THE MEASURE OF MAN AND OLDER AGE MORTALITY: EVIDENCE FROM THE GOULD SAMPLE

by

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ABSTRACT

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This paper documents differences in body size between white, black, and Indian mid-nineteenth century American men and investigates the socioeconomic and demographic determinants of frame size using a unique data set of Civil War soldiers. It finds that over time men have grown taller and heavier and have relatively less abdominal fat, implying that "modern" chronic diseases such as ischemic heart disease were common in the past. Abdominal fat in young adulthood was an excellent predictor of older age mortality from ischemic heart disease or stroke. Changes in frame size explain almost half of the mortality decline among white men between 1914 and 1988 and predict even sharper declines in older age mortality between 1988 and 2022.

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1 Introduction

Past populations were shorter-lived, smaller, lighter, and faced a heavier disease burden in old age. Among Union Army veterans age 60 to 74 in 1910, more than one-third had difficulty walking, almost one-third had valvular heart disease, over half of them had arthritis, and more than one-third of them had decreased breath and adventitious sounds (Costa 2000, 2002). Union Army soldiers in their thirties and Union Army veterans in their late fifties and early sixties had an average Body Mass Index (BMI) of only 23, compared to one of 26 for men in 1961 (Costa and Steckel 1997). The abundant information that we have on adult heights suggests that health cycled in the past. Troops who fought in the French and Indian Wars and in the American Revolution nearly attained the heights of those born in the 1930s (roughly 175cm), but then average height fell by 4cm in the ensuing half century, reaching a trough among those born in the 1880s before rising 6cm for those cohorts born in the middle of the twentieth century. Life expectancy at age 10 underwent similar cycles (Costa and Steckel 1997; Fogel 1986).

Painting an accurate picture of the health of past populations can help us assess trends in living standards, forecast future mortality rates, and understand theories of the epidemiological transition and the etiology of disease. The study of the epidemiological transition is still dominated by Omran's (1971) classic essay in which he postulated that there are three successive stages to the epidemiological transition: 1) the age of pestilence and famine, 2) the age of receding pandemics, and 3) the age of degenerative and man-made diseases.[1] During the second stage infectious and parasitic diseases dominate, heart disease rates are low and what heart disease there is is primarily rheumatic. During the third stage these types of diseases become less common and cancer, stroke, and ischemic heart disease become the prime killers.

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[1] The theory was later amended to add a fourth stage in which life-expectancy at older ages rises as the onset of chronic disease is delayed (Omran 1982; Olshansky and Ault 1986).

Were “modern” chronic diseases really uncommon in the past? Costa (forthcoming) finds that whereas heart disease accounts for 38 percent of all deaths among Union Army veterans observed at ages 50 to 64 and followed over a 17 year period, 18 out of those 38 percentage points are impossible to classify by type of heart disease. Ten of those 38 percentage points were due to cerebrovascular disease, 5 percent to valvular disease, and 4 percent to ischemic disease. In contrast, among men of the same age first observed in the 1970s over the same follow-up period, 52 percent of all deaths were due to heart disease and 42 out of those 52 percentage points were due to ischemic heart disease. Stroke accounted for none of the deaths in the modern sample. Was ischemic heart disease underdiagnosed in the past? Ischemic heart disease is diagnosed with exercise stress tests and with EKGs. Angina is often, but not always, a symptom. Arteriosclerosis and hypertension are precursors of both ischemic and cerebrovascular heart disease. Although differences in diagnoses do not allow us to make an exact comparison, our best numbers show that nine percent of Union Army veterans aged 60-74 in 1910 had arterioscerosis compared to 5 percent of men of the same age in 1994 (Costa 2002). We do not know what hypertension rates were before the availability of blood pressure tests. We do know that they are high today: 36 percent of white American men age 60 to 74 in the 1980s were hypertensive.

Anthropometric measures can provide some clues on disease prevalence in past populations. For example, in modern populations waist-hip ratio predicts hypertension and cerebrovascular and ischemic heart disease. Provided that the relationship has remained the same, measurements of waist-hip ratio could provide some clues on the prevalence of hypertension and ischemic heart disease.

This paper uses detailed anthropometric measurements to describe the body size of American men, white, black, and Indian, who fought in the Civil War. These anthropometric records can confirm or contradict prior findings on the health status of past populations. Steckel (1989) discovered that the slave population of the United States experienced an unusual pattern of growth; by four and a half years of age they were only at the 0.2 height centile, below the level of the poorest populations of developing countries but later experienced such remarkable catch-up growth that by adulthood they were only slightly shorter than northern, white men and were taller than most European populations. They were also heavier than northern whites (Fogel 1992). In contrast, the Plains Indians were the tallest recorded mid-nineteenth century population (Prince and Steckel 2001).

The paper also examines the socioeconomic predictors of body size to help us assess health status across different groups within society and to help us understand the etiology of chronic disease. The past literature has mainly focused on height, finding that white men living in the major cities and in other high mortality areas were shorter than those from remote rural areas. Although there were differences in height by occupation, these were small compared to the several centimeter occupational differences in stature among Europeans and to urban-rural differentials that were up to 3 cm in the United States (Costa and Steckel 1997; Floud et al. 1990; Haines et al. 2000).

Finally, the paper investigates the relationship between body size and mortality from heart disease at older ages to determine whether there have been any changes in the relationship over time. Costa (1993) found that the relation between height and subsequent mortality was similar among a sample of Union Army veterans and among modern, Norwegian males. However, the relationship between height and subsequent mortality is very sensitive to sample size and does not always hold up in all samples (e.g. Costa forthcoming). The body mass index (BMI), defined as weight in kilograms divided by the square of height in meters, is an even stronger predictor of mortality and morbidity than height. This is the first paper to study measures of abdominal fat and subsequent mortality in an historical population. If the relationship between body size and mortality is relatively constant over time, then anthropometric measures from populations in their 20s can be used to predict their older age mortality.

2 The Human Frame

The health indicators that this paper studies are height, BMI, measures of central body fat (waist-hip ratio, chest-shoulder ratio, and chest-height ratio), lifting capacity, and lung capacity. The environment shapes these measures of the human frame. Poor net nutritional status during the growing years (including the fetal stage) leads to a shorter population and poor current net nutritional status to a lighter population. Low birth weight for gestational age babies (an indicator of maternal or fetal malnutrition) not only grow up to be shorter (Paz et al. 1993; Lagerström et al. 1994), but they may also grow up to have greater abdominal fat deposits, controlling for body mass. Birth weight and early life infections predict adult lung capacity (Barker 1992). In present day Guatemala babies weighing less than 2500 grams at birth not only grow up smaller, but also with less muscle strength (Martorell et al. 1996).

