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Abstract

The definition of inequality is complicated and difficult to assess, and there are various means by which it is evaluated. This study uses the now well-accepted measures of body mass, height, and weight to assess inequality's relationship with current and cumulative net nutrition. Taller statures allow weight to be distributed over larger areas, and height is inversely related to body mass, however positively related to weight. Because weight increased with age and age inequality, the majority of net nutrition is beyond an individual's control, and stature inequality is smaller than weight because it is genetically determined. Current net nutrition was positively related to age, however, inversely related to regional inequality. Subsequently, current and cumulative net nutrition are related to inequality and increased across BMI and weight distributions.

JEL-Codes: I100, I140, I300, I320, N110, N120.

Keywords: body mass, stature, and weight inequality, current and cumulative net nutrition.

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I. Introduction

Reliable inequality studies across populations during development are scarce and not easy to interpret. Inequality over time is complicated, and there is little information about how resources are biologically distributed within economic systems, across characteristics, and over time. When other measures for income, wealth, and material well-being are scarce or unreliable, stature is one measure that reflects cumulative material conditions (Fogel, et al 1978; Fogel et al 1979). However, because it is genetically determined and follows a normal distribution, stature is less plastic and responsive to the immediate effects of privation by net nutritional conditions (Sokoloff and Vilaflor, 1982). The body mass index (BMI) is weight in kilograms divided by height in meters squared, and because weight is in BMI's numerator, BMI is more responsive to the immediate effects of material variation and inequality. Like BMI, weight as a measure for current biological and net nutritional conditions are more responsive to the immediate effects of economic variation, and measures for weight inequality are more sensitive than stature to the immediate effects of privation. This study, therefore, uses BMI, stature, and weight to measure late 19th and early 20th century United States net nutritional variation and inequality as economic development occurred.

Wealth holdings during economic development is an important measure for US economic inequality. When the value of mid-19th century personal estate is defined as $100 or more, 57.6 percent of white male headed households possessed wealth in 1860 and 57.20 percent in 1870

(Soltow, 1975, pp. 23-24). Wealth accumulation and inequality increased with age; older individuals accumulated more wealth, and it was distributed less equitably because wealth generating characteristics associated with inequality increased with age. About half of the poor were between ages 20 and 29, and the probability immigrants owned real or personal wealth was maximized between the ages of 60 and 69 (Ferrie, 1999, pp. 104-105). Wealth also varied by region, and western state residence increased the likelihood of holding wealth (Soltow, 1975, p. 42). Wealth accumulation and distribution in the US were related to international nativity, and British and German immigrants had greater wealth accumulation than the Irish (Soltow, 1975, p. 44; Ferrie, 1999, pp. 104-112). In the mid-19th century US, the English, Scottish, and Welch were more likely to own property than Germans, who were more likely to own property than the Irish (Soltow, 1975, p. 178).

Wealth inequality varied by socioeconomic status, and farmers had the highest average wealth, followed by skilled and white-collar workers; laborers had lower wealth levels (Ferrie, 1994, p. 6). Given higher wealth accumulation, farmers also had greater wealth equality, indicating that 19th century agricultural conditions were advantageous to wealth (Soltow, 1975, pp 107-108). Before and after slavery, wealth holdings were greater in the North, which was distributed more equally than other regions within the US (Atack and Bateman, 1987, pp. 88). The distribution of mid-19th century wealth was more equal for immigrants, farmers, whites, and males, whereas the distribution of wealth was less equal among the young, natives, non-farmers, women, non-whites, and illiterate (Atack and Bateman, 1989, p. 90). Subsequently, to the degree that BMI, height, and weight were related to biological inequality, younger individual's net nutrition was less likely to be affected by inequality, and farmers were taller because 19th

century US land was distributed more equally (Soltow, 1975; Atack and Bateman, 1981; Atack and Bateman, 1989).

Stature is also related to biological inequality. During late 19th and early 20th century's US development, there was a small inverse relationship between BMI and material wealth inequality (Carson and Hodges, 2014; Carson, 2013; Carson, 2009b). BMIs decrease at higher wealth levels due, in part, to the separation of food consumption from food production (Carson and Hodges, 2014; Carson 2013). Although the effects were small, late 19th and early 20th century BMIs were related to material inequality. There was also a small inverse relationship between BMI and average state wealth inequality (Carson, 2013, p. 90). The causal mechanism appears clear. At the lower end of the socioeconomic strata, greater inequality forecloses those at the bottom of the wealth distribution from the medical care, health interventions, nutrition that increases longevity, and reduces morbidity. This relationship between wealth inequality and BMI is related in one of at least two ways. First, BMIs increase in absolute wealth associated with greater access to land and physical resources, which were related to greater BMIs from more nutritious diets and lower disease levels. Second, BMIs decrease as relative inequality increases because the impact of the last dollar spent by a poor person is higher than the last dollar spent by a wealthy person (Subramanian and Kawachi, 2004; Wilkenson and Prichett, 2006, p. 1775). Limited information indicates that BMIs decreased by less than .1 percent units when material wealth inequality increased by one percent, (Carson, 2013, p. 92). However, little else is known about the relationship between net nutrition and inequality.

Three questions emerge when considering late 19th and early 20th century net nutrition inequality. First, how did current and cumulative net nutrition vary by gender and race? Black and white inequalities were similar by race; however, female BMIs and weight were distributed less equally than males. Second, of characteristics related to inequality, which had the greatest effect on individual BMIs? Stature had a significant contribution to BMI and weight variation, and race, age, and regional inequalities were significant factors for individual BMIs. Third, how did BMI, height, and weight inequality vary across distributions over time? Across distributions, BMIs increased at higher race, time, gender, socioeconomic status, age, and regional inequality quantiles, indicating that greater net nutrition dominated the effects of the inverse relationship between net nutrition and inequality across respective distributions.

II. Methodology

Body mass, height, and weight reflect the difference between calories consumed and calories required for work and to withstand the physical environment. However, each reflects different conditions and net nutrition over time. Average stature was the first biological measure used to reflect material net nutrition and reflects the cumulative net difference between calories consumed, calories required for work, and the physical environment (Fogel et al, 1978; Fogel et al. 1979; Fogel and Engerman, 1974). Body mass and weight are not as genetically determined and are more responsive to the immediate effects of the nutritional and physical environments. Because body mass, stature, and weight are measures for material and net nutrition, they are used to evaluate how resources are distributed within an economy, and because stature is genetically determined, the use of body mass and weight to measure inequality is complementary when other measures for material inequality are unavailable.

Standard deviation and variance are common measures to assess how resources are distributed within a population. However, because variances of biological measures increase with average BMI, height, and weight, their standard deviations are less reliable as measures for inequality. The coefficient of variation (CV) and Gini Coefficients are two measures that take account for increase in biological variances within averages and are preferred measures for biological inequality (Morodi and Baten, 2005, p. 1237). The coefficient of variation is

$$CV_{it} = \frac{\sigma_{it}}{\mu_{it}} \qquad \text{(Equation 1)}$$

where σ_{it} and μ_{it} are the standard deviation and mean of the i^{th} characteristic in period t. Inequality is higher with larger CV values, and lower when CV values are lower.

The Gini Coefficient is an additional measure for inequality across characteristics and time, and higher CV values indicate greater inequality, while lower CVs represent greater equality.

$$Gini = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|x_i - x_j\right|}{2\sum_{i=1}^{n}\sum_{j=1}^{n}x_j} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|x_i - x_j\right|}{2n^2\overline{x}} \qquad \text{(Equation 2)}$$

Let x_i equal wealth or income, n equals sample size, and $\overline{x}$ is the mean value of x. The Xs are ranked in ascending order, and calculation of the Gini Coefficient is linked to the Lorenz Curve. The closer the Gini Coefficient is to zero, the greater is equality, whereas the closer to one represents greater inequality.

III. Data

Stature was the first widely used biological measure to evaluate cumulative net nutrition; body mass and weight have been used in recent studies (Rashad and Komlos, 2016). Body mass, stature, and weight reflect net nutrition, and increase when calories consumed increase and are lower in nutritionally deprived populations. However, little is known about inequality using body mass, height, and weight.

