A century of trends in adult human height
NCD Risk Factor Collaboration (NCD-RiS-C)*

Abstract

Being taller is associated with enhanced longevity, and higher education and earnings. We reanalysed 1472 population-based studies, with measurement of height on more than 18.6 million participants to estimate mean height for people born between 1896 and 1996 in 200 countries. The largest gain in adult height over the past century has occurred in South Korean women and Iranian men, who became 20.2 cm (95% credible interval 17.5–22.7) and 16.5 cm (13.3–19.7) taller, respectively. In contrast, there was little change in adult height in some sub-Saharan African countries and in South Asia over the century of analysis. The tallest people over these 100 years are men born in the Netherlands in the last quarter of 20th century, whose average heights surpassed 182.5 cm, and the shortest were women born in Guatemala in 1896 (140.3 cm; 135.8–144.8). The height differential between the tallest and shortest populations was 19-20 cm a century ago, and has remained the same for women and increased for men a century later despite substantial changes in the ranking of countries.

DOI: 10.7554/eLife.13410.001

Introduction

Being taller is associated with enhanced longevity, lower risk of adverse pregnancy outcomes and cardiovascular and respiratory diseases, and higher risk of some cancers (Paajanen et al., 2010; Emerging Risk Factors Collaboration, 2012; Green et al., 2011; Nelson et al., 2015; Batty et al., 2010; World Cancer Research Fund / American Institute for Cancer Research, 2007, 2010; 2011; 2012; 2014a; 2014b; Nüesch et al., 2015; Davies et al., 2015; Zhang et al., 2015; Kozuki et al., 2015; Black et al., 2008). There is also evidence that taller people on average have higher education, earnings, and possibly even social position (Adair et al., 2013; Stulp et al., 2015; Barker et al., 2005; Strauss and Thomas, 1998; Chen and Zhou, 2007; Case and Paxson, 2008).

Although height is one of the most heritable human traits (Fisher, 1919; Lettre, 2011), cross-population differences are believed to be related to non-genetic, environmental factors. Of these, foetal growth (itself related to maternal size, nutrition and environmental exposures), and nutrition and infections during childhood and adolescence are particularly important determinants of height during adulthood (Cole, 2000; Silventoinen et al., 2000; Dubois et al., 2012; Haeffner et al., 2002; Sørensen et al., 1999; Victora et al., 2008; Eveleth and Tanner, 1990; Tanner, 1962; Tanner, 1992; Bogaert, 2013). Information on height, and its trends, can therefore help understand the health impacts of childhood and adolescent nutrition and environment, and of their social, economic, and political determinants, on both non-communicable diseases (NCDs) and on neonatal health and survival in the next generation (Cole, 2000; Tanner, 1992; Tanner, 1987).

Trends in men’s height have been analysed in Europe, the USA, and Japan for up to 250 years, using data on conscripts, voluntary military personnel, convicts, or slaves (Cole, 2000; Floud et al., 1990; Fogel et al., 1983; Schmidt et al., 1995; Floud et al., 2011; Tanner et al., 1982; Hatton and Bray, 2010; Tanner, 1981; Facchini and Gualdi-Russo, 1982). There are fewer historical data for women, and for other regions where focus has largely been on children and where adult data tend to be reported at one point in time or over short periods (Subramanian et al., 2011; Grasburger et al., 2014; Baten and Blum, 2012; Deaton, 2007; Mamidi et al., 2011; van Zanden et al., 2014). In this paper, we pooled worldwide population-based data to estimate height in adulthood for men and women born over a whole century throughout the world.
Results

We estimated that people born in 1896 were shortest in Asia and in Central and Andean Latin America (Figure 1 and Figure 2). The 1896 male birth cohort on average measured only 152.9 cm (credible interval 147.9–157.9) in Laos, which is the same as a well-nourished 12.5-year-old boy according to international growth standards (de Onis et al., 2007), followed by Timor-Leste and Guatemala. Women born in the same year in Guatemala were on average 140.3 cm (135.8–144.8), the same as a well-nourished 10-year-old girl. El Salvador, Peru, Bangladesh, South Korea, and Japan had the next shortest women. The tallest populations a century ago lived in Central and Northern Europe, North America, and some Pacific islands. The height of men born in Sweden, Norway, and the USA surpassed 171 cm, ~18–19 cm taller than men in Laos. Swedish women, with average adult height of 160.3 cm (158.2–162.4), were the tallest a century ago and 20 cm taller than women in Guatemala. Women were also taller than 158 cm in Norway, Iceland, the USA, and American Samoa.

Changes in adult height over the century of analysis varied drastically across countries. Notably, although the large increases in European men’s heights in the 19th and 20th century have been highlighted, we found that the largest gains since the 1896 birth cohort occurred in South Korean women and Iranian men, who became 20.2 cm (17.5–22.7) and 16.5 cm (13.3–19.7) taller, respectively (Figure 3, Figure 4, and Figure 5). As a result, South Korean women moved from the fifth shortest to the top tertile of tallest women in the world over the course of a century. Men in South Korea also had large gains relative to other countries, by 15.2 cm (12.3–18.1). There were also large gains in height in Japan, Greenland, some countries in Southern Europe (e.g., Greece) and Central Europe (e.g., Serbia and Poland, and for women Czech Republic). In contrast, there was little gain in height in many countries in sub-Saharan Africa and South Asia.

The pace of growth in height has not been uniform over the past century. The impressive rise in height in Japan stopped in people born after the early 1960s (Figure 6). In South Korea, the flattening began in the cohorts born in the 1980s for men and it may have just begun in women. As a result, South Korean men and women are now taller than their Japanese counterparts. The rise is
continuing in other East and Southeast Asian countries like China and Thailand, with Chinese men and women having surpassed the Japanese (but not yet as tall as South Koreans). The rise in adult
height also seems to have plateaued in South Asian countries like Bangladesh and India at much lower levels than in East Asia, e.g., 5–10 cm shorter than it did in Japan and South Korea.

**Figure 2.** Adult height for the 1896 and 1996 birth cohorts for women. See www.ncdrisc.org for interactive version.

DOI: 10.7554/eLife.13410.004
There were also variations in the time course of height change across high-income western countries, with height increase having plateaued in Northern European countries like Finland and in...
Figure 4. Height in adulthood for the 1896 and 1996 birth cohorts for men. The open circle shows the adult height attained by the 1896 birth cohort and the filled circle that of the 1996 birth cohort; the length of the connecting line represents the intervening years.
English-speaking countries like the UK for 2–3 decades (Larnkaer et al., 2006; Schönbeck et al., 2013), followed by Eastern Europe (Figure 7). The earliest of these occurred in the USA, which was one of the tallest nations a century ago but has now fallen behind its European counterparts after having had the smallest gain in height of any high-income country (Tanner, 1981; Komlos and Lauderdale, 2007; Komlos and Baur, 2004; Sokoloff and Villaflor, 1982). In contrast, height is still increasing in some Southern European countries (e.g., Spain), and in many countries in Latin America.

As an exception to the steady gains in most countries, adult height decreased or at best remained the same in many countries in sub-Saharan Africa for cohorts born after the early 1960s, by around 5 cm from its peak in some countries (see for example Niger, Rwanda, Sierra Leone, and Uganda in Figure 8). More recently, the same seems to have happened for men, but not women, in some countries in Central Asia (e.g., Azerbaijan and Uzbekistan) and Middle East and North Africa (e.g., Egypt and Yemen), whereas in others (e.g., Iran) both sexes continue to grow taller.

Men born in 1996 surpass average heights of 181 cm in the Netherlands, Belgium, Estonia, Latvia and Denmark, with Dutch men, at 182.5 cm (180.6–184.5), the tallest people on the planet. The gap with the shortest countries – Timor-Leste, Yemen and Laos, where men are only ~160 cm tall – is 22–23 cm, an increase of ~4 cm on the global gap in the 1896 birth cohort. Australia was the only non-European country where men born in 1996 were among the 25 tallest in the world. Women born in 1996 are shortest in Guatemala, with an average height of 149.4 cm (148.0–150.8), and are shorter than 151 cm in the Philippines, Bangladesh and Nepal. The tallest women live in Latvia, the Netherlands, Estonia and Czech Republic, with average height surpassing 168 cm, creating a 20 cm global gap in women’s height (Figure 5).

Male and female heights were correlated across countries in 1896 as well as in 1996. Men were taller than women in every country, on average by ~11 cm in the 1896 birth cohort and ~12 cm in the 1996 birth cohort (Figure 9). In the 1896 birth cohort, the male-female height gap in countries where average height was low was slightly larger than in taller nations. In other words, at the turn of the 20th century, men seem to have had a relative advantage over women in undernourished compared to better-nourished populations. A century later, the male-female height gap is about the same throughout the height range. Changes in male and female heights over the century of analysis were also correlated, which is in contrast to low correlation between changes in male and female BMIs as reported elsewhere (NCD Risk Factor Collaboration, 2016).

Change in population mean height was not correlated with change in mean BMI (NCD Risk Factor Collaboration, 2016) across countries for men (correlation coefficient = −0.016) and was weakly inversely correlated for women (correlation coefficient = −0.28) (Figure 10). Countries like Japan, Singapore and France had larger-than-median gains in height but little change in BMI, in contrast to places like the USA and Kiribati where height has increased less than the worldwide median while BMI has increased a great deal.

