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EVOLUTION OF HUMAN SKIN COLOR AND THERMOREGULATION

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Abstract- Researchers on human body heat conductivity 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 homoeothermic organisms should somehow maintain relatively constant level of core temperature. However, early humans not always were able to find sufficient food in order to fully provide organism's energy demands, including thermoregulation needs. In such conditions organism could compensate energy deficiency through solar radiation. 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 people in Africa.

Keywords- human skin color, thermoregulation, human body heat conductivity, human evolution.

Running Title- Evolution of human skin color.

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Introduction

People, since time immemorial, were interested why different nations' skin vary by pigmentation intensity. Even ancient Greeks knew that darker skin was typical for people from southern regions and in some way it was connected with solar radiation intensity. Modern science knows incomparably more about skin color biology then ancient Greeks had knew; although there are a lot of blank spots. In the beginning, scientists believed that dark skin pigmentation occurred as means of organism protection against ultraviolet (UV) radiation causing skin cancer. Although all skin cancer forms occur, as a rule, after puberty, which significantly impede natural selection pressure. There exist comprehensive publications on biochemistry and skin pigmentation genetics. There are contradictory data on possible role of skin color in vitamin D biosynthesis. According to alternative theory humans obtained dark skin in the process of evolution mainly for folate destruction prevention - vital substance having key value for reproductive capacity, in effect skin tone grew darker to protect from folate depletion to the increased exposure to sunlight [1]. It is out of our goal to analyze these researches, we confine ourselves by physiological aspects of human skin pigmentation only.

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: due sweat glands to increase and partial deprivation of hairs it struggles effectively against overheating (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 yet is generally no thicker than 2 mm. 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 [2]. 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) [3]. Recently we have succeeded to show that level of human BHC is correlated with amount of chromosomal Q-heterochromatic regions (Q-HRs) in genome [4,5]. Earlier it was showed that populations of modern humans differ significantly by amount of chromosomal Q-HRs in their genome [6-24]. It was also found out that these differences

are mainly related to the natural environment of residence of the human population and not to racial or ethnic features. In particular, the amount of chromosomal Q-HRs is considerably lower in the genome of populations living permanently in the Far North of Siberia, in mountain areas of the Pamir and the Tien-Shan, compared to those of steppe zones of Central Asia, low mountain subequatorial Africa (negroes of Mozambique, Angola, Zimbabwe and Guinea -Bissau) and India. The amount of Q-HRs in natives of Ethiopian upland is lower than of aboriginals of low mountain subequatorial Africa despite the fact that all of them live in one geographic latitude [14-21, 25,26].

Materials and Methods

Theoretical and methodological aspects BHC measuring methods are stated elsewhere [4]. Kyrgyz and Indian students (Uttar Pradesh State, India), who studied in Kyrgyz State Medical Academy in Bishkek were objects for research. Level of individuals BHC was conducted according to technique described earlier [5].

Particularly evaluation of individuals' BHC was carried out in closed room under the temperature of ~20˚C. In the beginning the examined individual's temperature of left hand palm and armpit with the aid of mercury thermometer was measured. Palm temperature measurement was essential for preparing "hot" water in order to detect hand heat conductivity with the method of calorimetry. In order to prepare "hot" water for the given individual we added the figure nine to thermometer readings. For example, if individual's palm temperature is 31˚C then the temperature of "hot" water for should be 40.0˚C.

Then we measured examined individual's "hand volume" (HV) as we called it for convenience. For this purpose, they slowly immersed the left hand till the wrist into vessel with water full to the brim. Under the above mentioned vessel there is another vessel without water. The water pushed out by the hand of examined individual flowed out into the second and was measured in milliliters. Then the value of that figure was multiplied by four with the aim that the received water volume allowed hand to exist free in the liquid and did not touch the vessel wall in the course of heat conductivity measurements. Such calculations were done in order to as much as possible decrease the influence of HV on the precision of estimation of heat conductivity of the given part of human body.

Examined individual sits on the chair, with body straitened, head is raised, hands are hanging on each side of the body naturally and muscles are relaxed. Then examined individual slowly immersed left hand till the wrist (up to there where HV was detected) into domestic everyday thermos, volume is two liters, placed on the level of shin and filled with "hot" water. During the hand heat conductivity measurement which lasts for 20 minutes, examined individual does not have to distract, hands should be in the water and should not touch the wall of the thermos. In the end of the experiment, changes of the water temperature in the thermos were measured by mercury thermometer correct to the tenth degrees of Celsius (t ˚C). For convenience of analysis of experiments, numerical results in every measurements when the level of mercury column coincide with uneven graduation line, its value was underestimated on one tenth part of degree in order to obtain even number. For example, if thermometer showed 1.5 ˚C it was written down as 1.4 ˚C. Shortly after hand immersion till the wrist into the thermos we layered on the water surface one teaspoon of vegetable oil for evaporation reduction. There were no other additional measures of protection against room temperature influence where researches were carried out. All measurements were carried out by specially trained medical personnel.

