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## Abstract

Much has been written about 19th century African American and white statures and body mass index values. However, little is known about their physical activity and calories required to sustain height and weight. This paper considers two alternative measures for biological conditions that address physical activity and available calories: basal metabolic rate and energy accounting. African-Americans had greater BMRs and required more calories per day than whites. Farmers and unskilled workers were in better physical condition and required more calories per day than workers in white-collar and skilled occupations. Nineteenth century BMRs and calories were greater in rural locations where greater physical activity was required and more calories were available.


JEL-Code: Q100, Q190, N110, N510.

Keywords: nutrition, energy accounting, Basal Metabolic Rate, US economic development.

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# Nineteenth Century US Black and White Physical Activity and Nutritional Trends among the Working Class

## I. Introduction

A generation of scholars has focused on the interaction between economics and human biology, and key variables in this interface are height, weight, and life expectancy. A large body of evidence demonstrates that individuals during the 19th century underwent considerable biological adaptation to their physical and economic surroundings (Fogel et al. 1978; Steckel, 1979; Komlos, 1987; Fogel, 1994; Carson 2009; Floud et al. 2011, pp. 15-39). For example, during the Industrial Revolution, the 1790s British male working class grew to an average 168 cms and consumed about 2,700 calories per day, while the French working class grew to only 163 cms and consumed about 2,400 calories per day (Fogel, 1994, p. 372; Fogel and Costa, 1997, p. 52; Floud et al. 2011, p. 56). There is an extensive literature that considers biological conditions during economic development, and existing studies rely almost exclusively on two biological measurements: stature and body mass index (BMI). However, because statures and BMIs only measure height and weight, they are incomplete net nutrition and health measures because neither provides insight into a population's physical activity and energy requirements; more complete physical activity and calorie estimates are available from extant data.

The use of height and weight data to measure biological living conditions is now a well-established method in economics (Fogel, 1994, p. 138; Steckel, 1995; Deaton, 2008; Case and Paxson, 2008; Steckel, 2009). A population's average stature reflects the net cumulative interaction between nutrition, disease climate, and the work environment (Tanner, 1962, pp. 1-27; Steckel, 1979, pp. 365-367), and a population's average BMI (weight (km)/ height ($m^2$)) reflects the net current balance between the same variables (Fogel, 1994, p. 375; Cawley, 2011, pp. 125-126).[1] When diets, health, and physical environments improve, average statures and BMIs increase and decrease when diets become less nutritious, disease environments deteriorate, or the physical environment places more stress on the body. By considering average versus individual values, genetic differences are mitigated, leaving only the relationship between the body's physical dimensions with the economic and physical environments.[2] Two additional measures that approximate health and well-being are the basal metabolic rate (BMR) and energy accounting. BMRs are the calories required to sustain a resting body (Wardlaw, Hample, and DiSilvestro, 2004, p. 455), and calories per day are an important measure for both the material and biological environments. Therefore, BMR provides a reasonable measure for physical activity, and energy accounting provides estimates for nutritional adequacy.

It is against this backdrop that this paper uses 19th century US prison data to consider three paths of inquiry into measuring black and white physical activity and dietary patterns that

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[1] Komlos and Brabec (2010) use BMI by birth year but indicate neither BMI by birth year or current period are superior to the other and provide different information. Period effects are the upper bound for the time that weight gain occurs; birth period effects are the lower bound.

[2] There is a complex relationship between heights and genetics, and in developed economies, nearly 90 percent of height is determined by genetics, while heights in developing economies are only 60 percent determined by genetics (Luke et al. 2001).

are not available when statures and BMIs are analyzed in isolation. First, how did black and white BMRs and calories vary over the course of the 19th century? The question is important because life expectancy has increased since 1840, while statures and BMIs underwent considerable decline. Less is known about net nutrition, and if net nutrition declined, it calls into question nutrition as the primary factor for increased life expectancy. Like other biological measurements, black and white BMRs and calories declined throughout the late 19th and early 20th centuries. Second, what was the relationship between occupations, BMRs, and calories? Because farmers and unskilled workers had greater BMI and BMR values, they received more calories per day and were more active and in better physical condition than workers in white collar and skilled occupations. Third, what was the relationship between residence, BMRs, and calories? Nineteenth century US BMRs and calories were greater in rural states where greater physical activity was required and nutrition was available.

## II. Basal Metabolic Rate and Energy Accounting

The basal metabolic rate is the daily amount of calories required by the body to maintain vital organ function while at rest, awake, and in a warm climate, and BMR is equivalent to one kilocalorie per minute or about 1400 kilocalories per day. BMRs are greater for lean muscle mass, cold temperatures, and younger ages. The combined use of BMIs and BMRs also provides an approximation for physical activity. A high BMI combined with a high BMR indicates a person is active and in better physical condition; individuals with high BMIs and low BMRs are physically less active (Strauss and Thomas, 1998, p. 774; Wardlaw, Hampl, and DiSilvestro, 2004; Stevens et al. 2002; Poston et al. 1999; Must and Evans, 2011, p. 25). As muscle mass declines with age, an individual's ideal BMR decreases; however, factors beyond age also slow BMRs. For example, receiving an insufficient amount of calories during one period slows

BMRs in future periods because the body comes to anticipate fewer calories in the future and effectively stores current calories for when it is deprived of them in the present (Neel, 1962; Prentice, 2005; Prentice et al. 2008; Speakman, 2008).

A second novel approach with the basal metabolic rate is its use in estimating calories required to maintain physical dimensions. There is a long history of deriving calories from physical measurements, and BMR and calorie equations are used in the biomedical literature to measure calories required to maintain a given height and weight (Harris and Benedict, 1919; Mifflin et al. 1990, p. 247).[3] Because males and females differ by percent muscle mass, they have different relationships with weight, height, and age.

$$BMR_{Male}=5+10\times Weight\ (kgs)+6.25\times Height\ (cms)-5\times Age$$

$$BMR_{Female}=-161+10\times Weight\ (kgs)+6.25\times Height\ (cms)-5\times Age$$

These Mifflin equations predict resting energy requirements for men and women in healthy, normal to moderately overweight categories, and the normal weight range assumption is important because the majority of 19th century males were in normal weight ranges (Mifflin et al. 1990, p. 247; Carson, 2009a and 2012). Since calories are estimated from height and weight, some degree of error is expected (Weijs et al, 2008, pp. 153-156); nevertheless, Mifflin equations

[3]Mifflin et al. 1990, p. 246. Calorie equations from height and weight were first proposed in 1919 with the Harris-Benedict equations. Harris-Benedict equations for males are $BMR_{Males}$=66.5+13.75weight(kg)+5.003height(cms)-6.775Age. Harris-Benedict equations for women are $BMR_{Females}$=655.1+9.563weight(kg)+1.85height(cms)-4.676Age. Among various energy equations, Mifflin et al. (1990) perform well for individuals in slightly overweight categories (Frankenfield et al. 2005; Weijs et al. 2008, p. 156).

provide reasonable approximations for BMRs (Frankenfield et al. 2005).[4] Approximations for average daily calorie requirements are then calculated by multiplying the BMR by a reasonable activity ratio, and because modern activity levels are lower than historic activity levels, modern activity levels are inappropriate to estimate historical calories.

