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Abstract

When other measures for material welfare are scarce or unreliable, the use of average stature and body mass index (BMI) values is common. BMI reflects the current difference between calories consumed, calories required for work, and to withstand the physical environment. This study evaluates 19th century macro-level nutrition and diseases associated with US BMI variation. Body mass was positively related to calories from dairy products and inversely related to malaria, which had a larger effect on net-nutrition than cholera. After controlling for nutrition and disease, black BMIs and weights were greater than whites, indicating that 19th century social preferences are an unlikely explanation for taller, fairer complexioned whites.

JEL-Codes: I120, I310, J310, J700, N310.

Keywords: nineteenth century US health, BMI variation by characteristics, malnourishment.

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Body Mass, Nutrition, and Disease: 19th Century Current Net Nutrition during Economic Development

I. Introduction

When other sources for material welfare are scarce or unreliable, biological measures reflect material welfare that are not available in standardized economic measures.[1] For example, the body mass index (BMI)—defined as weight in kilograms divided by height in meters squared—reflects current net nutrition (Fogel, 1994; Carson, 2009; Carson, 2012). Historical body mass values were in healthy normal and overweight categories, indicating that 19th century health may have varied less with BMI than previously believed. Nineteenth and early 20th century body mass varied little over time, and few individuals were in underweight or obese categories (Carson, 2009, p. 124; Carson, 2012, p. 380; Carson, 2013). Nonetheless, because of the shortage of weight and height data in historical samples linked to nutrition and disease environments, BMI studies that consider the relationship between body mass and macro-level

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[1] Stature was the first biological measure used to understand early health and economic development and reflects the net cumulative difference between calories consumed and calories required for work and to withstand the physical environment. As stature studies developed, attention transformed from evaluating stature variation over time to factors associated with stature variation. For example, Fogel et al (1978), Fogel et al (1979), and Fogel et al (1982) observed an unexpected mid-19th century stature diminution at the same time that income and wealth monotonically increased (Komlos, 1987; Komlos, 1998; Libergott, 1984; Bogart, 2009). Recent studies consider factors associated with stature variation over time, and the relative important of nutrition versus disease became the topic in stature studies (Komlos, 1987; Steckel, 2000, Coelho and McGuire, 2000; Haines, Craig, and Weiss, 2003).

nutrition and disease characteristics are yet to be made. This study links a late 19th century sample of male BMIs to macro-level nutrition, disease, and socio-economic effects to evaluate how current net nutrition varied with economic development.

Economic theory and development studies contribute to health and health policy formation. Adam Smith and later Gary Becker and Michael Grossman (Gayner, 1994) addressed important developments regarding the interaction between health, labor markets, and human capital theory. Smith addressed nutrition, physicians, and physician licensing (Gaynor, 1994, p. 119), while Becker (1993, pp. 54-55) considers firm investment decisions in employee health, the decisions individuals make in labor force participation, and personal health decisions. Grossman (1972a) and Grossman (1972b) extend demand theory into human capital and health, and individuals invest in personal health through education in ways similar to firms investing in labor and physical capital. Furthermore, there is a need to understand the long-run dynamics of health and nutrition, which are instrumental to evaluate health and economic policy. However, uninterrupted measures for health over the 19th and 20th centuries—such as the body mass index (BMI)—are scarce, and evaluating health measures over the 19th and 20th centuries associated with nutrition and disease has remained limited.

It is against this backdrop that this study considers three paths of inquiry into factors associated with late 19th century BMI variation. First, what was the historical relationship between BMI and nutrition? BMI variation was positively associated with dairy proteins, and white BMIs were more related ro access to dairy products than blacks. Second, how did nutrition and disease vary by race and age? Calorie demands associated with malaria were larger than cholera, and individual-level BMIs were lower in states with higher malaria and cholera mortality. Third, much has been written about how 19th century statures varied by race. After controlling for nutrition and disease, how did late 19th century net nutrition and BMIs vary by race and complexions? After controlling for nutrition and disease, black BMIs and weight were greater than whites, indicating that 19th century social preferences are an unlikely explanation for taller statures for individuals with fairer complexions.

II. BMI, Historical Health, and Nutrition

The body mass index offers unique insight into net nutrition and health during economic development, and when other measures for economic welfare are scarce or unreliable, BMI is now a well-accepted measure for current net-nutrition (Fogel, 1994; Coclanis and Komlos, 1995). BMIs are also related to morbidity and mortality (Waaler, 1984; Costa, 1993; Murray, 1997). For example, Waaler (1984) and Calle et al. (1999) find U-shaped relationships between mortality risk and body mass. Mortality is higher for individuals with BMIs below 18.5, and low BMI mortalities include tuberculosis, infectious disease, and starvation (Cuff, 1993; Fogel, 1994, Berrington et al, 2010). BMI related mortality risk is low and stable for BMIs between 19 and 27, and increases for BMIs greater than 27. Jee et al (2006) show the relationship is stable across ethnic groups, and Costa (1993) and Murray (1997) show that historical BMIs were related to mortality risk comparable to modern populations. Mortality risk is related to the modern obesity epidemic, and individuals in higher BMI categories are at greater mortality risk from the metabolic syndrome, diabetes, heart disease, stroke, and certain cancers (Davey-Smith, 2000; Atlas, 2011, pp. 101-107). Historical mortalities were related to childhood diseases, infections, and sanitation diseases, and modern mortalities are related to high BMIs and obesity, including diabetes, heart disease, and stroke. Nonetheless, 19th century BMIs were in stable, healthy ranges, and as a rule, 19th century US mortalities were not related to BMIs.

Table 1, Nineteenth Century BMI Studies

	Sample	*Observation Period*	*Δ Mixed-Race*	*Δ Farmer*	*BMI Δ over Time*	*BMI Δ Centimeter*
Cuff, 1993	West Point Cadets, Whites	1860-1885			.8	
Komlos and Coclanis, 1995	The Citadel, Whites	1860-1930			1.7	
Carson, 2009	Texas Prisoners, Whites and Blacks	1870-1920	-.3	.1 .2	Whites, .2 Blacks,-.4	
Bodenhorn, 2010	New York Legislators, Whites	1795-1840			-1.7	
Carson, 2012	US, Prisons, Whites and Blacks	1850-1929	White, Black Youth, -.4	.410	-1.06	-.072
Carson and Hodges, 2012	Philadelphia Prison, Whites and Blacks	1870-1910	Mixed-Race to Black, -.70	.104	.949	-.038
Carson, 2013 J.Bio Econ	US, Southern Prisons, Black and White	1840-1922	Black, 1.17 Mixed-Race, .815	.218	-1.77	-.069
Carson 2015	US, Prisons, Black and White	1840s-1920s		Black, .308 Mixed-Race, .505 White, .391	Black, -1,21 Mixed-Race, -2.30 White, -1.99	Black, -.070 Mixed Race, -.660 White, -.051
Komlos and Carson, 2017	US, McNeil Federal Prison, White	1882-1937		.51	-.77	-.04
Carson, (2019)	US, State Prisons	1840-1947	-1.41		Black, 1.13 Mixed-Race	Black, -.070 White,

		.867	-.049

Sources: Cuff (1993); Coclanis and Komlos (1995); Carson (2009); Bodenhorn (2010); Carson (2012); Carson and Hodges (2012); Carson (2013); Carson (2015); Komlos and Carson (2017); Carson (2019).

