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Abstract

Peer and cohort effects are important in health economics, and obesity may be related to social relationships, where obese individuals interact with other obese individuals. There were significant 19th century cohort effects, where BMIs were related to the cohort that an individual belonged. After accounting for individual relationships between BMI, demographic, socioeconomic, and residential characteristics, there were significant cohort effects associated with race, residence, and age. Moreover, cohort effects reduce the size of the individual relationships between BMI, race, and age, but results are mixed for BMI and residence. This indicates that historical cohort effects are important in BMI and obesity studies.

JEL-Codes: C100, C400, D100, I100, N300.

Keywords: 19th century BMIs, health cohort effects.

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I. Introduction

Cohort effects in the social sciences describe variations over time among individuals with a shared attribute or common life experience, such as birth period, socioeconomic status, and age. Network or peer effects are similar, however, reflect greater degrees of social connectedness, where cohort effects principally reflect the association of a characteristic, whether or not social or cognitive relationships are present. Cohort effects are ubiquitous and are particularly relevant in medical, epidemiological, and economic studies. For example, health and economic studies emphasize peer and network effects in youth smoking decisions, and teenagers are more likely to smoke if someone they are associated with smokes (Powell, Taurus, and Ross, 2005). However, smoking is a cognitive characteristic. Other health related variables—such as obesity—involve non-cognitive characteristics but are still related to health outcomes. This study, therefore, considers historical BMI cohort effects by race, age, socioeconomic status, and residence for 19th century weight variation to determine the magnitude that cohort effects had in historical obesity studies and health outcomes and how individual effects change after cohort effects are considered.

The body mass index (BMI) is defined as weight in kilograms divided by height in meters squared. Although more precise measures should be used when available, obesity is classified as a body mass index over 30, and BMIs and obesity increase when body weight is high but is low when stature is high. By modern standards, 19th century African-American and white BMIs were in normal weight categories and remained constant throughout the late 19th and early 20th centuries (Carson, 2009b; Carson, 2016). BMI is frequently interpreted as a measure for current net nutrition, and there is considerable debate regarding the source of the modern obesity epidemic (Cawley, 2011; Rashad and Komlos, 2016). The typical explanation for the rise of the modern obesity epidemic is an excess of calories consumed over calories expended for work and to fend off disease.

There are alternative obesity explanations beyond calories consumed versus calories expended (Offer, Pechey, and Ulijaszek, 2012; Popkin, 2009). For example, the types of calories consumed may also account for obesity, and consuming diets rich in saturated fats and simple sugars is related to insulin resistance, which prompts various hormonal responses associated with obesity (Popkin, 1993; Popkin, 2009; Riera-Crichton and Tefft, 2014). A related explanation for BMI variation is stress, which can trigger hormonal responses associated with obesity, and these hormonal secretions are related to weight gain and the dispersion of fat (Rosmund and Björntorp, 1998; Rudman et al. 1990, pp. 1 and 5). For example, the steroid cortisol is a hormone that is released under stressful conditions. Adiponectin is a protein that regulates fatty acid breakdown and glucose levels and is inversely related to adult percent body fat. Leptin is a cell signaling protein secreted by adipose tissue that regulates appetite, energy intake, hunger, and metabolism. Ghrelin is the amino acid counterpart of the hormone leptin that lines the stomach and increases before meals are consumed and decreases after consumption. Leptin regulates long-term energy balance by suppressing food intake and weight loss, while Ghrelin may play a role in meal initiation. As a result, imbalances between leptin and ghrelin may contribute to obesity (Klok, Jakobsdottir, and Drent, 2007). In sum, there are various explanations proposed for the modern obesity epidemic that are not well understood for historical populations associated with BMI cohort effects.

One recent explanation is that fat and obesity are related to peer effects, and modern populations may become obese when they associate with obese individuals (Christakis and Fowler, 2007; Fletcher, 2011; Cawley, 2015, pp. 253-254). A spill-over or peer effect occurs when a cost or benefit accrues to third parties not involved in an exchange, and if individuals adopt the diets and lifestyles of those with whom they associate, dietary and physical peer effects may develop. However, not all observed within-group variation is due to peer effects running from social relationships with the cohort an individual identifies. For example, age is an important cohort effect that is not necessarily related to peer effects because individuals in the same age category face similar biological processes, and it is clear that part of an individual's BMI is related to individual non-peer factors associated with their age classification (Sorkin et al. 1999). These cohort effects are observed in modern populations (Christakis and Fowler, 2007), but nothing is known whether there were cohort effects in historical populations and how these effects changed over time (Dawes, 2014, p. 30). To analyze historical BMI cohort effects, this study considers black and white race, age, residence, and occupation cohort-effects for working class males in the late 19th and early 20th century United States.

