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Demographic, Residential, and Socioeconomic Effects on the Distribution of 19th Century White Body Mass Index Values

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Abstract

Little research exists on the body mass index values of 19th century Americans of European descent. Using a new BMI data set and robust statistics, between 1860 and 1880, BMIs decreased across the distribution; however, after 1880, BMIs in the highest quantiles increased, while those in lower BMI quantiles continued to decrease. Late 19th and early 20th century white BMIs increased at older ages in higher quantiles and decreased in lower quantiles, indicating significant net biological disparity by age. During industrialization, white BMIs were lower in Kentucky, Missouri, and urban Philadelphia.

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I. Introduction

A 20th century health epidemic emerged where BMIs increased across ethnicities, age groups, and socioeconomic status (Flegal et al., 2010; Ogden et al., 2010; Henderson, 2005). Currently, more than half of Americans are overweight or obese, and increased obesity is associated with higher rates of type II diabetes, cardiovascular disease, musculoskeletal disorders, gall bladder disease, sleep apnea, and various cancers (Freedman, 2011; Finkelstein et al., 2003, p. 219). Estimated economic costs of overweight and obesity range from $50 to nearly $80 billion per year, and a considerable portion of these expenditures are covered by state and federal governments (Finkelstein et al., 2003, pp. 223-224). While much is known about the costs and consequences of the current dilemma, less in known regarding when the current trend toward obesity began, and valuable insight is gained by examining how average historical BMIs varied with US economic development. Therefore, to determine when the 20th century increase in white US BMIs began, this paper introduces a new 19th century data set of European-Americans and uses robust statistics to consider white BMI variation among lower socioeconomic groups.

A population's average BMI (weight (km.)/ height (m^2)) reflects the net current balance between nutrition, disease climate, and the work environment, and heavier 19th century BMIs are evidence of more robust health (Fogel, 1994, p. 375; Strauss and Thomas, 1998). For BMIs less than 20, Waaler (1984) finds an inverse relationship between BMIs and mortality risk. Costa (1993) and Murray (1997) apply Waaler's results to a historical population and find 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. Costa (2004, pp. 8-10) also demonstrates that 19th century blacks had greater BMI values than whites, and BMI values increased between 1860 and 1950 (Flegal et al., 2010; Flegal et al., 2009; Stevens et al., 1998; Abel et al., 2007; Sanchez et al., 1998; Stevens et al., 1992; Weinpahl et al., 1990). Cutler, Glaezer, and Shapiro (2003) find that US BMIs increased since the beginning of the 20th century; however, they find the majority of increased BMI values occurred during the last 25 years because people consume more calories, not because they are physically inactive.

It is against this backdrop that this paper addresses three paths of inquiry into 19th century US white BMI variation. First, how did white BMIs vary across the distribution by observation period? In the late 19th and early 20th centuries, BMIs decreased at the center of the BMI distribution but increased in higher quantiles after 1880. Therefore, while not necessarily obese, BMIs began to increase among the upper working class in the late 19th century. Second, how did BMIs vary with respect to age at the bottom, center, and top of the BMI distribution? At ages older than 50, average white BMIs increased in higher quantiles, and decreased in lower quantiles, indicating significant 19th century net current BMI variation by age. Third, how did white BMIs vary by residence across the distribution? During economic development, BMI values in Kentucky, Missouri, and urban Philadelphia were lower across the distribution than other regions, indicating that proximity to urban centers was deleterious to health during economic development.

II. Nineteenth Century United States White Prison Data

Prison Records

The data set used here to study 19th century BMI variation is part of a large historical prison sample. All state prison repositories were contacted and prisons included here are Arizona, Colorado, Idaho, Kentucky, Missouri, New Mexico, Oregon, Pennsylvania, Philadelphia, Tennessee, and Texas (Table 1). Most whites in the sample were imprisoned in Missouri, Tennessee, and Texas; however, Northern whites were from Philadelphia and Pennsylvania. The Far West is also represented in the sample. This data set creates a sample of over 73,000 white working class males to observe how BMI variation was related with 19th century US economic development.

