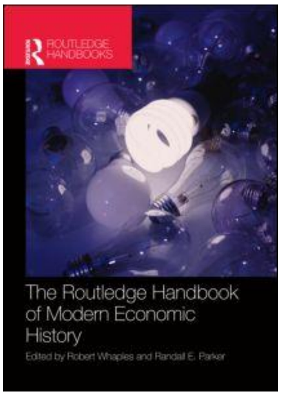

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Scott Alan Carson
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ANTHROPOMETRIC HISTORY: HEIGHTS, WEIGHTS, AND ECONOMIC CONDITIONS

Scott Alan Carson

Measuring and accounting for economic growth is among the economic historian's leading objectives. To better understand living conditions during economic development, anthropometrics is the application of economic theory and statistics to changes in the dimensions of the human body.

Stature and the body mass index (BMI) are the primary measures of the biological standard of living. Stature measures the net cumulative balance between nutrition, work effort, and the disease environment before adulthood, and, because more historical height data survive, physical stature has received more attention in historical anthropometric studies. BMI measures the net current balance between nutrition, work effort, and the disease environment, and is receiving increased attention in historical studies. Therefore, to better understand historical living standards during economic development, this chapter reviews the vast amount of stature and BMI studies and considers new areas where biological measurements have become standard measurements.

Historical anthropometrics of physical stature

The use of height data to measure living standards is now a well-established method in economics and economic history (Fogel 1994: 138; Steckel 1995, 2009; Deaton 2008; Case and Paxson 2008). A population's average stature reflects the cumulative interaction between nutrition, disease exposure, work, and the physical environment (Steckel 1979: 365–7; Tanner 1962: 1–27). Genes are important determinants of individuals' heights, but genetic differences approximately cancel in comparisons of averages across most large groups and nations, so in these situations average heights accurately reflect net nutrition. When diets, health, and physical environments improve, average stature increases, and it decreases when diets become less nutritious, disease environments deteriorate, or the physical environment places more stress on the body. Therefore, when traditional economic, income, and wealth measures are unavailable, stature provides considerable insights into understanding economic and social processes – and it provides an important complement to traditional economic measures when they are available. For example, Steckel (1995: 1912) demonstrates that adult male and female heights have correlations of 0.88 and 0.82 with log per capita income.

Nineteenth-century white heights

Despite the modern correlation between stature and economic development, and the demonstration by Steckel (1983: 5) and Komlos (1987: 903) that nineteenth-century individuals' statures were positively related with income, evidence from numerous studies shows that as average incomes increased during much of the 1800s white statures paradoxically declined. Figure 4.1 shows this pattern, which is known in the U.S. as the "antebellum paradox" (Fogel *et al.* 1982; Fogel *et al.* 1983; Komlos 1987; Margo and Steckel 1983; Costa 1993). A similar pattern holds for industrializing countries in Europe, a pattern known as the "early modern growth puzzle" (Fogel *et al.* 1982: 33; Nicholas and Steckel 1991: 948; Komlos 1998).

Attempts to explain the antebellum paradox and early modern growth puzzle have focused on nutrition, access to food, inequality, disease, population density, nativity, and socioeconomic conditions. Fogel *et al.* (1983: 473–6) recognized that nutrition was a primary source for stature variation, and Fogel *et al.* (1983) and Komlos (1987: 908–19) were the first to illustrate that height varied considerably with nutritional deficiencies. Physical stature responds to access to proteins and amino acids, and Haines *et al.* (2003, Table 7) demonstrate that nineteenth-century Union Army recruits were taller in counties that had greater access to proteins and calories. Baten and Murray (2000: 359–63) and Carson (2008a: 362–6) demonstrate that taller heights were related with greater access to dairy products (Bogin 2005). Therefore, among the most established relationships in anthropometric history is a positive relationship between height and nutrition, especially calcium and animal proteins.

Because the last dollar spent on health by a wealthy individual has a smaller impact than the last dollar spent on health by a poorer individual, modern statures are inversely related with income inequality (Wilkinson and Pickett 2006: 1775; Subramanian and Kawachi 2004).

