SPECIAL REPORT

Ramifications of increasing birth weight, accelerated growth and greater height on health, the obesity epidemic, and longevity

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[**Abstract**] **Objective** In spite of the many benefits of industrialization and modern food systems, today's nutrition and growth practices have become self destructive and have promoted the obesity epidemic. Current methods for dealing with this epidemic are not working, and a different approach is proposed based on a variety of findings. The objective of the paper is to stimulate leaders in health and medicine to consider a different view for reducing the obesity epidemic and chronic diseases. **Methods** A systems approach was followed to examine the health ramifications of nutritional practices, childhood growth, and the secular increase height and weight. Over 5,000 research papers and reports were reviewed. The highlights of data pointing to a different approach to human diet and physical development are summarized. **Results** Much evidence indicates that a plant-based diet that avoids increased birth weight, rapid growth, and tall stature is the best approach to avoid an overweight and obese population. Western nutrition and greater height have been major factors in promoting obesity and chronic diseases. Evidence from the Great Depression, famines, studies on calorie restricted diets, and data on long-lived people indicates that avoiding excessive animal protein and calories sharply reduces the risk of obesity and increases healthy longevity. Failure to manage the obesity epidemic will lead to economic disaster as medical care costs exceed many trillions of dollars a year. **Conclusion** During the last 60 years, the Western diet and promotion of rapid childhood growth have yielded the fattest population in human history. However, a life long program that focuses on plant foods, avoids high-calorie processed foods and implements portion control offers the best approach for Western countries to correct this problem and for non-Western countries to avoid repeating the mistakes of the West. Moderate birth weight, later sexual maturation and slower growth in stature and weight are important steps to minimize obesity, health problems and related economic costs.

[**Key words**] height; birth weight; obesity; heart disease; longevity; nutrition; Great Depression; famine; centenarians; caloric nutrition

INTRODUCTION

The industrial revolution has nearly eliminated malnutrition in the developed world and has increased our average life expectancy by over 25 years since 1900. Increased birth weight, rapid growth, greater weight, and taller height have been viewed as positive byproducts of the industrial revolution. However, current findings indicate that obesity and chronic diseases are out of control in many countries, and their continued growth has economic consequences that will not be sustainable by future societies. In view of recent findings, nutritionists, growth experts and health practitioners need a new paradigm on what is the optimum nutrition for children and whether promotion of increased height and lean body mass of our youth is driving the obesity epidemic. This is especially important for China and India who could replicate the obesity epidemic and related health problems of the West within the next few decades.

It is generally believed that larger birth weight,

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faster growth, and taller height are related to better health and lower coronary heart disease (CHD) and all-cause mortality[1-3]. It is not the purpose of this paper to re-iterate studies that support these beliefs but to present an overview of conflicting research. The paper's aim is to present evidence indicating that lower energy and protein intake, moderate birth weight, slower growth and not attaining one's maximum height potential may be a better path for avoiding widespread obesity, chronic disease and unsustainable medical costs.

Background

Greater height has been widely viewed as an indicator of social status and privilege[4]. This is a highly ingrained belief that we all learned in childhood. On the surface, this viewpoint makes sense because we are told that taller people earn more money, are smarter and stronger, and make better leaders. Since taller people tend to be the products of favorable environments during their youth, there is considerable truth to this perception. Unfortunately, in our height-biased world, these beliefs become self-fulfilling prophecies and create the false image that average or shorter height people are less talented and healthy. However, Sandberg, Samaras, and Rosenbloom reported that clinical research and empirical findings indicate that shorter height is not a physical or performance handicap[5,6].

The "taller is better" thesis is being challenged by a growing number of researchers who question the belief that maximizing growth and greater height is always better[7-14]. For example, Marini, *et al.*[11] have stated that lower energy intake, slower growth, and reduced height doesn't necessarily indicate impaired development and may have health advantages in adult life. Alexander[13] also noted that smaller humans would enhance our long-term survival. Cannon[10] observed: "Bigger and bigger is not better and better. To the contrary: the principle that accelerated growth means health, and that for this reason animal protein is the master nutrient, has proved disastrous." Rolland-Cachera[14] also conducted a literature review and found that rapid childhood growth in weight and height is related to cancer, cardiovascular disease, diabetes and obesity later in life. de Magalhaes and Faragher[15], reported that smaller individuals within the same species tend to live longer by avoiding the higher rate of cell division that results from producing and maintaining a bigger body.

It is commonly believed that greater height is healthier. However, this belief is contradicted by Holzenberger, *et al.*[16] who observed that failure to associate growth in height with reduced longevity is due to the masking effect of improved lifestyle and medical progress. In addition, a study by the World Cancer Research Fund and American Institute for Cancer Research (WCRF/AICR)[17] reported that the move to urban living and industrialization has increased our height and weight as well as obesity and chronic disease.

The following sections cover study methodology, how birth weight and rapid growth are related to the obesity epidemic and how height relates to cancer, CHD, all-cause mortality and longevity. Other topics include centenarian heights, animal studies, biological mechanisms, and nutrition.

METHODS

In the mid 1970s data on height and weight and their relation to longevity were collected from various encyclopedia covering baseball, football and basketball players. Subsequently, a study of US veterans was conducted at the Veterans Administration Hospital in San Diego. A systems approach was followed which explored the relation of body size to physiological factors, physical performance and ecological ramifications. Pub Med was used as a major literature search tool. Searches were made for height or weight and cancer, cardiovascular disease, all-cause mortality and longevity. Over 5000 publications were evaluated, including reports on physical performance, car accidents, spinal problems and their relation to body size.

