ONLINE FIRST

This is a provisional PDF only. Copyedited and fully formatted version will be made available soon.

ISSN: 0015-5659

e-ISSN: 1644-3284

The association between body height and longevity: evidence from a national population sample

Author: Piotr Paweł Chmielewski

DOI: 10.5603/FM.a2023.0005

Article type: Original article

Submitted: 2023-01-11

Accepted: 2023-01-19

Published online: 2023-01-26

The association between body height and longevity: evidence from a national population sample

Piotr Paweł Chmielewski, Adult height and longevity in Poland

Piotr Paweł Chmielewski

Division of Anatomy, Department of Human Morphology and Embryology, Faculty of Medicine, Wroclaw Medical University, Wroclaw, Poland

Address for correspondence: Piotr Paweł Chmielewski, PhD in Human Biology (Anatomy), Division of Anatomy, Department of Human Morphology and Embryology, Medical University, ul. Chałubinskiego 6a, 50–368 Wroclaw, Poland, e-mail: piotr.chmielewski@umed.wroc.pl

ABSTRACT

To date, numerous studies have reported that taller individuals are healthier and live longer. Nevertheless, the association between adult stature and longevity involves conflicting findings. This study investigated whether taller Polish adults live longer than their shorter counterparts. Data on declared height were available from 848,860 individuals who died in the years 2004–2008 in Poland. To allow for the cohort effect, the *Z*-values were generated. Separately for both sexes, Pearson's *r* coefficients of correlation were calculated. Subsequently, one way ANOVA was performed. The correlation between adult height and longevity was negative and statistically significant in both men and women. After eliminating the effects of secular trends in height, the correlation was very weak (r = –0.0044 in men and r = –0.0038 in women) but significant (p = 0.023 and p = 0.022, respectively). On balance, these findings do not bear out the hypothesis that taller individuals have a longevity advantage. Since taller stature had a predictable effect on lifespan in the oldest old (85+), these results strongly suggest that longevity favours smaller people. We discuss these findings in an attempt to identify the biological mechanisms that might be responsible for greater longevity in smaller people. We also analyze selected anthropological factors that pertain to height and longevity.

Key words: adult height, body height, lifespan, longevity, stature, survival

INTRODUCTION

Human body height is a polygenic trait that is controlled by several genomic loci [35]. Stature is also one of the most conspicuous morphological traits that has important ecological and social consequences [17]. Historically, taller individuals were more privileged as they were the richest people who had significantly more resources to address own demands and who were able to lead a healthy lifestyle [12]. An abundance of studies have reported that body height correlates positively with educational attainment, socioeconomic status (SES), income, wealth, reproductive success, overall health and survival [4, 19, 25–27]. However, these links are often complex and may be obscured by various interactions. For example, women prefer taller men but men prefer shorter women [25, 30, 31]. In general, body height and cardiovascular disease (CVD) mortality are inversely correlated [11]. Nonetheless, not all researchers agree that shorter people are more susceptible to CVD as individuals of similar body proportions, body mass index (BMI), educational attainment and SES should be compared with each other [29].

Several studies have revealed that taller people are healthier and have a longevity advantage over their shorter counterparts [11, 12, 15, 24, 26]. It is generally accepted that taller stature reflects better childhood nutrition and better environment and as such can be used as a genuine indicator of the health status and disease exposure in historical populations [11]. Furthermore, the hypothesis that taller individuals are healthier and live longer is widespread among physicians and anthropologists. This is because these early studies have long been interpreted as indicating that taller individuals have lower mortality rates and live longer. Nevertheless, the relationship between adult stature and longevity, which has recently been studied more intensively, remains unclear. For instance, compelling data from animal studies show that greater body size correlates with shorter lifespan within, but not between, mammalian species [1, 2, 6, 21]. Interestingly, recent findings indicate that greater body size, but especially body weight and BMI, is costly in terms of longevity, and smaller individuals outlive those that are larger. Moreover, a similar relationship has been shown in studies of various human populations [1, 2, 9, 13, 28, 29]. The aim of the current study is to explore the relationship between adult height and longevity in adults who died between 2004 and 2008 in Poland.

MATERIAL AND METHODS

For the purpose of the study, we collected data on all adult deaths in the years 2004–2008 in Poland from the national archives at the Ministry of the Interior and Administration in Warsaw. In total, records from 848,860 individuals, including 483,512 men (57%) and 365,348 women (43%), were available. These data derive from two sources: (1) signalments in the census obtained from identity card offices (body height declared on the identity card) and (2) the Universal Electronic System for Registration of the Population 'PESEL' (sex and dates of birth and death).

The collected data have a number of advantages. Firstly, the sample is very large and representative for the whole population. It is generally agreed that the collection of large samples is a *sine qua non* prerequisite. Secondly, the study sample involves typical causes of death. Numerous studies were confined to the data that were derived from small geographic areas, e.g. a given city or district, obtained in a short period of time or from individuals who died of a specific disease, e.g. CVD or cancer. Although this approach is justified for practical reasons, this can be precarious. Our data are based on reliable documents, i.e. death certificates, which were issued by the authorities. Although it is true that respondents often overestimate their height, these effects are significant when people advertise for dating, and not when they provide information on their stature for legal or official purposes [16, 23]. Thus, it should be emphasised that the use of declared height instead of measured height is acceptable.