Height, weight, fat patterning, and lung capacity are predictors of subsequent morbidity and mortality. Among Norwegian males all-cause mortality first declines with height to reach a minimum at heights close to 185cm and then starts to rise. Height appears to be inversely related to heart and respiratory diseases and postively related to the hormonal cancers (Barker 1992). All-cause mortality risk first declines rapidly at low weights as BMI increases, stays relatively flat over BMI levels from the low to high twenties, then starts to rise again, but less steeply than at very low BMIs. Low BMIs are associated with respiratory disease and high BMIs with cardiovascular disease. Lung capacity is associated with respiratory tract illnesses and chronic respiratory symptoms (Martinez, Taussig, and Morgan 1990; Eisen et al. 1987) and with mortality from respiratory diseases, lung cancer, and stroke (Strachan 1991; Loomis, Collman, and Kogan 1989).

Studies of recent population suggest that measures of central or abdominal body fat are better markers than height or BMI of risk of death, especially risk of fatal coronary heart disease (e.g. Folsom et al. 1993). Abdominal fat distribution is associated with antecedents of cardiovascular disease such as hypertension, non-insulin dependent diabetes, high plasma concentrations of atherogenic lipids. and low concentrations of high density lipoprotein cholesterol (Ohlson et al. 1985; Blair et al. 1984; Folsom et al. 1989).[2] One very common measure of abdominal fat is the waist-hip ratio, but there is also evidence that the ratio of chest circumference to biacromial (shoulder) diameter and of chest circumference to standing height are significantly and directly associated with coronary heart disease (Yao et al. 1991). There is still little agreement on the exact relationship between measures of abdominal fat and mortality risk. Among men, a waist-hip ratio above 0.95 or above 1 is generally considered high risk. However, in a young age group, particularly one in the military, it is rare to find men with waist-hip ratios above one. A 23-year follow-up study of WWII soldiers measured prior to discharge in 1946-47 shows that a standard deviation increase in waist-hip ratio above the mean increased mortality risk from ischemic and cerebrovascular heart disease by up to 1.24 times and that this relationship was linear (Terry et al. 1992). Yao et al. (1991) find that measures of central body fat are linearly related to cardiovascular disease mortality, but, like BMI, they have a U-shaped relation with all cause mortality. However, Schreiner et al. (1996) argue that when waist circumference is used as a surrogate for intra-abdominal fat area in men, a quadratic term should be included in the analysis as a predictor variable.

In the United States today, blacks have smaller waist circumferences than whites at the same levels of BMI (Okoson et al. 2000). Among men (but not women) no racial differences in the relationship between central obesity and disease have been detected (Freedman et al. 1995).

Whether anthropometric measures have direct pathogenic effects or are simply markers

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[2] Atherogenic lipids such as chylomicrons, very low density lipoproteins, and low density lipoproteins accelerate the deposition of lipids in the intima of the arteries. This deposition of lipids is associated with atherosclerosis. High levels of high density lipoproteins may protect against risk of atherosclerosis, perhaps because these lipoproteins may be scavengers for excess cholesterol present in arterial walls.

of other processes remains unclear. Consider the case of a high waist-hip ratio. Sustained adrenal overactivity, initiated by early growth restraint, may increase abdominal fat depositions and separately lead to hypertension and impaired glucose tolerance. Alternatively, the distinctive biochemical characteristics of intra-abdominal fat may perturb lipid and carbohydrate metabolism thus leading to cardiovascular disease and diabetes (Barker 1992).

3 Data

In the early part of 1863 the United States Sanitary Commission began its inquiry into the physical and social condition of soldiers. By the end of the war it had collected data on 23,785 men, consisting of 16,900 white Union soldiers, 1146 white Union sailors, 68 white Union marines, 2883 black Union soldiers (recruited both in the North and in the South), 1980 Confederate prisoners of war, 517 Indians (mainly Iroquois from upstate New York), and 291 students. Trained examiners armed with andrometers, spirometers, dynamometers, facial angle instruments, platform balances, calipers, and measuring tape measured men's body dimensions, weight, lifting strength, and vital capacity, and obtained basic demographic and socio-economic information. The data were first analyzed by Gould (1869) and the original forms filled in by the examiners are available in the New York Public Library. With the exception of the student records, all available records were put into machine readable form, yielding a sample of 20,213 men of which 2591 are black, 339 are Indians, 1417 are Confederate prisoners of war, and the remainder are white Union soldiers and sailors. A subsample of 521 white Union soldiers who survived to 1900 are linked to their pension records, providing mortality information. Men who survived the war (regardless of occupation) were only 0.02 inches shorter than all recruits at enlistment, suggesting that the war itself induced minimal survivorship selection on the basis of height and hence on early net nutritional status (Costa 2000).

The Sanitary Commission collected the sample (henceforth referred to as the Gould sample) by sending sixteen examiners to specific locations, including Washington, where the armies of the Potomac and the West were concentrated. Examiners were instructed to measure as many men as possible. When necessary, additional examiners were sent to a location and the sometimes accompanied an army corps to obtain further measurements. Compared to the Union Army as a whole, the location of the examiners increases the proportion of recruits who were born in the Middle Atlantic (especially New York City) relative to the Union Army. Therefore, the average recruit was shorter and the proportion of recruits who were farmers was smaller than in the Union Army (see the Data Appendix for details). The average recruit in the Gould sample was also more likely to be native-born. Because the Union Army was representative of the northern population in terms of geographic distribution, foreign birth, and household wealth (Fogel 1993), the men in the Gould sample are therefore more urban, native-born, and shorter than the population as a whole. Work with previous samples of Union Army veterans indicates that no biases are introduced in linkage to the pension records (Fogel 1993). The main factors predicting linkage were desertion and not having served at least 90 days.

The paper focuses on 7 anthropometric indicators: height (an indicator of frame size), BMI (a measure of total body fat), waist-hip ratio, the ratio of chest circumference to shoulder breadth, the ratio of chest circumference to height (all indicators of central body fat), lifting strength (an indicator of muscle strength), and vital capacity (a measure of lung capacity). The quality of these measurements is discussed in the Data Appendix, which also provides details about the other anthropometric variables available in the sample. Vital capacity is not comparable to modern measures, but can still be compared across different groups within the Gould sample. Socio-economic and demographic controls are race, birth place (classified as U.S., Ireland, Germany, Great Britain, Canada, and other foreign), a dummy indicating if the native-born were born in a city with a population of 50,000 or more in 1860, occupation (classified as agricultural, professional or proprietor, artisan, and laborer), whether the recruits' parents were native-born, education (classified as none, limited common school, good common school, high school, collegiate, and professional), whether the recruit was a seaman, and year of enlistment.