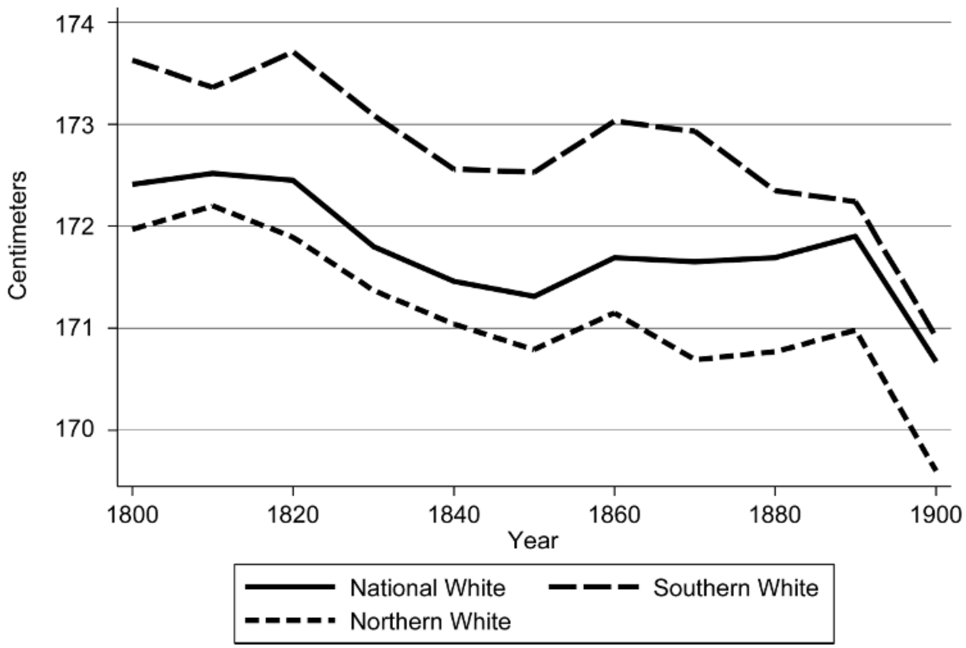

Figure 4.1 Nineteenth-century U.S. white male statures by birth year
Source: Carson (2009b).

Steckel (1983) demonstrates that historical heights were inversely related with income inequality as well. However, the relationship between stature and wealth are mixed. Wealth is a net cumulative measure for material welfare, and stature is a net cumulative measure for biological welfare. Haines *et al.* (2003: 46) find that county-level wealth was not associated with the height of Union Army recruits, while Carson (2009a: 51) finds that individual statures increased with state-level average wealth. Carson (2009a, 2010a) also demonstrates that heights were inversely related with state-level wealth inequality, and the height and wealth relationship was stable across the stature distribution. After accounting for both relative wealth inequality and absolute wealth, stature was more responsive to changes in absolute wealth than relative wealth inequality.

Inequality measures beyond income and wealth Gini coefficients have been developed to isolate the relationship between physical stature and inequality. Baten and Murray (2000) use Bavarian height coefficients of variation and find that inequality increased in the early nineteenth century. Income and wealth are also related to stages of the business cycle, and Woitek (2003: 250–5) finds that Hapsburg soldier heights were positively related with cyclical fluctuations, especially through the grain price channel. Therefore, heights were positively related with income and wealth changes and inversely related with inequality.

White statures varied regionally, and after controlling for insolation Southern whites reached taller statures than other early Americans (Carson 2009b: 155–6; Zehetmayer 2011). Part of the Southern height advantage was related to agriculture. The nineteenth-century opening of the New South to agriculture increased agricultural productivity, which was greater than elsewhere in the U.S. (Higgs 1977: 24; Margo and Steckel 1982: 519; Komlos and Coclanis 1997: 443). Before the Civil War, the South was self-sufficient in food production, and relatively high white wages and income may have also been associated with taller Southern white statures (Fogel 1994: 89, 132–3; Easterlin 1971: 41; Margo 2000). After the Civil War, the South was no longer self-sufficient in food production, and wages in the West South Central were generally lower than Midwest wages and comparable to those in the middle Atlantic region (Easterlin 1971: 41); Southern wages were in general lower than Northern wages. However, West South Central laborers' wages were comparable to those in the middle Atlantic region, and after emancipation wages in Louisiana, Mississippi, and Texas were higher than elsewhere, which may have increased Southern material and biological well-being (Rosenbloom 2002: 53, 124–5; Margo 2000; Higgs 1977: 26, 63, 102). Whites from the Great Lakes were taller than those from the Northeast and Plains. Another height pattern that has received considerable support is that migrants were taller than persisters, and the direction of the effect on height is consistent with broader geographic patterns. Internal migrants who located to the South were taller than those who immigrated to the North, and migrants to the North were shorter than migrants to the South (Carson 2009b: 155–6).

