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Human skin colour evolution and adaptation relates to folate and vitamin D

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Abstract. Human skin colour has evolved independently in different regions as an adaptation to varing geographic environments, closely related to ultraviolet radiation (UVR) exposure. For example, white skin color tends to become lighter at higher altitudes, UVR level typically decrease with altitude. Since human skin is directly exposed to sunlight, UVR significantly impacts its characteristics. This paper primarily examines the effects of UVR on skin and its relationship to the skin colour evolution through the lens of natural selection. Additionally, we explore the roles of folate and vitamin D in skin colour variation, noting that UVR influences their levels, which in turn can lead to health conditions. We conclude that folate, vitamin D, and UVR levels are critical factors in human skin colour evolution.

Keywords: human skin colour, folate, vitamin D, ultraviolet radiation.

1. Introduction

Skin colour varies across different regions and countries and is related to the adaptation process of natural selection, first proposed by Charles Darwin in 1859. Since the time of Darwin, the significance of natural selection in influencing the physical, physiological, and behavioral adjustments of organisms over successive generations has been fundamental in comprehending the variety of life. [1] Skin colour evolves independently due to various factors. Ultraviolet radiation (UVR) has been a key factor in the development of skin color, and is linked to geographic location. [2] A single cline arose from intense UVR exposure near the equator, leading to the development of dark, photoprotective skin rich in eumelanin. Another cline emerged to enable UVB photons to support cutaneous synthesis of vitamin D3 in environments with low UVB levels, resulting in the evolution of lighter skin. [3] UVA and UVB regulate two distinct processes for tanning: immediate and delayed tanning. [3] The International Commission on Illumination (CIE) has defined the wavelengths of UVR as UV-C (100–280 nm), UV-B (280–315 nm), and UV-A (315–400 nm). [4]

The balance between vitamin D and folate plays a crucial role in determining skin pigmentation. [5] Vitamin D and folate support the health of blood vessel linings and may help prevent cardiovascular disease (CVD). Exposure to ultraviolet radiation (UVR) stimulates the production of vitamin D in the skin, but it also degrades the active form of folate, 5-methyltetrahydrofolate (5-MTHF). [6] The primary function of vitamin D is to control the metabolism of bones and maintain the balance of calcium and phosphorus in the body. [7] Folate acts as a coenzyme in the transfer of one-carbon units essential for the synthesis of deoxythymidylate, purines, and various methylation reactions. [8] In this paper, we will find out if vitamin D and folate influence traits that are not favored by natural selection. The following section will discuss the functions of vitamin D and folate and their relationship to the evolution of human skin colour. In summary, this paper examines the relationship between the evolution of skin colour and the levels of vitamin D and folate in human body, as well as the respective roles of folate and vitamin D.

2. The relation between human skin colour and vitamin D

The variation in skin color is one of the most noticeable phenotypic traits in humans, and it arises from differences in pigmentation. Melanin is the pigment which determines the darkness of colour of human hair, skin and eyes. The closer a population is to the equator, the darker their skin color tends to be. For example, African populations (7.1881°N, 21.0936°E)have darker skin colour than European populations (54.9000°N, 25.3167° E). The level of UVR increases closer to the equator, establishing a relationship between human skin colour and UVR, which is the main topic relative to natural selection in this passage.

2.1. The function of vitamin D on health and disease

The primary function of vitamin D is to control the metabolism of bones and maintain the balance of calcium and phosphorus in the body.[7] Calcium is the main component of bones, as a result, if there is calcium deficiency, some bond diseases could occur. Referred to as a prevalent metabolic/endocrine irregularity, there has been recognition of a lack of vitamin D. [9] Vitamin D and calcium deficiencies are prevalent on a global scale, leading to nutritional rickets and osteomalacia. These conditions significantly affect the health, growth, and development of infants, children, and adolescents, with potential long-lasting or even fatal consequences extending into adulthood.[10] Children suffering from rickets may experience progressive bowing of the legs, broader wrists, and prominent forehead. Additionally, they may exhibit poor growth. Osteomalacia can result in bone pain and elevate the likelihood of fractures. As a consequent, patients with these two diseases have weak bones, which means their survival and reproduction rates decrease for them, since they are not agile enough to escape danger, and the difficulty of mating increases, leading to a low probability of having offspring. In natural selection, vitamin D plays a significant role in ensuring that a person is fit to survive and pass on their genes.