The normality of distribution was tested with the goodness-of-fit test χ^2as well as coefficients of asymmetry (*As*) and kurtosis (*K*). Student's *t*-test and one-way analysis of variance (ANOVA) were performed. In this study, we use a statistical approach that takes into account the effects of secular changes in height. In order to control the cohort effect, the *Z*-value, i.e. standard deviation (SD)-normalized difference from the arithmetic mean of each individual, was calculated for the body height of each individual, according to the formula:

Z = (actual height – mean height) ⁄ SD. Subsequently, Pearson's *r* coefficients of correlation were calculated separately for both sexes.

RESULTS

The distributions for height and lifespan in men and women did not differ from the normal distribution. Men were taller than women (arithmetic mean ± standard deviation, 171.6 ± 6.6 cm and 159.6 ± 6.2 cm, respectively, *t*-test, $p < 0.001$) and they had a lower age at death (67.9 ± 13.8 years and 75.0 ± 12.7 years, respectively, *t*-test, $p < 0.001$). For individuals who died at the age of 50 years and above, these results were as follows: 171.1 ± 6.4 cm and 71.1 ± 10.8 years for men and 159.4 ± 6.1 cm and 76.5 ± 10.8 years for women, all differences were statistically significant ($p < 0.001$).

The analysis revealed that taller individuals had shorter lifespans compared with their shorter peers (Table 1). In individuals who lived for at least 50 years, longevity was inversely correlated with adult height in men ($r = –0.27$, $p < 0.001$) and women ($r = –0.25$, $p < 0.001$). For both sexes, the longest lifespan was found for individuals born in December, and the shortest for those born in May. The amplitude of lifespan resulting from the month of birth effect was 16 months in men and 14 months in women. In the oldest old, i.e. people aged 85 years and above, there was an inverse relationship between body height and longevity (Figures 1 and 2).

When body height was plotted against lifespan, it turned out that smaller individuals, in general, had a longevity advantage. However, all of these effects waned after the calculation of the *Z*-values (Figures 3 and 4), when the influences of secular changes in body height were eliminated in the whole study sample. The coefficients of correlation were extremely low, i.e. $r = –0.0044$ for men and $r = –0.0038$ for women, but statistically significant ($p = 0.023$ and $p = 0.022$, respectively).

DISCUSSION

This research has revealed an inverse relationship between adult height and lifespan in both sexes, which is in agreement with several studies [9, 13, 28, 29, 32, 33]. Given that taller people have better nutrition and higher SES, including income and wealth [4, 19, 25–27], these findings convincingly demonstrate that taller stature is not associated with enhanced longevity in the studied population. Contrary to the popular belief that tallness is linked to better health and survival, these results strongly suggest that shorter people can outlive their taller counterparts. There are, however, both theoretical and empirical reasons for doubting that the observed relationship between stature and longevity is direct or causal. Probably, stature is just not a good predictor of longevity, and there are many other factors and processes at play.

It has been established that adult height represents the interactive effects of many processes [3], including the influences of genetic, epigenetic, nutritional, psychological, ecological and lifestyle-related factors such as pathogens, parasites, stress level, amount of sleep, diseases or disorders (Fig. 5). It should be remembered that not only environmental and life-style relate factors, such as an unhealthy diet and malnutrition, but also genetic disorders, such as Down syndrome, Russel-Silver syndrome, Noonan syndrome, Turner syndrome, Prader-Willi syndrome, dwarfism due to achondroplasia and other causes, as well as metabolic and developmental problems, such as diabetes, Cushing's syndrome, growth hormone (GH) deficiencies, renal dysfunctions, heart failure etc., can result in short stature.

Beard and Blaser [3] argued that infectious diseases in childhood can negatively affect adult stature. Indeed, numerous studies have shown that children who suffered from diarrhoea and dehydration were significantly shorter as adults than those children who did not have these problems. For example, a study by Martorell and associates [20] demonstrated that in Guatemala children relatively free from diarrhoea during the first seven years of life would be around 4 cm taller than children more frequently ill with diarrhoea. Interestingly, it has been estimated that each episode of diarrhoea in childhood is associated with a decrease in adult height by roughly 0.6 cm [5]. Furthermore, several other studies confirm the hypothesis that infectious diseases in the first years of life are important factors affecting adult stature. Clinical observations suggest that other medical problems and conditions, such as chronic granulomatous disease (CGD), can also result in diminished final height.