The Student t-test was used to compare the mean numbers of BHC characteristics.

Results

Our previous researches have shown that the knowledge of temperature (*T*) of palms and difference between palm and armpit *T* are necessary for qualitative evaluation ("express method") of the given individual BHC ability and the measurement of "hot" water *T* decrease in ˚C is necessary for obtaining certain quantitative estimation of human BHC [4].

As known, people differ from each other in temperature of a palm. However, it turned out that the *T* of a palm has great informative importance on BHC itself. Data on the distribution and mean number of the *T* of a palm in samples studied are presented in [Table-1]. As a [Table-1] shows, the average of Kyrgyz' *T* of a palm significantly lower than Indian's one.

Table 1- Distribution of temperature (in ˚C) of palms on individuals from India and Kyrgyzstan

Temperature (in ˚C)	Indians (n=51)	Kyrgyz of palms (n=60)
22		1
23		1
24		2
25		4
26		2
27		3
28		3
29		2
30	1	15
31	2	2
32	4	3
33	6	10
34	25	9
35	11	3
36	2	
Total	1725	1817
Mean number	38.82 ± 0.17;	30.28 ± 0.44;
Statistics	t = 7.008; df = 109; P = <0.001;	

Comparison of the same groups regarding the *T* differences between palm and armpit have provided very important data that promote the understanding of the nature of widen variability of BHC in the human population. Earlier we have found out that the less is *T* difference between palm and armpit, the higher is BHC of the individual and vice versa (r = -0.883). In other words, the lesser *T* difference between palm and armpit the faster temperature between different parts of body equates [4]. [Table-2] shows data on distribution of the *T* differences between palm and armpit of individuals from India and Kyrgyzstan

As it seen from this table *T* difference between palm and armpit of Indians by birth on average two times lesser than Kyrgyz have.

This result indirectly testifies that Indians BHC should be higher than Kyrgyz students'; such expectation meats with the facts [Table -3].

Table 2- Distribution of temperature differences (in ˚C) between palms and armpit on individuals from India and Kyrgyzstan

Differences of temperature (in ˚C)	Indians (n = 51)	Kyrgyz (n = 60)
0	1	
1	19	6
2	15	9
3	8	11
4	5	3
5	3	3
6	1	11
7		2
8		2
9		4
10		4
11		2
12		1
13		1
Total	114	303
Mean number	2.23 ± 0.18;	5.05 ± 0.42;
Statistics	t = 5.742; df = 109; P = <0.001;	

Table 3- Distribution of body heat conductivity (BHC) (in ˚C) on individuals from India and Kyrgyzstan

BHC (in ˚C)	Indians (n = 51)	Kyrgyz (n = 60)
1.2 2		
1.4		1
1.6		
1.8		2
2		5
2.2		3
2.4	1	5
2.6		5
2.8	1	4
3	2	11
3.2	2	7
3.4	5	2
3.6	6	1
3.8	7	3
4	6	3
4.2	9	1
4.4	5	1
4.6	3	1
4.8	2	3
5	1	
5.2	1	
Total	200	177
Mean number	3.93 ± 0.08;	2.95 ± 0.11;
Statistics	t = 6.961; df = 109; P = <0.001;	

Previously we have shown that both water *T* increase and decrease show heat conductivity ability of human hand tissue [3]. However later we have found out that for the estimation of human BHC it is better to confine by measuring decrease of *T* only for "hot" water [4]. As it seen from the Table 3 Indians, in comparison with Kyrgyz samples, show significantly high BHC which completely correspond to data received by "express method" [Table-1] and [Table-2].

Discussion

As for evolution of human skin it is known that:

a. From ~1.2 million years ago to less than 100,000 years ago, the ancestors of all people alive were as dark as modern Africans;
b. As populations began to migrate, the skin dark decreased proportionally to the distance North;
c. The genetic mutations leading to light skin, though different among East Asians and Europeans [27],

suggest the two groups experienced a similar selective pressure due to settlement in northern latitudes [28].

We tend to suppose that initial cause of our ancestors' in Africa dark skin pigmentation possibly was not UV-radiation but problems connected with thermoregulation. As is known mammals as well as humans 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 primitive humans get additional energy in the form of heat. In spite of the fact that heat energy penetrating to organism through skin is not used for useful physiological performance (for instance, does not participate in cellular metabolism), solar energy by circulating blood heating could promote maintenance of temperature homeostasis in body if there is deficiency of needed amount of calories.