The primary source for historical biological measures are military conscript and prison records. Military records are abundant and may represent net nutritional conditions among the upper-class (Sokoloff and Vilaflour, 1982, pp. 456-458; Komlos, 1987; Coclanis and Komlos, 1995, p. 93; Ellis, 2004, p. 27; Carson, 2008; Carson, 2009a). Nonetheless, because military records frequently only included height, military records are less useful when evaluating biological inequality. Because they accepted individuals from across socioeconomic groups, prison records have greater biological variation than military records. Moreover, because many individuals were incarcerated for theft and assault crimes, prison records are more likely to represent individuals of lower socioeconomic conditions, that segment of society more vulnerable to economic privation and change. Nonetheless, prison records are not above criticism. For example, inmates may not have had sufficient wealth and income to afford legal counsel at trial. Alternatively, if prison officials signaled guilt from physical dimensions, taller individuals with higher BMIs and greater weight may have been more likely to be in prison records. Subsequently, records for poorer individuals may have been more likely than military records to be included in prison records.

Inmate complexion is one means of classifying race that was recorded at the time individuals were admitted to prison. Individuals of African descent were recorded as light, medium, and dark black. Individuals of European ancestry were recorded as light, medium, and dark. This European classification system is further supported because individuals claiming birth in Europe but later incarcerated in US prisons were recorded with the same light, medium, and dark complexions. There were also individuals recorded as ‘mulatto’ incarcerated with combined black African and white European complexions. However, in the results that follow, individuals with combined African and European complexions are referred to as ‘mixed race.’

Prison enumerators also recorded a diverse set of occupations, which are classified here into five broad categories. Physicians, the Clergy, and government administrators are white-collar workers. Butchers, craftsman, and blacksmiths are skilled workers. Agricultural related workers are classified as farmers. Laborers, miners, and cooks are unskilled workers. Persons without recorded or illegible occupations are recorded as workers with no occupations.

There are two ways to evaluate body mass, height, and weight over time. Measured from birth, biological markers measure how conditions varied for the same cohort over time (Carson, 2019). Measured in the current year, biological markers measure how different groups experience the same biological conditions during the period of measurement. Measured in the current year, biological markers measure inequality by different groups during the period of measurement.

Table 1, Late 19th and Early 20th Century United States Prison Descriptive Statistics

	N	*Percent*	*BMI*	*S.D.*	*Cent*	*S.D.*	*Kilo*	*S.D.*
Gender								
Female	4,592	2.60	23.28	3.91	160.87	6.96	60.19	10.43
Male	172,277	97.40	23.07	2.50	170.56	6.90	67.13	8.42
Race								
Black	41,299	23.35	23.61	2.52	169.55	7.26	67.92	8.69
Mexican	6,710	3.79	22.91	2.33	167.10	6.67	63.97	7.38
Mulatto	27,255	15.41	23.44	2.49	169.83	7.24	67.66	8.57
White	101,605	57.45	22.76	2.53	170.96	6.88	66.56	8.50
Received								
1860s	2,613	1.48	23.33	2.53	170.33	7.05	67.73	8.57
1870s	14,899	8.42	23.34	2.57	170.46	7.30	67.84	8.61
1880s	26,196	14.81	23.11	2.45	170.24	7.28	67.03	8.48
1890s	34,397	19.45	23.17	2.48	170.04	7.02	67.01	8.39
1900s	47,037	26.59	23.00	2.53	170.02	7.03	66.51	8.55
1910s	42,482	24.02	22.99	2.60	170.59	6.94	66.91	8.59
1920s	6,462	3.65	23.04	2.80	170.74	6.94	67.16	9.00
1930s	2,783	1.57	22.44	2.81	173.30	6.76	67.42	9.33
Occupations								
No Occupations	26,573	15.02	23.26	2.50	169.12	7.24	66.58	8.63
Skilled	51,247	28.97	22.95	2.66	170.63	6.71	66.83	8.76
Unskilled	99,049	56.00	23.09	2.49	170.47	7.72	67.11	8.42
Ages								
Teens	25,441	14.38	22.19	2.30	168.05	7.25	62.71	7.73
Twenties	89,515	50.61	23.07	2.37	170.81	6.98	67.32	8.332
Thirties	37,673	21.30	23.61	2.67	170.83	6.93	68.05	3.82
Forties	15,757	8.93	23.59	2.88	170.24	6.96	68.39	9.40
Fifties	6,403	3.62	23.69	3.06	169.79	6.91	68.30	9.69
Sixties	2,050	1.16	23.63	3.13	169.11	7.18	67.58	9.88
Nativity								
Canada	1,610	.91	23.18	2.57	170.56	6.73	67.48	8.76
Europe	9,488	5.36	23.84	2.61	167.96	6.94	67.27	8.55
Great Britain	5,189	2.93	23.13	2.46	168.98	6.72	66.09	8.27
Latin America	6.734	3.81	22.93	2.28	166.76	6.66	63.76	7.29
US, Far West	3,915	2.21	22.87	2.39	171.87	6.95	67.57	8.20
US, Great Lakes	15,697	8.87	22.88	2.60	171.14	6.64	67.07	8.78
US, Middle Atlantic	24,491	13.85	22.86	2.50	169.16	6.66	65.48	8.41
US, Northeast	1,962	1.11	23.10	2.68	170.58	6.51	67.23	8.76
US, Plains	10,733	11.72	22.63	2.56	171.28	6.77	66.72	8.55

US, Southeast	57,978	32.78	23.26	2.55	170.41	7.15	67.57	8.57
US, Southwest	29,072	16.44	23.08	2.51	171.54	7.33	67.92	8.50
Birth Decade								
1790s	5	.00	24.40	1.04	172.59	10.08	72.67	6.72
1800s	46	.03	23.00	2.17	169.85	7.67	66.22	6.40
1810s	394	.22	23.73	2.90	170.92	7.46	69.42	10.18
1820s	1,272	.72	23.73	2.87	169.69	7.59	68.27	8.95
1830s	3,911	2.21	23.69	2.77	169.93	7.06	68.43	8.95
1840s	11,233	6.35	23.55	2.68	170.37	7.08	68.36	8.69
1850s	24,897	14.08	23.37	2.57	170.46	7.07	67.94	8.58
1860s	32,621	18.44	23.21	2.59	170.33	7.03	67.39	8.77
1870s	40,399	22.84	23.06	2.50	170.27	7.04	66.89	8.51
1880s	36,969	20.90	22.87	2.46	170.13	7.07	66.23	8.34
1890s	10,824	11.77	22.61	2.42	170.30	7.09	65.59	8.10
1900s	3,647	2.06	22.32	2.42	171.12	7.14	65.39	8.48
1910s	639	.36	21.69	2.17	174.42	6.65	66.00	7.62
1920s	12	.01	21.72	1.81	172.40	4.23	64.68	7.15

Source: Source: Arizona State Library, Archives and Public Records, 1700 W. Washington, Phoenix, AZ 85007; Colorado State Archives, 1313 Sherman Street, Room 120, Denver, CO 80203; Idaho State Archives, 2205 Old Penitentiary Road, Boise, Idaho 83712; Illinois State Archives, Margaret Cross Norton Building, Capital Complex, Springfield, IL 62756; Kentucky Department for Libraries and Archives, 300 Coffee Tree Road, Frankfort, KY 40602; Missouri State Archives, 600 West Main Street, Jefferson City, MO 65102; William F. Winter Archives and History Building, 200 North St., Jackson, MS 39201; Montana State Archives, 225 North Roberts, Helena, MT, 59620; Nebraska State Historical Society, 1500 R Street, Lincoln, Nebraska, 68501; New Mexico State Records and Archives, 1205 Camino Carlos Rey, Santa Fe, NM 87507Oregon State Archives, 800 Summer Street, Salem, OR 97310; Pennsylvania Historical and Museum Commission, 350 North Street, Harrisburg, PA 17120; Philadelphia City Archives, 3101 Market Street, Philadelphia, PA 19104; Tennessee State Library and Archives, 403 7th Avenue North, Nashville, TN 37243; Texas State Library and Archives Commission, 1201 Brazos St., Austin TX 78701; Utah State Archives, 346 South Rio Grande Street, Salt Lake City, UT 84101; Washington State Archives, 1129 Washington Street Southeast, Olympia, WA 98504.

