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A Quantile Approach to the Relationship between Body Mass, Wealth, and Inequality

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Abstract

Little research exists on the historical relationship between BMI variation, wealth, and inequality. This study finds that 19th century US black and white BMIs were distributed symmetrically; neither wasting nor obesity was common. Nineteenth century BMI values were also greater for blacks than whites. There was a positive relationship between 19th century BMIs and average state-level wealth, and an inverse relationship between BMI and wealth inequality. After controlling for wealth and inequality, rural agricultural farmers had greater BMI values than their urban counterparts in other occupations.

JEL-Code: I10, N00.

Keywords: BMI, wealth, inequality, and race.

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1. Introduction

A lively debate regarding the relationship between material inequality and modern health outcomes has arisen between social scientists on the one hand who maintain that inequality has deleterious effects on human health (Steckel, 1983; Wilkinson, 1996; Wilkonson and Picket, 2006; Lynch et al., 1998; Subramanian and Kawachi, 2004), and those on the other who hold the relationship is largely a statistical artifact. The causal mechanism appears clear. Greater relative inequality forecloses those at the lower end of the socioeconomic strata from the medical care, nutrition, and health intervention that may reduce morbidity and increase longevity. Moreover, the last dollar spent on health by a wealthy individual contributes less to health than the last dollar spent on health by poorer individuals. However, Angus Deaton (2002, p. 115) and Hugh Granville (1998) maintain that existing studies that consider the relationship between inequality and health are biased, because they do not address measurement error and omitted variable bias. The current study, therefore, adds to this discussion about the relationship between inequality and health by considering the relationship between 19th century BMIs, state-level wealth, and inequality across the BMI distribution.

A population's average BMI (weight (km.)/ height (m^2)) reflects the net current balance between nutrition, disease climate, and the work environment (Fogel, 1994, p. 375; Strauss and

Thomas, 1998), and heavier 19th century BMIs are evidence of more robust health. Historical BMI studies provide important insight on the evolution of health during industrialization. For BMIs less than 20, Waaler (1984) finds an inverse relationship between BMI and mortality risk, and a positive relationship for BMIs greater than 27. Costa (1993) applies Waaler's results to a historical population and finds the modern height and weight relationship with mortality applies to historical populations, and Jee et al (2006, p. 780, 784-785) find the relationship is stable across racial groups. The historical relationships between BMI and mortality may also be steeper than for modern populations. Cuff (1994) finds that mid-19th century West Point Cadet BMIs were low relative to modern BMI values and placed a large proportion of 19th century young northern white males into high relative mortality risk categories. Coclanis and Komlos (1995, pp. 102-103) find that late 19th century BMIs at The Citadel military academy were comparable to those of West Point Cadets. Costa (2004, pp. 8-10) demonstrates there were considerable differences between 19th century black and white BMIs, and blacks had greater BMI values than whites. Moreover, health risks associated with higher BMI values may also be greater for whites than blacks (Flegal et al., 2009, p. 507; Stevens et al., 1998; Abel et al., 2007; Sanchez et al., 1998; Stevens et al., 1992; Weinpahl et al., 1990). Costa finds that BMI values increased between 1860 and 1950, and Cutler, Glaezer, and Shapiro (2003) find that US BMIs have increased since the beginning of the 20th century, not because individuals were physically inactive but because people consume more calories.

It is against this backdrop that this study considers the relationship between 19th century BMIs, wealth, and socioeconomic variables across the BMI distribution. Three paths of inquiry are considered. First, how did black, mulatto, and white BMIs vary by race and was there a 19th century mulatto BMI advantage? Blacks consistently had greater BMI values than mulattos, and mulattos—in turn—had greater BMI values than whites. Therefore, there is no evidence of a 19th century mulatto BMI advantage.[1] Second, across the BMI distribution, how did BMI values vary with respect to average wealth and inequality? Consistent with stature studies, BMI values were greater in areas that had higher average wealth and greater equality. Third, how were BMIs related with socioeconomic status and population density? After controlling for wealth and inequality, rural agricultural farmers had greater BMI values than their urban counterparts in other occupations, and BMIs were inversely related with population density.

2. Nineteenth Century United States Prison, Wealth, and Population Data

For the first time, this study considers the historical relationship between BMIs, wealth, and inequality. To evaluate these BMI relationships with the physical environment, multiple data sets are constructed: 19th century US prison data, 19th century US state-level average wealth, gini coefficients, and population density.

Prison Data

The data used here to assess these relationships is a subset of a much larger 19th century prison sample. All state prison repositories were contacted and available records were acquired and entered into a master data set. These prison records include Arizona, California, Colorado, Idaho, Illinois, Kansas, Kentucky, Missouri, Ohio, Oregon, Pennsylvania, and Texas (Table 1). Physical descriptions were recorded at the time of incarceration by 19th century prison enumerators as a means of identification in the event that prisoners escaped and were later recaptured, and BMI values are constructed from height and weight data reported in the prison records.

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[1] Steckel (1979), Bodenhorn (1999), Bodenhorn (2001), Carson (2008), and Carson (2009) find evidence of a 19th century mulatto stature advantage over darker complexioned blacks.

Table 1, Nineteenth Century US Prison Sample

Prison	Number	Percent		Number	Percent
Arizona	77	.22	Kentucky	2,478	7.07
California	1,943	5.54	Missouri	4,653	13.24
Colorado	94	.27	Ohio	7,323	20.88
Idaho	14	.04	Oregon	238	.68
Illinois	1,305	3.72	Pennsylvania	5,495	15.67
Kansas	228	.65	Texas	11,221	32.00

Source: Data used to study black and white anthropometrics is a subset of a much larger 19^{th} century prison sample. All available records from American state repositories have been acquired and entered into a master file. These records include Arizona, California, Colorado, Idaho, Illinois, Kansas, Kentucky, Missouri, New Mexico, Ohio, Oregon, Pennsylvania, Texas, Utah and Washington.

