

# Height, Health, and Living Standards Conference Summary

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## Introduction

The purpose of the Height, Health, and Living Standards Conference, co-sponsored by the Center for Health and Wellbeing at Princeton University and the Behavioral and Social Research Program at the National Institute on Aging, was to bring together scholars who work on human height and its relationship to health, mortality and living standards. Taller people are healthier, live longer, earn more, and attain higher socioeconomic status. Numerous strands of research have examined different aspects of these associations. One line of research is on the long-term consequences of health and nutrition in childhood, as expressed by height, on mortality and economic status in adulthood. Another line of research uses height as a measure of living-standards, for the purposes of assessing changes in living standards over time and across countries. Researchers have also examined a range of issues at the micro level. Tall people earn more and have higher social status than short people, in rich countries as well as poor ones. Do returns to height reflect real productivity differences, are they a proxy for something else, or are they a phenomenon that is best explained by social psychologists?

Research on these issues comes from a variety of disciplines, including epidemiology, demography, history, and economics. Some research uses cross-country evidence; other research uses historical data, or contemporary micro data from wealthy or poor countries. Despite this diversity—or perhaps because of it—researchers studying height from different perspectives have a great deal to learn from each other’s work. A general goal of the meeting was to discuss findings that are common across the different strands of research, to pinpoint areas where there may be divergences of views or different interpretations of the evidence, and to discuss key research issues that have not yet been resolved.

To focus discussion, the conference was organized around four broad topics:

- the determinants of height
- height, health and mortality in adulthood
- height as a measure of living standards
- the economic consequences of height

For each topic, we invited two participants to start the discussion by providing brief overviews of relevant research. However, most of the conference was left for open discussion between the participants. All participants came prepared to discuss the theories that motivate their research, the most important pieces of evidence (from their own research or others’ research) that is relevant to each of the topics, and the major research questions that remain unanswered.

## Agenda

- 8:30-10:00 am      Session I: Childhood Determinants of Height  
Presenters: Noel Cameron and Reynaldo Martorell
- 10:30 am-12:00 pm      Session II: Height, Health and Mortality in Adulthood  
Presenters: David Barker and Dora Costa
- 1:00-2:30 pm      Session III: Height as a Measure of Living Standards Across  
Countries and Time  
Presenters: Sir Roderick Floud and Richard Steckel
- 3:00-4:30 pm      Session IV: Economic Consequences of Height  
Presenters: Anne Case and Jere Behrman

*The presenters have been asked to give short introductory remarks of no more than ten minutes to lead off discussion on each topic.*

## Attendees

Linda Adair	University of North Carolina
David Barker	University of Southampton
Jere Behrman	University of Pennsylvania
Noel Cameron	University of Loughborough
Anne Case	Princeton University
Dora Costa	MIT
Angus Deaton	Princeton University
Sir Roderick Floud	London Metropolitan University
Robert Fogel	University of Chicago
Bernard Harris	University of Southampton
John Komlos	University of Munich
Adriana Lleras-Muney	Princeton University
Trevon Logan	Ohio State University
Reynaldo Martorell	Emory University
Joel Mokyr	Northwestern University
Christina Paxson	Princeton University
Andrew Postlewaite	University of Pennsylvania
Daniel Silverman	University of Michigan
Burton Singer	Princeton University
Richard Steckel	Ohio State University
Richard Suzman	National Institute of Health
James Trussell	Princeton University
Hans-Joachim Voth	Universitat Pompeu Fabra

## Session I: Childhood Determinants of Height

Presenters: Reynaldo Martorell and Noel Cameron

### **Reynaldo Martorell: Early Childhood**

Reynaldo Martorell's presentation focused on the relationship between height, nutrition, and cognitive development in early childhood. He opened with a discussion on whether heights differ across countries because of genetic differences. The mean height of the well-off in developing countries hovers around the mean for developed countries, and social inequality is correlated with lower heights. The WHO Multicentre Growth Reference study examined children's growth in optimal environments in a number of different countries, with subjects who were restricted to children with optimal nutrition, breastfeeding, and healthcare. The study found that the mean heights of children from disparate countries were strikingly similar.

Malnutrition during the first few years of life is a major cause of low adult stature. UNICEF lists the causes of malnutrition to be, among other factors, insufficient access to food, inadequate child care, poor environments, and inadequate health services. These deficiencies lead to poor diets and infection, which can subsequently lead to malnutrition and death. Growth failure in utero and growth failure in the first two to three years of life contribute equal amounts to low adult stature. Children have very high nutritional needs per kilogram compared to adults, and are particularly sensitive to deficiencies.