The majority of 19th century US workers were in agricultural occupations (Steckel, 1983, p. 19), and farmers were more physically active than workers in other occupations. To estimate 19th century calories per day, each individual's imputed basal metabolic rate is calculated and sorted by occupations. These imputed occupation values are standardized by dividing each occupation by imputed farmer BMRs. Relative to imputed farmer's BMRs, the white collar worker imputed BMR value is .9713; average skilled worker imputed values are .9750; average unskilled imputed values are .9900; workers with no occupations are .9885 of imputed farmer values. To calculate calories, these farmer weighted imputed ratios are then multiplied by farmers' extra physical activity ratios of 1.9000 and BMRs. To estimate calories, the white collar BMR is multiplied by 1.8455; skilled worker BMRs are multiplied by 1.8525; unskilled worker BMRs are multiplied by 1.8811; workers with no occupation BMRs are multiplied by 1.8781.[5]

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[4] Mifflin equations are also robust across race, and to date, no studies demonstrate that significant errors exist for the Mifflin equations across US ethnic groups (Frankenfield et al. 2005, p. 786).

[5] For sedentary individuals, calories are attained by multiplying BMR by 1.200; for lightly active individuals, BMR is multiplied by 1.375; for moderately active individuals, BMR is multiplied by 1.550; for very active individuals, BMR is multiplied by 1.725; for extra active individuals, BMR is multiplied by 1.900 (Mifflin et al. 1993). Recent evidence also suggests it is difficult to judge the adequacy of historical diets using modern standards because infectious diseases are significant; it may under estimate nutrients consumed by 10 percent (Floud et al. 2011, p. 162).

## III. Nineteenth Century Physical Activity and Nutrition

The uses of BMRs and energy accounting have been used to uncover important historical patterns. The number of available calories is important in economics because greater available calories are associated with taller statures, greater BMIs, lower disease rates, and longer life expectancies (Floud et al. 2011). Cummings (1940) finds that mid-19th century annual white diets averaged 183.9 pounds of meat, 13.2 pounds of lard, 15.1 pounds of butter, 205 pounds of wheat flour, and 29.7 pounds of sweeteners. Cummings also estimates that US diets in 1879 provided 3,741 calories per day, and these calories were sufficient to maintain body weight under moderate to heavy work conditions. However, Cummings is unable to estimate the relationships between calories and individual-level characteristics, such as age, occupation, and residence. The first use of calories in economic history was to compare 19th century US slave calories with their white counterparts (Fogel and Engerman, 1974, p. 112, Figure 33). Fogel and Engerman use planation records to demonstrate that although African-Americans had worse material conditions, blacks consumed an average of 4,185 calories per days (Cummings, 1940) and received about 12 percent more calories per day than whites.[6] Atack and Bateman (1987, p. 210) provide estimates of 19th century diets and conclude that average annual US white diets averaged about 200 pounds of meat, 771 pounds of fluid milk, butter, and cheese, and 13.5 bushels of grain, which provided over 5,000 calories per day.

Nineteenth century diets varied regionally, and Shergold (1982, pp. 185-195) finds that Northeastern diets were high in grains, breads, and dairy products. (Floud et al. 2011, p. 313; US Census, 1975, p. 1175). Southern whites consumed more diverse and more abundant diets,

[6] Floud et al. (2011, p. 42) estimates adult slaves consumed about 4,200 calories per day.

which included pork, beef, corn and Irish potatoes. Slaves consumed sufficient calories that were heavily slated toward fat pork, corn, and rice (Fogel and Engerman, 1974, pp. 109-111; Kiple and King, 1981, p. 80; Hillard, 1972, pp. 62-69). Logan (2006) finds that the 19th century American dietary shares of carbohydrates, fats, and sugars varied with income, but the shares of proteins and fat did not. Early industrial diets were also surprisingly well balanced by modern standards (Logan, 2006, p. 534).

Historical calorie estimates are available from height, weight, age and activity level records. In addition to Harrison-Benedict and Mifflin energy equations, there are multiple ways to estimate calories, such as national balance sheets, consumption surveys, and health provider, poor house, military, and slave plantation records (Rosen, 1999; Floud et al. 2011, pp. 46-47). National food balance sheets estimate gross food calorie production, while calories from energy equations provide estimates for net calorie consumption. Calories from energy equations also have the advantage of integrating net calories associated with physical size to various personal characteristics, which is not possible with aggregate food balance sheet records. Modern calories estimated by the USDA are calculated from measuring the flow of raw and semi-processed foods by food disappearances,[7] and the total amount of food for domestic consumption is estimated from these USDA reports. Using USDA calorie estimates, Putnam (2000) finds that average calorie consumption was about 3,500 calories per day in 1909, however, consumption decreased to 3,000 calories per day by 1959. In the early 1980s, calories began to increase which has lasted until the present, and today, instead of minimum nutrition to sustain life, over nutrition is a primary health concern (Flegal et al. 2010; Cawley et al. 2011; Flegal et al. 2012). However,

[7] The USFA's Economic Research Service compiles and publishes annual production and disappearance tables for various US food groups.

these national balance sheet calorie estimates measure domestic production and do not account for net food consumption. Therefore, by combining height, weight, age, and activity levels, basal metabolic rate and energy accounting provide important insight into health to understand available nutrition during a given a time period.

## IV. Nineteenth Century Black and White Prison Data

A large historical sample with accompanying height, weight, and age is required to assess the relationship between 19th century nutrition, physical activity, and calories required to maintain health, and the two most common sources for historical physical measurements are military and prison records. Where military records may represent conditions among higher socioeconomic groups, prison records represent conditions among the working class. Moreover, because the 19th century military was racially segregated, military records may also not consider biological conditions for African-Americans (Carson, 2009a).