RESULTS

Between 1850 and 1950 nutritional scientists have focused on food systems to eliminate disease due to nutritional deficiencies, to lower vulnerability to infectious diseases and to promote a big, tall and strong popula-

tion[18,19]. Unfortunately, their success has created new health problems as described next.

Birth Weight, Rapid Growth and Obesity

Birth weight, obesity and long-term health. It is well established that our obesity epidemic is tied to excess nutrition in terms of physical needs during childhood, adolescence and adulthood. However, excessive intrauterine nutrition and greater birth weight are also important contributors to obesity. For example, Martorell, *et al.*[20] reported that lower birth weight adults are less likely to attain a high body mass index (BMI) compared to higher birth weight adults. In addition, birth weight is positively correlated with adult height, weight and BMI[3,4]. A study by Mardones, *et al.*[21] reported that birth weight is strongly and linearly correlated with the risk of later obesity. Other studies have shown that a rapid increase in weight during infancy is a precursor to later obesity[3,22]. Oken and Gillman reported that virtually all studies have found that birth weight is positively correlated with adult BMI[3,22]. Thus, the common belief that a larger baby is a healthy baby needs reexamination, especially since some large studies have found that infant mortality did not increase over the normal range of birth weight[3,22].

In contrast to the popular belief that higher birth weight is beneficial, a large study involving twins supports smaller birth weight as promoting longevity. This study found that identical twins lived ~1.5 years longer than fraternal twins (82 *vs.* 80.5 years), and both lived a few years longer than singletons. Identical twins are lighter in birth weight compared to fraternal twins and both are substantially lighter (~1 kg) than singletons[23].

Bradley[24] reported that low birth weight was common in non-developed populations. Yet, diabetes, cardiovascular disease, and western-type cancers were rare. Soltesz, *et al.*[25] also reported that higher birth weight promotes type 1 diabetes.

Chinese adults subjected to the Great Leap Forward famine during gestation were stronger, healthier and longer-lived than cohorts who were not exposed to famine[26]. (Famine infants tend to be lighter than non-famine infants.) Song speculated that only the strongest infants survived. Another possible explanation may be that the shorter and smaller body size of the famine survivors offset the negative aspects of intrauterine malnutrition. This would be especially true for children exposed to famine in the last trimester, who were at lower risk for later obesity.

New US findings on the Great Depression[27] indicate that infant mortality declined and life expectancy increased by 6.2 years, which exceeded the average life expectancy gains during the 20th C. All-cause mortality also declined for almost all ages.

The reasons for these gains were not clear, but these health improvements are consistent with studies showing reduced caloric intake increases health and longevity[2].

Birth weight is a function of three major factors: mother's height, pre pregnancy weight, and weight gain during pregnancy[3,25,28]. Since maternal height and weight are increasing, it is reasonable to expect that infants will continue to increase in weight during future decades aggravating the obesity epidemic.

Rapid growth. Another common belief is that rapid childhood growth reflects good health and nutrition. However, various species, such as lizards, trees and fish, demonstrate that rapidly growing individuals have lower long-term survival than slower growing individuals[29]. Jacobsen[30] found that girls who experienced menarche at 11 years had a 20% higher all-cause mortality compared to those who experienced it at 17 years. A high growth rate and early puberty also raised blood pressure in later life[31]. Okasha, *et al.*[32] also reported that early menarche increased breast cancer risk.

Rapid growth and early menarche are due to increased protein and energy consumption[3,33]. However, lower protein intake may be important in fighting cancer and promoting greater longevity[34]. In addition, biologists are well aware that slow growth is related to greater longevity; e. g., Rollo[35] reported that slow and protracted juvenile growth could produce large increases in longevity.

It is generally believed that lower growth in height and weight indicates poor nutrition. However, Marini, *et al.*[11] found that height and weight by themselves

are not reliable indicators of good nutrition. Other studies support their findings. For example, mortality declined among elderly Hawaiian Japanese men with decreasing body size and caloric intake down to 4,062 kilojoules (kJ) or 970 kilocalories (kcal) per day[36].

Rapid growth in height and weight during early childhood promotes type 1 diabetes[25]. Betts, *et al.*[37] reported that above average childhood growth contributes to the increase in type 1 and 2 diabetes in the industrialized world. (type 1 & 2 diabetes also increase with birth weight.) They also noted that the secular increase in type 2 diabetes correlates with increasing, rather than decreasing birth weight. Rolland-Cachera[14] found that accelerated childhood growth in weight and height was correlated with increased obesity and chronic disease in adulthood.

Recent studies have attributed a higher risk for CHD and diabetes to accelerated growth of lower birth weight infants[38,39]. The WCRF/AICR report[40] also noted that catch-up growth of low birth weight infants is correlated with the development of metabolic syndrome, CHD and cancer. Catch-up growth children do not usually attain the same height as their peer group[4], but overfeeding programs them for excessive adult weight and disease. Yajnik[41] also reported that when low birth weight children become tall, their risk for diabetes and CHD increases. Wells[39] believes this discordance between early smaller body size and later larger size places excessive loading on smaller organs designed to support lower food intake and lower body mass. Cameron and Demerath[42] also noted that rapid growth leads to telomere attrition and chronic diseases.

Based on current findings, Singhal, *et al.*[38] concluded that rapid growth promotes CHD and recommended that public health officials reconsider the policy of promoting rapid and early growth in children.

