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# Overweight Grandsons and Grandfathers' Starvation Exposure

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## Abstract

Much of the increase in the prevalence of overweight and obesity has been in developing countries with a history of famines and malnutrition. This paper is the first to examine overweight among adult grandsons of grandfathers exposed to starvation during developmental ages. I study grandsons born to grandfathers who served in the Union Army during the US Civil War (1861–5) where some grandfathers experienced severe net malnutrition because they suffered a harsh POW experience. I find that male-line but not female-line grandsons of grandfathers who surviveda severe captivity during their growing years faced a 21% increase in mean overweight and a 2% increase in mean BMI compared to grandsons of non-POWs. Male-line grandsons descended from grandfathers who experienced a harsh captivity faced a 22–28% greater risk of dying every year after age 45 relative to grandsons descended from non-POWs, with overweight accounting for 9–14% of the excess risk.

### JEL Classifications:

I10; N31; N32

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Adults worldwide have become 1.5kg heavier in each decade between 1975 and 2014 and much of the increase in the prevalence of overweight and obesity has been in developing countries (NCD Risk Factor Collaboration, 2016, 2017). While the declining money and time costs of calories and energy dense foods and reduced physical job demands have undoubtedly played a role in this increase (Cutler et al., 2003; Philipson, 2001; Lakdawalla and Philipson, 2009), countries which have experienced malnutrition and famines may face higher risks. Overweight and obesity are associated both with in-utero and post-natal famine exposure (Conti et al., 2021; Lumey et al., 2021; Ravelli et al., 1976; Zhou et al., 2018; Fund et al., 2019; Abeelen et al., 2012) and nutrition in early life has a demonstrable but small effect on adult obesity (Martorell et al., 2001). The implication of biological, including epigenetic, and behavioral mechanisms in these associations raises the question whether ancestors' famine exposure could reverberate across generations to affect descendants' overweight and obesity. Limited intergenerational evidence suggests that it could: the children of fathers exposed prenatally to the Dutch Hunger Winter were more likely to be heavier or obese than the children of unexposed fathers and of exposed and unexposed mothers (Veenendaal et al., 2013).

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This paper is the first to examine whether adult grandsons of grandfathers exposed to starvation during developmental ages were more likely to be overweight relative to their counterparts whose grandfathers were not exposed. It examines differences in overweight in response to grandfathers' exposure between male-line and female-line cousins and provides circumstantial evidence on some of the mechanisms behind multigenerational transmission of starvation exposure. It also investigates the implications of overweight for grandsons' longevity. The literature on famine exposure has not disentangled the direct effect of famine exposure on later own or descendant health from the indirect effect through overweight.

The developmental origins of disease hypothesis (Barker, 1992, 1994) has led to an extensive literature examining the in-utero and early childhood origins of older age health (Lumey and van Poppel, 2013; Heijmans et al., 2008; Almond, 2006; Cook et al., 2019; Currie and Vogl, 2013), including how genetic endowments interact with both early and later life environments to produce health (van den Berg et al., 2022; Baker et al., 2022; Rosenquist et al., 2015). A growing literature suggests that health originates in past generations and is transmitted to current generations via inheritable changes in gene function triggered by the environment (epigenetics). Plant and animal studies support such inheritance (Heard and Martienssen, 2014). Because of data requirements evidence of transgenerational transmission in human populations is limited to a small set of studies (Kaati et al., 2007; Bygren et al., 2001; Bygren, 2013; Vågerö et al., 2018, 2022; van den Berg and Pinger, 2016; Costa, 2021), all of which point to paternal grandfather's slowing growing years as a critical period for transmission to male-line grandsons.

My data enable me to trace the effects of a paternal ancestral shock using clear treatment and control groups while controlling for a rich array of family and socioeconomic factors. I collected a cousin sample of grandsons born between 1877 and 1929 and descended from US Civil War (1861–5) veteran grandfathers who served in the Union Army during their growing years. Each male-line cousin is matched to at least one female-line cousin. Some of the grandfathers experienced a single, acute episode of net malnutrition, inflicted on soldiers in an as good as random manner, because they were POWs. Conditions in Civil War POW camps deteriorated sharply when prisoner exchanges stopped, leading to starvation, disease, and death from the combined effects of insufficient food, disease and exposure to the elements. I follow the grandsons descended from children born *after* the war to white Union Army veterans who had *both* male-line and female-line grandsons to obtain information on height and weight from WWII draft registration records. I examine Body Mass Index (BMI), defined as weight in kilograms divided by height in meters squared. Grandsons of grandfathers who were non-POW veterans and former POWs imprisoned when camp conditions were better provide controls for grandsons of ex-POWs imprisoned when camp conditions were at their worst.

The cohort I examine was not overweight by present-day US standards. I observe their height and weight prior to the post-WWII changes in the US economy which increased caloric density and lowered physical activity.[1] Veterans' grandsons belonged to the cohorts where those of higher socioeconomic status were heavier (Costa, 2015). Although the

[1]The 1942 birth cohort marks the inflection point for increases in BMI in the US ( Rosenquist et al., 2015).

socioeconomic-BMI gradient has reversed in the US, a positive association between socioeconomic status and BMI still prevails in developing countries (Strauss and Thomas, 2008; Corsi and Subramanian, 2019).

