Tall or short? Thick or thin? Study shows many factors affect arm, leg size

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The front and back of a human right hand. Credit: Wikipedia.

For over 60 years, scientists have theorized that a person's body shape and size could be influenced by the climate of where they live. Now a new study from the University of Tennessee, Knoxville, suggests there's more to the equation.

The paper, co-authored by Kristen Savell, a third-year doctoral student in

the Department of Anthropology, is among the first to document how evolutionary selection has shaped variation in human limbs across the globe.

The study was published this week in the *Proceedings of the National Academy of Sciences*. Savell co-authored the work with Benjamin Auerbach, UT associate professor of anthropology, and Charles Roseman, associate professor of anthropology at the University of Illinois at Urbana-Champaign.

The study indicates that long bones of the arms and legs do not evolve independently as scientists have long assumed. Instead, "they are all evolving together in ways we didn't necessarily know," Savell said.

Since the mid-to-late 1900s, scientists have speculated that human populations have adapted to the environment based on their geographic latitude to maximize heat loss efficiency. Those in warmer climates tend to have longer limbs and narrower bodies, and those in colder climates tend to have shorter limbs and wider bodies. These theories are based on two scientific principles developed in the 1800s, which today are called Bergmann's Rule and Allen's Rule.

Researchers have studied the relationship between body proportions and latitude using groups in four geographic regions: sub-Saharan Africa, North Africa, Temperate Europe and the Arctic.

Savell and colleagues, using the same groups to obtain comparable data, compared the variation in lengths of four bones—humerus (upper arm), radius (forearm), femur (upper leg) and tibia (lower leg)—as well as the femoral head diameter and pelvic width among 14 human populations including more than 400 individuals.

They found that two of the bones—the forearm (radius) and lower leg

(tibia)—as well as overall body size did appear to evolve in direct response to natural selection as expected, becoming shorter at higher latitudes.

The growth of the arm (humerus) and thigh (femur), however, are influenced by more than just the direct response to natural selection. The femur does not change length in response to directional natural selection at all. Savell and colleagues also found that natural selection alone would drive the humerus to lengthen at higher latitudes with colder climates. This finding is contrary to Bergmann's and Allen's rules, which suggest natural selection would push the arm to shorten with higher latitudes. Savell and colleagues found that it was because of genetic correlations with the tibia and radius, which shorten with higher latitude, that the humerus also shortened. The response of the tibia and radius to natural selection, and their genetic relationship with the humerus, overcame the direct effects of natural selection on the humerus.

The study supports the idea that multiple forces, created by the interaction of traits through genetic correlation, influence human shape and size in combination with responses to natural selection dictated by the environment.

"Even when evolutionary patterns match expectations, the processes underlying them might not be," Savell said. "It is important for all biologists and biological anthropologists to be aware of the importance of knowing how different measurements covary with each other. It is also important that we understand the processes that are driving the patterns we observe in nature as well as studying the patterns themselves."

Savell noted that she and her collaborators are referring to changes in limb bone length on an evolutionary scale, so their data doesn't apply to differences between people that occur over individual lifetimes.

"What we're looking at is how adaptation to latitude, often interpreted as a proxy for climate, has affected proportions over many, many, many generations," she said.

More information: Kristen R. R. Savell et al. Constraint, natural selection, and the evolution of human body form, *Proceedings of the National Academy of Sciences* (2016). DOI: 10.1073/pnas.1603632113

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