There is also concern over prison entry requirements, and physical descriptions were recorded at the time of incarceration by prison enumerators as a means of identification, therefore, reflect pre-incarceration conditions. Between 1840 and 1920, prison officials routinely recorded the dates inmates were received, age, complexion, nativity, stature, pre-incarceration occupation, and crime. All records with complete age, height, weight, occupation, and nativity are used in this study. There was care recording inmate height and weight because in this pre-photographic age, accurate measurement had legal implications for identification in the event that inmates escaped and were later recaptured.

All historical BMI data have various biases, and prison and military records are the most common sources for historical biological measurements. One common shortfall for military samples is a truncation bias imposed by minimum stature requirements (Fogel et al, 1978, p. 85; Sokoloff and Vilaflor, 1982, p. 457, Figure 1; A'Hearn, 2004). By arbitrarily truncating shorter statures, military records downwardly bias BMI values, because shorter statures are associated with greater BMI values (Herbert, 1993, 1438). Therefore, the prison data may create a more comparison between 19th century prison inmate BMI distributions with the general public. However, prison records are not above scrutiny, because they may have selected many of the materially poorest individuals who were drawn from lower socioeconomic groups, that segment of society most vulnerable to economic change (Bogin, 1991, p. 288; Komlos and Baten, 2004, p. 199; Nicholas and Steckel, p. 944). However, if at the margins of subsistence, BMI variation was more sensitive to changes in demographic and socioeconomic factors, prison records may illustrate these effects more clearly than military samples.

To take advantage of 1860 and 1870 census wealth and inequality data, the prison data are restricted to birth between 1855 and 1875, and only blacks and whites are included (Carson, 2007). Fortunately, inmate enumerators were quite thorough when recording inmate complexion and occupation. For example, enumerators recorded inmates' race in a complexion category, and African-Americans were recorded as black, light-black, dark-black, and various shades of mulatto (Komlos and Coclanis, 1997). Whites were recorded as light, medium, dark, fair, and white. This white race scheme is further supported by European inmates in US prisons, who were also recorded as light, medium, dark, fair, and white.[2] To eliminate the effect of migration on BMIs, only inmates incarcerated in their native state are considered here.

Enumerators recorded a broad continuum of occupations and defined them narrowly, recording over 200 different occupations, which are classified here into four categories: workers who were merchants and high skilled workers are classified as white-collar workers; light

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[2] I am currently collecting 19th century Irish prison records. Irish prison enumerators also used light, medium, dark, fresh and sallow to describe white prisoners in prisons from a traditionally white population. To date, no inmate in an Irish prison has been recorded with a complexion consistent with African heritage.

manufacturing, craft workers, and carpenters are classified as skilled workers; workers in the agricultural sector are classified as farmers; laborers and miners are classified as unskilled workers (Tanner, 1977, p. 346; Ladurie, 1979; Margo and Steckel, 1992; p. 520). Unfortunately, inmate enumerators did not distinguish between farm and common laborers. Since common laborers probably came to maturity under less favorable biological conditions, this potentially overestimates the biological benefits of being a common laborer and underestimates the advantages of being a farm laborer.

Table 2, Nineteen Century US Prison Inmate Demographics and Occupations

Ages	*N*	*%*	*Mean BMI*	*S.D.*	*Native*	*N*	*%*	*Mean BMI*	*S.D.*
Teens	1,996	21.00	22.21	2.54	Northeast	1,044	10.98	21.88	2.16
20s	5,282	55.47	23.38	2.44	Middle Atlantic	749	7.88	22.72	2.34
30s	1,394	14.67	23.53	2.53	Great Lakes	462	4.86	23.00	2.42
40s	534	5.62	23.80	2.73	Plains	201	2.11	23.01	2.42
50s	247	2.60	23.82	3.08	Southeast	6,607	59.51	23.49	2.61
60s	44	.46	23.03	2.84	Southwest	438	4.61	22.87	2.49
70s	8	.08	24.36	4.11	Far West	4	.04	23.90	3.07
Occupations					*Decade Received*				
White-Collar	182	1.91	22.85	3.08	1850s	447	4.70	22.80	2.27
Skilled	1,129	11.88	22.81	2.53	1860s	2,287	24.06	23.28	2.59
Farmers	35	.37	23.29	3.28	1870s	6,771	71.24	23.18	2.59
Unskilled	5,050	53.13	23.33	2.52					
No Occupations	3,109	32.71	23.12	2.64					

Source: See Table 1

Table 2 presents inmate proportions and BMIs by age, occupations, nativity, and decade received. A diverse group of ages are recorded, and the most common groups were in their teens and twenties. Occupations reflect socioeconomic status, and while prison inmates typically came from lower working classes, there was a sizable proportion of inmates from white-collar and skilled occupations. Many inmates were unskilled, but not abnormally so relative to the overall population (Carson, 2008b). Most inmates in the prison sample were from the Southwest, with significant proportions from Great Lakes, Plains, and Middle Atlantic regions. More inmates were incarcerated during the 1870s than the 1860s, and whites were more prominent than blacks, although blacks were over represented in prisons relative to the overall black population (Carson, 2008b, pp. 360-362).

US Average Wealth and Wealth Inequality

To address the BMI inequality relationship, a large 19th century total wealth and state-level inequality data source is constructed. The 1860 and 1870 federal censuses have been the subject of numerous 19th century wealth studies and provide unique insight into the historical relationship between material conditions, inequality, and health as development occurred. Lee Soltow (1975) uses an 1860 and 1870 US wealth sample to demonstrate that wealth inequality did not start with industrialization and changed little between 1800 and 1940. Atack and Bateman (1981) use 1860 and 1870 census wealth to show that although wealth in the rural North was distributed more equitably than in the South, it was not a classical egalitarian society. Kearl, Pope, and Wimmer (1980) and Pope (1989) use census records to demonstrate that wealth in the Far West was distributed equitably; however, western wealth accumulation lagged behind that of the East.

