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Abstract

Nineteenth century white US statures varied with nutrition, disease exposure, and the physical environment. An additional explanation for stature growth is vitamin D production. Vitamin D is produced internally by the synthesis of cholesterol and sunlight in the epidermis. However, studies that link stature to insolation and vitamin D production rely on only one comprehensive data set. To test the relationship between insolation and stature further, this study broadens the sample to include both 19th century white Civil War recruits and prisoners, and illustrates that the relationship between stature and insolation was remarkably similar between white soldiers and prisoners, adding to the evidence that there is a positive relationship between stature and insolation.

JEL Code: I10.

Keywords: stature, insolation vitamin D.

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The Relationship between Stature and Insolation: Evidence from Soldiers and Prisoners

I. Introduction

The use of height data to measure living standards is now a well-established method in economics (Fogel, 1994, p. 138; Steckel, 1995; Steckel, 2009; Deaton, 2008; Case and Paxson, 2008). A populations' average stature reflects the cumulative interaction between nutrition, disease exposure, work, and the physical environment (Steckel, 1979, pp. 365-367; Tanner, 1962, pp. 1-27). By considering average versus individual stature, genetic differences are mitigated, leaving only economic and physical environment's relationship with stature. When diets, health, and physical environments improve, average stature increases and decreases when diets become less nutritious, disease environments deteriorate, or the physical environment places more stress on the body. Therefore, when traditional measures are unavailable, stature provides considerable insights into understanding historical processes.

Numerous studies consider 19th century US white stature variation, and a few patterns are now clear. Among the first unexpected findings was that while wages increased throughout the 19th century, white statures ironically declined (Table 1; Komos, 1987; Margo and Steckel, 1983; Costa, 1993). Other studies show that a broad set of explanatory variables were associated with 19th century stature variation. Better nutrition corresponds with taller average statures (Komlos, 1987; Haines, Craig, and Weiss, 2003). Exposure to disease and physically rigorous work regimens are associated with shorter statures. Average stature was also related with other characteristics, such as socioeconomic conditions, business cycles, and other measures for economic performance (Voth and Leunig, 1996, 2000, and 2006; Oxley, 2003 and 2006; Steckel, 2009, p. 7; Woitek, 2003; Sunder and Woiteck, 2005; Strauss, 1995; Svedburg, 2000; Steckel, 1983; Cavelaars et al, 2000; Alter and Oris, 2008). Still other studies rely more heavily on biological explanations, specifically solar radiation, human biology, and vitamin D production, and a stature-insolation relationship suggests there is a positive relationship between stature and vitamin D production (Carson, 2008, 2009). Nonetheless, these stature-insolation studies rely on a single population and are yet to be confirmed across independent samples.

Table 1, Comparison of 19th Century White Stature Studies

Study	*Birth Period*	*Sample*	*ΔStature*	*Farmer Stature Advantage*
Sokoloff and Vilaflour, 1983	1720-1753	Military, French and Indian War	2.5cm	.07 to .88cm
Margo and Steckel, 1983	1820-1840	Military, Civil War, Adult	.483	1.21
Komlos Cadets, 1987	1820s-1870s	Military, West Point, Youth	.720	Na, but +
Steckel and Haurin, 1994	1845-1900	Military, Ohio National Guard	-1.27	1.40
Komlos and Coclanis, The Citadel, 1995	1830-1930	Military, The Citadel	6.60	Na
Sunder, 2004	1830-19060	Prisoners, Tennessee	1.27	Na
Carson, 2008	Youth1840-1900 Adult, 1820-1890	Prisoners, Missouri	Youth .397 Adult .657	Youth .285 Adult .794
Carson, 2008	Youth 1810-1890 Adult 1780-1880	Prisoners, Pennsylvania	Youth .880 Adult -1.44	Youth 1.92 Adult 1.26
Carson, 2009	1800-1899	Prisoners, United States	-1.63	1.21
Carson, 2009	Youth 1850-1900 Adult 1820-1895	Prisoners, Texas	Youth -.245 Adult -1.01	Youth 1.88 Adult 1.58

Notes: Sokoloff and Vilaflour, 1983, Table, p. 462, time trend for native laborers and foreign artisans; Carson, 2009, US prisoners, p. 155; Carson, 2008, Missouri prisoners, pp.598-599; Carson, 2008, Pennsylvania prisoners, pp. 362-365; Steckel, 1994, pp. 160-161; Steckel and Haurin, 1994, p. 124; Komlos, 1987, p. 901. Birth decade is stature averaged across ages in 1820 and 1870; Komlos and Coclanis, 1995, p. 100. The Citadel is stature by birth decade; Margo and Steckel, 1983, pp. 169-170, Table 1. Non-farm is weighted average of the intercepts. Sunder (2004).

This study draws upon two large 19th century stature data sets—white Civil War recruits and white state penitentiary inmates—to assess factors associated with white stature variation and to determine if the stature-insolation hypothesis is observed across two independently collected samples. Three paths of inquiry are considered. First, how did 19th century white statures compare between two different socioeconomic groups? This paper demonstrates that the statures of soldiers and prisoners were similar throughout the 19th century. Second, how did soldier and prisoner statures vary with insolation, the primary source of vitamin D? The relationship between stature and insolation for Civil War soldiers and 19th century prisoners were remarkably similar, and sensitivity analysis demonstrates that stature-insolation effects were similar between soldiers and prisoners. Third, for both soldiers and prisoners, what was the relationship between stature and occupation? The farmer stature advantage among soldiers was comparable to the farmer stature advantage among prisoners, indicating the relationships between stature, insolation, and socioeconomic status were similar across two independent 19th century samples.