Martorell coordinated a study in Guatemala that gave randomly assigned villages Atole, a protein supplement (for the treatment group), or Fresco (for the control group). Atole has 9g more protein than Fresco, and children given Atole consumed 100Kcal per day more than children given Fresco. Analysis showed that boys given Atole were 2.8cm taller as adults than boys given Fresco, while girls given Atole were 2.0cm taller. Children given Atole also had greater head circumference.

In relation to growth stunting, what happens early in life has a big effect later in life. Sixty-five percent of children with severe growth retardation at age 3 have low adult stature. In addition, the birth weight of the next generation is negatively correlated with stunting. Stunted women also have a high incidence of intrapartum cesareans, with highest risk being for very short women who have babies with large heads.

### **Noel Cameron: A Biological Approach to Determinants of Height**

Noel Cameron's presentation focused on the biological determinants of height. Determining height is a complex process, and is influenced by both genetics and the environment. Critical periods in human development that influence height are the intra-uterine period, infancy, childhood, pubertal initiation, and sexual maturity. There is an increasing correlation between childhood height and adult height, but the father/son and mother/daughter genetic relationship doesn't appear until ages four to six, then remains relatively constant between 0.6 and 0.7.

Cameron posited that roughly 40% of height is due to parental genetics and 60% is due to environmental factors. Environmental determinants include timing, magnitude and constancy, and environmental factors include social environment, economic environment, nutrition, physical activity, and health. Biological determinants of height

include genetics, the endocrine system, tempo of growth and body composition. Biologically, hormone release by the pituitary gland, which influences height, is triggered by the hypothalamus. This mechanism resides in the reptilian brain, which responds to environmental influences.

The tempo of human growth is related to linear dimensions, body composition, proportions, maturation, and sexual dimorphism. Adult size is related to the tempo of growth- developing early has no effect on stature, but is correlated with higher weight for height indices. Likewise, timing of sexual maturation has no effect on stature, but early sexual maturers with high central adiposity (abdominal fat) are significantly taller than early maturers with low central adiposity.

## **Discussion:**

Discussion opened with a question on the potential benefits of using methods such as DNA sequencing to more fully understand the roles of genetics and the environment. Noel Cameron noted that this would be difficult, because the determinants of growth are so complex. For instance, no child grows as fast as it could, but rather grows to a point where the costs are not too great. He suggested that there needs to be more literature on compensatory growth. In questioning on the 40%-60% split between genetics and environment, new studies examining identical twins that include information on both biological parents and foster parents were cited as promising.

Questions then turned to the connection between low birth weight, growth timing, and adult height. Reynaldo Martorell noted that low birth weights outside of the normal range are problematic, but that low birth weight within the normal range is not a predictor of low adult stature. Adolescent growth spurt (AGS) timing is viewed as significant because children with higher socioeconomic status (SES) reach their AGS earlier. However, it was noted that AGS timing is not a reliable predictor of adult stature unless it is combined with body fat measures. Growth timing is also important earlier in life because infants who exhibit catch-up growth can overshoot and gain too much weight. This can result in high abdominal fat, which is a risk factor later in life.

How does one define an optimal environment- is an environment optimal if it maximizes height while surviving? First, growth requires trade-offs between other things, such as reproduction, so height maximization is not an end in itself. Second, it is difficult to define optimal environments. Similarly, optimal growth can't be defined as maximum growth. For instance, breast-fed babies grow differently than bottle-fed babies. Breast-fed babies are chubbier, then thin out rapidly after 2 years. Here, the weight to length measures are more important than simple length measures.

Discussion next turned to height dispersion. Angus Deaton asked if and why height dispersion is greater in poor countries than in rich ones. Since societies in the past were poorer than ours today, were height dispersions greater then than they are currently? Dora Costa noted that in 1860, within-family height dispersion in the United States was greater than it is today. Much of the observed dispersion is due to a long left tail in height distributions in poor societies. Other participants commented that when the left tail of Trinidad's height distribution is cut off, the standard deviation falls from four to three

inches. Differences in height dispersion exist between populations in the same society as well- although US blacks and whites have similar mean heights, the standard deviation in heights among blacks is much higher. Richard Steckel cautioned that a more efficient way of looking at undernourished populations is to examine average height by class or occupation, because focusing on average height and standard deviation won't help in identifying problem areas or populations.

The bulk of the remaining discussion focused on the relationship between height and cognitive development. Height was cited as an acceptable measure of cognitive development when there are no direct measures available. The correlation between stunting and poor cognition is a result of their shared determinants- David Barker noted that the first thing an undernourished baby surrenders is movement, which results in a loss of cognitive stimulation. Micronutrients were cited as integral to cognitive development. For instance, there is clear evidence on the relationship between iodine deficiency and cretinism.

