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Biomedical Anthropology and Climate: Exploring Physiological Adaptations as Causes of Ethnic Variation in Metabolic Diseases

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Introduction

It is well known that climate is a significant contributor to extant human biological variation. Since the mid-1950's, several authors have demonstrated that Bergman's and Allen's rules regarding body surface area and mass and mean annual temperature in mammals seem to hold for humans as a species, providing a basis for the understanding of body size and shape variation among indigenous human groups [1]. Studies in human population biology have also found that other climate related aspects such as the gradation of decreasing ultraviolet radiation intensity from the equator to the poles and the decrease in atmospheric oxygen as the altitude of terrestrial habitats increases has modified the biology of humans. Specifically, skin pigmentation markedly lightened in Homo sapiens groups that emigrated out of equatorial tropical Africa where there is a high intensity of ultraviolet radiation to areas such as northern Europe where the radiation is much less intense, and a variety of respiratory and reproductive physiological changes have also evolved in high altitude human populations to allow them to survive and reproduce in the ambient low oxygen atmosphere at high altitude [2]. These genetically based physiological changes in human groups occurred over a 15,000 to 30,000 year timeframe.

Biomedical anthropology is an emerging subfield in anthropology that focuses on the interface between human biological variation and medicine, and might be seen as complimentary to another emerging discipline, Darwinian medicine. While a good deal of emphasis in both disciplines is placed on concepts like the co-evolution of pathogens and human immunological capacity, there is also a developing notion that chronic metabolic disease problems may be related to physiological variation that evolved as past human populations adapted to environments characterized by specific climatic parameters. Because of evolutionarily recent migrationsto starkly different environments over the past 500-1000 years, these physiological adaptations that once benefitedpopulations in their native habitat may now have become maladaptations that produce metabolic disorders. An example of this adaptation- maladaptation changeis seen among African-Americans, whose higher rates of hypertension and attendant cardiovascular morbidity such as heart attacks and kidney failure relative to European-American groups may be related to a mismatch between ancestral climatic adaptations associated with a hot tropical environment and the relatively salt rich and sometimes freezing environment that characterize contemporary North America. There are several lines of evidence that point to this possibility.

Adaptations to Hot, Low Salt Environments and Hypertension

Current genetic and paleontological evidence suggests that all contemporary human populations descended from African ancestors some 100,000 to 200,000 years ago [3]. These ancestral populations evolved in a hot and largely "tropical" environment, and it is also true that modern sub-Saharan African populations as well as sub-Saharan African derived population such as African-Americans retain a"heat adapted" physiology, or more specifically a physiology that is adapted to a predominantly hot, wet environment [1,4,5]. Two important aspects of that physiology are the ability to copiously sweat to cool the body, which is a process that depletes body salt (sodium) levels, and the ability of the kidney to retain salt (sodium) during glomerular filtration when there is low availability of dietary salt. This physiology is quite adaptive as long as the environment remains hot with a dearth of available sodium. However, when populations migrated out of tropical Africa, they moved into cooler and more salt rich environments,which required an evolution of the ability to excrete excess salt (sodium), rather than just to retain it. This ability is necessary as sodium is a serological parameter that must be maintained within relatively narrow limits for survival; when the body cannot excrete sodium fast enough in the face of a high salt diet, there is significant body fluid expansion which can lead to hypertension [6].

Young and colleagues[4] have reported a geographic cline from the equator to the poles of "heat adapted" allelic variants at 5 functional genetic sites that regulate salt retention and blood vessel tone. Their data suggest that indigenous populations residing within 10 degrees of the equator have, on average, 74% "heat adapted" allelic variants at these loci, whereas populations living within 10 degrees of the arctic having only 43% "heat adapted" variants. After evaluating the data from 53 geographically dispersed populations, they hypothesized that the frequency of "heat adapted" alleles declined as migrant populations colonized ecologies that were cooler and salt rich, but then rose again in groups that migrated back to more salt poor tropical areas. These genetic changes were estimated to have taken 12,000-30,000 years.