It is important to note that in the recent past, tall people were thinner than short people[43]. However, Cohen and Strum[44] found that taller Americans are getting fatter at a faster rate than shorter people. This new trend is probably due to increasing height and weight of mothers, higher birth weight, accelerated growth, long-term over nutrition, and lack of physical activity.

Cancer and Height

Numerous studies have found a correlation between height and cancer, including an in-depth report by WCRF/AICR[17]. Gunnell, *et al.*[45] also reviewed about 300 studies on height and cancer and concluded that taller height was related to cancer. The WCRF/AICR report[46], based on a 5-years review of >7,000 papers on cancer and other chronic diseases, concluded that the evidence showing greater adult height is related to increased cancer risk is "... strong, consistent, and impressive." Song and Sung[47] also reported that a positive correlation with height was found for total cancer and site-specific cancers, such as the prostate, colorectal, breast, ovary, and uterine corpus. This 9-years study involved 344,519 women. While the risk of cancer for taller people is generally moderate, some types of cancers can reach higher levels, such as skin, prostate, breast, colon, and pancreatic cancers.

Coronary Heart Disease and Height

Many studies have found taller people have lower CHD[1,2,48]. These studies reported a 10% to 50% higher incidence or death for short people. Findings showing short people have more CHD reflect socioeconomic conditions. In addition, catch-up growth of smaller birth weight infants is also a factor since accelerated growth is related to CHD. In spite of catch-up growth, lower birth weight adults are still shorter than their peers, and this factor could confound study results that relate shorter height to CHD.

A large number of studies have not found a significant relation between height and CHD risk[2,47-53]. Song & Sung[47] and Song, *et al.*[54] found almost no relation between CHD and height in South Korea, based on 600,000 males and females. In addition, Hosegood and Campbell[55] did not find a CHD *vs.* height trend among 1,888 women in a 19-year longitudinal study.

In contrast to the preceding findings, a number of researchers have provided data showing shorter people have lower CHD or heart problems; e. g., Allebeck, *et al.*, Chen, *et al.*, Lasker, Mendall, *et al.*, Polednak, Osika, *et al.*, and Samaras, *et al.*[2,48,56]. In

addition, 163 cm (5′4") male Kitavans were free of CHD and stroke[2]. Other studies also found shorter people have lower CHD within Indian and Pakistani populations[2]. Studies involving millions of deaths have found shorter ethnic people in California and the US have ~50% lower mortality *vs.* taller ethnic people[23]. Within Native Americans, shorter males had lower CHD[48]. Another study found that Australian Chinese immigrants had much lower heart disease than the general population. The study attributed this advantage to their leanness. The Chinese in this study were shorter and lighter than the general Australian population.

When shorter people migrate from poor to prosperous countries, they have lower CHD mortality compared to the general population. For example, Jewish and Italian immigrants to New York had a lower CHD mortality compared to the taller general population[2]. The reasons for this lower mortality are probably related to their smaller height and reduced energy, saturated fat, and protein intake while growing up in their original countries combined with improved living standards and medical care in their new country. However, their mortality advantage may not be evident until middle or older ages[2]. In addition, the children of these immigrants grow taller and heavier and don't enjoy the mortality advantage of their foreign-born parents. Note that Shaper[23] reported that differences in CHD among various ethnic groups were not due to race, climate or geography.

Before urbanization and industrialization, CHD, as well as other chronic diseases, were rare[17]. In addition, many 20th C non-developed populations following plant-based diets were generally free of CHD. These pre-industrialization and non-developed populations were also short and lean. Thus, smaller body size did not appear to promote CHD but may have protected against it along with the diet that kept people smaller.

Osika and Montgomery[56] found that taller people had lower risk of heart attacks compared to shorter people. However, when they focused on people in lower economic brackets, tall people had a 71% higher risk of heart attacks compared to short people. This finding supports the Holzenberger, *et al.*[16] observation that an improved lifestyle masks the health risks of taller height.

Animal studies support the human findings; e.g., based on 350,000 dogs[57], bigger breeds had a cardiac mortality 6 times higher than small breeds. This was similar to a study of American football players, which found the largest players had a CHD death rate 6 times higher than the smallest players[2].

The preceding findings are supported by studies, which indicate that the hearts of shorter people have inherent advantages[58,59]. These advantages are discussed in a subsequent section on biological mechanisms.

The conflicting data presented here are the result of a number of confounding factors, which are identified in the Discussion section.

All-cause Mortality and Height

A number of studies have found a negative correlation between height and all-cause mortality[1,2]. As with CHD and stroke studies, the magnitude of risk generally varied from 10% to 50%. Waaler's[2] study of ~176,574 male and female deaths, found taller people had lower all-cause mortality. However, he also found elderly tall men and women experienced a substantial increase in mortality (~20%) compared to shorter cohorts. Song and Sung[47] also found a 7% decrease for women in all-cause mortality with each 5 cm increase in height. However, women who were 155~57 cm (5′1"-5′1.8") had a 4% lower risk than the tallest women (≥ 161 cm). In addition, McCarron, *et al.*[60], Liao, *et al.*[61], and Kannam, *et al.*[62] did not find a significant correlation between height and all-cause mortality.

A 19-year study[55] tracked the mortality of Bangladeshi women who averaged 27.9 year at baseline. Overall, height was unrelated to all-cause mortality. However, women in the height range of 148.0~151.2 cm had a 20% lower mortality compared to taller women (>151.3 cm).