Interestingly, taller stature might be associated with increased risk of cancer at different anatomic sites [14, 22, 28, 32, 34], even though it is unclear why taller and stouter people are more likely to develop cancer. However, tentative explanations can be offered. For example, taller and stockier individuals have significantly more cells in the body as opposed to their smaller and slimmer counterparts. It has recently been suggested that the sheer number of cells in the body can predict the relation between body size and cancer with no need to suggest additional factors [22]. Although cells are constantly repairing and maintaining themselves via the intake of energy from food, individuals within the same species that have a considerable amount of extracells are more prone to DNA damage and cancer. This is because more cells in the body increase the risk factor for DNA damage and somatic mutations. Furthermore, an organism that accumulates extra senescent cells, a situation that can occur in those organisms that produce more cells and need more new cells to replace older ones, is more likely to reach higher levels of chronic low-grade systemic inflammation, which is detrimental to health and survival [8, 10]. It should be remembered that biological factors related to greater height, such as hormonal and genetic influences, can directly stimulate cancer development and progression. It is well known that growth is physiologically costly, and smaller individuals within mammalian species tend to have lower mortality rates. For example, dogs, cows, horses and mice have been studied for years, and smaller individuals live longer [1, 2, 6, 21]. The data showing that smaller individuals outlive their larger counterparts suggest a role of biological factors (Table 2). Interestingly, animal studies indicate that caloric restriction reduces body size and extends lifespan. Additionally, several studies have demonstrated that tall people are less likely to reach advanced ages [7, 9, 13, 28, 29, 32–34].

However, several confounders, such as BMI, somatotypes, SES, educational attainment, smoking, health care etc., may influence the relationship between body height and longevity. Furthermore, it can be argued that adjusting for risk factors is a crude and inexact process. In addition, poor medical care can also affect results. Another confounder is that in upper economic classes, those who have spent their lives in the upper class are taller and have lower mortality rates than upper class individuals who were born in lower classes and worked up to the upper class. For example, a number of insurance studies have reported that taller men had lower mortality rates than their shorter counterparts. According to Samaras [29], body height is an index for greater body weight and thus BMI. Although taller and slimmer individuals can live longer than shorter and overweight people, greater body weight and BMI are related to increased mortality and morbidity.

This study has limitations that should be acknowledged. Firstly, only declared body height was used. Secondly, the analysis did not consider potentially significant confounding factors, such as BMI, SES, educational attainment etc., as these data were not available. However, the relationship between adult height and longevity can be established based on the study sample used for the analysis. It should be stressed that shorter individuals score *worse* in terms of SES, income and wealth, and since taller individuals score *better*, the finding that taller individuals do not live longer than their shorter counterparts is even more intriguing.

CONCLUSIONS

On balance, these results do not confirm the view that taller people live longer. The inverse relationship between height and longevity was reported for both sexes. After allowing for secular trends in stature, these effects waned but remained statistically significant, thereby suggesting that longevity favours smaller individuals in the studied population.

Conflict of interest: None declared

REFERENCES

1. Bartke A. Healthy aging: is smaller better? - a mini-review. Gerontology. 2012; 58:337–343, doi: 10.1159/000335166.
2. Bartke A. Somatic growth, aging, and longevity. NPJ Aging Mech Dis. 2017; 3:14, doi: 10.1038/s41514-017-0014-y.
3. Beard AS, Blaser MJ. The ecology of height: the effect of microbial transmission on human height. Perspect Biol Med. 2002; 45:475–498, doi: 10.1353/pbm.2002.0064.
4. Bielicki T, Charzewski J. Body height and upward social mobility. Ann. Hum. Biol. 1983; 10:403–408.
5. Black RE, Brown KH, Becker S. Effects of diarrhea associated with specific enteropathogens on the growth of children in rural Bangladesh. Pediatrics. 1984; 73:799–805.
6. Blagosklonny MV. Big mice die young but large animals live longer. Aging (Albany NY). 2013; 5:227–233, doi: 10.18632/aging.100551.
7. Chmielewski P, Borysławski K. Understanding the links between month of birth, body height, and longevity: why some studies reveal that shorter people live longer – further evidence of seasonal programming from the Polish population. Anthropol Rev. 2016; 79:375–395, doi: 10.1515/anre-2016-0028.
8. Chmielewski P. Leukocyte count, systemic inflammation, and health status in older adults: a narrative review. Anthropol Rev. 2018; 81:81–101, doi: 10.2478/anre-2018-0007.
9. Chmielewski P. The relationship between adult stature and longevity: tall men are unlikely to outlive their short peers – evidence from a study of all adult deaths in Poland in the years 2004–2008. Anthropol Rev. 2016; 79:439–460, doi: 10.1515/anre-2016-0032.

