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Review Article

The Role of Human Skin Color and Body Heat Conductivity in Adaptation to Hot and Cold Climates

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Received Date: June 25, 2022; Accepted Date: July 06, 2022; Published Date: July 14, 2022.

Citation: Abyt Ibraimov, Stalbek Akhunbaev and Orozali Uzakov, (2022). The Role of Human Skin Color and Body Heat Conductivity in Adaptation to Hot and Cold Climates. *J. Biomedical Research and Clinical Reviews*, 7(2); **DOI:** 10.31579/2692-9406/123

Abstract.

As is known *Homo s. sapiens* is the only living creature that has managed to inhabit the whole of the Earth, while remaining a single tropical biological species. The case is really unique considering that all this happened in an unprecedentedly short (by evolutionary scale) period of time, if the beginning of this process is considered to be its exit outside of East Africa about 30 000 - 50 000 years ago. However, science does not know everything about how all this happened to a species that itself emerged relatively recently (130 000 - 200 000 year ago) and nevertheless managed to do what other species failed to do. One of the important questions that arises when comprehending this phenomenon is reduced to the following: what features of a human him to make such an unprecedented breakthrough in the settlement of the planet? In particular, what biological advantages or prerequisites did the ancestors of modern man possess when they decided to leave Africa? Usually, such advantages include its large neocortex with a high-functioning mind, high physiological plasticity, perfect system of physiological thermoregulation, the structural features of the upper limbs, unique sexual and reproductive behavior, etc., etc. Without disputing the importance of these well-studied advantages, we would like to add to this list two more that could play an important role in the settlement of all climatogeographic zones of Africa and Eurasia by man: variability of the skin color and the level of heat conductivity of his body. We believe that the skin color and the heat-conducting ability of the human body are involved in his adaptation to heat and cold climates through thermoregulation systems. After all, the skin is the largest human organ that is in direct contact with the ambient temperature.

Key words: human skin color; human body heat conductivity; human thermoregulation; human adaptation; cell thermoregulation; chromosomal Q-heterochromatin.

Introduction

Homo sapiens, as a species, was formed in Africa and, remaining a single tropical species, it managed to master the whole oikumene, continuing to expand its zone of permanent residence and abundance. The case is really unique considering that all this happened in an unprecedentedly short (by evolutionary scale) period of time, if the beginning of this process is considered to be its exit outside of East Africa about 30 000 - 50 000 years ago. However, science does not know everything about how all this happened to a species that itself emerged relatively recently (130 000 - 200 000 year ago) and nevertheless managed to do what other species failed to do.

One of the important questions that arises when comprehending this phenomenon is reduced to the following: what features of a human him to make such an unprecedented breakthrough in the settlement of the planet? In particular, what biological advantages or prerequisites did the ancestors of modern man possess when they decided to leave Africa? Usually, such advantages include its large neocortex with a high-functioning mind, high physiological plasticity, perfect system of physiological thermoregulation, the structural features of the upper limbs, unique sexual and reproductive behavior, etc., etc. Without disputing the importance of these well-studied advantages, we would like to add to this list two more that could play an important role in the settlement of all climatogeographic zones of Africa and Eurasia by man: variability of the skin color and the level of heat conductivity of his body. We believe that the skin color and the heat-conducting ability of the human body are involved in its adaptation to heat and cold climates through thermoregulation systems.

Man has always had to adapt to the climate and its changes, starting from the time of its appearance in conditions that were quite complex. The question of how exactly man managed to conquer all the lands of the Earth remains generally unclear. It is considered that man was initially well adapted to a hot and dry climate. This consideration is based on two arguments: 1) man as a species was formed in the tropical and subtropical climates of Africa; 2) man has very effective physiological mechanisms of thermoregulation to combat the overheating of his body. To all this, man, depending on the specifics of his permanent place of residence and lifestyle, has developed many behavioral and cultural reactions. However, the question remains whether the above-mentioned human characteristics were enough to master (populate) all ecological zones, including high geographical latitudes and high-altitude areas?

Facts and their interpretation.