II. Data

Testing the stature-insolation hypothesis across independent samples requires three unique data sources. First, a reasonable measure for solar radiation is necessary. Second, two independently drawn stature samples are required. Military records represent biological living conditions among a higher socioeconomic segment of society, and prison records represent conditions among a lower socioeconomic status segment of society.

United States' Insolation

Calcium and vitamin D are two chemical elements required throughout life for healthy bone and teeth formation; however, their abundance are most critical during younger ages (Wardlaw, Hampl, and Divilestro, 2004, pp. 394-396; Tortolani et al, 2002, p. 60). Calcium generally comes from dairy products, and vitamin D in not dietary but is produced by the synthesis of cholesterol and sunlight in the epidermises' stratum granulosum (Holick, 2007 video; Holick, 2004a, pp. 363-364; Nesby-O'dell, 2002, p. 187; Loomis, 1967, p. 501; Norman, 1998, p. 1108; Holick, 2007). Greater direct sunlight (insolation) produces more vitamin D, and vitamin D is related to adult terminal statures (Xiong et al, 2005, pp. 228, 230-231; X-ZLiu et al, 2003; Ginsburg et al 1998; Uitterlinden et al, 2004).[1] After the circulatory system contains sufficient amounts of vitamin D and to avoid vitamin D toxicity, vitamin D production is restricted within the stratum granulosum and residual vitamin D is broken down into inert matter (Holick et al, 1981, pp. 591-592; Jablonski, 2006, p. 62; Holick, 2001, p. 20; Holick, 2004a, p. 363). This self-limiting vitamin D effect may account for white stature variation with insolation, because at North American latitudes whites are close to the natural threshold where vitamin D production is curtailed (Jablonski, 2006, p. 62; Carson, 2009, pp. 150 and 154). At the opposite extreme, insufficient vitamin D has been linked to rickets,

[1] Carson (2009, pp. 150 and 154) demonstrates that 19th statures were related to various factors, including the primary source of vitamin D production (insolation).

osteomalasia, auto-immune diseases, and certain cancers (Holick, 2001, p. 28; Garland et al, 2006, pp. 252-256; Grant et al, 2003, p. 372).

To account for the relationship between vitamin D and stature, a measure is constructed that accounts for solar radiation. Insolation is the incoming direct sunlight that reaches the earth, its atmosphere, and surface objects.[2] Insolation and ultraviolate B are also the primary source of vitamin D production (Holick, 1981, p. 590; Holick, 2007, p. 270). Because of its distance from the equator, European insolation is comparatively low, and before their migration to North America, Europeans at low insolation latitudes had to be more efficient in vitamin D production. As early hominids migrated out of Africa to Northern latitudes, they received less solar radiation, and through the process of natural selection, darker pigmented hominids were less successful hunter-gatherers in Northern latitudes and were selected-out (Loomis, 1967, pp. 503-504).

Because US historical insolation is unavailable, a modern insolation index (1993-2003) is constructed, and monthly insolation values are measured from January through June. The insolation index measures statewide average insolation levels across each of the states based on the hours of direct sunlight per day at county centroids in each state.[3]

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[2] Insolation is an acronym for incident solar radiation, and is a measure for sunlight energy received for a given surface area at a given time. If w equals watts, m equals meters, and i equals insolation, $i = \frac{w}{m^2} = \frac{kwh}{m^2 \cdot day}$. Data for US insolation is available from the National Aeronautics and Space Administration at http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi.

[3] Insolation is not the insolation in the county that surround's the state's centroid, but insolation in each county's geographic center. The range of state insolation values extends from Maine's minimum of 3.43 hours of direct sunlight to Arizona's maximum of 5.22 hours of direct sunlight per day.

Each state estimate was then determined by summing the average hours of direct sunlight for each county (at its centroid), weighted by the proportion of the county's total land area (in square miles) to the state's total land area (in square miles). While this index is a rough approximation for historical insolation, it provides sufficient detail to capture state latitudinal insolation variation and consequently, vitamin D production. Predictably, Southern states have greater insolation than Northern states. For example, Texas receives 1.43, or 29 percent, more hours of direct sunlight per day than New York. It is also difficult to interpret insolation's net direct effect on human health, because greater insolation reduces calories required to maintain body temperature and produces more vitamin D, but greater insolation also warms surface temperatures, which may have made disease environments less healthy from water-borne diseases, especially in the South (Steckel, 1992, p. 501).