10. Chmielewski PP, Strzelec B. Elevated leukocyte count as a harbinger of systemic inflammation, disease progression, and poor prognosis: a review. Folia Morphol. 2018; 77:171–178, doi: 10.5603/FM.a2017.0101.
11. Finch CE, Crimmins EM. Inflammatory exposure and historical changes in human life-spans. Science. 2004; 305:1736–1739, doi: 10.1126/science.1092556.
12. Gunnell D, Rogers J, Dieppe P. Height and health: predicting longevity from bone length in archaeological remains. J Epidemiol Community Health. 2001; 55:505–507, doi: 10.1136/jech.55.7.505.
13. He Q, Morris BJ, Grove JS, Petrovitch H, Ross W, Masaki KH, Rodriguez B, Chen R, Donlon TA, Willcox DC, Willcox BJ. Shorter men live longer: association of height with longevity and FOXO3 genotype in American men of Japanese ancestry. PLoS One. 2014; 9:e94385, doi: 10.1371/journal.pone.0094385.
14. Kabat GC, Anderson ML, Heo M, Hosgood HD 3rd, Kamensky V, Bea JW, Hou L, Lane DS, Wactawski-Wende J, Manson JE, Rohan TE. Adult stature and risk of cancer at different anatomic sites in a cohort of postmenopausal women. Cancer Epidemiol Biomarkers Prev. 2013; 22:1353–1363, doi: 10.1158/1055-9965.EPI-13-0305.
15. Kemkes-Grottenthaler A. The short die young: the interrelationship between stature and longevity-evidence from skeletal remains. Am J Phys Anthropol. 2005; 128:340–347, doi: 10.1002/ajpa.20146.
16. Krzyżanowska M, Umławska W. Measured versus self-reported body height. Int J Anthropol. 2002; 17:113–120.
17. Little MA. Evolutionary strategies for body size. Front. Endocrinol. 2020; 11:107, doi: 10.3389/fendo.2020.00107.
18. Maier AB, van Heemst D, Westendorp RG. Relation between body height and replicative capacity of human fibroblasts in nonagenarians. J Gerontol A Biol Sci Med Sci. 2008; 63:43–45, doi: 10.1093/gerona/63.1.43.
19. Marco-Gracia FJ, Puche J. The association between male height and lifespan in rural Spain, birth cohorts 1835-1939. Econ Hum Biol. 2021; 43:101022, doi: 0.1016/j.ehb.2021.101022.
20. Martorell R, Habicht JP, Yarbrough C, Lechtig A, Klein RE, Western KA. Acute morbidity and physical growth in rural Guatemalan children. Am J Dis Child. 1975; 129:1296–1301, doi: 10.1001/archpedi.1975.02120480022007.

21. Miller RA, Harper JM, Galecki A, Burke DT. Big mice die young: early life body weight predicts longevity in genetically heterogeneous mice. Aging Cell. 2002; 1:22–29, doi: 10.1046/j.1474-9728.2002.00006.x.
22. Nunney L. Size matters: height, cell number and a person's risk of cancer. Proc Biol Sci. 2018; 285: 20181743, doi: 10.1098/rspb.2018.1743.
23. Olfert MD, Barr ML, Charlier CM, Famodu OA, Zhou W, Mathews AE, Byrd-Bredbenner C, Colby SE. Self-Reported vs. Measured Height, Weight, and BMI in Young Adults. Int J Environ Res Public Health. 2018; 15: 2216, doi: 10.3390/ijerph15102216.
24. Paajanen TA, Oksala NK, Kuukasjärvi P, Karhunen PJ. Short stature is associated with coronary heart disease: a systematic review of the literature and a meta-analysis. Eur Heart J. 2010; 31:1802–1809, doi: 10.1093/eurheartj/ehq155.
25. Pawlowski B, Dunbar RIM, Lipowicz A. Tall men have more reproductive success. Nature. 2000; 403: 156, doi: 10.1038/35003107.
26. Perkins JM, Subramanian SV, Davey Smith G, Özaltin E. Adult height, nutrition, and population health. Nutr Rev. 2016; 74:149–165, doi: 10.1093/nutrit/nuv105.
27. Rietveld CA, Hessels J, van der Zwan P. The stature of the self-employed and its relation with earnings and satisfaction. Econ Hum Biol. 2015; 17: 59–74, doi: 10.1016/j.ehb.2015.02.001.
28. Salaris L, Poulain M, Samaras TT. Height and survival at older ages among men born in an inland village in Sardinia (Italy), 1866-2006. Biodemography Soc Biol. 2012; 58: 1–13, doi: 10.1080/19485565.2012.666118.
29. Samaras TT. Shorter height is related to lower cardiovascular disease risk - a narrative review. Indian Heart J. 2013; 65: 66–71, doi: 10.1016/j.ihj.2012.12.016.
30. Sear R, Marlowe FW. How universal are human mate choices? Size does not matter when Hadza foragers are choosing a mate. Biology Letters. 2009; 5: 606–609, doi: 10.1098/rsbl.2009.0342.
31. Sear R. Height and reproductive success. How a Gambian population compares with the West. Human Nature. 2006; 17: 405–418, doi: 10.1007/s12110-006-1003-1.
32. Sohn K. Now, the Taller Die Earlier: The Curse of Cancer. J Gerontol A Biol Sci Med Sci. 2016; 71: 713–719, doi: 10.1093/gerona/glv065.
33. Wilhelmsen L, Svärdsudd K, Eriksson H, Rosengren A, Hansson PO, Welin C, Odén A, Welin L. Factors associated with reaching 90 years of age: a study of men born in 1913 in

Gothenburg, Sweden. J Intern Med. 2011; 269: 441–451, doi: 10.1111/j.1365-2796.2010.02331.x.

34. Wirén S, Häggström C, Ulmer H, Manjer J, Bjørge T, Nagel G, Johansen D, Hallmans G, Engeland A, Concin H, Jonsson H, Selmer R, Tretli S, Stocks T, Stattin P. Pooled cohort study on height and risk of cancer and cancer death. Cancer Causes Control. 2014; 25: 151–159, doi: 10.1007/s10552-013-0317-7.

35. You C, Zhou Z, Wen J, Li Y, Pang CH, Du H, Wang Z, Zhou XH, King DA, Liu CT, Huang J. Polygenic Scores and Parental Predictors: An Adult Height Study Based on the United Kingdom Biobank and the Framingham Heart Study. Front Genet. 2021; 12: 669441, doi: 10.3389/fgene.2021.669441.