Disease and death rates have long been suspected of adversely influencing stature, and Fogel *et al.* (1983) suggest that part of the antebellum paradox and early industrial growth puzzle may be attributable to increased disease burdens and higher death rates. However, where the relationship between height and nutrition is widely agreed upon, the relationship between height and disease is less settled. Komlos (1992: 329) suggests that, since both urban black males and females were likely exposed to the same disease environments but female heights decreased at least a decade prior to male heights, disease is an unlikely source to explain the antebellum stature decline. Voth and Leunig (1996) indicate that, because individuals who survived British smallpox epidemics were shorter than those not exposed, smallpox may have been associated with shorter statures; moreover, near eradication of smallpox in the 1820s substantially improved heights. However, Heintel and Baten (1998) dismiss the significance and magnitude that smallpox had on British stature, suggesting that the Voth and Leunig findings were due to changes in military minimum stature requirements, obfuscating the measured relationship between height and smallpox. Attempting to explain declining antebellum American statures, Coelho and McGuire (2000) propose that disease environments stunted slave childhood statures. Steckel (2000) defends his earlier position that poor nutrition led to stunting and notes that poor nutrition also makes individuals more prone to disease. Haines *et al.* (2003: 406) demonstrate that height is inversely related with the crude death rate, while Carson (2010b) suggests that, because of catch-up growth, long-term institutional change is more likely than short-run disease insults to influence agricultural productivity and physical stature variation. As a result, isolating the relationship between height and disease is an area that warrants greater attention in historical stature studies.

Population density has been proposed as a variable associated with historical stature variation (Goodman and Martin 2002: 35). Height may be short when population density is low because low population density is related with limited labor specialization, failure for markets to extend, and lower increases in agricultural productivity. However, height may have decreased with population density because high population density is related with depleted resources per capita and increased disease networks that propagate disease and diminish human health (Steckel et al. 2002: 80). Carson (2009a: 47–52, 2010a: 474–6) demonstrates that physical statures both increased and decreased with population density. Statures increased with population density in states with fewer than 42 persons per square mile; maximum stature was reached in states with 42 persons per square mile, which was approximately the mid-nineteenth-century population density of Illinois. Nonetheless, stature was shorter in states with more than 42 persons per square mile.

Proximity to rivers and lakes represents access to trade routes, and whites living in close proximity to waterways may have been taller because close proximity to trade routes decreased transportation costs and increased access to nutrition during industrialization. On the other hand, proximity to waterways may have reduced stature because it facilitated the export of food and the spread of disease. Haines *et al.* (2003: 407) demonstrate that close proximity to trade routes was associated with shorter statures but do not distinguish between geographic and industrialized regions. Carson (2008b: 364, 2011c) demonstrates that whites in close proximity to Northeastern waterways were taller than whites living in counties with no access to waterways, and Northeastern industrializing centers decreased the price of acquiring nutrition. Alternatively, Southern agricultural communities that exported nutrition increased the relative price of food, which was exported to Northeastern industrial centers, and Southern whites with close proximity to the Mississippi River were shorter than individuals who were not in close proximity to waterways. Similar results are found for proximity to roads and turnpikes (Peracchi 2008).

Still other studies rely more heavily on biological explanations, specifically solar radiation. Carson (2008c, 2009b) shows a positive relationship between stature and vitamin D production. Calcium and vitamin D are required throughout life for healthy bone and teeth formation; however, their abundance for healthy skeletal development is most critical at younger ages (Wardlaw *et al.* 2004: 394–6; Tortolani *et al.* 2002: 60; Loomis 1967). In order of importance, the three most important sources of vitamin D production are the amount of time exposed to sunlight, skin pigmentation, and nativity (Holick *et al.* 1981: 590; Carson 2008c). Calcium generally comes from dairy products, and vitamin D is produced by the synthesis of cholesterol and sunlight in the epidermis's stratum basale, granulosum, and spinosum (Loomis 1967: 501; Norman 1998: 1108; Holick 2007).[1] Greater direct sunlight (insolation) produces more vitamin D, and vitamin D is related to adult terminal stature (Xiong *et al.* 2005: 228, 230–1; Liu *et al.* 2003; Ginsburg *et al.* 1998;

Uitterlinden *et al.* 2004). However, vitamin D production also depends on melanin in the stratum corneum (Norman 1998: 1108). Greater melanin (skin pigmentation) interferes with cholesterol's synthesis into vitamin D in the stratum granulosum, and darker pigmentation filters between 50 and 95 per cent of the sunlight that reaches the stratum granulosum (Loomis 1967: 502; Weisberg *et al.* 2004: 1703S; Holick, 2007: 270). Therefore, darker skin is considerably less efficient than lighter skin at producing vitamin D, and darker skin is more common in Southern latitudes where more hours of direct sunlight offset inefficient vitamin D production (Norman 1998: 1109–10). In the U.S., Southern states are closer to the equator and receive more insolation, while Northern states are farther from the equator and receive less direct sunlight. Before the mandated addition of vitamin D to the U.S. milk supply in the 1930s, statures were taller in states that received more sunlight per day.