Figure 1, 1860 US Inequality by State

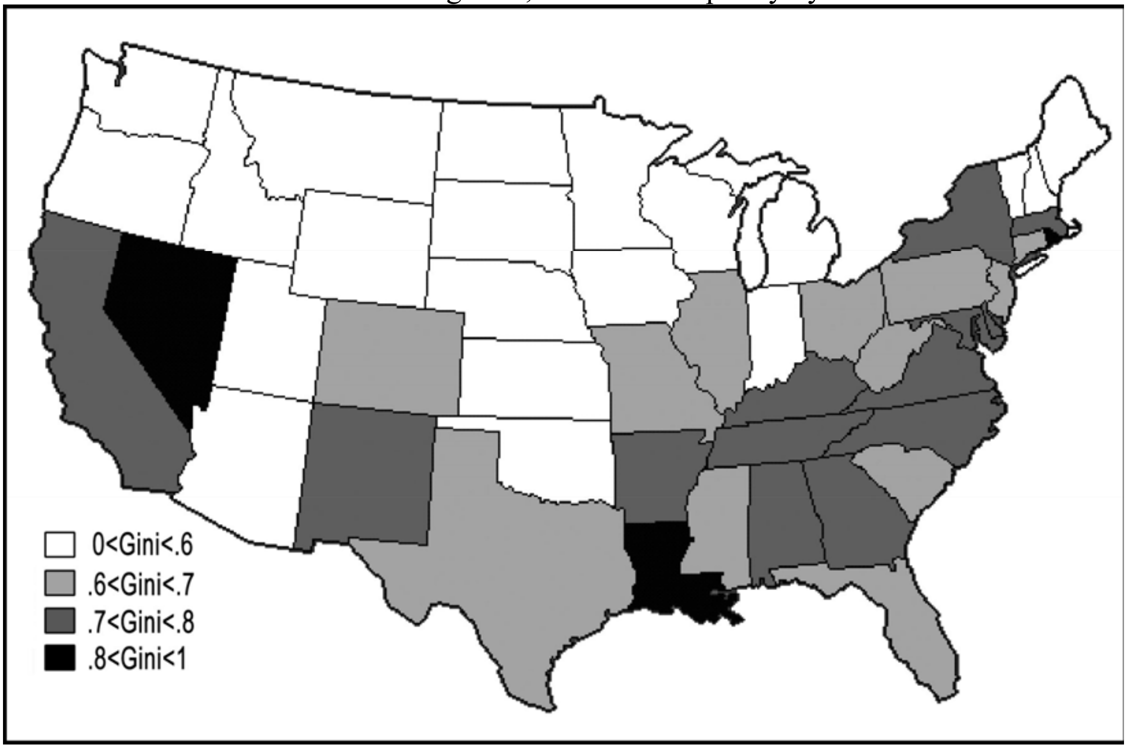
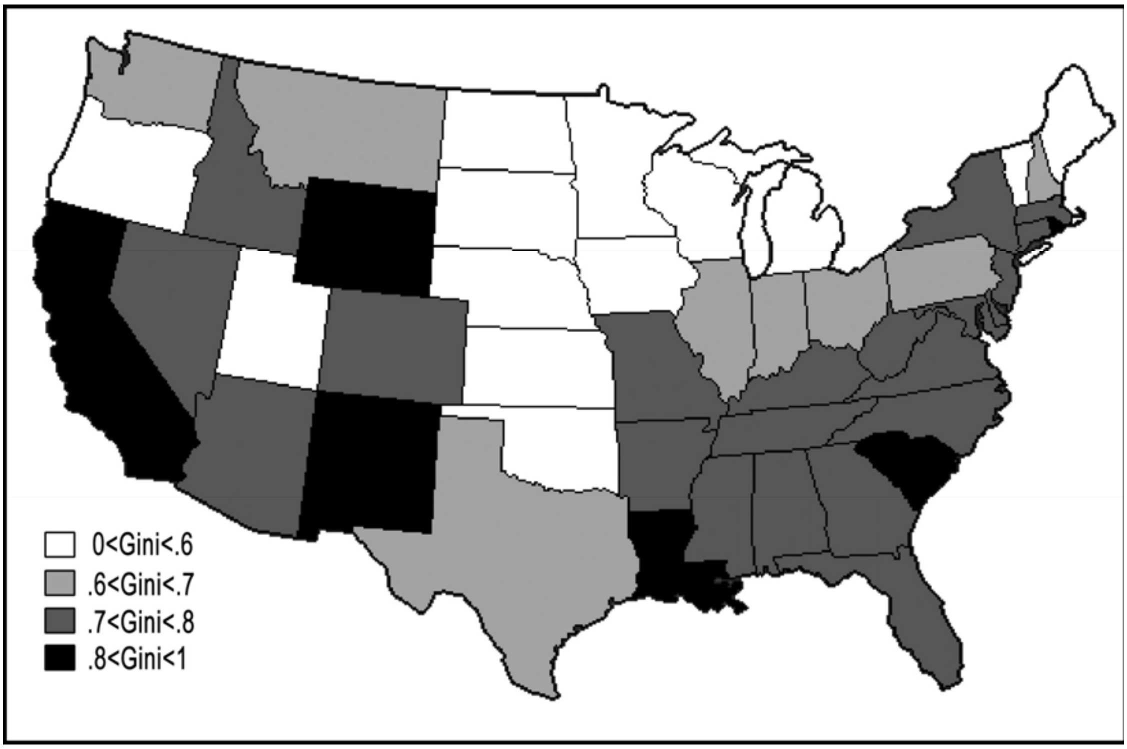


Figure 2, 1870 US Inequality by State



Using wealth from the Integrated Public Use Microdata Series (IPUMS) state-level wealth, and wealth inequality estimates are calculated for male headed households over the age of 18 (Figures 1 and 2).[3] Eighteen sixty and 1870 total US wealth inequality were .71606 and .71220, respectively. On the other hand, average total wealth decreased between 1860 and 1870 from $3,289 in 1860 to $3,018 in 1870 (Figures 3 and 4). While maintaining relatively high wealth equality, Northern wealth holdings increased between 1860 and 1870.. Nevertheless, it was the North's industrialization that may have threatened Northern biological conditions. In 1860, the South had the greatest average wealth but had greater wealth inequality than the North. With the end of slavery, Southern wealth declined considerably but continued to have high wealth inequality (Soltow, 1975; Easterlin, 1971). Of course, the difference was Southern chattel slavery, and once slaves were freed, southern average wealth declined.

