Review

Paleodermatology

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Abstract

The study of the human skin evolution, allows a new vision to ancient questions such as the significance of human skin color variation, the correlations between bipedality and loss of body hair, and the correlations among epidermal appendages and structures of the skin with the changes on environment and evolution of humans.

Paleodermatology would be an appropriated term to designate the study of the human skin evolution. The etymology of this word comes from a Greek root (*paleo* = ancient). It is a multidisciplinary subject for researchers such as dermatologists, anthropologists, physiologists, and orthopedics. It should include the evaluations regarding physiology, thermoregulation, and the evolution of the human skin structures.

Introduction

Human evolution has been characterized by a marked decrease in body hair and an increase in the importance of pigment in naked epidermis as a screen against the harmful effects of solar radiation[1]. Humans are not hairless. The number and density of hair follicles are not substantially different from those of our nearest primate relatives. The uniqueness of human skin is that it lacks vibrissae; because human hair is miniaturized, the skin appears to be naked.[2] By contrast with the skin of other primates, human hair follicles are richly enervated and human epidermis is relatively thick. In addition, human skin contains a special distribution of sudoriparous glands. These characteristics have been the subject of multidisciplinary research for the last 15 years. "Paleodermatology," from the Greek root "paleo" (ancient), is an appropriate term for the study of cutaneous evolution, including the evaluation of physiology, thermoregulation, and structure.

General considerations

Mammals are homeothermic endotherms, able to maintain highly regulated body temperatures by controlling endogenous heat production.[3,4] Homeotherms produce enough heat to maintain a constant body temperature. The body temperatures of poikilotherms, such as reptiles and amphibians, fluctuate with environmental temperature changes; these species cannot regulate body temperature and the sun is their most important source of heat.

Except for thermophilic and hyperthermophilic bacteria, most species[5] have a preferred environmental temperature, which allows them to regulate an internal temperature close to 25–37 °C. The high metabolic rate of homeotherms requires that they process large amounts of energy. The maintenance of body temperature at a constant level is necessary to provide biochemical stability independent of external temperature.[4]

Heat is exchanged between an organism and its environment by physical processes, such as radiation, conduction, convection, and evaporation.[6,7] Physiologic control of heat exchange depends mainly on postural adjustments which alter the surface area available for heat transfer. The area of the human silhouette exposed to solar radiation can be multiplied by a factor of three or one-third, depending on whether the person assumes a crouched or extended position.[8] Furthermore, changes in insulation caused by piloerection and variations in cutaneous blood flow modify the process of heat transfer.[4]

For many species, evaporative heat loss is the most important means of active heat regulation, and sweating is the most effective evaporative heat loss mechanism in humans. Some animals, such as horses and cattle, can also use sweating for thermoregulation. Panting and saliva spreading are useful for many animals but not humans.

Sweat glands of humans and animals

Only mammals have sweat glands. Humans have 2–4 million eccrine sweat glands, which are distributed over nearly the entire body surface.[4] The palms and soles contain the highest concentration of eccrine glands (620/cm^2), followed by the scalp and chest.[4] Although each gland weighs only 30–40 µg, the total mass of eccrine sweat glands roughly equals that of one kidney. A well-acclimatized person can sweat as much as

2.5 L/h. Apocrine sweat glands are important for most mammals, including primates. Humans probably have the lowest density of apocrine glands of all primate species. The localization of these glands to restricted hairy regions, and the fact that they do not appear to be stimulated by heat exposure, make it difficult to determine their exact function.

The preoptic hypothalamus area plays an essential role in regulating body temperature.[9,10] Acetylcholine is the major neurotransmitter released from periglandular nerve endings.[9,10] Early mammals were probably small and probably depended on behavioral mechanisms for the control of body temperature. As their range extended beyond the forests, however, they became exposed to more solar radiation. Thus, particularly in the setting of exercise, humans needed new evaporative heat loss mechanisms for the prevention of hyperthermia. The first of these mechanisms was probably panting, as this is widespread in other mammals and in birds. Until species became larger, this form of evaporative loss was adequate.[4] In open environments, large mammals survive by using cool venous blood which drains from the nasal mucosa to reduce the temperature of the blood entering the brain through the carotid arteries.[6,11] Human ability to effect such selective brain cooling is limited because of the size of the nasal chambers and the absence of a carotid rete.[11,12] Sweating, together with an increase in the number of the eccrine sweat glands, seems to be a response to the challenge of keeping the brain cool in a tropical or equatorial environment.

Naked skin

An insulating layer of body hair is important for the thermoregulation of most animals.[3] Naked skin cannot be considered a general feature of aquatic or semiaquatic mammals, because most (including polar bears, sea lions, and seals) have a dense covering of body hair. Naked aquatic animals, such as whales and dolphins, are characterized by a large size, which provides low thermal conductance.[3] Amongst nonaquatic mammals, naked skin appears to be an adaptation which facilitates heat loss in special conditions; for example, armadillos and other burrowing animals spend most of their lives underground. These considerations do not apply to hominids, and so our naked skin evolved for a different reason. Most anthropologists believe that bipedality was a critical adaptation in response to the human need to forage on low-density or scattered resources in equatorial environments.[12,13] Archeologic data from Laetoli, a 3-million-year-old archeologic site in northern Tanzania, showed fossil footprints with a modern anatomic shape.[14,15] Fossil foot bones from early hominids confirm that bipedality existed 4 million years ago.[15,16] Bipedality was, according to Wheeler,[3,17] a preadaptation to the loss of body hair.