During the nineteenth century, white statures varied by socioeconomic status, and among the most established patterns is that farmers were consistently taller than workers in other occupations (Margo and Steckel 1982: 525; Steckel 1979: 373). Farmers traditionally had greater access to superior diets and nutrition and were removed from urban environments, where disease is more easily propagated. Workers in occupations with greater exposure to direct sunlight may have also grown taller because they were exposed to greater insolation as children and produced more vitamin D, which contributed to healthy bone formation (Tortolani *et al.* 2002). Islam *et al.* (2007) demonstrate that children exposed to more direct sunlight produce more vitamin D, and, if there was little movement away from parental occupation, nineteenth-century occupations may also be a good indicator for the occupational environment in which individuals came to maturity (Margo and Steckel 1992: 520; Wannamethee *et al.* 1996: 1256–62; Nyström-Peck and Lundberg 1995: 734–7). Historical heights were taller in states that received more insolation and farmers and unskilled workers, who spent more time outdoors during adolescent ages, were taller than workers in other occupations.

Nineteenth-century black heights

Three important early studies in African-Americans' heights were Fogel and Engerman (1974), Fogel (1989), and Steckel (1986). Fogel finds that nineteenth-century adult U.S. black statures were comparable with various white samples, indicating that adult slaves received sufficient calories for work effort and to fend off disease (Komlos 1992: 327). However, using the heights of coastal slave children, Steckel (1986) demonstrates that slave children were chronically stunted compared with their white counterparts and concludes that, while adult slaves received sufficient calories to reach tall terminal statures, slave children received inadequate dietary provisions until they entered the adult slave labor force. Therefore, slave and free-black heights have received considerable attention and provide valuable insight into nineteenth-century black living standards.

Various factors led to differences between nineteenth-century black and white statures and an unexpected finding is that African-American male heights increased during the antebellum period, while white statures declined (Figure 4.2; Fogel *et al.* 1978: 465; Steckel 1986; Komlos 1992: 309; Komlos and Coclanis 1997: 445). If, however, Southern planters and overseers rationally allocated slave nutrition and medical allotments to maximize their own wealth, slave heights would have increased with antebellum slave prices and probably decreased – at least temporarily – with slavery's elimination (Rees *et al.* 2003: 22; Steckel 1995; Fogel *et al.* 1983: 464–6; Margo and Steckel 1982: 520; Komlos and Coclanis 1997: 438–42; Komlos 1998: 787; Carson 2008c, 2009b, 2010a, 2010b). In the postbellum period, black statures temporarily declined but increased in the early twentieth century (Carson 2009c). In contrast, the statures of

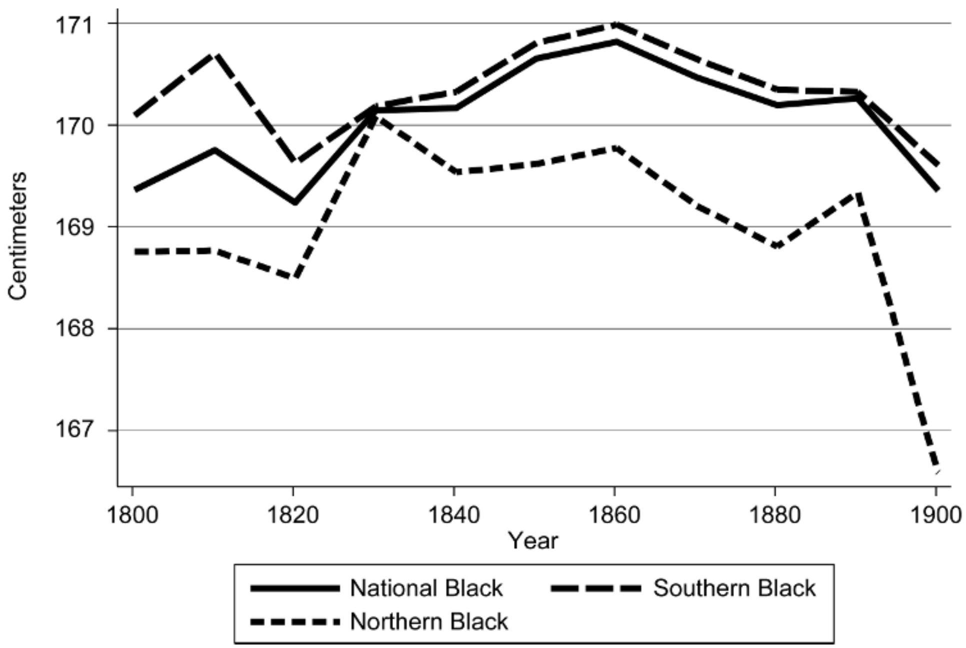

Figure 4.2 Nineteenth-century U.S. African-American male statures by year of birth
Source: Carson (2009b).

free blacks declined with industrialization and mirrored those of market-dependent nineteenth-century whites (Komlos 1992, 1998; Bodenhorn 1999: 984).