[3] No upper bound is placed on ages and all US geographic regions are considered.

Figure 3, 1860 US Average State Wealth

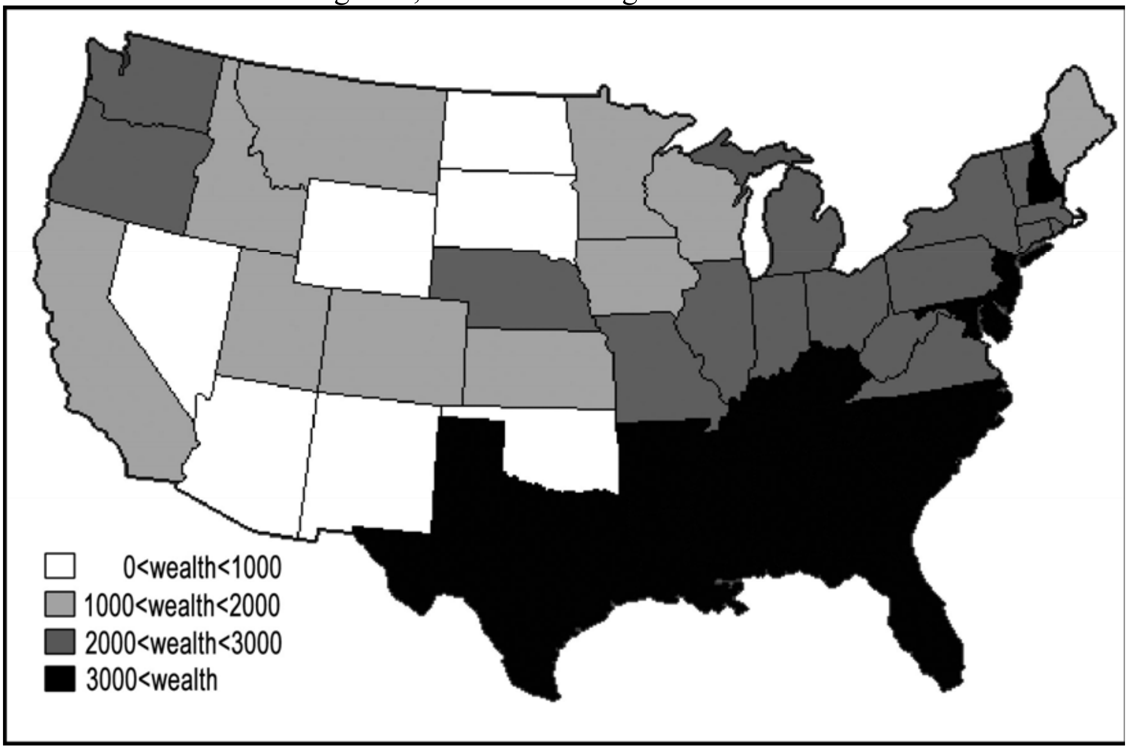
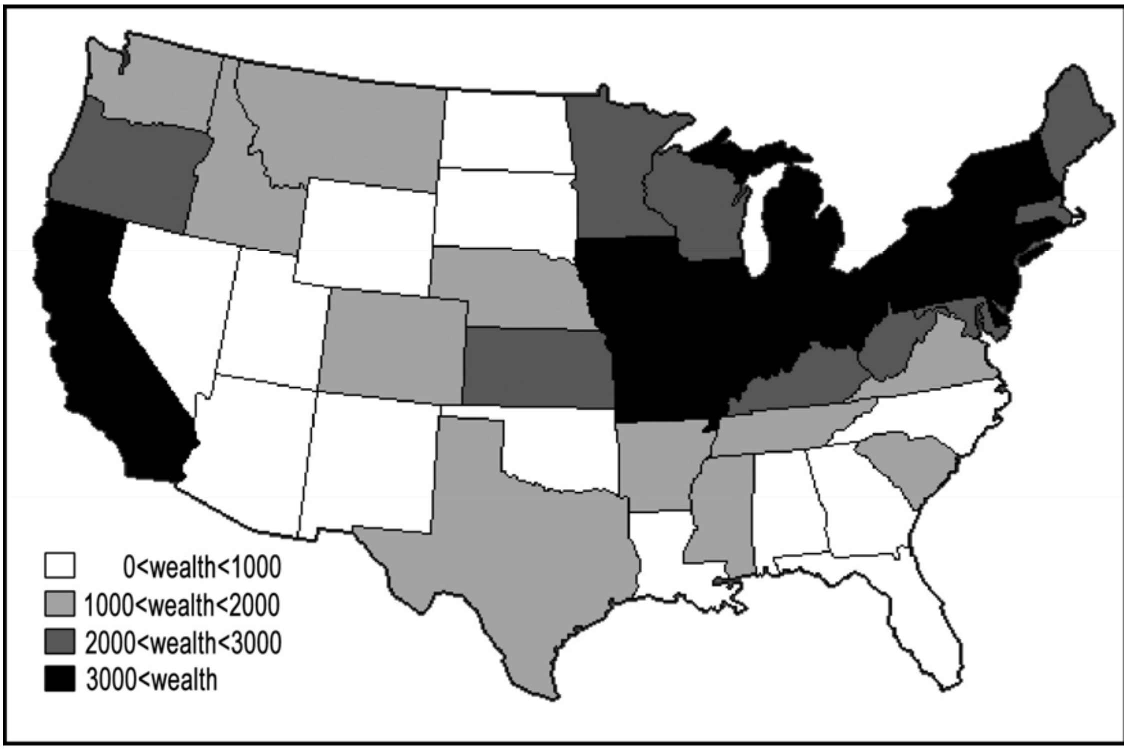