Table 1, Whites in 19th Century US State Penitentiaries

Prison	*N*	*Percent*	*Prison*	*N*	*Percent*
Arizona	2,156	2.93	Oregon	1,683	2.29
Colorado	3,502	4.76	Pennsylvania	11,214	15.24
Idaho	575	.78	Philadelphia	11,410	15.51
Kentucky	6,602	8.97	Tennessee	10,384	14.11
Missouri	7,984	10.85	Texas	16,083	21.86
New Mexico	1,993	2.71	Total	73,586	100.00

Source: 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, Montana, Nebraska, New Mexico, Ohio, Oregon, Pennsylvania, Texas, 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 were collected. There was care recording inmate height and weight because 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 of military samples is a truncation bias imposed by minimum stature requirements (Sokoloff and Vilaflor, 1982, p. 457, Figure 1). Because shorter statures are associated with greater BMI values, military stature enlistment requirements arbitrarily truncates shorter statures, upwardly biasing military BMI values (Herbert, 1993, p. 1438). Fortunately, prison data do not suffer from this stature truncation bias. However, prison records are not above scrutiny. The prison data 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, 1991, p. 944). Moreover, if at the margins of subsistence, demographic and socioeconomic factors contributed more to BMI variation, prison records may illustrate these effects more clearly than military samples. Therefore, the prison data represents a reasonable data source for 19th century white working class BMI values.

Fortunately, inmate enumerators were quite thorough when recording inmate complexion and occupation. For example, enumerators recorded white complexions as light, medium, dark, and fair. The white inmate complexion classification is further supported by European immigrant complexions, which were also of fair complexion and recorded as light, medium, and dark. Enumerators recorded a broad continuum of occupations and defined them narrowly, recording over 200 different occupations, which are classified here into four categories: merchants and high skilled workers are classified as white-collar workers; light 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 encountered less favorable biological conditions than farm laborers, this potentially overstates the biological benefits of being a common laborer and underestimates the advantages that accrued to farm laborers. Because the purpose of this study is to compare 19th century US white male BMIs across the distribution, blacks, females, and immigrants are excluded from the analysis.

Table 2, Nineteenth Century White BMI Descriptive Statistics

Ages	*N*	*%*	*Mean*	*S.D.*	*Decade Received*	*N*	*%*	*Mean*	*S.D.*
Teens	10,035	13.64	21.70	2.20	1840s	165	.22	23.43	2.60
20s	36,607	49.75	22.52	2.19	1850s	839	1.14	22.49	2.18
30s	16,191	22.00	22.86	2.54	1860s	1,307	1.78	22.79	2.38
40s	6,841	9.30	23.14	2.78	1870s	8,748	11.89	22.35	2.30
50s	2,841	3.86	23.24	2.94	1880s	10,888	14.80	22.58	2.30
60s	896	1.22	23.04	3.24	1890s	14,114	19.18	22.71	2.41
70s	175	.24	23.32	3.32	1900s	17,782	24.16	22.65	2.46
Nativity					1910s	18,533	25.19	22.49	2.48
Northeast	10,327	14.03	22.39	2.31	1920s	1,210	1.64	22.62	2.81
Middle Atlantic	15,014	20.40	22.86	2.41	Occupations				
Great Lakes	6,105	8.30	22.78	2.52	White Collar	7,024	9.54	22.60	2.79
Plains	8,167	11.10	22.38	2.42	Skilled	16,395	22.28	22.66	2.42
Southeast	22,048	29.96	22.54	2.47	Farmer	7,307	9.93	22.68	2.45
Southwest	9,900	13.45	22.39	2.34	Unskilled	32,289	43.88	22.57	2.34
Far West	2,025	2.75	22.82	2.32	No Occupation	10,571	14.36	22.39	2.38

Source: See Table 1.

Table 2 presents white inmate proportions for age, birth decade, occupations, and nativity. Although average BMI values are included, they are not reliable because of possible compositional effects, which are accounted for in the regression models that follow. Age percentages demonstrate that youths were more likely to commit and be incarcerated for criminal behavior; 63 percent of whites in the sample were in their teens and 20s. Whites were primarily born in the South and observed between 1880 and 1910. Reflecting their lack of time to acquire skills, most whites were unskilled or without listed occupations.