Table 1. Body height (arithmetic mean ± standard deviation, SD, in cm) in adults who died at a given age in the years 2004-2008 in Poland

Age at death	**Men**			**Women**		
	N	**Mean**	**SD**	***N***	**Mean**	**SD**
50	12305	174.3	6.5	4312	162.1	5.7
55	171622	173.4	6.3	7373	161.7	5.8
60	19335	172.5	6.1	9181	161.6	5.5
65	18301	171.6	6.1	9447	161.0	5.7
70	25826	171.0	6.0	14903	160.3	5.6
75	30493	170.5	6.1	22658	159.8	5.9
80	27263	170.0	6.3	29103	159.1	6.0
85	17186	169.5	6.6	25836	158.5	6.1
90	5443	168.7	6.8	10983	157.3	6.2
95	2266	167.5	6.9	6009	156.5	6.4
100	261	167.0	6.9	820	155.3	6.3

Table 2. Putative mechanisms providing smaller people with a longevity advantage

Biological factors	**Explanation**
The total number of cells in the body	Tall people have more somatic cells, thus allowing greater exposure to DNA damage and molecular entropy. The sheer number of cells

	in the body predicts the relationship between adult height and cancer risk with no need to suggest additional factors [22]
Longer telomeres and more cell replications	Although the results are inconclusive, most studies indicate that longer telomeres are related to greater longevity. Some studies suggest taller nonagenarians have shorter telomeres [18]. Taller individuals use up more cells in the initial production of a larger body and in the daily replacement of damaged or dead cells they are at a disadvantage as they continuously need more cells as opposed to smaller individuals
Lower levels of growth hormone (GH) and reduced insulin/IGF-1 signalling	Insulin/IGF-1 signalling is an evolutionarily conserved pathway that participates in various molecular processes and regulates lifespan across species. Reduced GH/insulin/IGF-1 signalling seems beneficial in terms of longevity. Taller individuals have higher levels of GH and more active insulin/IGF-1 signalling [1, 2]
Less hyperactive mTOR, which is a central hub of nutrient signalling	mTOR is an important sensor for nutrient signals that is involved in the longevity pathway. Taller and stouter individuals eat more as opposed to their shorter counterparts, assuming that larger and stockier individuals have more active mTOR, this central hub of nutrient signalling can be involved in the link between body size and longevity [6]
Desirable levels of certain biochemical parameters	Shorter and slimmer individuals who follow a healthy diet tend to have lower levels of total cholesterol and C-reactive protein (CRP) and higher levels of SHBG [13, 28]

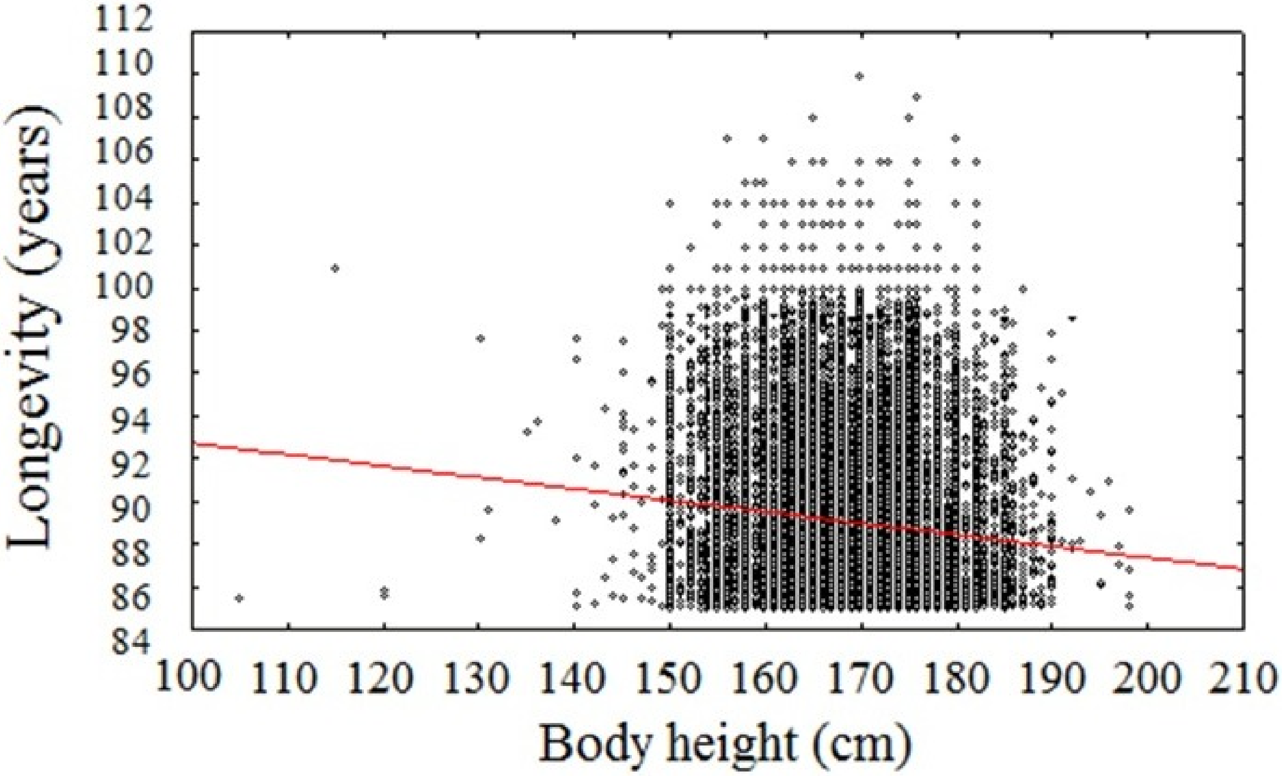
Figure 1. The relationship between actual height and longevity in men aged 85 and above (*N* = 39,191).