Figure 4, 1870 US Average State Wealth



Population Density

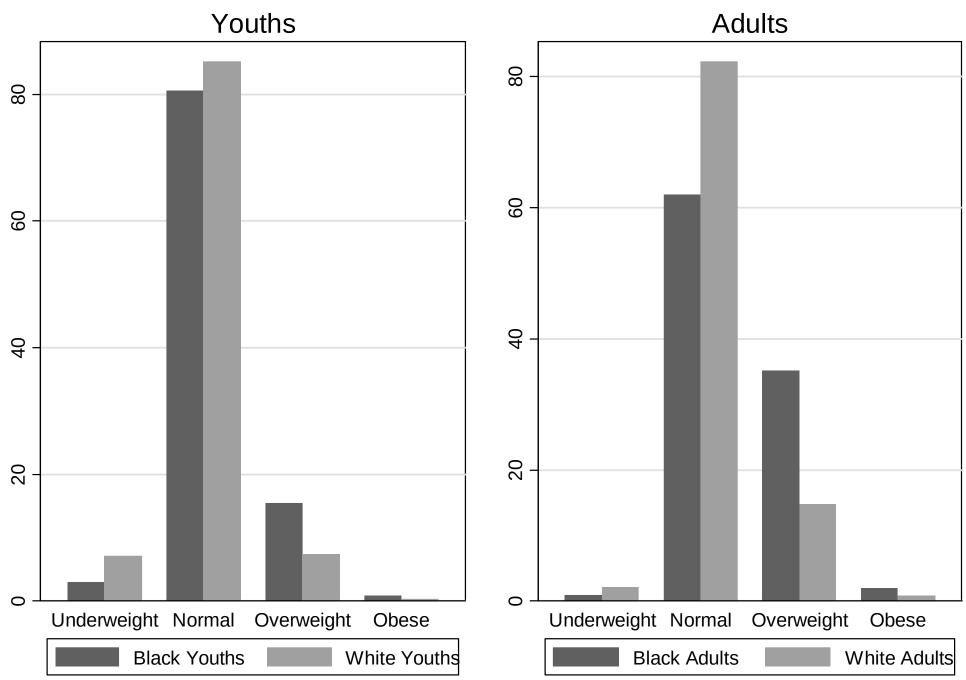
Among the first recognized characteristics associated with biological conditions was population density, and the relationship between BMI and population density was likely negative (Steckel and Rose, 2002). Because of spill-over effects, larger population concentrations are related with deteriorating health through a more virile disease environment and higher relative food prices. Therefore, state population density from 1860 and 1870 US population census samples are included here to account for the relationship between BMI and state population density.

3. Nineteenth Century US Black and White BMI Distributions

The shape of the BMI distribution tells us much about a population's current biological conditions, and views differ about how 19th century BMIs were distributed. On the one hand, BMIs may have been low because the 17th and 18th centuries had meager diets relative to work expenditures, which continued into the 19th century (Fogel, 1994, p. 373). On the other, 19th century BMIs may have increased as US agricultural settlement produced more nutritious diets relative to calories consumed for work and to fend off disease. Given similar means, if the BMI distribution is positively skewed, there are a disproportionate number of underweight individuals, and if the BMI distribution is negatively skewed, there are a disproportionate number of overweight individuals. Average black youth and adult BMIs were 22.69 and 24.26, respectively; average white youth and adult BMIs were 21.66 and 22.71 respectively, indicating that average black BMIs were heavier than white BMIs, (Costa, 2004; Carson, 2009a; Flegal, 2010; Flegal et al., 2009, p. 507; Fernandez et al., 2003; Aloia et al, 1999, p. 116; Evans et al., 2006). However, heavier 19th century black BMIs are not necessarily a sign of better health, because black statures were shorter than whites, and shorter statures are associated with heavier BMIs (Herbert et al., 1993, p. 1438).

Using the World Health Organization BMI classification coding system for modern standards, BMIs less than 18.5 are classified as underweight; BMIs between 18.5 and 24.9 are normal; BMIs between 24.9 and 29.9 are overweight; BMIs greater than 30 are obese. By considering the percentages of black and white males who fell into the underweight, normal, overweight, and obese categories, a better understanding is gained for how 19th century BMIs were distributed.

Figure 5, Youth and Adult BMIs by Race



Source: See Table 1.

Figure 5 illustrates that the percentages of 19th century black and white BMIs overwhelmingly fell within the normal BMI interval; therefore, wasting was not common among the 19th century working class. Moreover, it is striking that proportionally so many whites relative to blacks fell into the underweight category, indicating that although blacks came to shorter terminal statures, they were less likely to be underweight. A BMI less than 19 marks the threshold corresponding with increased mortality risk, and 40 percent of West Point Cadets between ages 20 and 21 were underweight (Cuff, 1994, p. 178). However, 19th century 20 and 21 year old prison proportions in lower BMI categories were considerably less than West Point Cadets. Only 2.0 percent of blacks and 4.5 percent of white prisoners between ages 20 and 21 were less than 19, indicating that working class youth were less likely than soldiers to have low BMI values. Morbid obesity is defined as a BMI>40 and is linked to elevated risks of diabetes, cardiovascular disease, and cancer (Pi-Sunyer, 1991, p. 1599s; Kenchaiah, 2002, pp. 306-312; Calle et al, 2003, pp. 1628-1630). There were few 19th century cases of black or white morbid obesity in the sample. Therefore, rather than wide-spread wasting among the lower class, working class BMIs were in normal weight ranges and wasting was uncommon; therefore, 19th century health that was poor by modern standards had little to do with BMI classifications.