Military Records

All historical height data have various biases. Data used to study 19th century white military statures is drawn from the Union Army Recruits in White Regiments books archived at the University of Chicago's Center for Population Economics. [4] The White Regiment records were first gathered by collecting a sample of early 19th century males mustered into the Union Army between 1861 and 1865. A list of over 20,000 companies was then extracted. A target sample of approximately 40,000 individuals was decided upon, and 331 companies were selected, producing an initial sample size of 39,616 soldiers. After eliminating immigrants and soldiers born before 1800 and after 1849, there are 24,820 white native military recruits available from these white regiment

[4]Union Army Recruits in White Regiment data is accessed at http://www.cpe.uchicago.edu/data/data.html.

records to compare the statures of a high socioeconomic status military cohort to those in a lower socioeconomic status prison cohort.

Table 2, Nineteenth Century US State Enlistment State and Penitentiaries

	White Recruits		*White Prisoners*	
Prison	N	Percent	N	Percent
Alabama	23	.09	218	.72
Arkansas	23	.09	97	.32
Connecticut	421	1.70	212	.70
Deleware	301	1.21	76	.25
Wasington DC	21	.08	62	.21
Georgia	25	10	280	.93
Illinois	1,289	5.19	1,431	4.73
Indiana	1,505	6.06	942	3.12
Iowa	118	.48	173	.57
Kansas	15	.06	34	.11
Kentucky	1,015	4.09	2,749	9.09
Louisiana	25	.10	357	1.18
Massachusetts	620	2.50	689	2.28
Maryland	439	1.77	703	2.33
Maine	478	1.93	209	.69
Michigan	510	2.05	245	.81
Minnesota	1	.00	13	.04
Mississippi	16	.07	176	.58
Missouri	418	1.68	1,416	4.68
Nebraska	2	.01	4	.01
New Hampshire	445	1.79	109	.36
New Jersey	584	2.35	463	1.53
New Mexico	68	.27	38	.13
New York	5,134	20.68	4,727	15.63
North Carolina	113	.46	269	.89
Ohio	5.491	22.12	4,954	16.39
Pennsylvania	3,832	15.44	6,247	20.66
Rhode Island	44	.18	92	.30
South Carolina	24	.10	166	.55
Tennessee	321	1.29	1,015	.36
Texas	3	.01	251	.83
Vermont	624	.251	298	.99
Virginia	529	2.13	1,306	4.32
Wisconsin	175	.71	119	.39
West Virginia	168	.68	94	.31
Total	24,820	100.00	30,234	100.00

Source: Data used to study 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.

Notes: Stature is in centimeters. The occupation classification scheme is consistent with Ferrie (1997).

Regiment enumerators recorded soldier characteristics at the time of enlistment, and only soldiers identified as whites by military enlistment officers are included in the White Regiment books. Physical descriptions in the White Regiment books were recorded at the time of enlistment with great care as a means of identification because accurate measurements had identification implications in the event of death or desertion; accurate physical descriptions were also used to limit bounty jumping, where recruits enlisted to collect financial enlistment rewards, only to desert and collect additional enlistment bonuses at other recruiting stations. Military enumerators routinely recorded conscription dates, age, nativity, and stature; therefore, enlistment characteristics reflect pre-incarceration conditions. Regiment enumerators also recorded pre-military occupations, and these occupations are classified into four categories: merchants and high skilled workers are classified as white-collar workers; light manufacturers, craft workers, and carpenters are classified skilled workers; agricultural workers are classified as farmers; laborers and miners are classified as unskilled workers. Most recruits were from middle-Atlantic states, such as Ohio, New York, and Pennsylvania (Table 2). The soldier sample is also probably rural because most white soldiers in the sample were farmers.[5]

United States' Prison Data

To contrast the stature-insolation relationship of a high socioeconomic group with low socioeconomic group, a data set from a lower socioeconomic group is required. Prisoners, that segment of society most vulnerable to economic change, may have selected a number of the materially poorest individuals, although there were skilled prisoners in the sample (Bogin, 1991, p. 288; Komlos and Baten, 2004, p. 199; Nicholas

[5] Costa, 1993, p. 359.

and Steckel, p. 944). Moreover, if at the margins of subsistence, demographic, socioeconomic factors, and insolation were more significant in stature attainment, prison records may illustrate these effects more clearly. Most whites in the prison sample were imprisoned in Ohio, Missouri, Texas, and Pennsylvania prisons (Table 2).

There also is concern over prison entry requirements, and physical descriptions were recorded by prison enumerators at the time of incarceration as a means of identification, therefore, reflect pre-incarceration conditions. Between 1830 and 1920, prison officials routinely recorded the dates inmates were received, age, complexion, nativity, stature, pre-incarceration occupation, and crime. All prison records with complete age, stature, occupation, and nativity were collected. There was care recording inmate statures because accurate measurement had legal implications for identification in the event that inmates escaped and were later recaptured.[6] Arrests and prosecutions across states may have resulted in various selection biases that may affect the results of this analysis. However, white stature variations within US prisons are consistent with other stature studies (Steckel, 1979; Margo and Steckel, 1982; Nicholas and Steckel, 1991, pp. 941-943; Komlos, 1992; Komlos and Coclanis, 1997; Bodenhorn, 1999; Sünder, 2004).