It is against this backdrop that this study considers three paths of inquiry into late 19th and early 20th century BMI cohort effects. First, using average male BMIs by ethnicity, this study demonstrates that there were considerable race, age, occupation, and cohort effects. Second, it is well-documented that African-American BMIs were historically greater than whites (Costa, 2004; Carson, 2009; Carson, 2012; Carson 2015a), and there are biological differences that go beyond social conditions that contribute to heavier black BMIs (Heyward and Wagner, 1997; Barondess et al. 2000; Carson, 2008; Carson, 2009; Carson, 2014). Third, individuals in the same socioeconomic cohort face similar nutrition, disease environment, and physical activity.

How were 19th century BMIs related to socioeconomic cohort effects? When occupations are included, individual relationships between BMIs and occupations are significant, but occupation cohort effects are not significant, illustrating that BMIs are related to individual conditions by socioeconomic status and not cohort effects.

II. Peer, Cohort Effects, and Assortative Mating

Health and obesity may be related to cohort effects, where obese individuals are more likely to associate with individuals of similar weight and physical activity levels. These modern BMI peer effects are first considered by Christakis and Fowler (2007), who demonstrate that the likelihood a person is obese increases by 57% if they have a friend who is obese. These social relationships extend to family members, and if a sibling is obese, it increases the likelihood of obesity by 40% (Christakis and Fowler, 2007, pp. 370, 375-377). Christakis and Fowler also find that there are three degrees of social separation between individuals before social relationships are no longer significant, which indicates peer effects are limited to only a few degrees of separation (Dunbar, 2013, pp. 62-65). Assortative mating is the pattern where individuals with similar geno or phenotypes mate with each other more often than is related to random variation, and assortative mating on BMIs may be associated with the obesity epidemic (Silventoinen et al. 2003). However, obese individuals do not necessarily become obese after associating with obese individuals but may choose to associate with other obese individuals, indicating that the strength of the association remains suggestive.

While the peer effects that Christakis and Fowler (2007) and Silventoinen et al (2003) observe are novel contributions to the obesity literature, it has not gone without challenge, and it was not long before the peer-effect causal interpretation came under examination (Renna, Grafova, and Thokur, 2008; Cohen-Cole, and Fletcher, 2004). Cohen-Cole and Fletcher (2008), Trogden, Nonemaker, and Paise (2008), and Reena, Grafova, and Thakur (2008) find that the relationship between obesity and peer effects does not exist or is limited only to females after accounting for endogenous relationships. These studies consider within group variation to be the result of peer effects or social networks, when the relationships are age, socioeconomic status, and residence cohort effects. These studies take advantage of large-scale randomly selected data sets, instrumental variables, and panel data to show that this obesity relationship may not exist after accounting for reverse causation and omitted variables. Moreover, peer effects are not cohort effects, and this study considers how historical BMIs varied with individual and cohort effects.

There are at least three non-causal reasons why obese individuals associate with other obese individuals: endogenous or causal effects, exogenous or contextual effects, and correlation effects. First, endogenous effects occur when peer weights influence the weight of those with whom they associate (Renna, Grafova, and Thokur, 2008, p. 378). Second, exogenous effects exist when peer characteristics interact with the likelihood of obesity other than how weight influences BMI. For example, contextual effects—such as income, race, education, and weight gain—are associated as other comingling factors. Third, correlation effects occur when obese individuals choose to associate with other obese individuals, making the observed positive relationship between obesity and peer effects a product of selection, which produces the perceived relationship between obesity and peer effects rather than a genuine causal relationship. In sum, there are important cohort effects associated with obesity and BMIs; however, how these relationships interacted and how they varied overtime are not well understood and require greater attention.

III. Nineteenth Century Black and White Males in US Prisons

To consider historical BMI and obesity cohort effect variation across characteristics requires a large 19^{th} and the 20^{th} century data set. The two most common sources of historical BMI measurements are military and prison records. Nineteenth century educational opportunities were higher in the military, indicating that historical military records reflect conditions among higher socioeconomic groups (Sokoloff and Vilaflor, 1982, pp. 456-458; Ellis, 2004, p. 27; Komlos, 1987; Coclanis and Komlos, 1995, p. 93). One common shortfall of military samples—which may have been related to BMI distributions—is a truncation bias imposed by minimum stature requirements (Fogel et al, 1978, p. 85; Sokoloff and Vilaflor, 1982, p. 457, Figure 1). Fortunately, prison records do not suffer from such a constraint and the subsequent truncation bias observed in military samples, and prison records represent conditions among the working class. However, prison records are not above scrutiny. For example, prison records may represent many of the materially poorest individuals who were drawn from lower socioeconomic groups, that segment of society most vulnerable to economic change (Bogin, 1991, p. 288; Komlos and Baten, 2004, p. 199; Steckel et al. 2019). Law enforcement may have incarcerated some of the materially poorest individuals who turned to theft to survive. On the other hand, prison records may have selected many of the most physically fit individuals who turned to crime because their physical size gave them an advantage in assault crimes, and law enforcement may have incarcerated taller, more physically fit individuals under the presumption that larger stature and greater physical size represented guilt.