4. Nineteenth Century BMIs, Wealth, Inequality, and Socioeconomic Status

The timing and extent of BMI variation not only reflects the relationship between diet and disease but also wealth, its distribution, population density, urbanization, and industrialization. To better understand the interaction between socioeconomic and demographic characteristics, a quantile regression function is constructed. Let BMI_i represent the BMI of the i^{th} individual and x_i the vector of covariates representing birth cohort, socioeconomic status, and demographic characteristics. The conditional quantile function is

$$BMI_i = Q_y\left(p|x\right) = \theta x + \eta S\left(p\right),\ p \in \left(0,1\right)$$

which is the p[th] BMI quantile, given x. The coefficient vector θ is obtained using techniques presented in Koenker and Bassett (1982) and Hendricks and Koenker (1992). The interpretation of the coefficient θ_i is the influence of the i[th] covariate on the distribution at the p[th] quantile. For example, the age coefficient at the median (.5 quantile) is the BMI increase that keeps an "average" inmate's BMI on the median if age increases by one year. When estimating BMI regression models, quantile estimation offers several advantages over least squares. Two advantages in anthropometric research are more robust estimation in the face of an unknown truncation point and greater description of covariate effects across the BMI distribution.

We test which variables were associated with 19[th] century US BMIs. To start, the BMI of the i[th] individual, in the j[th] state in time t at the p[th] quantile is assumed to be

$$BMI_{ijt} = \alpha^{p} + \sum_{i=1}^{2} \beta^{p}_{Race} Race_{i} + \beta^{p}_{Cent} Centimeters_{i} + \sum_{A=14}^{50s} \beta^{p}_{Age,t} Age^{p}_{Age,t} + \beta^{p}_{FarmLab} Farmers \,\&\, Laborers^{p}_{i,t}$$
$$+ \beta^{p}_{TW} Total\,Wealth_{j,t} + \beta^{p}_{Gini} Gini^{p}_{j,t} + \beta^{p}_{Pop} Population\,Density_{j,t} + \sum_{c=1}^{2} \beta^{p}_{c} Census_{i} + \varepsilon^{p}_{i}$$

Black and mulatto dummy variables are included to test the relationship between BMI values and skin pigmentation. Height in centimeters is included to assess the inverse relationship between BMI and stature. To account for the relationship between age and BMI, dummy variables for ages 14 through 19 are included; adult age dummy variables are added for 10-year categories between ages 30 through 59. Occupation dummy variables are included to address how socioeconomic status and wealth were related with BMIs. State-level continuous wealth and gini variables are included to account for the relationship between BMI, material prosperity, and inequality. State-level population density is included to account for how BMIs varied with urbanization and population concentration.

Table 3 presents BMI estimates for race, age, occupations, wealth, inequality, and population density. Model 1 presents BMI least squares estimates for race, demographic, occupations, wealth, inequality, and population density as defined previously. To illustrate how BMIs were related with the same characteristics across the BMI distribution, models 2 through 6 use the same model specification for the 0.25, 0.50, 0.75, 0.90, and 0.95 quantiles.

Table 3, Nineteenth Century BMI Variation by Race, Demographics, Occupations, and Wealth

	Model 1, OLS	*Model 2, 25th*	*Model 3, 50th*	*Model 4, 75th*	*Model 5, 90th*	*Model 6, 95th*
Intercept	31.20***	25.32***	26.31***	29.48***	34.10***	42.10***
Race						
White	Reference	Reference	Reference	Reference	Reference	Reference
Black	1.24***	1.29***	1.36***	1.26***	1.19***	1.30***
Mulatto	.804***	.854***	.866***	.838***	.408	.602
Stature						
Centimeters	-.069***	-.041***	-.044***	-.062***	-.088***	-.132***
Ages						
14	-3.18***	-3.00***	-2.84***	-3.29***	-3.84***	-3.12***
15	-3.17***	-3.32***	-3.32***	-3.41***	-2.67***	-2.84***
16	-2.39***	-2.17***	-2.17***	-2.59***	-3.10***	-2.24***
17	-1.50***	-1.58***	-1.58***	-1.46***	-1.31***	-1.64***
18	-1.35***	-1.15***	-1.15***	-1.38***	-1.39***	-1.70***
19	-.733***	-.518***	-.518***	-.860***	-1.00***	-1.15***
20s	Reference	Reference	Reference	Reference	Reference	Reference
30s	.301***	.195***	.384***	.337***	.492***	.686***
40s	.478***	.283**	.409***	.514***	.665***	.931**
50s	.423**	.031	.322**	.450***	1.10***	.866***
Occupations						
Farmer and Laborers	.395***	.462***	.406***	.271*	.211*	.522**
White-collar and Skilled	Reference	Reference	Reference	Reference	Reference	Reference
Wealth						
Total Wealth	.002***	.002***	.002***	.003***	.004***	.004***
Gini	-.022***	-.020***	-.024***	-.032***	-.037***	-.043***
Population Densitye						
Population Density	-.072***	-.062***	-.079***	-.113***	-.135***	-.143***
Census						
1850	-.268***	-.257	-.364**	-.378	-.116	-.234
1860	Reference	Reference	Reference	Reference	Reference	Reference
1870	2.41***	2.06***	2.68***	3.95***	4.93***	4.96***
N	9,505	9,505	9,505	9,505	9,505	9,505
R^2	.1812	.0974	.1060	.1041	.1085	.1195

Source: See Table 1.

Notes: Because US historical insolation is unavailable, a modern insolation index (1993-2003) is constructed, and monthly insolation values are measured from January thru June. The insolation index measures the hours of direct sunlight per day at county centroids in each state and is weighted by a county's square miles relative to square miles in the state.[4] While this index is a rough approximation for historical insolation, it provides sufficient detail to capture state latitudinal insolation variation and consequently, vitamin D production.