Males were the most likely to be included in US prisons, and whites were proportionally a larger part of the prison population than blacks (Table 1). However, compared to the general population, blacks took up a larger portion of the prison population than whites (Steckel, 2000; Haines, 2000). Inmates were primarily born in the 1870s and incarcerated between 1900 and 1910. Most individuals were unskilled, indicating prison records represent conditions among the working class. During the 19th century, various states introduced vagrancy laws, with the intent to reduce loitering and unemployment among the working class (Brands, 2010, p. 156). Be it from low wealth or lack of human capital, individuals in their 20s were the most likely to be incarcerated (Hirshchi and Gottfredson, 1983; Gottfredson and Hirshi, 1990). Europeans were the most likely international group to be incarcerated in US prisons. Individuals born in the South were the most likely to be incarcerated among individuals born in the US.

IV. Results

4.1 *Biological Inequality by Characteristics*

Table 2, Female-Male, Black-White BMI, Centimeters, and Kilograms Averages

	BMI		*Centimeters*		*Kilograms*	
	Mean	SD	Mean	SD	Mean	SD
Black Female	23.18	3.74	160.86	7.22	59.96	9.99
White Female	23.54	4.28	161.06	6.68	61.04	11.47
Black Male	23.63	2.46	171.12	6.76	68.27	8.46
White Male	22.75	2.49	169.93	7.01	66.65	8.41
	CV	Gini	CV	Gini	CV	Gini
Black Female	.161	.084	.043	.025	.167	.088
White Female	.182	.095	.042	.023	.188	.0992
Black Male	.103	.057	.041	.023	.124	.069
White Male	.110	.060	.040	.022	.126	.070

Source: See Table 1.

Table 2 indicates that women had higher BMIs than men, blacks had the highest BMIs, and individuals with no occupation—many of them in the agricultural sector—had higher BMIs than workers in other occupations (Atack and Bateman, 1987, pp. 63-64). BMIs increased with age and varied by nativity, and European immigrants had the highest BMIs. Whites were the tallest group by race, which contributed to lower BMIs (Carson, 2009a; Carson, 2012; Komlos and Carson, 2017). Although they were not the tallest racial group, blacks and mulattos had the heaviest weights (Table 2; Carson 2015). Individuals from the South, West, and those born during the early 19th century had the greatest weight.

White male BMIs were positively skewed around 22.75. Black male average BMI was around 23.56 (Carson, 2008; Carson, 2009a). White female BMIs were 23.54, while black female average BMI was 23.13 (Carson, 2018). Much of higher female BMIs relative to males was related to height because BMIs are inversely related to height and women are shorter than men (Gray and Wolfe, 1980). White male average height was 171.12 centimeters, whereas black male average height was 170.05 (Carson, 2008; Carson, 2009a). White female average height was 161.06 centimeters, whereas black female average height was 160.91, indicating there was less stature difference by race among women than men. Taller male statures were due to sexual dimorphism (Gray and Wolf, 1980). White males were taller than darker complexioned males (Steckel, 1979); however, white male average weight was 66.65 kilograms, while black male average weight was 68.17 kilograms. White females were taller than darker complexioned females (Carson, 2013, p. 129; Carson 2011, p. 159; Carson, 2018), and white female average weight was 61.04 kilograms, while black average female weight was 57.83 kilograms. Subsequently, black and white male BMIs were lower than females; however, black females had low BMIs and shorter average stature, and much of higher black male BMIs was due to taller white male statures.

Table 3, Coefficient of Variation and Gini Coefficients by Characteristics

	BMI		*Cent*		*Kilo*	
	CV	Gini	CV	Gini	CV	Gini
Gender						
Female	.168	.088	.043	.024	.173	.092
Male	.108	.059	.041	.023	.126	.070
Race						
Black	.107	.058	.043	.024	.128	.071
Mexican	.102	.056	.040	.022	.115	.064
Mulatto	.106	.058	.043	.024	.127	.071
White	.111	.060	.040	.023	.127	.070
Received						
1860s	.108	.060	.042	.023	.127	.071
1870s	.110	.061	.043	.024	.127	.071
1880s	.105	.058	.043	.024	.127	.071
1890s	.107	.058	.041	.023	.125	.070
1900s	.110	.060	.041	.023	.129	.071
1910s	.113	.061	.041	.023	.128	.071
1920s	.122	.065	.041	.023	.133	.072
1930s	.125	.067	.039	.022	.138	.075
Occupations						
No Occupations	.107	.059	.043	.024	.130	.072
Skilled	.116	.063	.039	.022	.131	.072
Unskilled	.108	.059	.042	.0244	.126	.070
Ages						
Teens	.104	.057	.043	.024	.123	.069
Twenties	.102	.057	.041	.023	.119	.067
Thirties	.115	.062	.041	.023	.123	.072
Forties	.122	.066	.041	.023	.137	.076
Fifties	.129	.069	.041	.023	.142	.078
Sixties	.133	.072	.042	.024	.146	.080
Nativity						
Canada	.111	.061	.040	.022	.030	.072
Europe	.109	.059	.041	.023	.127	.070
Great Britain	.106	.058	.040	.022	.125	.070
Latin America	.099	.054	.040	.022	.114	.063
US, Far West	.105	.057	.040	.023	.121	.067
US, Great Lakes	.114	.061	.039	.022	.131	.072
US, Middle Atlantic	.109	.059	.039	.022	.129	.071
US, Northeast	.116	.063	.038	.021	.130	.072

US, Plains	.113	.061	.040	.022	.128	.071
US, Southeast	.110	.060	.042	.023	.127	.071
US, Southwest	.109	.059	.042	.024	.125	.070
Birth Decade						
1790s	.043	.018	.058	.029	.092	.044
1800s	.094	.050	.045	.025	.097	.051
1810s	.122	.065	.044	.024	.147	.080
1820s	.121	.065	.045	.025	.131	.073
1830s	.117	.063	.042	.023	.131	.072
1840s	.114	.062	.042	.023	.127	.071
1850s	.110	.060	.042	.023	.126	.070
1860s	.112	.061	.041	.023	.130	.072
1870s	.109	.059	.041	.023	.127	.070
1880s	.107	.059	.042	.023	.126	.070
1890s	.107	.058	.042	.023	.124	.069
1900s	.109	.059	.042	.023	.130	.071
1910s	.100	.055	.038	.021	.116	.064
1920s	.083	.044	.025	.013	.111	.060

Source: See Table 1.

Women and whites by race had the greatest net nutrition inequality (Table 3). From the prison records, it is not possible to assess which women were pregnant or which had had children, and part of women's greater BMI inequality is explained by late 19th and early 20th century variation in pregnancies and childless women. Net nutrition by race illustrates that white women had greater BMIs, taller statures, and greater weight than black women (Komlos and Brabec, 2010).

The direct effect of changes in biological markers occur when average biological markers increase with characteristics and inequality. For example, individual BMIs increase directly with age because individuals gain weight with age. However, adult statures decrease after age 50, which offsets BMI diminution associated with diminishing marginal BMI contributions associated with inequality (Carson, 2013, p. 92). White women also had greater BMI and weight inequality than black women. White male BMI and weight inequality was greater than blacks. For current net nutrition inequality measured with BMI and weight increased over time, with the greatest net nutrition inequality observed in the early 20th century. Cumulative net nutrition inequality measured by stature was highest in the 1870s and 1880s. By socioeconomic status, skilled workers had the greatest current net nutrition inequality, while unskilled and workers without occupations had the greatest cumulative net nutrition inequality. For the most part, current and cumulative net nutrition inequality increased with age. Individuals from the Southwest had the greatest net nutrition equality, and cumulative net nutrition inequality decreased throughout the 19th century. The indirect effect between BMI and characteristics can be negative, because the impact of the last dollar spent by a poor person is greater than the last dollar spent by a wealthy person and offsets direct associations with average BMI (Carson, 2013, p. 92).