**Discussion**

We found that over the past century adult height has changed substantially and unevenly in the world’s countries, with no indication of convergence across countries. The height differential between the tallest and shortest populations was ~19 cm for men and ~20 cm for women a century ago, and has remained about the same for women and increased for men a century later despite substantial changes in the ranking of countries in terms of adult height.

Data from military conscripts and personnel have allowed reconstructing long-term trends in height in some European countries and the USA, albeit largely for men, and treating it as a ‘mirror’ to social and environmental conditions that affect nutrition, health and economic prosperity, in each generation and across generations (Tanner, 1987; Fogel, 2004; Komlos, 2009; Martins et al., 2014; Martorell, 1995). Our results on the large gains in continental European countries, and that
Figure 5. Height in adulthood for the 1896 and 1996 birth cohorts for women. The open circle shows the adult height attained by the 1896 birth cohort and the filled circle that of the 1996 birth cohort; the length of the
they have overtaken English-speaking countries like the USA, are consistent with these earlier studies although these earlier analyses covered fewer countries in Eastern and Southern Europe, and used some self-reported data with simple adjustments that cannot fully correct for their bias (Hatton and Bray, 2010; Facchini and Gualdi-Russo, 1982; Baten and Blum, 2012).

Less has been known about trends in women’s height, and those in non-English-speaking/non-European parts of the world. We found that some of the most important changes in height have happened in these under-investigated populations. In particular, South Korean and Japanese men and women, and Iranian men, have had larger gains than European men, and similar trends are now happening in China and Thailand. These gains may partially account for the fact that women in Japan and South Korea have achieved the first and fourth highest life expectancy in the world (see also below). In contrast to East Asia’s impressive gains, the rise in height seems to have stopped early in South Asia and reversed in Africa, reversing or diminishing Africa’s earlier advantage over Asia. Prior

---

**Figure 6.** Trends in height for the adult populations of selected countries in Asia. The solid line represents the posterior mean and the shaded area the 95% credible interval of the estimates. The points show the actual data from each country, together with its 95% confidence interval due to sampling. The solid line and shaded area show estimated height at 18 years of age, while the data points show height at the actual age of measurement. The divergence between estimates and data for earlier birth cohorts is because participants from these birth cohorts were generally older when their heights were measured.

DOI: 10.7554/eLife.13410.008
studies have documented a rise in stunting in children in sub-Saharan Africa which continued to the mid-1990s (Stevens et al., 2012). Our results indicate that such childhood adversity may have carried forward to adulthood and be affecting health in the region. The early African advantage over Asia may also have been partly due to having a more diverse diet compared to the vegetable and cereal diet in Asia, partly facilitated by lower population density (Deaton, 2007; Moradi, 2010). Rising population, coupled with worsening economic status during structural adjustment, may have undermined earlier dietary advantage (Stevens et al., 2012; Pongou et al., 2006; Weil et al., 1990; Sundberg, 2009).

The main strengths of our study are its novel scope of estimating a century of trends in adult height for all countries in the world and for both sexes. Our population-based results complement the individual-level studies on the genetic and environmental determinants of within-population variation in height, and will help develop and test hypotheses about the determinants of adult height, and its health consequences. We achieved this by using a large number of population-based data sources from all regions of the world. We put particular emphasis on data quality and used only population-based data that had measured height, which avoids bias in self-reported height. Data were analysed according to a common protocol before being pooled, and characteristics and quality of data sources were verified through repeated checks by Collaborating Group members. Finally, we pooled data using a statistical model that could characterize non-linear trends and that used all available data while giving more weight to national data than to subnational and community surveys.
Although we have gathered an unprecedentedly comprehensive database of human height and growth, and have applied a statistical model that maximally utilizes the information in these sources, data in some countries were rather limited or were from community or sub-national studies. This is reflected in larger uncertainty of the estimated height in these countries. To overcome this, surveillance of growth, which has focused largely on children, should also systematically monitor adolescents and adults given the increasingly abundant evidence on their effects on adult health and human capital. Even measured height data can be subject to measurement error depending on how closely study protocols are followed. Finally, we did not have separate data on leg and trunk lengths, which may differ in their determinants, especially in relation to age at menarche and pre- vs. post-pubertal growth and nutrition, and health effects (Tanner et al., 1982; Frisch and Revelle, 1971).

Greater height in adulthood is both beneficially (cardiovascular and respiratory diseases) and harmfully (colorectal, postmenopausal breast and ovarian cancers, and possibly pancreatic, prostate and premenopausal breast cancers) associated with several diseases, independently of its inverse correlation with BMI (Paajanen et al., 2010; Emerging Risk Factors Collaboration, 2012; Green et al., 2011; Nelson et al., 2015; Batty et al., 2010; World Cancer Research Fund / American Institute for Cancer Research, 2007, 2010, 2011; 2012; 2014a; 2014b; Nüesch et al., 2015; Davies et al., 2015; Zhang et al., 2015). If the associations in epidemiological studies are causal, which is supported by the more recent evidence from Mendelian randomisation studies (Green et al., 2011; Nüesch et al., 2015; Davies et al., 2015; Zhang et al., 2015), the ~20 cm
height range in the world is associated with a 17% lower risk of cardiovascular mortality and 20–40% higher risk of various site-specific cancers, in tall versus short countries. Consistent with individual-level evidence on the association between taller height and lower all-cause mortality in adult ages (Emerging Risk Factors Collaboration, 2012), gains in mean population height in successive cohorts are associated with lower mortality in middle and older ages in countries with reliable mortality data (correlation coefficient = −0.58 for men and −0.68 for women) (Figure 11), demonstrating the large impacts of height gain on population health and longevity. Further, short maternal stature increases the risk of small-for-gestational-age and preterm births, both risk factors for neonatal mortality, and of pregnancy complications (Kozuki et al., 2015; Black et al., 2008). Therefore, improvements vs. stagnation in women’s height can influence trends in infant and maternal mortality.

Our study also shows the potential for using height in early adulthood as an indicator that integrates across different dimensions of sustainable human development. Adult height signifies not only foetal and early childhood nutrition, which was included in the Millennium Development Goals, but also that of adolescents (Lancet, 2014). Further, adult height is a link between these early-life experiences and NCDs, longevity, education and earnings. It can easily be measured in health surveys and can be used to investigate differences across countries and trends over time, as done in our work, as well as within-country inequalities. Therefore, height in early adulthood, which varies substantially across countries and over time, provides a measurable indicator for sustainable development, with links to health and longevity, nutrition, education and economic productivity.

Materials and methods

Overview

We estimated trends in mean height for adults born from 1896 to 1996 (i.e., people who had reached their 18th birthday from 1914 to 2014) in 200 countries and territories. Countries were organized into 20 regions, mostly based on a combination of geography and national income (Supplementary file 1). Our study had two steps, described below. First, we identified, accessed, and re-analysed population-based measurement studies of human anthropometry. We then used a statistical model to estimate trends for all countries and territories.

Data sources

We used data sources that were representative of a national, subnational, or community population and had measured height. We did not use self-reported height because it is subject to systematic bias that varies by geography, time, age, sex, and socioeconomic characteristics like education and ethnicity (Engstrom et al., 2003; Connor Gorber et al., 2007; Wetmore and Mokdad, 2012; Schenker et al., 2010; Ezzati et al., 2006; Clarke et al., 2014; Hayes et al., 2011).
Data sources were included in the NCD-RisC database if:

- measured data on height, weight, waist circumference, or hip circumference were available;
- study participants were five years of age and older;
- data were collected using a probabilistic sampling method with a defined sampling frame;
- data were representative of the general population at the national, subnational, or community level;
- data were from the countries and territories listed in Supplementary file 1.

We excluded data sources on population subgroups whose anthropometric status may differ systematically from the general population, including:

- studies that had included or excluded people based on their health status or cardiovascular risk;
- ethnic minorities;
- specific educational, occupational, or socioeconomic subgroups of the population; and
- those recruited through health facilities, with the exception noted below.

We used school-based data in countries where secondary school enrolment was 70% or higher, and used data whose sampling frame was health insurance schemes in countries where at least 80% of the population were insured. We used data collected through general practice and primary care clinics in high-income countries with universal insurance, because contact with the primary care systems tends to be at least as good as response rates for population-based surveys. No studies were excluded based on the level of height.

We used multiple routes for identifying and accessing data. We accessed publicly available population-based multi-country and national measurement surveys (e.g., Demographic and Health Surveys, and surveys identified via the Inter-University Consortium for Political and Social Research and European Health Interview & Health Examination Surveys Database) as well as the World Health Organization (WHO) STEPwise approach to Surveillance (STEPS) surveys. We requested identification and access to population-based data sources from ministries of health and other national health agencies, via WHO and its regional offices. Requests were also sent via the World Heart Federation.
to its national partners. We made a similar request to the NCD Risk Factor Collaboration (NCD-RisC; www.ncdrisc.org), a worldwide network of health researchers and practitioners working on NCD risk factors.