Cuff (1993) was among the first to observe BMI variation over time and shows that historical BMIs were low by modern standards. Cuff (1993, p. 177) finds that West Point Cadet BMIs were low but improved from 20.7 in the 1850s to 21.6 in the 1880s. Coclanis and Komlos (1995) use military records to show that military recruit BMIs were low throughout the late 19th and early 20th centuries, and 40 percent of West Point Cadets were in the underweight category (Cuff, 1993). However, Carson (2009, p. 124) and subsequent studies show that prisoner BMIs were in higher categories and did not vary appreciably over time (Carson, 2016). Existing studies for late 19th and early 20th century female BMIs show a similar pattern that lower socioeconomic status females—like males—were unlikely to be in either underweight or obese categories but were in healthy, normal, and overweight categories (Carson, 2018, p. 316). For both women and men, BMIs were inversely related to height; however, compared to men, women's BMIs were around twice as sensitive to height (Carson, 2009; Carson, 2012; Carson, 2018). Individuals with darker complexions had higher BMI values, and agricultural worker BMIs were higher than workers in other occupations.

After accounting for race and socioeconomic status, little is known about how late 19th and early 20th century BMI variation was related to nutrition and disease. Like statures, BMIs were positively related to nutrition, and disease put greater stress on diets that diverted calories from nutrition to fight the deleterious effects of disease (Steckel, 2000; Coelho and McGuire, 2000). This study, therefore, combines BMI, nutrition, and disease variables to show how 19th century male BMIs were related to nutrition, disease, demographics, socioeconomic status, and nativity.

III. Nineteenth Century BMI and Nutrition Data

Military and prison records are two common sources for late 19th and early 20th century weight and height data. While plentiful, military records frequently did not record weight, which limits their use in BMI studies (Cuff, 1993; Komlos and Coclanis, 1995). Moreover, military records reflect conditions among upper socioeconomic groups, and their current net nutrition may not have varied as much with material conditions as individuals in lower socioeconomic groups (Bereczki et al., 2019, p. 190; Meinzer et al, 2019, p. 239; Ellis, 2004; Sokoloff and Vilaflour, 1982). Because blacks were less likely to enroll in military service—especially during the antebellum period—military records are also less likely to reflect conditions for older individuals and individuals of African descent. [2]

Inmates were recorded with varying degrees of socioeconomic status and are alternatives to military records that reflect a more diverse spectrum of 19th century nutritional conditions. Prison records also include greater racial differences because military records disproportionately represent conditions among individuals of European decent in the United States, whereas prison records reflect ancestry from both Africa and Europe. After the American Civil War, vagrancy laws were inacted and enforced to encourage previously enslaved blacks to remain in the US labor force (Brands, 2010, p. 156). Nonetheless, prison records are not above reproach. For example, if incarceration was related to biological conditions, prison records may

[2] African-American military recruits served in the military. However, through World War II, US military units were segregated.

disproportionately represent individual's material and nutritional conditions from lower socioeconomic groups (Meinzer et al. 2019, p. 239). Alternatively, if law enforcement targeted individuals with taller physical statures and higher BMI values, prison records may represent net nutritional conditions for individuals in better net nutritional conditions. Therefore, care is taken when evaluating late 19th and early 20th century prison records, and a reasonable inference is that prison records represent net nutritional conditions for a diverse set of individuals from working-class and lower socioeconomic groups.

The prisons included in this study are from Arizona, Colorado, Idaho, Illinois, Kentucky, Missouri, Mississippi, Montana, Nebraska, New Mexico, Oregon, East and West Pennsylvania, Philadelphia, Tennessee, Texas, and Washington. Because there are too few female records to link to 19th century nutrition, disease, and population density data, only black and white males are considered in this study (Carson, 2008; Carson, 2009, Carson, 2018). Prison enumerators recorded an extensive set of pre-incarceration occupations and defined them narrowly. White-collar occupations include physicians, bankers, and government administrators. Skilled occupations include butchers, blacksmiths, and craftsman. Agricultural workers include farmers, ranchers, and stockmen. Unskilled workers include laborers, cooks, and miners. A final category is included for individuals with no listed occupation or occupations that were not legible in prison registries.

Complexions reflect the racial diversity of the 19th century United States (Steckel, 2000, Table 10.1, p. 435; Haines, 2000, Table 8.1, p. 306). Individuals of African ancestry were recorded as light, medium, and dark black. Individuals of European ancestry were the most common complexion in the prison sample and were recorded as white, light, medium, and dark (Carson, 2009; Carson, 2019). This white complexion category is supported further because individuals claiming European birth in US prisons are also recorded with the same white, light, medium, and dark complexions. There were individuals in the sample of combined mixed African and European ancestry recorded as various shades of 'mulattoes.' However, until the 1930s, in both federal censuses and prison records, individuals of combined African and European ancestry were referred to as "mulattos" in prison and census records and are referred to as "mixed-race" in the results that follow.

Table 2, Nineteenth Century Descriptive Statistics of Prisoners in US Prisons

	N	*Percent*		*N*	*Percent*
Ethnic			**Birth Decade**		
Black	10,292	24.15	1860s	1,030	2.42
Mixed-Race	8,450	19.83	1870s	10,702	25.11
White	23,877	56.02	1880s	15,720	36.88
Age			1890s	7,818	18.34
Teens	4,116	9.66	1900s	5,103	11.97
20s	19,095	44.80	1910s	2,107	4.94
30s	9,925	23.29	1920s	127	.30
40s	5,747	13.48	1930s	12	.03
50s	2,979	6.99	**Residence State**		
60s	718	1.68	Arizona	267	.63
70s	39	.09	Colorado	410	.96
Native			Idaho	47	.11
Great Lakes	3,325	7.80	Illinois	1,073	2.52
Middle Atlantic	10,393	24.39	Kentucky	4,153	9.74
Northeast	704	1.65	Missouri	2,464	5.78
Plains	2,273	5.33	Mississippi	204	.48
Southeast	19,396	45.51	Montana	909	2.13
Southwest	6,528	15.32	Nebraska	226	.53
Occupations			New Mexico	242	.57
White-Collars	3,022	7.09	Oregon	685	1.61
Skilled	6,964	16.34	PA, East	2,610	6.12
Farmer	3,462	8.12	PA, West	3,304	7.75
Unskilled	20,346	47.74	Philadelphia	3,473	8.15
No Occupations	8,825	20.71	Tennessee	9,115	21.39
Decade Received			Texas	13,288	31.18
1840s	6,090	14.29	Washington	149	.35
1850s	22,355	52.45			
1860s	14,174	33.26			

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.

Prison records include inmates born between 1845 and 1865 and observed between 1860 and 1930 (Table 1). Crimes are committed by the young, and there was a large share of males in their teens and 20s (Hirschi and Gottfredson, 1983; Gottfredson and Hirschi, 1990; Carson, 2009; Carson 2018; Baten and Steckel, 2019; Baten et al, 2014). Individuals of European ancestry were the most common racial group, and there was a greater share of inmates of African descent in the prison sample than among the general population (Table 1; Steckel, 2000, Table 10.1, p. 435; Haines, 2000, Table 8.1, p. 306). Most individuals were native to the South, but there were individuals from the Plains and Middle Atlantic in the sample. Unskilled workers were the most common occupational category, and there was a considerable share of individuals with skilled and white collar occupations. There were also fewer farmers in the prison sample relative to the general population (Rosenbloom, 2002, p. 88).