Using the modern World Health Organization (WHO) BMI classification coding system, individuals with BMIs less than 18.5 are considered 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. Because BMIs are sensitive to age, two age groupings are presented in Figure 1: youths and adults.

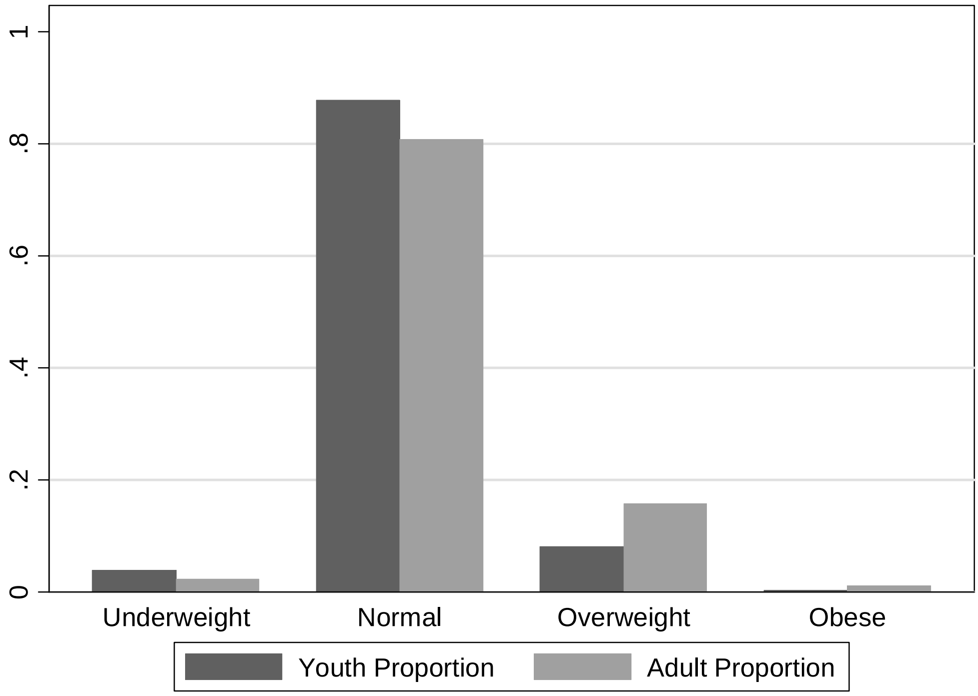

Figure 1, Nineteenth Century White Underweight, Normal, Overweight, and BMI Percentages

The shape of the BMI distribution tells us much about a population's current biological conditions, and there are differing views 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. On the other hand, BMIs may have increased as US agricultural development expanded, producing greater agricultural output and more nutritious diets relative to calories consumed for work and to fend off disease. Figure 1 illustrates that the overwhelming proportion of 19th century white BMIs fell within the normal category, and neither starvation nor obesity were common among the 19th century white working class.

These historical BMIs are compared with modern standards, where approximately 36 percent of adult American men are overweight and 23 percent obese (Sturm and Wells, 2001, p. 231; Calle, et al, 1999, p. 1103; Findelstein et al., 2003. p. 219). BMIs less than 19 mark the threshold corresponding with an increase in mortality risk, and 40 percent of West Point Cadets between the ages 20 and 21 had BMIs less than 19 (Cuff, 1994, p. 178). However, only 4.14 percent of white working class males between 20 and 21 years old had BMIs less than 19, indicating that 19th century working class white youths were not as likely as West Point Cadets to be in low BMI categories.

Morbid obesity is defined as a BMI>40, and cases of 19th century white working class morbid obesity were nearly non-existent; only .009 percent of whites in the prisons were morbidly obese. This contrasts with 2.9 percent of morbidly obesity in modern US samples (Steinbrook, 2004, p. 1077; Flegal, 2010), indicating that modern whites are over 300 times more likely than inmates in 19th century US prisons to be morbidly obese. Therefore, compared to a modern developed economy, whites in 19th century US prisons were in moderate weight ranges, morbid obesity was nearly unheard of, and health among lower socioeconomic groups that was poor by modern standards had little to do with BMI classification.