Studies on human body heat conductivity (BHC) variability in population have given some reasons to believe that probably dark skin pigmentation of early humans in Africa occurred not only as a means of organism protection against ultraviolet radiation, but as a means able to provide supplementary energy (solar heat) for maintenance of temperature homeostasis in a body. Dark pigmentation has acquired such value also due to the fact that by that time our remote ancestors' skin was deprived of hair. Early non hairy hominids being homoiothermic organisms should somehow maintain relatively constant level of core temperature. Though thermal energy penetrated into a body through skin is not used for useful physiological work performance in organism (for instance, does not participate in cellular metabolism), solar energy, by heating blood circulating in skin, could promote maintenance of temperature homeostasis in bodies of first humans in Africa [1-3].

Based on these studies, we came to the conclusion that the initial cause of our ancestors in Africa dark skin pigmentation possibly was not UV-radiation but problems connected with thermoregulation. For example, Jablonsky and Chaplin [4] think that 'skin pigmentation is probably one of the best examples of natural selection acting on a human trait. It is the product of two opposing clines, one emphasizing dark constitutive pigmentation and photoprotection against high loads of UVA and UVB near the equator and the other favoring light constitutive pigmentation to promote seasonal, UVB-induced photosynthesis of vitamin D3 near the poles.' We fully share their idea on possible human skin color selective value. However, it is difficult to agree with their unambiguous confirmation that 'Skin color is largely a matter of vitamins'. We think that skin color is largely a matter of thermoregulation; while 'a matter of vitamins' is secondary issue.

Our objections to the role of UV in the evolution of skin color are the following conclusions:

As is known the higher sea level the stronger damage effects of UV radiation. That is why the hypothesis stated that during evolution process human's dark skin occurred as way to protect from damage effect of UV radiation is probably not the sole true point of view. If it is true then skin of indigenous people of Ethiopian Highlands would be darker than Negroes of neighboring South Sudan have. American Indians are spread throughout the continent, including high altitudes, however they do not differ extremely by skin color.

It is difficult to suppose that first human in Africa who were able to yield the fire, make clothes and had speech were not able to protect naked parts of their bodies from burning sun by natural or man-made items. Even their contemporary, more developed descendants did not strive to protect their skins from direct sun rays.

The assumption that our ancestors' dark skin color originated first of all for satisfaction of growing thermoregulation needs seems to be more probable. Man, as well as mammals should maintain extremely high level of metabolism in order to preserve relatively constant body core temperature. This is possible during regular organism supply with food reach in calories only. If to this we add the following: brain of adult human consumes more than 20% of calories (infants' brain consumes up to 50% of calories) entering to our organism, then it becomes clear how energy source was important for the first hominids. Therefore natural selection could favor dark skin pigmentation, as black color is capable to absorb better visible part of solar radiation so that organisms of humans get additional thermal energy in the form of heat.

As we think dark human's skin color, as in the past and in the present has significant value in thermoregulation because: a) our distant ancestors (as well as some populations in the modern world) are experiencing a shortage of high-calorie food, since the African savannas are very scarce relative to food resources suitable for humans. It is no coincidence that primitive people were scavengers for a long time in order to extract bone marrow from the remains of dead animals as a source of high-calorie food, primarily to maintain a relatively constant core temperature; b) supplementary thermal energy necessity became extremely critical after their deprivation of hair; c) apparently measures of cultural (clothes and habitation), technical (tools of labor and hunting weapons) and social (care for children, elderly and sick people) adaptation had been insufficient in order to provide members of community with sufficient amount of calories.

Not all mammals, including higher primates, in Africa have dark skin. Skin color of chimpanzee, for instance, is not black but light.

As populations began to migrate, the skin dark decreased proportionally to the distance North. New genetic researches of skin color suggest that Europeans lightened up quite recently, perhaps only 6000 to 12,000 years ago. Such recent changes in skin color show that humans are still evolving. Then why Europeans with light skin living in Africa or Australia more than 400 years do not resemble natives. The answer may be simple: a) these migrants get their daily bread in other conditions than our African ancestors had; b) "white" people can afford breakfast for themselves, share their dinner and give supper to enemies.

It has long been established that in terms of the number of melanocytes, skin cells in people belonging to different racial groups do not differ.

If skin color depended only on the intensity of UV radiation, then we would be entitled to expect that residents of high-altitude areas would have the darkest skins. However, among the aborigines of Tibet, the Himalayas, the Andes, the Pamirs or the Tien Shan, the skin color does not differ from the indigenous inhabitants of the lowlands living at the same geographical latitudes.