To identify major sources not accessed through the above routes, we searched and reviewed published studies. Specifically, we searched Medline (via PubMed) for articles published between 1st January 1950 and 12th March 2013 using the search terms ‘body size’[mh:noexp] OR ‘body height’[mh:noexp] OR ‘body weight’[mh:noexp] OR ‘birth weight’[mh:noexp] OR ‘overweight’[mh:noexp] OR ‘obesity’[mh] OR ‘thinness’[mh:noexp] OR ‘Waist-Hip Ratio’[mh:noexp] or ‘Waist Circumference’[mh:noexp] or ‘body mass index’ [mh:noexp]) AND (‘Humans’[mh]) AND (‘1950’[PDAT]: ‘2013’[PDAT]) AND (‘Health Surveys’[mh] OR ‘Epidemiological Monitoring’[mh] OR ‘Prevalence’[mh]) NOT Comment[ptyp] NOT Case Reports[ptyp].

Articles were screened according to the inclusion and exclusion criteria described above. The number of articles identified and retained is summarised in Supplementary file 2. As described above, we contacted the corresponding authors of all eligible studies and invited them to join NCD-RisC. We did similar searches for other cardio-metabolic risk factors including blood pressure, serum cholesterol, and blood glucose. All eligible studies were invited to join NCD-RisC and were requested to analyse data on all cardio-metabolic risk factors.

Anonymised individual record data from sources included in NCD-RisC were re-analysed by the Pooled Analysis and Writing Group or by data holders according to a common protocol. All re-analysed data sources included mean height in standard age groups (18 years, 19 years, 20–29 years, followed by 10 year age groups and 80+ years), as well as sample sizes and standard errors.

**Figure 11.** Association between change in probability of dying from any cause between 50 and 70 years of age and change in adult height by country for cohorts born between 1898 and 1946. Probability of death was calculated using a cohort life table. Mortality data were available for 1950 to 2013. The 1898 birth cohort is the first cohort whose mortality experience at 50–54 years of age was seen in the data, and the 1946 birth cohort the last cohort whose mortality experience at 65–69 years of age was seen in the data. The dotted line shows the linear association. The 62 countries included have vital registration that is >80% complete and have data on all-cause mortality for at least 30 cohorts. The countries are Argentina, Australia, Austria, Azerbaijan, Belarus, Belgium, Belize, Brazil, Bulgaria, Canada, Chile, China (Hong Kong SAR), Colombia, Costa Rica, Croatia, Cuba, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Guatemala, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Macedonia (TFYR), Malta, Mauritius, Mexico, Moldova, Netherlands, New Zealand, Norway, Poland, Portugal, Puerto Rico, Romania, Russian Federation, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Trinidad and Tobago, Turkmenistan, Ukraine, United Kingdom, United States of America, Uruguay, Uzbekistan and Venezuela.

DOI: 10.7554/eLife.13410.013
analyses incorporated appropriate sample weights and complex survey design when applicable. To ensure summaries were prepared according to the study protocol, the Pooled Analysis and Writing Group provided computer code to NCD-RisC members who requested assistance. We also recorded information about the study population, period of measurement and sampling approach. This information was used to establish that each data source was population-based, and to assess whether it covered the whole country, multiple subnational regions, or one or a small number of communities, and whether it was rural, urban, or combined. All submitted data were checked by at least two independent members of the Pooled Analysis and Writing Group to ensure that their sample selection met the inclusion criteria and that height was measured and not self-reported. Questions and clarifications about sample design and measurement method were discussed with the Collaborating Group members and resolved before data were incorporated in the database. We also extracted data from additional national health surveys, one subnational STEPS survey, and six MONICA sites from published reports.

We identified duplicate data sources by comparing studies from the same country and year. Additionally, NCD-RisC members received the list of all data sources in the database and were asked to ensure that the included data from their country met the inclusion criteria and that there were no duplicates. Data sources used in our analysis are listed in Supplementary file 3.

In this paper, we used data on height in adulthood (18 years of age and older) from the NCD-RisC database for participants born between 1896 and 1996. We used 1472 population-based data sources with measurements on over 18.6 million adults born between 1896 and 1996 whose height had been measured. We did not use data from the 1860–1895 cohorts because data on these early cohorts were available for only six countries (American Samoa, India, Japan, Norway, Switzerland and USA). We had data for 179 of the 200 countries for which estimates were made; these 179 countries covered 97% of the world’s population. All countries had some data on people born after 1946 (second half of analysis period); 134 had data on people born between 1921 and 1945; and 72 had data on people born in 1920 or earlier. Across regions, there were between an average of 2.0 data sources per country in the Caribbean to 34 sources per country in high-income Asia Pacific. 1108 sources had data on men as well as women, 153 only on men, and 211 only on women.

**Statistical methods**

The statistical method is described in detail elsewhere (Danaei et al., 2011; Finucane et al., 2014). In summary, the model had a hierarchical structure in which estimates of mean height for each country and year were nested in regional levels and trends, which were in turn nested in those of super-regions and worldwide. In this structure, estimates of mean height for each country and year were informed by its own data, if available, and by data from other years in the same country and in other countries, especially those in the same region with data for similar time periods. The hierarchical structure shares information to a greater degree when data are non-existent or weakly informative (e.g., because they have a small sample size), and to a lesser extent in data-rich countries and regions.

We used birth cohort as the time scale of analysis. We calculated the birth cohort for each observation by subtracting the mid-age of its age group from the year in which data were collected. We modelled trends in height by birth cohort as a combination of linear and non-linear trends, both with a hierarchical structure; the non-linear trend was specified using a second-order random walk (Rue and Held, 2005). The model also included a term that allowed each birth cohort’s height to change as it aged, e.g., because there is gradual loss of height during ageing and because as a cohort ages those who survive may be taller. The model described by Finucane et al (Finucane et al., 2014) had used a cubic spline for age associations of risk factor levels. In practice, the estimated change in population mean height over age was linear with a small slope of over 0.2 cm shorter for men and 0.3 cm shorter for women with each decade of older age. Therefore, we used a linear specification for computational efficiency.

While all our data were from samples of the general population, 796 (54%) of data sources represented national populations, another 199 (14%) major sub-national regions (e.g., one or more provinces or regions of a country), and the remaining 477 (32%) one or a small number of communities. The model accounted for the fact that sub-national and community studies, while informative, might systematically differ from nationally representative ones, and also have larger variation relative to
the true values than national studies (e.g., see data from China, India, Japan and the UK in Figure 6 and Figure 7).

We fitted the Bayesian model with the Markov chain Monte Carlo (MCMC) algorithm. We monitored mixing and convergence using trace plots and Brooks–Gelman–Rubin diagnostics (Brooks and Gelman, 1998). We obtained 5000 post burn-in samples from the posterior distribution of model parameters, used to obtain the posterior distribution of mean height. The reported credible intervals represent the 2.5th–97.5th percentiles of the posterior distribution. We report mean height at age 18 years for each birth cohort; heights at other ages are available from the authors. All analyses were done separately by sex because height and its trends over time may differ between men and women.

We tested how well our statistical model predicts missing values by removing data from 10% of countries with data (i.e., created the appearance of countries with no data where we actually had data). The countries whose data were withheld were randomly selected from the following three groups: data-rich (more than 25 cohorts of data, with at least five cohorts after 1960), data-poor (up to and including 12 cohorts of data for women and 8 cohorts for men), and average data availability (13 to 25 cohorts for women, 9 to 25 cohorts for men, or more than 25 cohorts in total with fewer than five after 1960). In total, there were 64 data-rich countries for women and 51 for men; 57 data-poor countries for women and 58 for men; and 56 countries for women and 60 for men that had average data availability. We fitted the model to the data from the remaining 90% of countries and made estimates of the held-out observations. We repeated the test five times, holding out a different subset of data in each repetition. We calculated the differences between the held-out data and the estimates. We also checked the 95% credible intervals of the estimates; in a model with good external predictive validity, 95% of held-out values would be included in the 95% credible intervals.

Our model performed extremely well; specifically, the estimates of mean height were unbiased as evidenced with median errors that were very close to zero globally, and less than ±0.2 cm in every subset of withheld data (Supplementary file 4). Even the 25th and 75th percentiles of errors rarely exceeded ±1 cm. Median absolute error was only about 0.5 cm, and did not exceed 1.0 cm in subsets of withheld data. The 95% credible intervals of estimated mean heights covered 97% of true data for both men and women, which implies good estimation of uncertainty; among subgroups of data, coverage was never < 90%.

Acknowledgements

ME was awarded funding to carry out the research from the Wellcome Trust and Grand Challenges Canada. We thank Christina Banks, Quentin Hennocq, Dheeya Rizmie, and Yasaman Vali for assistance with data extraction. We thank WHO country and regional offices and World Heart Federation for support in data identification and access.