I find that among *male-line* grandsons age 18 to 59 those whose grandfathers experienced a harsh captivity during their late *growing years* faced a roughly 0.06 increase in the probability of being overweight (a 21% increase relative to mean overweight) and a 0.4 increase in BMI (a 2% increase relative to mean BMI) compared to grandsons of non-POWs. The increase was even larger when both the father and the grandson faced poor in-utero conditions, as proxied by season of birth. There was no association between a veteran grandfather's ex-POW status and *female-line* grandsons' overweight even though there was an association between a veteran grandfather's overweight and his grandsons' overweight, regardless of descent from sons or daughters. Male-line (but not female-line) grandsons descended from grandfathers who experienced a harsh captivity faced a 22–28% increased risk of death every year after age 45, with the increase in overweight accounting for 9–14% of this increase. My circumstantial evidence is consistent with an epigenetic explanation.

The echoes of ancestral malnutrition in descendants' overweight and longevity implies that the benefits of policies which reduce net nutritional deficiencies, whether from insufficient food or disease, can compound across generations and reduce health inequalities across families, regions, and countries. Overweight is associated with coronary heart disease, stroke, type 2 diabetes, and some cancers, among other conditions.[2] The medical costs of obesity are high (Cawley and Chad, 2012) and a high BMI is associated with reduced labor force participation rates among older men (Gruber and Kubik, 1997; Costa, 1996).[3] The epidemic of coronary heart disease in today's developed countries which peaked in the US in the 1960s was experienced by cohorts whose ancestors faced a low and variable food supply. The findings have implications for countries with a history of famines and malnutrition (Luke et al., 2021). Although individuals in these countries are thin by US standards, overweight arising from ancestral malnutrition can be a harbinger of poor later health and thus of reduced work levels at older ages.

## 1 Transmission of Overweight to Descendants

Body Mass Index (BMI) commonly is regarded as a function of energy expenditures (N), energy intake or food (F), and genetics (G),

$$\mathrm{BMI}_t = b(N_{t-1}, F_{t-1}, G)\,.$$

Energy expenditures include energy spent to earn income to buy goods and energy spent in leisure activities. Parents will influence their children's BMI in at least four ways. First, they will provide children with the wealth and human capital which determines how energy intensive their jobs are and the income children have to buy different types of foods and to

[2]See https://www.cdc.gov/healthyweight/effects/index.html.
[3]The inverse association between obesity and wages in developed countries largely arises from correlated but unmeasured labor market attributes (Behrman and Rosenzweig, 2001).

engage in different types of leisure activities. Second, they affect the stock of children's past consumption, i.e. they will introduce their children to foods and leisure activities which are habit forming. Third, they will invest in children's cognitive and non-cognitive skills which will enable their adult children to be better producers of health, including BMI. Fourth, parents provide children with a genetic inheritance. This genetic inheritance encompasses not just a fixed set of genes but also epigenetics, that is an heritable modification of gene expression whereby some gene functions are switched on or off.

BMI thus can be thought of as

$$\mathrm{BMI}_t = b(N_{t-1}, F_{t-1}, P_t)$$

$$P_t = g(G, I_A, I_{t-1})$$

where the epigenome $P_t$ depends on genes ($G$), ancestral investments ($I_A$), and own investments ($I_{t-1}$), including those during the prenatal period. Biological signatures of epigenetic change are associated with obesity in humans and changes in diet and exercise affect these signatures (see the review by Ling and Rönn (2019)). Animal studies provide evidence of the reversability of epigenetic signatures with maternal nutritional supplementation (Dolinoy et al., 2007; Bernal et al., 2013) and exercise of mature males in the case of metabolic health (McPherson et al., 2017). Both ancestral and own investments may have a higher payoff during critical periods such as ancestral slow growth ages when epigenetic modification is more likely or early and late gestation when epigenetic erasure and then reprogramming occurs (Bygren, 2013; Baxter and Drake, 2019). Individuals need not know that they are investing in their epigenome; they may simply make investments in their own health. This dynamic epigenetic inheritance is passed down to children at conception.

I will estimate the treatment effect $E(\mathrm{BMI}_{t,D=1} - \mathrm{BMI}_{t,D=0})$, where BMI is grandsons' BMI and the treatment ($\mathrm{D} = 1$) is the grandfather's exposure to starvation during his growing years. I will examine whether grandpaternal treatment to affect grandsons' BMI is consistent with epigenetic, habit formation, and socioeconomic pathways of transmission. These pathways are not necessarily mutually exclusive.[4]

The **epigenetic hypothesis** predicts for a paternal health shock or treatment

$$E(\mathrm{BMI}_{t,D=1} - \mathrm{BMI}_{t,D=0}) > 0 \text{ for male-line but not female-line grandsons}$$

Unlike other biological mechanisms, epigenetic imprinting is sex-specific. Because the Y chromosome is transmitted only to men, transmission of an epigenetic effect along the Y

[4]Even if I could observe markers of $E(P_{t,D=1} - P_{t,D=0})$, strictly speaking, I could not identify $E(P_{t,D=1} - P_{t,D=0})$ because while an exogenous ancestral health shock will be uncorrelated with investments in $P_t$ prior to the shock the shock can affect later investments in $P_t$, making the treatment exogenous to investments before it occurs but not to investments after it occurs.

chromosome, as hypothesized in the Överkalix studies (Bygren et al., 2001; Pembrey et al., 2014), occurs only for sons and male-line grandsons.