Table 1, Nineteenth Century Black and White Populations in US Prisons

| | *Black* | | *White* | | | *Black* | | *White* | |
|---|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | | N | % | N | % |
| Arizona | 194 | .29 | 2,156 | 2.93 | Oregon | 45 | .07 | 1,683 | 2.29 |
| Colorado | 483 | .71 | 3,502 | 4.76 | Pennsylvania | 2,685 | 3.96 | 11,214 | 15.24 |
| Idaho | 36 | .05 | 575 | .78 | Philadelphia | 5,481 | 8.08 | 11,410 | 15.51 |
| Kentucky | 6,167 | 9.09 | 6,602 | 8.97 | Tennessee | 20,940 | 30.88 | 10,384 | 14.11 |
| Missouri | 4,292 | 6.33 | 7,984 | 10.85 | Texas | 27,154 | 40.04 | 16,083 | 21.86 |
| New Mexico | 344 | .51 | 1,993 | 2.71 | Total | 67,821 | 100.00 | 73,586 | 100.00 |

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

All historical data have biases, and there is always concern over entry requirements, be it to prison or the military. Moreover, there is concern over who the prisoners represent because prisons may have selected taller, healthier individuals, or they may have selected short, poor individuals. By taking the spectrum of crimes, this selection concern is reduced, and prisoners are representative of the working class. This study, therefore, considers African-American and white physical activity and calories from prison records, and most blacks in the sample were imprisoned in the Deep South and Border States—Kentucky, Missouri, and Texas (Table 1). Whites in the sample were imprisoned in Missouri and Texas, but whites were also from Pennsylvania and the Far West. Physical descriptions were recorded by prison enumerators at the time of incarceration as a means of identification, and therefore reflect pre-incarceration conditions. Because accurate recordings had legal implications for identification in the event that inmates escaped, there was care recording inmate age, height, and weight measurements. Between 1840 and 1920, prison officials routinely recorded the dates inmates were received, age, complexion, nativity, height, weight, pre-incarceration occupation, and crime, and all records with complete height and weight descriptions are collected for this study. How arrests and prosecutions varied across states may have resulted in various selection biases that affect the results of this analysis. However, black and white stature and BMI variations across US prisons are consistent with other historical health studies (Costa, 2004; Cuff, 1993; Coclanis and Komlos, 1995).

Inmate enumerators were quite thorough when recording inmate complexion and pre-incarceration occupation. For example, enumerators recorded inmates' race in a complexion category, and African-Americans were recorded as black, light-black, dark-black, and various shades of mulatto (Komlos and Coclanis, 1997). Enumerators recorded white complexions as light, medium, dark, and fair. The white inmate complexion classification is supported further by European immigrant complexions, who were always of fair complexion and were also recorded as light, medium, and dark. While mulatto inmates possessed genetic traits from both European and African ancestry, they were treated as blacks in the 19th century US and later, and later in this study, when comparing whites to blacks, are grouped with blacks.

Enumerators recorded a broad continuum of occupations and defined them narrowly, recording over 200 different occupations, which are classified here into four categories: merchants and high skilled workers are classified as white-collar workers; light manufacturing, craft workers, and carpenters are classified as skilled workers; workers in the agricultural sector are classified as farmers; laborers and miners are classified as unskilled workers (Tanner, 1977, p. 346; Ladurie, 1979; Margo and Steckel, 1992; p. 520). Calorie requirements are then adjusted from occupation actively levels. Because the purpose of this study is black and white BMRs and calories, females and the foreign born are excluded from the analysis.

