VIEWPOINT

Some Bio-Medical Mechanisms in Athletic Prowess

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ABSTRACT

Variations in somato-genetic patterns in muscle-fibre biology, biochemical metabolic pathways and pulmonary physiology are hypothesized to have been concentrated by natural selection over the centuries in the Afrocentric peoples displaced from West Africa to the New World. These phenotypic and genotypic characteristics are attributed to provide the athletic prowess so well documented in African-Americans. Not the least of coincidence seems to be the influence of the compensatory mechanisms on oxygen transport and its availability to the tissues, in response to the sickle cell gene. The reduced availability coupled with reduced myoglobin in the preponderant fast-twitch muscle fibres which are adapted for rapid energy (ATP) regeneration, all give a NET outcome of muscle anatomical and biochemical advantages which support outstanding performances in athleticism.

Algunos de los Mecanismos Biomédicos de las Proezas Atléticas

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RESUMEN

Existe la hipótesis de que los patrones somatogenéticos en la biología fibromuscular, las vías meta-bólicas bioquímicas, y la fisiología pulmonar, se han concentrado mediante selección natural a lo largo de siglos, en los pueblos afrocéntricos desplazados desde África Occidental al Nuevo Mundo. A estas características fenotípicas y genotípicas se les atribuye las proezas atléticas, tan bien docu-mentadas en los afroamericanos. Tampoco parece ser coincidencia en lo más mínimo, la influencia de los mecanismos compensatorios de transporte de oxígeno, y su disponibilidad en los tejidos, en respuesta al gene de la célula falciforme. Esta disponibilidad reducida acoplada con la mioglobina reducida en las fibras musculares de contracción rápida preponderantes que están adaptadas para la rápida re-generación de energía (ATP), producen de conjunto un resultado neto en términos de ventajas musculares anatómicas y bioquímicas que constituyen la base de las actuaciones destacadas en el atletismo.

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INTRODUCTION

For several decades the disproportionate success of individuals of African descent in a wide range of athletic activities has been the subject of intense speculation and debate. Today, despite being a mere 12 per cent of the American population, African-Americans constitute a clear majority of that country's greatest athletes. Also, the disproportionate success in the area of sports, by the largely Afrocentric populations in the islands of the Caribbean, beg the questions, why and how. There are outstanding Caribbean and American athletes of African descent who are testimony to the tremendous physical ability displayed by the descendants of West African-related forebears.

Hypothesis

Success of individuals of West African descent in athletic activities involving speed and power is based on (a) biomechanical and biochemical differences between themselves and Caucasian and Asian athletes (1), and (b) biochemical differences between themselves and all other Africans (2).

The African biomechanical advantages of lower subcu-

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taneous fat, longer arms and legs and narrower hips, that influence power-to-weight ratio and stride length, are well known and generally uncontroversial outcomes of human evolution in tropical climates (1, 2). The essence of this hypothesis is the claim that the biochemical differences – essentially differences in glucose conversion rates between West African and West African-descended populations and all other groups, including other black Africans, began but did not end with the sickling of the haemoglobin molecule, wherein valine is substituted for glutamic acid, as the sixth amino acid of the beta chain of the haemoglobin molecule. This mutation appears to have triggered a series of physiological adjustments, which have had favourable athletic consequences.

These adjustments or compensatory mechanisms, include a higher percentage of fast-twitch muscle fibres, greater activity in the phosphagenic, glycolytic, and lactate dehydrogenase metabolic pathways and greater rate of ventilation, all of which have been scientifically tested and evaluated. These alterations affect the individual's process in storing and utilizing energy for skeletal muscle contraction, and enhances their ability to build lean muscle mass.

DISCUSSION

The sickle-cell trait, and the biological adaptations it triggered, would have considerable medical and physiological consequences. Because these sickle-shaped cells are less hospitable to the malarial plasmodium than normal red blood cells, the debilitating effects of malarial infection are reduced in individuals who inherit this kind of red corpuscle from just one parent.

While it is now indisputable that heterozygous individuals possess a selective advantage in areas of high malarial infection, the connection between sickle-cell trait and athletic ability or physical prowess was not immediately clear.

The hypothesis that the athletic prowess of people of West African origin is linked to their development of biological defenses against falciparum malaria is not as new or as radical as it might seem (3).