Figure 2. The relationship between actual height and longevity in women aged 85 and above (*N* = 75,405).

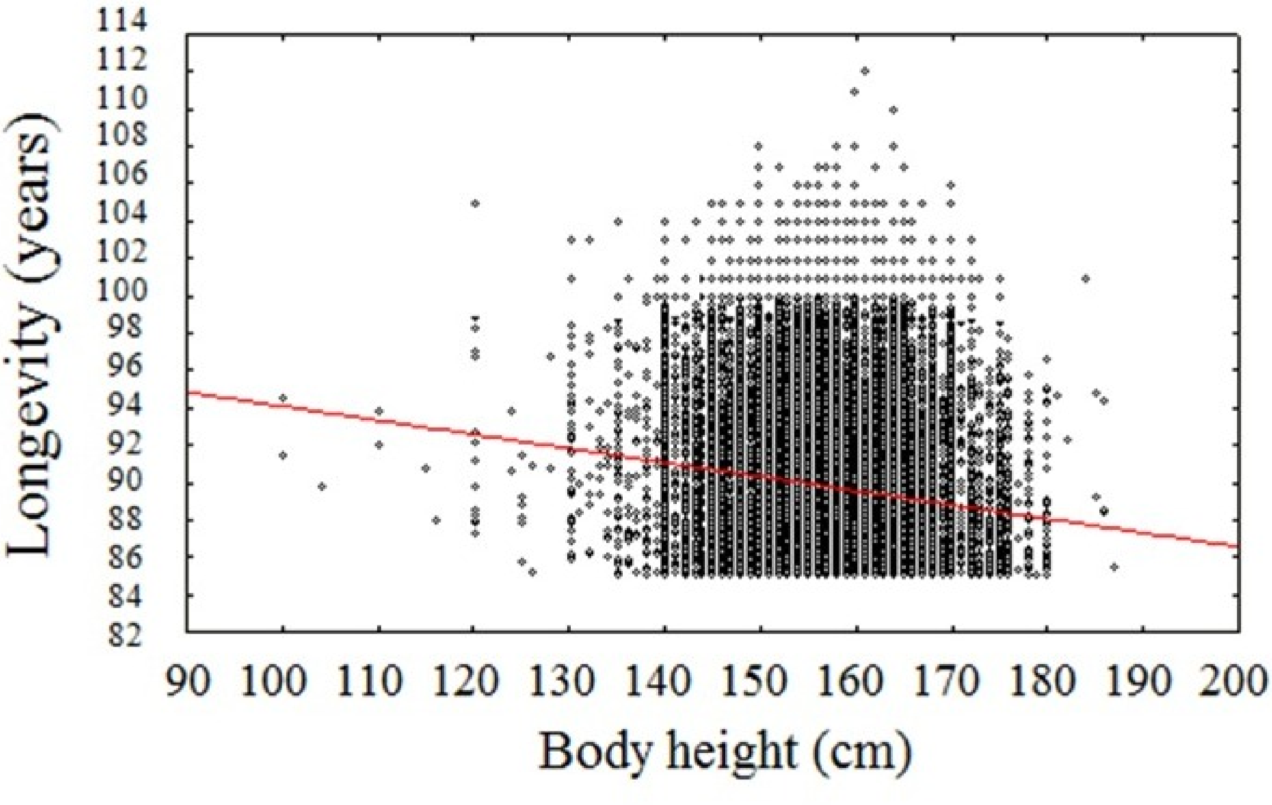
Figure 3. The relationship between normalised height and longevity in men (*N* = 483,512).

Figure 4. The relationship between normalised height and longevity in women (*N* = 365,348).