III. Demographics, Socioeconomic Status, Geography, and White BMIs

To better understand the interaction of socioeconomic and demographic characteristics with the conditional BMI distribution, a quantile regression function is constructed. Let BMI_i represent the BMI of the ith inmate and x_i the vector of covariates representing observation period, 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 pth BMI quantile, given x. The coefficient vector θ is obtained using techniques presented in Koenker and Bassett (1978 and 1982) and Hendricks and Koenker (1992). The interpretation of the coefficient θ_i is the influence of the ith covariate on the BMI distribution at the pth quantile. For example, the age coefficient at the median (.5 quantile) is the BMI increase that keeps an "average" individual's BMI at the median if age increases by one year. When estimating BMI regressions, quantile estimation offers several advantages over least squares estimation. Two advantages in anthropometric research are more robust estimation in the face of an unknown stature truncation point and greater description of covariate effects across the BMI distribution (Conley and Galenson, 1994).

We test which of these variables were associated with 19th century white BMI variation. The ith individual's BMI is assumed to be related with age, observation decade, socioeconomic status, and residence.

$$BMI_i^p = \alpha + \beta_C^p Centimeters_i + \sum_{a=1}^{15} \beta_a^p Age_i + \sum_{t=1}^{10} \beta_t^p Decade\mathrm{Re}ceived_i + \sum_{l=1}^{3} \beta_l^p Occupation_i + \beta_R^p \,\mathrm{Re}\,sidence_i + \varepsilon_i^p$$

Dummy variables are included for youth ages 14 through 22; adult age dummies are included in ten year age intervals from the 30s through the 70s. Dummy variables are included for decade measured from 1840 through the 1920s. Occupation dummy variables are for white-collar, skilled, farmers, and unskilled occupations. Residence dummy variables are included for state residence at the time of measurement.

Table 3's model 1 presents least squares estimates to illustrate how white BMIs were related with demographic, measurement period, occupation, and residence; models

2 through 6 present quantile estimates for the same model specification across the BMI distribution.

Table 3, National Quantile BMI Models Related to Demographic and Environmental Conditions

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
	OLS	*.25*	*.50*	*.75*	*.90*	*.95*
Intercept	31.52***	28.08***	30.14***	32.86***	36.81***	40.56***
Height						
Centimeters	-.050***	-.039***	-.042***	-.049***	-.065***	-.081***
Ages						
14	-2.49***	-2.49***	-2.41***	-2.38***	-2.85***	-2.68***
15	-2.16***	-2.47***	-2.55***	-2.05***	-1.70***	-1.47***
16	-1.77***	-1.56***	-1.83***	-1.98***	-2.21***	-2.24***
17	-1.33***	-1.23***	-1.34***	-1.50***	-1.58***	-1.66***
18	-.942***	-.871***	-.963***	-1.08***	-1.06***	-1.22***
19	-.592***	-.515***	-.595***	-.730***	-.732***	-.855***
20	-.387***	-.293***	-.352***	-.513***	-.523***	-.724***
21	-.263***	-.147***	-.211***	-.390***	-.432***	-.580***
22	-.176***	-.120***	-.183***	-.247***	-.265***	-.389***
23-29	Reference	Reference	Reference	Reference	Reference	Reference
30s	.224***	-.014	.136***	.301***	.551***	.781***
40s	.487***	.115***	.291***	.617***	1.15***	1.60***
50s	.567***	.144***	.368***	.773***	1.28***	1.79***
60s	.325***	-.299***	-.019	.537***	1.63***	2.05***
70s	.597**	-.473***	.235	1.43**	2.73***	3.52***
Observation Period						
1840s	1.13***	1.17***	1.11***	1.05***	1.91***	1.71***
1850s	-.056	.056	-.074	-.239	-.258	-.224
1860s	Reference	Reference	Reference	Reference	Reference	Reference
1870s	-.625***	-.603***	-.736***	-.751***	-.592***	-.669***
1880s	-.739***	-.627***	-.804***	-.898***	-.809***	-.930***
1890s	-.613***	-.550***	-.733***	-.783***	-.636***	-.585***
1900s	-.623***	-.624***	-.772***	-.726***	-.592***	-.538***
1910s	-.641***	-.656***	-.761***	-.736***	-.542***	-.439**
1920s	-.886***	-1.06***	-1.20***	-.955***	-.605***	-.298
Occupations						
White Collar	.185***	-.039	.043	.242***	.531***	.729***
Skilled	.279***	.310***	.272***	.251***	.287***	.220***
Farmer	.414***	.433***	.363***	.418***	.412***	.448***
Unskilled	.394***	.421***	.412***	.380***	.386***	.316***