Linkage to the pension records provides information on year and cause of death. The pension sample is further restricted to the 51 percent of men whose pension records provide information on cause of death. For the most part, these were men with a surviving spouse and men who lived longer. How serious is this restriction? As discussed later, treating men without cause of death information as censored yields similar findings in terms of magnitude as excluding these men from the analysis. Causes of death are coded as death from ischemic or cerebrovascular heart disease and death from other causes.[3]

How accurate are causes of death? Even today causes of death determined without autopsies cannot be considered accurate – they are at best guesses based upon existing medical conditions. Nonetheless, the causes of death noted on death certificates are consistent with the reports of the examining surgeons. These exams were given to anyone asking a pension increase and their receipt did not depend upon socioeconomic factors. For a large sample of Union Army veterans, Costa (forthcoming) finds that conditions reported by the examining surgeons in 1900 predicted mortality by cause. Valvular heart disease in 1900 predicted death from valvular heart disease but not death from ischemic heart disease; stroke, angina, and varicose veins predicted death from cerebrovascular disease; stroke predicted death from ischemic heart disease; irregular pulse predicted death from myocarditis; bronchitis and emphysema predicted death from respiratory causes; gastritis weakly predicted death from stomach ailments; and prostate problems predicted death from genito-urinary causes. Men with vague and unclassifiable causes of death

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[3] Ischemic includes all mentions of atherosclerosis, arteriosclerosis, coronary occlusion, coronary thrombosis, and angina and also undefined heart disease. This heart disease category excludes valvular heart disease and myocarditis. See Fleming (1997) and Finlayson (1985) for a history of diagnosis of ischemic heart disease.

tended to be men without a surviving spouse. Social class was not a predictor.

Height and body fat measures in the Gould sample are compared with those of the post World War II military from two anthropometric surveys used for designing uniforms and equipment for military personnel. These are the 1950 Survey of Flying Personnel conducted by the Air Force and the 1988 Anthropometric Survey of the U.S. Army. The latter survey includes blacks. The two surveys provide data on height, BMI, waist-hip ratio, the ratio of chest circumference to shoulder breadth, and of chest circumference to height. The measurements in these surveys are comparable to those in the Gould sample (see the Data Appendix for further details).

4 Trends

Table 1 shows that, with the exception of height and lifting capacity, reweighting the white Gould sample so it is geographically representative of the white Union Army has very little effect on the means of anthropometric measures. The analysis will therefore focus on the unweighted sample.

Table 1 shows that there were substantial differences in anthropometric characteristics across races. Indians were the tallest, the heaviest, had the highest waist-hip and chest-shoulder ratios, and had the greatest lifting strength and vital capacity. At ages 31-35 they were two cm taller than all whites and one cm taller than native-born whites in the unweighted Gould sample. However, differences between whites and Indians in height and vital capacity in the youngest age groups were small, suggesting that by the 1840s, Indians in New York State had experienced a relative deterioration in health. Note also that vital capacity does not decline after age 25, as would be expected, suggesting that older cohorts of Indians were in better health than younger cohorts. At younger ages (when they were still growing), blacks were the shortest, but by older ages almost achieved the heights of whites. Blacks' vital capacity was lower at all ages (and does

Table 1: Anthropometric and Health Indicators of Union Soldiers in the Gould Sample by Race and Age

	Age	Height (cm)	BMI	Waist-hip ratio	Chest-shoulder ratio	Chest-height ratio	Lifting strength (kg)	Vital capacity (l)
White								
	16-20	168.817	22.048	0.849	2.506	0.521	139.696	3.069
	21-25	170.848	22.892	0.855	2.570	0.536	154.728	3.139
	26-30	170.845	23.099	0.863	2.596	0.542	156.333	2.984
	31-35	170.623	23.151	0.865	2.655	0.546	159.447	2.900
White, Reweighted								
	16-20	169.007	22.070	0.848	2.466	0.520	140.249	3.075
	21-25	171.496	22.991	0.853	2.538	0.536	157.784	3.172
	26-30	171.749	23.175	0.859	2.581	0.544	160.615	3.036
	31-34	171.775	23.194	0.860	2.608	0.543	164.258	2.932
Black								
	16-20	166.333	22.517	0.859	2.431	0.520	133.005	2.633
	21-25	168.110	23.827	0.858	2.375	0.534	150.954	2.731
	26-30	169.386	24.057	0.861	2.431	0.538	155.953	2.712
	31-35	169.821	23.861	0.865	2.446	0.537	162.285	2.734
Indian								
	16-20	167.685	22.589	0.865	2.451	0.535	143.259	3.080
	21-25	171.011	23.944	0.872	2.622	0.543	163.025	3.100
	26-30	173.289	24.781	0.880	2.803	0.547	179.428	3.073
	31-35	172.986	24.875	0.884	2.772	0.548	181.198	3.107

Note: The data include seamen and exclude men in low vigor to facilate comparisons with modern data. Vital capacity is not comparable to modern measures. Indians are largely Iroquois from upstate New York. The reweighted white sample was reweighted to have the same distribution of region of birth as the Union Army as a whole.

Table 2: Anthropometric Measures of Military Men Circa 1950 and 1988

Year	Race	Age	Height (cm)	BMI	Waist-hip ratio	Chest-shoulder ratio	Chest-height ratio
1946-1947	White	16-20		22.7	0.820		
		21-25		23.2	0.833		
		26-30		23.8	0.850		
		31-35		24.0	0.862		
1950	White						
		21-25	175.797	23.288	0.825	2.409	0.547
		26-30	175.682	24.110	0.848	2.472	0.563
		31-35	175.290	24.687	0.861	2.507	0.571
1988	White						
		16-20	176.026	24.382	0.830	2.455	0.550
		21-25	175.644	24.956	0.847	2.491	0.563
		26-30	177.452	25.308	0.860	2.517	0.566
		31-35	175.310	26.096	0.873	2.555	0.578
1988	Black						
		16-20	174.690	24.240	0.822	2.419	0.543
		21-25	175.912	25.341	0.828	2.425	0.552
		26-30	176.620	26.191	0.845	2.480	0.563
		31-35	176.181	26.100	0.860	2.481	0.566

The 1946-1947 data are from published tabulations in Terry et al. (1992). The 1950 data are from the 1950 Survey of Flying Personnel. No numbers are given for men age 16-20 because the sample sizes were too small. The 1988 data are from the 1988 Anthropometric Survey of the U.S. Army.

not decline with age), but their other anthropometric measures were comparable.