Since "heat adapted" alleles help to retain salt and numerous studies have shown that excessive dietary salt is a risk factor for hypertension due to the process noted above, it is reasonable to hypothesize that contemporary populations with "heat adapted" alleles are more susceptible to hypertension and its sequelae if they have recently (say within the last 500 years) migrated to cooler salt rich environments or if they have had salt substantially increased in their diets [4,5]. One "heat adapted" group that has migrated to a salt rich cooler environment from a tropical ecology over that time frame and who have also had salt substantially increased in their diet is African-Americans; thus, thesegenetic findingscan partially explain why African-Americans,

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living in the salt abundant environments of North America have a high incidence of hypertension and cardiovascular morbidity [1,4].

Maladaptation to Cold Environments and Hypertension

Since the middle of the last century, numerous studies have documented a seasonal variation in casual blood pressures in population groups that live in temperate climates, such that the highest blood pressures are measured in winter [7]. More recent studies using ambulatory blood pressure monitors that evaluate pressure over the whole day reveal that the ambient temperature has a substantial effect on diurnal blood pressure variation, changing pressures by as much as five to 15 mmHg with seasonal weather changes, such that the highest pressures occur when the temperature is cold [8].

When cold or freezing conditions are experienced in unprotected humans, there is a sympathetically driven immediate vasoconstriction of peripheral arteries, which conserves body heat. If left unchecked, the lack of blood flow to the peripheral tissues (fingers, hands, toes, etc.) will lead to frostbite and subsequent tissue loss [5]. To combat this damage, ancestral human populations who migrated out of Africa to temperate and cold climates evolved a peripheral cold induced vasodilatory (CIVD) response through natural selection. This response is characterized by a periodic release of the arterial constriction in the face of the cold, allowing blood flow to the peripheral tissues [5]. What this means evolutionarily, is that our ancestral African "heat adapted" physiology was further changed by the experience of cold climates, or as we know it today, the experience of winter [5].

Numerous studies have found that African-Americans who largely retain the ancestral "heat adapted" physiology evince more intense vasoconstrictive responses to cold stress, showing either inadequate or no CIVD [5]. While the bulk of the studies that report the enhanced vasoconstrictive response have used a standard cold pressor test where the hand or foot is immersed in 4°C ice water, subsequent studies have found first, that even cold to the face can cause the accentuated vasoconstrictive response among African-Americans and second, that African-Americans may also have an enhanced myocardial and vasoconstrictive reactivity during passive exposure to temperatures between 8 to 10 degrees centigrade [9]. What these more recent findings mean realistically, is that the exposure of the face during the below or near freezing days of winter is likely sufficient to induce the vasoconstrictive cold responses among African-Americans.

Why this is important from the perspective of hypertension development in African- Americans is that cold induced vasoconstriction increases blood pressure due to the increase in peripheral resistance and chronic vasoconstriction can lead to sustained hypertension [5]. Thus, it is reasonable to suggest that the African-Americans living in the temperate and colder climates of North America experience chronic cold stress through the winter months, potentiating chronic vasoconstriction which may contribute to their higher incidence of hypertension. Interestingly, the vasoconstriction associated with cold stress is caused by the actions of the sympathetic hormones epinephrine and norepinephrine, and recent research suggests that not only are sympathetic hormone receptors more sensitive among African-Americans than those of European-Americans, but also that epinephrine has a larger effect on diurnal blood pressure changein African –Americans than European-Americans as well [9].

Final Thoughts

Biomedical anthropology as an emerging part of our discipline can make important contributions to the study of human health because the content assesses how the evolutionary basis of our biological variation contributes to health disparities. While my focus here is on climatic adaptations, the interface between culture and biology is equally as important, as are studies of how humans interact with other aspects of their local ecology. I have presented data regarding hypertension and cardiovascular disease in African-Americans, primarily because there has been a great deal of medical interest in understanding the cardiovascular health differences between African- and European-Americans. However, there are likely other metabolic diseases including diabetes, lipid disorders and cancers whose prevalences vary by ethnicity which are also likely related to biological adaptations that have yet to be understood. It is incumbent upon our discipline to pursue this research area, as it will bring greater understanding as to why we differ and it will also lead to an improvement in our overall health.

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