Many studies show short people have lower all-cause mortality, such as Mori, *et al.*[63], Sear[2], Krakauer, *et al.*[2], and Willcox, *et al.*[2]. For example, Mori, *et al.*[63] found taller Japanese subjects

experienced a 6%/cm increase in mortality. In addition, a California study of five ethnic groups involving 1 million deaths showed a progressive decline in mortality with decreasing height with Whites and Blacks having the highest mortality and the Chinese and Japanese the lowest. An analysis based on US Government data involved many millions of deaths and found Whites and Blacks had about twice the mortality as shorter Asians[23]. Native Americans and Latinos were in between these groups in height and mortality. An insurance study also reported that shorter middle-aged men and women had lower mortality vs. taller people[2].

The previously mentioned Chinese famine study[26] involved ~ 1 million people. The all-cause mortality of pre-famine, famine and post-famine cohorts was tracked to 51 year of age. Unexpectedly, it was the birth cohort exposed to famine that had the lowest mortality. The birth weights and heights of the cohorts were not given but there is a strong correlation between birth weight and adult height[2,3,5]. Famine infants would have had low birth weights due to poor nutrition[26]. Infants born during the Finnish famine showed no difference in mortality when researchers tracked the famine survivors into their eighties[26]. Since small infants tend to be smaller adults, reduced adult size and moderate food intake may have offset the negative aspects of malnutrition during the famine.

Support for the Chinese findings comes from the Dutch famine, which found that adults (18 to 57 year) exposed to the famine during their fetal stage had a slightly lower mortality compared to those conceived after the famine[64]. However, adults who were exposed to famine during the later part of pregnancy had a 25% lower all-cause mortality compared to those conceived after the famine. This finding may be due to the lower adult BMI associated with late-term famine exposure.

Immigrants often have lower all-cause mortality compared to the general population in their new country. One study found a substantial reduction in mortality for Mexican, Vietnamese, Chinese and Southern European immigrants[2]. These examples are supported by migration of Turks to Germany and Greeks, Italians and Chinese to Australia. The likely reasons for this reduced mortality include: (1) early energy-restricted plant-based nutrition and reduced growth in their original country and (2) improved health care and standard of living in their new country.

Longevity and Height

A major reason the "tall is healthier" proponents' report that tall people live longer is: taller, developed countries have longer life expectancies vs. shorter, non-developed countries. When applied to countries of similar lifestyles and medical care, life expectancy is an indicator of longevity. However, when the life expectancy of developed countries is compared to non-developed populations, the results are misleading. For example, life expectancy of non-developed countries is sharply reduced by high infant, child and maternal mortality due to infections and medical problems that are avoided in the developed world. In the recent past, the elderly in the non-developed world died from basically the same problems that killed young people[65]. However, today 70% of the elderly in both the developed and non-developed worlds die from chronic diseases (e. g., CHD, cancer and diabetes)[66]. These diseases are related to smoking, obesity, and nutritional excesses.

Extensive findings support the "smaller is healthier" thesis; e. g., Table 1 lists several studies showing shorter people live longer than taller ones[2,23]. The loss of life per centimeter (cm) is often found to be ~ 0.5 year/cm among highly diverse populations in the developed world. Also, US White male vs. female populations show a-0.5 year/cm, which is essentially the same as when short and tall males are compared[23]. Figure 1 also shows shorter baseball players live longer than tall ones[53].

In 1961, the World Health Organization found that 45-year old Greeks had the longest life expectancy in the Western world. Males averaged 167.6 cm, which was shorter than central and northern Europe. Greeks from Crete were 1.6 cm shorter and lived longer than mainland Greeks[2,67].

A study of 40,000 WWII veterans did not find short men lived longer; e. g., men who died between 57 and 84 year of age who were 179 cm (510.5") had the highest life expectancy of about 77.8 year. Short

and tall men had a lower life expectancy of 76.8 year. Heights at enlistment were used. (Unpublished report by J Ferrie, March 7, 2008.)

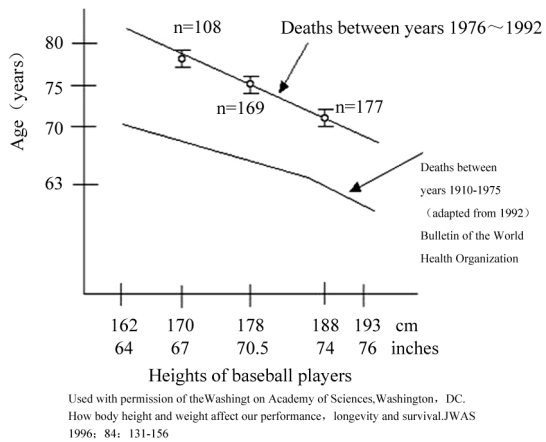

Figure 1 Height and longevity of professional baseball players

A Spanish study[16], tracked 1.3 million men (20～30years old) over a 70-year period. Shorter men lived longer. Adjustment for various confounders did not change the results (Figure 2). A smaller Sardinian study[68] showed the same trend as the Spanish study. This study tracked male Sardinians over a 70-year period. Heights were based on military enlistment records for both studies.