Table 1, Nineteenth Century US State Penitentiaries

Prison	*Black*		*White*	
	N	*Percent*	*N*	*Percent*
Arizona	194	.29	2,156	2.93
Colorado	483	.71	3,502	4.76
Idaho	36	.05	575	.78
Kentucky	6,167	9.09	6,602	8.97
Missouri	4,294	6.33	7,987	10.85
New Mexico	344	.51	1,993	2.71
Oregon	45	.07	1,683	2.29
Pennsylvania	2,685	3.96	11,214	15.24
Philadelphia	5,481	8.08	11,411	15.51
Tennessee	20,942	30.88	10,384	14.11
Texas	27,154	40.04	16,083	21.85
Total	67,825	100.00	73,590	100.00

Source: All state prison repositories were contacted and available records were acquired and entered into a master data set. These prison records include Arizona, California, Colorado, Idaho, Illinois, Kansas, Kentucky, Missouri, Montana, Nebraska, New Mexico, Ohio, Oregon, Pennsylvania, Texas, and Washington.

The data used here is part of a large 19th century prison sample.[1] Most blacks in the sample were imprisoned in the Deep South or Border States—Kentucky, Missouri, and Texas. Most whites were imprisoned in Pennsylvania and Texas, but whites were also from the Far West (Table 1). Physical descriptions were recorded by prison enumerators at the time of incarceration as a means of identification, therefore, reflect pre-incarceration occupations. Between 1840 and 1920, prison officials regularly recorded the dates inmates were received, age,

[1] All state prison repositories were contacted and available records were acquired and entered into a master data set. These prison records include Arizona, California, Colorado, Idaho, Illinois, Kansas, Kentucky, Missouri, Montana, Nebraska, New Mexico, Ohio, Oregon, Pennsylvania, Texas, and Washington (Table 1).

complexion, nativity, stature, pre-incarceration occupation, and crime. All records with complete age, stature, weight, occupations, and nativity are included in this study. Because in the event that inmates escaped and were recaptured, there was care recording inmate height and weight measurements, and accurate recordings had legal implications for identification. Arrests and prosecutions across states may have resulted in various selection biases that affect the results of this analysis. However, black and white stature variations across US prisons are consistent with other historical health studies (Costa, 2004; Cuff, 1994). Because the purpose of this study is 19th century black and white male weights, females and immigrants are excluded from the analysis.

Inmate enumerators were thorough when recording complexion and pre-incarceration occupation. Enumerators recorded inmates' race in a complexion category, and African-Americans were recorded as black, light-black, dark-black, and various shades of "mulattos" (Komlos and Coclanis, 1997). Enumerators recorded white complexions as light, medium, dark, and fair. The white inmate complexion classification is supported further by European immigrant complexions because European inmates were always of fair complexion and recorded in US prisons as light, medium, and dark. Until the 1930s, in both prison and census records, individuals of combined African and European descent were classified as mulatto. However, in the results that follow, individuals of African and European ancestry are referred to as "mixed race." While mixed-race inmates possessed genetic traits from individuals of African and European ancestry, they were treated as blacks in the 19th century US and when comparing blacks to whites, mixed-races are grouped here with blacks. The Arizona prison was the only prison that recorded photographs with complexion classification, and it is clear from these prison records that individuals classified as mixed-races had fair complexions and of African and

European decent. These complexion recordings demonstrate that ethnicity in the prison sample generates a unique and reliable comparison for historical US blacks, mixed-race, and whites.

Enumerators recorded a broad range of occupations and defined them narrowly, recording over 200 different occupations, which are classified here into four categories. Merchants and high skilled workers are classified as white-collar workers. Light manufacturing, craft workers, and carpenters are classified as skilled workers. Workers in the agricultural sector are classified as farmers. Laborers and miners are classified as unskilled workers (Tanner, 1977, p. 346; Ladurie, 1979; Margo and Steckel, 1992; p. 520). A final category is included of individuals without or illegibly listed occupations. However, because their physical size may have had greater returns in physically demanding agricultural occupations, greater BMIs reflect both net nutrition and occupation comparative advantage, where individuals with greater BMIs were in agricultural occupations (Margo and Steckel, 1992, p. 518; Steckel and Haurin, 1994, pp. 120-122).