Three patterns emerge when comparing black and white BMIs by wealth, socioeconomic status, and population density. First, any discussion of 19th century BMIs must account for race and the relationship between whites, blacks, and mulattos. Steckel (1979) and Bodenhorn (1999) demonstrate that there was a 19th century mulatto stature advantage and attribute taller mulatto statures to social preferences that favored lighter complexions. If these social preferences extended to BMIs, mulattos will have greater BMI values than darker complexioned blacks. However, Table 3, illustrates that after accounting for statures, darker complexioned blacks consistently had heavier BMIs than mulattos and whites, indicating there is no evidence of a 19th century mulatto BMI advantage. From human biology, blacks are leaner and have lower percent body fat than whites, and darker complexioned blacks have heavier BMI values across the BMI distribution (Flegal, 2010; Steckel 1979; Flegal et al., 2009, p. 507; Fernandez et al., 2003; Aloia et al, 1999, p. 116; Evans et al., 2006). During the late 19th and early 20th centuries, black incomes also probably doubled, and blacks devoted a higher share of their incomes than whites to food acquisition, which may have contributed to heavier black BMIs (Higgs, 1977, p. 107; Bodenhorn, 1999, pp. 985-993; Flegal et al., 2002).

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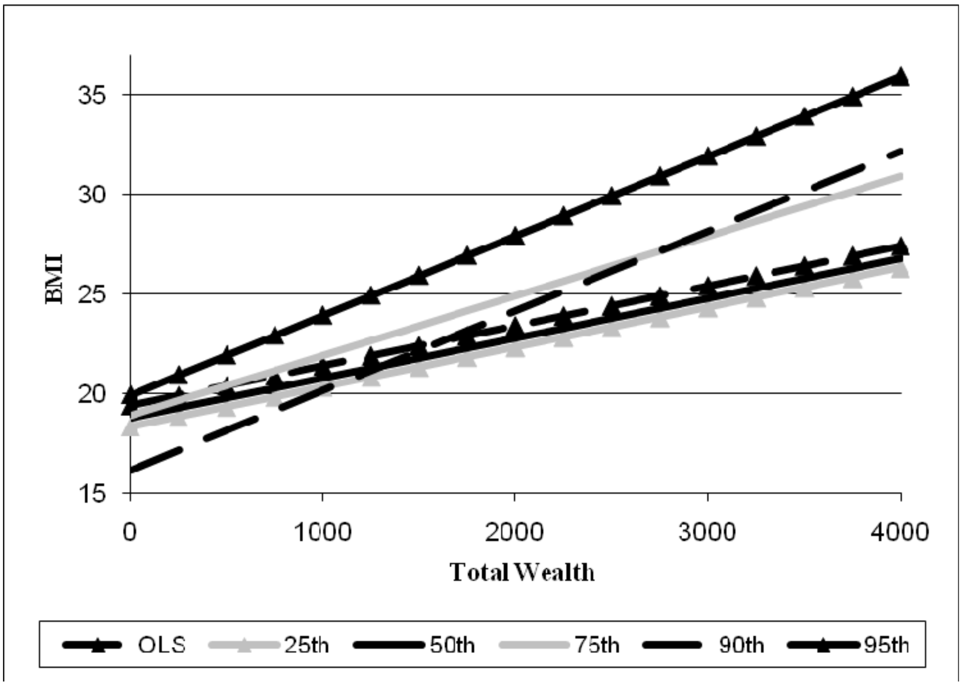
[4] Insolation is not the insolation in the county that surround's the state's centroid, but insolation in each county's geographic center. The range of state insolation values extends from Maine's minimum of 3.43 hours of direct sunlight to Arizona's maximum of 5.22 hours of direct sunlight per day.

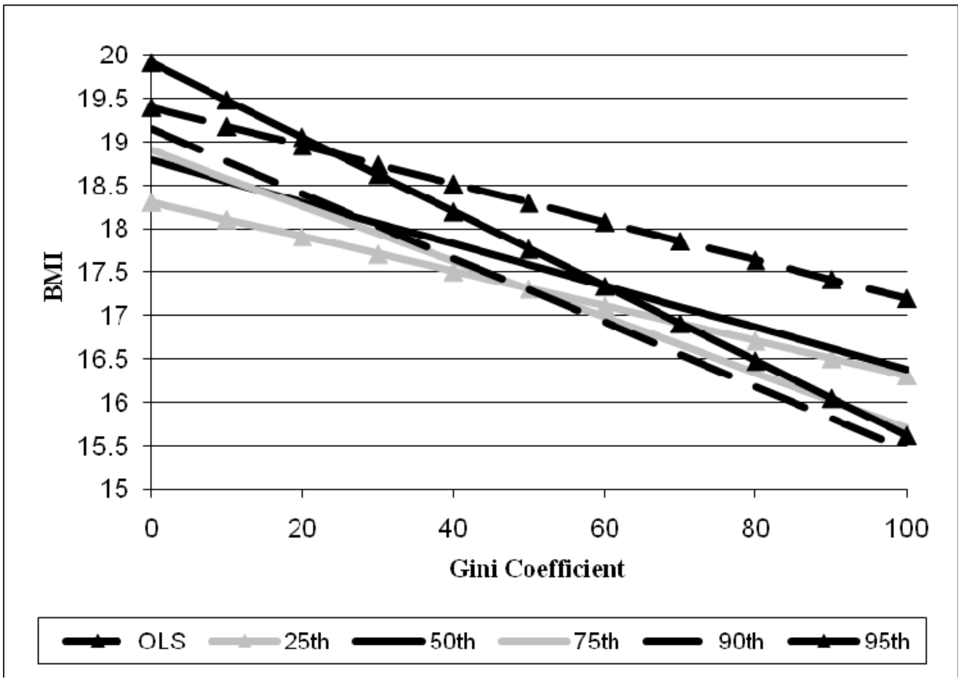
Figure 6, Nineteenth Century BMIs by Total Wealth across Quantiles



Source: Table 3, Models 1 through 6.

Note: Estimated BMI values are adjusted for height. BMIs in the 50^{th} quantile have an average height of 171.09 cms. BMIs in the 75^{th} quantile have height of 170.64 cms. BMIs in the 90^{th} quantile have an average height of 169.98 cms. BMIs in the 95^{th} quantile have an average height of 168.0757.