A question was raised about whether evidence exists on the effects of catch-up growth on brain development. There is support for the idea that the combined effects of nutrition supplements and stimulation can lead to improvements in cognitive skills. However, the earlier the intervention, the better. In studies on Korean children adopted in the United States, a difference was seen between children adopted before the age of two, and those adopted between two and five. Both groups benefited from being placed in richer environments, but, on average, early adoptees had IQ's 5 points higher than late adoptees.

A concern was raised that public health interventions aimed at undernourished children could aid in height but miss cognitive ability. It was noted that height matters, regardless of cognitive skills, in terms of obstetric risk and physical strength.

Historically, did the populations of the past have both worse height outcomes and worse cognitive outcomes due to undernourishment? Studies have shown that IQ scores have increased over time, and one paper claims that this is due to nutrition. There was some controversy over whether growth after age two predicts adult income and education. It was accepted, however, that early stunting has a much larger negative effect on cognitive development than later deprivation. Joel Mokyr noted that Martha Williams, a Northwestern graduate student, had written her dissertation on the premise that poorer populations in the past had worse cognitive outcomes due to deprivation, but was harshly criticized because some thought that she was equating poverty with low cognitive abilities. Angus Deaton raised a related question about how improved cognition relates to economic history and economic growth models. If innovation is driven by nutrition, could nutrition have driven periods of technological growth? Joachim Voth suggested that prior to 1900, lack of schooling could have been a bigger problem than lower cognitive abilities. Robert Fogel noted that it is not the smartest people who are smarter now than they were in the past, but the much greater number of people who are 'smart enough' to propel growth.

## Session II: Height, Health, and Mortality in Adulthood

Presenters: David Barker and Dora Costa

### **David Barker:**

David Barker's presentation focused on height, early nutrition, and health outcomes later in life. Height is shaped by genes and the condition of life. The fetal origins hypothesis posits that coronary heart disease (CHD), Type 2 diabetes, and hypertension originate in the developmental plasticity of the womb. There are two ways to identify disease risks: the older way, by identifying genetic defects, and the new model, which examines how the environment alters gene expression during critical periods.

Data from England and Wales show that counties with shorter average heights had higher incidence of stroke and CHD. Height has two components, prenatal and postnatal. Neonatal deaths reflect the mother's health status, whereas post-neonatal deaths are the result of being born into a world with infection and malnutrition. Stroke is related to neonatal mortality but not post-neonatal mortality, while heart disease is related to both.

A study conducted in Helsinki recorded height and weight measurements of 13,000 children in 1934-1944. Social conditions are known, as are hospitalizations later in life. Children who later developed stroke had below-average BMI at every stage, the socioeconomic conditions they were born into did not matter, and their mothers were short. Three pelvic measurements were taken of the mothers in the study. The conjugate measurement, which measures the pelvis from back to front, is a marker of a woman's early childhood. Smaller measurements reflect poor nutrition early in life. Children with mothers who have a conjugate measurement of less than 18cm have an increased risk for stroke and hypertension. Systems of the body are established early—one explanation of low stature is that poor protein in the mother can lead to poor protein in the baby, which can subsequently lead to an inability to grow.

In the study, men born small, who remained smaller and thinner before the age of two, had a higher risk of CHD. Smaller babies can have altered liver functions, leading to higher risk of CHD. In addition, maximum fetal renal growth occurs before 34 weeks of gestation. Individuals who were small at 34 weeks and have a smaller number of kidney units, but who grow a bigger body later, put their kidneys under strain. The smaller babies caught up in BMI after two years, but tempo of growth is what matters.

Barker described a cycle of inequality that leads to intergenerational health transfers. Mothers acquire metabolic incompetence in their infancy through deficient, unbalanced, and unvaried diets. In turn, the mother's fetus has slow growth, functional incapacity, and metabolic incompetence. The infant has continued slow growth, poor cognitive development, and metabolic incompetence. The child consumes excess calories and has an unvaried diet, leading to fat accumulation- this leads to adult risk factors for CHD, type 2 diabetes, and osteoporosis. In this way, women carry their own deficiencies to their offspring.

The "Stroke Belt" in the Southeast of the United States has a high incidence of stroke that can't be explained by studying people today, but can be explained by the metabolic incompetence of girls in the previous generation. This shows that it is necessary to look at intergenerational effects when studying health outcomes.

### **Dora Costa: Height, Health, and Mortality in Adulthood**

Dora Costa's presentation focused on height, health, and mortality in adulthood. She cited a 1984 Waaler study that shows that short people have a greater risk of all-cause mortality. Short people are also at greater risk from heart disease, whereas tall people are at greater risk from cancer. Costa cited earlier research that found that the shorter twin of a pair of identical twins was more likely to die from heart disease, whereas the taller one was more likely to die of cancer.

Data from Union Army veterans show that the tall were at a lower risk of death, although there may be an uptick in risk among the very tall. It is possible that this relationship exists due to shared environmental factors such as infectious disease, inflammation, and atherosclerosis and thrombosis. There may be direct effects of infectious diseases on organs that also affect height—for instance, reduced fetal height can lead to organ insufficiency.

