BIOLOGY

How much of human height is genetic and how much is due to nutrition?

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Credit: Getty Images

This question can be rephrased as: "How much variation (difference between individuals) in height is attributable to genetic effects and how much to nutritional effects?" The short answer to this question is that about 60 to 80 percent of the difference in height between individuals is determined by genetic factors, whereas 20 to 40 percent can be attributed to environmental effects, mainly nutrition. This answer is based on estimates of the "heritability" of human height: the proportion of the total variation in height due to genetic factors.

Human height is a quantitative, or metric, trait, i.e., a characteristic that is measured in quantity, and is controlled by multiple genes and environmental factors. Many studies have estimated the heritability of human height. Often, these studies determine heritability by estimating the degree of resemblance between relatives. One can separate genetic effect from environmental effects by correlating genetic similarity between relatives (twin, siblings, parents and offspring) with their similarity in height. To accurately measure how genetically similar relatives are, one can measure the number of genetic markers they share. For example, Peter M. Visscher of the Queensland Institute of Medical Research in Australia recently reported that the heritability of height is 80 percent, based on 3,375 pairs of Australian twins and siblings. This estimate is considered to be unbiased, as it was based on a large population of twins and siblings and a broad survey of genetic markers. In the U.S., the heritability of height was estimated as 80 percent for white men. These estimates are well supported by another study of 8,798 pairs of Finnish twins, in which the heritability was 78 percent for men and 75 percent for women. Other studies have shown height heritability among whites to be even higher than 80 percent.

Because different ethnic populations have different genetic backgrounds and live in different environments, however, height heritability can vary from one population to another, and even from men to women. In Asian populations, the heritability of height is much lower than 80 percent. For example, in 2004 Miao-Xin Li of Hunan Normal University in China and his colleagues estimated a height heritability of 65 percent, based on a Chinese population of 385 families. In African populations, height heritability is also lower: 65 percent for the population of western Africa, according to a 1978 study by D. F. Roberts, then at Newcastle University in England, and colleagues. Such diversities in heritability are mainly due to the different genetic background of ethnic groups and the distinct environments (climates, dietary habits and lifestyle) they experience.

Heritability allows us to examine how genetics directly impact an individual's height. For example, a population of white men has a heritability of 80 percent and an average height of 178 centimeters (roughly five feet, 10 inches). If we meet a white man in the street who is 183 cm (six feet) tall, the heritability tells us what fraction of his extra height is caused by genetic variants and what fraction is due to his environment (dietary habit and lifestyle). The man is five centimeters taller than the average. Thus, 80 percent of the extra five centimeters, or four centimeters, is due to genetic variants, whereas one centimeter is due to environmental effects, such as nutrition.

Heritability can also be used to predict an individual's height if the parents' heights are known. For example, say a man 175 cm tall marries a woman 165 cm tall, and both are from a Chinese population with a population mean of 170 cm for men and 160 cm for women. We can predict the height of their children, assuming the heritability is 65 percent for men and 60 percent for women in this population. For a son, the expected height difference from the population mean is: 0.65 x [(175 - 170) + (165 - 160)] / 2, which equals 3.25 cm; for a daughter, the difference is 0.6 x [(175 - 170) + (165 - 160)] / 2, which equals 3 cm. Thus, the expected height of a son is 170 + 3.2, or 173.2 cm, and of a daughter 160 + 3, or 163 cm. On the other hand, environmental effects can add 1.75 cm to a son's height: 0.35 x [(175 - 170) + (165 - 160)] / 2, and 2 cm to a daughter's: 0.4 x [(175 - 170) + (165 - 160)] / 2. Of course, these predictions only reflect the mean expected height for each of the two siblings (brothers and sisters); the actual observed height may be different.

From these calculations, we realize the environment (mainly nutrients) can only change about 2 centimeters for a given offspring's height in this Chinese population. Does that mean that no matter what happens in the child's environment, the height can never change more than this? Can special treatment and nutrient supplements increase the height further? The answer is yes. The most important nutrient for final height is protein in childhood. Minerals, in particular calcium, and vitamins A and D also influence height. Because of this, malnutrition in childhood is detrimental to height. In general, boys will reach maximum height in their late teens, whereas girls reach their maximum heights around their mid-teens. Thus, adequate nutrition before puberty is crucial for height.

In addition, although diseases of childhood can inhibit ultimate stature, human growth hormone treatments can remedy such growth defects. Height accelerated by such treatment or special supplements, however, cannot be predicted based on heritability. There are two reasons: first, heritability has not been estimated in a growth hormone-treated population. Second, genes and growth hormones can interact synergistically to affect height, i.e., their effects may not be simply adding to each other but could be multiplying the ultimate effect.

The question remains, however, why different populations of a similar genetic background might have a differing heritability. The answer is, of course, environmental effects. When a given environment maximizes the genetic potential of a population for a given trait, this population tends to have a higher heritability for that trait, and vice versa. In developed countries, nutrition for childhood development is strong, which maximizes the genetic potential for height assuming no selection or new mutations. Thus, the overall heritability estimates tend to be higher, i.e., 80 percent. In contrast, in developing countries, nutrition deficits lead to a lower heritability. The fact that the mean height of the U.S. population has almost plateaued in the past decade suggests that the nutrient environment has almost maximized the genetic potential of height, at least in this country. Improved nutrition elsewhere may have similar benefits in terms of stature.

Dr. Chao-Qiang Lai has written this article in his personal capacity and the views expressed do not necessarily represent the views of the U.S. Department of Agriculture, Agricultural Research Service.

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