The **epigenetic hypothesis** further predicts that the treatment effect will be stronger if the treatment occurs developmental transition ages, including during the grandfather's slow growing years (Bygren, 2013), and if own and fathers' in-utero conditions are poor (Baxter and Drake, 2019). While a **cultural hypothesis** with extreme sex patterning could lead to psychological POW trauma transmitted to sons alone and the transmitted trauma in turn could lead to overweight, it is hard to reconcile a cultural hypothesis with mediation by in-utero conditions.

The **habit formation hypothesis** presupposes that grandfathers respond to starvation by over-eating, adopting a high fat diet and/or engaging in less physical activity, both in jobs and in daily life, leading to

$$E(\mathrm{BMI}_{t,\,D=1} - \mathrm{BMI}_{t,\,D=0}) > 0 \text{ for grandfathers.}$$

Grandfathers' increase in BMI could arise from **biological** changes which impede the rate of weight loss (e.g., changes in endocrine function, carbohydrate and fat utilization, neuroendocrine signaling, and hormones secreted from the gastrointestinal tract) and these changes may persist.[5] Such changes may be more likely to persist if they occur during the growing years.

**Habit formation** would instill the grandfathers' unhealthy behaviors in their children and their children's children, leading to

$$E(\mathrm{BMI}_{t,\,D=1} - \mathrm{BMI}_{t,\,D=0}) > 0 \text{ for both male}-\text{line and female}-\text{line grandsons}$$

and to correlation between veterans' and grandsons' BMI.

$$\rho(\mathrm{BMI}_V, \mathrm{BMI}_G) > 0 \text{ for both male-line and female-line grandsons,}$$

where $\mathrm{BMI}_V$ is the veteran's BMI and $\mathrm{BMI}_G$ is the grandson's BMI. Habit formation implies that if exposed grandfathers are more likely to be overweight regardless of age at exposure then grandsons also will be more overweight regardless of age of exposure of the grandfather.

Grandfathers' overweight may trigger an epigenetic change in their children and grandchildren. Evidence on whether paternal obesity is associated with greater glucose impairment in female or male offspring is mixed (Kaspar et al., 2020; MacKay et al., 2022). Without sex-specific transmission, this hypothesis is indistinguishable from habit formation. With sex-specific transmission, $\rho(\mathrm{BMI}_V, \mathrm{BMI}_G) > 0$ for either male- or female-line grandsons but not for both.

[5]Obese individuals who participated in the television weight loss contest, The Biggest Loser, had a lower metabolic rate years after the end of the competition compared to their baseline.

The **socioeconomic hypothesis** predicts that in a time period when a higher BMI was associated with a higher socioeconomic status (Costa, 2015) and when fathers' socioeconomic status was inherited by both sons and daughters (Costa et al., 2018; Costa, 2021),

$$E(\text{BMI}_{t,\,D=1} - \text{BMI}_{t,\,D=0}) < 0 \text{ for grandfathers and both male-line and female-line grandsons}.$$

Because occupational adjustments to health shocks are harder at older ages, the socioeconomic hypothesis predicts that BMI differences should be greater among the descendants of grandfathers who were treated at older ages because they would be more likely to have lower wealth and to be in lower status occupations.

My treatment is the grandfather's POW exposure which I group into none (non-POWs), exposure to harsh conditions (non-exchange ex-POWs or men captured between July 1863 and July 1864), and exposure to milder captivity conditions (exchange ex-POWs or men captured before July 1863 or after July 1864). My outcomes are both BMI and overweight (a $\text{BMI} \geq 25$), where $O$ is equal to one if the grandson was overweight or obese. The advantage of examining overweight is that the healthy BMI range is broad. I estimate the treatment effects $E(\text{BMI}_{NE} - \text{BMI}_0)$, $E(\text{BMI}_E - \text{BMI}_0)$, and $E(\text{BMI}_{NE} - \text{BMI}_E)$ and $E(O_{NE} - O_0)$, $E(O_E - O_0)$, and $E(O_{NE} - O_E)$ where the subscripts $NE$, $E$, and 0 represent non-exchange ex-POW, exchange ex-POW, and a non-POW, respectively.