Somatotype and Genotype

The first indicator that individuals of West African descent had developed what would be described as "compensating mechanisms" as a response to the debilitating effects of sickle cell trait, came from an elaborate study of Olympic athletes from the 1968 Games in Mexico City (4). More than 1000 athletes, of both genders, of every racial group, and from all parts of the world, participated in the project, which was named the Program of Genetics and Human Biology. Unlike previous studies, which had been limited to the morphological basis of performance, the Mexico City study attempted to examine the possible genetic bases for body structure and sports performance. As a result, in addition to somatotyping, the Mexico City study collected and analyzed a number of genetic and anthropological characteristics of the athletes.

Among the factors included were investigations of the sports histories of the families of the athletes; genetic traits of the athletes, especially those that might be correlated with sports ability; and those aspects of the athletes' physiques that represented the interaction of their genetic endowments with the environmental factors involved in training. The 1265 athletes, performing in 129 separate Olympic events, were grouped into four major racial categories: Caucasoid, Mongoloid, Mestizo (Indian plus Caucasoid) and Negroid. The classifications were based on identification and somatotype photographs, as well as physical characteristics including skin color; general body shape; proportions of segments of the limbs; facial structure; form of eyes, lips, and nose; and colour and texture of hair. Like the Tanner study of the athletes from the 1960 Olympic Games, the Mexico City survey confirmed the relationship between body type and athletic performance as well as the differences in body proportions between the Negroids and the other groups. Not only were the Negroids significantly narrower in hip breadth than the Caucasoids (slightly less so than the two other groups), but the Negroids were found to have longer arms and legs, and a shorter trunk, than the other groups. Despite these differences, the study concluded, "it would appear that the same somatotypes excel at the specified events regardless of race, and that the functional requirements of the events demand similar somatotypes." However, the most interesting and important finding of the study was not produced by anthropometric measurements, but by tests to determine a possible association between athletic ability and single gene systems. Investigated were the ABO, MN, and Rh red cell types, haptoglobin, glucose-6-phosphate dehydrogenase, and acid phosphatase. Although the study failed to link athletic capability to a single gene system, the authors expressed "surprise" that "a sizeable number of Negroid Olympic athletes manifested the sickle-cell trait."

The authors noted, "In view of the importance of haemoglobin in the transport of oxygen to tissues, one might expect very slight differences in function or amount of haemoglobin to be reflected in athletic potential. Especially in the case of haemoglobin S (the sickle gene), one might suppose that the great oxygen demand, which accompanies certain athletic activities, might cause a certain amount of *in vivo* sickling of red cells even though this is not observed in heterozygotes under other conditions. Such persons might, therefore, be at a disadvantage, and even a small disadvantage would be expected to prevent such persons attaining Olympic status. It was surprising to discover that this was not the case."

The finding that a shortage of haemoglobin had not adversely affected the athletic capabilities of black athletes, was magnified by the fact that the 1968 Olympics were staged at the high altitude of Mexico City. "One could imagine," the authors wrote, "that a greater oxygen deficit would be associated with this altitude and that persons heterozygous

for haemoglobin S would be more likely to form sickle cells *in vivo* than at lower altitudes."

Eight years after the Mexico City report, an article in the Journal of the National Medical Association (5), the official organ of the African Medical Group in the USA, provided additional evidence that adjustments had been made in the energy metabolizing systems of people of West African descent. The Mexico City study had expressed surprise that Negroid athletes with sickle-cell trait had been able to compete effectively at the very highest levels, despite deficiencies in their oxygen transportation systems. This article, based on a massive study, would reveal it was not only individuals with sickle-cell trait who had lower than average haemoglobin levels, but that African Americans generally had significantly lower haemoglobin levels than their white counterparts. It would also raise, for the first time, the critical issue of how African-Americans coped so well with this apparent biological handicap.

Conducted in ten states and in New York City, the study involved nearly 30 000 individuals, divided into twenty-four age groups, from the first year to the ninth decade. To eliminate the possibility that the racial differences in haemoglobin levels were caused by socio-economic factors, the study included matched comparisons of blacks and whites with reported high levels of iron intake and higher incomes, and athletes of both races. Nonetheless, the results clearly indicated that, without exception, there were significant racial differences in haemoglobin levels, at every age group, and for both genders. This "systematic difference," the authors wrote, "is fully evident even during the period of rapid adolescent gain in haemoglobin levels in the male, and during the period of declining haemoglobin levels in the seventh and eighth decades."

Speculating on whether the observed difference in haemoglobin levels between the races was of environmental or genetic origin, the authors explained that if it were the latter, then this "would also raise the possibility of mechanisms for oxygen transport beyond those provided by the respiratory pigments." Two years later, another team of researchers, also writing in the Journal of the National Medical Association reported, "some compensatory mechanism must exist to counteract this relative deficiency of haemoglobin, since a significant difference has even been demonstrated in healthy athletes."