Table 2, National BMI Cohort Effects

Blacks					*Whites*				
Ages	N	%	BMI	S.D.	*Ages*	N	%	BMI	S.D.
Teens	14,045	20.74	22.60	2.33	Teens	10,037	13.64	21.72	2.80
20s	36,131	53.27	23.79	2.70	20s	36,609	49.75	22.54	2.34
30s	11,074	16.33	24.04	2.47	30s	16,191	22.00	22.86	2.54
40s	4,216	6.22	24.23	2.62	40s	6,841	9.30	23.14	2.78
50s	1,678	2.47	24.35	2.63	50s	2,841	3.86	23.24	2.94
60s	557	.82	24.15	2.54	60s	896	1.22	23.04	3.24
70s	124	.18	23.56	2.51	70s	175	.24	23.32	3.60
Decade Received					*Decade Received*				
1840s	20	.03	23.98	1.98	1840s	165	.22	23.43	2.60
1850s	55	.08	24.06	3.32	1850s	839	1.14	22.49	2.18
1860s	980	1.44	23.94	2.71	1860s	1,307	1.78	22.79	2.38
1870s	7,615	11.23	23.92	2.49	1870s	8,748	11.89	22.35	2.30
1880s	12,510	18.44	23.61	2.44	1880s	10,888	14.80	22.58	2.30
1890s	14,285	21.06	23.68	2.37	1890s	14,115	19.18	22.71	2.44
1900s	16,319	24.06	23.57	2.38	1900s	17,782	24.16	22.65	2.46
1910s	15,092	22.25	23.48	3.30	1910s	18,536	25.19	22.50	2.99
1920s	949	1.40	23.62	2.47	1920s	1,210	1.64	22.61	2.81
Occupations					*Occupations*				
White-Collar	1,747	2.58	23.48	2.48	White-Collar	7,024	9.54	22.60	2.79
Skilled	5,147	7.59	23.67	2.57	Skilled	16,396	22.28	22.67	2.76
Farmer	6,411	9.45	23.80	2.37	Farmer	7,307	9.93	22.68	2.45
Unskilled	38,553	56.84	23.57	2.76	Unskilled	32,292	43.88	22.57	2.49
No Occupation	15,967	23.54	23.71	2.45	No Occupation	10,571	14.36	22.39	2.38
Nativity					*Nativity*				
Northeast	2,727	4.02	23.21	2.23	Northeast	10,328	14.03	22.39	2.36
Middle Atlantic	3,384	4.99	23.51	2.34	Middle Atlantic	15,014	20.40	22.86	2.41
Great Lakes	1,223	1.80	23.47	2.50	Great Lakes	6,107	8.30	22.84	3.83
Plains	3,594	5.30	23.36	5.08	Plains	8,168	11.10	22.37	2.43
Southeast	36,376	53.63	23.76	2.45	Southeast	22,048	29.96	22.54	2.47
Southwest	20,292	29.82	23.52	2.42	Southwest	9,900	13.45	22.39	2.34
Far West	229	.34	23.57	2.39	Far West	2,025	2.75	22.82	2.32
Prison					*Prison*				

Arizona	194	.29	23.34	2.20	Arizona	2,156	2.93	22.78	2.39
Colorado	483	.71	24.08	2.52	Colorado	3,502	4.76	23.24	2.45
Idaho	36	.05	23.89	2.64	Idaho	575	.78	22.77	2.36
Kentucky	6,167	9.09	23.33	2.55	Kentucky	6,602	8.97	22.31	2.40
Missouri	4,294	6.33	23.08	4.72	Missouri	7,987	10.85	22.04	3.47
New Mexico	344	.51	23.82	2.68	New Mexico	1,993	2.71	22.93	2.65
Oregon	45	.07	24.65	2.56	Oregon	1,683	2.29	23.59	2.29
Pennsylvania	2,685	3.96	23.60	2.33	Pennsylvania	11,214	15.24	22.93	2.41
Philadelphia	5,481	8.08	23.45	2.26	Philadelphia	11,411	15.51	22.33	2.32
Tennessee	20,942	30.88	23.84	2.43	Tennessee	10,384	14.11	22.82	2.49
Texas	27,154	40.04	23.65	2.42	Texas	16,083	21.85	22.42	2.37

Source: See Table 1.

Table 2 presents black and white inmates' proportions by age, birth decade, occupations, and nativity. Whites were a larger portion of the prison population than blacks; 52 percent of the US prison population was white. However, blacks were a larger proportion of the prison population than they were of the general population (Haines, 2000, Table 8.1, p. 306; Steckel, 2000b, Table 10.1, p, 435). Age percentages demonstrate that black inmates were incarcerated at younger ages, while whites were incarcerated at older ages. To primarily prevent blacks from not working after the Civil War, various vagrancy laws were established that imprisoned persons for not working (Brands, 2010, p. 156). For both blacks and whites, young inmates were more likely to be incarcerated than adults (Hirshci and Gottreddson, 1983; Gottfreddson and Hirshci, 1990). During the early 19th century, blacks were less likely to be incarcerated because their incarceration imposed costs on slave owner's foregone earnings. However, with passage of the 13th amendment, slave owners no longer had claims on black labor, and free blacks who broke the law were turned over to state penal systems to pay the social cost of their crime.[2] Nineteenth

[2] Southern law evolved to favor plantation law, which generally allowed slave owners to recover slave labor on plantations while slaves were punished (Komlos and Coclanis, 1997, p. 436; Wahl, 1996, 1997; Friedman, 1993).

century whites in US prisons were more likely than blacks to be white-collar, skilled workers, and farmers. Blacks were more likely to be unskilled.

Cohort effects are estimated with average BMI by observable characteristics and observation decade. For example, Table 2 presents black and white aggregate cohort effects by age, decade received, occupations, and residence, and these cohort effects are averaged by observation decade and state of residence to create each category's cohort effect. Black and white BMI cohort effects have the same ordinal rankings by age, occupation, and residence. However, while both black and white observation period cohort effects are the largest in the early 19th century, whites had greater average BMIs in the 1940s. In sum, the prison sample provides a large data set that accounts for individual and BMI cohort relationships during the late 19th and early 20th centuries.