Table 2, Nineteenth Century US Stature and BMI by Race

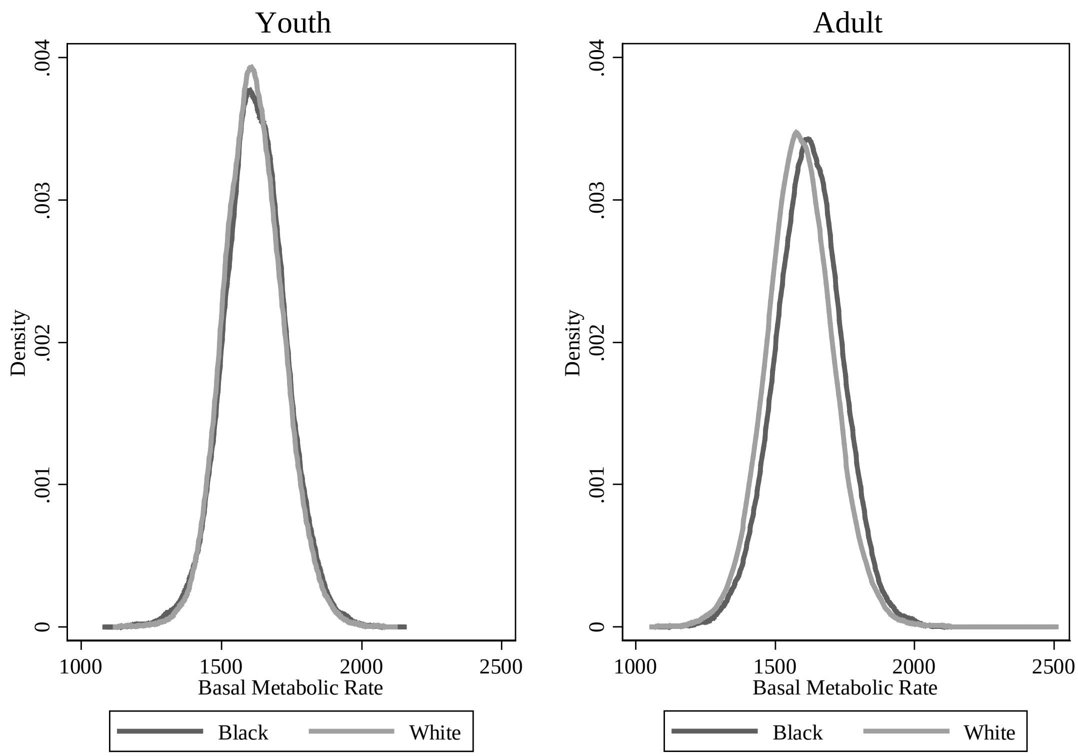
| | *Blacks* | | | | *Whites* | | | |
|---|---|---|---|---|---|---|---|---|
| | N | Percent | Centimeters | BMI | N | Percent | Centimeters | BMI |
| *Ages* | | | | | | | | |
| Teens | 14,044 | 20.71 | 167.63 | 22.60 | 10,035 | 13.64 | 169.60 | 21.70 |
| Twenties | 36,128 | 53.27 | 170.78 | 23.78 | 36,607 | 49.75 | 171.81 | 22.52 |
| Thirties | 11,074 | 16.33 | 170.94 | 24.04 | 16,191 | 22.00 | 171.66 | 22.86 |
| Forties | 4,216 | 6.22 | 170.36 | 24.28 | 6,841 | 9.30 | 171.28 | 23.14 |
| Fifties | 1,678 | 2.47 | 169.72 | 24.33 | 2,841 | 3.86 | 171.04 | 23.24 |
| Sixties | 557 | .82 | 169.42 | 24.15 | 896 | 1.22 | 170.63 | 23.04 |
| Seventies | 124 | .18 | 160.09 | 23.56 | 175 | .24 | 169.81 | 23.32 |
| *Residence* | | | | | | | | |
| Arizona | 194 | .29 | 171.61 | 23.34 | 2,156 | 2.93 | 171.23 | 22.78 |
| Colorado | 483 | .71 | 170.55 | 24.08 | 3,502 | 4.76 | 171.20 | 23.24 |
| Idaho | 36 | .05 | 170.28 | 23.89 | 575 | .78 | 172.88 | 22.77 |
| Kentucky | 6.167 | 9.09 | 169.30 | 23.33 | 6,602 | 8.97 | 172.09 | 22.31 |
| Missouri | 4,292 | 6.33 | 169.46 | 22.99 | 7,984 | 10.85 | 171.46 | 22.00 |
| New Mexico | 344 | .51 | 171.57 | 23.82 | 1,993 | 2.71 | 172.45 | 22.93 |
| Oregon | 45 | .07 | 169.24 | 24.65 | 1,683 | 2.29 | 170.77 | 23.59 |
| Pennsylvania | 2,685 | 3.96 | 168.45 | 23.60 | 11,214 | 15.24 | 169.34 | 22.93 |
| Philadelphia | 5,481 | 8.08 | 168.20 | 23.45 | 11,410 | 15.51 | 169.08 | 22.32 |
| Tennessee | 20,940 | 30.88 | 169.06 | 23.83 | 10,384 | 14.11 | 171.73 | 22.82 |
| Texas | 27,154 | 40.04 | 171.65 | 23.65 | 16,083 | 21.86 | 173.79 | 22.42 |
| *Received* | | | | | | | | |
| 1840s | 20 | .03 | 175.80 | 23.98 | 165 | .22 | 175.37 | 23.43 |
| 1850s | 55 | .08 | 171.06 | 24.06 | 839 | 1.14 | 173.28 | 22.49 |
| 1860s | 980 | 1.44 | 168.59 | 23.94 | 1,307 | 1.78 | 172.10 | 22.79 |
| 1870s | 7,615 | 11.23 | 170.03 | 23.92 | 8,748 | 11.89 | 171.11 | 22.35 |
| 1880s | 12,508 | 18.44 | 170.85 | 23.60 | 10,888 | 14.80 | 171.40 | 22.58 |
| 1890s | 14,285 | 21.06 | 170.00 | 23.68 | 14,114 | 19.18 | 171.60 | 22.71 |
| 1900s | 16,319 | 24.06 | 169.58 | 23.57 | 17,782 | 24.16 | 170.76 | 22.65 |
| 1910s | 15,090 | 22.25 | 170.20 | 23.46 | 18,533 | 25.19 | 171.72 | 22.49 |
| 1920s | 949 | 1.40 | 169.83 | 23.62 | 1,210 | 1.64 | 171.76 | 22.61 |
| *Occupations* | | | | | | | | |
| White-Collar | 1,747 | 2.58 | 169.68 | 23.48 | 7,024 | 9.55 | 171.10 | 22.60 |
| Skilled | 5,147 | 7.59 | 170.09 | 23.67 | 16,395 | 22.28 | 170.90 | 22.66 |
| Farmer | 6,411 | 9.45 | 171.54 | 23.80 | 7,307 | 9.93 | 173.23 | 22.68 |
| Unskilled | 38,551 | 56.84 | 170.39 | 23.56 | 32,289 | 43.88 | 171.44 | 22.59 |
| No Occupation | 15,965 | 23.54 | 168.79 | 23.70 | 10,571 | 14.37 | 170.81 | 22.39 |
| Total | 67,821 | 100.00 | 170.08 | 23.62 | 73,586 | 100.00 | 171.38 | 22.58 |

Source: See Table 1.

Whites were a larger percent of the prison population than blacks; 52 percent of the US prison population was white. Age percentages demonstrate that black inmates were incarcerated at younger ages, while whites were incarcerated at older ages (Table 2). During the early 19th century, blacks were less likely to be incarcerated; 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 exact their social debt.[8] Nineteenth century whites within US prisons were more likely than blacks to be white-collar, skilled workers, and farmers. Blacks were more likely to be unskilled.

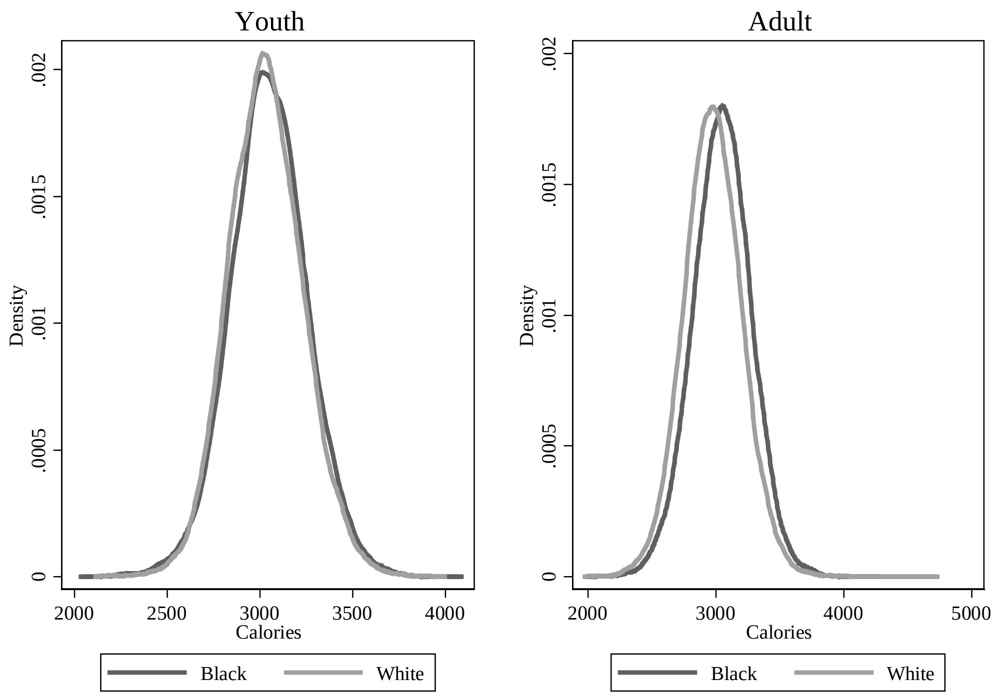
[8] Southern law evolved to favor plantation law, which generally allowed slave owners to recover slave labor on plantations while slaves were punished (Komlos and Coclanis, 1997, p. 436; Wahl, 1996, 1997; Friedman, 1993).