NCD Risk Factor Collaboration (NCD-RisC)

Pooled Analysis and Writing (* equal contribution)

James Bentham (Imperial College London, UK)*; Mariachiara Di Cesare (Middlesex University, UK; Imperial College London, UK)*; Gretchen A Stevens (World Health Organization, Switzerland); Bin Zhou (Imperial College London, UK); Honor Bixby (Imperial College London, UK); Melanie Cowan (World Health Organization, Switzerland); Léa Fortunato (Imperial College London, UK); James E Bennett (Imperial College London, UK); Goodarz Danaei (Harvard T.H. Chan School of Public Health, USA); Kaveh Hajifathalian (Harvard T.H. Chan School of Public Health, USA); Yuan Lu (Harvard T.H. Chan School of Public Health, USA); Leanne M Riley (World Health Organization, Switzerland); Avula Laxmaiah (Indian Council of Medical Research, India); Vasilis Kontis (Imperial College London, UK); Christopher J Paciorek (University of California, Berkeley, USA); Elio Riboli (Imperial College London, UK); Majid Ezzati (Imperial College London, UK; WHO Collaborating Centre on NCD Surveillance and Epidemiology, UK).

Country and Regional Data (* equal contribution; listed alphabetically)

Ziad A Abdeen (Al-Quds University, Palestine)*; Zargar Abdul Hamid (Center for Diabetes and Endocrine Care, India)*; Niveen M Abu-Rmeileh (Birzeit University, Palestine)*; Benjamin Acosta-Cazares
Severino, Italy)*; Viviane C Cardoso (University of São Paulo, Brazil)*; Axel C Carlsson (Karolinska Institutet, Sweden)*; Maria J Carvalho (University of Porto, Portugal)*; Felipe F Casanueva (Santiago de Compostela University, Spain)*; Juan-Pablo Casas (University College London, UK)*; Carmelo A Caserta (Associazione Calabrese di Epatologia, Italy)*; Snehalatha Chamkuttan (India Diabetes Research Foundation, India)*; Angelique W Chan (Duke-NUS Graduate Medical School, Singapore)*; Queenie Chan (Imperial College London, UK)*; Himanshu K Chaturvedi (National Institute of Medical Statistics, India)*; Nishi Chaturvedi (University College London, UK)*; Chien-Jen Chen (Academia Sinica, Taiwan)*; Fangfang Chen (Capital Institute of Pediatrics, China)*; Huashuai Chen (Duke University, USA)*; Shuohua Chen (Kailuan General Hospital, China)*; Zhengming Chen (University of Oxford, UK)*; Ching-Yu Cheng (Duke-NUS Graduate Medical School, Singapore)*; Angela Chetrit (The Gertner Institute for Epidemiology and Health Policy Research, Israel)*; Arnaud Chiolero (Lausanne University Hospital, Switzerland)*; Shu-Ti Chiou (Ministry of Health and Welfare, Taiwan)*; Adela Chirita-Emandi (Victor Babes University of Medicine and Pharmacy Timisoara, Romania)*; Belong Cho (Seoul National University College of Medicine, South Korea)*; Yumi Cho (Korea Centers for Disease Control and Prevention, South Korea)*; Kaare Christensen (University of Southern Denmark, Denmark)*; Jerzy Chudek (Medical University of Silesia, Poland)*; Renata Cifkova (Charles University in Prague, Czech Republic)*; Frank Claessens (Katholieke Universiteit Leuven, Belgium)*; Els Clays (Ghent University, Belgium)*; Hans Concin (Agency for Preventive and Social Medicine, Austria)*; Cyrus Cooper (University of Southampton, UK)*; Rachel Cooper (University College London, UK)*; Tara C Coppinger (Cork Institute of Technology, Ireland)*; Simona Costanzo (IRCCS Istituto Neurologico Mediterraneo Neurordi, Italy)*; Dominique Cottel (Institut Pasteur de Lille, France)*; Chris Cowell (Westmead Institute of Sydney, Australia)*; Cora L Craig (Canadian Fitness and Lifestyle Research Institute, Canada)*; Ana B Crujeiras (CIBEROBN, Spain)*; Graziella D’Arrigo (National Council of Research, Italy)*; Eleonora d’Orsi (Federal University of Santa Catarina, Brazil)*; Jean Dalongeville (Institut Pasteur de Lille, France)*; Albertino Damasceno (Eduardo Mondlane University, Mozambique)*; Camilla T Damsgaard (University of Copenhagen, Denmark)*; Goodarz Danaei (Harvard TH Chan School of Public Health, USA)*; Rachel Dankner (The Gertner Institute for Epidemiology and Health Policy Research, Israel)*; Luc Dauchet (Lille University Hospital, France)*; Guy De Backer (Ghent University, Belgium)*; Dirk De Bacquer (Ghent University, Belgium)*; Giovanni de Gaetano (IRCCS Istituto Neurologico Mediterraneo Neurordi, Italy)*; Stefaan De Henauw (Ghent University, Belgium)*; Delphine De Smedt (Ghent University, Belgium)*; Mohan Deepa (Madras Diabetes Research Foundation, India)*; Alexander D Deev (National Research Centre for Preventive Medicine, Russia)*; Abbas Dehghan (Erasmus Medical Center Rotterdam, The Netherlands)*; Hélène Delisle (University of Montreal, Canada)*; Francis Delpeuch (Institut de Recherche pour le Développement, France)*; Valérie Deschamps (French Public Health Agency, France)*; Kloidan Dhana (Erasmus Medical Center Rotterdam, The Netherlands)*; Augusto F Di Castelnuovo (IRCCS Istituto Neurologico Mediterraneo Neurordi, Italy)*; Juvenal Soares Dias-da-Costa (Universidade do Vale do Rio dos Sinos, Brazil)*; Alejandro Diaz (National Council of Scientific and Technical Research, Argentina)*; Shirin Djalalínia (Non-Communicable Diseases Research Center, Iran)*; Ha TP Do (National Institute of Nutrition, Vietnam)*; Annette J Dobson (University of Queensland, Australia)*; Chiara Donfrancesco (Istituto Superiore di Sanità, Italy)*; Silvana P Donoso (Universidad de Cuenca, Ecuador)*; Angela Döring (Helmholtz Zentrum München, Germany)*; Kouamelam Doua (Ministère de la Santé et de la Lutte contre le Sida, Côte d’Ivoire)*; Wojciech Drygas (The Cardinal Wyszynski Institute of Cardiology, Poland)*; Vilnis Dzerve (University of Latvia, Latvia)*; Eruke E Egbagbe (University of Benin, Nigeria)*; Robert Eggerstens (University of Gothenburg, Sweden)*; Ulf Ekelund (Norwegian School of Sport Sciences, Norway)*; Jallila El Ati (National Institute of Nutrition and Food Technology, Tunisia)*; Paul Elliott (Imperial College London, UK)*; Reina Engele-Stone (University of California Davis, USA)*; Rajiv T Erasmus (University of Stellenbosch, South Africa)*; Cihangir Erem (Karadeniz Technical University, Turkey)*; Louise Erikson (University of Southern Denmark, Denmark)*; Jorge Escobedo-de la Peña (Instituto Mexicano del Seguro Social, Mexico)*; Alun Evans (The Queen’s University of Belfast, UK)*; David Fahe (University of Züri, Switzerland)*; Caroline H Fall (University of Southampton, UK)*; Farshad Farzadfar (Tehran University of Medical Sciences, Iran)*; Francisco J Felix-Redondo (Centro de Salud Villanueva Norte, Spain)*; Trevor S Ferguson (The University of the West Indies, Jamaica)*; Daniel Fernández-Bergés (Hospital Don Benito-Villanueva de la Serena, Spain)*; Daniel Ferrante (Ministry of Health, Argentina)*; Marika Ferrari (Council for Agricultural Research and Economics, Italy)*; Catterina Ferreccio (Pontificia Universidad Católica de Chile, Chile)
Czech Republic); Urho M Kujala (University of Jyväskyla, Finland); Krzysztof Kula (Medical University of Lodz, Poland); Daan Kromhout (Wageningen University, The Netherlands); Herculina S zer (University Hospital Ulm, Germany); Steinar Krokstad (Norwegian University of Science and Technology, Norway); Grazyna Jasienska (Jagiellonian University Medical College, Poland); Bojan Jelakovic (University of Zagreb School of Medicine, Croatia); Chao Qiang Jiang (Guangzhou 12th Hospital, China); Michel Joffres (Simon Fraser University, Canada); Mattias Johansson (International Agency for Research on Cancer, France); Jost B Jonas (Ruprecht-Karls-University of Heidelberg, Germany); Torben Jørgensen (Research Centre for Prevention and Health, Denmark); Pradeep Joshi (World Health Organization Country Office, India); Anna Juolevi (National Institute for Health and Welfare, Finland); Gregor Jurak (University of Ljubljana, Slovenia); Vesna Jureša (University of Zagreb, Croatia); Rudolf Kaaks (German Cancer Research Center, Germany); Anthony Kafatos (University of Crete, Greece); Ofra Kalter-Leibovici (The Gartner Institute for Epidemiology and Health Policy Research, Israel); Efthymios Kapantais (Hellenic Medical Association for Obesity, Greece); Amir Kasaeian (Tehran University of Medical Science, Iran); Joanne Katz (Johns Hopkins Bloomberg School of Public Health, USA); Prabhdeep