2.2. Relation between vitamin D, the amount of melanin, and ultraviolet radiation

Melanin determines the colour of our skin. There are two kinds of melanin, eumelanin (brown-black) and pheomelanin (red-yellow). Eumelanin is a polymer of dihydroxy indole carboxylic acids and their reduced forms, which appears brown-black. Pheomelanin is a polymer of benzothiazine units that is mainly responsible for red hair and freckles, giving it a red-brown color.[4] In regions with low UVR, there is a strong selective pressure for individuals to have lower levels of melanin synthesis in order to increase fitness by allowing more UV to penetrate the skin.[2] As the amount of melanin decreases, it can be compromised with low level of UVR and enough amount of vitamin D can be made to ensure the strength of bones. In the opposite way, people who live in areas with high UVR need more melanin to protect their skin from sunburn and disease like skin cancer since there is sufficient vitamin D synthesis activated by the strong UVR. However, UVR not only induces production of vitamin D in the skin, but also suppresses T cell responses in the host, and vitamin D deficiency is also linked to inflammatory bowel disease (IBD).[11] IBD symptoms include fever, diarrhea, fatigue, and blood in stool. So, moderate amounts of UVR determine whether a person maintains health and well-being, making them more likely to be favored by natural selection.

3. The relation between folate and human skin colour

3.1. The function of folate on health and disease

Folic acid, a type of vitamin B that is soluble in water and can be found in fruits, legumes, cereals, and leafy green vegetables, plays a crucial role in the development of placental tissue and the formation of neural tubes.[12] In the 1950s and 1960s, conducted studies showed recognized prenatal folic acid supplementation as a method of preventing pregnancy-induced megaloblastic anemia.[13] Folate acts as a coenzyme, facilitating the transfer of one-carbon units that are essential for the synthesis of deoxy thymidylate, purines and various methylation reactions. When consumed, folate is absorbed in the intestines, circulates through the body, and is transported to cells where it undergoes modifications to become functional.[8] Folate plays a crucial role in human fertility. Purine and thymidylate synthesis are crucial processes involved in the production of DNA and RNA. Therefore, it is evident that these reactions, which rely on folate, play a vital role in supporting fetal growth and development, as well as the overall reproductive health of both parents.[13] As a result, if there is a folate deficiency, the survival rate of newborn babies decreases, which in turn lowers the reproduction rate and makes it less favorable for natural selection. Scientists determined that a satisfactory amount of folate, equivalent to 600 DFEs or 450 μg per day, is necessary for maintaining adequate folate levels in pregnant women. It is important to note that most estimated dietary intakes of folate were below 400 μg per day.[13] However, for excessive intake of folate inpregnant women could lead to gender-specific neurodevelopmental toxicity in their babies, which may negatively impact reproductive success and affect natural selection.

3.2. The relation between folate and UVR

Exposure to ultraviolet radiation (UVR) promotes vitamin D production in the skin, but it also degrades the active form of folate, 5-methyltetrahydrofolate (5-MTHF).[6] Skin pigmentation is thought to evolve along two natural selection gradients: one leading to increased melanization near the equator to protect against ultraviolet radiation (UVR)-induced folate degradation, and the other leading to reduced melanization farther from the equator to allow for sufficient UVB-induced vitamin D synthesis. As a result, individuals with darker skin pigmentation may face an elevated risk of vitamin D deficiency in regions with lower UVR exposure. Conversely, those with lighter skin may be at risk of folate depletion in regions with higher UVR exposure.[6] Thus, the balance of melanin levels , which determines UVR absorption by the skin, plays a significant role in folate synthesis and in disease related to folate.

4. Conclusion

In summary, folate and vitamin D synthesis are closely linked to human skin colour. When the levels of these nutrients deviate from the normal, it can lead to diseases that affect survival and reproduction rates, which are crucial factor in natural selection. After humans migrated from Africa, skin colour evolved differently in various area in order to minimize the disease risks, like rickets and inflammatory bowel disease. As mentioned earlier, high levels of UVR cause folate degradation, while low level of UVR result in insufficient vitamin D synthesis. Consequently, people living at different latitudes, with varying levels of UVR, evolved through natural selection. In ancient times, darker-skinned individuals living in areas with low level of UVR absorbed less sunlight, leading to a higher risk of rickets due to vitamin D deficiency, which impacted their ability to respond to emergencies like escaping a landslide. Over time, the number of dark-skinned individuals in low UVR regions decreased, which is why people in those areas tend to have lighter skin, and the reverse is true for high UVR regions.

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