Fortunately, inmate enumerators were quite thorough when recording inmate complexion and occupation. For example, enumerators recorded inmates' race in a complexion category, and enumerators recorded white complexions as light, medium, dark, and fair. The white inmate complexion classification is further supported by European immigrant complexions, which were always of fair complexion and were also

[6] Many inmate statures were recorded at quarter, eighth, and even sixteenth increments.

recorded as light, medium, and dark.[7] Inmate enumerators recorded a broad continuum of occupations and defined them narrowly, recording over 200 different occupations, which are classified here into four categories: merchants and high skilled workers are classified as white-collar workers; light manufacturing, craft workers, and carpenters are classified as skilled workers; workers in the agricultural sector are classified as farmers; laborers and miners are classified as unskilled workers (Tanner, 1977, p. 346; Ladurie, 1979; Margo and Steckel, 1992; p. 520). Unfortunately, inmate enumerators did not distinguish between farm and common laborers. Since common laborers probably encountered less favorable biological conditions during childhood and adolescence, this potentially overestimates the biological benefits of being a common laborer and underestimates the advantages of being a farm laborer. To make meaningful comparisons across the soldier and prisoner samples, only white males are included in this analysis, and age, nativity, and birth-cohort characteristics are restricted in each sample to only males born between 1800 and 1849 in the same states and between the ages of 15 and 59.

Soldier and Prisoner Summary Statistics

Because the height distribution is itself a function of the age distribution, a height index is constructed for both soldier and prisoner samples to determine if statures were distributed symmetrically and whether there were arbitrary truncation points imposed on soldier and prisoner statures, either by military recruitment standards, law enforcement,

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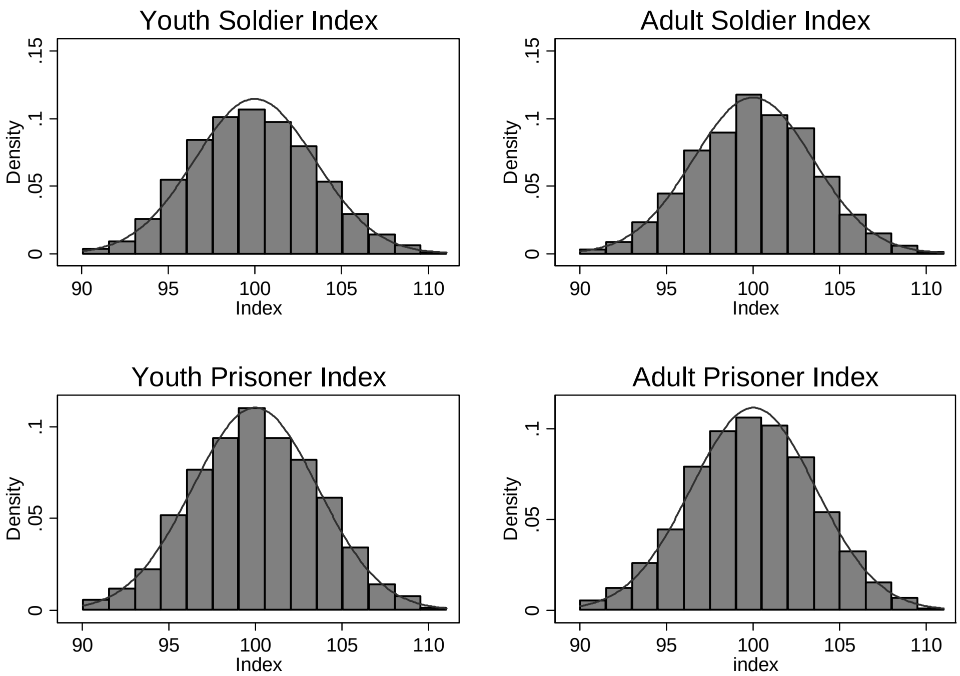
[7] I am currently collecting 19th century Irish prison records. Irish prison enumerators also used light, medium, dark, fresh and sallow to describe white prisoners in Irish prisons from a traditionally white population. To date, no inmate in an Irish prison has been recorded with a complexion consistent with African heritage.

or state legislation. This index is calculated by first calculating the average stature for each age group; each observation is then divided by the average stature for the relevant age group (Komlos, 1987, p. 899). Figure 1 demonstrates that white soldier and prisoner statures were distributed approximately symmetric and there is little evidence of stature heaping or arbitrary truncation points.

Figure 1, National Black and White Stature Histograms by Age Group



Source: see Table 2.