Kaur (National Institute of Epidemiology, India); Maryam Kavousi (Errasmus Medical Center Rotterdam, The Netherlands); Ulrich Keil (University of Münster, Germany); Lital Keinan Boker (Israel Center for Disease Control, Israel); Sirrka Keinänen-Kiukaanniemi (Oulu University Hospital, Finland); Roya Keshishian (Research Institute for Primalmic Preven- tion of Non Communicable Disease, Iran); Han CG Kemper (VU University Medical Center, The Netherlands); Andre P Kentig (South African Medical Research Council, South Africa); Mathilde Kersting (Research Institute of Child Nutrition, Germany); Timothy Key (University of Oxford, UK); Yousef Saleh Khader (Jordan University of Science and Technology, Jordan); Davood Khalili (Shahid Beheshti University of Medical Sciences, Iran); Young-Ho Kang (Seoul National University, South Korea); Kay-Tee H Khaw (University of Cambridge, UK); Ilse MSL Khouw (FrieslandCampina, Singapore); Stefan Kiechl (Medical University Innsbruck, Austria); Japhet Killewo (Muhimbili University of Health and Allied Sciences, Tanzania); Jeongseon Kim (National Cancer Center, South Korea); Jeannette Kliment (Statistics Austria, Austria); Jurate Kurmienė (Lithuanian University of Health Sciences, Lithuania); Bhawesh Koirala (B P Koirala Institute of Health Sciences, Nepal); Elin Kolle (Norwegian School of Sport Sciences, Norway); Patrick Kolsteren (Institute of Tropical Medicine, Belgium); Paul Korovits (Tartu University Clinics, Estonia); Seppo Koskinen (National Institute for Health and Welfare, Finland); Katsuyasu Kouda (Kindai University Faculty of Medicine, Japan); Young-Ho Khang (Seoul National University, South Korea); Catherine Kyobutungi (African Population and Health Research Center, Kenya); Fatima Zahra Laamiri (Higher Institute of Nursing Profes- sions and Technical Health, Morocco); Tiina Laatikainen (National Institute for Health and Welfare, Finland); Carl Lachat (Ghent University, Belgium); Youcef Laid (National Institute of Public Health of Algeria, Algeria); Tai Hing Lam (University of Hong Kong, China); Orlando Landrove (Ministerio de Salud Pública, Cuba); Vera Lanska (Institute for Clinical and Experimental Medicine, Czech Republic); Georg Lappas (Sahlgrenska Academy, Sweden); Bagher Larjani (Endocrinology and Metabolism Research Center, Iran); Lars E Laugsand (Norwegian University of Science and Technology, Norway); Avula Laxmaiah (Indian Council of Medical Research, India); Khanh Le Nguyen Bao (National Institute of Nutrition, Vietnam); Tuyen D Le (National Institute of Nutrition, Vietnam);
Catherine Leclercq (Food and Agriculture Organization, Italy)*; Jeannette Lee (National University of Singapore, Singapore)*; Jeonghee Lee (National Cancer Center, South Korea)*; Terho Lehtimäki (Tampere University Hospital, Finland)*; Rampal Lekhraj (Universiti Putra Malaysia, Malaysia)*; Luz M León-Muñoz (Universidad Autónoma de Madrid, Spain)*; Yanping Li (Harvard TH Chan School of Public Health, USA)*; Christa L Lilly (West Virginia University, USA)*; Wei-Yen Lim (National University of Singapore, Singapore)*; M Fernanda Lima-Costa (Osvaldo Cruz Foundation Rene Rachou Research Institute, Brazil)*; Hsien-Ho Lin (National Taiwan University, Taiwan)*; Xu Lin (University of Chinese Academy of Sciences, China)*; Allan Linneberg (Research Centre for Prevention and Health, Denmark)*; Lauren Lissner (University of Gothenburg, Sweden)*; Mieczyslaw Litwin (The Children’s Memorial Health Institute, Poland)*; Ming Liu (Beijing Anzhen Hospital, Capital Medical University, China)*; Roberto Lorbeer (University Medicine Greifswald, Germany)*; Paulo A Lotufo (University of São Paulo, Brazil)*; José Eugenio Lozano (Consejería de Sanidad Junta de Castilla y León, Spain)*; Dalia Luksiene (Lithuanian University of Health Sciences, Lithuania)*; Annamari Lundqvist (National Institute for Health and Welfare, Finland)*; Nuno Lunet (Universidade do Porto, Portugal)*; Per Lyts (University of Uppsala, Sweden)*; Guansheng Ma (Peking University, China)*; Jun Ma (Peking University, China)*; George LL Machado-Coelho (Universidade Federal de Ouro Preto, Brazil)*; Suka Machi (The Jikei University School of Medicine, Japan)*; Stefania Maggi (National Research Council, Italy)*; Dianna J Maglione (Baker IDI Heart and Diabetes Institute, Australia)*; Bernard Maire (Institut de Recherche pour le Développement, France)*; Marcia Makdisse (Hospital Israelita Albert Einstein, Brazil)*; Reza Malekzadeh (Tehran University of Medical Sciences, Iran)*; Rahal Malhotra (Duke-NUS Graduate Medical School, Singapore)*; Kodavanti Mallikharjuna Rao (Indian Council of Medical Research, India)*; Sofia Malutina (Institute of Internal and Preventive Medicine, Russia)*; Yannis Manios (Harokopio University, Greece)*; Jim I Mann (University of Otago, New Zealand)*; Enzo Manzato (University of Padova, Italy)*; Paula Margozzini (Pontificia Universidad Católica de Chile, Chile)*; Oonagh Markey (University of Reading, UK)*; Pedro Marques-Vidal (Lausanne University Hospital, Switzerland)*; Jaume Marrugat (Institut Hospital del Mar d’Investigacions Mèdiques, Spain)*; Yves Martin-Prelé (Institut de Recherche pour le Développement, France)*; Reynaldo Martorell (Emory University, USA)*; Shariq R Masoodi (Sher-i-Kashmir Institute of Medical Sciences, India)*; Ellis B Mathiesen (UIT The Arctic University of Norway, Norway)*; Tandi E Matsha (Cape Peninsula University of Technology, South Africa)*; Artur Mazur (University of Rzeszow, Poland)*; Jean Claude Mbanya (University of Yaoundé 1, Cameroon)*; Shelly R McFarlane (The University of the West Indies, Jamaica)*; Stephen T McGarvey (Brown University, USA)*; Martin McKee (London School of Hygiene & Tropical Medicine, UK)*; Stela McLachlan (University of Edinburgh, UK)*; Rachael M McLean (University of Otago, New Zealand)*; Breige A McNulty (University College Dublin, Ireland)*; Safiah Md Yusof (Universiti Teknologi MARA, Malaysia)*; Soummi Mediene-Benchekor (University of Oran 1, Algeria)*; Aline Meirhaeghe (Institut National de la Santé et de la Recherche Médicale, France)*; Christa Meisinger (Helmholtz Zentrum München, Germany)*; Ana Maria B Menezes (Universidade Federal de Pelotas, Brazil)*; Gert BM Mensink (Robert Koch Institute, Germany)*; Indrapal I Meshram (Indian Council of Medical Research, India)*; Andres Metzpalu (University of Tartu, Estonia)*; Jie Mi (Capital Institute of Pediatrics, China)*; Kim F Michaelsen (University of Copenhagen, Denmark)*; Karit Mikkel (University of Tartu, Estonia)*; Jody C Miller (University of Otago, New Zealand)*; Juan Francisco Miquel (Ministry of Health Malaysia, Malaysia)*; George M. Molnar (University of Northern Colorado, USA)*; Carlos Mondo (Mulago Hospital, Uganda)*; Eric A Monterrubio (Instituto Nacional de Salud Pública, Mexico)*; Kotsedi Daniel K Monyeki (University of Witwatersrand, South Africa)*; Leila B Moreira (University of Porto, Portugal)*; Malgorzata Mossakowska (International Institute of Molecular and Cell Biology, Poland)*; Aya Mostafa (Ain Shams University, Egypt)*; Jorge Mota (University of Porto, Portugal)*; Mohammad Esmaeel Motlagh (Ahvaz Jundishapur University of Medical Sciences, Iran)*; Jorge Motta (Gorgas