There is a large literature on determinants of height. People from large cities or low socioeconomic classes tend to be shorter; there is a relationship between height and local ecology. In Union Army data, those born in the second quarter were shorter than those born in the first quarter. This is most likely due to insufficient maternal nutrition during the winter months of early pregnancy. Studies find that there was more within family height variation in the past than there is today. There is also a relationship between infection, diet, and stature. Height depends on net nutritional status, and poor diet can lead to infection, which can lead to greater nutritional needs even when healthy.

There are caveats to using height as a measure of wellbeing. For instance, the height-mortality relationship is a very large sample phenomenon. Sub-samples in Waaler don't show a height-mortality relationship, and the relationship between BMI and mortality shows up more consistently in small samples. Researchers need to move beyond heights to more direct and indirect measures of infectious disease and nutritional intake.

### **Discussion:**

Discussion opened with Jere Behrman asking why the male and female patterns are different in the Finnish data. David Barker responded that it is harder to throw a girl off of her linear height path. This is probably linked to the fact that boys grow faster and so might be more vulnerable to nutritional insults. It was well known that the babies who got rickets in the United States were the fast-growing ones, not the smaller ones. Even though girls may exhibit catch-up growth, the concern is that they could still have flat pelvises due to malnutrition in infancy. Women also have greater BMI catch-up. However, this can be a problem- being in the lowest third of BMI at age two and the highest third of BMI at age eleven is a strong predictor of heart disease.

Reynaldo Martorell raised the concern that it might be a public health dilemma to give undernourished children nutritional supplements, because it may be condemning them to chronic disease by encouraging obesity. David Barker answered that the Finnish data show that growth in length, weight, and BMI under the age of two reduces CHD. After two, the story is different, and the growth is compensatory. He does not see a public

health dilemma, but does note that a paper shows that the combination of birth weight and current waist circumference is an amazing predictor of CHD.

Next, John Komlos noted that Waaler doesn't control for socioeconomic status, and asked how much of the effect on height is due to biology and how much is due to socioeconomic status. Dora Costa responded that in the Union Army data, where she can't control for socioeconomic status, she still finds a relationship. She also noted that there is a lot of variation within socioeconomic categories. When asked how she was able to find height relationships in the Union Army data given such a small sample size, she responded that although she found one, a differently drawn sample might not.

Adriana Lleras-Muney asked how big the biological risk factors are versus behavioral risk factors, such as smoking. David Barker asserted that antenatal nutrition is more important than behavioral factors. He also noted that there has been a shift from thinking about chronic disease in terms of current factors to thinking about it in terms of factors established at birth.

Burt Singer asked about the part of the population who face a higher incidence of disease due to biological and nutritional risk factors, but who never develop stroke or heart disease. What is protective, and what can one do from a public health standpoint? David remarked that plasticity in utero and early childhood alters the metabolism and confers vulnerability to things later. Unfortunately, once you're developed, the only thing you can control is your behavior. In the Finnish data, those with lower incomes have a higher incidence of CHD. However, this relationship only holds in the quarter of men who were thin at birth, but not in the other three quarters of men. It was noted that there are many people in the lower strata don't develop stroke or CHD, and that what's protective for them may offer insight into what others can do.

A question was raised about the difference between being biologically short and short for environmental reasons. Do these people face different health outcomes? David Barker remarked that when an egg from one woman is implanted into another, the size of the baby is unrelated to the donor mother, but is related to the birth mother.

Subsequently, Richard Steckel asked how close we are to designer health care and health therapies. Can we investigate and design therapies for individuals? David Barker responded by saying that there is a body of evidence that shows response to hypertensive medications is conditioned by early development. It is also clear that peri-conceptual diet is very important, and may be more important than diet during pregnancy. In order to tailor diets and therapies to individuals, one would need to examine gene expression and have a comprehensive history of a person.

It was noted that the correlation between within-sex pairs of parental and child height is not as great as expected, especially the correlation with mother's height. David Barker noted that within sex correlations are fairly high, and increase significantly over the first three years of a child's life to reach a level of 0.6-0.7. A related question was asked about what proportion of inheritance is a result of the mother's own environmental conditions. Barker responded that it is not known, and that examining gene expression is currently a bigger question.

Based on the idea that kidney and liver function is related to CHD and other adult diseases, it was noted that examining whether changes in kidney and liver size as a result of pelvic constriction have the same result as changes due to some other effect. David

Barker responded that a large body of knowledge links hypertension to fetal kidney cells, but it is unclear what in the mother triggers kidney underdevelopment.