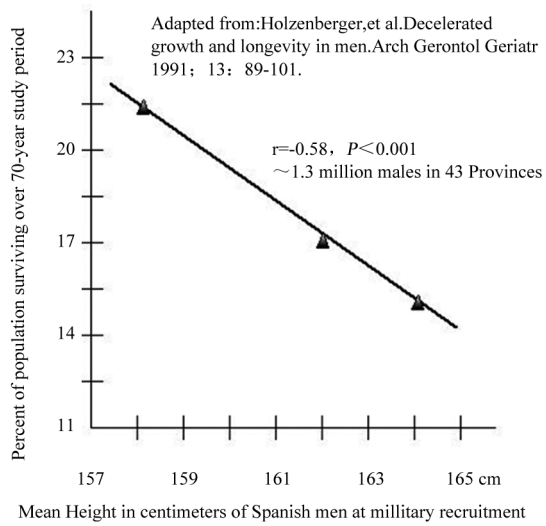

Figure 2 Decline in survival with increasing height for Spanish Males

A study by Yates, *et al.*[69] tracked 2,357 male physicians from a mean age of 72 year to > 90 year. The authors attributed the greater longevity of the shorter survivors *vs.* non-survivors to smoking abstinence, blood pressure control, regular exercise and weight management. However, men who survived to 90 year were also 0.6 cm shorter, 1.3 kg lighter and 0.3 BMI points lower than non-survivors. The smaller survivors also had lower hypertension, diabetes, cancer, CHD, and stroke.

Table 1 Summary of lower longevity with greater height

Study	Number of. deaths	correlation coeficient (r)	S/ND[a]	Slope (year/cm)
Ohio Residents	1,679	-0.32	S	-0.47
US Males vs Females[b]	195	ND	ND	-0.52
Baseball players	3,281	-0.31	S	-0.35
Football players	200	-0.33	S	-0.81
Famous people	257	-0.23	S	-0.42
Spaniards	>1 million	-0.59	S	ND
Sardinians	634	-0.12	S	ND
Harvard Athletes	634	-0.12	S	ND
Harvard Athletes	938	ND	ND	-0.70
19th C French males & females	400	-0.18	S	-0.51
Finnish Athletes	2,613	-0.86	S	-0.49
US Veterans	373	-0.23	S	-0.47
Elderly Swedes	116	-0.26	S	-0.52[c]
Averager and slope		-0.34		-0.53year/cm

Note: [a]S = significant; ND = no data; [b]birth cohort; 1980-83; [c]email from C krahauer, 7/24/02.

Table 2 Life expectancy (LE) ranking for developed populations (A rank of 1 equals the highest LE)

Top six populations in order of LE ranking	Six tallest populations in order of LE ranking
Andorra (located between France & Spain) (1)	Sweden (7)
Macau (located near Hong Kong) (2)	Norway (20)
Japan(3)	The Netherlands (28)
San Marino (located in central Italy) (4)	Germany (32)
Singapore (5)	Finland (38)
Hong Kong (6)	Denmark (47)
Average Rank: 3.5	Average Rank: 29

Samaras and Heigh[70] evaluated over 4,500 men and women for the age groups of 85 year and 90 year. Compared to 85-year olds, taller 90-year old males experienced a reduction in percentage of the population by 5% and the shorter 90-year old group increased by 5%. A similar pattern was found for women.

Among developed populations, the top populations in life expectancy are shorter than the tallest populations. Table 2 compares the six populations with the highest life expectancy in the world to the six tallest populations in mainland Europe[23]. The six shorter populations have a ranking of 3.5 *vs.* 29 for the tallest.

Most health practitioners would probably predict that life expectancy would decline during economic downturns. However, this does not appear to be true. Compared to periods of prosperity, life expectancy increased substantially for Americans born during the Great Depression[27]. This unexpected event also occurred during other recessions and depressions. This finding is supported by WW II data; e. g., European mortality from chronic diseases declined with reduced meat and calorie intake[3]. In addition, during the 1989 ~ 2000 Cuban economic crisis, prices rose and food consumption declined along with lower heart disease and stroke[19]. Type 2 diabetes, weight and obesity dropped as well.

It is well known that shorter women live longer than taller men throughout most of the world. Table 3 shows that men lost 0.5 year/cm compared to women. This finding is similar to that shown in Table 1 for various sample populations. Males were 8.7% taller than females and they had a 9.2% shorter life expectancy[23]. This is consistent with five previous examples published in 2003[71]. The difference in life expectancy between males and females is usually attributed to female hormones. However, Batallie, *et al.*[72] reported that prospective studies have not found a relation between CHD and sex hormones. It appears that the main factors for female longevity are smaller bodies, longer telomeres and a greater cell replication potential compared to males[73]. Miller also found that men and women of the same height had about the same average life span[2]. Small male mice also live longer than larger female siblings.

Additional findings on the greater longevity of shorter people include Japanese Hawaiians, black South Africans and 65-year old southern Europeans vs. northern Europeans[2,52,67].

Table 3 Male-Female life expectancy (LE) and height differences for birth years of 1980 ~ 1983

Gender	Height	Life Expectancy[1]
Male	179.09 cm	71.2 years
Female	164.70 cm	78.4 years
Difference	14.39 cm	-7.2 years
Difference	8.7 % taller males	-9.2% lower LE

Note:[1] Life expectancies for 1980 and 1984 were averaged. Data for 1982 and 1983 were not available.

Centenarians and Height

According to the "taller is healthier" thesis, taller people live longer. If this were true, tall people should be

disproportionately represented in the centenarian population. However, it is rare to find men over 183 cm that reach 100 y; e. g., Roth[74] reported that centenarians tend to be lean and short (adjusted for shrinkage). While tall people were less common in past centuries, there have been many tall people over the last 150 year, including Presidents Washington, Jefferson and Jackson, who were ≥185 cm (6′1). However, with advances in treating cancer, CHD and diabetes, we can expect more tall people to reach 100 year in the future.