Chinese University of Hong Kong, China); Eugène Sobngwi (University of Yaoundé 1, Cameroon); Stefan Söderberg (Umeå University, Sweden); Moesijanti YE Soekatri (Health Polytechnics Institute, Indonesia); Vincenzo Solfrizzi (University of Bari, Italy); Emily Sonestedt (Lund University, Sweden); Yi Song (Peking University, China); Thorkild IA Sørensen (University of Copenhagen, Denmark); Maroje Soric (University of Zagreb, Croatia); Charles Sossa Jérôme (Institut Régional de Santé Publique, West Africa); Aicha Soumare (University of Bordeaux, France); Jan A Staessen (University of Leuven, Belgium); Gregor Starc (University of Ljubljana, Slovenia); Maria G Stathopoulou (INSERM, France); Kaspar Staub (University of Zurich, Switzerland); Bill Stavreski (Heart Foundation, Australia); Jostein Steene-Johannessen (Norwegian School of Sport Sciences, Norway); Peter Stehle (Helmholtz Zentrum München, Germany); Aryeh D Stein (Emory University, USA); George S Stergiou (Sotiria Hospital, Greece); Jochanan Stessman (Hadassah University Medical Center, Israel); Jutta Stieber (Helmholtz Zentrum München, Germany); Doris Stöckl (Helmholtz Zentrum München, Germany); Tanja Stocks (Lund University, Sweden); Jakub Stokwiszewski (National Institute of Public Health-National Institute of Hygiene, Poland); Gareth Stratton (Swansea University, UK); Karien Stronks (University of Amsterdam, The Netherlands); Maria Wany Strufuld (Federal University of São Paulo, Brazil); Chien-An Sun (Fu Jen Catholic University, Taiwan); Johan Sundström (Uppsala University, Sweden); Yn-Tz Sung (The Chinese University of Hong Kong, China); Jordi Sunyer (ISGlobal Centre for Research in Environmental Epidemiology, Spain); Paibul Suriyawongpaisal (Mahidol University, Thailand); Boyd A Swinburn (The University of Auckland, New Zealand); Rody G Sy (University of the Philippines, Philippines); Lucjan Szponar (National Food and Nutrition Institute, Poland); E Shyong Tai (National University of Singapore, Singapore); Mari-Liis Tammesoo (University of Tartu, Estonia); Abdonas Tamosiunas (Lithuanian University of Health Sciences, Lithuania); Line Tang (Research Centre for Prevention and Health, Denmark); Xun Tang (Peking University Health Science Center, China); Frank Tanser (University of KwaZulu-Natal, South Africa); Yong Tao (Peking University, China); Mohammed Rasoul Tarawneh (Ministry of Health, Jordan); Jakob Tarp (University of Southern Denmark, Denmark); Carolina B Tarqui-Mamani (National Institute of Health, Peru); Anne Taylor (The University of Adelaide, Australia); Félicité Tchibindat (UNICEF, Cameroon); Holger Theobald (Karolinska Institutet, Sweden); Lutgarde Thijs (University of Leuven, Belgium); Betina H Thuesen (Research Centre for Prevention and Health, Denmark); Anne Tjonneland (Danish Cancer Society Research Centre, Denmark); Hanna K Tolonen (National Institute for Health and Welfare, Finland); Janne S Tolstrup (University of Southern Denmark, Denmark); Murat Topbas (Karadeniz Technical University, Turkey); Roman Topór-Madry (Jagiellonian University Medical College, Poland); Maties Torrent (IB-SALUT Area de Salut de Menorca, Spain); Stefania Toselli (University of Bologna, Italy); Pierre Traissac (Institut de Recherche pour le Développement, France); Antonia Trichopoulou (Hellenic Health Foundation, Greece); Dimitrios Trichopoulos (Harvard TH Chan School of Public Health, USA); Carolin B Tarqui-Mamani (National Institute of Health, Peru); Oanh TH Trinh (University of Pharmacy and Medicine of Ho Chi Minh City, Vietnam); Atul Trivedi (Government Medical College, India); Lechaba Tshepo (Sefako Makgatho Health Science University, South Africa); Marshall K Tulloch-Reid (The University of the West Indies, Jamaica); Tomi-Pekka Tuomainen (University of Eastern Finland, Finland); Jaakko Tuomilehto (Dasman Diabetes Institute, Kuwait); Maria L Turley (Ministry of Health, New Zealand); Per Tynelius (Karolinska Institutet, Sweden); Theofilos Tzotzas (Hellenic Medical Association for Obesity, Greece); Christophe Tzourio (University of Bordeaux, France); Peter Ueda (Harvard TH Chan School of Public Health, USA); Flora AM Ukoli (Meharry Medical College, USA); Hanno Ulmer (Medical University of Innsbruck, Austria); Belgin Unal (Dokuz Eylul University, Turkey); Hannu MT Uusitalo (University of Tampere Tays Eye Center, Finland); Gonzalo Valdivia (Pontificia Universidad Católica de Chile, Chile); Susana Vale (University of Porto, Portugal); Damaskini Valvi (Harvard TH Chan School of Public Health, USA); Yvonne T van der Schouw (University Medical Center Utrecht, The Netherlands); Koen Van Herck ( Ghent University, Belgium); Hoang Van Minh (Hanoi School of Public Health, Vietnam); Lenie van Rossem (University Medical Center Utrecht, The Netherlands); Irene GM van Valkengoed (Academic Medical Center of University of Amsterdam, The Netherlands); Dirk Vanderschueren (Katholieke Universiteit Leuven, Belgium); Diego Vanuzzo (Centro di Prevenzione Cardiovascolare Udine, Italy); Lars Vatten (Norwegian University of Science and Technology, Norway); Tomas Vega (Consejería de Sanidad Junta de Castilla y León, Spain); Gustavo Velasquez-Melendez (Universidade Federal de Minas Gerais, Brazil); Giovanni Veronesi (University of Insribua, Italy); WM Monique Verschuren (National Institute for Public Health and the Environment, The Netherlands); Roosmarijn Verstraeten (Institute of Tropical Medicine, Belgium); Cesar G Victora
(Universidade Federal de Pelotas, Brazil)*; Giovanni Viegi (Italian National Research Council, Italy)*; Lucie Viet (National Institute for Public Health and the Environment, The Netherlands)*; Eira Viikari-Juntura (Finnish Institute of Occupational Health, Finland)*; Paolo Vineis (Imperial College London, UK)*; Jesus Vioque (Universidad Miguel Hernandez, Spain)*; Jyrki K Virtanen (University of Eastern Finland, Finland)*; Sophie Visvikis-Siest (INSERM, France)*; Bharathi Viswanathan (Ministry of Health, Seychelles)*; Peter Vollenweider (Lausanne University Hospital, Switzerland)*; Sari Voutilainen (University of Eastern Finland, Finland)*; Ana Vrdoljak (UHC Zagreb, Croatia)*; Martine Vrijheid (ISGlobal Centre for Research in Environmental Epidemiology, Spain)*; Alisha N Wade (University of the Witwatersrand, South Africa)*; Aline Wade (University of Strasbourg, France)*; Janette Walton (University College Cork, Ireland)*; Wan Nazaimoon Wan Mohamud (Institute for Medical Research, Malaysia)*; Ming-Dong Wang (Public Health Agency of Canada, Canada)*; Qian Wang (Xinjiang Medical University, China)*; Ya Xing Wang (Beijing Tongren Hospital, China)*; S Goya Wannamethee (University College London, UK)*; Nicholas Wareham (University of Cambridge, UK)*; Deepa Weerasekera (Ministry of Health, New Zealand)*; Peter H Whincup (St George’s, University of London, UK)*; Kurt Widhalm (Medical University of Vienna, Austria)*; Indah S Widyahening (Universitas Indonesia, Indonesia)*; Andrzej Wieczek (Medical University of Silesia, Poland)*; Alet H Wijga (National Institute for Public Health and the Environment, The Netherlands)*; Rainford J Wilks (The University of the West Indies, Jamaica)*; Johann Willeit (Medical University Innsbruck, Austria)*; Tom Wilskaard (UIT The Arctic University of Norway, Norway)*; Bogdan Wojtyniak (National Institute of Public Health-National Institute of Hygiene, Poland)*; Jyh Eiin Wong (Universiti Kebangsaan Malaysia, Malaysia)*; Tien Yin Wong (Duke-NUS Graduate Medical School, Singapore)*; Jean Woo (The Chinese University of Hong Kong, China)*; Mark Woodward (University of Sydney, Australia; University of Oxford, UK)*; Frederick C Wu (University of Manchester, UK)*; Jianfeng Wu (Shandong University of Traditional Chinese Medicine, China)*; Shou Ling Wu (Kailuan General Hospital, China)*; Haiquan Xu (Institute of Food and Nutrition Development of Ministry of Agriculture, China)*; Liang Xu (Capital Medical University, China)*; Uruwan Yamborisut (Mahidol University, Thailand)*; Weili Yan (Children’s Hospital of Fudan University, China)*; Xiaoguang Yang (Chinese Center for Disease Control and Prevention, China)*; Nazan Yardim (Ministry of Health, Turkey)*; Xingwang Ye (University of Chinese Academy of Sciences, China)*; Panayiotis Yiallouros (University of Cyprus, Cyprus)*; Akihiro Yoshihara (Niigata University, Japan)*; Qi Sheng You (Capital Medical University, China)*; Novie O Younger-Coleman (The University of the West Indies, Jamaica)*; Ahmad F Yusoff (Ministry of Health Malaysia, Malaysia)*; Ahmad A Zainuddin (Universiti Teknologi MARA, Malaysia)*; Sabina Zambon (University of Padova, Italy)*; Tomasz Zdrojewski (Medical University of Gdansk, Poland)*; Yi Zeng (Duke University, USA)*; Dong Zhao (Beijing Anzhen Hospital, Capital Medical University, China)*; Wenhua Zhao (Chinese Center for Disease Control and Prevention, China)*; Yingfeng Zheng (Singapore Eye Research Institute, Singapore)*; Maigeng Zhou (Chinese Center for Disease Control and Prevention, China)*; Dan Zhu (Inner Mongolia Medical University, China)*; Esther Zimmermann (Bispebjerg and Frederiksberg Hospitals, Denmark)*; Julio Zuñiga Cisneros (Gorgias Memorial Institute of Public Health, Panama).