Next, the effect of seasonality on height and health was discussed. Dora Costa noted that in the Union Army data, being born in the 2<sup>nd</sup> quarter was associated with negative height outcomes versus being born in the 4<sup>th</sup> quarter. This is likely because women who gave birth in the spring faced more restricted nutrition intake while pregnant during the winter. This effect is much smaller in data from 1960-1980. There is also a negative effect on height associated with being born in the 3<sup>rd</sup> quarter in the Union Army data, because the summer is a time of high rates of infectious disease, but not in more recent data. This may be due to being born into a season with high summer diarrhea, although there was some argument about whether this was actually the cause. Karen Rolf, et al, who use data from 1900-1930, find a seasonal effect for people born in the 1920's but not for people born later. Anne Case noted that earlier research found that Austrian men born in the spring were 0.6cm taller than those born in the fall. A question was raised about whether we know which in utero deprivations matter for which outcomes. David Barker responded that we don't, but that the thinking must include timing. Critical periods for different organs occur at different times, so it depends on the nature of the insult and timing. People conceived during the Dutch Famine were worse off than those conceived before or after. Variations in the supply of nutrients from healthy mothers to healthy babies can also have huge effects.

A question was posed about whether data exist from randomized interventions for perinatal nutrition and long-term health outcomes. The Dutch Famine was cited as an unfortunate natural experiment. However, there are data limitations, and a randomized trial can be a blunt instrument. Researchers need to address issues of individual vulnerability- this would also have good commercial potential. Another natural experiment could have been occupation policy in Germany after WWII. The zone of occupation could have had a large effect, because the Americans fed their occupied populations better than did the French.

Chris Paxson asked about the effects of prenatal smoking. David Barker replied that the issue is overblown, and that there are high rates of heart disease among women in Southern India where smoking is almost non-existent. He noted that nutrition has a far greater effect than smoking. Although smoking reduces the oxygen delivered to a baby, he stated that no one has found that smoking during pregnancy has long-term health consequences. Anne Case noted that she and Chris Paxson find that smoking during pregnancy has an effect on test scores at ages 5, 7, 10, and 11, but Barker replied that it may not be a direct consequence. Case countered, citing studies on prenatal nicotine exposure in animals, and saying that smoking creates hypoxia in fetuses, but Barker pointed out that seal fetuses have the ability to regulate oxygen when their mothers dive.

Turning the discussion back toward seasonal effects, James Trussell then asked whether different types of people tended to become pregnant at different times, which may explain why height outcomes varied seasonally in the Union Army data. Dora Costa noted that she found no observable characteristics in the data that showed prenatal sorting. David Barker explained that stem cell allocation begins even before embryonic implantation in the uterus. These allocations are hugely related to environment. The fetus is its most sensitive at the beginning, but it is not known how sensitive the human egg is even before fertilization. Richard Steckel pointed out that the survival of slaves varied

profoundly with season of birth, and that the worst time to be conceived was in the late winter or early spring.

On a related note, Adriana Lleras-Muney asked why women who have severe morning sickness early in pregnancy still have healthy babies. David Barker explained that if the mother is well-nourished at conception, then stops eating, the baby can enlarge the placenta to get more nutrients flowing through. This is similar to the strategy for raising large lambs. Farmers ensure that a ewe has high pre-conception nutrition, deprives the ewe of nutrition early in pregnancy, then moves the ewe to more abundant pastures later in pregnancy. Barker also noted that modest insults to diet of pregnant ewes have long-term effects, but that the most dramatic experiments have been on mice. Mice whose mothers were undernourished one day before and one day after conception had serious negative effects.

## Session III: Height as a Measure of Living Standards across Countries and Time

### **Sir Roderick Floud:**

Sir Roderick Floud's presentation focused on the historical use of height as a measure of wellbeing. There is a history of attempts to measure economic and social welfare. The new "Happy Planet Index," for example, takes into account measures of environmental footprint, life expectancy, and happiness. The use of heights fits into this tradition of initially ridiculed measures that slowly gain acceptance.

Height was first used as an explainer for mortality, but was subsequently used as a proxy for conventional monetized standard of living indices, such as GDP per capita. Waaler and Barker's use of anthropometric measures shifted height's use back to a measure of morbidity and mortality. More recently, there is a concern with BMI and obesity, and a parallel literature examining the relationship between height, health, and productivity in developing societies. One shortcoming in research on height is the failure to develop a standard vocabulary.

There are a number of advantages of using height as a standard of living. It is much easier to measure than monetized indices, even when using truncated military datasets. It is also easier to compare between different male societies between time and space. There are no exchange rates and no PPP, and it reflects non-monetary activities such as leisure. Height is well correlated with life expectancy and health outcomes during lifetimes. There are links between height and labor productivity, and height is a good measure of both labor and social mobility.