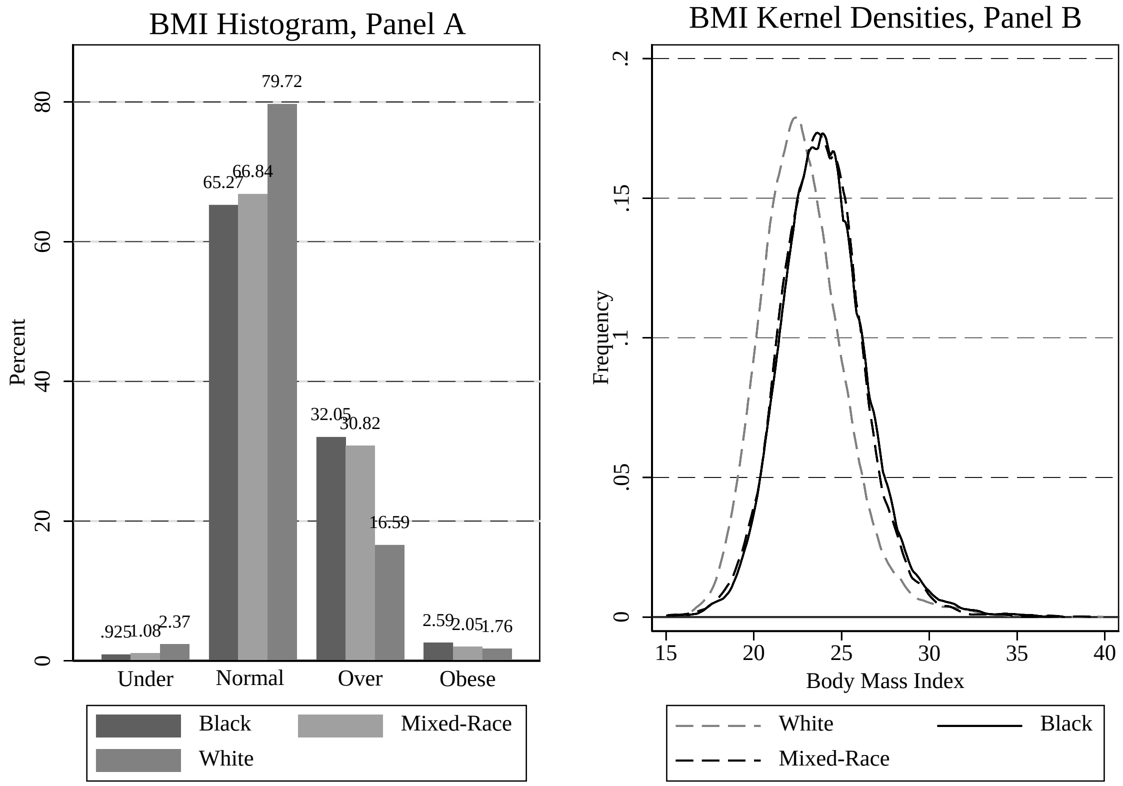

Figure 1, Late 19th and Early 20th Century Weight Classifications and Body Mass

Source: See Figure 2.

Among contemporary populations, BMIs are used to classify weight status. Although more precise measures should be used when available, BMIs lower than 18.5 are classified as underweight. BMIs between 18.5 and 24.9 are classified as normal weight. BMIs between 24.9 and 29.9 are classified as overweight, while individuals with BMIs greater than 29.9 are classified as obese. Among black and white males linked to census population's nutrition, and mortality schedules, the majority were in the normal and overweight BMI categories, and late 19th century BMIs were low by contemporary standards (Figure 1; Carson, 2016). Moreover, there were more individuals in obese than underweight categories, indicating that lower BMI diseases during the late 19th century were uncommon.

To the degree that biological marker inequality reflects material inequality, there was inequality among 19th century blacks and whites; inequality between youths and adults. Stature inequality is used to measure inequality among the height data (Moradi and Baten, 2005). However, stature is genetically determined and calcified, which changes little with the immediate effects of biological and net nutrition. Alternatively, BMI and weight inequality are more plastic and responsive to the immediate effects of material environment. The white BMI Gini Coefficient is .0620, and the Coefficient of Variation is .11088. Black Gini Coefficient is .0565 and the BMI Coefficient of Variation is .10301. The child BMI Gini Coefficient is .06103 and the Coefficient of Variation is .11142. The adult BMI Gini Coefficient is .05976, and the adult BMI Coefficient of Variation is .10896. Subsequently, white inequality was less equal than blacks, and childhood inequality was less equal than adults.

IV. Late 19th and Early 20th Century US BMIs by Nutrition Disease, and Socioeconomic Status

BMIs of the i^{th} individual are now regressed on height, demographic characteristics, socioeconomic status, nutrition, and disease variables. Because there is a non-linear relationship between BMI classification and mortality, a multinomial model is used to evaluate relationships between BMIs and characteristics (Waaler, 1984; Carson, 2009; Carson, 2012). Let p_j be the probability that an individual is classified in underweight, overweight, and obese categories relative to the normal BMI category.

Multinomial Logit

$$\log\left(\frac{p_j}{p_{Normal}}\right) = \alpha + \beta_c Centimeters_i + \sum_{r=1}^{2}\beta_r Complexions_i + \sum_{a=1}^{16}\beta_a Age_i + \sum_{n=1}^{5}\beta_n Nativity_i$$

$$+\sum_{l=1}^{4}\beta_l Occupation_i + \beta_b\left(\frac{Butter_j}{Capita}\right) + \sum_{d=1}^{2}\beta_d Disease_i + \sum_{t=1}^{7}\beta_t Observation\,Decade_i + \varepsilon_t$$

and

Ordinary Least Squares

$$BMI_i = \alpha + \beta_c Centimeters_i + \sum_{r=1}^{2}\beta_r Complexions_i + \sum_{a=1}^{16}\beta_a Age_i + \sum_{n=1}^{5}\beta_n Nativity_i$$

$$+\sum_{l=1}^{4}\beta_l Occupation_i + \beta_b\left(\frac{Butter_j}{Capita}\right) + \sum_{d=1}^{2}\beta_d Disease_i + \sum_{t=1}^{7}\beta_t Observation\,Decade_i + \varepsilon_t$$

Stature in centimeters is included to account for the inverse relationship between BMI and height (Carson, 2009; Carson, 2012; Komlos and Carson, 2017). White, black, and mixed-race complexion dummy variables are included to account for the relationship between BMI and race (Carson, 2016, pp. 142-143). Annual youth age dummy variables are included to account for the positive relationship between BMI classification and youth ages. Adult age decade dummy variables are included to account for the positive relationship between BMI and adult ages. Nativity within the US illustrates the relationship between cumulative net nutrition and environment, and five regional nativity variables are included: Northeast, Middle-Atlantic, Great Lakes, Southeast, and Southwest. Occupation dummy variables are included for white-collar, skilled, farmers, and unskilled workers. A state-level index variable for butter per capita is included to account for the relationship between BMI and animal proteins (Hilliard, 1972; Carson, 2020). During the 19th century, cholera and malaria were two common mortalities, and state-level disease index values are included to account for the inverse relationship between BMI and disease mortality (Coelho and McGuire, 2011, Table C.1, pp. 241-242). There are two ways to evaluate BMIs over time. Measured since birth, average BMIs represent cumulative net nutrition as a cohort ages from birth through measurement period. Alternatively, BMIs measured by observation period represent current net nutrition for diverse cohorts facing the same conditions during the period of measurement. Subsequently, BMI measurements in Table 3 are for both net nutritional conditions for biological conditions as the same birth cohort varied throughout life and for diverse cohorts measured in the same period (Komlos and Brabec, 2010; Carson, 2019, p. 32).