The Okinawans are an example of very short people with great longevity. They have the world's highest percentage (580/million) of centenarians, and males average 148.3 cm (4′10") and females 136.6 cm (4′6")[23]. Adjusting for shrinkage would suggest that men were roughly 152 cm (~5′) and women 142 cm (4′8) in their youth. Studies from Italy[75] and Cuba[76] reported that the youthful heights of centenarians were 156 cm for Italian males and 153.8 cm for Cuban males.

Sardinians have the highest percentage of centenarians in Europe[77]. They are also the shortest Europeans. This advantage could be lost with adoption of different dietary and lifestyle patterns; e. g., fast food is now being consumed in Sardinia.

A report on WW I centenarians found that most were of medium height[78]. Specific heights were not available, but WW I military recruits averaged about 171 cm (5′7.5"). A possible reason for shorter veterans not doing as well is that many grew up in poor urban areas that were unsanitary, congested and centers for communicable diseases. In addition, malnutrition and sickness would have produced shorter and less healthy men compared to taller recruits from healthier rural areas.

Super Centenarians and Height

While super centenarians are rare, some data on their heights are available. A sample of ten super centenarians was provided by Robert D. Young of the Gerontology Research Group [e-mail communication from A. Bartke, 12/29/08]. Nine of the super centenarians were 140 ~ 161 cm (4′7" to 5′3") while the tenth was a taller woman, 173 cm (5′8"). The average height for these ten super centenarians was 151 cm (4′11.6"). No weights were provided. However, George Francis died at 112 year and was described as never more than 45.5 kg (100 lb). He was rejected from the military (WW I) because he was too short. This would have made him less than 150 cm in his youth.

Animal Longevity and Body Size

Robust animal findings indicate that smaller configurations live longer. Rollo[2] found that smaller body size produced greater longevity in mice based on a meta-analysis of ~800 studies. Bartke reported that small rats live longer than normal and giant size rats[79]. Miller and Austad also showed smaller dogs generally live longer than bigger ones[80]; e. g., miniature poodles live longer than standard size poodles.

Among large animals, smaller horses live longer than larger ones, genetically small cattle live longer than normal size animals, and smaller Asian elephants live longer than the taller and larger African elephants.

Compared to larger species, why do smaller species have shorter lives while the smaller configuration within the same species usually lives longer? Bigger species may benefit from lower metabolism and heart rate due to the effects of scaling[81]. Bigger species of animals also grow at a slower rate. In addition, the evolutionary process may have selected for an increased number of cell replications and improved cellular and DNA repair systems as a species evolves into a larger physical size.

Biological Mechanisms Related to Height and Longevity

A few biological mechanisms support the "tall is healthier" thesis, such as greater height reflects abundant nutrition and a healthful environment during youth. Other factors include a lower resting heart rate and metabolism. While most people view robustness and larger muscle mass as an indicator of good health, long-living people do not support this configuration, and the healthy body types tend to be quite lean[17,74]. In addition, women have less muscle mass but live longer than more muscular men. In contrast, many biolog-

ical mechanisms support the "small is healthier" thesis. These are summarized next and are based on similar body proportions between short and tall people.

Longer Telomeres and more Cell Replications

Short people have more potential cell duplications in old age compared to tall ones[73]. Thus, short people can replace defective or dead cells for a longer time compared to tall ones. In addition, studies show that DNA telomere length is an indicator of replication potential and greater health and future longevity. Note that men and women are born with the same length telomeres, but men have shorter telomeres in adulthood due to their larger size. More importantly, they use more replications to maintain their additional cells over a lifetime. (Billions of cells are replaced daily.) It should be noted that other factors besides height affect telomere length. These may include genetics, income and educational level, and exercise.

Fewer Cells and Lower Cancer Risk

A short body may have 40 trillion fewer cells compared to a tall one. Thus, cancer risk is lower since fewer cells are exposed to carcinogens and free radicals. Okasha, *et al.*[32] and the WCRF/AICR[17] reported that cancer increases with height.

Lower Generation of Free Radicals

Shorter people with lower total body mass and energy intake are exposed to fewer free radicals produced by normal metabolism and exposure to radiation, cosmic rays, bacteria, viruses, parasites and toxins with lower damage to DNA, cell structures, proteins, fats and extra cellular components[82].

Most Organs are Larger in Comparison to Body Weight

Most organs (except the heart, lungs and spleen) are relatively larger in shorter people[83] and thus have a greater functional capacity, especially at advanced ages.

Women also have relatively larger organs compared to men, which may explain their greater longevity.

Lower DNA Damage

Short people have lower DNA damage[3]. A data analysis found 19% taller people have up to 85% more DNA damage than shorter people[23]. This is probably due to rapid childhood growth, which diverts body resources from maintenance and repair to building a bigger body. Reduced exposure to thermal energy, toxins, bacteria, radiation, etc. would also reduce DNA damage in shorter people.

Lower Risk of Cardiovascular Disease

Shorter people have lower blood pressure and the heart does less work in proportion to its size per stroke. They are also at lower risk of greater left ventricular mass, which is related to lower CHD mortality. In addition, the smaller heart is more efficient at pumping blood through the body[58]. Another benefit is lower risk of atrial fibrillation, which is related to smaller heart size[59]. A few other advantages follow:

- Taller people have higher BMIs than shorter people, and it is well established that a higher BMI correlates with an increase in virtually all cardiovascular risk factors.