No Occupation	Reference	Reference	Reference	Reference	Reference	Reference
Prisons						
Arizona	.131**	.241***	.227***	-.005	-.046	-.058
Colorado	.520***	.608***	.604***	.475***	.284***	.255**
Idaho	.217**	.317**	.319***	.132	-.159	-.321
Kentucky	-.376***	-.393***	-.351***	-.318***	-.314***	-.305***
Missouri	-.607***	-.512***	-.587***	-.665***	-.839***	-.960***
New Mexico	.374***	.282***	.452***	.475***	.386***	.681***
Oregon	1.08***	1.12***	1.17***	1.08***	.934***	.814***
Pennsylvania	.221***	.225***	.297***	.302***	.153**	.159
Philadelphia	-.234***	-.087***	-.162***	-.327***	-.573***	-.690***
Tennessee	.493***	.509***	.570***	.542***	.499***	.457***
Texas	Reference	Reference	Reference	Reference	Reference	Reference
N	73,586	73,586	73,586	73,586	73,586	73,586
R^2	.0757	.0377	.0412	.0454	.0561	.0694

Source: See Table 1.

Note: The following geographic classification scheme is consistent with Carlino and Sill (2000): New England= CT, ME, MA, NH, RI and VT; Middle Atlantic= DE, DC, MD, NJ, NY, and PA; Great Lakes= IL, IN, MI, OH, and WI; Plains= IA, KS, MN, MO, NE, ND, and SD; South East= AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, and WV; South West= AZ, NM, OK, and TX; Far West= CA, CO, ID, MT, NV, OR, UT, WA, and WY. *** Significant at .01; **Significant at .05; *Significant at .10.

Three general patterns emerge when comparing 19th century white statures with age, birth period, and nativity. First, to the degree that BMI represents net current access to calories relative to energy expended for work and to fend off disease, white BMIs decreased throughout the late 19th and early 20th centuries (Figure 2). Between 1840 and 1880, white BMIs in the lowest 25th quantile decreased by 8.0 percent and by 9.3 percent in the 95th quantile, indicating that white biological conditions deteriorated across the BMI distribution throughout the first half of the 19th century (Komlos and Coclanis, 1997; Carson, 2009, p. 154). However, between 1880 and 1920, BMIs in the lowest 25th quantile decreased by another 2.09 percent and increased by 2.46 percent in the highest 95th quantile. Therefore, BMIs increased among the upper working class in the late 19th century and the increase was well underway by the end of the 19th and beginning of the 20th centuries (Costa, 2004; Cutler, Glaezer, and Shapiro, 2003).