It was not until almost two decades after the authors of the Mexico City study had pointed to genetic systems related to energy metabolism as areas where explanations for differences in athletic ability might be found, that a study to determine whether there are racial differences in fibre type proportion and how the skeletal muscles receive energy, was proposed. By that time, in 1986, research over the previous decade had established that not only was skeletal muscle composed of two types of fibres fast-twitch and slow-twitch that deploy different metabolic pathways, but that the proportion of those fibres influenced athletic performance.

Conducted at Laval University in Quebec, Canada (6), the study to determine racial differences in fibre type proportion consisted of 46 men: 23 black African students from Cameroon, Senegal, Zaire, Ivory Coast, and Burundi, and an equal number of Caucasians. Since training influences enzyme activity in both fast-twitch and slow-twitch fibres, all the men selected had either never trained or had been inactive for several months. The groups were also matched by age, height, body weight and body mass index.

The study, conducted by geneticist and exercise physiologist Claude Bouchard and exercise biochemist Jean-Aime Simoneau, revealed that the groups differed in both fibre type proportion and muscle enzyme activity levels. Muscle biopsies clearly showed not only that the mixed group of Africans had a higher percentage of fast-twitch fibres and a lower level of slow-twitch fibres than their Caucasian counterparts, but also that the Africans had significantly higher activity, about 30 to 40 per cent, in their phosphagenic, glycolytic, and lactate dehydrogenase metabolic pathways. The authors concluded that "the racial differences observed between Africans and Caucasians in fibre type proportion and enzyme activities … may well result from inherited variation. These data suggest that sedentary male black individuals are, in terms of muscle characteristics, well endowed for sports events of short duration."

It may also be true that the study, by excluding African Americans, Afro-Caribbeans, and other West African-descended groups in the Diaspora, significantly underestimated the differences between Europeans and those West Africans whose ancestors had been transported across the Atlantic. Such differences may exist not only because of the eugenic effects of the slave trade, but also because there is reason to believe that not all West Africans are equally endowed with fast-twitch muscle fibre, and that the ancestors of many of the most outstanding athletes of West African descent in the Diaspora may have come, disproportionately from a relatively small area of West Africa (7).

Pulmonary Function

A study was conducted at the State University of New York at Buffalo (8) to "determine whether the lower FVC (Forced Vital Capacity) observed in healthy blacks results in a ventilatory adjustment to exercise which differs from that observed in healthy Caucasians."

Eighteen white and fourteen black subjects were studied, ages eight to thirty years, and were matched for gender, age, height and weight. The results confirmed that lung volumes were ten to fifteen per cent greater in white subjects than in blacks of the same gender, age, and size; that there were clear differences in the breathing patterns of the two racial groups during exercise; and that blacks, despite their smaller lung capacity, consumed more oxygen in every phase of exercise than their white counterparts. This was possible, the researchers determined, because minute ventilation, the

provision of oxygen to the total area of the lungs, was higher in blacks at all workloads and became more significant as the workload increased. Blacks, the study found, compensated for their smaller lung capacity by increasing the frequency of their breathing, which was achieved by a proportionate reduction of both the inspiratory and expiratory cycles.

Biochemical Differences

The black athlete, primarily because of a higher ratio of fast-twitch muscle fibre, will convert glucose into energy more rapidly than his white counterpart. Energy for muscle contraction, including all physical and athletic activities, is created by the breakdown of glucose by processes which result in formation of adenosine triphosphate (ATP).

The first stage of the process is cytosolic and is known as glycolysis, and produces ATP at a rate more than twice that of the second stage which is intra-mitochondrial. The first stage is also far less efficient, producing far less energy per glucose molecule. Both black and white athletes will convert glucose to ATP by both glycolysis – anaerobic metabolism(oxygen not required) – and by mitochondrial metabolism (oxygen required), but in different ratios. This difference in the relative efficiency or effectiveness of these metabolic pathways in the athletes will play a decisive role in performance and is largely responsible for the greater athletic success of African Americans and others of West African descent.

Skeletal muscle is composed of two types of fibre, slow-twitch and fast-twitch, classified by their speed of contraction, oxidative capacity, and resistance to fatigue. Slow-twitch or red fibres, with their high myoglobin content and resulting greater oxidative capacity, generate ATP primarily by the slow but efficient process of aerobic metabolism. In this process, oxygen, bound to haemoglobin in red blood cells, is carried to the muscles by the capillaries. Myoglobin, an iron-protein compound, is essential for the transfer of oxygen from the cell membrane to the mitochondria, where the oxygen is consumed.