- Free radical generation is correlated with daily total energy expenditure. Since shorter people following the same activity levels generate fewer free radicals, their heart muscle cells are exposed to reduced damage.

- C-reactive protein (CRP) levels tend to be higher in taller people[83], and CRP is related to increased risk of cardiovascular disease.

- The hearts of taller people work harder because they pump more blood a greater distance and height.

Lower Exposure to Toxins and Bacteria

Shorter people consume less food. Consequently, they have lower intake of naturally occurring toxins, pesticides, antibiotics and food-borne pathogens[84]. They also experience fewer harmful byproducts of digestion.

Lower BMI for same Body Proportions

Taller people of the same body proportions have higher BMI's; e. g., a 20% taller person will have a BMI that is 4.2 kg/m^2 greater than a shorter person[81,83]. This could increase all-cause mortality by ~42%. This increase in mortality is probably due to undesirable changes in various biological parameters, such as insulin, lipids, insulin-like growth factor-1 (IGF-1), IGF binding protein-1, glucose, and CRP[83]. A 24-year study on the impact of BMI on cerebral atrophy in women found a 13% to 16% increase in temporal lobe atrophy per 1 kg/m^2 increase in BMI[85].

Lower Body Temperature

While empirical data on lower body temperature of shorter people are scarce, the theoretical aspects make sense. Bigger mammals, such as elephants and football players, are at high risk for heat stroke because their surface area is much smaller in relation to their body mass; e. g., they can't dissipate the heat generated fast enough and body temperature rises resulting in heat stroke.

Physical Advantages of Smaller Bodies

Independent of health and longevity, physical performance varies between taller and shorter people. Mainly due to our major sports, bigger bodies are viewed in a highly positive light. There is no doubt that taller, bigger people have greater brute strength and a longer reach. They can perform exceptionally well in basketball, American football, and swimming. However, shorter, lighter people have inherent advantages compared to taller people. These advantages include faster reaction times, stronger strength to weight ratios (easier to lift or move their bodies), faster acceleration, greater endurance, greater agility, and faster rotational capability[86]. They are also less susceptible to injuries or death in car accidents.

Nutritional Considerations

It is clear that the Western diet has had good and bad effects over the last 100 year. However, we now exceed the ideal nutritional requirements for our living style. Popkin[19] noted that the global emphasis on animal protein and processed foods has been devastating for our health.

Too many calories, nutrient deficient foods, and too much animal protein and saturated fat have promoted various chronic diseases[9,10,17,19]. In addition, experimental and cohort studies involving humans and non-human primates support the health and longevity benefits of lower calorie diets[34,66,87]. The WCRF/AIRC report[88] notes that energy restriction postpones the onset of cancer and other age-dependent diseases. For example, a longitudinal study found 80% of monkeys subjected to caloric restriction (CR) were alive after 20 years compared to 50% of normal fed monkeys[87]. CR also delayed the onset of heart disease, cancer, diabetes and brain atrophy. Since the study was started with adult monkeys, reduced size due to CR was only related to lower weight. The study is on going and requires about another 20 years to reach completion.

Empirical CR studies are supported by thermodynamic analysis. Based on the first and second laws of thermodynamics, Silva and Annnamalai[89] found that an 18% reduction in caloric intake increased lifespan by 20.44 years for males to 23.96 years for females. Based on their data, Samaras calculated that males lost 0.57 year/cm in longevity compared to females This 0.57 year/cm value compares closely to empirical findings (Table 1) which show a 0.53 year/cm loss of life with increasing height.

Protein is an essential macronutrient. However, a growing amount of evidence indicates that excess animal protein has harmful ramifications[19]. A misguided focus on animal products and processed foods started about 150 years ago. However, Fontana[66], Campbell and Campbell[9] and others have found that protein promotes cancer,

other chronic diseases and aging. Most of us eat too much protein, and animal protein has a number of negative aspects; e. g., increased growth hormone, IGF-1, insulin and cancer. Campbell and Campbell[9] concluded that while animal protein produces taller, bigger bodies, it also increases chronic diseases and reduces longevity. Lopez and Barja[90], and Cameron and Demerath[42] have also related increased protein to

cancer, chronic diseases, reduced longevity, osteoporosis, and hip fractures. However, vegetable protein appears protective against these ailments. In addition, a high animal protein diet increases insulin, insulin resistance, CVD, and obesity and reduces longevity[91,92].

Fontana, *et al*.[34] found that reduced protein intake in humans lowered IGF-1 levels and may be an important factor in reducing cancer and increasing longevity. Early childhood introduction of protein from cow's milk was also related to type 1 diabetes[37]. Silva and Annamalai[89] found that when protein was decreased to 12% of total calories, longevity increased by 3.3 y.

Another problem related to animal protein is that mass production of animal food is not sustainable over the long run[10]. Mass production of animal protein consumes too much water and energy, destroys ecosystems, contaminates the land, and promotes warming of the planet. Mass production of animal foods also creates huge increases in saturated fat consumption, which, along with animal protein, promote widespread obesity.

In summary, much evidence indicates that lower energy plant-based diets can reduce obesity and chronic disease, increase healthy longevity and are sustainable over the long run.

DISCUSSION

The preceding material indicates that there are a variety of conflicting findings related to body height, chronic diseases, and longevity. The principal reason for this is that height is only 10% to 15% of the total picture. Genetics, rapid growth, socioeconomic class, smoking, drinking, diet, childhood illness and stunting have a much larger impact on one's health and longevity. Other factors include body type, BMI and discordance between smaller birth size and later adult height and weight due to increased nutrition, which promote poor health in later adulthood. Failure to adjust BMI when taller people are compared to shorter people also leads to errors[81]. For example, if we compare 10% taller people to shorter people, their BMIs should be 10% greater to assure that similar body types are being evaluated.