Additional information

**Funding**

| Funders         | Grant reference number | Author     |
|-----------------|------------------------|------------|
| Grand Challenges Canada |                       | Majid Ezzati|
| Wellcome Trust  | 101506/Z/13/Z          | Majid Ezzati|

The funders had no role in study design, data collection and interpretation, or the decision to submit the work for publication.

**Author contributions**

NCD-RisC, collectively contributed to the research and manuscript. Members of the Country and Regional Data Group collected and reanalysed data, and checked pooled data for accuracy of information about their study and other studies in their country. MDC led data collection and JB led the statistical analysis and prepared results. Members of the Pooled Analysis and Writing Group collated
data, checked all data sources in consultation with the Country and Regional Data Group, analysed pooled data, and prepared results. ME designed the study, oversaw research, and wrote the first draft of the report with input from other members of Pooled Analysis and Writing Group. Members of Country and Regional Data Group commented on draft report.

**Additional files**

**Supplementary files**
- Supplementary file 1. Regions used for the Bayesian hierarchical model such that information was shared among countries within each region, among regions in a super-region, and among super-regions in the world. Numbers in brackets show number of countries in each region or super-region. DOI: 10.7554/eLife.13410.014
- Supplementary file 2. Flowchart of secondary search for data sources. DOI: 10.7554/eLife.13410.015
- Supplementary file 3. Data sources used in the study, by country. DOI: 10.7554/eLife.13410.016
- Supplementary file 4. Results of model validation. The validation procedure is described in the main text. DOI: 10.7554/eLife.13410.017

**References**

Adair LS, Fall CH, Osmond C, Stein AD, Martorell R, Ramirez-Zea M, Sachdev HS, Dahly DL, Bas I, Norris SA, Micklesfield L, Hallal P, Victora CG, COHORTS group. 2013. Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. *Lancet* **382**:525–534. doi: 10.1016/S0140-6736(13)60103-8

Barker DJ, Eriksson JG, Forsén T, Osmond C. 2005. Infant growth and income 50 years later. *Archives of Disease in Childhood* **90**:272–273. doi: 10.1136/adc.2003.033464

Baten J, Blum M. 2012. Growing Tall but Unequal: Findings and New Background Evidence on Anthropometric Welfare in 156 Countries, 1810–1989. *Economic History of Developing Regions* **27**:S66–S85. doi: 10.1080/20780389.2012.657489

Batty GD, Barzi F, Woodward M, Jamrozik K, Woo J, Kim HC, Ueshima H, Huxley RR, Asia Pacific Cohort Studies Collaboration. 2010. Adult height and cancer mortality in Asia: the Asia Pacific Cohort Studies Collaboration. *Annals of Oncology* **21**:646–654. doi: 10.1093/annonc/mdp363

Black RE, Allen LH, Bhutta ZA, Caulfield LE, de Onis M, Ezzati M, Mathers C, Rivera J, Maternal and Child Undernutrition Study Group. 2008. Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* **371**:243–260. doi: 10.1016/S0140-6736(07)61690-0

Bogin B. 2013. Secular changes in childhood, adolescent and adult stature. *Nestle Nutrition Institute Workshop Series* **71**:115–126. doi: 10.1159/000342581

Brooks SP, Gelman A. 1998. General methods for monitoring convergence of iterative simulations. *Journal of Computational and Graphical Statistics* **7**:434–455 . doi: 10.2307/1390675

Case A, Paxson C. 2008. Stature and status: Height, ability, and labor market outcomes. *Journal of Political Economy* **116**:499–532. doi: 10.1086/589524

Chen Y, Zhou LA. 2007. The long-term health and economic consequences of the 1959-1961 famine in China. *Journal of Health Economics* **26**:659–681. doi: 10.1016/j.jhealeco.2006.12.006

Clarke P, Sastry N, Duffy D, Ailshire J. 2014. Accuracy of self-reported versus measured weight over adolescence and young adulthood: findings from the national longitudinal study of adolescent health, 1996–2008. *American Journal of Epidemiology* **180**:153–159. doi: 10.1093/aje/kou133

Cole TJ. 2000. Secular trends in growth. *The Proceedings of the Nutrition Society* **59**:317–324. doi: 10.1017/S0029665100000355

Connor Gorber S, Tremblay M, Moher D, Gorber B. 2007. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. *Obesity Reviews* **8**:307–326. doi: 10.1111/j.1467-789X.2007.00347.x

Danaei G, Finucane MM, Lin JK, Singh GM, Paciorek CJ, Cowan MJ, Farzadfar F, Stevens GA, Lim SS, Riley LM, Ezzati M, Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Blood Pressure). 2011. National, regional, and global trends in systolic blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and 5.4 million participants. *Lancet* **377**:568–577. doi: 10.1016/S0140-6736(10)62036-3

Davies NW, Gaunt TR, Lewis SJ, Holly J, Donovan JL, Hamdy FC, Kemp JP, Eeles R, Easton D, Kote-Jarai Z, Ali Olama AA, Benlloch S, Muir K, Giles GG, Wiklund F, Gronberg H, Hainman CA, Schleutker J, Nordestgaard BG, Travis RC, et al. 2015. The effects of height and BMI on prostate cancer incidence and mortality: a Mendelian
randomization study in 20,848 cases and 20,214 controls from the PRACTICAL consortium. Cancer Causes & Control 26:1603–1616. doi: 10.1007/s10552-015-0654-9

de Onis M, Onyango AW, Borghesi E, Siyam A, Nishida C, Siekmann J. 2007. Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World Health Organization 85:660–667. doi: 10.2471/BLT.07.043497

Deaton A. 2007. Height, health, and development. Proceedings of the National Academy of Sciences 104:13232–13237. doi: 10.1073/pnas.0611500104

Dubois L, Ohm Kyvik K, Girard M, Tatone-Tokuda F, Pérusse D, Hjelmborg J, Skyttea A, Rasmussen F, Wright MJ, Lichtenstein P, Martin NG. 2012. Genetic and environmental contributions to weight, height, and BMI from birth to 19 years of age: an international study of over 12,000 twin pairs. PLoS One 7:e30153. doi: 10.1371/journal.pone.0030153

Emerging Risk Factors Collaboration. 2012. Adult height and the risk of cause-specific death and vascular morbidity in 1 million people: individual participant meta-analysis. International Journal of Epidemiology 41:1419–1433. doi: 10.1093/ije/dys086

Engstrom JL, Paterson SA, Doherty A, Trabulsi M, Speer KL. 2003. Accuracy of self-reported height and weight in women: an integrative review of the literature. Journal of Midwifery & Women’s Health 48:338–345. doi: 10.1016/S1526-9523(03)00281-2

Eveleth PB, Tanner JM. 1990. Worldwide Variation in Human Growth. Cambridge: Cambridge University Press.

Ezzati M, Martin H, Skjold S, Vander Hoorn S, Murray CJ. 2006. Trends in national and state-level obesity in the USA after correction for self-report bias: analysis of health surveys. Journal of the Royal Society of Medicine 99:250–257. doi: 10.1258/jrsm.99.5.250

Facchinetti F, Gualdi-Russo E. 1982. Secular anthropometric changes in a sample of Italian adults. Journal of Human Evolution 11:703–714. doi: 10.1016/S0047-2484(82)80059-6

Finucane MM, Paciorek CJ, Danaei G, Ezzati M. 2014. Bayesian Estimation of Population-Level Trends in Measures of Health Status. Statistical Science 29:18–25. doi: 10.1214/13-STS427

Fisher RA. 1919. XV.—The Correlation between Relatives on the Supposition of Mendelian Inheritance. Transactions of the Royal Society of Edinburgh 52:399–433. doi: 10.1017/S0080456800012163

Fogel RW, Floud R. 2004. 2004. The Escape From Hunger and Premature Death, 1700-2100: Europe, America, and the Third World. Cambridge: Cambridge University Press.

Fogel RW, Harris B, Hong S. 2011. The Changing Body: Health, Nutrition and Human Development in the Western World Since 1700. Cambridge, UK: New York, United States of America: Cambridge University Press.