Figure 1, Nineteenth Century Black and White Male Basal Metabolic Rate




Source: See Table 1.

Figure 2, Nineteenth Century Black and White Male Calories




Source: See Table 1.

How BMRs and calories are distributed provides insight into a population's physical activity, and Mifflin equations offer a flexible means to assess how BMRs and calories were allocated. Figures 1 and 2 use BMR and calorie Kernel density estimates to demonstrate that black and white BMR and calorie distributions were symmetrical, and neither too few nor too many calories were available.[9] Average black youth and adult BMRs were 1,620 calories per day, while average white youth and adult BMRs were 1,645 and 1,588, respectively. Average black youth and adult calories were 3,049 and 3,047 per day, while average white youth and

[9] BMR and calorie distributions are less skewed than income and wealth distributions because the tails of the BMR and calorie distributions are restricted by minimum subsistence calorie requirements in the left tail of the calorie distribution and limited capacity to use energy in the right (Floud et al. 2011, p. 50).

adult calories were 3,032 and 2,975 per day, respectively. During a period of increasing modern obesity, these 19th century diets contrast with modern US calories of 3,654 per day (Rosen, 1999, p. 14; Putnam, 2000; Shapouri and Rosen, 2007). Modern Europeans consume 3,394 calories per day, and Asians consume 2,648 calories per day.[10] Daily average calories available in sub-Saharan Africa are only 2,176 calories per day.[11] Therefore, 19th century North American black and white calories were greater than 18th century French and English calories and compare favorably with calories available in modern developing countries (Fogel, 1993, p. 12; Logan, 2006, p. 534).

## V. The Comparative Effects of Demographics, Socioeconomic Characteristics, and Residence on 19th Century Black and White BMRs and Calories

We now test how BMRs and calories were related to race, age, observation period, residence, and occupations. A model is presented first for BMRs, and a similar model is estimated for calories.

Table 3, Nineteenth Century Basal Metabolic Rate by Demographics, Residence and Occupations

| | *Model 1* | | *Model 2* | | *Model 3* | |
|---|---|---|---|---|---|---|
| | Total Coeff | S.D. | Black Coeff | S.D. | White Coeff | S.D. |
| Intercept | 1639.37*** | 1.37 | 1651.58*** | 1.84 | 1635.42*** | 1.88 |
| *Race* | | | | | | |
| Black | 8.92*** | .667 | | | | |
| Mulatto | 6.24*** | 1.02 | -2.04*** | 1.04 | | |
| White | Reference | | Reference | | | |
| *Ages* | | | | | | |
| 14 | -178.50*** | 4.93 | -182.39*** | 5.33 | -167.28*** | 13.23 |
| 15 | -129.08*** | 3.18 | -134.36*** | 3.53 | -117.24*** | 7.13 |
| 16 | -81.26*** | 1.93 | -87.32*** | 2.39 | -70.11*** | 3.28 |
| 17 | -44.29*** | 1.51 | -48.92*** | 2.01 | -38.08*** | 2.29 |
| 18 | -22.44*** | 1.23 | -29.31*** | 1.65 | -13.58*** | 1.84 |
| 19 | -4.73*** | 1.20 | -10.48*** | 1.70 | 1.58 | 1.69 |
| 20 | 6.50*** | 1.21 | 2.81* | 1.69 | 10.39*** | 1.72 |
| 21 | 10.48*** | 1.18 | 7.82*** | 1.67 | 13.17*** | 1.66 |
| 22 | 9.98*** | 1.13 | 8.03*** | 1.60 | 11.64*** | 1.58 |
| 23-29 | Reference | | Reference | | Reference | |
| 30s | -35.00*** | .834 | -33.93*** | 1.28 | -35.23*** | 1.10 |
| 40s | -84.535*** | 1.21 | -83.30*** | 1.91 | -81.03*** | 1.56 |
| 50s | -138.22*** | 1.81 | -145.32*** | 2.86 | -133.59*** | 2.34 |
| 60s | -200.03*** | 3.20 | -208.82*** | 4.72 | -194.33*** | 4.28 |
| 70s | -269.09*** | 8.75 | -299.35*** | 22.58 | -247.41*** | 10.25 |
| *Year* | | | | | | |
| 1840s | 104.14*** | 8.75 | 118.39*** | 22.58 | 102.28*** | 9.54 |
| 1850s | 44.15*** | 3.85 | 42.70*** | 13.96 | 43.14*** | 4.19 |
| 1860s | 26.68*** | 2.45 | 17.65*** | 3.63 | 33.81*** | 3.33 |
| 1870s | 14.58*** | 1.13 | 18.85*** | 1.53 | 11.43*** | 1.41 |
| 1880s | 9.28*** | .912 | 11.47*** | 1.28 | 7.60*** | 1.33 |
| 1890s | 6.88*** | .867 | 5.66*** | 1.22 | 8.93*** | 1.24 |
| 1900s | Reference | | Reference | | Reference | |
| 1910s | -2.93*** | .887 | -3.47*** | 1.28 | -2.19* | 1.24 |
| 1920s | -5.85** | 2.55 | -4.50 | 3.82 | -7.01** | 2.52 |
| *Residence* | | | | | | |
| Arizona | -24.27*** | 2.35 | -9.04 | 7.77 | -24.84*** | 2.52 |
| Colorado | -14.96** | 1.85 | -7.63 | 4.95 | -14.88*** | 2.09 |
| Idaho | -1.56 | 4.35 | -12.06 | 15.24 | -.185 | 4.57 |
| Kentucky | -39.38*** | 1.17 | -41.84*** | 1.57 | -36.57*** | 1.76 |
| Missouri | -44.89*** | 1.20 | -49.75*** | 1.89 | -41.84*** | 1.61 |
| New Mexico | -6.13*** | 2.32 | -.290 | 5.65 | -6.20** | 2.59 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Oregon | -11.79** | 2.68 | -12.63 | 13.31 | -10.39*** | 2.81 |
| Pennsylvania | -63.31*** | 1.12 | -53.59*** | 2.26 | -51.84*** | 1.37 |
| Philadelphia | -63.80*** | 1.01 | -59.05*** | 1.63 | -64.74*** | 1.35 |
| Tennessee | -15.10*** | .997 | -16.99*** | 1.36 | -11.50*** | 1.53 |
| Texas | Reference | | Reference | | Reference | |
| *Occupations* | | | | | | |
| White-Collar | -1.27 | 1.51 | -10.07*** | 2.85 | 1.54 | 1.88 |
| Skilled | 1.55 | 1.16 | -1.78 | 1.99 | 3.24*** | 1.50 |
| Farmer | 24.42*** | 1.27 | 22.84*** | 1.81 | 25.36*** | 1.80 |
| Unskilled | 10.77*** | 1.00 | 10.14*** | 1.45 | 10.51*** | 1.41 |
| No Occupation | Reference | | Reference | | Reference | |
| N | 141,407 | | 67,821 | | 73,586 | |
| $R^2$ | .1911 | | .1815 | | .1857 | |
| F | 794.44 | | 382.39 | | 105.41 | |

Source: See Table 1.