Figure 7, Nineteenth Century BMIs by Gini Coefficients across Quantiles



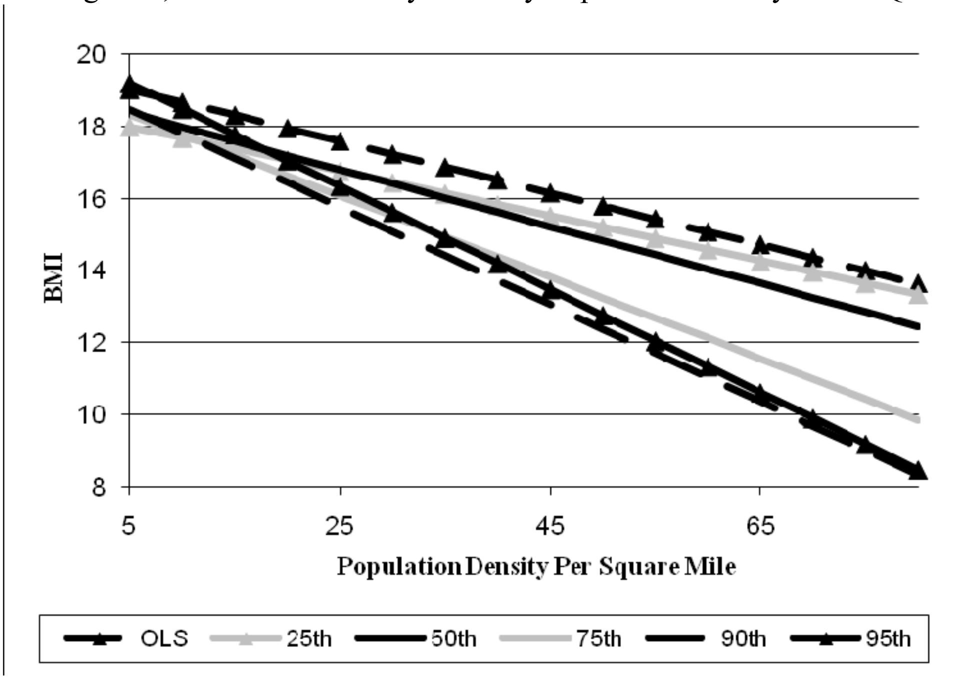
Source: Table 3, Models 1 through 6.

Note: See Figure 6.

Second, wealth is related with BMIs in at least two ways, and these mechanisms are broadly classified here into the absolute wealth and relative wealth inequality hypotheses. First, BMIs increase with absolute wealth because material wealth is associated with greater access to land, nutrition, and improved biological conditions, which are associated with greater BMI values through rural lifestyles and more nutritious diets. The second hypothesis—the relative wealth hypothesis—is that BMI values decrease with wealth inequality because the last dollar spent on health by a wealthy individual is less than the last dollar spent on health by a poorer individual (Wilkinson and Pickett, 2006, p. 1775; Subramianian and Kawachi, 2004). Both absolute wealth and wealth inequality were related with 19th century BMI variation, and BMI returns increased with wealth across the BMI distribution by 100 percent (Table 3 and Figure 6). On the other hand, BMI returns decreased with wealth inequality across the BMI distribution by 115 percent (Table 3 and Figure 7).

Third, across the BMI distribution, 19th century BMIs were related with occupations, and farmers and laborers had higher BMI values than white-collar and skilled workers (Table 3), indicating that farmers and laborers had sufficient calories to maintain weight because they were closer to nutritious diets and more physically active than workers in other occupations. Modern agricultural workers and physically active laborers use between 2.5 and 6.8 energy multiples of basal metabolic rate (FAO/WHO, 1995; Fogel, 1997, p. 448). However, part of high farmer and laborer BMI values were related with physical activity, and BMIs represent an individual's composition between muscle and fat, which are related to physical activity, therefore, occupations. Occupations requiring greater physical activity decreased fat and increased muscle. Therefore, physically active farmers had heavier BMIs than sedentary white-collar and skilled occupations. On the other hand, modern white-collar and skilled workers only use between 1.5 and 2.5 energy multiples of basal metabolic rate, and because of distance from nutritious diets and sedentary occupations, white-collar and skilled workers had low BMI values.

Figure 8, Nineteenth Century BMIs by Population Density across Quantiles



Source: Table 3, Models 1 through 6.

Note: See Figure 6. Population density is per square mile.

Other patterns are consistent with expectations. BMIs were lower for larger population densities (Figure 8; Steckel and Rose, 2002), and BMI returns with population density decreased across the distribution by 131 percent. Across different model specifications, there is also an inverse relationship between BMI and physical stature (Carson, 2009). Therefore, after controlling for various characteristics, there were complex interactions across the BMI distribution between 19th century race, stature, age, socioeconomic status, wealth, inequality, and population density, and with the exception of the mulatto stature advantage, relationships between BMI and observable characteristics are similar with 19th century stature relationships.

5. Discussion

This study adds to the discussion about the relationship between inequality and health and demonstrates that there was an inverse relationship between BMI and inequality across the 19th century lower class BMI distribution. Unlike black and white stature studies, there was no 19th century mulatto BMI advantage. Rather, after controlling for stature, mulatto and white BMI values were unexpectedly lower than black BMIs, the result of greater bone mineral density and lean muscle mass for darker complexioned blacks. BMIs increased at higher wealth levels, and the largest gains accrued at the top of the distribution. Rural farmers, who were frequently shielded from market development and industrialization, had greater BMI values than their urbanized counterparts in market integrated occupations. Moreover, throughout the 19th century, rural US farmers had greater access to more nutritious diets than workers in other occupations and lived in rural environments that required greater physical activity and where disease was less easily propagated, which allowed for heavier farmer BMIs. Therefore, except the mulatto stature advantage, 19th century BMI variation and net current biological conditions are the result of a complex set of demographic and socioeconomic characteristics and confirm patterns in stature variation, inequality, and net cumulative biological conditions.

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