## 2. Methods

Identification of the relationship between grandfathers' trauma and their grandchildren's BMI depends on the comparison of descendants of non-POW veterans and ex-POWs captured during the prisoner exchange period (before July 1863 or after June 1864) and the non-exchange period (between July 1863 and July 1864). Most POWs were exchanged immediately until mid-1863 when prisoner exchanges stopped as the two sides argued over the terms, particularly the treatment of black soldiers (who could be enslaved) and their white officers (who could be hanged as the leaders of a slave insurrection). Men captured after mid-1863 faced more time in captivity and ever worsening conditions as the crowds of prisoners increased. Death rates, officially attributed to scurvy, diarrhea, and dysentery, rose (Costa and Kahn, 2007). Crowding at Andersonville, the most notorious Confederate camp and one which is over-sampled in my data, began to improve in September with transfers to other prison camps and unofficial exchanges (Marvel, 1994). Official exchanges began again in December of 1864.

Union Army military records for individual soldiers support evidence from captivity narratives and sporadic information on numbers of prisoners, rations, and death rates that conditions deteriorated sharply when the exchange system stopped. Among survivors to 1900 from a random sample of Union Army infantry soldiers, wartime records mention scurvy for 11% of all non-POWs; 14% of ex-POWs captured before July 1863; 23% for ex-POWs captured between July 1863 and July 1864; and 14% for ex-POWs captured after June 1864 (Costa, 2012).[6] Among ex-POWs who survived to 1900, average time in captivity was 16 days for men captured before July 1863, 231 days for non-exchange period ex-POWs, and 125 days for men captured after June 1864. Veterans who survived both to 1900 and who still were in their growing years were more likely to be stunted at older ages if they had been non-exchange ex-POWs.[7] Photos of the era show men reduced to living skeletons and captivity narratives recount soldiers weighing less than 100 pounds when they returned home (Costa and Kahn, 2008).

How valid is using non-POWs and exchange ex-POWs as control groups for non-exchange ex-POWs? Concerns that exchange POWs were partially "treated" suggests comparing descendants of non-exchange ex-POWs with descendants of non-POWs. Worries about selection on unobservables in who is captured argues for comparing descendants of non-exchange ex-POWs with descendants of exchange ex-POWs.[8] Both comparisons most likely underestimate the true mortality cost of descending from a grandfather who experienced extreme stress because of selective within camp survival of the hardiest non-exchange ex-POWs. In a sample of POWs, 4% of men captured before July 1863 died in captivity versus 27% captured July 1863 or later (Costa and Kahn, 2007; Costa, 2012).

Recall that only the epigenetic hypothesis predicts transmission of the grandfather's ex-POW status to his male-line but not his female-line grandsons. I therefore test for BMI differences both by the grandfather's ex-POW status and by whether the son was descended from sons or daughters. I examine how BMI differences change as controls are added for the grandfather's overweight and his post-war socioeconomic characteristics and for the socioeconomic characteristics of the grandson and of his parents. I pool male-line and female-line grandsons into one sample. Each male-line grandson is matched to at least one female-line cousin (pairings are not necessarily unique and a male-line grandson could be matched to more than one cousin or could share the cousin match with another male-line grandson). My main specifications account for unobservable veteran or veteran family characteristics by including a random effect. I estimate for grandson $i$ in veteran family $V$, the linear regression and probit models

$$BMI_i = \beta_0 + \beta_1 M_i + \beta_2 P_{E,iV} + \beta_3 P_{N,iV} + \beta_4 (M_i \times P_{E,iV}) + \beta_5 (M_i \times P_{N,iV}) + \beta_6 C_{iV} + \beta_7 C_i + u_{iV} + \epsilon_i \quad (1)$$

$$\Pr(O_i = 1 \mid X) = \Phi(\beta_0 + \beta_1 M_i + \beta_2 P_{E,iV} + \beta_3 P_{N,iV} + \beta_4 (M_i \times P_{E,iV}) + \beta_5 (M_i \times P_{N,iV}) + \beta_6 C_{iV} + \beta_7 C_i + \beta_8 C_i + u_{iV} + \epsilon_i) \quad (2)$$

where $O_i$ is a dummy variable equal to one if the grandson was overweight, $M$ is a dummy variable equal to one if the grandson was a male-line grandson, $P_{E,iV}$ and $P_{N,iV}$ indicate that the grandfather was an exchange or non-exchange ex-POW (non-POW is omitted), $C_{iV}$ is a

[6]Scurvy develops after 8–12 weeks of vitamin C deficiency.

[7]The differences between height at first enlistment and the first height measurement after age 40 was 0.34 inches for non-POWs, 0.40 inches for exchange ex-POWs, and 0.21 inches for non-POWs.

[8]I have not uncovered anything in the historical record which implies that men who surrendered in different time periods were different from their comrades who were not captured. Men were captured in groups when officers made the decision to surrender or individually in the chaos of battle or on scouting missions.

vector of controls specific to the veteran and $C_i$ is vector of controls specific to the grandson, $u_{iV}$ is the error term common to all grandsons of a given veteran, and $\epsilon_i$ is the error term specific to a grandson. I cluster the standard errors on the veteran to account for potential heteroskedasticity. Note that the underlying model assumption is that $u_{iV}$ is uncorrelated with the explanatory variables and that $\epsilon_i$ is $\dot{\text{iid}}$. Random effects may provide gains in efficiency relative to clustering alone. I examine models with no random effect and clustering and also with a random effect alone (under the assumption that the $\epsilon_i$ are $\dot{\text{iid}}$). I also estimate logit models for ease of comparison with other results in the literature.