Table 4, Nineteenth Century Calories by Demographics, Residence and Occupations

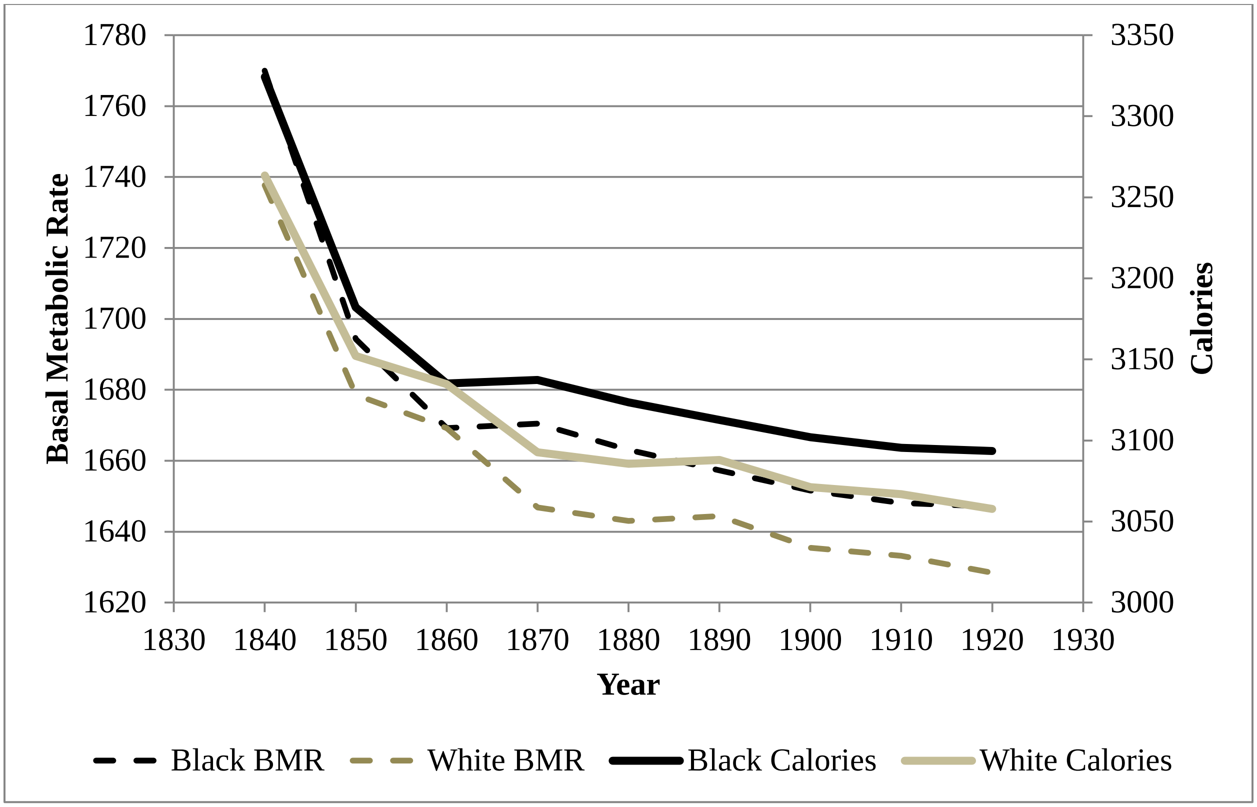
| | *Model 1* | | *Model 2* | | *Model 3* | |
|---|---|---|---|---|---|---|
| | Total Coeff | S.D. | Black Coeff | S.D. | White Coeff | S.D. |
| Intercept | 3078.93*** | 2.66 | 3101.98*** | 3.46 | 3071.21*** | 3.52 |
| *Race* | | | | | | |
| Black | 16.80*** | 1.25 | | | | |
| Mulatto | 11.74*** | 1.92 | -3.82** | 1.95 | | |
| White | Reference | | Reference | | | |
| *Ages* | | | | | | |
| 14 | -335.70*** | 9.28 | -342.84*** | 10.02 | -314.40*** | 24.95 |
| 15 | -242.71*** | 5.98 | -252.57*** | 6.64 | -220.16*** | 13.40 |
| 16 | -152.79*** | 3.63 | -164.17*** | 4.50 | -131.64*** | 6.17 |
| 17 | -83.21*** | 2.84 | -91.94*** | 3.79 | -71.40*** | 4.30 |
| 18 | -42.10*** | 2.30 | -55.04*** | 3.09 | -25.37*** | 3.45 |
| 19 | -8.83** | 2.25 | -19.65*** | 3.19 | 3.04 | 3.16 |
| 20 | 12.27*** | 2.27 | 5.30* | 1.67 | 19.57*** | 3.23 |
| 21 | 19.78*** | 2.21 | 14.74*** | 3.13 | 21.82*** | 3.11 |
| 22 | 18.79*** | 2.11 | 15.10*** | 3.00 | 21.87*** | 2.97 |
| 23-29 | Reference | | Reference | | Reference | |
| 30s | -65.71*** | 1.56 | -63.77*** | 2.40 | -65.98*** | 2.06 |
| 40s | -158.67*** | 2.26 | -167.84*** | 3.59 | -151.76*** | 2.92 |
| 50s | -259.36*** | 3.39 | -273.03*** | 5.37 | -250.15*** | 4.37 |
| 60s | -375.28*** | 6.01 | -392.41*** | 8.86 | -363.76*** | 8.02 |
| 70s | -504.89*** | 14.21 | -562.55*** | 19.93 | -463.08*** | 19.16 |
| *Year* | | | | | | |
| 1840s | 195.59*** | 16.43 | 222.26*** | 42.40 | 192.16*** | 17.92 |
| 1850s | 82.93*** | 7.23 | 80.20*** | 26.17 | 80.98*** | 7.86 |
| 1860s | 50.68*** | 4.60 | 33.14*** | 6.82 | 63.46*** | 6.24 |
| 1870s | 27.40*** | 1.94 | 35.40*** | 2.88 | 21.45*** | 2.64 |
| 1880s | 17.49*** | 1.71 | 21.53*** | 2.40 | 14.36*** | 2.49 |
| 1890s | 12.95*** | 1.63 | 10.62*** | 2.29 | 16.78*** | 2.33 |
| 1900s | Reference | | Reference | | Reference | |
| 1910s | -5.18*** | 1.67 | -6.58*** | 2.40 | -4.28* | 2.32 |
| 1920s | -11.18*** | 4.79 | -8.48 | 7.19 | -13.48** | 6.44 |
| *Residence* | | | | | | |
| Arizona | -45.66*** | 4.40 | -17.11 | 14.54 | -46.56*** | 4.73 |
| Colorado | -28.19*** | 3.48 | -14.54* | 9.28 | -27.89*** | 3.91 |
| Idaho | -3.08 | 8.13 | -22.56 | 28.61 | -.382 | 8.54 |
| Kentucky | -74.01*** | 2.20 | -78.63*** | 2.95 | -68.56*** | 3.30 |
| Missouri | -84.33*** | 2.25 | -93.46*** | 3.54 | -78.38*** | 3.01 |
| New Mexico | -11.46*** | 4.35 | -1.16 | 10.57 | -11.44** | 4.86 |
| Oregon | -22.33*** | 5.02 | -23.87 | 24.97 | -19.61*** | 5.26 |
| Pennsylvania | -100.08*** | 2.09 | -100.57*** | 4.23 | -97.16*** | 2.56 |
| Philadelphia | -119.78*** | 1.90 | -110.95*** | 3.07 | -121.29*** | 2.52 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tennessee | -28.48*** | 1.87 | -32.04*** | 2.56 | -21.51*** | 2.88 |
| Texas | Reference | | Reference | | Reference | |
| *Occupations* | | | | | | |
| White-Collar | -53.95*** | 2.81 | -70.93*** | 5.28 | -48.53*** | 3.49 |
| Skilled | -37.74*** | 2.16 | -44.48*** | 3.71 | -34.39*** | 2.79 |
| Farmer | 81.50*** | 2.40 | 78.72*** | 3.42 | 83.14*** | 3.39 |
| Unskilled | 29.85*** | 1.88 | 23.82*** | 2.72 | 24.58*** | 2.64 |
| No Occupation | Reference | | Reference | | Reference | |
| N | 141,407 | | 67,821 | | 73,586 | |
| $R^2$ | .2193 | | .1968 | | .2158 | |