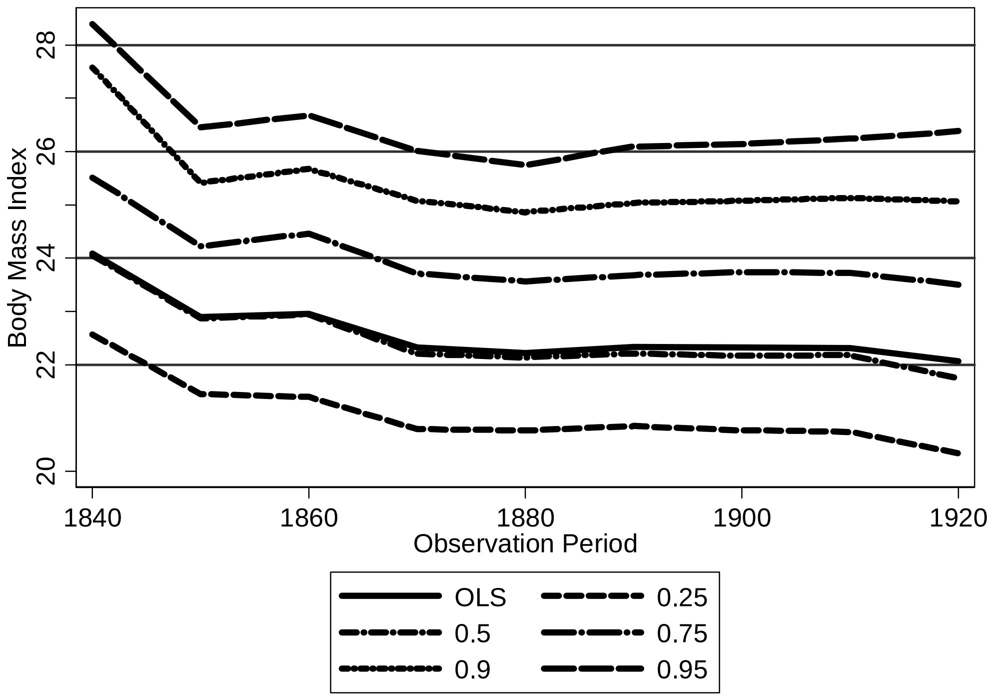

Figure 2, Nineteenth Century Black and White BMI Variation by Observation Period. Source: See Table 3, Models 2 through 6. White average BMI values imputed with an average stature of 170.767 centimeters.

Second, between ages 14 and 23, at the center of the distribution, BMIs increased with age by 12 percent (Figure 3). Adult BMIs increased until around age 50, after which they remained approximately constant. However, it is in the tails of the distribution that adult BMI variation with age is most telling. Between age 30 and age 70, white BMIs in the lower tail of the distribution decreased by over 2 percent and increased by 10 percent in the upper tail of the distribution, indicating a new source of biological disparity by age that remains unexamined in other 19th century biological markers (Carson, 2011). Among the older working class, white net current biological welfare decreased with age among the working class, however, increased with age among the upper working class.