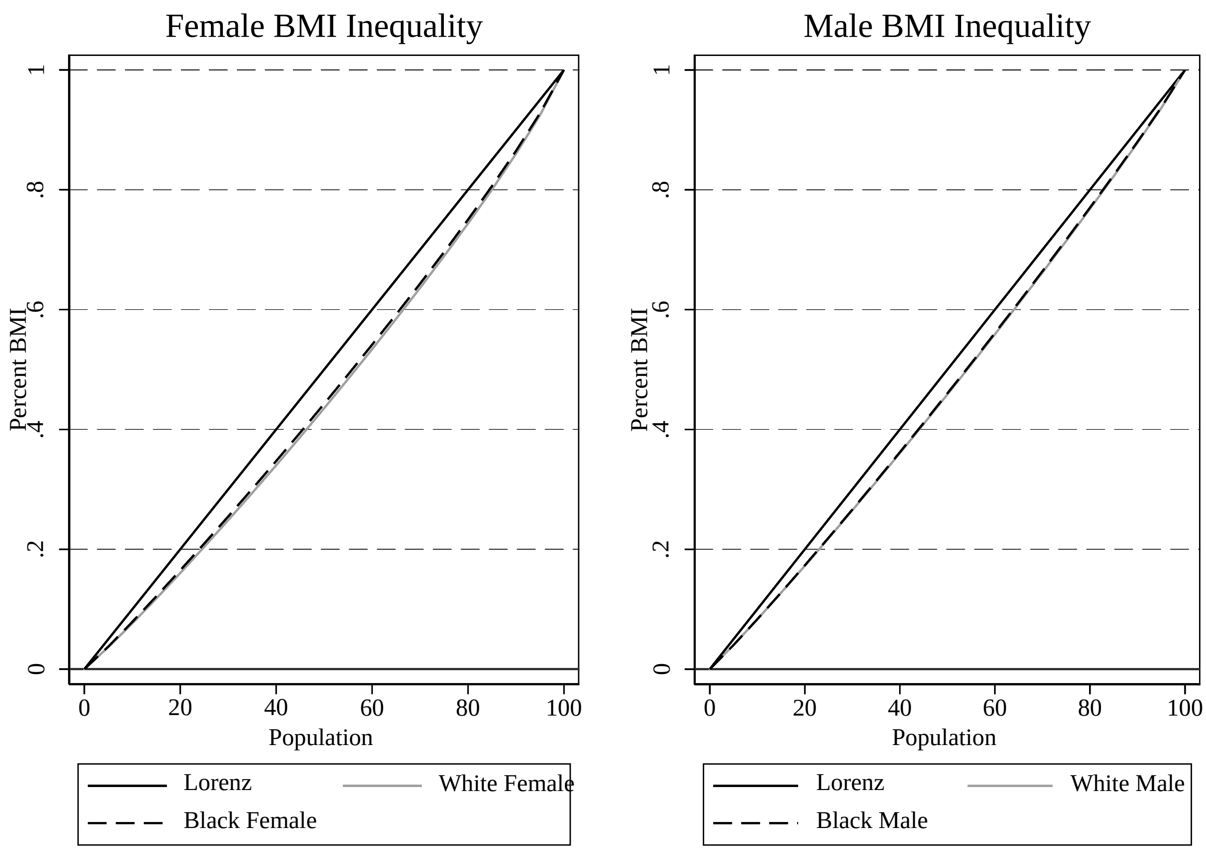


Figure 1, Female-Male, Black-White BMI Lorenz Curves

Source: See Table 1.

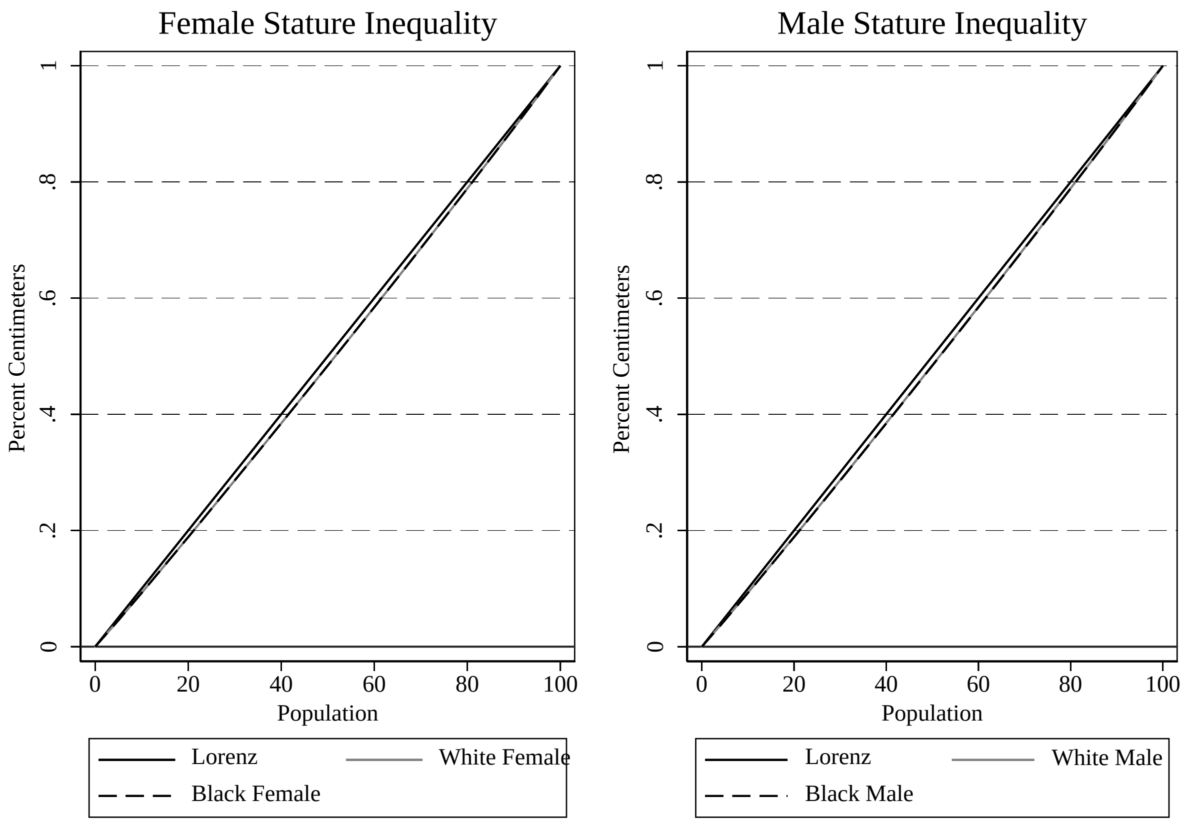


Figure 2, Female-Male, Black-White Stature Lorenz Curves

Source: See Table 1.