Table 3, National Military and Prison Data White Descriptive Statistics

	White Recruits				*White Prisoners*				*Mean Difference*
Ages	N	Percent	Mean	S.D.	N	Percent	Mean	S.D.	
Teens	6,993	28.15	169.80	6.52	1,917	6.34	169.34	6.49	.46
20s	12,239	49.26	173.37	6.27	12,883	42.61	171.73	6.50	1.64
30s	3,962	15.95	174.11	6.37	7,896	26.12	172.39	6.49	1.72
40s	1,560	6.28	173.56	6.34	4,797	15.87	172.29	6.69	1.27
50s	91	.37	175.80	6.03	2,741	9.07	171.96	6.55	3.84
Birth Decade									
1800s	51	.21	176.23	5.60	783	2.59	172.40	6.47	3.83
1810s	662	2.66	173.72	6.51	2,248	7.44	172.61	6.62	1.11
1820s	3,022	12.16	173.90	6.42	3,843	12.71	172.48	6.81	1.42
1830s	7,931	31.92	173.93	6.29	7,496	24.79	171.93	6.60	2
1840s	13,179	53.04	171.25	6.54	15,864	52.47	171.55	6.48	-.3
Occupation									
White-Collar	365	1.51	172.29	6.73	3,086	10.21	171.43	6.35	.86
Skilled	4,466	18.44	172.20	6.40	8,852	29.28	171.40	6.41	.80
Farmer	14,119	58.29	173.06	6.60	4,678	15.47	173.37	6.44	-.31
Unskilled	5,274	21.77	171.34	6.48	13,618	45.04	171.74	6.70	-.40
Nativity									
North East	2,632	10.59	172.45	6.29	1,609	5.32	171.15	6.54	1.3
Middle Atlantic	10,323	41.55	171.74	6.45	12,307	40.71	170.60	6.35	1.14
Great Lakes	8,980	36.14	173.07	6.57	7,662	25.34	172.65	6.41	.42
Plains	555	2.23	172.80	7.19	1,640	6.42	172.05	6.59	.75
Southeast	2,284	9.19	173.91	6.86	6,727	22.25	173.30	6.47	.61
Southwest	71	.29	166.04	7.71	289	.96	166.60	6.17	-.56

Source: See Table 2.

Notes: Stature is in centimeters. Youth age is between ages 15 and 22. The occupation classification scheme is consistent with Ferrie (1997); The following geographic classification scheme is consistent with Carlino and Sill (2000): New England= CT, ME, MA, NH, RI and VT; Middle Atlantic= DE, DC, MD, NJ, NY, and PA; Great Lakes= IL, IN, MI, OH, and WI; Plains= IA, KS, MN, MO, NE, ND, and SD; South East= AL,

AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, and WV; South West= AZ, NM, OK, and TX; Far West= CA, CO, ID, MT, NV, OR, UT, WA, and WY.

Table 3 presents white soldier and prisoner ages, birth decade, occupations, and nativity percentages. Although average statures are included, they are not reliable because of possible compositional effects, which are accounted for in the regression models that follow. Age percentages demonstrate that soldiers were enumerated at younger ages, prisoners at older ages. Consistent with older prisoner ages, prisoner birth years were earlier in the 19th century than soldier birth years. Occupation distributions illustrate the counterintuitive result that inmates were consistently more skilled than soldiers. Much of this may be attributable to age profiles; prisoners were older than soldiers, were further along in their occupational life cycle, therefore, more likely skilled than soldiers. Soldier average age was 24.96; prisoner average wage was 32.30. Farmers in the soldier sample were overrepresented compared to farmers in the census (McPherson, 1988, pp. 607-608); unskilled workers in the prison sample were overrepresented compared to unskilled workers in the census (Rosenbloom, 2000, p. 88). Soldiers were also more likely to be from the Northeast and Great Lakes, while prisoners were more likely to be from the Plains and Southern states. Therefore, soldiers were more likely than prisoners to be young farmers from the Northeast and Great Lakes, while prisoners were more likely to be skilled from Plains and Southern states.[8]

[8] Because prison enumerators failed to distinguish between common and farm laborers, many unskilled prisoners were also farmers.

III. Comparative Effects of Demographics, Socioeconomic Status on White Characteristics

Nineteenth century soldiers and prisoner statures were related to age, birth years, occupations, migration, and nativity. They may have also been related to insolation, which is the primary source of vitamin D production (Holick, 2007 video). We test which of these variables were associated with stature, and separate regressions are run on the military and prison samples. To start, soldiers and prisoners are partitioned into separate groups, and the i[th] soldier and prisoner statures are assumed to be related with age, birth period, occupation, migration, nativity, and insolation.

$$Centimeter_i = \alpha + \sum_{a=15}^{50} \beta_a Age_{i,a} + \sum_{t=1800}^{1839} \beta_t Birth_{i,t} + \sum_{l=1}^{4} \beta_l Occupation_{i,l} + \sum_{n=1}^{6} \beta_n Nativity_{i,n}$$

$$+ \beta_{Mig} Migration_{i,Mig} + \beta_{Isol} Insol_{i,Insol} + \beta_{Insol^2} Insol^2_{i,Insol^2} + \varepsilon_i$$

Dummy variables are included for youth ages 15 through 22; adult age dummies are included for 40 and 50 year old age intervals. Birth decade dummies are in ten year intervals from 1800 through 1849. Dummy variables are included for white-collar, skilled, and agricultural occupations. Nativity dummy variables are included for birth in Northeast, Middle-Atlantic, Plains, Southeast, and Southwest regions. Lastly, continuous insolation and insolation squared terms are included to account for insolation and vitamin D production.

Tables 4 and 5’s Model 1 includes unrestricted age, birth, occupations, nativity variables, and continuous insolation variables. This unrestricted model is then compared in Models 2 through 5 to restricted models for insolation, socioeconomic status, birth periods, and nativity.

Table 4, Nineteenth Century White Prisoner Statures related to Birth Decade,

Occupations, Nativity, and Insolation.