My basic controls are the grandson's age group when BMI was reported, his quarter and region of birth, and the enlistment characteristics of his grandfather. I investigate whether the results persist when I add one year birth dummies for the veteran and his grandsons (fixed effects for the linear case). I examine whether the results persist when I control for the grandfather's overweight circa 1900 and for the grandfather's post enlistment occupational class, the fathers' socioeconomic characteristics, the geographic proximity of the grandfather to the grandchild, the parents' years of education, and the grandson's years of education and occupation in 1940.

I estimate the impact of grandfather's ex-POW status within and across male and female lines. I first difference and estimate $(\hat{\beta}_{M=1, POW=N} - \hat{\beta}_{M=1, POW=0})$, $(\hat{\beta}_{M=0, POW=N} - \hat{\beta}_{M=0, POW=0})$, $(\hat{\beta}_{M=1, POW=E} - \hat{\beta}_{M=1, POW=0})$, $(\hat{\beta}_{M=0, POW=E} - \hat{\beta}_{M=0, POW=0})$, $(\hat{\beta}_{M=1, POW=N} - \hat{\beta}_{M=1, POW=E})$, and $(\hat{\beta}_{M=0, POW=N} - \hat{\beta}_{M=0, POW=E})$, where $\hat{\beta}$ is either the OLS coefficient or the marginal, $M = 1$ indicates male-line, $M = 0$ indicates female-line, and grandfather's ex-POW status is $POW = N$ (non-exchange), $POW = E$ (exchange), or and $POW = 0$ (non-POW). I then double-difference to obtain

$$DD_{N0} = (\hat{\beta}_{M=1, POW=N} - \hat{\beta}_{M=1, POW=0}) - (\hat{\beta}_{M=0, POW=N} - \hat{\beta}_{M=0, POW=0}),$$

$$DD_{E0} = (\hat{\beta}_{M=1, POW=E} - \hat{\beta}_{M=1, POW=0}) - (\hat{\beta}_{M=0, POW=E} - \hat{\beta}_{M=0, POW=0}),$$

$$DD_{NE} = (\hat{\beta}_{M=1, POW=N} - \hat{\beta}_{M=1, POW=E}) - (\hat{\beta}_{M=0, POW=N} - \hat{\beta}_{M=0, POW=E}).$$

I investigate how the grandson's and son's season of birth mediates the effect of grandfather's ex-POW status among male-line grandsons, the only line for which I find an association between grandfather's ex-POW status and grandson BMI. I interact the grandfather's ex-POW status with the male-line grandson's and son's season of birth, which for these cohorts proxies for late gestational maternal nutrition (Doblhammer and Vaupel, 2001), to estimate

$$BMI_i = \beta_0 + \beta_1(W_i \times W_{Fi} \times P_{N,iV}) + \beta_2(W_i \times W_{Fi} \times P_{E,iV}) + \beta_3 C_{iV} + \beta_3 C_i + \epsilon_i, \qquad (3)$$

where $W_i$ represents a winter (the first half of the year) birth for grandson i and $W_{Fi}$ represents a winter birth for his father. I omit grandsons in-utero or born during WWI or the

Influenza Pandemic to avoid confounding season of birth with wartime fertility selection or Pandemic effects.

I investigate whether transmission of overweight differs between the male and female lines by establishing the correlation between a veteran's overweight and his grandsons' overweight. I run regressions for male-line and female-line grandsons separately of the form

$$BMI_i = \beta_0 + \beta_1 P_{E,iV} + \beta_2 P_{N,iV} + \beta_3 C_i + \beta_4 O_{Vi} + \epsilon_i \,. \quad (4)$$

where $O_{Vi}$ is a dummy equal to one if the veteran grandfather was overweight.

I examine the implications of overweight for grandsons' longevity by running Cox proportional hazard models for both male-line and female-line grandsons. My sample consists of matched male-line and female-line cousins where both survived to age 45 conditional on both having BMI observed prior to age 45.[9] I estimate

$$h_i(t) = h_0(t)\exp(\beta_x X_i)$$

where $t$ is years lived after age 45, $h_0(t)$ is the baseline hazard and $X_i$ is a vector of characteristics specific to each grandson $i$. I specify $\beta_x X_i$ as

$$\beta_0 + \beta_1 P_{E,Vi} + \beta_2 P_{N,Vi} + \beta_4 C_{Vi} + \beta_5 C_i \text{ or} \quad (5)$$

$$\beta_0 + \beta_1 P_{E,Vi} + \beta_2 P_{N,Vi} + \beta_3 O_i + \beta_4 C_{Vi} + \beta_5 C_i \quad (6)$$

where $O_i$ is a dummy indicator equal to one if the grandson was overweight. I cluster on the grandfather and stratify on birth cohort. As explained in the Appendix, I also conduct a formal mediation analysis to determine whether a male-line grandson's BMI mediates the effect of grandfather's ex-POW status on male-line grandsons' mortality (see Appendix Equations A.13 and A.14).