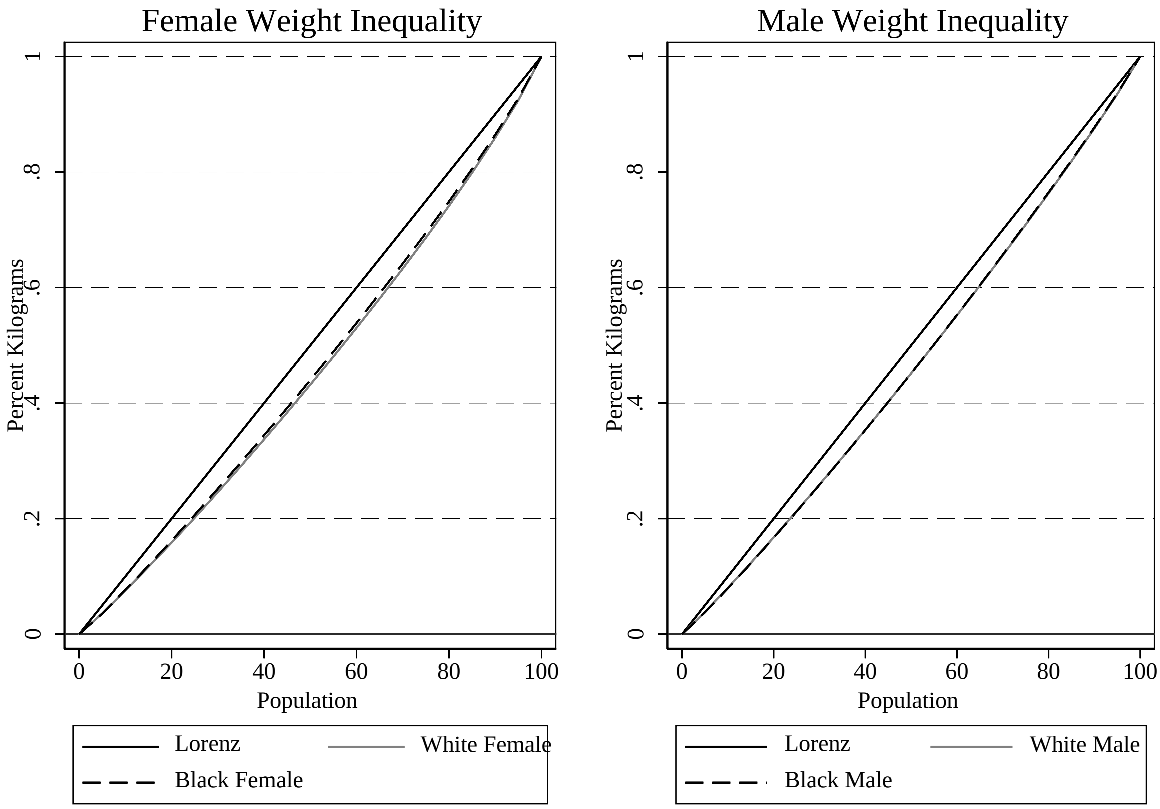


Figure 3, Female-Male, Black-White BMI Lorenz Curves

Source: See Table 1.

Average BMI, stature, and weight reflect a population's cumulative and current net nutrition. They do not, however, reflect how biological resources are distributed within a population. Figures 1 through 3 compare female-male, black-white BMI, height, and weight inequality in the late 19th and early 20th century United States. Stature Lorenz curves illustrate greater stature equality than BMI and weight equality, and current net nutrition that was not as genetically determined as stature (Sokloff and Vilaflor, 1982).

Figure 4 demonstrates that throughout the late 19th and early 20th centuries, black and white male BMI inequality were similar by race. However, by age and race, black and white female BMIs, height, and weight inequality varied more than males. For each of the biological inequality measures, young and old age groups had greater equality than middle ages.

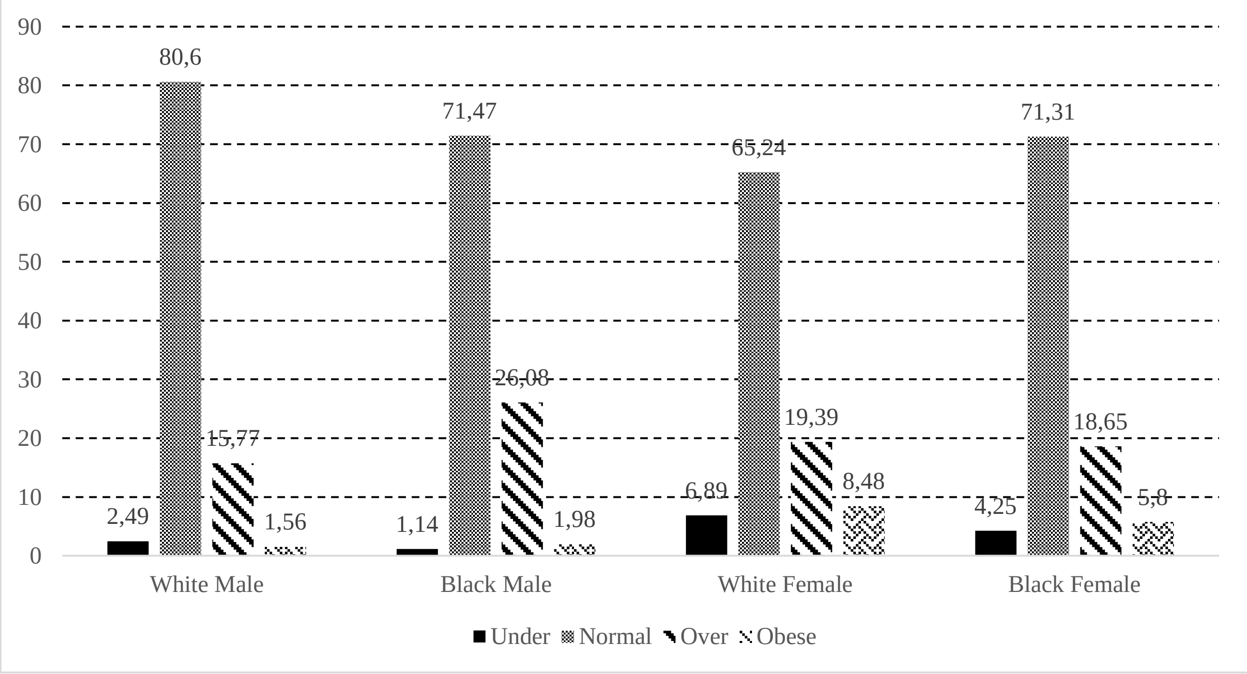


Figure 4, BMI by Race and Gender

Source: See Table 1.

4.2 BMI and Inequality Model

Because BMI growth occurs simultaneously in nutrition and inequality, the net nutrition inequality consequences are difficult to isolate. The relationship between biological markers, net nutrition, and inequality are explained with a Slutsky equation, and changes in biological markers are used to explain direct and indirect effects. More formally, consider the simple nutrition relationship where BMI is a function of access to wealth and inequality, and inequality is a function of wealth.

$$BMI\left(Wealth, Inequality(Wealth)\right) \qquad \text{(Equation 3)}$$

$$\frac{\partial BMI_{Compensated}}{\partial Wealth} = \frac{\partial BMI_{Uncompensated}}{\partial Wealth} + \frac{\partial BMI_{Uncompensated}}{\partial Inequality} \cdot \frac{\partial Inequality}{\partial Wealth} \qquad \text{(Equation 4)}$$

Equation 4 illustrates the overall effect of a BMI change on net nutrition and the indirect effect of how BMIs are affected by diminishing returns to BMI associated with inequality. Subsequently, the overall effect between individual BMIs and inequality depends on the net direct relationship between BMI average characteristics and the indirect, inverse relationship with the diminishing marginal BMI contribution to characteristics.

In econometric applications, important variables can be measured on a scale which is arbitrary and difficult to interpret, such as the effect of inequality on net nutrition. In such cases, interest is on how individuals compare to a population. As a result, it is reasonable to consider what the effect of a one standard deviation Gini Coefficient increase is relative to the distribution. A standardized coefficient regression shows how a dependent variable change per one-unit standard deviation's increase with an independent variable.

4.2.1 BMI Inequality

Body mass, height, and weight standardized coefficients indicate that height had the greatest effect in BMI and weight variation because characteristics associated with diverse biological conditions increased at older ages, and the majority of the BMI-inequality relationship is beyond an individuals' control. BMIs and weight increased with age (Table 2). However, individual BMIs were inversely related to regional inequality, indicating the inverse relationship between race inequality offset the positive relationship between BMI, region, and race, thereby decreasing marginal returns to BMI (Table 4; Hilliard, 1972).

4.2.2 Stature Inequality

Stature variation by inequality was—for the most part—smaller than BMI and weight variation by inequality, reflecting that statures are more genetically determined than BMI and weight. Nonetheless, because of sexual dimorphism, statures varied the most with gender inequality, and females have greater stature inequality than males (Gray and Wolf, 1980). The negative relationship between stature and gender inequality indicates shorter individuals, such as women, received considerably greater marginal stature contributions than men, and taller men received smaller marginal stature contributions than women. Stature variation by race inequality also had a negative relationship, indicating that shorter individuals received considerably greater marginal stature contributions than fairer complexioned individuals. Taller, fairer complexioned individuals received smaller marginal stature contributions than darker complexioned individuals (Carson, 2008; Carson, 2009). Alternatively, stature increased in nativity inequality, and areas where average net nutrition increased with average cumulative nutrition were taller than areas with differences in marginal contributions (Hilliard, 1972).