Table 3, BMIs, Nutrition, Disease, Demographics, and Socioeconomic Effects

	Total	*Ln BMI*	*Total*	*Black*	*White*	*Youth*	*Adult*
Intercept	33.17***	355***	33.30***	36.91***	30.98***	34.42***	32.76***
Height							
Centimeters	-.062***	-.003***	-.062***	-.076***	-.049***	-.070***	-.059***
Complexion							
White	Reference	Reference	Reference		Reference	Reference	Reference
Black	1.26***	.054***	1.26***	.133***		1.11***	1.33***
Mixed-Race	1.18***	.052***	1.17***	Reference		1.09***	1.22***
Ages							
12	-4.62***	-.213***	-4.46***	-5.26***	-2.09	-4.87***	
13	-4.46***	-.205***	-4.30***	-5.11***	-1.83***	-4.72***	
14	-3.36***	-.148***	-3.20***	-3.87***	-2.27***	-3.53***	
15	-3.31***	-.148***	-3.16***	-3.64***	-2.90***	-3.46***	
16	-2.53***	-.112***	-2.41***	-2.96***	-1.98***	-2.64***	
17	-1.71***	-.075***	-1.60***	-1.99***	-1.40***	-1.77***	
18	-1.37***	-.060***	-1.28***	-1.62***	-1.09***	-1.39***	
19	-.859***	-.037***	-.791***	-1.01***	-.695***	-.859***	
20	-.523***	-.023***	-.475***	-.745***	-.308***	-.523***	
21	-.266***	-.012***	-.220***	-.320***	-.219***	-.237***	
22	-.180***	-.012***	-.149***	-.220***	-.157**	-.145**	
23-29	Reference	Reference	Reference	Reference	Reference	Reference	Reference
30s	.132***	.006***	.113***	.168***	.130***		.094**

40s	.279***	.011***	.264***	.254***	.300***		.231***
50s	.309***	.012***	.274***	.147	.402***		.244***
60s	.086	.002	.111	-.119	.215		-.005
70s	-.628	-.033	-.487	-1.27	-.420		-.739
Nativity							
Northeast	.106	.005	.087	-.523*	.121	-.176	.113
Middle Atlantic	-.391***	-.016***	-.411***	-.686***	-.313***	-.745***	-.316***
Great Lakes	.017	.001	.016	-.224	.022	-.031	.008
Plains	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Southeast	.124*	.006**	.138**	.131	.022	.275**	.034
Southwest	-.157**	-.007**	-.158**	.049	-.372***	-.251**	-.127
Occupations							
White-Collar	.065	.002	.066	-.374***	.234***	-.044	-.001
Skilled	.061	.003	.059	-.022	.154***	-.041	.014
Farmer	.283***	.013***	.264***	.071	.450***	.511***	.211***
Unskilled	.187***	.009***	.194***	.024	.314***	.374***	.073***
No Occupation	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Nutrition							
Butter	.019***	8.33^{-4}***	.019***	-.002	.016***	.023***	.173***
Disease							
Cholera	-.003**	-1.32^{-4}**	-.002	8.25^{-4}	-.006***	-.013***	-.001
Malaria	-.010**	-3.79^{-4}**	-.013***	8.70^{-4}	-.018***	-.004	-.019***
Observation Decade							
1860s	.250***	.011***		.280**	.207*	.298***	.316
1870s	.236***	.010**		.340***	.128***	.268***	.185***
1880s	Reference	Reference		Reference	Reference	Reference	Reference
1890s	.110***	4.21^{-04}		.017	.158***		.125***
1900s	.061	.002		-.118	.132		.096
1910s	.032	-2.12^{-4}		-.181	.101		.104
1920s	.928**	.033**		.474	.953**		1.03***
1930s	.055	-.005			-.117		.147
Birth Period							
1840s			.021				
1850s			Reference				
1860s			-.048*				
N	42,619	42,619	42,619	18,742	23,877	12,544	30,075

R^2	.1135	.1174	.1122	.1032	.0501	.1809	.0830

Notes: *** Significant at .01; ** significant at .05; * significant at .10.

Source: See Table 2.

Little is known about how late 19th century BMIs were related to nutrition, disease environment, and socioeconomic status, and three patterns emerge when evaluating late 19th century US male BMIs. First, fluid-milk is a preferred measure for the relationship between BMI, calcium, and protein; however, 19th century agricultural census fluid milk estimates are unavailable. Butter per capita proxies for access to dairy, and current net nutrition was positively related to dairy products (Table 3). In the 1840 through 1860 deci-annual censuses, late 19th century BMIs were higher in states that had greater access to butter and dairy output per capita. Dairy products provided sufficient quantities of animal proteins for comparatively inexpensive calories from dairy and cheese, while the more expensive meats were consumed less frequently (Brands, 2010, p. 202; Jankauskas and Grupe, 2019, p. 41). Animal proteins from slaughtered animals were expensive because meat was a short-lived agricultural resource, whereas animal proteins from dairy products were renewable and less expensive (Jankaukas and Grupe, 2019, p. 29; Meisner et al, 2019, p. 238). Protein and amino acids are essential in building muscle mass and providing calories necessary to withstand disease, and animal proteins are a primary source of proteins and fats from slaughtered animals (Scrimshaw, 2000, p. 1398). Furthermore, BMI responds to dairy consumption by race and age. Individuals of African descent did not synthesize the lactase enzyme the same as individuals of north European descent (Kiple, 1981, p. 84), and African-American BMIs were not significantly related to access to dairy production (Table 3, Model 4). Individuals of African-descent in North America were more likely to be lactase intolerant, subsequently, less likely to consume dairy products. (Table, 3; Kiple and

King, 1981, pp. 11 and 85; Kiple, 1977, p. 285). BMIs were also collectively related to nutrition, and the dairy restricted F-statistic is F(1, 42,580)=24.32, p=.000.