However, there are also disadvantages of height as a measure. Height can't be used as a simple proxy for monetized measures. Heights declined while real wages were improving in Britain during the Industrial Revolution- pollution and living conditions are also an issue. Even when trends in height data are clear, attribution of underlying causes is difficult. Disentangling causation of changes in heights is almost impossible. In addition, change in height is an intergenerational phenomenon. Changes between cohorts are limited, and it takes several generations of immigrants to obtain the characteristics of a host population. Finally, height won't vary over short periods sufficiently to be used as a measure of short-term changes in living standards.

Height is significant in measuring long-term changes in history. Researchers need to look at generational change, physical capacity, and health and human capital capabilities on the long-term development of economy.

### **Richard Steckel**

Richard Steckel opened his presentation by posing the question: why are some regions rich and healthy while others are poor and unhealthy? Geographic determinism, touted by scholars such as Huntington, Diamond, and Sachs, is one explanation. Another explanation is that it is due to effects of human creations, technology, institutions, and law, an idea supported by Becker, Landes, North, and Acemoglu. A lab to study these

ideas can be found in height data over time. There is height data for over 300 years, and skeletons before that.

There are many determinants and consequences of height. Determinants include socioeconomic status, diet, disease, and genetics. Stature affects mortality and morbidity outcomes. Growth velocity, highest under age three and during the adolescent growth spurt, can be compressed by famine and disease. Adult heights capture many diverse sources- from the mother's health through adulthood- which makes them hard to analyze.

There are patterns in height across countries. The relationship between average height and per capita GDP is non-linear; height is a better measure of deprivation than opulence. Average height versus life expectancy is a more linear trend. We have 1200 years of adult male height trends in Northern Europe that show that height was greatest in the early middle ages, when there was a warmer climate, and reached a minimum in the Little Ice Age of the 17<sup>th</sup> and 18<sup>th</sup> centuries.

It is possible to use skeletons to measure height. Femur length can be used to approximate height, and determine age and sex. Body proportions change as people get taller, and elasticity of leg length is greater than that for height. Deprivation can also be seen through various skeletal characteristics, such as dental hypoplasia. Anemia is reflected in the eye orbits, and certain specific diseases are evidenced in bone.

A study Steckel has completed using skeletons shows that Native Americans in the Great Plains were tall, but there were huge differences between tribes. Buffalo provided a protein source, and ecological conditions such as rainfall, education, biomass, and exposure to disease were all relevant for heights of various regions. The transition to reservations was beneficial to height, possibly because of peace.

Height records also show that during industrialization, soldiers in the United States and Britain exhibited declining heights, but the Dutch and French did not. It appears that early industrializers paid a bigger price than late ones.

## **Discussion:**

Discussion began with a question about why heights fell as incomes rose during the Industrial Revolutions of Britain and the United States. One possible cause of the discrepancy is that trade barriers were lowered as incomes rose, possibly leading to the spread of disease. In the United States, the spread of schools meant that children were exposed to diseases such as diphtheria that could have led to stunting. In addition, there was a growth in income inequality when heights declined. This signified growing poverty and a growing share of vulnerable people. Rising food prices were also given as an explanation. Roderick Floud cautioned that instead of asking what's wrong with height as a measure, one could also ask what's wrong with other measures such as GDP. Real wage data have moved around as much as height.

Discussion turned to what decreasing height trends can tell us about standards of living. This depends on the period. It was noted that there are limitations in examining changes in height- researchers are in danger of seeing deviations then finding an explanation without taking generational changes into account. It was suggested that the critical periods for growth are in utero and in the first two years of life, and this is the place where one should look for explanations of height declines. While it is possible that

improvements in SES can lead to catch-up, socioeconomic conditions have substantial inertia and seldom greatly improve.

In reference to working with skeletons, a question was asked about how reliably height can be predicted solely from femur length. It was observed that certain nutritional insults can lead to relatively longer torsos. Given this, is it clear that the relationship between femur length and height holds constant through the centuries? Noel Cameron noted that data on leg length from Japan showed that increases in Japanese height were the result of lengthening of the tibia, rather than the femur. This was a result of the in utero allocation between the leg and brain.

Trevon Logan asked whether it is possible to model and rank the factors that could be important to determining height at any particular point in the life cycle. Identifying sensitive periods can limit the possibilities, and it is important to speak with physicians and biologists about what may be important. However, the identification problem may never be resolved. Richard Steckel suggested that implantable microchips that collect biological measurements on a routine basis are being developed and could be used for this purpose.

In response to a question from Dan Silverman about skeletons, Richard Steckel responded that he hopes to study 300,000 skeletons. There are over one million skeletons available for study in Europe, many of them with complete archaeological information. Skeletons without context are useless, but it is possible to glean information from tree rings and GIS data, and construct a package of information. He is trying to get detailed information on 75,000 skeletons in Europe.