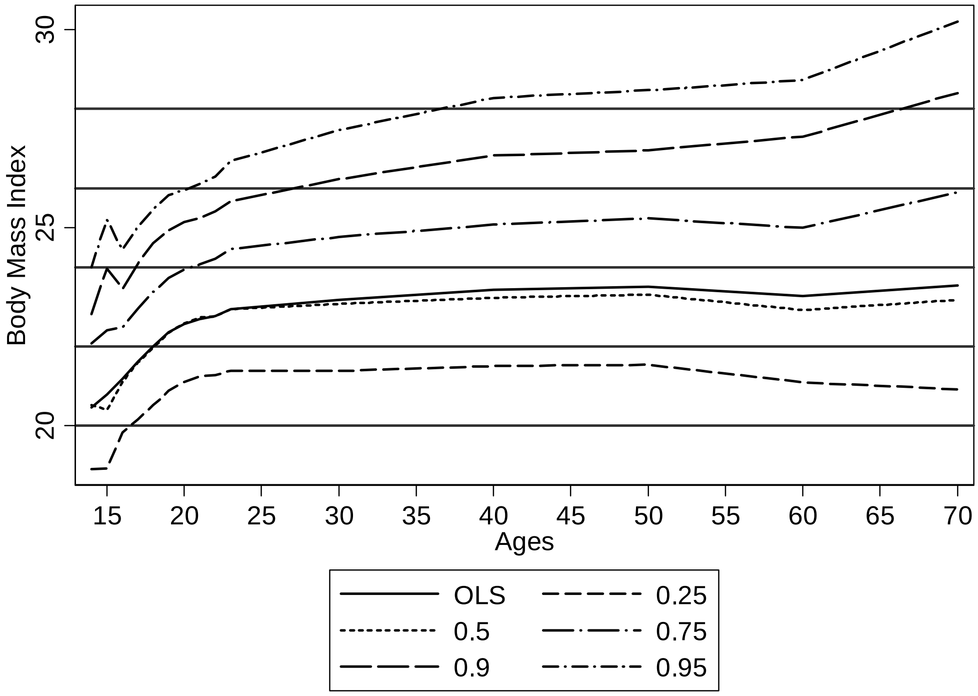

Figure 3, Nineteenth Century Black and White BMI Variation by Age

Source: See Table 3, Models 2 through 6. White average BMI values imputed with an average stature of 170.767 centimeters.

Third, 19th century white BMIs in Kentucky, Missouri, and urban Philadelphia were lower than elsewhere within the US and was most pronounced at the bottom of the BMI distribution. A defining characteristic of the antebellum Jacksonian economy was early industrialization, and as the Northeast agricultural sector commercialized, the physical distance of households from dairy production increased; most of this development occurred before refrigeration was available (Craig et al., 2004). Pennsylvania and Philadelphia illustrate the effects of industrialization on white BMI variation. In 1840, most of Pennsylvania's dairy and agricultural production was from single family farms that primarily produced butter and cheese; little agricultural surplus was left over for market. By 1900, Pennsylvania's dairy sector transformed into a highly organized commercial industry, supplying the dairy and agricultural demands in rural markets in rapidly developing Pennsylvania (Fletcher, 1955, p. 165; Cochrane, 1977, pp. 76 and 77). Farmers near urban centers adulterated milk with widespread milk watering and whitening; storing milk in cans hastened spoilage and by the practice of feeding wiskey mash to cows (Fletcher, 1955, pp. 195-202). Livestock farming, which produced beef, pork, and poultry products, was an important source for nutrition; however, conditions in livestock farming and the dairy sector were unsanitary and butchering practices unhealthy (Fletcher, 1955, pp. 237-238). Therefore, BMIs were low in urban Philadelphia and inversely related with industrialization, urbanization, and agricultural commercialization.

Other patterns are consistent with expectations. Across the BMI distribution, there was an inverse relationship between BMIs and height, and this relationship was smaller at lower BMI quantiles and larger at higher BMI quantiles. Across the distribution, late 19th and early 20th century BMIs were also related with occupations, and farmers had heavier BMIs than workers in other occupations. Part of heavier farmer BMIs may be related to physical activity. Agricultural workers used between 2.5 and 6.8 energy multiples of sleeping basal metabolic rate (FAO/WHO, 1985; Fogel, 1994), indicating that US farmers had sufficient calories to maintain weight because they were closer to nutritious diets and more physically active than workers in other occupations. White-collar workers only used between 1.5 and 2.5 energy multiples of sleeping basal metabolic rate, and because of their physical inactivity relative to calories consumed, sedentary white-collar workers' BMIs were higher at the top of the distribution.

IV. Conclusions

A modern health epidemic has emerged where BMIs have increased across age groups, ethnicities, and national boundaries. This study illustrates that 19th century US white male BMIs were related to industrialization. White BMIs were distributed symmetrically and neither wasting nor obesity was common. Between 1840 and 1880, BMIs illustrate a period of dietary stress. BMIs in the lower tail of the distribution declined after 1880. However, upper working class BMI values increased after 1880 in the upper tail of the distribution, indicating that increasing BMI values may have had their origin in the late 19th century. Although BMIs in the center of the distribution were constant after age 50, BMIs in the lower tail of the distribution decreased in older ages, however, increased in the upper tail of the BMI distribution, indicating there was considerable 19th century biological inequality at older ages among the working class. Reflecting the state of 19th century industrialization, white BMIs varied geographically, and BMIs in the mid-west and Northeast were low compared to those in the South and West. BMIs varied by occupation, and rural farmers had greater BMI values across the distribution than workers in other occupations. Therefore, 19th century white BMIs varied across the distribution and were the result of a complex set of demographic and socioeconomic characteristics related to economic and social for forces shaping the US economy.

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