Davey-Smith[2] found that mortality was strongly related to SES throughout one's life; e.g., men who had higher socioeconomic status (SES) throughout life had lower mortality than those who only had higher SES during middle or older years but had lower SES in earlier years. In addition, life-long upper SES men were the tallest. Thus, shorter men with current upper class status would have a higher mortality due to their lower SES in previous years. This is consistent with the Osika and Montgomery[56] findings that among the poor, taller people have a substantially higher risk of CVD.

Failure to track cohorts throughout their entire lifespan can also lead to erroneous findings because mortality rates can cross-over at older ages. For example, US Latinos and Native Americans have higher mortality rates at younger ages compared to the general population, but their rates fall below those of the general population in middle age. In addition, the rates can fall sharply so that their overall age-adjusted mortality is lower than the general population. This crossover tends to occur at later ages for both CHD and all-cause mortality.

Findings showing taller people have less CVD cannot be correct from a biological viewpoint because CVD has increased dramatically since 1900 in the Western world along with increased height. It is also well established that short populations in the non-developed world experience little or no CVD, such as Kitava and Papua New Guinea[2].

In view of the preceding, what conclusions on the validity of the findings can be drawn? Most epidemiologists and demographers believe that tall people are healthier and live longer, pointing to the correlation between greater average life expectancy and height of developed populations. In contrast many biologists and longevity researchers believe that shorter and smaller people live longer[2,73,74,78]. After review of the research, the author believes that the data showing shorter people live longer is far stronger than opposing findings. This conclusion is based on worldwide findings, the large sampling sizes involved in some of the studies, the consistency of several studies on the loss of life per centimeter increase in height, and the mix of hom-

ogeneous and heterogeneous population samples[2]. In addition, many of the mortality and longevity studies showing shorter people live longer tracked all their cohorts into advanced ages or until they were all dead. Few studies showing taller people live longer followed this procedure. Another factor is that 9% taller males have 9% lower life expectancy compared to women[23]. In addition, men lost 0.5 year/cm compared to women, which was similar to male vs male comparisons. Monkey[87] and other animal studies provide strong support for the smaller live longer thesis[2,79]. Shorter telomeres, inherent cardiac risk factors and increased DNA damage provide biological mechanisms to support the findings that increased height and greater weight or BMI have negative ramifications.

The future costs of not controlling the obesity epidemic and chronic diseases are exceptional. For example, an agency of the US Government estimated that the annual health care costs in 2030 will reach $16 trillion[9]. The costs for China and India will probably approach trillions of dollars due to their larger populations.

In addition to poorer health and obesity, other undesirable changes are related to increasing body size. These include poorer physical performance and greater water, food, energy and resource consumption. The impacts of larger body size on economic costs, increased pollution, ecological damage and intelligence are also important topics. It should be noted that a population of larger people requires huge increases in food, water, energy, natural resources and money to supply their increased demands. These topics are of major importance but are covered elsewhere[94-100].

CONCLUSIONS

In 1979, Pritikin[101] observed: "... we pay a high price for our increased physical stature! Both men and women are more likely to develop atherosclerosis younger, and die of strokes and heart attacks earlier, and be fatter in their middle age--though some won't live that long."

Tall, average, and short people excel in many human activities[86]. In addition, intelligence is not related to height[94]. Therefore, height should not be viewed as good or bad on an individual level. Using height and weight as an index of health should be replaced by the use of biochemical parameters, individual nutritional analysis, and daily functioning.

A systematic program is needed to eliminate calorie-dense beverages from our diet, reduce calories and saturated fat from school lunch programs, and to severely limit high-calorie snacks for children and adults[19]. As mentioned, reduced calories and improved nutrition should be initiated in early childhood.

Failure to change our attitude toward height, will result in future generational increases in height through genetic engineering. However, the most important objective should be to promote a plant-based diet and public education on the health hazards of over nutrition from pregnancy through adulthood. Several years ago, Cannon[18] stated that nutritional scientists need to develop recommendations to avoid chronic diseases in middle age *vs.* policies to grow big babies and big young people.

The global obesity epidemic correlates with the secular increase in height. This observation is certainly consistent with Forsen, *et al.*[102] findings that children born to heavier mothers were taller and heavier at 7 years of age and subsequently gained weight at a faster rate than their peers born to lighter mothers.

Overweight parents and infants that are large for gestational age promote overweight children[103]. Many studies find early childhood overweight leads to adult overweight or obesity. Besides reducing animal protein, portion control is an important measure to minimize obesity. The French Government initiated this in the late 19th C. by establishing clinics to teach young mothers to avoid overfeeding their children[104].

Continuation of the present weight trend is a threat to every nation's national security because it will drain resources from education, research, public services, infrastructure, and military budgets. It will also become difficult to recruit lean young people for construction work, emergency services, firefighting, and police or military service.

In conclusion, leading researchers have cautioned against promoting animal protein consumption, higher birth weight infants, accelerated growth and increased

height and body weight. These secular trends contribute to the obesity epidemic and chronic diseases. Therefore, it appears that a diet that provides moderately lower birth weight, slower growth, lower childhood weight and slightly reduced adult height can help reduce public health problems and health care costs.

Conflict of Interest

No conflict of interests applies to this paper.

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