]. This statement needs clarification. The heat cannot transfer from the blood to the cells for the following reasons: 1) in homeothermic organisms, the temperature (T) in the cells is higher than in the circulating blood. The transfer of heat from circulation system to cells is impossible, because the second law of thermodynamics; 2) cells, with rare exceptions (endothelial cells lining the inner surface of blood vessels) are not in direct contact with blood; 3) the readings of thermometers reflect T only circulating blood, where the thermometry is performed, and not T inside the cells [14]. We cannot know T inside cells because of diversity of organelles in it. There are 230 types of cells functioning in the human body, which differ in their metabolic rate, cell cycle end the amount of heat they produce. In addition, there is no method that allows measuring cell T as a whole, since the existing ones can only work with organelles (nucleus, mitochondria, ribosomes, or ER [16]. In the same way, we cannot speak about human body temperature because of the heterogeneity of its constituent tissues and organs. The term human body temperature lacks common sense, since thermometers reflect the T of circulating blood in the capillaries of the part of the body where the thermometry is performed, but not the cells. Since it is impossible to measure the temperature of cells and bodies, the thermophysical characteristics of a human can still be judged by the thermal conductivity of their body [14].

Human BHC in norm and pathology

People differ from each other in skin color, eye shape, hair texture, height, body build (constitution) and other external features. All of them are the result of adaptation to the environment. Most of these traits do not significantly affect a human's daily life, except for some cultural biases related to skin color, eye shape or hair texture. Human BHC, although not visible, is as constitutional traits as the above-mentioned anatomical features because it does not change during ontogeny. However, there is one essential difference between these human constitutional features: it is desirable for a person to know and understand the level of his/her BHC when it concerns health, choice of profession and sport. The reason is simple: a) in norm people do not differ significantly in the mechanisms of organ-based physiological thermoregulation; b) the differences of people lie in the fact that thermoregulation at the level of the organism is carried out in the body with different physical conditions (heat conductivity). In this sense, we have encountered a problem alien for classical courses of normal physiology. Speaking about human health and choice of profession, we mean, first, the resistance of a given body to cold or heat. The role of BHC is particularly important when choosing a sport: it is hardly advisable for an individual with a low BHC to engage in a sport that requires efficient removal of excess heat outside the body (marathon running, professional soccer or boxing). On the other hand, it is dangerous for a person with a high BHC to engage in water and winter sports or mountaineering because of the risk of rapid body cooling [17]. The important role of BHC in predisposing to the development of purely human forms of pathologies (obesity, alcoholism, drug abuse, atherosclerosis and high-altitude pulmonary edema) has already been discussed (for details see [18-20]). Answer to the question why only humans differ from each other by BHC is known. Among the three higher primates (Homo sapiens, Pan troglodytes and Gorilla gorilla), which have chromosomal Q-HRs in addition to C-HRs, only human populations are differ by a variability of the number Q-HRs: from 0 to ten in an individual. In chimpanzee and gorilla populations, individuals practically do not differ in the number of Q-HRs. The reason lies in the peculiarity of the distribution of Q-HRs on the chromosomes of man and the two great apes. In the human karyotype, Q-HRs are distributed with different frequencies,

which allows the birth of children with different numbers of Q-HRs. In chimpanzee Q-HRs have been found at the chromosomes Nos. 14, 15, 17, 22, and 23. 'The frequency of brilliant polymorphisms in the chimpanzee is considerably higher than in man; in man their incidence averages from about 2.9-4.2 (Buckton et al., 1976), while in the chimpanzee it has been estimated to be equal to 8.77 (Lin et al., 1973), and to 8.85 (Seuanez,1977). ...Q-band polymorphisms are also evident at the telomeres of many chromosomes of the chimpanzee complement' [4]. Concerning the Q-HRs in a gorilla it is known, that: 'In this species, autosomal brilliant Q-band polymorphisms have been found in the centromere region of chromosome 3, the terminal satellites of the acrocentric chromosomes 12, 13, 14, 15, and 16, and at the proximal short arm regions of chromosome 22 and 23. The frequency of brilliant autosomal polymorphisms accounted for 14.8 in specimens of gorilla, which is approximately five times the number observed in man' [5]. In chimpanzees and gorillas Q-HRs are present with high frequency and they are evenly distributed, which does not allow the birth of offspring with different numbers of Q-HRs in the karyotype. Therefore, only humans can differ in BHC, which allowed them to eventually master all climatogeographic regions of the Earth [21-26].

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