Table 4, Multinomial Logit for BMIs, Nutrition, Disease, Demographics, and Socioeconomic Effects

	Underweight	*Overweight*	*Obese*	*Underweight*	*Overweight*	*Obese*
Intercept						
Height						
Centimeters	1.04***	.965***	.888***	1.04***	.965***	.887***
Complexion						
White	Reference	Reference	Reference	Reference	Reference	Reference
Black	.421***	2.43***	2.01***	.421***	2.43***	1.99***
Mixed-Race	.383***	2.38***	1.64***	.382***	2.35***	1.55***
Ages						
12	172.60***	.247***	3.40^{-166}	127.74***	.276***	2.60^{-218}
13	77.21***	1.9^{-167}	.638	55.25***	1.40^{-203}	.755
14	16.16***	.118***	1.40^{-148}	12.38***	.132***	9.70^{-200}
15	22.84***	.105***	.317**	17.74***	.118***	.383*
16	10.98***	.130***	.229**	8.76***	.143***	.266**
17	4.69***	.279***	.362**	3.80***	.305***	.418*
18	4.04***	.376***	.359***	3.41***	.404***	.401**
19	2.47***	.490***	.471**	2.14***	.520***	.503*
20	1.49*	.614***	.446**	1.33	.644***	.473**
21	1.08	.786***	.898	.988	.818***	.947
22	1.31	.881**	.866	1.23	.906*	.881
23-29	Reference	Reference	Reference	Reference	Reference	Reference
30s	.903	1.16***	1.32*	1.04	1.11***	1.51***
40s	.846	1.25***	2.18***	1.19	1.21***	3.12***
50s	1.04	1.37***	2.04***	1.64***	1.30***	3.68***
60s	1.61	1.38**	1.27	2.78***	1.23**	3.45***
70s	6.17***	2.76**	.661	11.66***	2.26**	4.40
Nativity						
Northeast	.688	.991	1.20	.689	.978	1.08
Middle Atlantic	1.14	.701***	.571**	1.12	.693***	.469***
Great Lakes	.823	.920	1.14	.813	.919	1.10
Plains	Reference	Reference	Reference	Reference	Reference	Reference
Southeast	.857	1.06	1.07	.832	1.07	1.05
Southwest	1.34	.857**	1.18	1.27	.867**	1.06
Occupations						
White-Collar	1.27	1.10*	2.08***	1.30*	1.09	2.11***
Skilled	.924	.984	1.36**	.927	.977	1.34**

Farmer	.692**	1.14**	1.13	.701**	1.11**	1.12
Unskilled	.655***	1.14***	.993	.652***	1.14***	.999
No Occupation	Reference	Reference	Reference	Reference	Reference	Reference
Nutrition						
Butter	.962***	1.01***	1.01	.964***	1.01***	1.01
Disease						
Cholera	1.00	.996***	1.01	1.00	.997**	1.00
Malaria	.970*	.996	.983	.976	.992	.982
Observation Decade						
1860s	.687	.121**	1.53			
1870s	.780**	1.22***	1.66***			
1880s	Reference	Reference	Reference			
1890s	1.23	1.04	1.82***			
1900s	1.45*	1.06	1.95***			
1910s	1.63	.993	2.73***			
1920s	1.38	.815	10.85***			
1930s	3.99	.703	20.33***			
Birth Period						
1840s				1.26**	1.01	.946
1850s				Reference	Reference	Reference
1860s				1.30***	.977	1.02
N	42,619	42,619	42,619	42,619	42,619	42,619
R^2	.0631	.0631	.0631	.0620	.0620	.0620

Notes: *** Significant at .01; ** significant at .05; * significant at .10.

Source: See Table 2.

Second, current and cumulative net nutrition were inversely related to disease from calories required to withstand disease (Afshin, Sur, Fay, Cornaby, and Ferrara, 2019). Fogel (1986) was the first in historical economics to suggest a relationship between net nutrition and mortality, and there have been various follow-up studies that examine the relationship between stature and disease mortality. Garland Brinkley (1997) demonstrates that the 19th century decrease in stature and Southern agricultural output was partly the result of disease. Steckel (2000) indicates that identifying the relationship between stature, nutrition, and disease is difficult. Coelho and McGuire (2000, p. 232) indicate a considerable share of stature variation is related to disease, while Haines, Craig, and Weiss (2003) illustrate that both nutrition and disease have the expected relationships with stature variation. Komlos and Lauderdale (2007, p. 295) demonstrate that statures were related to disease, while Floud et al. (2011, p. 162) and Carson (2020) emphasize the role of disease in stature and net nutrition variation. This study compares the effects of epidemic diseases of cholera and malaria on BMI variation. Caloric demands for malaria were greater than cholera, and BMIs were lower for individuals in states with higher malaria mortality. Moreover, cholera and malaria are two epidemic diseases, indicating that current net nutrition may be inversely related to epidemic diseases, whereas stature—a measure for cumulative net nutrition—may be related to endemic diseases (Rosenberg, 1962, p. 17; Kiple, 2003, pp. 74-78 and 203-207; Carson, 2020). BMIs were also collectively related to disease, and the disease restricted F-statistics is $F(2, 42{,}580)=3.16$, $p=.0423$.

Third, there is considerable research for stature variation by net nutrition, disease, and race. Nevertheless, how historical BMIs varied by nutrition, disease, and race is yet to be considered. Individuals of African and European descent have the ability to reach similar adult average statures when brought to maturity under ideal biological conditions. However, ideal conditions may have varied between blacks and whites (Tanner, 1977; Carson, 2008; Carson, 2009). Steckel (1979) finds that average black statures were shorter than whites. Bodenhorn (1999) and Bodenhorn (2002) indicate this difference was attributed to 19^{th} century social preferences that disproportionately favored individuals with fairer complexions. Alternatively, if the black-white average stature difference was due to 19^{th} century social preferences, whites should have had greater BMIs and heavier weight than darker complexioned blacks. In fact, after controlling for nutrition and disease, the opposite is true, and late 19^{th} and early 20^{th} century

BMIs for individuals with darker complexions were greater than individuals with fairer complexions.

Multiple reinforcing explanations account for the relationship between BMI and race. BMIs are inversely related to height, and taller statures provide greater physical dimensions to distribute weight (Steckel, 1979; Carson, 2012; Komlos and Carson, 2017; Carson, 2009; Carson, 2008). After emancipation, blacks devoted a higher share of their incomes than whites to the acquisition of food and nutrition (Higgs, 1977, pp. 105-107). Nonetheless, greater black BMIs persist after controlling for stature, diet, and disease and a biological explanation may account for greater black BMIs (Curtin, 1969; Kiple, 1985, pp. 9-23). For example, muscle is heavier than fat, and individuals with darker skin pigmentation have greater protein in muscle tissue (Schutte et al. 1984; Wagner and Hayward, 2000; Barondess et al. 1997; Aloia et al. 1997). BMIs were also collectively related to skin complexion, and the complexion restricted F-statistic is $F(2, 42{,}580)=998.41$, $p=.000$.

Other patterns are consistent with expectations. Socioeconomic status is related to BMIs, and rural agricultural farmers systematically had greater BMIs than individuals in urban skilled and unskilled occupations (Carson, 2009; Carson, 2012; Komlos and Carson, 2017). While state-level nutrition and disease account for access to available calories to withstand the effects of disease, they do not account for relative access individuals had to nutrition associated with socioeconomic status, and individuals in close proximity to rural agriculture faced lower relative prices when acquiring nutrition and required fewer calories to withstand disease. BMIs were collectively related to socioeconomic status, and the occupation restricted F-statistic is $F(2, 42{,}580)=3.16$, $p=.0423$.

Because BMIs are evaluated in this study from birth year, this reflects conditions accruing to similar cohorts, and individuals from the Southeast had the greatest net nutrition, while individuals from the Middle Atlantic and Southwest had the lowest net nutrition (Ransom and Sutch, 1977, pp. 151-155; Atack and Bateman, 1987; Carson, 2009; Carson, 2012). However, interpreting BMI variation by nativity is complicated because BMIs are the ratio of weight to height, and Southern cumulative net nutrition exceeded other areas within the US. Middle-Atlantic and Northeastern net nutrition was lower because of regional weights (Table, 3). BMIs were collectively related to nativity, and the nativity restricted F-statistic is $F(5, 42{,}580)=26.00$, $p=.000$. Subsequently, 19^{th} century BMI variation was positively related to access to animal proteins in dairy, inversely related with disease exposure, and positively related to darker skin complexion.