4.2.3 Weight Inequality

Weights increased in both race and age inequality, indicating that increasing average weight with age and race subjugated the inverse relationship between weight and age inequality. Individual weight also increased with race inequality, indicating the direct effect of racial net nutritional inequality offset the indirect inverse effect of diminishing marginal returns to BMI associated with race. Although period received, gender, and occupation net effects were smaller than race and age, their positive direct effects on BMI by birth decade offset the inverse relationship. However, the indirect inverse relationship between marginal increases in decade received offset the positive relationship between BMI and current observation period. The regional indirect inverse relationship was greater than the regional positive relationship between BMI and positive regional effects.

V. Current and Cumulative Net Nutrition across Distributions

To better understand the relationship between net nutrition and inequality variation across their respective distributions, BMI, stature, and weight quantile regression functions are constructed. When estimating regression functions, quantile estimation offers advantages over least squares estimation. For example, a BMI quantile regression provides greater description across the distribution and when there is an unknown truncation point. Quantile estimation also provides more accurate description when the dependent variable is not normally distributed, and late 19th and early 20th century BMIs were not normally distributed (Carson, 2016).

Let γ_i be the BMI, height, and weight of the i^{th} individual expressed as a function of the x_i covariate.

$$\gamma_i = Q_\beta\left(p \middle| X\right) = \theta^p x_j + \eta S\left(p\right),\ p \in \left(0,1\right) \qquad \text{(Equation 5)}$$

which is the pth BMI, height, and weight quantiles, given x. The coefficient vector, θ, is derived by estimation techniques in Koenker and Basset (1978) and Koenker and Hendricks (1992), and the interpretation of θ_j is how BMI changes with the jth covariate at the pth quantile. For example, the coefficient for skilled workers at the median is the change in BMI required to keep a skilled worker's BMI at the distribution's median.

To isolate how black and white biological measures were related to inequality across distributions, the BMIs, stature, and weight of the ith individual are regressed on height and inequality characteristics.

BMI Inequality

$$BMI_i^p = \theta_0^p + \theta_1^p Centimeters_i + \theta_2^p Race\,Gini_j + \theta_3^p \,\mathrm{Re}ceived\,Gini_j + \theta_4^p Gender_j$$

$$+\theta_5^p Occupational\,Gini_j + \theta_6^p Age\,Gini_j + \theta_7^p \,\mathrm{Re}gion\,Gini_j + \theta_8^p Birth\,Gini_j + \varepsilon_i^p \quad \text{(Equation 6)}$$

Stature Inequality

$$Centimeters_i^p = \theta_0^p + \theta_1^p Race\,Gini_j + \theta_2^p \,\mathrm{Re}ceived\,Gini_j + \theta_3^p Gender_j + \theta_4^p Occupational\,Gini_j$$

$$+\theta_6^p Age\,Gini_j + \theta_7^p \,\mathrm{Re}gion\,Gini_j + \theta_8^p Birth\,Gini_j + \varepsilon_i^p \quad \text{(Equation 7)}$$

Weight Inequality

$$Ki\log rams_i^p = \theta_0^p + \theta_1^p Centimeters_i + \theta_2^p Race\,Gini_j + \theta_3^p \,\mathrm{Re}ceived\,Gini_j + \theta_4^p Gender_j$$

$$+\theta_5^p Occupational\,Gini_j + \theta_6^p Age\,Gini_j + \theta_7^p \,\mathrm{Re}gion\,Gini_j + \theta_8^p Birth\,Gini_j + \varepsilon_i^p \quad \text{(Equation 8)}$$

Stature in centimeters is included in Equation 6 to account for the inverse relationship between BMI and height (Carson, 2009; Carson, 2012; Komlos and Carson, 2017), while stature in centimeters is included in Equation 8 to account for the positive relationship between weight and height (Carson, 2020). Gini coefficients are included for race, period received, gender occupations, age, region, and birth year inequality.

Table 4, Quantile BMI by Inequality

	BMI	Standardized Coefficients	1%	5%	10%	25%	50%	75%	90%	95%	99%
Intercept	43.78***		35.71***	43.86***	46.15***	43.19***	39.72***	46.41***	46.15***	32.84***	5.65**
Centimeters	-.050***	-0.138***	-.020***	-.025***	-.027***	-.034***	-.042***	-.052***	-.070***	-.086***	-.141***
Race Gini	-2.29***	-0.112***	-1.26***	-1.82***	-2.10***	-2.29***	-2.60***	-2.79***	-2.75***	-2.35***	-0.525
Received Gini	.329***	0.023***	.184*	-0.023	-0.006	0.050	.194***	.357***	.762***	1.08***	1.65***
Gender Gini	-.149***	-0.027***	-.541***	-.487***	-.446***	-.417***	-.314***	-.094***	.427***	.841***	1.76***
Occupation Gini	-.233***	-0.014***	-.324***	-.455***	-.502***	-.569***	-.457***	-.221***	.347***	.666***	2.48***
Age Gini	.575***	0.119***	.254***	.291***	.335***	.430***	.530***	.662***	.796***	.993***	-1.52***
Region Gini	-.920***	-0.089***	-1.03***	-1.10***	-1.17***	-1.15***	-1.04***	-.878***	-.643***	-.460***	0.149
Birth Gini	.595***	0.044***	.295***	.268***	-.291***	.408***	.621***	.729***	.724***	.664***	.983***
N	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869
R^2	0.0532		0.0172	0.0240	0.0264	0.0297	0.0305	0.0317	0.0373	0.0474	0.0903

Source: See Table 1.

Table 5, Quantile Centimeters by Inequality

	Centimeters	*Standardized Coefficients*	*1%*	*5%*	*10%*	*25%*	*50%*	*75%*	*90%*	*95%*	*99%*
Intercept	370.45***		431.75***	358.95***	363.43***	363.88***	371.34***	373.20***	377.79***	375.36***	364.65***
Race Gini	-9.85***	-0.089***	-9.07***	-8.11***	-8.52***	-9.94***	-10.18***	-10.26***	-10.55***	-9.23***	-9.23***
Received Gini	-5.33***	-.031***	-12.42***	-5.47***	-3.86***	-6.28***	-5.04***	-4.27***	-6.91***	-5.46***	-3.89*
Gender Gini	-82.48***	-.213***	-99.68***	-77.17***	-81.68***	-80.06***	-82.87***	-83.67***	-84.34***	-85.44***	-80.70***
Occupation Gini	-2.24***	-.023***	-3.80***	-4.77***	-4.11***	-3.01***	-1.61***	-1.40***	0.003	.351***	0.554
Age Gini	1.16***	.038***	0.216	.831***	1.04***	1.28***	1.05***	1.14***	1.36***	1.24***	1.74***

Native Gini	10.60***	.116***	0.547	6.36***	7.81***	10.69***	10.26***	11.48***	13.18***	13.33***	12.80***
Birth Gini	-0.121	-0.002	1.82	0.318	0.413	0.012	-.256**	-.500***	-0.463	-.394*	-0.094
N	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869
R^2	0.0619	0.0619	0.0472	0.0450	0.0431	0.0361	0.0277	0.0241	0.0240	0.0255	0.0207

Source: See Table 1.