Over a span of one hundred years, men in the military have become taller and heavier, but their waist-hip ratios and chest-shoulder ratios have not increased (see Table 2). The heights of white Americans age 26-30 rose from 171cm to 177 cm in 1988. The BMIs of white soldiers in the oldest age group rose from 23 to 26. Note that the increase in BMI is more pronounced at older ages, a phenomenon previously noted in Costa and Steckel (1997) and attributable to the accumulated effects of work intensity and of working conditions, high rates of chronic disease at older ages, and the accumulated effects of differences in nutritional intakes and physical activity.

Table 3: Differences in Central Body Fat Between the Gould Sample and the Post-World War II Military by Race Controlling for Age and BMI

	Waist-hip ratio		Chest-shoulder ratio		Chest-height ratio	
Year	White	Black	White	Black	White	Black
1950	-0.031‡		-0.174‡		0.011‡	
	(0.001)		(0.008)		(0.001)	
1988	-0.027‡	-0.034‡	-0.123‡	-0.012	0.007‡	0.005‡
	(0.002)	(0.003)	(0.012)	(0.016)	(0.001)	(0.001)
Adjusted R^2	0.199	0.251	0.044	0.029	0.336	0.520

Coefficients indicate the difference relative to the Gould sample and are from a regression which included BMI and dummies for age categories. The foreign-born were excluded from the sample. Standard errors are in parentheses. The symbol ‡ indicates that the coefficient is significantly different from 0 at the 1 percent level.

Although the BMIs of men circa 1950 were greater than those of Civil War soldiers, the waist-hip and chest-shoulder ratios of Civil War soldiers were greater. Controlling for BMI, both waist-hip and chest-shoulder ratios were significantly greater in the Gould sample than in either the 1950 or 1988 military (see Table 3). Chest-height ratio, however, was smaller in the Gould sample.

Tables 1 and 2 also show that whereas in the Gould sample blacks and whites are similar in terms of central body fat, in 1988 measures of central body fat were lower in blacks even when their BMIs were greater. Controlling for BMI and age with ordinary least squares regressions shows that all measures of central body fat are statistically significantly smaller in blacks than in whites. The difference in ratios was 0.02 for waist-hip, 0.07 for chest-shoulder, and 0.01 for chest-height. The absence of a difference between blacks and whites in measures of central body fat in the Gould sample may therefore be an indicator of the greater environmental stress faced by blacks in the mid-nineteenth century.

Anthropometric measures in the Gould sample are not highly correlated (see Table 4). The measure of abdominal fat that is most strongly correlated with BMI is chest-height ratio. The correlation between BMI and waist-hip ratio is low. Correlations, particularly those between BMI

Table 4: Correlation of Anthropometric and Health Indicators in the Gould Sample

	Height (cm)	BMI	Waist-hip ratio	Chest-shoulder ratio	Chest-height ratio	Lifting strength (kg)	Vital capacity (l)
Height (cm)	1.000						
BMI	-0.031	1.000					
Waist-hip ratio	-0.037	0.184	1.000				
Chest-shoulder ratio	0.121	0.065	0.007	1.000			
Chest-height ratio	-0.093	0.313	0.098	0.540	1.000		
Lifting strength (kg)	0.319	0.284	0.037	0.107	0.112	1.000	
Vital capacity (l)	0.366	0.071	-0.010	0.089	0.050	0.302	1.000

Correlations are for men of all races age 16-35 and exclude those in low vigor.

and abdominal fat measures, are much stronger in the modern army (see Table 5). This pattern would be expected if excessive nutritional intake determines waist-hip ratio today but if poor net nutritional intake determined waist-hip ratio in the past.

5 Anthropometric Measures: Correlates

Examining the correlates of anthropometric measures in the Gould sample, particularly race, foreign birth, size of city of birth, parents' foreign birth, occupation, and education provides information on how different groups fared controlling for observable demographic and socioeconomic factors and on the links between adverse conditions and outcomes.

The results that are shown are from an ordinary least squares regressions of the form,

$$y_i \quad = \quad \beta_0 + A_i\beta_A + R_i'\beta_R + N_i'\beta_N + O_i'\beta_O + \beta_V V_i + \beta_S S_i + M_i'\beta_M \ , \tag{1}$$

where the dependent variable y_i is either height, BMI, waist-hip ratio, chest-shoulder ratio, chest-height ratio, lifting strength, or vital capacity. The independent variables include a vector of

Table 5: Correlation of Anthropometric Measures in the 1988 Army

	Height (cm)	BMI	Waist-hip ratio	Chest-shoulder ratio	Chest-height ratio
Height	1.000				
BMI	0.015	1.000			
Waist-hip ratio	-0.063	0.390	1.000		
Chest-shoulder ratio	-0.013	0.694	0.460	1.000	
Chest-height ratio	-0.246	0.849	0.534	0.787	1.000

The correlations are across both white and black men.

anthropometric controls (A). These are BMI in the case of the abdominal fat measures, height and BMI in the case of lifting strength, and height in the case of vital capacity. Additional controls include dummies for race (R), nativity (N), and occupation (O), a dummy variable equal to one if the man was in low vigor (V), a dummy variable equal to one if the man was a seaman (S), and a set of miscellaneous controls (M) comprising age dummies, year of enlistment dummies, and dummies indicating missing or inapplicable information for place of birth, occupation, education, and year of enlistment. Robust standard errors, clustering on the 16 examiners, are given.

Tables 6, 7, and 8 confirm that differences in anthropometric characteristics across races were substantial. Indians were the tallest and had a greater BMI than whites. Blacks were the shortest and had the highest BMI. Note that because of their relatively small stature a higher BMI would lower their mortality risk and therefore may explain why the mortality rates of blacks and whites were not significantly different from each other above age 15 (Fogel 1992).[4] Compared to whites, blacks had significantly lower lifting strength and vital capacity. The anthropometric

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[4] Among Norwegian men age 50-64 in the late 1950s, mortality risk is minimized at higher weights for the short than for the tall. For a tables of values see (Fogel 1993). Although we do not know whether this held true for the nineteenth century, the relationship between height and subsequent mortality and BMI and subsequent mortality is similar for Union Army Veterans and for Norwegians in the late 1950s (Costa and Steckel 1997; Costa 1993).