A considerable body of evidence demonstrates that nineteenth-century mulattos were taller than darker-complexioned blacks, and to explain the difference Steckel and Bodenhorn point to social practices (Steckel 1979: 375; Margo and Steckel 1982; Bodenhorn 1999: 384). An additional explanation for taller mulatto statures may be biological. Lighter-complexioned blacks were taller than darker-complexioned blacks because less melanin in the stratum corneum allowed more sunlight to penetrate the stratum granulosum, producing more vitamin D. Furthermore, the black diaspora from Africa to North American latitudes placed blacks into geographic regions where they received less direct sunlight and produced less vitamin D; therefore, Northern blacks may also have been shorter than Southern blacks because they produced less vitamin D (Xiong *et al.* 2005: 228–31; Ginsburg *et al.* 1998: 320).

Isolating the relationship between nineteenth-century black stature, income, and wealth is more elusive than for whites because slaves held no wealth before, and little wealth after, emancipation. Slave biological and material conditions probably improved during the late antebellum period, and blacks in the postbellum period devoted a higher share of their incomes to food acquisition (Higgs 1977: 102–5). Carson (2008c, 2010b) demonstrates that black statures increased during the antebellum period and declined temporarily with emancipation. Therefore, blacks fared poorly under slavery but their biological standard of living improved during the late antebellum period of prosperity, declined temporarily when slavery was eliminated, then increased as they acclimated to life beyond the slave system.

Black farmers were also taller than non-farmers, and average black unskilled workers and field hands were taller than household servants and skilled slaves (Metzer 1975: 134; Margo and Steckel 1982: 525). That unskilled black workers were also tall suggests that most unskilled workers were agricultural workers, who received sufficient nutrition allocations and worked outdoors.

Black statures also varied regionally, and Southwestern blacks reached the tallest statures (Komlos 1992: 314; Bodenhorn 1999: 384; Carson 2009b: 155). During the antebellum period, slaves were shielded from income and price variation, and, although Southwestern slavery was arduous and demanded many calories for work, Southwestern slaves lived in more recently settled and productive farmlands. After emancipation, Southwestern blacks were exposed to greater income variation and were unprepared for life beyond the slave system, either in terms of experience or human capital. The relative price of dairy and calcium were lowest in dairy-producing regions, such as the Great Lakes states, but nineteenth-century blacks were overwhelmingly native to the South, which was low in dairy production (Bodenhorn 1999: 988–93). Northeastern blacks, especially youth, encountered adverse biological environments, and contemporary reports of rickets – a result of childhood vitamin D deficiency – may have contributed to shorter Northeastern black statures (Kiple and Kiple 1977: 293–4; Tortolani *et al.* 2002: 62).

Nineteenth-century female and other minority statures

Because of data limitations, there continues to be a paucity of historical stature studies that consider the biological conditions of women. Scholars studying nineteenth-century females in England have produced considerable research, and, like males, females experienced the early modern growth puzzle. English female statures declined throughout the nineteenth century (Johnson and Nicholas 1995; Nicholas and Oxley 1996; Oxley 2004). Sunder (2011) finds that mid-nineteenth-century elite white U.S. female heights increased, and Komlos (1992) finds that black females' statures deteriorated during the early nineteenth century, at least a decade earlier than male stature decline began. Moreover, urban black women were shorter than rural black females. Using nineteenth-century state prison records, Carson (2011a) contrasts the heights of comparable U.S. African-American and white females during a period of relatively rapid economic development. White females were consistently taller than black females, and whites from the Great Lakes and Plains states and black Southwestern females were the tallest. U.S. females were tall compared with their European counterparts. The height of females began to decline in the antebellum period, possibly before that of males. The recovery of physical stature was also earlier among women than among men.

Other populations have received attention. During the nineteenth century, Mexico experienced substantial political instability, yet, because nineteenth-century Mexican populations remained near biological subsistence, Mexican biological living standards did not change appreciably. Like other populations experiencing rapid economic growth, heights in nineteenth-century Northern Mexico tended to stagnate or decline slightly during the earliest period of economic development. Agricultural output also influenced Mexican biological living conditions, and Mexican corn output probably doubled during the first half of the nineteenth century (McCaa 2000: 288). If greater corn output had been diverted into livestock feed, animal proteins may have become more abundant and improved Mexican diets. Mexican disease environments were also altered during the nineteenth century. With Mexican independence came greater strides toward improving public health. In 1804, a smallpox vaccine was introduced to the Mexican population and, later, measles and other diseases were reduced (McCaa 2000: 289). However, early forms of Mexican economic development and modernization were not accompanied by urbanization.