V. Demographics, Occupations, and BMIs: Insights from Sensitivity Analysis

Body mass responds to two general characteristics: choice and non-choice characteristics. Choice characteristics are those over which individuals can alter, such as residence and occupation, whereas non-choice characteristics are genetic and pre-determined, such as gender and age. F-statistics test the significance when a set of collective variables are restricted from a model. They do not, however, address the collective magnitude for a set of variables relative to the unrestricted set of variables. The strength of association for collective effects is measured by the magnitude of collective effects when factors are omitted from a model (Miller, 2004, p. 37), and are calculated with the percentage change for a restricted model's sum of squared regression (SSR_r) relative to the unrestricted models sum of squared regressions (SSR_u).[3]

[3] SSE_u and SSE_r are unrestricted and restricted sum of squared errors.

$$\%\Delta SSR = \frac{SSR_r - SSR_u}{SSR_u} = \frac{SSE_u - SSE_r}{SST - SSE_u} = \frac{R_r^2 - R_u^2}{R_u^2} = \%\Delta R^2$$

Table 5, BMIs, Nutrition, Disease, Demographics, and Socioeconomic Stats Sensitivity Analysis

	Total	*Height Omitted*	*Complexion Omitted*	*Ages Omitted*	*Nativity Omitted*	*Occupations Omitted*	*Butter Omitted*	*Diseases Omitted*	*Observation Year Omitted*
Intercept	33.17***	22.48***	35.83***	30.94***	33.15***	33.21***	33.46***	33.02***	33.29***
Height									
Centimeters	-.062***		-.073***	-.049***	-.061***	-.062***	-.062***	.062***	-.062***
Complexion									
White	Reference	Reference		Reference	Reference	Reference	Reference	Reference	Reference
Black	1.26***	1.41***		1.26***	1.24***	1.28***	1.24***	1.26***	1.26***
Mixed-Race	1.18***	1.30***		1.20***	1.22***	1.14***	1.17***	1.19***	1.17***
Ages									
12	-4.62***	-3.40***	-4.54***		-4.54***	-4.64***	-4.59***	-4.62***	-4.48***
13	-4.46***	- 3.43*****	-4.33***		-4.36***	-4.47***	-4.42***	-4.46***	-4.32***
14	-3.36***	-2.60***	-3.27***		-3.28***	-3.36***	-3.33***	-3.35***	-3.21***
15	-3.31***	-2.72***	-3.30***		-3.26***	-3.33***	-3.29***	-3.31***	-3.17***
16	-2.53***	-2.11***	-2.56***		-2.48***	-2.54***	-2.51***	-2.53***	-2.42***
17	-1.71***	-1.44***	-1.77***		-1.68***	-1.72***	-1.69***	-1.70***	-1.61***
18	-1.37***	-1.19***	-1.41***		-1.34***	-1.38***	-1.35***	-1.36***	-1.29***
19	-.859***	-.778***	-.907***		-.830***	-.877***	-.839***	-.854***	-.797***
20	-.530***	-.477***	-.574***		-.512***	-.549***	-.516***	-.527***	-.479***
21	-.266***	-.247***	-.279***		-.247***	-.279***	-.254***	-.262***	-.223***
22	-.180***	-.176***	-.175***		-.166***	-.186***	-.172***	-.177***	-.152***
23-29	Reference	Reference	Reference		Reference	Reference	Reference	Reference	Reference
30s	.132***	.115***	.087**		.110***	.132***	.115***	.124***	.113***
40s	.279***	.275***	.218***		.244***	.289***	.248***	.267***	.266***
50s	.309***	.339***	.201**		.257***	.318***	.266***	.285***	.279***

60s	.086	.140***	-.033		.009	.103	.031	.049	.123
70s	-.628	-.657	-.783		-.713	-.611	-.697	-.680	-.471
Nativity									
Northeast	.106	.169	-.095	.109		.080	.080	.209*	.089
Middle Atlantic	-.391***	-.244***	-.465***	-.293***		-.427***	-.300***	-.302***	-.403***
Great Lakes	.017	.030	-.084	.044		.003	.076	.077	.018
Plains	Reference	Reference	Reference	Reference		Reference	Reference	Reference	Reference
Southeast	.124*	.085	.374***	.092		.108	.026	.190***	.145**
Southwest	-.157**	-.289***	.326***	-.076		-.132**	-.128*	-.136**	-.147**
Occupations									
White-Collar	.065	.078	-.161***	.206***	.053		.072	.059	.062
Skilled	.061	.068	-.149***	.207***	.053		.070*	.055	.057
Farmer	.283***	.224***	.098*	.403***	.292***		.288***	.275***	.258***
Unskilled	.187***	.174***	.126***	.268***	.185***		.195***	.179***	.192***
No Occupation	Reference	Reference	Reference	Reference	Reference		Reference	Reference	Reference
Nutrition									
Butter	.019***	.019***	-.001	.005	-.007***	.020***		.021***	.018***
Disease									
Cholera	-.003**	-.002	-.004***	.006***	-.001	-.002	-.003**		-.001
Malaria	-.010**	-.014***	-.004	-.032***	-.009**	.007	-.015***		-.015***
Observation Decade									
1860s	.250***	.259***	.187**	-.804***	.310***	.255***	.235***	.242***	
1870s	.236***	.229***	.226***	-.173***	.248***	.228***	.226***	.229***	
1880s	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	
1890s	.110***	.162***	.066	.353***	.148***	.114***	.128***	.119***	
1900s	.061	.110	.010	.403***	.141**	.056	.093	.076	
1910s	.032	.100	-.053	.367***	.164	.027	.080	.058	
1920s	.928**	1.01**	.824**	1.13***	1.11***	.943	.985**	.971**	
1930s	.055	.066	-.076	-.068	.253	.045	.171	.115	

N	42,619	42,619	42,619	42,619	42,619	42,619	42,619	42,619	42,619
R^2	.1135	.0885	.0737	.0824	.1108	.1125	.1130	.1134	.1122
RMSE	2.4188	2.4527	2.4724	2.4604	2.4223	2.4200	2.4195	2.4189	2.4205

Notes: *** Significant at .01; ** significant at .05; * significant at .10.

Source: See Table 2.

BMIs and stature vary the most with non-choice characteristics (Carson, 2018, HM). For example, the complexion restricted percentage change in R^2 is negative 35.07 percent, negative 27.40 percent for age, and negative 22.03 percent for height. Individuals also do not choose nativity, and the nativity restricted R^2 is negative 2.38 percent. Collective choice variation by occupations is negative .881 percent, negative 1.15 percent for observation years, negative .441 percent for nutrition, and only negative .088 percent for disease. Subsequently, the percent magnitude of BMI variation associated with non-choice characteristics are the majority of current net nutrition variation, and state-level nutrition and disease collectively had little effect on BMI variation.