Table 6: Height and BMI OLS Regressions

	Height (cm)		BMI	
	Coefficient	Std Err	Coefficient	Std Err
Dummy=1 if				
White				
Indian	0.778^{*}	0.398	$0.556^{\ddagger}$	0.164
Black	$-2.459^{\ddagger}$	0.309	$0.783^{\dagger}$	0.303
Dummy=1 if born in				
U.S.				
Ireland	$-1.312^{\ddagger}$	0.342	0.023	0.142
Germany	$-2.555^{\ddagger}$	0.734	$0.898^{\ddagger}$	0.310
Canada	-0.237	0.425	0.141	0.139
Great Britain	$-3.196^{\ddagger}$	0.192	-0.058	0.132
Other foreign country	$-2.013^{\ddagger}$	0.576	0.232	0.173
Dummy=1 if occupation				
Agricultural				
Professional or proprietor	$-1.222^{\ddagger}$	0.285	$-0.543^{\ddagger}$	0.118
Artisan	$-0.962^{\ddagger}$	0.101	$-0.256^{\dagger}$	0.094
Laborer	$-1.016^{\ddagger}$	0.141	-0.055	0.084
Dummy=1 if in low vigor	-0.098	0.130	$-0.708^{\ddagger}$	0.056
Dummy=1 if seaman	$-1.755^{\ddagger}$	0.566	$0.202^{\dagger}$	0.085
R^2	0.0787		0.098	
Observations	16,438		16,273	

Covariates include age dummies, year of enlistment dummmies, and dummies indicating missing or unapplicable information for place of birth, occupation, and year of enlistment. The constant term is not shown. Robust standard errors (clustering on the examiner) are given. The symbols $*$, †, and ‡ indicate that the coefficient is significantly different from 0 at the 10, 5, and 1 percent level, respectively.

Table 7: Waist-hip, Chest-Shoulder, and Chest-Height Ratios OLS Regressions

	Waist-hip Ratio		Chest-Shoulder Ratio		Chest-Height Ratio	
	Coefi-cient	Std Err	Coefi-cient	Std Err	Coefi-cient	Std Err
BMI	0.004‡	0.001	-0.007	0.010	0.008‡	0.001
Dummy=1 if						
White						
Indian	0.008†	0.004	0.067	0.133	0.005‡	0.001
Black	0.002	0.006	-0.146	0.147	-0.006	0.005
Dummy=1 if born in						
U.S.						
Ireland	0.011‡	0.003	-0.177‡	0.042	0.003	0.003
Germany	0.012	0.008	0.029	0.074	0.001	0.003
Canada	0.002	0.003	-0.138‡	0.039	0.000	0.001
Great Britain	0.015‡	0.005	-0.057	0.082	0.016	0.010
Other foreign country	0.007*	0.004	-0.070	0.060	-0.001	0.004
Dummy=1 if occupation						
Agricultural						
Professional or proprietor	-0.009‡	0.002	-0.152‡	0.033	-0.005‡	0.001
Artisan	-0.002	0.002	-0.091‡	0.025	-0.002‡	0.001
Laborer	-0.003	0.002	-0.111‡	0.034	-0.002‡	0.001
Dummy=1 if in low vigor	-0.004	0.003	-0.056	0.039	0.000	0.001
Dummy=1 if seaman	0.016*	0.009	-0.154	0.158	0.006‡	0.002
Adjusted R^2	0.046		0.083		0.162	
Observations	11,517		14,133		14,152	

Covariates include age dummies, year of enlistment dummmies, and dummies indicating missing or unapplicable information for place of birth, occupation, and year of enlistment. The constant term is not shown. Robust standard errors (clustering on the examiner) are given.

Table 8: Lifting Strength and Vital Capacity OLS Regressions

	Lifting Strength (kg)		Vital Capacity (l)	
	Coeficient	Std Err	Coeficient	Std Err
Height (cm)	1.598‡	0.053	0.040‡	0.003
BMI	5.048‡	0.214	0.044‡	
Dummy=1 if				
White				
Indian	3.055	3.658	0.011	0.-92
Black	-7.398*	3.933	-0.323‡	0.101
Dummy=1 if born in				
U.S.				
Ireland	-6.562†	2.406	-0.031	0.058
Germany	-7.557†	3.430	-0.116*	0.059
Canada	3.911†	1.420	0.024	0.025
Great Britain	-3.341	3.264	-0.003	0.047
Other foreign country	-5.705	3.869	0.141*	0.068
Dummy=1 if occupation				
Agricultural				
Professional or proprietor	-2.617†	1.006	-0.008	0.034
Artisan	-0.310	1.063	0.008	0.021
Laborer	-2.650†	1.236	-0.012	0.011
Dummy=1 if in low vigor	-20.181‡	1.803	-0.251‡	0.028
Dummy=1 if seaman	-12.959‡	4.320	0.014	0.028
Adjusted R^2	0.243		0.188	
Observations	13,652		15,827	

Covariates include age dummies, year of enlistment dummmies, and dummies indicating missing or unapplicable information for place of birth, occupation, and year of enlistment. The constant term is not shown. Robust standard errors (clustering on the examiner) are given.

characteristics of blacks who enlisted in free, northern states and those who enlisted in the south were similar. Central body fat did not differ between blacks and whites, but recall that in recent data blacks' measures of central body fat are significantly lower. Central body fat was greater among Indians than among whites, though this could reflect racial differences in body morphology.

Tables 6, 7, and 8 show that there were also substantial differences by nativity and occupation. The foreign-born (with the exception of Canadians) were shorter than the native-born. Only Germans made up for their short heights with a greater BMI. The waist-hip ratios of the foreign-born were greater than those of the native-born and their lifting strength was smaller. Men working in agriculture were taller, heavier, had less abdominal fat, and had more lifting strength than men in non-agricultural occupations. Seamen were shorter, heavier, had more abdominal fat, and less lifting strength. Gould (1869) argued that the short heights of seamen were not due to the navy selecting shorter men, but to enduring the hardships of a seafaring life while still in the growing years (age 25 in the nineteenth century). Finally, note that war-time experience, proxied by being in low vigor, affects only BMI, lifting strength, and vital capacity.