IV. Individual and Cohort Effects for Black and White BMIs

BMIs of the ith individual are now regressed on stature, complexion, age, socioeconomic status, and residence. Waaler's U-shaped relationship between BMI and mortality risk complicates coefficient interpretation and estimation because traditional regression model coefficients are un-directional; however, low and high BMIs were associated with greater mortality risk, making multinomial logit models the appropriate estimation technique (Carson, 2018, p. 317).

$$\log\left(\frac{p_j}{p_{Normal}}\right) = \alpha + \beta_H Centimeters_i + \sum_{r=1}^{2}\beta_r Race_i + \sum_{a=1}^{14}\beta_a Age_i + \sum_{l=1}^{4}\beta_l Occupation_i$$

$$+ \sum_{t=1}^{8}\beta_t Observation\,Period_i + \sum_{p=1}^{10}\beta_p \mathrm{Re}\,sidence_i + \sum_{c=1}^{4}\beta_c Cohort\,Effects_i + \varepsilon_i \qquad (1)$$

Centimeters are included to account for the inverse relationship between BMIs and height (Herbert et al., 1993, p. 1438; Carson, 2009; Carson, 2012; Komlos and Carson, 2017). Black and mixed-race dummy variables are included to control for the relationship between BMI and skin complexion. Age dummy variables are included to account for how BMIs varied by age (Sorkin et al. 1999; Williams and Woods, 2006), while occupation dummy variables are included to account for BMIs and socioeconomic status. There are two ways to evaluate BMI variation over time. Measured by birth year, BMI variation reflects how net nutrition varied for the same cohorts since birth. Measured by current period, BMI variation reflects how diverse cohorts experienced the same biological conditions during the period of measurement (Carson, 2019, p. 32). Decade received dummy variables are included here to account for the relationship between BMIs and characteristics for diverse groups during the period of measurement. Residence variables are included to account for how BMIs varied by regional differences at the time of measurement.

Table 3's Model 1 represents individual demographic, socioeconomic effects, and time characteristics but omits cohort effects that are included in Model 2. BMIs are classified into underweight, normal, overweight, and obese categories, and Models 3 through 5 present multinomial BMI model estimates relative likelihood of being in the j^{th} BMI category relative to the normal category. Least squares BMI estimates for only black observations are included in Model 6, while Model 7 does the same for whites and are used in the next section's decompositions.

Table 3, Nineteenth Century US BMIs by Demographics, Socioeconomic Status, Residence, and Cohort effects

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*
	Total, No cohort effects	Total, cohort effects	Under	Over	Obese	Blacks	Whites
Intercept	32.86***	-14.76***	3.15^{14}	2.55^{-15}***	9.19^{-12}***	-8.19***	-5.92*
Heights							
Centimeters	-.060***	-.059***	1.04***	.963***	.884***	-.069***	-.049***
Race							
White	Reference	Reference	Reference	Reference	Reference		
Black	1.13***	.729***	.326***	1.47***	.733	Reference	
Mixed-race	.763***	.543***	.453***	1.38***	.776	-.323***	
Ages							
14	-3.42***	-2.64***	8.47***	.153***	.405*	-2.87***	-1.73***
15	-2.86***	-2.05***	4.13***	.169***	.694	-2.29***	-1.38***
16	-2.16***	-1.38***	2.51***	.253***	.372**	-1.56***	-1.03***
17	-1.55***	-.773***	1.28	.387***	.550*	-.895***	-.580***
18	-1.15***	-.373***	.878	.587***	.634	-.483***	-.204*
19	-.735***	.038	.586***	.849*	.878	-.022	.133
20	-.487***	-.480***	1.12	.623***	.468***	-.594***	-.373***
21	-.297***	-.300***	1.01	.760***	.628***	-.351***	-.264***
22	-.184***	-.190***	.936	.837***	.742**	-.209***	-.181***
23-29	Reference	Reference	Reference	Reference	Reference	Reference	Reference
30s	.211***	.030	1.36***	1.10***	1.65***	.013	.053
40s	.420***	.055	1.71***	1.11***	2.27***	-.074	.141**
50s	.461***	.016	2.18***	1.17***	2.14***	-.206***	.155*
60s	.235***	-.058	2.85***	1.17**	2.12***	-.237***	.050
70s	.091	-.171	4.14***	.923	2.85***	-.917***	.351
Occupations							
White Collar	.073**	-.045	1.08	1.04	1.50***	-.220***	.029
Skilled	.181***	.078***	.705***	1.04	1.07	-.021	.137***
Farmer	.378***	.282***	.572***	1.20***	1.35**	.275***	.303***
Unskilled	.301***	.132***	.705***	1.10***	1.03	.082***	.193***
No Occupations	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Decade Received							
1840s	.165***	.307	1.20	1.03	.955	-.004	.758***
1850s	.590***	1.16***	.334***	2.12***	.584	1.29***	1.10***
1860s	.607***	.044	1.29	.992	.856	.077	.126