## 3. Data

My analytical sample consists of 3,048 male-line grandsons and their 3,177 male female-line cousins, descended from 840 grandfathers who were age 17–24 during the non-exchange period. Union Army soldiers were growing rapidly until age 21 and then more slowly until age 25 (Wilson and Pope, 2003). All grandsons have self-reported information on height and weight from draft cards. BMI was calculated from height and weight and I trimmed the top and bottom 0.5% of the BMI distribution to avoid outliers potentially driven by incorrect information. I also have information on grandsons whose grandfathers were age 25 or older during the non-exchange period, yielding an additional 1,069 male-line grandsons and the same number of male female-line cousins.

[9]A grandfather's ex-POW status was not associated with male-line grandsons' mortality prior to age 45 but was with mortality after age 45 (Costa, 2021). Examining mortality after age 45 would introduce selection in survival.

All grandsons descended from children born after the war to white Union Army veterans who survived to 1900. I constructed this transgenerational database by building on databases of Union Army veterans and their children, over-sampling ex-POWs. Veterans and their children and grandchildren were traced through birth, death, and census records. The databases have been used and described in detail in Costa et al. (2018) and Costa (2021). Life expectancies are similar to those obtained from genealogies of the northern-born. Because linkage was carried out using multiple sources and focused on entire families, linkage rates are extremely high relative to what is typical using historical data. For example, 96% of veterans were linked to the 1880 census and among veterans' children who were alive at the time of the census, 87% of sons and 85% of daughters were linked to any census, and 97% of grandsons and 96% of granddaughters were linked to the 1940 census (Costa, 2021). While sons and daughters are equally likely to be found in the census records, a limitation of the draft records which provide height and weight is the absence of information for women and for most sons because they were born too early.

Men born between 1877 and 1929 (inclusive) registered for the draft under several selective service acts which ended in 1947. Men born between 1877–1897 were part of the "Old Man's Draft" implemented to inventory manpower. Conditional on being alive in 1940, 99% of grandsons are linked to their draft cards. 98% of grandchildren have usable BMI information, including after the tails are trimmed (see Appendix Table A.1). Linkage rates were high regardless of descent from sons or daughters or grandfathers' ex-POW status. Grandsons' BMI by age group was similar that observed among examined military service registrants whose height and weight were measured (Karpinos, 1958) and, as expected, grandsons' BMI increases with age (see Appendix Table A.2).

The sample of ex-POW descendants is biased towards healthy survivors. Veterans had to survive POW camps and live to 1900.[10] They were healthy enough to marry and have children after the war. Their children had to survive to have children. Grandsons who survived to draft age were more likely to be healthy. There is no evidence of selection on socioeconomic status or of marriage selection after the war (see the Appendix, section A.1).

My dependent variables are BMI and the fraction overweight, defined as a BMI of 25 or more. Only small fractions of the analytical sample were underweight ($\mathrm{BMI} < 18$) or obese ($\mathrm{BMI} \geq 30$). Average age when height and weight were reported was 33 (see Appendix Table A.3).

My control variables consist of three types: those which control for pre-war differences between grandfathers, those which control for post-war differences between grandfathers and parents, and those which control for differences between grandchildren. Control variables include the veteran's overweight and for grandfathers, fathers, and grandsons, occupational class, property ownership, educational characteristics, and geographic and demographic controls.[11] Details and variable means are in the Appendix, section A.2.

[10]It is possible to trace survivorship after 1900. Non-exchange ex-POWs faced higher mortality rates than exchange ex-POWs or non-POWs (Costa, 2012). There were no mortality differentials among their wives (Costa et al., 2018).
[11]Height and weight are available for veterans from records of examining surgeons working for the veteran pension system.

## 4. Veterans' Overweight

Ex-POWs in their late 40s and early 50s were more likely to be overweight compared to non-POWs. Figure 1 shows that among veterans who survived to 1900 and who had children surviving to age 45 (and thus eligible to be in the sample), the distribution of BMI measured circa 1900 is shifted to right when comparing non-exchange ex-POWs with non-POWs and with exchange ex-POWs. (Kolmogorov-Smirnov tests, shown in the notes to Figure 1, reveal that the distributions are not the same.) Controlling for veterans' pre-enlistment and post-war characteristics, a non-exchange ex-POW was 1.8 times more likely to be overweight and had a BMI that was greater by 0.7 than that of a non-POW. Compared to an exchange ex-POW, a non-exchange ex-POW ex-POW was 1.4 times more likely to be overweight and his BMI was greater by 0.7 (see the Appendix, section A.3).

## 5. Grandsons' Overweight

The BMI of male-line grandsons of non-exchange ex-POWs increased after a BMI of 25 compared to the BMI of grandsons descended from non-POWs (see Figure 2, which plots BMI densities by grandfather's ex-POW status for both male-line and female-line grandsons), The BMI of male-line grandsons of exchange ex-POWs relative to non-POWs also increased after a BMI of 25 but the increase was less than that observed for grandsons of non-exchange ex-POWs. In contrast, among female-line grandsons, the BMI of grandsons descended from non-exchange ex-POWs rarely exceeds of non-POWs and exchange ex-POW descendants. (Kolmogorov-Smirnov tests for the equality of the distributions are given in the footnote to Figure 2.) The greater BMI of male-line grandsons comes from their higher weight. They were not taller than female-line grandsons (see Appendix Figure A.1).