Restricting the sample to the native-born allows me to examine the effects of parents' nativity, size of city of birth, and education (not shown). Having a US-born father and mother significantly increases average height relative to having parents who are born abroad and there is weak evidence that having just one US-born parent increases height as well, though not by as much. Men with both parents born in the US were lighter than men with parents born abroad, even controlling for height. Those born in large cities were shorter, lighter, and had less lifting strength, but they also had less abdominal fat. Babies born in the Philadelphia alsmhouse had birth weights that compared favorably to those of mid-twentieth century babies (Goldin and Margo 1989), suggesting that life in a large city was best experienced in the protected environment of the womb. Finally, education (measured by none, limited common school, good common school, collegiate, and professional) has no predictive power, perhaps both because the labor market returns to formal education were low and because knowledge of mid-nineteenth medicine may only have harmed health.

6 Anthropometric Measures: Older Age Mortality

Were anthropometric measures good predictors of subsequent mortality among Union Army veterans? To test this, I examined whether height, BMI, abdominal fat, muscle strength, and vital capacity predicted mortality from ischemic heart disease and stroke conditional on survival to 1900. The discussion in this section is restricted to height, BMI, and abdominal fat because muscle strength and vital capacity were not good predictors and the sample size was too small to examine deaths from respiratory disease. Recall that sample size is small because a full pension record was input only for the first randomly chosen 521 men whose pension records indicated that they survived to 1900. A further 49 percent of men are lost because of missing information on cause of death. Other men are missing anthropometric information, particularly waist-hip ratio which was not recorded on all forms. The sample was also restricted to men measured at age 21-35.[5] The men in the linked sample range in age from 56 to 72, but the mean was 61.

I model Union Army veterans' waiting time until death from ischemic or cerebrovascular heart disease by means of a Cox proportional hazard model. The hazard, $\lambda(t)$, or the rate at which spells are completed after duration t given that they last until at least t, is

$$\lambda(t) = \exp(x'\beta)\lambda_0(t) \tag{2}$$

where λ_0 is the baseline hazard and $\exp(x'\beta)$ is the relative hazard. The covariates of primary interest are health measures and these consist of dummy variables for BMI below 20 and above

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[5] Including younger ages made the results very sensitive to sample choice.

24, a dummy equal to one if the veterans' height was one standard deviation above the mean and dummies equal to one if the veterans' abdominal fat measures were one standard deviation above the mean and one standard deviation below the mean. Additional controls include age in 1900, occupation from the Gould sample (agricultural, professional or proprietor, artisan, or laborer), and a dummy equal to one if the recruit was in low vigor when measured.[6] I use an independent competing risk framework, treating individuals who die from a cause of death other than ischemic or cerebrovascular disease as censored. Note that this model assumes that the risk of death from ischemic or cerebrovascular heart disease is independent of the risk of all other causes of death.

Table 9 shows that waist-hip ratio is a good predictor of subsequent mortality. Both high and low waist-hip ratios predict ischemic and stroke mortality. A waist-hip ratio that was more than one standard deviation above the mean increases mortality risk by 2.9 times relative to the mean controlling for BMI. A low waist-hip ratio increases mortality risk by 4.4 times. Neither a height dummy nor dummy variables indicating high and low BMI levels were statistically significant. Because persistence of BMI over the life-cycle was low (Costa and Steckel 1997) and because BMI was affected by wartime stress, BMI may be a poor predictor of older age mortality. The point estimates suggest that optimal BMI was between 20 and 24. High and low chest-shoulder ratios are insignificant, but do elevate mortality risk. High and low chest-height ratios are insignificant and lower mortality risk.

Several robustness tests suggest that waist-hip ratio predicts subsequent mortality. When I examined death from all types of heart disease, a low waist-hip ratio remained a statistically significant predictor, though a high waist-hip ratio no longer was. The hazard ratio for a high waist-hip ratio was 2.025 ($\hat{\sigma}$=1.021), the hazard ratio for a low waist-hip ratio was 3.303 ($\hat{\sigma}$=1.370), the hazard ratio for a high BMI was 1.046 ($\hat{\sigma}$=0.463), the hazard ratio for a low BMI was

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[6] BMI performed better in terms of statistical significance when used as a linear variable rather than as an indicator variable.

Table 9: Hazard Ratios for Death from Cerebrovascular and Ischemic Disease Independent Competing Risk Hazard Model

	1	2	3	4	5	6	7
Dummy=1 if tall	1.032					0.419	0.483
	(0.382)					(0.314)	(0.276)
Dummy=1 if							
High BMI		1.114				1.169	1.145
		(0.373)				(0.571)	(0.574)
Low BMI		1.149				0.963	1.294
		(0.369)				(0.522)	(0.574)
High waist-hip ratio			$3.358^{\dagger}$			2.946^{*}	
			(1.890)			(1.696)	
Low waist-hip ratio			$4.518^{\ddagger}$			$4.370^{\ddagger}$	
			(2.053)			(2.154)	
High chest-shoulder ratio				1.651			1.791
				(0.683)			(0.759)
Low chest-shoulder ratio				1.442			1.606
				(1.220)			(1.438)
High chest-height ratio					0.407		
					(0.425)		
Low chest-height ratio					0.444		
					(0.244)		
Degrees of freedom	7	8	8	8	8	11	11
χ^2 for proportional hazards assumption	4.71	6.12	8.70	7.40	7.15	12.75	8.42
Log likelihood	-239.725	-239.625	-108.652	-127.747	-126.866	-107.707	-126.762
Observations	161	161	88	99	99	88	99

Years until death are measured from 1900. The dummy variables are equal to one if the individual is one standard deviation above (for tall or high) or below (for low) the sample mean. However, in the case of BMI, this was rounded so that a high BMI is one above 24 and a low BMI is one below 20. The symbols $*$, †, and ‡ indicate that the coefficient is significantly different from 1 at the 10, 5, and 1 percent level, respectively. Standard errors in parentheses. Covariates include age in 1900, occupation from the Gould sample, and whether the recruit was in low vigor during the war. The log likelihood is for the test that all coefficients are significantly different from 1. I cannot reject the hypothesis that all coefficients in the regression are jointly statistically significantly different from 1. The proportional hazards assumption is tested by testing for a non-zero slope in the generalized linear regression of the scaled Schoenfeld residuals on a function of time. I cannot reject the hypothesis that the proportional hazards assumption is met.