Roderick Floud's point about height being useless for short-term analysis was challenged. It was noted that children's heights are very sensitive to short-term changes in conditions. Richard Steckel noted that David Barker's work gave new meaning to the relationship between height and standard of living, not only in childhood, but also what it can tell us about conditions later in life. It is one single number that measures net nutrition in childhood and predicts quality of life in adulthood. Floud commented that by using data on children one may learn something from short-term movements, but that the more one learns about intergenerational effects, the more difficult it is to determine effects on children. It was noted that height trends raise a number of questions that help direct research. The use of height by age and weight by age measures of public health was the result of work by medical biologists after WWII on third world countries. Twenty years later, economists began examining life span and its predictive value. Richard Suzman noted that given how much science has changed over the last fifteen years, with genome sequencing and the many studies done using DNA, the fact that there are no identified height genes is puzzling. David Barker later responded that although genomic discoveries have not yet had an effect on biologists understanding of the field, it will in the future.

Burton Singer asked whether Richard Steckel had evidence on plains Indians that goes back before European invasions. Richard responded that he does, and that there is enormous variation in height across the Western hemisphere. Mayans in Southern Mexico and the Anasazi in the American Southwest were the shortest, whereas plains Indians were the tallest, probably due to the buffalo, a high protein diet, local vegetation, and trade among tribes. The best place to live may have been coastal Brazil, where there was abundant seafood and the skeletons showed very few lesions and good dental health.

Richard Steckel noted that the huge inequality that must have existed in Mayan civilization to leave such enormous monuments contributed to their short stature. The same pattern exists worldwide among populations that left monuments.

Burt Singer then asked Richard Steckel whether he has linked his skeletal databases with Andy Cliff's infectious disease history database. Richard responded that he hasn't, but that he can get information on tuberculosis from skeletons. He noted that there is a huge frontier in skeletal biology. It may be possible to extract biochemical information from skeletons that tells something about diet.

Reynaldo Martorell noted that height can be a good indicator of short-term standard of living. It is in fact a preferred indicator for tracking millennium development goals since weight can be confounded by childhood obesity. He cautioned against overemphasizing intergenerational effects. He referred to his table that shows that despite enormous variation in maternal heights, birth length is very similar across populations.

Joel Mokyr commented that the apparently paradoxical relationship between declining heights and increasing wages is not actually difficult to explain, but is what should be expected. There is a high compensation differential between field labor and coal mine labor, but coal mines are a much less healthy environment. Wage increases are a result of paying people to move to less pleasant environments. It was noted that infant mortality can also increase as incomes rise due to things like breastfeeding practices. David Barker noted that this might be related to intergenerational effects. There was a decline in neonatal mortality in 1900, when there were no obvious changes in standard of living. However, changes 25 years earlier can explain the decline.

## Session IV: Economic Consequences of Height

Presenters: Anne Case and Jere Behrman

### **Anne Case: Height and Labor Market Earnings**

Anne Case's presentation focused on the relationship between height and labor market earnings, occupational choice, and cognitive ability. Many studies have shown that taller people earn more and hold higher status jobs. Case cited earlier research that reported that executives were taller than average workers. Even within occupations, taller men hold higher status jobs. In the US today, white collar workers are ½ to 1 inch taller than blue collar workers. In the UK, data from the 1970 British Cohort Study show that professionals and managers are much taller than manual laborers. Regressions with log earning and height show a 2.5% wage premium for every inch of height. In developing countries, the height premium is thought to reflect strength, whereas in developed countries, social scientists have pegged the height premium to self esteem and labor market discrimination.

Height is also linked with cognitive ability. Literature spanning a century shows a correlation between height and intelligence, although the precise links are not understood. Nutrition, chemical connections, the uterine environment, and genetics are all possible mechanisms linking height and cognition. There is also a tension in the literature about whether teachers discriminate in favor of tall children. Even before schooling, however, height is related to cognitive ability. Longer infants perform better at processing information. At age 3, taller children perform better on verbal tests, and this is true throughout childhood. Research Case cited showed that cognitive ability is correlated with growth at the two points of highest velocity.

Anne's current study with Chris Paxson, analyzes data from the 1970 BCS, which included tests for cognitive ability, such as the EPVT, figure drawing, and copy design. Even including a rich set of SES controls (parents' class at birth, parents' education and height, prenatal smoking, low birth weight) a significant relationship between height and cognition remains. In the Fragile Families data, there is a link between height and cognitive ability even when controlling for all of these SES variables and the mother's PPVT score.

Cognitive ability predicts labor market outcomes. In the BCS, there is a significant correlation between height at age 30 and earnings. However, this relationship disappears when test scores are included. In the 1958 birth cohort, height is not significant when test scores are controlled for. Height is also related to occupational choice. Using the Dictionary of Occupational Titles, each occupation was assigned a strength and intelligence score. One added inch in height makes a person 9.5% more likely to be in a professional occupation. Taller people sort out of jobs that require strength and into jobs that require intelligence.