There are many other questions that still have no answers. Let's consider only one of them. Such commonly known fact as some populations' ability to live consuming minor amount of food still has no scientific justification. For instance, physiological basis of capability of individuals from India to survive consuming minor amount of food, which would bring a European of the same height, doing the same work to death, is not thoroughly studied.

Now consider the role of the human body conductivity in adapting to heat and cold. Our own experience in the search for the genetic basis of human adaptation to extreme natural conditions in Eurasia (the Extreme North of Siberia and the high altitudes of the Pamirs and Tien-Shan) suggest that chromosomal heterochromatin regions (HRs) constitute the relevant genetic material. In particular chromosomal Q-heterochromatin regions (Q-HRs) meet the requirements of modern theory is based on the following facts: a) consistent interpopulation differences in the quantitative content of chromosomal Q-HRs in the genome of human populations have been established; b) these differences have been proven to be related to features of the ecological environment of the place of permanent residence, rather than to racial and ethnic composition; c) the quantity of chromosomal Q-HRs in a population's genome tends to decrease from low to high geographical latitudes, and from low to high altitude [5-15].

Based on our investigations of chromosomal HRs variability in human populations, as well as on the analysis of existing literary data on the condensed chromatin (CC), structure of interphase nucleus and redundant DNA in the genome of higher eukaryotes, an attempt is made to justify the view of possible participation of CC in cell thermoregulation [16; 17].

CC, being the densest domains in a cell, apparently conducts heat between the nucleus and cytoplasm when there is a difference in temperature between them. The assumed heat conductivity effect of CC is stipulated by its principal features: a condensed state during the interphase, association with the lamina and the inner nuclear membrane, replication at the end of the S period of a cell cycle, formation of the chromocenter, genetic inertness, and wide variability in the quantitative contents both within and between species [18-21].

Chromosomes have both internal (repair, recombination, rearrangement, modification, restriction) and external (replication, transcription, packaging, organized movement) molecular activities, which are accompanied, inter alia, by some heat output. If for any reasons the temperature in a nucleus begins to exceed that in cytoplasm there is a need for dissipation of surplus heat outside the nucleus. To do this the nucleus has two options: increasing its volume or increasing the heat conductivity of the nuclear membrane. The first option is limited for obvious reasons. The second option is the more promising one should the heat conductivity of the nuclear membrane be increased somehow. Since the nuclear envelope consists of double-membrane extension of the rough endoplasmic reticulum, the nuclear membrane cannot essentially change its structure. Apparently, nature 'found' a very simple and effective solution: it increased its heat conductivity through compression of the internal layer of the nuclear membrane by CC [16-21].

Discussion.

Thermoregulation on organism level relates to the most studied section of human physiology and its basic principles are well known. However, we have few scientific data concerning skin color value for thermoregulation but the role of skin in temperature homeostasis maintenance in organism is obvious, for example, heat dissipation through sweating. The largest and most massive (weight approximately 10 kg) of the organs of the body, the skin of the average adult human exceeds 2 m^2. It is the organ that regulates body temperature through control of surface blood flow and sweating and detects critical information about the ambient environment and objects touched [22].

However, the role of skin in thermoregulation is able to be significantly more, if we take its color into consideration. We were interested in possible role of skin color in thermoregulation after we had found out that individuals in population considerably vary by their body heat conductivity (BHC) [23]. Recently we have succeeded to show that level of human BHC is correlated with amount of chromosomal Q-heterochromatic regions (Q-HRs) in genome [24; 40]. Earlier it was showed that populations of modern humans differ significantly by number of chromosomal Q-HRs in their genome [5-15; 25-35]. Of course, we are conscious of dark skin drawback: it overheats under the sun. However, as it seems to us natural selection found very simple and efficient solution. For example, we were able to show that the indigenous inhabitants of low geographical latitudes (India, Pakistan and Southern China) have the level of BHC is almost two times higher than the Kyrgyz permanently residing in the Pamirs and Tien-Shan [24]. Unfortunately, we were not succeeded to estimate BHC of African natives. But taking number of chromosomal Q-HRs in their genome [9; 29] into consideration we may suppose that their BHC should be higher than natives of the temperate and northern latitudes of Eurasia.