Table 1 compares male-line and female-line grandsons descended from grandfathers at risk of captivity at ages 17–24 to show that both BMI and the probability of overweight increased among male-line grandsons descended from non-exchange ex-POWs relative to non-POWs but the same was not true for female-line grandsons. The increase in BMI was roughly 0.4 and the increase in the probability of overweight was roughly 0.06 for male-line grandsons descended from non-exchange ex-POWs compared to those descended from non-POWs. The comparable increases for female-line grandsons were either small or negative. The double-difference estimates yield increases of 0.4 in BMI and 0.06 in the probability of overweight. Male-line grandsons descended from exchange ex-POWs did not have a statistically significantly different BMI compared to male-line grandsons descended from non-POWs. In comparing male-line grandsons descended from non-exchange ex-POWs to those descended from exchange ex-POWs, the increase in BMI was 0.3 and the increase in overweight was 0.08. The double-difference estimates imply an increase of 0.4 in BMI and of 0.08 in overweight. The results are robust to different error term assumptions (see Appendix Table A.6) and to the inclusion of controls for the grandfather's and grandsons' single year of birth (see Appendix Table A.7).[12]

[12]Section A.4 in the Appendix also includes a discussion of the number of hypotheses.

The results in Table 1 are similar when I include controls for the veteran's post-war socioeconomic status and his overweight circa 1900, the father's socioeconomic status, parents' education, and own socioeconomic status and education. The double-difference estimates for grandfather's non-exchange ex-POW status relative to non-POW status yield increases of 0.5 in BMI and 0.07 in the probability of overweight. Results are marginally stronger when I redefine the sample to include only cousins whose ages when BMI was observed did not differ by more than five years ($N = 2{,}384$). A male-line grandson descended from a non-exchange ex-POW rather than a non-POW had a BMI which was greater by 0.634 ($\sigma = 0.253$, $p - \text{value} = 0.011$) whereas a female-line grandson had a BMI which was lower by 0.185 ($\sigma = 0.247$, $p - \text{value} = 0.456$).

Quantile regressions demonstrate that the biggest increases in BMI for male-line grandsons descended non-exchange ex-POWs relative to non-POWs are at the 75th rather than the 50th or 25th quantile. Nonetheless, there are increases at all quantiles (see Appendix Table A.8).

Veterans' overweight is associated with higher BMI among both male-line and female-line grandsons. Among female-line grandsons, grandfathers' overweight increased BMI by 0.7. Among male-line grandsons, grandfathers' overweight increased BMI by 0.6 to 0.5, with the association falling as additional controls, including the grandfather's ex-POW status, were added (see Appendix Table A.9). There was no evidence that the relationship between grandsons' BMI and veterans' overweight varied by veterans' ex-POW status (results not shown).

Season of birth mediates the relationship between grandfathers' ex-POW status and their male-line grandsons' BMI. Table 2 shows that the relationship is strongest when both fathers and grandsons were born in the first half of the year, with BMI increasing by 1.1 for grandsons descended from non-exchange ex-POWs relative to non-POWs. In contrast, when both fathers and sons were born in the second half of the year, BMI increased by only 0.3. The difference of 0.8 is statistically significant at the 5% level. The father's season of birth was a stronger mediator of the relationship between the grandfather's ex-POW status and his male-line grandsons' BMI than grandsons' season of birth. Season of birth was a weaker mediator for the BMI of grandsons descended from non-exchange relative to exchange ex-POWs.

The relationship between grandsons' BMI and grandfathers' ex-POW status is seen among male-line grandsons whose grandfathers were at risk of captivity during but not after their growing years (see Appendix Figure A.2). In contrast, among veteran grandfathers the increase in BMI between non-exchange ex-POWs and non-POWs, while greatest among veterans captive during their growing years, was not statistically significantly different from that observed among veterans held captive at older ages (see Appendix Figure A.3). Transmission at developmental ages only but effects for all grandfathers is more consistent with an epigenetic than with a habit formation hypothesis.

Figure 2 suggests that both obesity ($\text{BMI} \geq 30$) and overweight but not obese ($25 \leq \text{BMI} < 30$) increased among male-line grandsons descended from non-exchange ex-

POWs. A more formal analysis (with the caveat that the fraction of obese grandsons was 0.04) shows that the probability of obesity among male-line grandsons increased by 0.02 if they descended from non-exchange ex-POWs relative to non-POWs, a 50 percent increase relative to the mean, and by 0.01 if descended from a non-exchange ex-POW relative to an exchange ex-POW. The probability of overweight but not obese increased by 0.06, an increase of 24% relative to the mean, if descended from a non-exchange ex-POW relative to a non-POW and by 0.04 if descended from a non-exchange ex-POW relative to an exchange ex-POW (see the Appendix, section A.5).