Source: See Table 1.

Three general patterns emerge when comparing black and white BMRs and calories. First, black and white BMR and calorie allocations declined throughout the 19th century (Figure 3; Floud et al. 2011, p. 314), and much of it was structural. In the early 19th century, most of the US labor force was tied to agricultural occupations (Steckel, 1983). The 19th century's industrialization moved farm workers into factories, and with it, removed farmers from the physical environments where high BMRs and calories were required in modern skilled occupations, where lower BMRs and greater calorie consumption is common. Nineteenth century net nutrition also has much to do with morbidity and mortality, and before the mid-20th century, the increase in life expectancy is, to a great extent, attributable to better nutrition and improved sanitation conditions (Haines and Anderson, 1988; Fogel, 1993). Declining late 19th and early 20th century US black and white calories indicate that nutrition was not the primary cause of increased life expectancy because nutrition decreased as life expectancy increased. Therefore, black and white net nutrition declined throughout the late 19th and early 20th centuries, and life expectancy increases since the 1840s are unlikely due to improved nutrition (Oeppen and Vaupel, 2002).

Figure 3, Nineteenth Century Black and White US Basal Metabolic Rate and Calories Over Time




Source: See Tables 3 and 4, Models 2 and 3.

Second, BMRs and calories are related with occupations and socioeconomic status, and physically active farmers consistently had greater BMRs and received greater calories per day than workers in other occupations. Part of farmers' greater physical activity and nutrition were due to occupation requirements for work, and occupations that require greater physical activity require more calories. BMIs and BMRs also represent an individual's physical fitness, which are related to physical activity (Table 2; Strauss and Thomas, 1998, p. 774), and white collar and skilled workers were physically less active, had lower BMRs, and consumed fewer calories per day than physically active agricultural workers. Therefore, physically active farmers and unskilled workers had taller statures, heavier BMIs, greater BMRs, and consumed more calories per day than workers in other occupations, indicating they were more physically active, had greater percent muscle mass, and required more calories per day to maintain health (Wardlaw, Hampl, and DiSilvestro, 2004; Stevens et al. 2002; Poston et al. 1999; Must and Evans, 2011).

Third, BMRs and calories varied by residence, and rural Texans had both greater BMRs and consumed more calories per day than individuals in other regions. Primary staples in Southern diets were corn and pork, and a large proportion of calories were supplied by meat and animal proteins (Hilliard, 1972, pp. 62-69; Fogel, 1994, p. 136; Bodenhorn, 1999, p. 98;9 Fogel, 1994, pp. 132-137; Bodenhorn, 1999, p. 988); however, blacks did not share equally with whites in animal protein consumption, and slaves consumed a higher proportion of saturated fats (Hilliard, 1972, pp. 63-64; Ransom and Sutch, 1977, p. 11). As part of its 1846 admission into the Union, Texas was the only state that retained the right to distribute its public domain independently from the federal government. To attract and hold its population, early Texas policies liberally distributed land into the private sector. In 1870, easy land policies led to a large-scale Texas cattle industry (Cochrane, 1977, pp. 88-89), and animal proteins and fats are more calorie dense than plant-based crops (Hilliard, 1972, pp. 63-64).

Alternatively, BMRs and calories were lower in the upper South, which was agriculturally less productive than the Deep South. Primary crops in the Upper South were corn and tobacco, and the supply of animal proteins came largely from feral pigs (Cochrane, 1977, pp. 72-77). Still farther North, Philadelphia had both the lowest BMRs and the fewest calories per capita available in the US, indicating that urban workers were physically less active and received fewer calories per day than workers in rural locations. Moreover, diets in the Northeast were starchy and contained proportionally lower amounts of animal proteins than other locations (Cochrane, 1977, p. 72; Shergold, 1982, pp. 185-195). Consequently, 19$^{th}$ century black and white BMRs and calories varied by residence, and individuals in the Deep South had greater BMRs and access to more calories because the South was agriculturally productive, which required greater physical activity but compensated for greater physical activity with better net nutrition.

Other patterns are consistent with expectations. Calorie consumption varies with age, and Steckel (1986) indicates 19$^{th}$ century slave children received sub-standard dietary allotments and sought to enter the adult labor force as soon as they were able. Compared to a modern adult male benchmark, adult females consume about 90 percent of the calories consumed by adult males (Shergold, 1982). This contrasts with 19$^{th}$ century males between 19 and 21 years old who received 100.00 percent of 23 to 29 years old calories; adolescents between 16 and 18 received about 96 percent of the calories allocated to adult males, while 14 and 15 year olds received 91 percent of male workers' calorie allotment between the ages of 23 and 29. Therefore, both black and white youth BMRs and calories were lower than adults, indicating that adolescents received fewer calories per day. Nonetheless, white youth calories were closer to white adult calories than their black counterparts, supporting the assertion that 19$^{th}$ century blacks sought to escape sub-standard dietary allotments by entering the adult labor force as soon as they were able.