Bipedalism and naked skin in humans

Bipedalism was an early adaptation of hominids in East Africa. This anatomic modification was probably related to climatic changes that transformed a wet environment of forests into dry savannahs. Therefore, a body form that reduced sun exposure at high elevations was advantageous. An animal with a bipedal posture possesses the ideal body form, as the major axis of the body has been rotated from a horizontal to a vertical position.[3] In addition, in a bipedal position, a greater proportion of the body surface is higher above the ground; this position helps to increase the rate of heat loss by both evaporation and forced convection.[17] It is possible to consider bipedality itself as a thermoregulatory adaptation to life in hot environments.

The functionally naked skin of humans, with its wide distribution of eccrine sweat glands, provides the necessary cooling defense against hyperthermia. Although most savannah animals have cutaneous sweat glands, the thermoregulatory effectiveness of these glands is reduced by pelage, which restricts airflow over the skin surface.[3]

Approximately 17% of the total body surface area of a quadruped is exposed to solar radiation when the sun approaches its zenith.[17] Model experiments, however, show that only 7% of the total body surface of a biped would be exposed when the sun is overhead.[17] Garn[18] and Porter[19] believe that the modern distribution of body hair in humans is a remnant of the ancient necessities of early hominids. They point out that tufts of sternal and pubic hair are sites at which sweat drops are checked and have an opportunity to evaporate. When moist with sweat, long, wavy, scrotal, perineal, and axillary hair may limit the development of sores due to friction from limb motion.[18,19] Eyebrows and eyelashes may have a similar purpose in the prevention of eye damage.

Humans probably retained cranial hair because it can protect more than 40% of exposed skin where insulation is greatest, despite the fact that it covers only 10% of the total body surface area. If the upper shoulders are included, another area of retained body hair in humans, over 70% of the body is shielded.[3]

Some differences in the distribution of hair between genders, such as the fact that women have naked shoulders and less body hair than men, are probably related to sexual selection. Dixson *et al.*[20–22] recently evaluated how masculine somatotype and hirsuteness are determinants of sexual attractiveness in many populations around the world. European, African, and Asian women associate trunk hair with attractiveness.[20–22] It is thought that these results are consistent with effects of sexual selection on visual signals that convey health, physical prowess, age, and underlying endocrine conditions in the human male.[21]

Other adaptations of human skin

Naked skin has serious disadvantages when thermal stress results from direct solar radiation, because body hair acts as a shield, reflecting heat before it reaches the skin. The ubiquitous occurrence of tyrosinase in eukaryotic organisms is evidence that melanogenesis appeared early in evolution.[5] Melanin pigment has a wide range of important physiologic roles, such as protection of skin, hair, and eyes from ultraviolet radiation, heat control, and possibly adaptive skin coloration.[2] Melanin can increase the strength properties of many structures, such as the beetle's exoskeleton.[23] Melanocytes have immune functions and are involved in the release of acetylcholine, which is important for the regulation of body temperature.[9,10,23] Melanocytes are involved in the cutaneous production of a cutaneous extra-neuronal cholinergic system, which may explain some features of sweating and sebum production control.[23,24] The existence of melanocytes in nonexposed areas of the body, such as the meninges, is probably related to some ancient melanocytic functions. Light perception in bacteria, animals, and plants ultimately involves organic molecules that undergo simple reactions when hit by a small amount of photons.[23] The development of photosensitive cells originally helped in simple tasks, such as orientation and the search for food and shelter.[23]

Pigments, such as melanin, are molecules that absorb certain wavelengths of white light. The remaining wavelengths in the solar spectrum are reflected from, or transmitted through, the pigment system, creating a perception of color.[23] With time, the capability of melanocytes to produce melanin after sun exposure possibly was useful to provide environmental camouflage and for sharp control of the amount of light in the skin. The intensity of human coloration may be correlated with the levels of solar ultraviolet radiation reaching the Earth's surface at different latitudes. Protection against premature aging and skin cancer could be reasons for the darkness of human skin in tropical environments; however, the main reasons for this adaptation seem to be the regulation of vitamin D synthesis[25,26] and the protection of light-sensitive substances in skin, such as folate, from photodestruction.[1,26]

Another important problem occurs when environmental temperatures fall, because naked skin is unable to retain a large amount of body heat. This may explain the acquisition of two other distinctive human features: an insulation layer of subcutaneous fat[15] and a cutaneous blood supply greatly in excess of that needed for metabolism.[2] In cold environments, these two structures can act together to decrease heat loss. The subcutaneous fat layer, however, can easily be overcome during heat stress by the vasodilatation of cutaneous capillaries, allowing increased heat loss from the core to the surface of the body.

Conclusions

Quevedo *et al.*[1] described *Homo sapiens* as a species with special features, such as "a relatively hairless, pigmented integument along with bipedalism, a versatile grasping hand, enlarged brain, speech, lack of estrous cycle, intimate family units, pregnancy while rearing dependent young and complex material and intellectual culture." Anthropologists, physiologists, and sociologists have studied most of these features. Paleodermatology, the multidisciplinary study of human skin evolution, is an excellent opportunity to integrate our knowledge of this fascinating evaluation of our past.

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