VI. Decomposing Biological Differences by Complexions and Characteristics

Little is known about how historical black and white BMIs were affected by nutrition, disease, and race. A Blinder-Oaxaca decomposition separates black and white BMI return differences into structural returns to characteristics and compositional characteristic differences. Let BMI_h and BMI_l equal high and low body mass, respectively. θ_{0h} and θ_{0l} are autonomous BMI components explained by the intercept. θ_{1h} and θ_{1l} are the BMI returns to high and low characteristics, such as access to dairy products and disease. High and low average compositional characteristic matrices are $\overline{X}_h$ and $\overline{X}_h$. Because blacks have higher BMIs, they are considered to be the base structure, whereas adults are classified as the base structure by age (Carson, 2009; Carson, 2012).

High BMI Function: $BMI_h = \theta_{0h} + \theta_{1h}\overline{X}_h$

Low BMI Function: $BMI_l = \theta_{0l} + \theta_{1l}\overline{X}_l$

The high and low BMI gap is:

$$\Delta BMI = BMI_h - BMI_l = BMI_h = \theta_{0h} + \theta_{1h}\overline{X}_h - \theta_{0l} + \theta_{1l}\overline{X}_l$$

Decomposing the BMI difference is constructed by selecting appropriate counterfactuals, which are high BMI returns to characteristics observed at low average returns to characteristics and low BMI returns to characteristics observed at high average return to characteristics.

$$\theta_h\overline{X}_l - \theta_h\overline{X}_l = 0$$

$$\theta_l\overline{X}_h - \theta_l\overline{X}_h = 0$$

Corresponding Oaxaca decompositions are

$$\Delta BMI = BMI_h - BMI_l = \left(\theta_{0h} - \theta_{0l}\right) + \left(\theta_{1h} - \theta_{1l}\right)\overline{X}_h + \left(\overline{X}_h - \overline{X}_l\right)\theta_l$$

$$\Delta BMI = BMI_h - BMI_l = \left(\theta_{0h} - \theta_{0l}\right) + \left(\theta_{1h} - \theta_{1l}\right)\overline{X}_l + \left(\overline{X}_h - \overline{X}_l\right)\theta_l$$

The first right hand side element, $\left(\theta_{0h} - \theta_{0l}\right)$, is the BMI difference explained by unobserved differences in the intercept. The second right-hand side differences, $\left(\theta_{1h} - \theta_{1l}\right)\overline{X}_h$ and $\left(\theta_{1h} - \theta_{1l}\right)\overline{X}_l$, are the high and low differences observed at the $\overline{X}_h$ and $\overline{X}_l$ counterfactuals, respectively. The third right hand side elements, $\left(\overline{X}_h - \overline{X}_l\right)\theta_h$ and $\left(\overline{X}_h - \overline{X}_l\right)\theta_l$ are the high and low BMI differences observed at high and low returns to average characteristics, θ_{1h} and θ_{1l}.

Table 6, Height and Weight Regressions by Nutrition, Disease, Demographics, and Socioeconomic Status

	Height (cm)	*Weight (kg)*	*Height (cm)*	*Weight (kg)*	*Youth BMIs*	*Adult BMIs*
Intercept	172.43***	-40.54***	172.47***	-40.14***	27.80***	33.16***
Height						
Centimeters		.623***		.623***	-.033***	-.060***

Complexion						
White	Reference	Reference	Reference	Reference	Reference	Reference
Black	-2.41***	3.74***	-2.40***	3.74***	1.12***	1.31***
Mixed-Race	-1.92***	3.50***	-1.90***	3.47***	1.17***	1.18***
Ages						
12	-19.70***	-10.26***	-19.54***	-9.81***		
13	-16.66***	-10.80***	-16.45***	-10.33***		
14	-12.21***	-8.50***	-12.07***	-8.07***		
15	-9.59***	-8.87***	-9.46***	-8.44***		
16	-6.83***	-6.89***	-6.71***	-6.54***		
17	-4.39***	-4.79***	-4.27***	-4.48***		
18	-2.80***	-3.89***	-2.70***	-3.65***		
19	-1.31***	-2.50***	-1.20***	-2.30***		
20	-.857***	-1.52***	-.769***	-1.37***		
21	-.291*	-.776***	-.209	-.647***		
22	-.052	-.534***	.025	-.448***		
23-29	Reference	Reference	Reference	Reference		
30s	.269**	.405***	-.158*	.353***		
40s	.074	.831***	-.690***	.789***		
50s	-.498**	.909***	-1.45***	.817***		
60s	-.866**	.291	-2.02***	.370		
70s	.465	-1.78	-.676	-1.35		
Nativity						
Northeast	-1.01***	.309	-.991***	.255	-.002	.070
Middle Atlantic	-2.38***	-1.12***	-2.31***	-1.17***	-.484***	-.373***
Great Lakes	-.199	.061	-.186	.058	.065	.010
Plains	Reference	Reference	Reference	Reference	Reference	Reference
Southeast	.625***	.297	.624***	.338*	.125	.006
Southwest	2.13***	-.563***	2.17***	-.562***	-.175	-.181**
Occupations						
White-Collar	-.214	.212	-.240*	.214	.268**	.047
Skilled	-.113	.182	-.113	.176	.234***	.053
Farmer	.947***	.830***	.942***	.776***	.695***	.248***
Unskilled	.216**	.544***	.211**	.563***	.419***	.093**
No Occupation	Reference	Reference	Reference	Reference	Reference	Reference
Nutrition						
Butter	-.009	.057***	-.013	.057***	.002	.017***
Disease						
Cholera	-.012***	-.009**	-.009**	-.007	-.001	-.001
Malaria	.069***	-.030**	.069***	-.040***	-.021**	-.022***
Observation						

Decade						
1860s	-.143	.699***				
1870s	.118	.674***				
1880s	Reference	Reference				
1890s	-.840***	.315**				
1900s	-.795***	.174				
1910s	-1.11***	.101				
1920s	-1.28*	2.62**				
1930s	-.177	.222				
Birth Period						
1840s			.143	.038		
1850s	Reference	Reference	Reference	Reference		
1860s			-.175**	-.133		
N	42,619	42,619	42,619	42,619	12,544	30,075
R^2	.1017	.3357	.1006	.3347	.0880	.0802

Notes: *** Significant at .01; ** significant at .05; * significant at .10.

Source: See Table 2.

Table 7, Black-White BMI by Nutrition, Disease, and Socioeconomics Status Oaxaca

Race	$(\beta_b - \beta_w)\bar{X}_w$	$(\bar{X}_b - \bar{X}_w)\beta_b$	$(\beta_b - \beta_w)\bar{X}_w$	$(\bar{X}_b - \bar{X}_w)\beta_b$
Level				
Sum	.665	.269	1.11	-.175
Total		.934		.934
Proportions				
Intercept	6.35		6.35	
Height	-4.96	.065	-4.94	.041
Ages	-.097	-.173	-.130	-.140
Nativity	-.126	.296	.124	.046
Occupation	-.278	.036	-.264	-.009
Nutrition	-.279	.010	-.190	-.079
Disease	.146	.001	.183	-.036
Observation Period	-.046	.054	.019	-.011
Sum	.712	.288	1.19	-.187
Total		1		1
Age	$(\beta_a - \beta_y)\bar{X}_y$	$(\bar{X}_a - \bar{X}_y)\beta_y$	$(\beta_a - \beta_y)\bar{X}_a$	$(\bar{X}_a - \bar{X}_y)\beta_y$
Levels				
Sum	.711	-.204	.661	-.154
Total		.507		.507
Proportions				
Intercept	10.59		10.59	
Height	-9.15	-.105	-9.20	-.057
Complexions	.115	-.343	.090	-.317
Nativity	-.091	-.041	-.049	-.083
Occupations	-.405	.040	-.495	.130
Nutrition	.360	.023	.380	.002
Disease	-.015	.022	-.013	.021
Sum	1.40	-.403	1.30	-.301
Total		1		1

Source: See Tables 2 and 3.