Coefficient	Unrestricted	Insolation Omitted	SES Omitted	Birth-Period Omitted	Nativity Omitted
Intercept	135.11***	172.14***	133.03***	132.23***	102.18***
Ages					
15	-8.77***	-8.80***	-8.73***	-8.71***	-8.48***
16	-6.19***	-6.20***	-6.19***	-6.21***	-6.05***
17	-3.19***	-3.19***	-3.14***	-3.25***	-3.06***
18	-2.68***	-2.67***	2.64***	-2.73***	-2.62***
19	-1.34***	-1.34***	-1.26***	-1.38***	-1.33***
20	-1.14***	-1.14	-1.07***	-1.15***	-1.12***
21	-.478***	-.472***	-.417**	-.502***	-.490***
22	-.263	-.253	-.235	-.295*	-.267
23-29	Reference	Reference	Reference	Reference	Reference
30s	.374***	.370***	.353***	.432***	.415***
40s	.184	.171	.203	.324***	.218*
50s	-.277**	-.292**	1.231*	-.084	-.239*
Birth Decade					
1800	.993***	1.06***	1.08***		.773***
1810	1.26***	1.30***	1.29***		1.19***
1820	.938***	.970***	.967***		.960***
1830	.318***	.338***	.324***		.360***
1840	Reference	Reference	Reference	Reference	Reference
Occupations					
White Collar	-.135	-.158		-.200	-.182
Skilled	-.249***	-.254***		-.218**	-.277***
Farmer	1.27***	1.27***		1.31***	1.45***
Unskilled	Reference	Reference	Reference	Reference	Reference
Nativity					
Northeast	-.160***	-1.72***	-1.82***	-1.46***	
Middle Atlantic	-1.92***	-2.09***	-2.13***	-1.80***	
Great Lakes	Reference	Reference	Reference	Reference	Reference
Plains	-.429**	-.646***	-.529***	-.481***	
Southeast	.709***	.463***	.577***	.868***	
Southwest	3.87***	.803*	3.88***	4.10***	
Migration					
Migrant	.472***	.409***	.497***	.448***	.172**
Non-Migrant	Reference	Reference	Reference	Reference	Reference
Insolation					
Insolation	19.45***		20.58***	21.18***	33.10***
Insolation^2	-2.55***		-2.69***	-2.79***	-3.88***

N	30,234	30,234	30,234	30,234	30,234
R^2	.0592	.0582	.0535	.0554	.0483

Source: See Table 2.

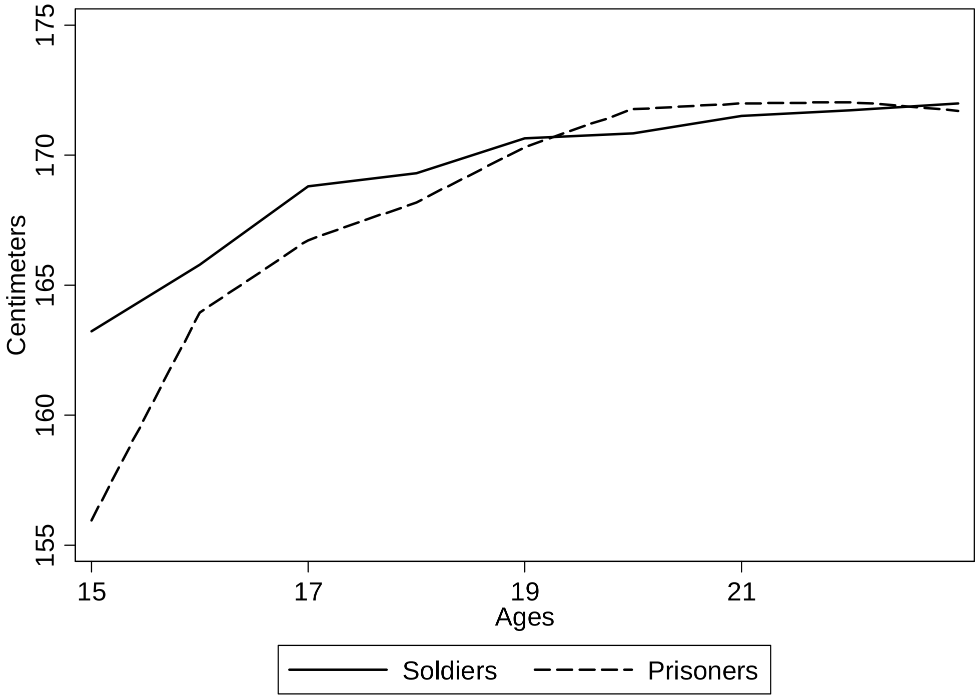
Table 5, Nineteenth Century White Soldier Statures related to Birth Decade, Occupations, Nativity, and Insolation.