On the whole, we see efforts for maintaining temperature homeostasis under conditions different from climate of the Eastern Africa as follows: 1) an individual with less chromosomal Q-HRs in the North maintain more effectively temperature homeostasis in organism because of low BHC, permitting to preserve additional amount of produced heat in organism longer and slow down the body cooling rate from external cold; 2) an individual with high BHC in the North, constantly loosing additional amount of metabolic heat through conduction which is necessary for organism in terms of cold climate and exposing to relatively fast cooling because of cold, has to produce larger amount of heat and/or consume more high-calorie food for heat production, which is not always simple and healthy; 3) an individual with low BHC in the South (where environment temperature is higher than body temperature) besides his own internal heat production receives additional heat from environment by means of conduction, which, as it is known, is not used in useful physiological work. That is why these individuals' bodies overheat faster and they have to return heat surplus (through sweating, polypnoe, forced rest, behavioral reactions and etc.) to environment at the cost of significant decrease of physical and mental activities that finally negatively influences on their adaptation to hot climate; 4) an individual with big amount of Q-HRs in genome in the South having body with high BHC perhaps adapts better to high temperature of environment, more effectively leveling temperature differences in different parts of the body and faster directing surplus heat flow from organism to environment, including the way of heat radiation.

We suppose that *H. sapiens*, besides those inherent in all mammals possesses an additional but very fine and simple mechanism of thermoregulation. In the present case, in order to preserve temperature homeostasis under different environmental conditions, in addition to physiological, behavioral and biochemical mechanisms such as skin colors and wide variability by BHC was used [3; 36; 37; 40].

Concluding remarks.

We do not question that dark skin of early humans in Africa occurred under exposure to solar radiation; it is indeed lead to melanin accumulation in melanocytes. However, this do not signify that our ancestors had no choice other than have black skin, like Sudan Negroes have. We would like only to notice that first humans already had intellect - the most perfect weapon invented by natural selection. Possessing intellect our ancestors could be aware about harmful influence of tropical sun but also ways of protection from it. They, however, like many modern descendants living in tropical zones did not cover their non-hairy part of body from sun rays. The reason for such behavior probably is that they used solar radiation as supplementary source of thermal energy for heating circulated blood in organism.

The problem is something else: how to deal with excess thermal energy accumulated in the body in conditions of low geographical latitudes, in other words from the heat? Here, the problem, as we believe, was solved by changing the level of human body heat conductivity (BHC), which is provided due to the wide variability of the number of chromosomal heterochromatin regions in the genome of human populations. Skin colors and the wide variability of human BHC have no direct causal relationship and, apparently, they evolved independently of each other. Natural selection, apparently, supported them in the right combination, when the harmful influence of one of them (dark skin color) was compensated (softened) by the other; in the case of a hot climate, a relatively high level of human BHC contributed to the effective dissipation of excess heat outside his body.

Probably the answer on the question why North or high-altitude natives has less pigmented skin than African aborigines should be stated that here, pressure of selection on dark skin became less severe. Apparently, people succeeded to occupy these climatic zones were able to get high caloric food of animal origin in sufficient amount for thermoregulation needs without additional solar energy.

Apparently, skin color plays a minor role in human adaptation to a cold climate. Here, from our point of view, the heat-conducting ability of the whole body, which is associated with cell thermoregulation, is extremely important [3; 16; 17; 40; 41]. In particular, a body with a low heat conductivity protects the entire organism from cold as a kind of thermal insulation material, delaying heat dissipation into the environment. At the level of individual cells, this is due to the fact that the layer of condensed chromatin around the interphase nuclear envelope, which conducts heat from the nucleus to the cytoplasm, is relatively less dense due to the small number of chromosomal Q-heterochromatin regions, characteristic of the genome of indigenous inhabitants of high latitudes and high altitudes, as well as in migrants capable of good adaptation to the climate of the Far North or the highlands of the Pamirs and Tien Shan [5;10-13].

Man, like most living beings on Earth, is fighting for a place under the Sun. In this case, for a "warm place", in the sense that solar heat is used by a man as an additional source of thermal energy, in addition to the energy extracted from eating to maintain temperature homeostasis. As for the fight against the harmful effects of UV radiation on the body, it seems to be achieved by means developed by other living beings in the process of evolution.

Acknowledgements.

We apologize to that authors whose work is not cited or is cited only through reviews. The reason for this is only the space limitations of the publication.

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DOI: 10.31579/2692-9406/123