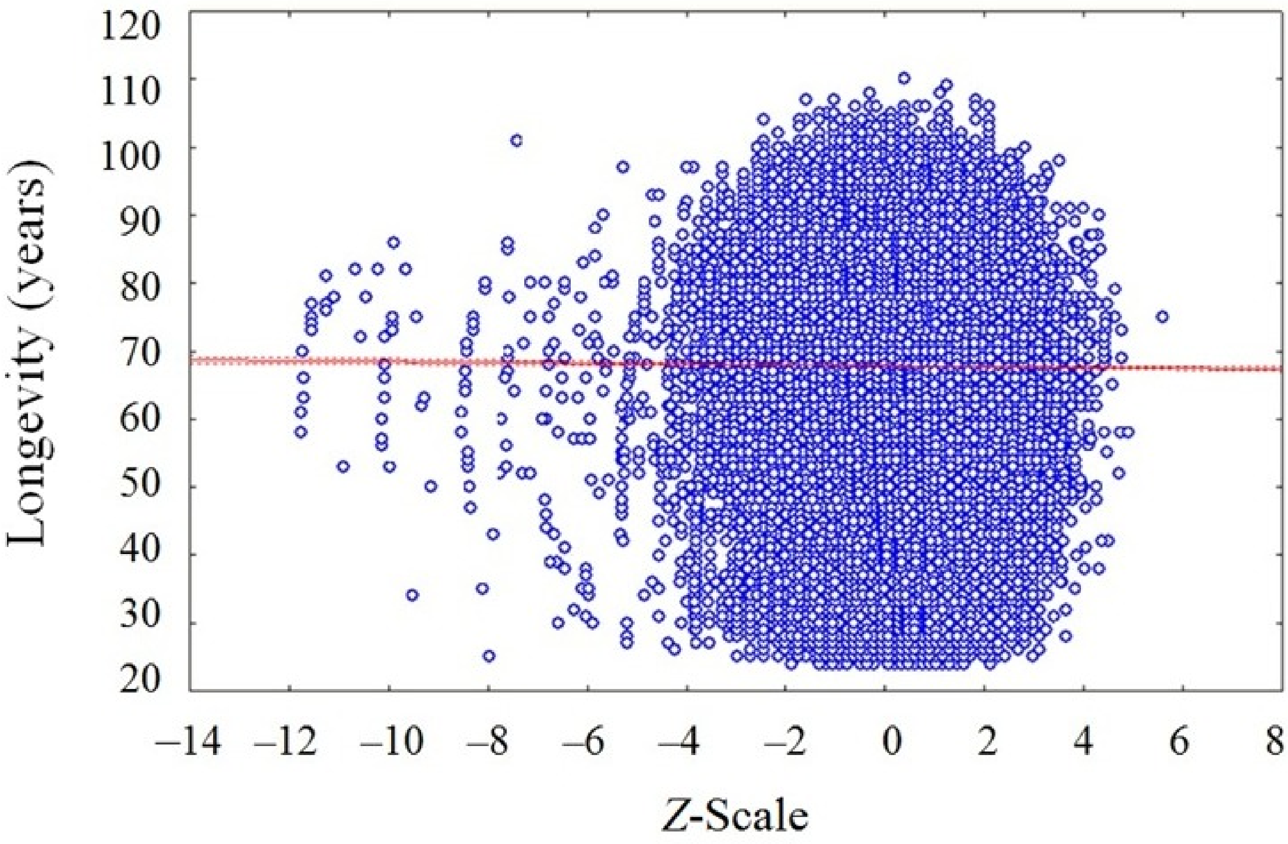
Figure 5. A constellation of factors that affect growth and development and are crucial for adult stature in humans.



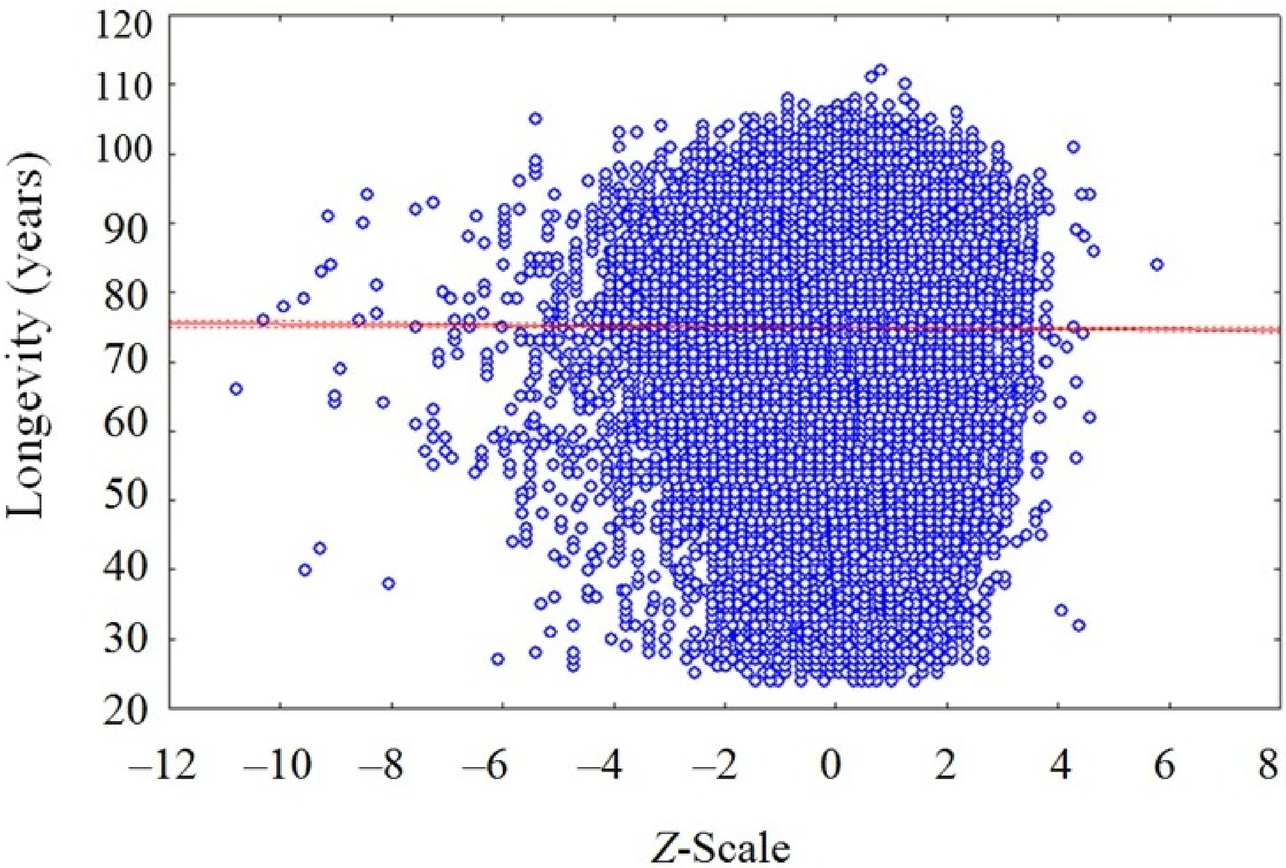
Longevity (years)
112
110
108
106
104
102
100
98
96
94
92
90
88
86
84
100 110 120 130 140 150 160 170 180 190 200 210
Body height (cm)