1870s	.202***	.143***	1.05	1.05*	1.12	.161***	.042
1880s	-.044**	.011	1.08	1.04*	.823**	.012	-.055*
1890s	.054***	-.079***	1.03	.906***	.924	-.072**	-.061*
1900s	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1910s	-.071***	.190***	.947	1.14***	1.39***	.099***	.176***
1920s	-.290***	.032	1.36***	1.03	1.63**	.078	.017
Residence							
Arizona	.032	.330***	.487***	1.10	1.10	-.018	.449***
Colorado	.431***	.288***	.421***	1.13***	.892	.062	.417***
Idaho	.187**	.463***	.367***	1.35***	.975	.440	.512***
Kentucky	-.477***	-.098***	1.07	.993	.856	-.062	-.045
Missouri	-.675***	.022	.756***	1.00	.798	.019	.086*
New Mexico	.255***	.347***	.967	1.28***	1.37*	.082	.488***
Oregon	.914***	.500***	.555**	1.30***	.719	.241	.688***
Pennsylvania	-.014	.086***	.758***	1.07**	.706***	-.273***	.318***
Philadelphia	-.435***	-.017	.552***	.897***	.391***	-.247***	.192***
Tennessee	.373***	.017	.950	.988	.700***	-.108***	.157***
Texas	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Cohort Effects							
Race		.341***	1.23	1.52***	2.08***		
Age		.835***	.379***	1.65***	2.35***	.931***	.786***
Occupations		.058	.757*	1.03	.571***	.021	.005
Residence		.827***	.440***	2.05***	2.19***	.941***	.794***
N	141,407	141,407	141,407	141,407	141,407	67,821	73,586
R^2	.1361	.1466	.0778	.0778	.0778	.1358	.0855

Source: See Table 1.

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

Three paths of inquiry are considered for late 19th and early 20th century BMI variation.[3] First, cohort effects are pervasive in social sciences and medicine. However, individual effects may mask the relationship between individual and cohort effects. After accounting for individual effects, Table 3 illustrates that the cohort individuals belonged to were positively

[3] To account for possible reverse causation between BMI and weight, age effects, race effects, occupation effects, and residence effects, the model is tested with a Hausman test. The estimated test statistic is 50.97. The chi-square critical value is 56.94. This test indicates OLS estimates are consistent and appropriate.

related to BMI variation, yet most individual effects persist after cohort effects are considered. For example, BMIs increase with age, and BMI age cohort effects had the largest effects with BMI variation. BMI cohort residence effects were comparable to age effects, and the magnitude of age and residence were comparable between African and European Americans. However, socioeconomic status cohort effects were not significant in BMI variation. Cohort effects were also significant for individual weight classification, and greater average cohort effects were associated with a greater likelihood of being overweight and obese, and higher cohort effects predictably decreased the likelihood of being underweight. BMIs were collectively related to cohort effects, and when cohort effects are restricted, the cohort restricted F-statistic is $F(4, 141{,}363)=451.82$, $p=.0000$, indicating that individual BMIs were collectively related to cohort effects.

Second, 19th century statures were related to skin complexion, and after accounting for complexion cohort effects, individual complexions had a positive relationship with BMI. Steckel (1979) is the first to uncover that individuals with fairer complexions were taller than darker complexioned individuals, and Bodenhorn (1999) attributes taller stature of fairer complexioned individuals to 19th century social preference that favored fairer over darker complexions. However, if fairer complexioned individuals received better net nutrition because of social preferences, they should have had greater BMIs than darker complexioned blacks. In fact, the opposite is true, and after cohort effects are considered, blacks had greater BMI values than mixed-race individuals, who had greater BMIs than whites. Black and mixed race individuals were also more likely to be overweight but were not related to an individual's likelihood of being obese. Black and mixed-race individuals were also less likely to be categorized as underweight. Nonetheless, BMIs may have varied because of race cohort effects, and black cohort effects were significant in BMI studies because blacks and whites have different muscle compositions, and historical black BMIs were greater than whites (Barondess et al. 1997; Wagner and Heyward, 2000; Aloia et al., 1999, p. 116; Evans et al., 2006; Flegal et al., 2012; Flegal et al., 2010 p. 240; Carson, 2009; Carson, 2012). Blacks were also shorter than whites, and shorter statures are associated with greater BMIs (Herbert et al., 1993, p. 1438; Carson, 2009; Carson, 2012; Komlos and Carson, 2017). However, after accounting for complexion cohort effects, individual black BMIs were greater than mixed-race and white BMIs, and when race cohort effects are excluded, it upwardly biases the relationship between the individual relationship between BMI and race, indicating there is a positive relationship between BMI, race cohort effects, and race. BMIs were also collectively related to race, and the individual-level race restricted F-statistic is $F(2, 141{,}363)=66.33$, $p=.0000$.