	Unrestricted	Insolation Omitted	SES Omitted	Birth-Period Omitted	Nativity Omitted
Coefficient					
Intercept	68.90***	171.67***	52.39***	69.03***	90.32***
Ages					
15	-15.76***	-15.18***	-15.09***	-16.24***	-15.25***
16	-7.76***	-7.77***	-7.68***	-8.75***	-7.73***
17	-4.98***	-4.94***	-4.87***	-5.97***	-4.97***
18	-3.53***	3.51***	-3.30***	-4.53***	-3.53***
19	-1.41***	-1.39***	-1.25***	-2.40***	-1.41***
20	.059	.085	.196	-.934***	.060
21	.274	.288	.373*	-.719***	.271
22	.336*	.333*	.413**	-.31**	.336*
23-29	Reference	Reference	Reference	Reference	Reference
30s	.315*	.314*	.301*	.482***	.337**
40s	-.216	-.251	-.216	-.037	-.168
50s	1.14	1.10	1.39	1.89***	1.13
Birth Decade					
1800	2.16	2.29*	1.85		2.26*
1810	1.22***	1.21***	1.21***		1.26***
1820	1.15***	1.12***	1.16***		1.16***
1830	1.18***	1.18***	1.23***		1.18***
1840	Reference	Reference	Reference	Reference	Reference
Occupations					
White Collar	.136	.157		.152	.099
Skilled	.115	.156		.130	.082
Farmer	1.50***	1.63***		1.52***	1.50***
Unskilled	Reference	Reference	Reference	Reference	Reference
Nativity					
Northeast	.018	-.167	-.072	.059	
Middle Atlantic	1.56***	1.11***	1.61***	1.49***	
Great Lakes	Reference	Reference	Reference	Reference	Reference
Plains	1.03***	.844***	1.18***	1.04***	
Southeast	.187***	.968***	.937***	.838***	
Southwest	4.03**	-6.27***	4.35**	4.13**	
Migration					
Migrant	.075	.015	.135	.079	.079
Non-Migrant	Reference	Reference	Reference	Reference	Reference
Insolation					
Insolation	53.90***		62.62***	54.38***	41.77***
Insolation^2	-7.03***		-8.12***	-7.10***	-5.31***

N	24,820	24,820	24,820	24,820	24,820
R^2	.1076	.1040	.0964	.1061	.1060

Source: See Table 2.

Figure 2, Soldier and Prisoner Youth Statures by Age



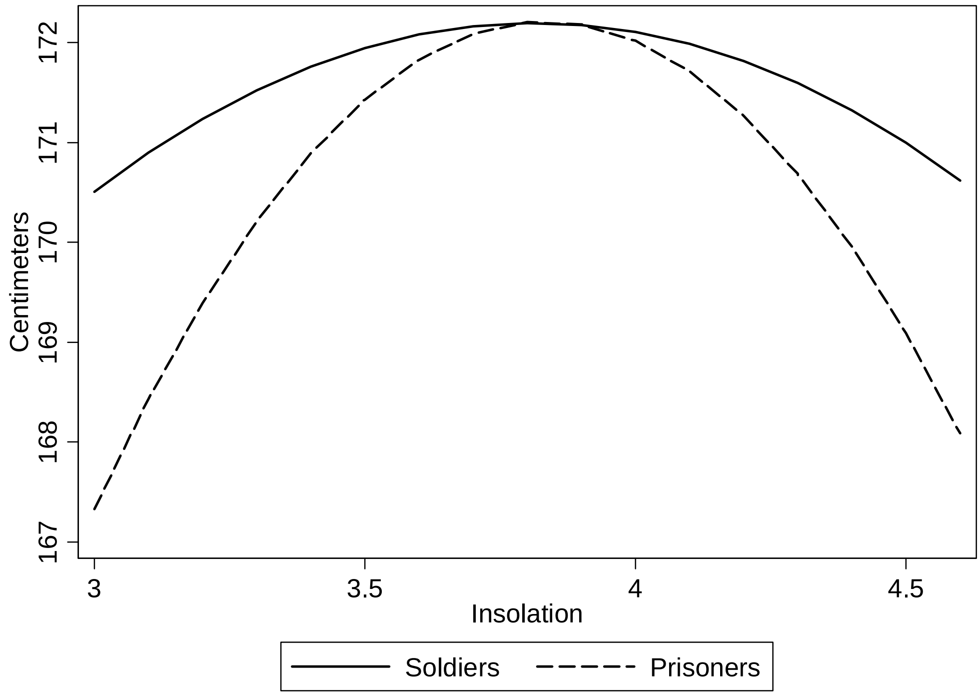
Source: See Tables 4 and 5.

Figure 3, Nineteenth Century Soldier and Prisoner Statures by Birth Decade

Source: See Tables 4 and 5.

Three general patterns emerge when comparing 19th century white soldier and prisoner statures. First, stature comparisons by age and birth year demonstrate that soldiers and prisoners reached about the same terminal statures (Figures 2 and 3). The majority of soldiers were from the agricultural class, that socioeconomic group that received better nutrition allocations and lived in rural environments, where infectious disease was less easily propagated (Lee, 1997). Early 19th century agriculture was in the early stages of commercialization, and the majority of Northeastern farmers lived on self-sufficient family farm units (Carson, 2008, p. 349). Prisoners were also taller because they were of Southern nativity, which was biologically beneficial because the South was rural, self-sufficient in food production, and the South also received more solar radiation.

Figure 4, Nineteenth Century Soldier and Prisoner Statures by Insolation



Source: See Tables 4 and 5.