1.112 ($\hat{\sigma}$=0.447), and the hazard ratio for tall was 0.664 ($\hat{\sigma}$=0.328). When I examined all cause mortality, censoring on violent deaths, I found that a low waist-hip ratio was a statistically significant predictor, but not a high waist-hip ratio, though the magnitude of the hazard ratio was in the right direction. The hazard ratio for a high waist-hip ratio was 1.782 ($\hat{\sigma}$=0.676), the hazard ratio for low waist-hip ratio was 2.212 ($\hat{\sigma}$=0.713), the hazard ratio for a high BMI was 1.110 ($\hat{\sigma}$=0.353), the hazard ratio for a low BMI was 1.245 ($\hat{\sigma}$=0.361), and the hazard ratio for tall was 0.759 ($\hat{\sigma}$=0.253). When I treated men without cause of death information as censored (admittedly an assumption that violates independence), I found that both high and low waist-hip ratio were statistically significant predictors of death from cerebrovascular or ischemic heart disease. The respective hazard ratios for high waist-hip ratio, low waist-hip ratio, high BMI, low BMI, and tall were 2.302 ($\hat{\sigma}$=1.160), 4.026 ($\hat{\sigma}$=1.778), 0.993 ($\hat{\sigma}$=0.430), 1.009 ($\hat{\sigma}$=0.445), and 0.397 ($\hat{\sigma}$=0.295), respectively.

How did the predicted mortality experience of whites, African-Americans, and Indians differ? Using regression 6 in Table 9 and anthropometric means for white men from the Gould sample yields a predicted mortality rate from ischemic heart disease or stroke of 23.7 percent by 1914. Blacks' predicted 14 year mortality rate from ischemic heart disease and stroke was 22.7 percent (using black sample means and the white mortality regression), similar to that for whites. The predicted 14 year mortality rate of Indians was 19.5 percent, lower than that of whites or blacks.

How would Union Army veterans have fared if in their youth they had the characteristics of men in the 1950 military? Answering this question will help us understand the magnitude of the hazard estimates and also provide some clues about the importance of anthropometic changes to the decline in mortality. Assuming that the baseline hazard had remained unchanged, Union Army veterans' 14 year all-cause mortality rate would have been lower by up to 15 percent, implying that changes in frame size explain up to 47 percent of the total decline in all cause mortality at older ages from 1914 to 1988. As previously noted, the predicted mortality rate from ischemic heart disease or stroke was 23.7 percent by 1914 using the anthropometric means for white men from the Gould sample. Substituting the anthropometric means for whites in the 1950 military into the regression equation decreased the heart disease mortality rate to 20.0 percent. Thus, rather having 45 percent of the sample dying from ischemic heart disease or stroke, only 37 percent would have died.[7]

Changes in body size predict that older age mortality rates will have declined at a much more rapid rate by 2022. Substituting in the anthropometric means for whites in the 1988 military into the regression equation decreased the heart mortality to 17.6 percent and implies a reduction in the all-cause 1900 14 year mortality rate of 11 percent.[8] On an annual basis the percentage point decline in mortality rates due to changes in body shape between 1914 and 1988 was 0.20. Between 1988 and 2022 changes in body size imply an annual percentage point decline in mortality rates of 0.38.

Changes in body size also predict that the expected mortality decline among black men will be smaller than that of white men. Today, blacks' greater BMI puts them at higher risk. Using the sample means for black men in the 1988 army lowers the predicted 14 year ischemic

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[7] The means for whites for high waist-hip ratio (above 0.91), low waist hip ratio (less than or equal to 0.81), tall (above 176.8 cm), high BMI (above 24), and low BMI (below 20) were 0.110, 0.144, 0.135, 0.278, and 0.318 in the Gould sample. The same means for whites in the 1950 military were 0.076, 0.217, 0.419, 24.0, 0.473, and 0.243. Among men in the Gould sample linked to the pension records, 55 percent of the sample had died by 1914 and 45 percent of all deaths were from ischemic heart disease or stroke. Twenty-five percent of the sample was therefore dead from ischemic heart or stroke by 1914. The regression results suggest that mortality from stroke or ischemic heart disease would have fallen by 19 percent if men had had a modern frame size. Therefore only 20 percent of the sample would have died from ischemic heart or stroke and only 47 percent of the sample would have died. (Note that this is an upper bound because men who died of heart disease may have died of other causes.) Life tables for the death registration states show in 1900 a 61 year-old (the mean age in the Gould sample) had a 54 percent chance of dying before age 75. By 1988 a 61 year old's 14 year mortality rate had fallen to 38 percent.

[8] The sample means for high waist-hip ratio, low waist-hip ratio, tall, high BMI, and low BMI in the 1988 data were 0.071, 0.149, 0.430, 0.663, and 0.124, respectively. The regression results imply that mortality from ischemic heart disease or stroke would have fallen by 26 percent or that only 33 percent of the sample would have died from ischemic heart disease or stroke. Only 48 percent of the sample would then have died from all causes.

disease and stroke mortality rate to only 22.1 percent from 22.7 using the means in the Gould sample.[9]

7 Conclusion

This paper has shown that there have been substantial changes in the human frame over the last hundred years. Not only have men become taller and heavier, but, controlling for total body fat, they now have less abdominal fat as well. This type of fat patterning predicts hypertension and ischemic and cerebrovascular disease in modern populations and predicted death from ischemic and cerebrovascular disease in a past population where cause of death information is relatively rare. The findings suggest that hypertension and ischemic and cerebrovascular heart disease were present in this past population and may even have been as prevalent as they are today. The findings are consistent with reports of high arteriosclerosis rates in past populations (Costa 2002) and suggest that our view of the epidemiological theory needs to be more nuanced. Although infectious and parasitic diseases were highly visible in the past, the burden of "modern" chronic disease was still there. This burden was not evenly distributed. Examining height, BMI, abdominal fat distribution, lifting strength, and vital capacity showed that in the mid-nineteenth century populations who were at greater risk of developing modern chronic diseases included the foreign born and large city dwellers. Although black slaves experienced severe nutritional deprivation in early childhood, an experience that is reflected in their heights, waist-hip ratios, and vital capacity, their heavier weights as adults provided enough protection so that their predicted older age mortality was similar to that of whites. There was also suggestive evidence that the Indians

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[9] The means for blacks for in the Gould sample were 0.103, 0.106, 0.087, 0.489, and 0.176, for high waist-hip ratio, low waist-hip ratio, tall, high BMI, and low BMI, respectively. In the 1988 army the respective means were 0.018, 0.199, 0.716, and 0.091.

of upper new York State experienced a deterioration in health status, contemporaneous with increased contact with whites and with the movement to reservations.