The statures of Chinese who emigrated from Southern China to the U.S. compared favorably with other Chinese. Between 1830 and 1870, Chinese male youth stature declined by over two centimeters and deteriorated throughout the nineteenth century, precisely when China's population growth was high, agriculture nearly collapsed, and political events created economic upheaval associated with biological privation. Chinese statures did not vary with socioeconomic status or residence. Consequently, the biological conditions facing nineteenth-century people fleeing China were deteriorating and occurred across the socioeconomic strata.

In one of the more novel applications of anthropometrics, Steckel and Prince (2001) and Prince and Steckel (2003) consider the heights of mid-nineteenth-century American Indians and find that Plains nomadic groups were tallest among a broad comparison of mid-nineteenth-century North American indigenous populations due to low population densities, close access to a high-protein food source, warmer winter clothing, barter between tribes, and more equitable living arrangements. Komlos (2003) also demonstrates that rural Georgia American Indians were quite tall.

Other areas related to historical height studies are receiving increased attention. Barker (1992) postulates that several adult health conditions are related to in-utero conditions. For example, adult hypertension and ischemic stroke have been linked to in-utero conditions, and neurological demyelination diseases have been linked to insufficient material access to iodine during the second trimester. Recent efforts also couple adult height and intelligence (Case and Paxson 2008; Deaton 2008; Mankiw and Weinzierl 2007; Maurer 2010). In one of the more original applications to historical height studies, Steckel and Prince use both Old and New World skeletal remains to study linear enamel hypoplasias, porotic hyperostosis, anemia, height, and infectious disease (Steckel *et al.* 2002).

Historical anthropometrics of the BMI

A population's average BMI (weight [kg]/height [m^2]) reflects the net current balance between nutrition, disease climate, and the work environment, and heavier nineteenth-century BMIs are evidence of more robust health (Fogel 1994: 375; Strauss and Thomas 1998). When BMI values are low, net current biological living conditions are substandard, and weight-to-height ratios may be wasted. BMIs have also been linked to modern health outcomes (Waaler 1984; Stevens *et al.* 1998: 1–7; Calle *et al.* 1999: 1097–104; Kenchaiah *et al.* 2002: 305–13; Calle *et al.* 2003: 1625–38; Pi-Sunyer 1991: 1595s-600s; Jee *et al.* 2006; Costa 1993); however, the strength of this association across sub-populations remains debatable (Henderson 2005: 340; Flegal *et al.* 2009: 240). Historical BMI studies provide important insight into the evolution of health during economic development. For BMIs of less than 20, Waaler (1984) and Koch (2011) find an inverse relationship between BMI and mortality risk. Costa (1993) and Murray (1997) apply Waaler's results to historical populations and find the modern height and weight relationship is consistent with the relationship in the past, and Jee *et al.* (2006: 780, 784–5) find the relationship is stable across racial groups. Costa (2004: 8–10) demonstrates that there were considerable differences between nineteenth-century black and white BMIs, and that blacks had greater BMI values than whites (Flegal *et al.* 2010). The health risks associated with heavier BMIs may also have been greater for whites than for blacks (Flegal *et al.* 2009: 507; Stevens *et al.* 1998; Abell *et al.* 2007; Sanchez *et al.* 2000; Stevens *et al.* 1992; Wienpahl *et al.* 1990). Costa finds that BMI values increased between 1860 and 1950, while Cutler *et al.* (2003) find that U.S. BMIs have increased since the beginning of the twentieth century; however, the majority of increased BMI values have occurred since 1980 because people consume more calories, not because they are physically less active.

An increasing number of studies consider nineteenth-century white BMI variation. Cuff (1993) finds that mid-nineteenth-century West Point cadet BMIs were low compared with modern BMI values, and placed a large proportion of young nineteenth-century Northern males into a high relative mortality risk category. Coclanis and Komlos (1995: 102–3) also find that BMI values of late nineteenth-century students at the Citadel military academy were comparable with those of West Point cadets. Carson (2009d) finds that, in contrast to modern distributions, most Southern BMI values were in normal weight ranges. There was also little change in BMI values between 1876 and 1920. Farmers were consistently heavier than non-farmers, and Southwestern men were taller and had lower BMI values than their counterparts from other regions within the U.S.