Second, consistent with the insolation-stature hypothesis, insolation was positively related with soldier and prisoner statures and increased with insolation at a decreasing rate (Figure 4), and soldier and prisoner's average stature reached a maximum in insolation at 3.82 hours of incident solar radiation per day. Nonetheless, there were differences between how soldier and prisoner statures, and soldier and prisoner stature variation was sensitive to socioeconomic status. If soldier and prisoner statures are observed at average US insolation levels, soldiers and prisoners came to comparable terminal statures, 171.72 and 171.99 cms respectively. If, on the other hand, soldier and prisoner statures are observed at US insolation extremes, the soldier-prisoner stature differential was large. For example, observed at the lowest state-insolation level, Maine, soldiers were shorter than prisoners, 171.04 to 171.81 centimeters, respectively. Observed at the highest state-insolation level, Arizona, prisoners were taller than soldiers, 167.15 to 158.7 centimeters, respectively. The prisoner stature advantage in insolation indicates prisoner's, who likely received smaller stature benefits from other sources and had larger stature growth with insolation. Therefore, there was an absolute maximum stature that whites reach with insolation, and insolation effects differed by socioeconomic status at the extremes. [9]

Sensitivity analysis indicates the omission of insolation had considerable interaction with nativity. A joint test for soldiers and prisoner statures on insolation variables illustrates that insolation's omission over estimates the effect of nativity with stature, while having little effect on other variable slope coefficients; insolation omission also upwardly biases the intercept (Soldiers, F-Statistic: 48.36, p=.0000; Prisoners, F-Statistic: 14.68, p=.0000), indicating that when insolation is omitted the asymptotic bias on stature with nativity variables and the intercept are positive (Woolridge, 2002, p. 62; Woolridge, 2003. p. 92, Table 3.2).

Third, after controlling for insolation, 19th century farmers were at a biological advantage to workers in other occupations, and the farmer stature advantage for both soldiers and prisoners was remarkably similar (Table 3, Models 1 and 4). Farmers

[9] Average US insolation is 4.33; average Maine insolation is 3.43; average Missouri insolation is 4.16; average Arizona is 5.22.

traditionally had greater access to superior diets and nutrition. An additional explanation to nutrition and disease is that farmers worked outdoors and were exposed to greater sunlight during adolescent ages. Islam et al. (2007, pp. 383-388) demonstrates that children were exposed to more sunlight and produced more vitamin D, and if there was little movement away from parental occupations, 19th century occupations may also be a good indicator for the occupational environment in which individuals came to maturity (Costa, 1993, p. 367; Margo and Steckel, 1992, p. 520; Burdieu, Ferrie, and Kesztenbaum, 2009).

Occupation omission effects on restricted model coefficients are similar between soldiers and prisoners. A joint test on socioeconomic status has little effect on other restricted model slope coefficients; however, socioeconomic status was jointly related with stature (F-statistic: Soldiers, 104.52, p=.0000; Prisoners, 62.75, p=.0000). Socioeconomic status omission did not influence the stature relationship with other variables. Consequently, stature and socioeconomic status may also be related to inslotion and vitamin D production but not other variables (Badiwala et al., 2003, pp. 659-660; Holick, et al., 1981, p. 590).

Other patterns are consistent with expectations. Both soldier and prisoner statures declined throughout the first half the 19th century (Figure 3). Between 1800 and 1840, white soldier and prisoner statures declined by about two cms. These stature declines are comparable to those observed for National Guardsman reported by Steckel and Haurin (1994) and prisoners reported by Carson (2008 and 2009). Moreover, birth period omission effects are similar between soldiers and prisoners. A joint test on birth-period effects has little influence on other restricted model slope coefficients; however, birth-period was related with stature variation (F-statistic: Soldiers: 13.68, p=.0000; Prisoners: 32.07, p=.0000), indicating that birth-period was significantly related with stature, and the omission of birth-period variables does not influence other variable interactions with stature.

White statures varied regionally, and Southern whites were taller than Northern whites. Part of the Southern stature advantage was also related to Southern agriculture. The 19th century opening of the New South to agriculture increased Southwestern agricultural productivity, which was higher than elsewhere within the US (Margo and Steckel, 1983, pp. 169-170; Steckel and Haurin, 1994, pp. 125-127). Nativity omission effects on restricted model coefficients are similar between soldiers and prisoners. A joint test on nativity for both soldiers and prisoners downwardly biases the relationship between being a insolation and stature (F-Statistic, Soldiers: 8.73, p=.0000; Prisoners: F-Statistic, 69.01, p=.0000).

IV. Conclusion

This paper uses two large independently collected samples of European-American soldiers and prisoners to test how white statures varied by insolation for two different socioeconomic groups. Three observations are observed and are consistent with the existing literature. First, white Civil War recruits and prisoners came to about the same statures; however, this result must be interpreted with caution. While soldiers came from the agricultural class, prisoners were from the South and benefited from greater agricultural productivity; the South also receives more insolation. Second, soldier and prisoner statures were related with insolation in remarkably similar ways. White soldier and prisoner statures increased with insolation at a decreasing rate, and the threshold where stature reaches its maximum in insolation is similar. Third, although the soldier sample is clearly drawn from higher socioeconomic status, the farmer stature advantage for military and prison samples was similar. The effects of insolation omission are also coming into focus. Nativity was related to stature, and this paper demonstrates that studies that do not account for nativity may underestimate the relationship between stature and nativity. The effect of omitting socioeconomic status and birth period variables however has little relationship between stature and other variables.

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