Third, 19th century black and white farmers had greater body mass index values then workers in other occupations (Carson, 2013b, p. 72), and BMIs varied because rural agricultural workers were closer to nutrition and more physically active than workers in other occupations (Carson, 2014). However, when occupation cohort effects are included, individual relationships between BMIs and occupations continue to be significant, but occupation-cohort effects are insignificant, indicating that BMI variation by socioeconomic status is individual rather than cohort related. Moreover, there is a downward bias to individual occupation effects when occupation cohort effects are omitted, indicating that much of the relationship between BMI and occupations is explained by the environment associated with individual socioeconomic status. For example, farmers may receive better net nutrition as a cohort because they are in close proximity to nutritious diets and removed from physical environments where infectious diseases increase and required more calories. Alternatively, white collar and skilled workers as a group may have consumed the equivalent of calories relative to work effort exerted and had lower BMIs. Farmer cohort effects were even larger than unskilled workers and illustrates there were considerable occupational amenities, such as nutrition and mild disease environments associated with occupation cohorts, and farmers and unskilled workers are more physically active than workers in other occupations. Occupations were collectively related to BMIs, and the occupation restricted F-statistic is F(4, 141,363)=32.14, p=.0000, indicating that BMIs were related to socioeconomic effects after cohort effects are excluded.

Other patterns are consistent with expectations. Historical BMIs varied by region, and once regional BMI cohort effects are included, individuals in the West had higher BMIs (Comer, 2000, p. 1312). BMIs were greater in the New South than the Old South. However, once the BMI residence-cohort effects are included, the Southern BMI advantage is accounted for by the residential BMI cohort effects, while the Far West BMI advantage, and the upper South BMI penalty persists, indicating that most of the individual Southern BMI advantage had little to do with individual characteristics but due to the Southern net nutritional and physical activity levels. BMIs were collectively related to residence effects, and the residence restricted F-statistic is F(10, 141,363)=23.55, p=.0000.

Youth BMIs are lower than adult BMIs, and younger individuals have lower BMIs because their stature change is greater than weight change. On the other hand, older individuals have higher BMIs because their stature loss is greater than weight loss, which increases BMI.[4] The age-obesity relationship is also sensitive to when privation occurs. For example, if an

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[4] $BMI = \frac{w(k)}{h(m)^2}; \Rightarrow \ln BMI = \ln w - 2\ln h.\ \varepsilon_h = \frac{\%\Delta BMI}{\%\Delta h} = -2;\ \varepsilon_w = \frac{\%\Delta BMI}{\%\Delta h} = 1.$

individual receives too few calories during their youth, they are less likely to reach taller statures as an adult and are more likely to be obese because BMIs are inversely related with statures (Herbert et al. 1993, p. 1438; Carson, 2009; Carson, 2012). Alternatively, if an individual receives enough calories during their youth, they reach taller statures and have lower BMIs because they have greater physical dimensions to distribute weights. BMIs were collectively related to age, and the age restricted F-statistic is $F(14, 141{,}363)=166.17$, $p=.0000$, indicating BMIs collective individual effects were significantly related to age. In sum, individual historical BMI were related to both individual and cohort effects, and the majority of the individual relationships between BMI, demographic, socioeconomic, and residential effects persist after controlling for cohort effects.

V. Cohort Effects, Demographics, and BMIs: Insights from Sensitivity Analysis

Research indicates there is considerable biological variation with choice characteristics, such as occupations and residence. F-statistics test the relationship when a collective set of variables are restricted from a model. They do not, however, illustrate the relative magnitude when a sub-class of variables is restricted from a model. This magnitude effect is measured when a variable sub-class is restricted from a model (Miller, 2004, p. 37), which is calculated as the percentage change of restricted model's sum of squared regression (SSR_R) difference relative to the unrestricted model (SSR_u).

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

BMIs and stature vary the most when non-choice characteristics are restricted from a model (Carson 2018b), such as race and age. Nonetheless, regression and sensitivity analysis for choice characteristics is important because it represents systematic net nutritional conditions at the margins. The age restricted percent change in R^2 is negative 9.2 percent. However, the cohort restricted percentage change in R^2 is negative 7.16 percent, indicating that cohort effects are collectively among the largest factors in BMI variation. By comparison, the race restricted percentage change in R^2 is negative .556 percent, and after cohort effects are accounted for, the effect of race is smaller, indicating much of BMI variation by race is related to race cohort effects (Carson, 2015a). Choice characteristics continue to have marginal but measureable effects in BMI variation. The occupation restricted percentage change in R^2 is negative .556 percent; year observed percentage change in R^2 is .887 percent, and location restricted percentage change in R^2 is negative .010 percent. Subsequently, the BMI percentage magnitude variation associated with cohort effects is nearly as large as characteristics and BMI variation is smaller after cohorts are included.

VI. Explaining Black and White BMIs with Cohort Effects

A Blinder-Oaxaca decomposition is constructed on the black and white BMI differences to account for black and white physical activity and nutritional differences (Oaxaca, 1973). These decompositions are used to identify statistical discrimination but are also widely used to distinguish between dependent variable differences that are due to returns to characteristics and average characteristics. Let γ_b and γ_w equal black and white BMIs. α_b and α_w are the autonomous BMI components that accrue to blacks and whites. β_b and β_w are the black and white BMI returns associated with BMI enhancing characteristics, such as age and residence. X_b and X_w are black and mixed-race characteristic matrices, and blacks are the base structure.