The shape of the BMI distribution tells us about a population's current biological conditions, and there are differing views about how nineteenth-century BMIs were distributed. On the one hand, BMIs may have been low because diets were meager relative to work expenditures. On the other, output growth created larger quantities of food and more nutritious diets as U.S. agricultural settlement produced greater output and more nutritious diets relative to calories consumed for work and to fend off disease. The overwhelming proportion of nineteenth-century black and white BMIs were symmetrically distributed, fell within the normal BMI category, and neither underweight nor obesity was the historical dilemma facing nineteenth-century U.S. populations. Carson (2012) finds that 17 per cent of adult white males in the 1800s were overweight or obese, as were 33 per cent of adult black males. In addition, 17 per cent of white male youths were overweight or obese, as were 17 per cent of black male youths. These historical BMIs are compared with modern U.S. values, where approximately 36 per cent of adult American men are overweight and 23 per cent are obese (Finkelstein *et al.* 2003; Sturm and Wells 2001: 231; Calle *et al.* 1999: 1103; Flegal *et al.* 2010). BMIs of less than 19 mark a threshold corresponding with increased mortality risk, and 40 per cent of West Point cadets between the ages of 20 and 21 had BMIs of less than 19 (Cuff 1993: 178). However, BMIs of black and white 20- and 21-year-olds in nineteenth-century U.S. prisons were considerably greater than the threshold of 19, and only 2.05 and 1.49 per cent of whites and blacks had BMIs of less than 19.

Morbid obesity is defined as a BMI greater than 40, and there is an alarming modern trend toward overweight and obesity (Finkelstein *et al.* 2003; Flegal *et al.* 2010; Flegal *et al.* 2009). There are numerous plausible explanations to account for this increase: behavioral, genetic, lifestyle changes, and changes in the relative price of food (Freedman 2011). Morbid obesity is also linked to type II diabetes, stroke, and cardiovascular disease (Finkelstein *et al.* 2003; Pi-Sunyer 1991: 1599s; Kenchaiah *et al.* 2002: 306–12; Calle *et al.* 2003: 1628–30). Cases of nineteenth-century black and white morbid obesity among the working class were nearly non-existent. Only 0.016 per cent of historical U.S. blacks and 0.014 per cent of whites were morbidly obese (Carson 2009d, 2012). This contrasts with 2.9 per cent in modern samples and indicates that modern Americans are more likely to be obese.

Like white heights, white BMI values (see Figure 4.3) declined throughout the nineteenth and early twentieth centuries (Carson 2008b, 2009d, 2012). Farmers had greater BMI values than workers in other occupations and were less likely to be underweight. Part of farmers' higher BMIs was probably related to physical activity, and BMIs represent an individual's composition between muscle and fat, which are related to physical activity and occupation. Occupations requiring greater physical activity are known to decrease fat and increase muscle. Modern agricultural workers use between 2.5 and 6.8 energy multiples of basal metabolic rate (Food and Agricultural Organization of the United Nations *et al.* 1985), indicating that, because they are close to nutritious diets and more physically active, farmers have sufficient calories to maintain weight. Black and white BMIs in the Northeast and Upper South were consistently lower than the Deep South and Far West (Carson 2012). BMIs were also related to industrialization and urbanization, and individuals from Philadelphia had lower BMIs and were less

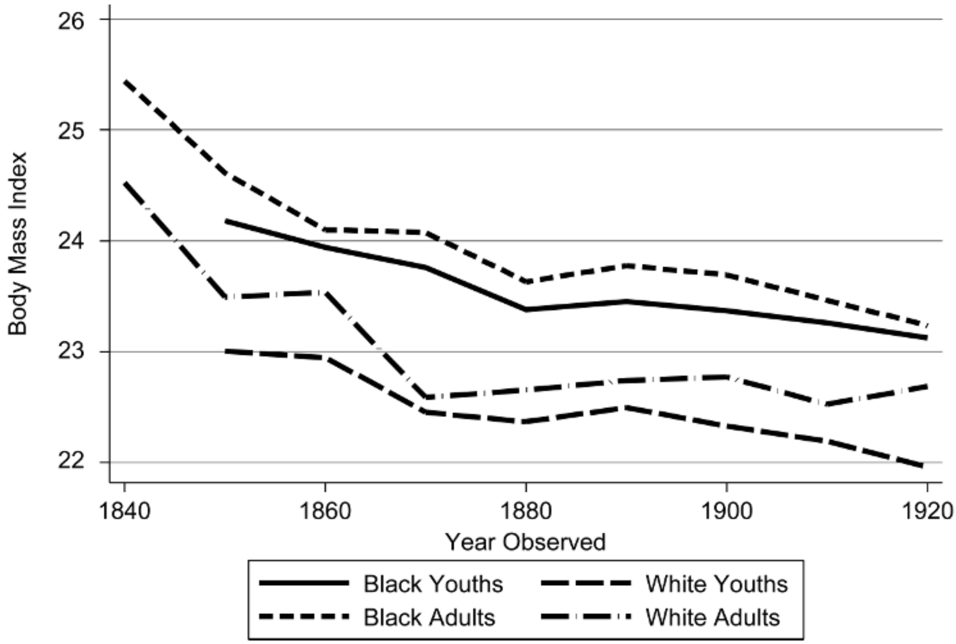

Figure 4.3 Nineteenth-century U.S. African-American and white male BMIs
Source: Carson (2012).

likely to be overweight or obese but also less likely to be underweight, suggesting that urban BMIs were more likely to be in normal weight ranges.