### **Jere Behrman.- Consequences of height in developing countries**

Jere Behrman's presentation focused on the consequences of height in developing countries. Many studies examine the relationship between height and wages. A 1997 study showed that a 1% increase in height leads to a 2.4% increase in wages. Height is associated with wages in developing countries for both men and women who work in the market sector. This leads to the question about what height is representing—it could reflect strength, it could serve as a signal to employers of productivity, or it could reflect the impact of early childhood nutrition on productivity that works through cognitive development, schooling investments. He noted, however, that the association of height with wages is small relative to its association with some other variables. For example, the estimated effect of literacy on wages has been estimated to be equivalent to a gain in height of 30 centimeters (over 11 inches).

Behrman then turned to his new analysis on data from a randomized nutritional intervention in Guatemala. The intervention was conducted in 1969-77 with children between the ages of 0 and 7. These children have been followed up periodically, most recently when they were between the ages of 25 and 41. OLS regressions show that schooling and adult height have significant associations with wages in this population. In instrumental variable regressions that use the original assignment to treatment or control groups and other variables as instruments, schooling appears more important and height becomes insignificant. In IV models that include reading comprehension, schooling and height as (endogenous) explanatory variables, only reading comprehension skills are positively correlated with wages. Reading comprehension skills appear to be most important for hours worked and income per hour, although muscular strength is also correlated with income per hour.

This analysis indicates that height, in itself, is not significantly associated with wages or productivity. A tentative conclusion is that height represents other things that do affect productivity—for example, early childhood nutrition may affect wages through improvements in reading comprehension scores.

### **Discussion:**

Discussion started with comments about the methodology of analysis relating height, cognitive ability, and SES. The use of propensity matching instead of IV regressions was suggested for Jere Behrman's paper. Angus Deaton explained that propensity matching requires a different set of assumptions, but that IV is worse because one can only pretend to control for unobservables. With matching, at least you know what you're converging to.

Noel Cameron noted that almost all child growth data adjusts for maturation, and asked whether Anne Case's historical height measures do this. Anne responded that the children were only measured at particular points in time, so this was not possible. She explained that girls reach their adolescent growth spurts earlier than boys, so that healthier girls had done much of their growing before age 11. Girls who pick up a greater amount of height after age 11 had significantly lower scores on cognitive ability tests in

early childhood. Even the healthiest boys had yet to reach their AGS by age 11. Boys who picked up height between ages 11 and 16 score well on early tests, but boys who pick up more between 16 and 33 (i.e. those with late onset AGS) perform the poorest on tests. There is limited data, however, on physical maturation. Case noted that children from higher social classes are always taller, but children from lower classes partially catch up after 16.

Linda Adair observed that a life-course perspective is used in many papers, wherein a small child is perceived as more fragile, starts school later and performs poorly on tests. Parental investment then starts changing, with the tallest and brightest children getting more encouragement. The papers presented are taking points in time instead of looking at full life-course data. David Barker remarked that there are two models- Adair's "accumulation of misery" model, and a model of chronic disease that looks at switches. If a child grows well pre-birth and 1 year after birth, income later in life doesn't matter in terms of disease.

Linda Adair noted that height is now becoming a requirement in developing countries for jobs in the public view, such as sales-people. English is also a growing requirement, and English scores are highly correlated to height, IQ, and future earnings. In addition, there is no relationship between BMI and physically demanding jobs- cognitive abilities have a greater effect. Reynaldo Martorell commented that rural occupations are becoming much more diversified, and no longer solely require physical labor. Anne Case noted the literature in psychology and economics that claim a link between height and esteem, but said that in reality lawyers really are taller than shopkeepers, which could be why lawyers are perceived as taller.

Reynaldo Martorell asked about the state of the discussion on the use of instrumental variables. Angus Deaton explained that although people are divided into camps, opinions are changing in favor of non-IV estimators. If the response one's looking at is heterogeneous across units, IV estimates converge on the choice of an instrument, so the choice in instrument will give you different estimates every time. Even with genuine random numbers, bias is possible. Short of randomized control trials, it is impossible to control for unobservable variables.

Rick Steckel asked about income within occupations, and suggested that using longitudinal data, one could examine the heights of who gets promoted.

Joel Mokyr noted that we have very little way of knowing about the intelligence of people in the past. Is it justified to say that cognitive skills have improved over time as a result of improved nutrition? Joachim Voth cautioned against testing the limits of this logic, as one could imply that since taller people have more sexual partners, people 500 years ago never reproduced. In conclusion, Mokyr commented that at least short people have the advantage when traveling on airplanes.