Black and white BMI equations are

$$\gamma_b = \alpha_b + \beta_b X_b \qquad (2)$$

and

$$\gamma_w = \alpha_w + \beta_w X_w \qquad (3)$$

The difference between black and white BMIs is

$$\Delta\gamma = \gamma_b - \gamma_w = \alpha_b + \beta_b X_b - \alpha_w - \beta_w X_w \qquad (4)$$

Assigning appropriate counterfactuals is central to decompositions, and Equation 5 is white BMI returns to characteristics observed at average black characteristics, while Equation 6 is the black BMI returns to characteristics observed at average white characteristics.

$$\beta_w X_b - \beta_w X_b = 0 \qquad (5)$$

and

$$\beta_b X_w - \beta_b X_w = 0 \qquad (6)$$

Adding Equation 5 to Equation 4 is the decomposition between blacks and whites for black returns to characteristics observed at average white characteristics (Equation 7), and adding Equation 4 to Equation 6 is the decomposition for white returns to characteristics observed at average black characteristics (Equation 8).

$$\begin{aligned} y_b - y_w &= \alpha_b + \beta_b X_b - \alpha_w - \beta_w X_w + \beta_w X_b - \beta_w X_b \qquad (7) \\ &= (\alpha_b - \alpha_w) + (\beta_b - \beta_w) X_b + (X_b - X_w)\beta_w \end{aligned}$$

$$\begin{aligned} y_b - y_w &= \alpha_b + \beta_b X_b - \alpha_w - \beta_w X_w + \beta_b X_w - \beta_b X_w \qquad (8) \\ &= (\alpha_b - \alpha_w) + (\beta_b - \beta_w) X_w + (X_b - X_w)\beta_b \end{aligned}$$

The first right hand side element, $\left(\alpha_b - \alpha_w\right)$, is the black and mixed-race BMI differential due to non-identifiable characteristics, such as differences in diets and genetics. The second right hand side factor, $\left(X_b - X_w\right)\beta_b$, is the activity and calorie component associated with differences in returns to characteristics. The third right hand side variable, $\left(\beta_b - \beta_w\right)X_b$, is the average activity and calorie component associated with differences associated with differences in average characteristics. To isolate cohort effects, two decompositions are conducted. The first decomposes the difference in 19th century black and white BMIs by height, demographics, occupations, observation period, and residence (Table 5, Equation 7). The second decomposition considers the same black and white BMI difference related to the same variables and adds variables to account for the black-white BMI differences related to cohort effects (Table 5, Equation 8).

Table 5, Decomposing Late 19th and Early 20th Century Black and White BMIs by Demographics, Socioeconomic, and Residence

	Equation 7		*Equation 8*	
Levels	$\left(\beta_b - \beta_w\right) X_b$	$\left(X_b - X_w\right) \beta_w$	$\left(\beta_b - \beta_w\right) X_w$	$\left(X_b - X_w\right) \beta_b$
Sum	1.09	-.098	.953	.035
Total		.988		.988
Proportions				
Intercept	-2.30		-2.30	
Centimeters	-3.44	.015	-3.45	.021
Ages	-.129	-.068	-.108	-.090
Occupations	-.085	.001	-.112	.028
Decade	.006	-.023	.003	-.019
Received				
Residence	-.152	-.089	-.260	-019
Cohort Effects	7.20	.064	7.19	.077
Sum	1.10	-.099	.965	.035
Total		1		1

See: Tables 1 and 4.

Using coefficients from Table 4, Models 6 and 7, there was nearly a one unit BMI difference between blacks and whites. However, the sources of black-white BMI differences are important, and independent of characteristics, blacks had greater BMIs than whites (Carson 2015, citations). Black BMI returns to height was the leading black characteristic and was greater than whites, followed by age, residence, and occupations. However, white returns to cohorts were sufficiently large to be the greatest source of BMI variation than blacks, making returns to cohorts the greatest source of white BMI variation.

VII. Conclusion

Considerable research is devoted to social interaction. Smoking has been shown to be related with cohort relationships, and a person is more likely to smoke if they associate with fellow smokers. While identifying peer and cohort effects is difficult, there were considerable age, race, and residence cohort effects among late 19th and early 20th century males. However, BMIs were not collectively related to socioeconomic cohort effects, indicating that current net nutrition variation by socioeconomic status was related to individual conditions—such as diets and physical activity—than socioeconomics cohort effects. This study finds there were significant cohort effects across age, race, and residence; however, individual effects persist after cohort effects are included. Blacks had greater BMIs than fairer complexioned mixed-races and whites. Much of the relationship between BMI and occupations is explained by socioeconomic environment, and individual white-color and skilled cohort effects with BMI are reduced considerably. However, when cohort effects are included, individual relationships between BMI and characteristics are smaller. Subsequently, individual and cohort effects are ubiquitous in net nutrition studies, and cohort effects need to be considered in historical and current BMIs studies.

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