Fogel RW, Gregory A, Wachtler KW. 1990. Height, Health and History: Nutritional Status in the United Kingdom, 1750-1980. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511983245

Floud, R., Fogel RW, Engerman SL, Floud R. 1983. Secular changes in American and British stature and nutrition. The Journal of Interdisciplinary History 14:445–481. doi: 10.2307/203716

Floud RW. 2004. The Escape From Hunger and Premature Death, 1700-2100: Europe, America, and the Third World. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511983245

Frisch RE, Reveille R. 1971. Height and weight at menarche and a hypothesis of menarche. Archives of Disease in Childhood 46:695–701. doi: 10.1136/adc.46.6.695

Grasgruber P, Casek J, Kalina T, Sebera M. 2014. The role of nutrition and genetics as key determinants of the positive height trend. Economics and Human Biology 15:81–100. doi: 10.1016/j.ehb.2014.07.002

Green J, Cairns BJ, Casabonne D, Wright FL, Reeves G, Beral V, Million Women Study collaborators. 2011. Height and cancer incidence in the Million Women Study: prospective cohort, and meta-analysis of prospective studies of height and total cancer risk. Lancet Oncology 12:785–794. doi: 10.1016/S1470-2241(11)70154-1

Haefner LS, Barbieri MA, Rona RJ, Bettiol H, Silva AA. 2002. The relative strength of weight and length at birth in contrast to social factors as determinants of height at 18 years in Brazil. Annals of Human Biology 29:627–640. doi: 10.1080/03014460210145847

Hatton TJ, Bray BE. 2010. Long run trends in the heights of European men, 19th-20th centuries. Economics and Human Biology 8:405–413. doi: 10.1016/j.ehb.2010.03.001

Hayes AJ, Clarke PM, Lung TW. 2011. Change in bias in self-reported body mass index in Australia between 1995 and 2008 and the evaluation of correction equations. Population Health Metrics 9:53. doi: 10.1186/1478-7964-9-53

Komlos J, Baur M. 2004. From the tallest to (one of) the fattest: the enigmatic fate of the American population in the 20th century. Archives of Disease in Childhood 89:57–61. doi: 10.1136/adc.89.1.654

Komlos J, Baur M. 2004. From the tallest to (one of) the fattest: the enigmatic fate of the American population in the 20th century. Archives of Disease in Childhood 89:57–61. doi: 10.1136/adc.89.1.654

Komlos J, Baur M. 2004. From the tallest to (one of) the fattest: the enigmatic fate of the American population in the 20th century. Archives of Disease in Childhood 89:57–61. doi: 10.1136/adc.89.1.654

Komlos J, Lauderdale BE. 2007. The mysterious trend in American heights in the 20th century. Annals of Human Biology 34:206–215. doi: 10.1080/03014460601116803

Komlos J. 2009. Anthropometric history: an overview of a quarter century of research. Anthropologischer Anzeiger 67:341–356. doi: 10.1127/0003-5548/2009/0027

Kozuki N, Katz J, Lee AC, Vogel JP, Silveira MF, Sania A, Stevens GA, Cousins S, Caulfield LE, Christian P, Huybregts L, Roberfroid D, Schmiegelow et al. 2015. Short Maternal Stature Increases Risk of Small-for-Gestational-Age and Preterm Births in Low- and Middle-Income Countries: Individual Participant Data Meta-Analysis and Population Attributable Fraction. Journal of Nutrition 145:2542–2550. doi: 10.3945/jn.115.216374

Lancet. 2014. Women, children, and adolescents: the post-2015 agenda. Lancet 384:1159. doi: 10.1016/S0140-6736(14)61707-7

Larsen A, Atstrup Schrøder S, Schmidt IM, Hørby Jørgensen M, Fleischer Michaelsen K. 2006. Secular change in adult stature has come to a halt in northern Europe and Italy. Acta Paediatrica 95:754–755. doi: 10.1080/08035250500527323
Lettre G. 2011. Recent progress in the study of the genetics of height. *Human Genetics* **129**:465–472. doi: 10.1007/s00439-011-0969-x

Mamidi RS, Kulkarni B, Singh A. 2011. Secular trends in height in different states of India in relation to socioeconomic characteristics and dietary intakes. *Food and Nutrition Bulletin* **32**:23–34. doi: 10.1177/156482651103200103

Martins CS, Fernandes-Rosa FL, Espineira AR, de Souza RM, de Castro M, Barbieri MA, Bettiol H, Jorge AL, Antonini SR. 2014. The growth hormone receptor exon 3 polymorphism is not associated with height or metabolic traits in healthy young adults. *Growth Hormone & IGF Research* **24**:123–129. doi: 10.1016/j.ghir.2014.04.005

Martorell R. 1995. Results and implications of the INCAP follow-up study. *Journal of Nutrition* **125**:1127S–1138.

Moradi A. 2010. Nutritional status and economic development in sub-Saharan Africa, 1950-1980. *Economics and Human Biology* **8**:16–29. doi: 10.1016/j.ehb.2009.12.002

NCD Risk Factor Collaboration (NCD-RisC). 2016. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet* **387**:1377–1396. doi: 10.1016/S0140-6736(16)30054-X

Nelson CP, Hamby SE, Saleheen D, Hopewell JC, Zeng L, Assimes TL, Kanoni S, Willenborg C, Burgess S, Amouyel P, Anand S, Blankenberg S, Boehm BO, Clarke RJ, Collins R, Dedoussis G, Farrall M, Franks PW, Groop L, Hall AS, et al. 2015. Genetically determined height and coronary artery disease. *New England Journal of Medicine* **372**:1608–1618. doi: 10.1056/NEJMoa1404881

Niesch E, Dale C, Palmer TM, White J, Keating BJ, van Iperen EP, Goel A, Padmanabhan S, Asselbergs FW, Verschuren WM, Wijmenga C, Van der Schouw YT, Onland-Moret NC, Lange LA, Hovingh GK, Sivapalaratnam S, Morris RW, Whincup PH, Wannamethee GS, Gaunt TR, et al. 2015. Adult height, coronary heart disease and stroke: a multi-locus Mendelian randomization meta-analysis. *International Journal of Epidemiology*. doi: 10.1093/ije/dyv074

Paajanen TA, Oksala NK, Kuukasjärvi P, Karhunen PJ. 2010. Short stature is associated with coronary heart disease: a systematic review of the literature and a meta-analysis. *European Heart Journal* **31**:1802–1809. doi: 10.1093/eurheartj/ehq155

Pongou R, Salomon JA, Ezzati M. 2006. Health impacts of macroeconomic crises and policies: determinants of variation in childhood malnutrition trends in Cameroon. *International Journal of Epidemiology* **35**:648–656. doi: 10.1093/ije/dyl016

Rue H, Held L. 2005. *Gaussian Markov Random Fields: Theory and Applications*. Boca Raton: Chapman & Hall/CRC.

Schenker N, Raghunathan TE, Bondarenko I. 2010. Improving on analyses of self-reported data in a large-scale health survey by using information from an examination-based survey. *Statistics in Medicine* **29**:533–545. doi: 10.1002/sim.3809

Schmidt IM, Jørgensen MH, Michaelsen KF. 1995. Height of conscripts in Europe: is postneonatal mortality a predictor? *Annals of Human Biology* **22**:57–67. doi: 10.1080/0144695950003702

Schönbeck Y, Talma H, van Dommelen P, Bakker B, Buitendijk SE, HiraSing RA, van Buuren S. 2013. The world's tallest nation has stopped growing taller: the height of Dutch children from 1955 to 2009. *Pediatric Research* **73**:371–377. doi: 10.1038/pr.2012.189

Silventoinen K, Kaprio J, Lahelma E, Koskenvuo M. 2000. Relative effect of genetic and environmental factors on body height: differences across birth cohorts among Finnish men and women. *American Journal of Public Health* **90**:627–630. doi: 10.2105/ AJPH.90.4.627

Sokoloff KL, Villafior GC. 1982. The early achievement of modern stature in America. *Social Science History* **6**:453–481. doi: 10.1177/016104078200600221

Stevens GA, Finucane MM, Paciorek CJ, Flaxman SR, Donner AJ, Ezzati M, Nutrition Impact Model Study Group (Child Growth). 2012. Trends in mild, moderate, and severe stunting and underweight, and progress towards MDG 1 in 141 developing countries: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet* **380**:824–834. doi: 10.1016/S0140-6736(12)60647-3

Strauss J, Thomas D. 1998. Health, nutrition, and economic development. *Journal of Economic Literature* **36**:766–817.

Stulp G, Barrett L, Trope FC, Mills M. 2015. Does natural selection favour taller stature among the tallest people on earth? *Proceedings. Biological Sciences / the Royal Society* **282**:20150211. doi: 10.1098/rspb.2015.0211

Subramanian SV, Özaltin E, Finlay JE. 2011. Height of nations: a socioeconomic analysis of cohort differences and patterns among women in 54 low- to middle-income countries. *PLoS One* **6**:e18962. doi: 10.1371/journal.pone.0018962

Sundberg S. 2009. Agriculture, poverty and growth in Africa: linkages and policy challenges. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* **4**. doi: 10.1079/PAVSNRR20094005

Sørensen HT, Sabroe S, Rothman KJ, Gillman M, Steffensen FH, Fischer P, Sørensen TI. 1999. Birth weight and length as predictors for adult height. *American Journal of Epidemiology* **149**:726–729. doi: 10.1093/oxfordjournals.aje.a009881

Tanner JM, Hayashi T, Preece MA, Cameron N. 1982. Increase in length of leg relative to trunk in Japanese children and adults from 1957 to 1977; comparison with British and with Japanese Americans. *Annals of Human Biology* **9**:411–423. doi: 10.1080/03014468.200005951

Tanner JM. 1962. *Growth at Adolescence*. Oxford: Blackwell Scientific Publications.

Tanner JM. 1981. *A History of the Study of Human Growth*. Cambridge: Cambridge University Press.

NCD Risk Factor Collaboration (NCD-RisC). eLife 2016;5:e13410. DOI: 10.7554/eLife.13410
