The Evolution of Human Physical Activity

Public Symposium · Friday, May 14, 2021

Co-chairs:
Tatum Simonson, University of California, San Diego
Daniel Lieberman, Harvard University

Sponsored by:
Center for Academic Research and Training in Anthropogeny (CARTA)

ABSTRACTS

The Evolution of Walking and Running

Daniel Lieberman, Harvard University

All animals need to be physically active, but the human lineage clearly underwent selection to be considerably more physically active than our relatively inactive ape ancestors and cousins including chimpanzees and gorillas. This selection likely occurred in at least two stages, first involving the most fundamental type of moderate physical activity, walking, and then the most fundamental type of vigorous physical activity, running. In terms of walking, the earliest hominins were likely selected to become bipedal in order to help them efficiently walk longer distances to forage. Bipedal walking brought many benefits and led to further selection for making and using tools, but also rendered hominins slow and awkward, hence vulnerable to predation. With the origins of hunting and gathering in the genus *Homo*, however, there was additional selection for endurance running which helped hominins become scavengers and hunters. Until recently, hunter-gatherers engaged in several hours a day of moderate physical activity from walking 9-15 km per day, as well as regular vigorous physical activity from occasional long-distance running. Industrial and post-industrial innovations, however, have changed how much and the ways we walk and run, and they enable humans to no longer have to engage in much physical activity. Today we face a growing epidemic of physical inactivity that increases people's vulnerability to a wide range of chronic non-infectious diseases as well as infectious diseases including COVID-19.

The Evolution of Human Metabolism

Herman Pontzer, Duke University

From an evolutionary perspective, life is a game of turning energy into offspring. The strategies that species use to acquire energy, in the form of food, and allocate energy to the essential tasks of growth, maintenance, movement, and reproduction, are incredibly diverse and reflect the ecological pressures and opportunities encountered. In this talk, I discuss the deep evolutionary history of the human metabolic strategy and our divergence from other apes, focusing on metabolic changes over three timescales. First, from measures of daily energy expenditure (kilocalories per day) in living primates, we see evidence of a metabolic slowdown early in the evolution of the primate order, perhaps 65 million years ago. Primates today burn roughly 50% less energy each day than other placental mammals, and this slower metabolism likely underlies the slow pace of growth, reproduction, and aging in humans and other primates. Second, metabolic rate accelerated in the human lineage as it diverged from that of chimpanzees and bonobos. The timing of this increase in daily energy expenditure likely coincides with the development of hunting and gathering with the genus *Homo*, beginning ~2.5 million years ago. Today, humans' greater daily expenditures fuel our big brains, big babies, and high levels of physical activity. Lastly, when we examine metabolic adaptations over a lifetime, we find that the metabolisms of humans and other species are dynamic and responsive, changing in response to physical activity and diet to keep daily energy expenditure within a narrow range. Understanding our metabolic flexibility - changing energy allocation among tasks in response to local conditions - is important for reconstructing our evolutionary past and for managing our health today.

A Human Genetic Mechanism for Endurance Running

Ellen Breen, University of California, San Diego

Humans are unusual among primates in being capable of sustained long-distance running, a key phenotype that emerged in genus *Homo* about 2 million years ago (Mya). The underlying genetic changes that defined this exercise phenotype are not well understood. About 2-3 mya, an exon deletion in the CMP-Neu5Ac hydroxylase (CMAH) gene became fixed in our ancestral lineage, completely eliminating the hydroxylase activity required to add an oxygen atom to the sialic acid Neu5Ac to form Neu5Gc. Thus unlike the case in other old world primates, human cells do not express Neu5Gc, and instead have an excess of Neu5Ac on cell surfaces and secreted glycoconjugates. Modeling Cmah loss in mice allows us to explore potential mechanisms involved in the evolution of this hominin endurance phenotype. Untrained Cmah-/- mice demonstrate a remarkable increase in endurance during treadmill running exercise and voluntarily run further and faster when housed with a running wheel. Cmah-/- mice also exhibit skeletal muscle adaptations that are known to occur in exercise training, including more capillaries, enhanced mitochondrial respiration and greater fatigue resistance, despite remaining sedentary. Metabolic pathway analysis of sedentary and exercise trained Cmah-/- mice reveal increased and decreased patterns in Cmah-/- mice that augment those that occur with exercise training. In particular, elevations in amino acid and pentosphosphate pathways were identified. Taking a closer look at the final steps of the oxygen transport in peripheral skeletal muscle, our data suggest that loss of Cmah-/- may allow for more efficient transfer of oxygen from hemoglobin in red blood cells to deoxy-Mb, increased endothelial cell permeability and, enhanced mitochondrial activation in Cmah-/- myofibers at very low, near limiting extracellular oxygen levels for mitochondrial respiration. Taken together, these data suggest that CMAH loss may have contributed to multiple adaptations in genus *Homo* that improved skeletal muscle capacity for oxygen delivery and/or utilization, and perhaps provided a selective advantage during the transition towards persistence hunting and other features of *Homo*, such as increased foraging range and resource exploration.