Changes in frame size (height, BMI, and waist-hip ratio) have lowered risk of death from ischemic heart disease or stroke (though other factors may have raised it) and explain almost half of the mortality decline among white men between 1914 and 1988. Low birth weights and exposure to infectious disease, poor nutritional intake, and the demands of work both during the growing years and in adulthood have been pointed to as factors that contribute to a high risk frame. The observed relationships between ethnicity and race (better predictors of environmental stress than such variables as occupation) suggest that humans' ability to control the environment has made changes in health in mortality possible. Rising wealth and advances in agriculture and in industry have improved nutritional status and lowered our need for manual labor. Knowledge of the germ theory of disease spurred sanitary reforms that reduced infectious disease rates.

Changes in frame size are still on-going. Men in the 1988 military were heavier and taller than men in the military of the 1950s but had the same abdominal fat patterning controlling for BMI. When these men reach late middle age in 2022, their mortality rates will be even lower than those faced by men in the late 1980s. Changes in frame size imply that, cetribus paribus, mortality rates will decline at a much more rapid rate than they have in the past. Because not all improvements in early life conditions are manifested as changes in frame size and because medical interventions at older ages are likely to continue to lower mortality rates, future declines in mortality rates may be sizable.

Data Appendix

The Gould sample was collected from the Statistical Bureau Archives of the United States Sanitary Commission in the New York Public Library. The data are available from the National Bureau of Economic Research, http://www.nber.org and also from the Center for Population Economics at the University of Chicago, http://www.cpe.uchicago.edu. A randomly chosen sub-sample was then linked to the pension records in the National Archives. Only men who survived to 1900 were linked and collection stopped once the sample exceeded 500 people. The 1950 Survey of Flying Personnel and the 1988 Anthropometric Survey U.S. Army were obtained from the Human Systems Information Analysis Center (HSIAC) of the United States Military.

7.1 The Gould Sample

Every effort was made by the United States Sanitary Commission to ensure accuracy in measurement. Examiners were trained, furnished with printed instructions, and provided with measuring instruments. Reports from Examiners were sent in weekly and returns were tabulated as soon as possible to check for errors. When a discrepancy did arise, the examiner was consulted for further information (Gould 1869: 225-228). Although later measurements were thought to be more reliable (Gould 1869: 256) there is little difference in the means. Some erroneous measurements did result from examiners' misunderstanding of the instructions, but mismeasurement was a problem only for variables that are of minor interest, such as head circumferences and facial angles (Gould 1869: 239).

Two different basic forms were used by the examiners. The exact questions are available from National Bureau of Economic Research Working Paper No. 8843, "The Measure of Man and Older Age Mortality: Evidence from the Gould Sample." Form E was the first schedule used, for close to 8000 men, until it was replaced by Form EE. In addition, a schedule of social questions accompanied Form E. The machine-readable data set contains 6,512 Form E schedules (including 2,216 abridged versions of Form E) and 13,701 Form EE schedules. Only 252 social question schedules were found (and input) but these could not be linked to their accompanying Form E schedules.

Table 10: Comparison of White Soldiers in the Gould Sample with White Soldiers in the Union Army

	(1) Gould Sample	(2) Union Army
Percent of recruits born in New England	11.5	13.8
Percent of recruits born in Middle Atlantic	37.3	24.7
Percent of recruits born in North Central	18.0	26.4
Percent of recruits born in other U.S. states	14.3	10.5
Percent of recruits foreign-born	19.9	24.6
Percent of recruits farmers (age 18-34)	44.4	53.4
Mean height of recruits age 25-29 (cm)	171.3	172.7
Mean height of recruits age 30-34 (cm)	171.3	172.8
Mean height of recruits age 35 or over (cm)	171.0	172.6

Sources: Nativities in (1) are from Gould (1869: 256) and in (2) from Gould (1869: 104-105). Percent farmer in (1) is from the machine-readable Gould sample and in (2) from Fogel et al. (1990). Heights in (1) are from the machine-readable Gould sample and in (2) from Gould (1869: 27). The machine-readable Gould sample was restricted to white soldiers only (seamen were excluded).

As previously noted, relative to the Union Army the Gould sample over-represents recruits born in the Middle Atlantic, yielding a shorter sample and one with fewer farmers (see Table 10).

7.2 Anthropometric Variables Used in the Analysis

All variables in the Gould sample were originally measured in inches and pounds and were converted to metric units. In general men removed their shoes, coats, and waistcoats for the examination but retained their trousers and under-clothing. However, examiners were specifically instructed to measure chest circumference under the shirt.

- **Height**. In the Gould sample heights were measured with an andrometer.
- **Weight**. In the Gould sample weight was measured with platform scales graduated to quarters of a pound.

- **Waist circumference**. In the Gould sample waist circumference is measured as circumference of the waist above the hips and below the ribs. The midpoint is the natural waist circumference and this is what is measured in the 1950 and 1988 military surveys.

- **Hip circumference**. In the Gould sample circumference around the hips is measured on the level of the trochanters. This is generally, but not always, equivalent to measuring maximal buttock circumference. The 1950 and 1988 military samples use the latter measures.

- **Chest circumference**. Chest circumference was measured over the nipples and under clothing. For Form EE measurements, examiners were told to measure both while the lungs were fully inflated and after exhalation. No instructions were given for Form E. I used the mean value of circumference at maximal inspiration and circumference at full exhalation. The mean value calculated from Form EE was similar to that calculated from Form E. Restricting the sample to Form EE did not affect the mortality regressions.

- **Shoulder breadth**. In Form E how breadth of shoulders was to be measured was unspecified but in Form E it was measured as breadth of shoulders between the acromion processes. Means across the two forms, however, were similar.

- **Lifting Strength**. Lifting strength was strength in pulling upward, as measured by a dynamometer. Because lifting strength depends upon how the dynamometer was constructed, measures in the Gould sample may not be comparable to recent measures.

- **Vital Capacity**. Vital capacity is measured by having the subject inspire maximally and then expire as rapidly and as completely as possible into a spirometer. Total lung capacity is reached at the point of maximal inspiration and residual volume is the amount of air left in the patient's lungs after maximal expiration. The difference between total lung capacity and residual volume is forced vital capacity, simply referred to as vital capacity in the paper. Measurements of vital capacity in the Gould sample understate true vital capacity and are not even comparable with measurements performed in the nineteenth century because of widespread differences in measurement by instrument (Hutchinson 1852). However, that vital capacity in the sample increases, as expected, with height and BMI, and decreases with age among men aged 25-49 provides evidence of its reliability within the Gould sample.

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