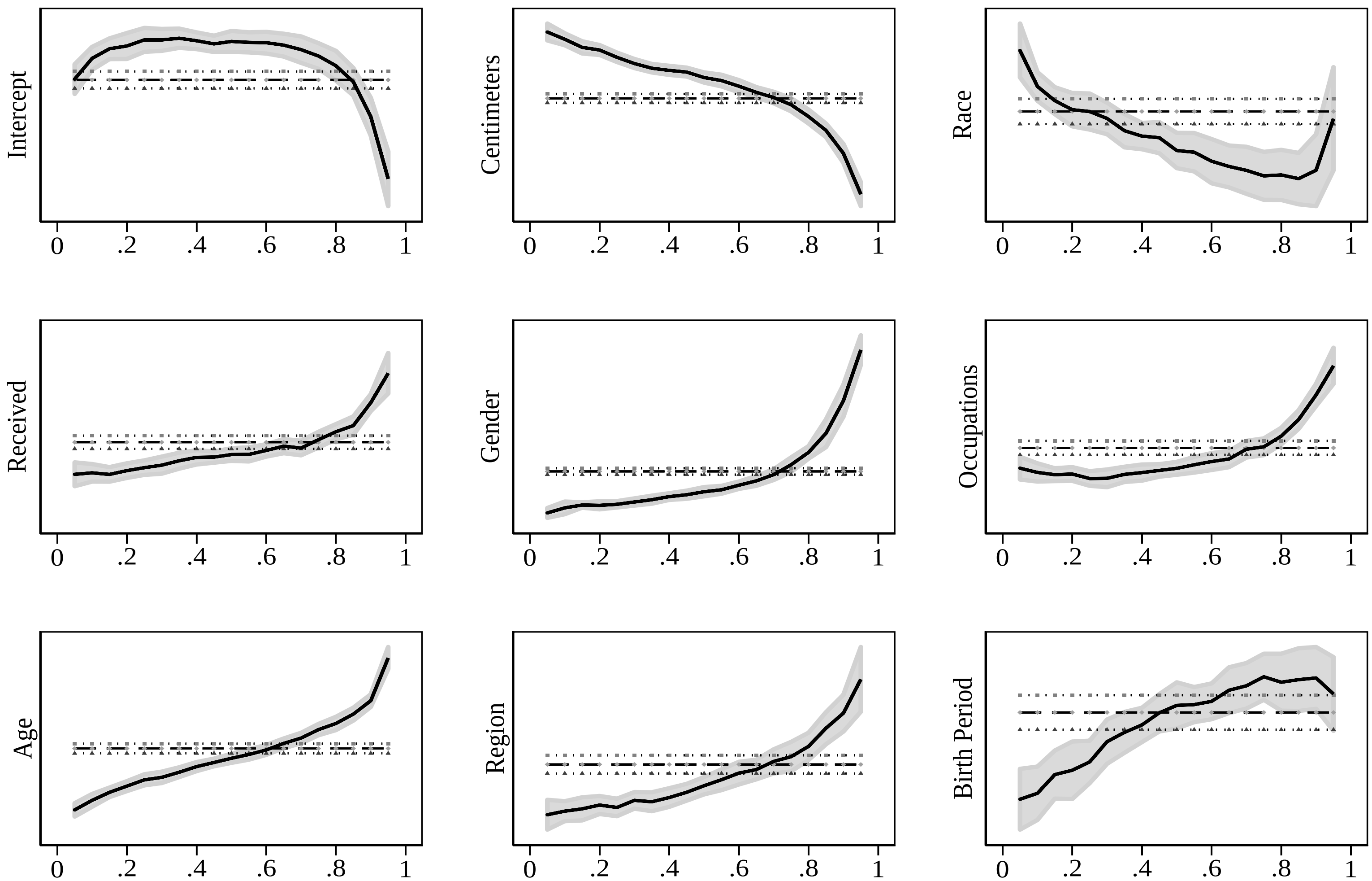
Table 6, Quantile Kilograms by Inequality

	Kilograms	Standardized Coefficients	1%	5%	10%	25%	50%	75%	90%	95%	99%
Intercept	-41.02***		5.68	3.27	-5.22	-13.88***	-28.60***	-48.79***	-90.15***	-119.45***	-221.31***
Centimeters	.622***	0.514***	.528***	.565***	.580***	.598***	.632***	.655***	.663***	.654***	.607***
Race Gini	4.26***	0.064***	1.39***	2.63***	3.35***	3.62***	4.02***	4.56***	4.64***	5.14***	6.03***
Received Gini	-2.23***	-.023***	-2.77***	-3.89***	-4.01***	-3.73***	-3.12***	-2.21***	0.445	2.36***	8.96***
Gender Gini	-.528***	-.020***	-1.73***	-1.74***	-1.56***	-1.41***	-1.05***	-.362***	1.60***	2.99***	6.02***
Occupation Gini	0.214	0.003	-1.45***	-1.15***	-.908***	-.328*	-0.048	.336**	1.50***	2.17***	5.40***
Age Gini	.863***	.077***	.410***	.501***	.568***	.695***	.837***	.999***	1.17***	1.39***	1.95***
Region Gini	-2.40***	-.079***	-2.14***	-2.53***	-2.51***	-2.57***	-2.51***	-2.33***	-2.24***	-2.18***	-1.60***
Birth Gini	.065***	.005***	.111***	0.036	.067***	0.028	0.037	.124**	0.242	0.428	2.22***
N	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869
R^2	0.2981	0.2981	0.1924	0.1881	0.1852	0.1809	0.1781	0.1672	0.1473	0.1293	0.0963

Source: See Table 1.

Tables 4, 5, and 6 present individual BMIs as functions of race, observation period, gender, occupations, age, region, and birth period Gini Coefficients, and confidence intervals illustrate that covariate inequality effects varied significantly across BMI, stature, and weight distributions. BMIs increased across distributions in observation period, age, and birth period inequality, indicating that that higher BMIs with age and time offset the negative marginal inequality effects associated with age and observation period. The effect of increased average BMIs to observation period, age, and birth period offset the inverse relationship between BMI and diminishing marginal contributions from the last dollar spent over time and by age. Stature returns across quantiles increased mildly by socioeconomic status, age, and regional inequality, whereas stature returns decreased across the stature distribution by race, period received, gender, and birth period inequality. Weight returns across quantiles increased by stature, race, period received, gender, socioeconomic status, age, region and birth period, indicating that across the weight distribution the direct effect between average BMI and characteristic offset the inverse inequality relationship.

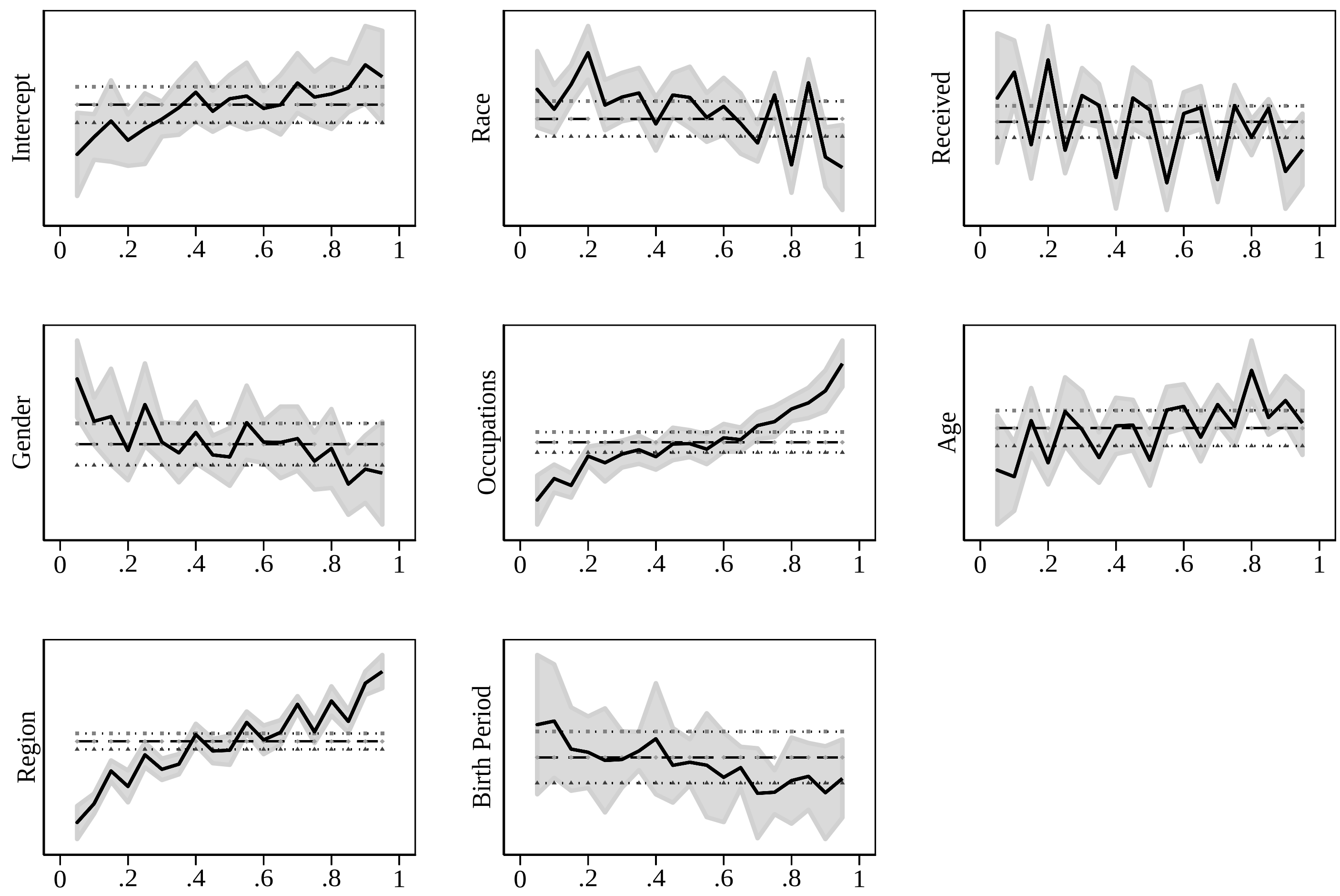
Figure 5, BMI by Characteristics across Quantiles



Source: See Table 4.