In sharp contrast, fast-twitch or white fibres, with their lower myoglobin content and considerably lower oxidative capacity, are less able to utilize aerobic metabolism for the production of ATP and are therefore more dependent on glycolysis or anaerobic metabolism. This is why the ability to regenerate ATP during activities requiring short bursts of power is so physiologically meaningful.

Muscle biopsies have concluded, as stated earlier, that people of African descent have significantly higher levels of activity in their phosphagenic, glycolytic, and lactate dehydrogenase metabolic pathways than their Caucasian counterparts. The production and regeneration of ATP takes place in the glycolytic and phosphagenic pathways. Higher levels of activity result, therefore, not just in faster production of ATP but also in its more efficient regeneration. When ATP is depleted, it is very rapidly replaced through a reaction that consumes creatine phosphate. Creatine phosphate acts like a battery, as a source for ATP energy and recharging of itself from the new ATP that is generated by cellular oxidations when the muscle is resting. Skeletal muscle converts chemical energy into mechanical work with relative efficiency; only thirty to fifty per cent being wasted as heat. As a result, even small differences in chemical energy generation are physiologically meaningful.

Faster production and increased regeneration of ATP, however, does not fully explain African-American biochemical superiority in athletic events requiring speed and power. There is also considerably greater activity in the lactate dehydrogenase pathway of people of West African descent. A primary function of this pathway is to reduce muscle fatigue by converting lactic acid back to glucose and refeeding the muscles. This cyclic set of reactions, from muscles to liver and back to muscles, is known as the Cori cycle.

The postponement of muscle fatigue during prolonged anaerobic activity is dependent on a number of factors, the most important of which is the rate at which lactic acid is removed and reconverted to glucose. The rate of lactic acid removal is partially regulated by the activity of the lactate dehydrogenase metabolic pathway, which explains why increased activity in this pathway is so athletically meaningful.

The recycling of waste products, such as lactic acid by the liver is vital to the proper functioning of the muscular and nervous systems, among others. If the glycogen reserves stored in the muscles were depleted during intense physical activity, blood glucose would become the major source of energy. This sequence could lower blood glucose levels sufficiently to seriously compromise the nervous system. Additionally, during prolonged intense activity, if glucose is not available, muscle resorts to the use of fat for fuel, which is less efficient for combustion than carbohydrates. Consequently, an athlete engaged in fairly prolonged anaerobic activity such as sprinting, would be far less effective without a mechanism to increase the supply of glucose. This is what is accomplished during the Cori cycle, the cyclic set of reactions initiated by increased activity in the lactate dehydrogenase pathway.

CONCLUSION

It is this compelling array of somato-genetic variation, exhibited in muscle-fibre biology, biochemical metabolic pathways and pulmonary physiology, which is hypothesized to have been concentrated by natural selection over the centuries in the Afrocentric peoples displaced from West Africa to the New World. This is adduced to provide the athletic prowess so well documented in this group of descendants.

Not the least of coincidence seems to be the influence of the compensatory sickle cell gene on oxygen transport and availability to the tissues. The reduced availability coupled with the reduced oxygen myoglobin in the preponderant fast-twitch muscle fibres which are adapted for rapid anaerobic energy (ATP) regeneration, all give a net outcome of muscle anatomical and biochemical advantages which proffer a

superior performance in athleticism.

REFERENCES

1. Metheny E. Some differences in bodily proportions between American Negro and white male college students as related to athletic performance. Res Q 1939; **10:** 41–53.
2. Tanner JM. The Physique of the Olympic Athlete. George Allen and Unwin. London, 1964.
3. Carlson DG. African Fever: A Study of British Science, Technology, and Politics in West Africa, 1787-1864. Science History Publications, 1984.
4. Caray AL, Levine L, Carter, IEL. Genetic and Anthropological studies of Olympic Athletes. Academic Press, 1974.
5. Garn SM, Smith NJ, Clark DC. Lifelong differences in hemoglobin levels between Blacks and Whites. J Natl Med Assoc 1975; **67:** 91–6.
6. Ama PFM, Lagasse P, Bouchard C, Simoneau JA. Anaerobic Performances in Black and White subjects. Med Sci Sports and Exer 1990; **22:** 508–11.
7. Davidson B. The African Slave Trade. Little, Brown and Co. Boston, 1970.
8. Damon A. Negro-white differences in pulmonary function (vital capacity, timed vital capacity, and expiratory flow rate). Hum Biol 1966; **38:** 381–93.