Much has also been written about the nineteenth-century mulatto stature advantage, and U.S. mulattos were taller than their darker-complexioned counterparts (Steckel 1979; Bodenhorn 1999: 984; Carson 2008c, 2009b). However, the relationship between BMI and skin pigmentation is more complicated than height, because blacks have greater per cent muscle mass, and muscle is heavier than fat (Flegal *et al.* 2010: 240; Flegal *et al.* 2009: 507; Fernandez *et al.* 2003; Aloia *et al.* 1999: 116; Evans *et al.* 2006). Darker-complexioned blacks were also shorter than mulattos, and shorter statures are associated with greater BMI values (Herbert *et al.* 1993: 1438; Carson 2009d: 125). Blacks were shorter, which may also reflect their basal metabolic rate and early life conditions, because shifts in relative well-being over the life cycle complicate BMI interpretation. However, modern black BMIs are greater than whites, suggesting poor early life conditions are less likely to explain greater BMI values than greater per cent muscle mass. After controlling for height, darker-complexioned blacks had greater BMI values than mulattos, indicating that the cumulative advantage of taller white statures was dominated by blacks' greater per cent muscle mass.

Conclusion and future directions

Measuring and accounting for health during economic development is augmented by the development of anthropometric measures, and a few patterns are increasingly clear. Nineteenth-century white heights experienced the antebellum paradox, where statures declined while income and wealth increased. They were positively related with income and wealth and inversely related to inequality. White heights may also have been related to stages of the business cycle;

however, because of catch-up growth, height variation may be less sensitive to the business cycle than it is to structural differences and institutional change. Nineteenth-century white height was also related to socioeconomic status, and rural farmers were taller than workers in other occupations. Heights were related to urbanization and region within the U.S., and rural Southerners were taller than other regions within the U.S. Migrants were taller than persisters, and heights were related with proximity to waterways. Northeastern whites were taller near waterways, and Southern whites were shorter near the Mississippi River. There was an inverted U-shape between height and state population density, and white heights were shorter in both sparsely and densely populated states and tallest in moderately populated states.

Nineteenth-century black heights over time differed markedly from white height variation, and enslaved black statures increased when Southern agricultural conditions in the late antebellum period improved and decreased with slavery's removal. However, like U.S. whites, free market-dependent black statures declined throughout the nineteenth century. Moreover, there was a distinct height advantage for mulattos compared with darker-complexioned blacks. Nineteenth-century socioeconomic status was also related with black height, and rural farmers were taller than workers in other occupations. Black Southerners were taller than blacks in other regions within the U.S., and black migrants were taller than persisters. Therefore, nineteenth-century black height variation was the result of complex interactions with nutrition, income, inequality, and the physical environment, and, while numerous black height patterns were comparable with those of whites, there were distinctive differences that reflected the economic, social, and physical environments in which each group came to maturity.

There are also several areas where the relationship between height and economic variables is less clear. We are in the early stages of establishing the relationships between health and in-utero conditions related with height and intelligence, and pushing the research frontier further back into the past to include underrepresented groups and paleo-peoples. Among the most promising areas of research is the relationship between height, disease, and death rates.

Diets in developed economies have undergone a nutritional transition, and nineteenth-century diets abundant in proteins, fiber, and complex carbohydrates have been replaced with simple sugars and saturated fats (Popkin 1993: 145–8). Black and white BMIs have simultaneously increased from normal to overweight and obese categories. BMIs were historically related with several economic variables, and nineteenth-century farmers consistently had higher BMI values than workers in other occupations. Heavier farmer BMI values also reflect the physical labor workers performed, and more rigorous occupational demands likely contributed to heavier farmer BMIs. Black and white BMIs were heavier in the nineteenth-century American South and lower in the industrializing North.

While these nineteenth-century stature and BMI patterns for African-Americans and whites shed light on historical health and socioeconomic patterns, the record is not complete. Researchers exploring stature patterns will continue to unearth new data sets, especially for periods following extreme poverty, such as after wars or widespread and prolonged famine. Efforts are underway that consider novel areas in stature, such as the relationships between in-utero conditions and later life conditions, and between height and intelligence. Historical BMI studies are not as advanced, and future studies will develop new data sets across the socio-economic strata. Similarly, little is known about the relationship between stature, BMI, and historical labor force participation, which is an important link between labor and health economics. Therefore, stature and BMI studies provide a vital glimpse into health during economic development and are indispensible tools in understanding economic history and historical health economics.

Notes

1 There are few dietary sources for vitamin D.

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