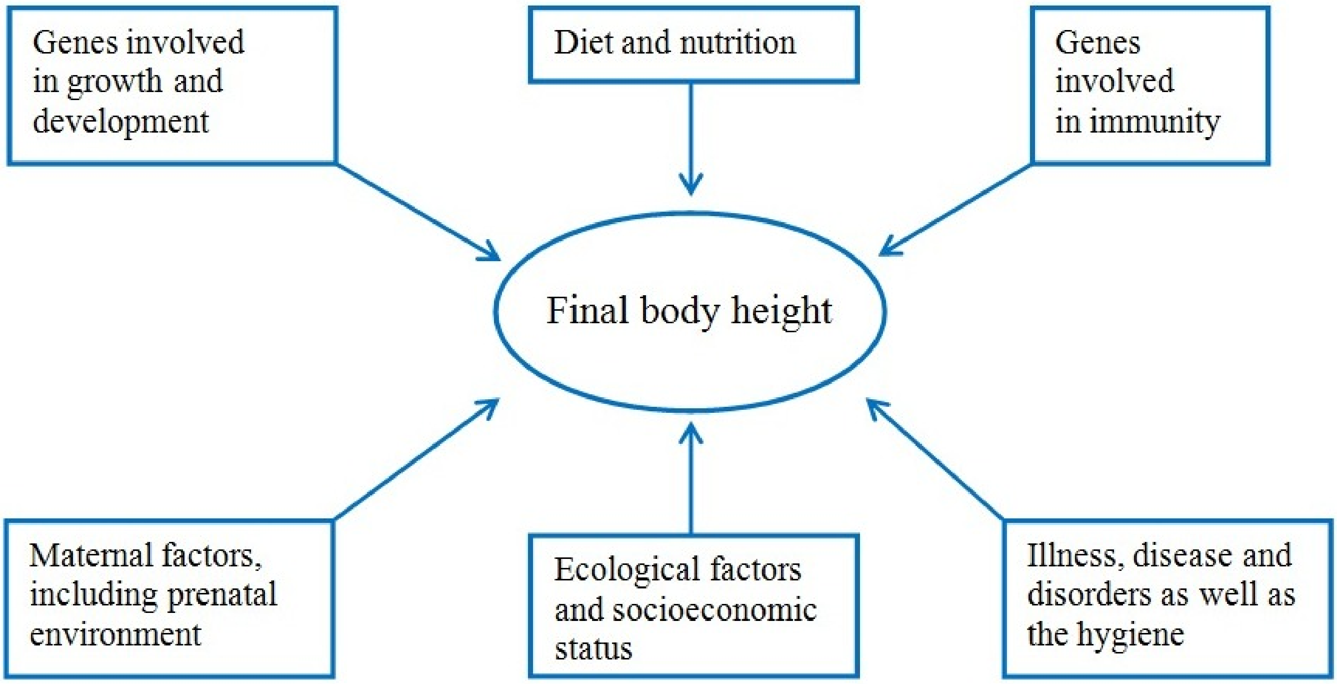
Longevity (years)
114
112
110
108
106
104
102
100
98
96
94
92
90
88
86
84
82
90 100 110 120 130 140 150 160 170 180 190 200
Body height (cm)



120
110
100
90
80
70
60
50
40
30
20
Longevity (years)
–14
–12
–10
–8
–6
–4
–2
0
2
4
6
8
Z-Scale



Longevity (years)
120
110
100
90
80
70
60
50
40
30
20
–12
–10
–8
–6
–4
–2
0
2
4
6
8
Z-Scale


Genes involved in growth and development
Diet and nutrition
Genes involved in immunity
Final body height
Maternal factors, including prenatal environment
Ecological factors and socioeconomic status
Illness, disease and disorders as well as the hygiene