Although the difference is small, blacks consistently had greater BMRs and consumed more calories than whites (Fogel and Engerman,1974). BMRs and calories increase with physical activity, and 19$^{th}$ century blacks were physically more active than whites. To keep slaves healthy, slave masters had to feed slaves more calories to maintain slave plantation productivity (Fogal and Engerman, 1974, Figure 33, p. 112; Atack and Bateman, 1987, p. 210; Reese et al. 2003). After slavery, blacks were agricultural laborers and sharecroppers and devoted a higher proportion of their incomes to food acquisition (Higgs, 1977, p. 105; Ransom and Sutch, 1977, p. 210). Modern human biology studies also demonstrate that blacks have greater BMIs than whites because blacks have greater percent muscle mass, and muscle requires more calories than fat (Wagner and Heyward, 2000). It does not follow, however, that greater 19th century black BMRs and calorie allotments represent a more varied and nutritious diet because the quality of black calories lacked proteins and were skewed toward more calorie dense foods that had little nutritional content (Kiple and King, 1981, pp. 80-95; Ransom and Sutch, 1977, pp. 11-12, 152; Hilliard et al. 1972, pp. 63-64). Therefore, 19th century blacks were more physically active than whites, and consumed diets with more calories.

## VI. Accounting for 19th Century Black and White Basal Metabolic Rates and Calories

To more fully account for the source of the black-white BMR and calorie differentials, Blinder-Oaxaca decompositions are constructed on the black-white BMR and caloric differential (Oaxaca, 1973). Let $BMR_b$ and $BMR_w$ represent the BMRs of blacks and whites, respectively; $\alpha_b$ and $\alpha_w$ are the autonomous BMR components that accrue to blacks and whites; $\beta_b$ and $\beta_w$ are the black and white BMR returns associated with specific BMR enhancing characteristics, such as age and occupation. $X_b$ and $X_w$ are mean black and white characteristic matrices, and black BMRs are assumed to be the base structure. Similar decompositions are then constructed for the black and white calorie differential.

$$\Delta BMR = BMR_b - BMR_w = (\alpha_b - \alpha_w) + (\beta_b - \beta_w)\overline{X}_b + \beta_w(\overline{X}_b - \overline{X}_w)$$

The second right-hand side element is the component of the BMR and calorie differentials due to characteristic returns. The third right-hand side element are the parts of the BMR and calorie differentials due to differences in average characteristics and is undetermined because whites may have had characteristics associated with greater BMR and calorie values, but blacks were shorter and were more likely to live in the South.

Table 5, Nineteenth Century National Prison Basal Metabolic Rate and Calories Oaxaca Decompositions

| | | | | |
|---|---|---|---|---|
| **Basal Metabolic Rate** | | | | |
| *Levels* | | | | |
| Sum | 47.25 | 15.46 | 46.36 | 16.34 |
| Total | | 62.70 | | 62.70 |
| *Proportions* | | | | |
| Intercept | .857 | | .857 | |
| Ages | -.055 | .045 | -.071 | .061 |
| Received | .005 | -.004 | .006 | -.005 |
| Residence | -.011 | .171 | -.035 | .195 |
| Occupations | -.042 | .035 | -.018 | .011 |
| Sum | .753 | .247 | .740 | .261 |
| Total | | 1 | | 1 |
| | | | | |
| **Calories** | | | | |
| *Levels* | | | | |
| Sum | 40.13 | 39.50 | 39.06 | 40.57 |
| Total | | 79.63 | | 79.63 |
| *Proportions* | | | | |
| Intercept | .675 | | .675 | |
| Ages | -.095 | .071 | -.113 | .089 |
| Received | .007 | -.005 | .009 | -.007 |
| Residence | -.018 | .253 | -.053 | .287 |
| Occupations | -.065 | .178 | -.028 | .141 |
| Sum | .504 | .496 | .491 | .510 |
| Total | | 1 | | 1 |

Source: Tables 3 and 4, Models 2 and 3.

Using Table 3 and 4 coefficients (Models 7 and 8), BMR and calorie decompositions indicate the majority of greater black BMRs and calories were due to non-identifiable black characteristics, such as greater percent muscle mass and physical productivity that favored blacks (Table 5; Barondess et al. 1997; Flegal et al. 2010, p. 240). Measured in levels, the black and white BMR differential was due to returns, while the calorie differential was equally dispersed between returns and mean characteristics. Measured in proportions, the greatest explainable shares of the BMR and calorie differentials were due to occupations, which are a direct measure of socioeconomic status (Komlos, 1987), and whites had greater BMR and calorie returns than darker complexioned blacks. The black and white differentials declined throughout the 19th century, and white youth had greater BMR and calorie returns than blacks. Consequently, the black-white BMR differential is explained by characteristic returns, while the calorie differential is explained equally by returns and mean characteristics.

## VII. Conclusions

This study uses two less frequently considered biological measurements—basal metabolic rate and energy accounting—to shed new light on a generation's old question on the nature of 19th century biological conditions. Where statures and BMI studies offer insight into late 19th and early 20th century biological conditions, they provide little information on physical fitness and calories. However, BMRs and energy accounting offer insight into both physical activity and calories required to maintain health. Since 1840, life expectancy in developed economies have increased linearly, while black and white nutrition declined, indicating that much of the late 19th and 20th century longevity increase was not due to improvements in nutrition but better sanitation and medical intervention.

BMRs and energy accounting also offer insight into health by occupations and social status. Farmers and unskilled workers were more physically active, had greater percent muscle mass, and were in better health than skilled and white-collar workers. Basal metabolic rate and energy accounting also offers insights into regional health. During the 19th century antebellum period, the rural South produced a net agricultural surplus, and BMRs and calories were highest in Texas, indicating that agricultural workers were more physically active and produced a calorie surplus relative to work effort performed. Much has been written about the biological conditions and diets of 19th century black slaves, and this study finds that blacks had greater BMRs and received more calories per day. Blacks also received greater dietary allotments under slavery, but these calories were provided not out of slave master benevolence but because blacks were required to perform greater work effort. Therefore, while 17th and 18th century European workers toiled to produce a sufficient number of calories, 19th century US workers were well on their way to improved biological living conditions, as demonstrated through higher basal metabolic rates and more calorie abundant diets.

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