Genetic Drivers of Human Thermoregulatory Skin Traits

Yana Kamberov, University of Pennsylvania

Humans use sweating as the primary mechanism to dump body heat. Humans' ability to effectively harness sweating as a thermoregulatory mechanism is a product of the evolution of a massively increased sweat gland density and a drastic reduction in the size of body hair. Accordingly, humans have the distinction of being the "the naked sweaty ape." I will present the advances our lab has made in identifying the genetic basis for how these unique and essential adaptations of human physiology evolved and discuss the implications of these findings for studying the development and evolution of other adaptive human traits.

The Rise and Fall of Climbing in Human Evolution

Jandy Hanna, West Virginia School of Osteopathic Medicine

Most primates live and move in the trees, but humans have evolved to move bipedally on the ground. Primates' arboreal life-style has long been thought to have allowed the evolution of human beings' unusual form of movement. We know much about how horizontal movement on branches (or simulated branches) differs in primates relative to most other mammals. But only recently have we begun to learn about how vertical movement (i.e. climbing) is accomplished by non-human primates, and how such movement may have permitted early human ancestors to move upright. However, climbing is a physically challenging activity, and not all primates (including humans) do it the same way. Body size plays a role in how muscles are able to accomplish overcoming gravity. But muscles consume energy to do this. What are the biomechanical and energetics costs of climbing? Key findings regarding the biomechanics of climbing, and what these data may mean for understanding human movement and exercise, are discussed.

The Anatomical Basis of Aggression in Hominins

David Carrier, University of Utah

Our thesis, that humans are at some level anatomically specialized for physical aggression, is based on two premises. First, although humans are arguably the most empathic and cooperative species on the planet, we also have a real problem with violence. Second, to the extent we can find ways to reduce aggression, intolerance, and violence in the future we should do so. As scientists, we know that the best solutions to our most important problems stem from understanding. Evidence that human aggression is partially tied to male contest competition (i.e., mating competition through the use of force or threat of force) comes from a growing number of subfields within evolutionary anthropology: primatology, archaeology, population genetics, sexual selection theory, and evolutionary psychology. I believe the field of comparative physiology can also contribute to a better understanding of the evolutionary basis of human violence by (1) determining if the anatomical and physiological characters that are known to distinguish hominins from the other great apes actually improve fighting performance, and (2) assessing the extent to which these characters are expressed differently in males and females, i.e., are sexually dimorphic. In this presentation, I will present results from two experiments we have done to test the controversial hypothesis that hominins are anatomically specialized for fighting by punching with a clenched fist. Our results are consistent with the suggestion that selection on male contest competition played a role in the evolution of the shape of the human hand and the pronounced difference in upper body strength observed between human males and females. Thus, our results add to a growing body of evidence suggesting that the evolutionary roots of much of the aggression, intolerance, and violence that plagues modern societies ultimately lies in the selection that shaped our mating system. Acknowledging and understanding the legacy of male interpersonal and group aggression can help guide policy directed at reducing violence in the future.

Evolutionary Links Between Physical Activity and the Brain

David Raichlen, University of Southern California

Recent work suggests exercise can have important beneficial effects on the aging brain, however the underlying mechanisms remain poorly understood. An evolutionary-neuroscience approach may help us better understand these mechanisms and can provide a foundation for developing novel interventions to improve brain aging. Here, we suggest that, from an evolutionary perspective, physical activity mainly occurred during foraging, which combines aerobic activity with cognitively demanding tasks (e.g., spatial navigation and executive cognitive functions). Thus, mechanisms linked to neuroplasticity, including hippocampal neurogenesis, may be triggered by physical activity as a way to enhance cognitive needs during foraging tasks. If correct, simultaneous physical and cognitive challenges may lead to the strongest brain benefits. Using this evolutionary approach to brain health, we can form a foundation for novel interventions to improve brain aging today.

Physical Activity and Women's Reproductive Health

Grazyna Jasienska, Jagiellonian University

It is generally assumed that humans need physical activity to stay healthy, but health recommendations are rarely different for women and men. However, the effects of physical activity on female physiology and health are much more complex. Just like in men, activity is beneficial for many aspects of health, but physically active women also face important physiological trade-offs, or, in other words, quid pro quos. In this talk, I will discuss beneficial aspects of exercise for women, especially in prevention of breast cancer, but I will also point to suppressive effects of activity on reproductive function. Physical activity influences levels of hormones that are crucial for female health – estrogens and progesterone. But how much and in what way these hormones are affected depends not only on the type and intensity of physical activity, but also on other factors, such as the quality of environment that women experienced during their own fetal development and childhood.

Human Adaptation to High Altitudes and Aquatic Environments

Tatum Simonson, University of California, San Diego

Humans have persisted for hundreds of generations under challenging environmental extremes. Adaptations to such environments have been essential for survival, enabling populations to trek successfully among high mountain tops or to dive deeply into vast seas. Unique genetic signatures, resulting from thousands of years of strong selective pressures in these environments, have been discovered within the DNA of present-day populations. These findings provide important clues into evolutionary processes in humans, including the impact of archaic contributions, and have been linked to key traits associated with oxygen transport and utilization relevant to health and disease.