Notes: Estimated with Stata's bsqreg and grqreg.

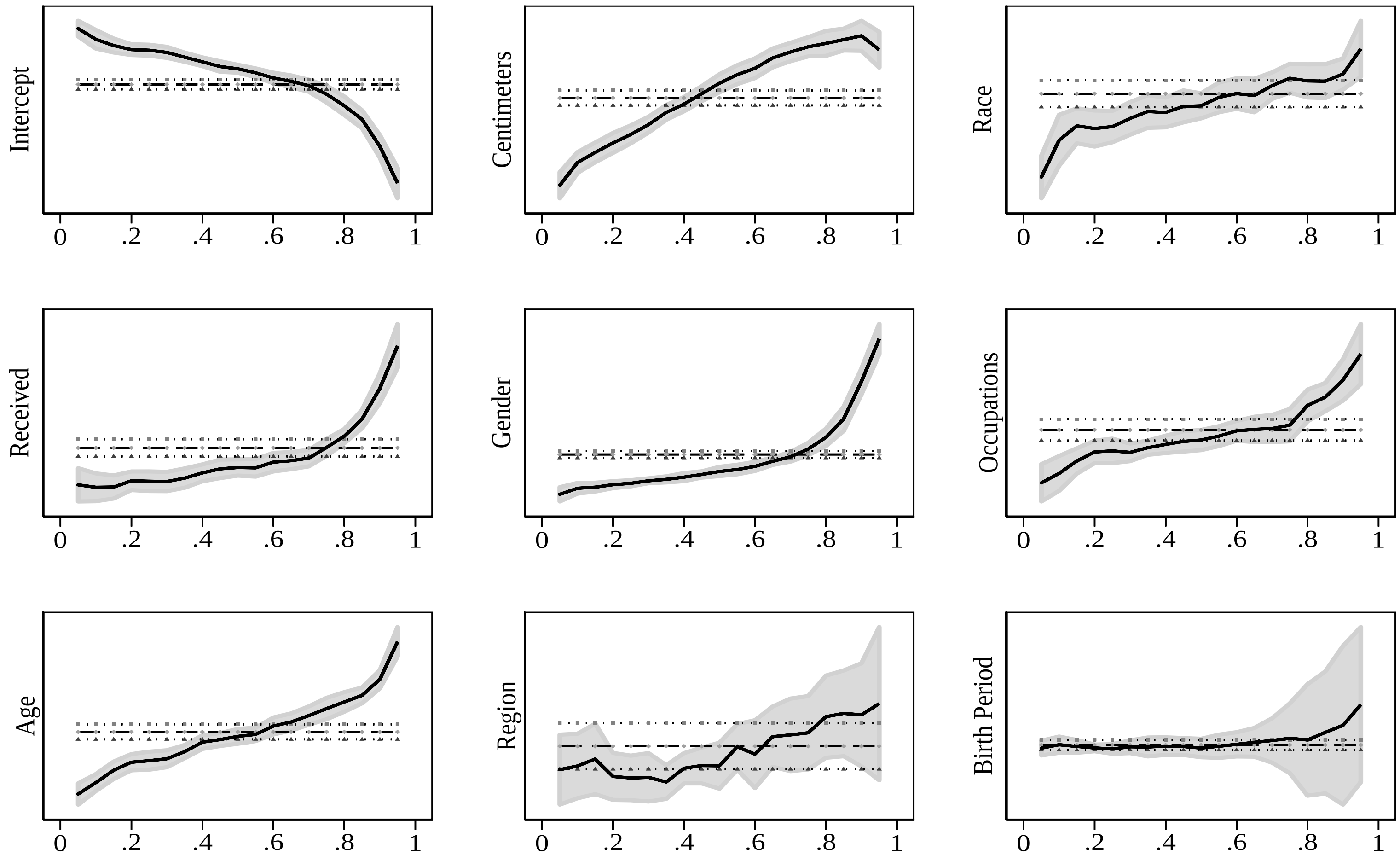
Figure 6, Stature by Characteristics across Quantiles



Source: See Table 5.

Notes: Estimated with Stata's bsqreg and grqreg.

Figure 7, Weight by Characteristics across Quantiles



Source: See Table 6.

Notes: Estimated with Stata's bsqreg and grqreg.

Quantile functions are also used to test the statistical tests for coefficient equality across distributions. Figures 5, 6, and 7 illustrate that each of the coefficients were significant and were not constant across BMI, stature, and weight quantiles. Across distributions, BMIs increased at higher race, time, gender, socioeconomic status, age, and region inequality quantiles, indicating that higher average net nutrition dominated the effects of the inverse relationship between net nutrition and inequality across the BMI distribution (Figure 5, Table 7). However, the inverse relationship between net nutrition measured by height and diminishing marginal contributions to race, observation period, and gender offset average stature increases across the height distribution (Figure 6, Table 7). Like BMIs, weight returns to characteristics increased across the distribution, and the direct increase in heavier weight with inequality offset the inverse relationship between weight and inequality (Figure 7, Table 7). Nevertheless, individual cumulative net nutrition measured with stature, socioeconomic status, age, region, and birth period across the stature distribution, indicating that greater socioeconomic status, age, and region dominated diminished returns across distributions by characteristic inequality.

Table 7, Quantile Inequality across BMI, Centimeter, and Kilogram Distributions

	BMI		*Centimeters*		*Kilograms*	
	Statistic	F	Statistic	F	Statistic	F
Centimeters	178.42	.0000			1,290.38	.0000
Race Gini	238.41	.0000	16.31	.0000	159.50	.0000
Received Gini	37.26	.0000	59.98	.0000	78.72	.0000
Sex Gini	156.49	.0000	38.70	.0000	441.51	.0000
Occupation Gini	155.00	.0000	57.28	.0000	45.39	.0000
Age Gini	688.59	.0000	45.43	.0000	169.66	.0000
Region Gini	23.52	.0000	366.58	.0000	2.68	.0058
Birth Gini	97.81	.0000	50.89	.0000	20.80	.0000

Source: See Tables 4, 5, and 6.

Notes: F-test across quantiles using Stata sqreg and test commands.

VI. Conclusions

The definition of inequality is complicated, and there are various means by which it is evaluated. This study considers inequality by net nutrition, and women's BMIs were distributed less equitably than men. Black and white inequalities were similar by race, and female BMIs and weight were distributed less equally than men. Inequality is affected by the direct relationship between a characteristic's influence on a biological measure and its indirect decrease in biological measures impact of the last dollar spent by a wealthy person is less than a poor person. The overall effect depends on which effect dominates. Stature was a significant contributor to BMI and weight inequality, and like wealth inequality, biological inequality increased with age because characteristics associated with inequality increased with age. Period received, age, and region inequality contributed to individual BMI variation, whereas BMIs varied little with occupation, birth, and period received biological inequality. Across its distribution, BMI returns increased at higher race, time, gender, socioeconomic status, and regional inequality quantiles, and greater net nutrition dominated the inverse effects between nutrition and inequality across net nutrition distributions. Across the stature distribution, returns increased with occupations, age, and region inequality and decreased with gender, race, birth period, and observation period inequality. Across the weight distribution, returns increased with each characteristic. Subsequently, net nutritional inequality reflected biological and unique late 19th and early 20th century institutions across distributions and socioeconomic groups.

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