We think such hypothesis has nothing new and unexpected. Early human should be ready for continuous active movement in order to get food. This is possible if human being, like every homoeothermic organism, is capable to maintain relatively constant body temperature. As is known cold-blooded (poikilotherm) animals start their active living only after heating their bodies to some extent under sun rays. Thereby our ancestors benefited by already existing, tested in animal world, method.

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 highlands, however they do not differ extremely by skin color. It is obvious without special anthropological researches that skin color of Kyrgyz-highlanders (livestock breeders) of Pamir and Tien-Shan is lighter than of Kyrgyz-farmers from lowlands.

The hypothesis that our ancestors' dark skin color originated first of all for satisfaction of growing thermoregulation needs seems to be more probable. Indeed it is difficult to suppose that first people 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. Passing by in morning hours African

villages it is possible to see how natives start their "working day": they spend some time by sitting with naked face and chest turning to rising sun. It would be easier to justify such picture by unemployment. However, as is known, advices of satiated: breakfast eat by yourself, dinner share with a friend and supper give your enemy are still not acceptable for many people of Africa and India. Of course we are not going to present this simple observation for serious scientific argument for the benefit of our hypothesis. This is only the cause for thoughts that probably such simple everyday reaction of natives may hide biological sense. If breakfast is absent, then maybe it is better to start preparing for food search by heating preliminarily their bodies with morning sun heat.

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. As is seen from Tables 1-3 level of BHC of Indian natives is almost two times higher than Kyrgyz have. Unfortunately, we were not succeeded to estimate BHC of African natives. But taking amount of chromosomal Q-HRs in their genome [11,16] into consideration we may suppose that their BHC should be higher than Indians from Uttar Pradesh State have. It was found out that natives of southern latitudes of Eurasia and Africa differ by high amount of chromosomal Q-HRs in genome (see above). If our data on high BHC of Indians natives, who like Africans characterized by large amount of chromosomal Q-HRs in genome, will be confirmed in future for Africa's aborigines then we may think that natural selection moderate deficiency of our remote ancestors' dark skin by increasing their BHC. As our recent researches have shown individuals with high BHC take surplus heat out of organism better and vice versa [4]. Probably that is why *Homo s. sapiens* could occupy all temperature zones of Earth, remaining single tropical biological species [25,26].

Role of skin in thermoregulation on human organism level is studied thoroughly. Particularly temperature regulation in humans includes involuntary (physiologic) and voluntary (behavioral) activity [29]. Voluntary temperature regulation involves the conscious actions taken by people to maintain thermal comfort, including the seeking of shade and shelter and the wearing or shedding of clothing. Involuntary temperature regulation in the skin has been studied in great detail and they comprise:

a. perceiving and transmitting its own temperature to the central nervous system;
b. regulating heat transfer between the body's core and the skin through the cutaneous circulation;
c. serving as a superficial casing through which body heat is conducted from the vascular layers to the surface;
d. acting as an interface for the loss or gain of heat to or from the environment by radiation, convection, or conduction;
e. acting as a surface for the spreading of sweat necessary for evaporative cooling [30,31].

The ability of sweat glands to respond to heat stress is adversely affected by sunburn [32]. As is seen from this review, composed by Jablonsky [33], on skin role in humans' thermoregulation, there is no information on possible value of skin color in temperature homeostasis maintenance.

Then what place skin color occupies in human's thermoregulation? As we think dark human's skin color, as in the past and in the present has significant value in thermoregulation because:

1. Our remote African ancestors (like some populations in modern world) experienced shortage of high-caloric food important first of all for relatively constant core temperature maintenance;
2. Supplementary energy necessity became extremely critical after their deprivation of hair;
3. 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.

There are other questions that still have no answers. Let's consider only two 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 an European of the same height, doing the same work to death, is not thoroughly studied. Not all mammals, including higher primates, in Africa have dark skin. Skin color of chimpanzee, for instance, is not black but light.

Probably the answer on the question why North or high altitude natives have 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. Indeed 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 [34].

Then why Europeans with light skin living in Africa or Australia more than 300 years do not resemble natives. The answer may be simple: a) these outsiders 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.

And finally Jablonsky and Chaplin [35] 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 D_3 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.

Conclusion

We do not question that dark skin of early people 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 although first people

did not possess lion's claws, speed of cheetah or power of elephant, they had 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 energy for heating circulated blood in organism. But if organism was overheated they could hide in shadow or take part of surplus heat out of body through high heat conductive skin by heat radiation, perspiration (evaporation) and convection.

It is possible to give an answer on the question why anthropologists still have not paid any attention to the role of solar heat and dark human skin pigmentation in thermoregulation; each manual on physiology state that heat is not able to be used by organism as source of energy. We do not question this seemingly indisputable assumption only because by all appearances our African ancestors used fire for body heating rather than for food cooking, they even did not suspect that they raise blood temperature in skin in doing so.

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