Using coefficients from Table 3, Models 4 and 5, there was a nearly one unit BMI difference between black and white BMIs. However, the sources of structural and compositional differences are significant. From proportional differences in black and white returns to cumulative net nutrition, the greatest source of black returns by race was the autonomous intercept. Among returns to characteristics, white returns to height, nutrition, and socioeconomic status were the largest component to black and white characteristics. Whites had greater returns to age, but much of the age-related BMI difference was associated with compositional effects rather than returns to characteristics, indicating less of a causal black and white BMI explanation by age.

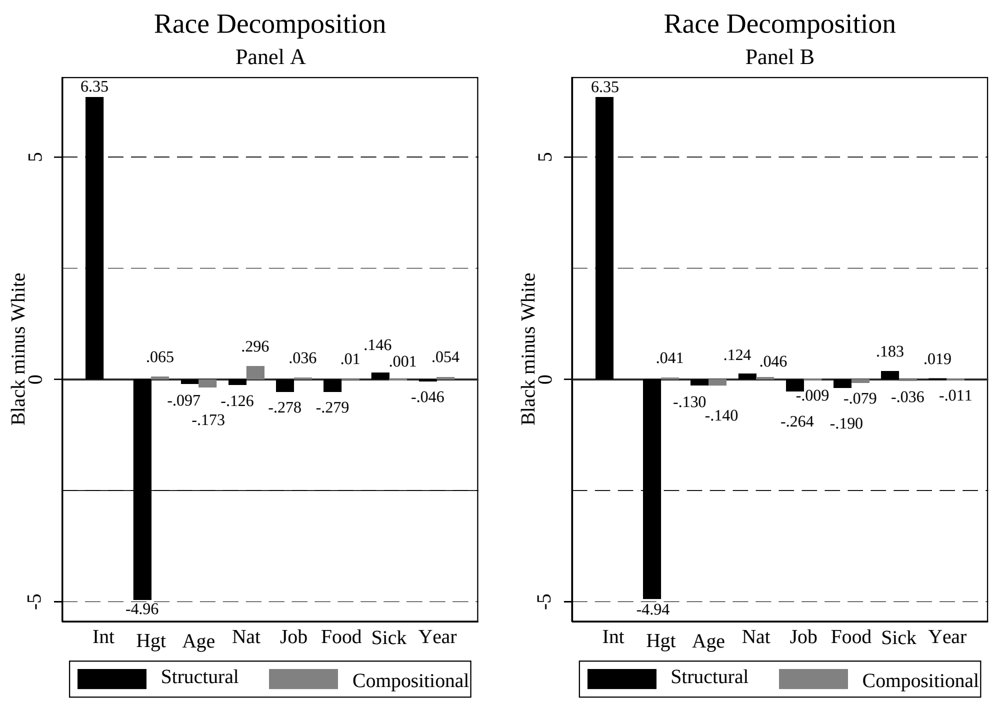

Figure 2, Late 19th and Early 20th Century Black and White BMI Sources of BMI Variation

Using coefficients from Table 3, Models 6 and 7 there was a smaller difference between BMIs by age; and there was only half of one BMI unit difference by age. The greatest source of BMI difference by age was in the adult unobservable advantages in the intercept. Youths had the greatest returns to cumulative net nutrition. Youths also had the greatest BMI returns to occupations, disease, and nativity, while adults had the greatest BMI returns to complexions and nutrition.

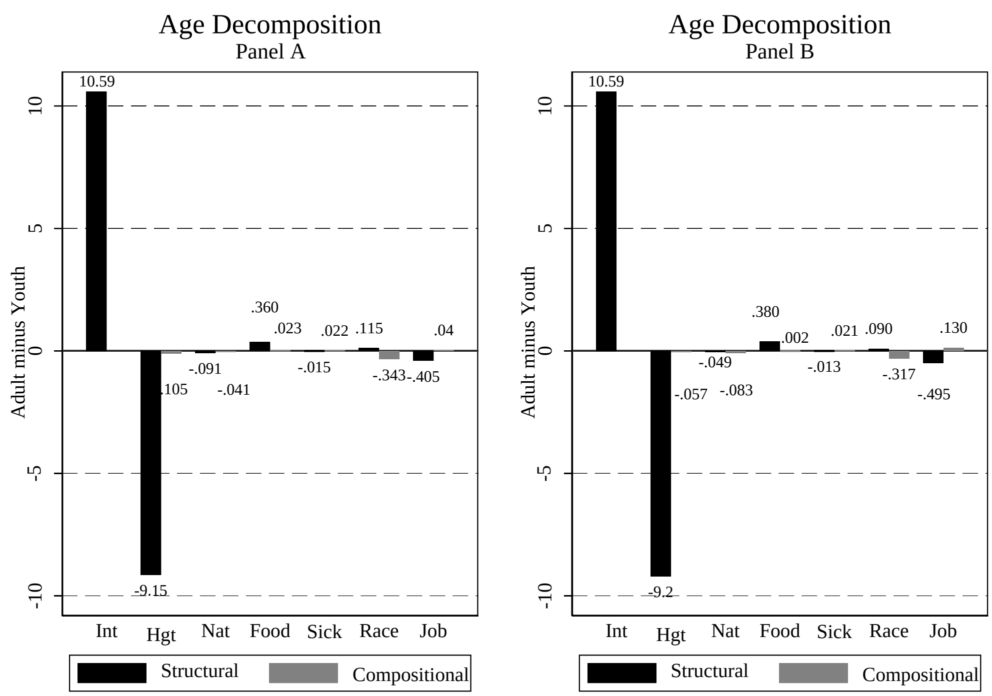

Figure 3, Late 19th and Early 20th Century Youth and Adult Sources of BMI Variation

VII. Conclusion

The long-run dynamics of health and net nutrition in policy formation outlines the contours of US economic development. When monetary measures are scarce or unreliable, BMIs are used to evaluate access to net nutrition and health. Before the modern obesity epidemic, when other measures for economic welfare are scarce or unreliable, BMIs are used to evaluate access to material welfare. When available, fluid milk is a preferred measure to test the relationship between dairy production and net nutrition. Butter per capita is a proxy for fluid milk per capita and was positively related to 19th century BMIs. Reflecting biological differences between blacks and whites, African-Americans are more likely to be lactase intolerant, and black BMIs did not respond to butter per capita, whereas white BMIs were positively related to butter per capita. Net nutrition and BMIs were negatively related to disease exposure, and cholera and malaria mortalities are two 19th century epidemic diseases that were negatively related to BMIs. While individuals of African and European descent have the ability to reach similar terminal statures when brought to maturity under ideal net nutrition, 19th century blacks were shorter than whites. Subsequently, net nutrition was positively related to access to 19th century dairy production, negatively related to malaria and cholera, and BMIs were higher for individuals with darker complexions.

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