The findings are most consistent with an epigenetics hypothesis. Recall that the epigenetic hypothesis predicted that 1) male-line but not female-line grandsons would be overweight, 2) transmission would be stronger during the grandfather's slow growing years, that is ages 17–24, and 3) transmission would be more likely if own and fathers' in-utero conditions were poor. While transmission through the male-line only is consistent with a cultural hypothesis with extreme sex patterning, such an hypothesis is hard to reconcile with mediation by in-utero conditions. A habit formation hypothesis with sex-patterning is unlikely because all veteran grandfathers who experienced a harsh captivity were over-weight, not just those who experienced a harsh captivity during their growing years. A socioeconomic hypothesis is unlikely both because I have extensive controls for socioeconomic status and because a grandfather would experience the most adverse socioeconomic effects if he experienced captivity after his later growing years, when he would have had fewer opportunities to adjust his human capital.

### 5.1. Magnitudes

The increase of 0.06 in the fraction overweight among male-line grandsons descended from non-exchange ex-POWs during their growing years compared to male-line grandsons descended from non-POWs represents a 21% increase relative to mean overweight of 0.29 among all grandsons. The increase in BMI relative to the mean is more modest: a 0.4 increase in BMI represents a 2% increase relative to mean BMI of 23.67. A 1.1 increase in BMI for a male-line grandson who was born in the first half of the year to a father also born in the first half of the year and descended from a non-exchange ex-POW relative to a non-POW is a 5% increase relative to mean BMI.

The increase in BMI among male-line grandsons by the grandfather's ex-POW status was smaller than that observed among veterans by their own ex-POW status, as expected from mediation by season of birth. The increase in BMI of 0.4 was statistically distinguishable from an increase of 0.7 (as observed among veterans). The percentage increase relative to BMI was more modest: the increase in BMI among veterans was 3% relative to mean BMI whereas for male-line grandsons the increase was 2%. Recall that the odds of overweight among non-exchange ex-POW veterans relative to non-POWs was 1.8. Estimating the relationship between grandsons' overweight and their grandfathers' non-exchange ex-POW status using a logit model leads to an odds of overweight of 1.4 for male-line grandsons descended from non-exchange ex-POW veterans relative to non-POWs (see Appendix Table A.10).

The magnitude of the relationship between male-line grandchildren's overweight and their grandfathers' non-exchange ex-POW status (odds of 1.4) is on par with estimates of overweight after exposure to the Dutch Hunger Winter. The odds of overweight were 1.6 (albeit statistically insignificant) for women exposed at age 18 and higher to the Dutch Hunger Winter compared to women with no exposure (Abeelen et al., 2012) and the odds of overweight at age 18 were 1.3 for men exposed in utero to the Dutch Hunger Winter compared to their unexposed peers (Lumey et al., 2021). These magnitudes are greater than the 1.1 increase in overweight among women exposed to the Chinese famine in utero (Zhou et al., 2018).

My estimates of increases in BMI are lower than those observed in studies of the Dutch Hunger Winter but similar to those seen in other studies. Among the children of women exposed in-utero to the Influenza Pandemic, BMI was 0.4 or 2% higher compared to non-exposed controls (Cook et al., 2019). Among elderly Holocaust survivors BMI was 0.8 higher compared to non-exposed controls (Fund et al., 2019), or 3% higher relative to the mean. In contrast, the increase in the BMI of children of men in utero during the Dutch Hunger Winter was 1.4 higher, an increase of 6% relative to the mean (Veenendaal et al., 2013).

A caveat to comparisons with modern-day Western populations is that both veterans and their grandsons were relatively thin. Examining odds ratios will magnify effects among veterans and their grandsons relative to modern populations. Examining differences in BMI will compress these effects.

## 6. Grandsons' Overweight and Their Mortality

Overweight grandsons were more likely to die at any age after age 45 than non-overweight grandsons (see Figure 3). The differences were particularly large among male-line grandsons. Among male-line grandsons, the overweight lived on average 26.5 years after age 45 compared to 29.4 years for the non-overweight, a difference of 2.9 years. Among female-line grandsons, mean years lived after age 45 for the overweight was 27.0 years compared to 29.3 years for the non-overweight, a difference of 1.7 years. Some of this difference in overweight and longevity between male-line and female-line grandsons is because grandfathers' ex-POW status was associated with the longevity of male-line grandsons only (see Figure 4 and Costa (2021)). Among male-line grandsons surviving to age 45, those descended from a non-exchange ex-POW lived an additional 27.5 years whereas those descended from a non-POW lived an additional 29.3 years or 1.8 more years. In contrast, female-line grandsons were longer-lived if descended from non-exchange ex-POWs (29.3 years) rather than non-POWs (28.5 years).

Grandfather's ex-POW status during their growing years predicted male-line grandsons mortality independent of grandsons' overweight and grandsons' overweight predicted mortality of all grandsons independent of grandfather's ex-POW status. The association between a grandfather's ex-POW status and his male-line grandsons' mortality could be explained in part by grandsons' overweight (see Table 3). Male-line grandsons whose paternal grandfathers were non-exchange ex-POWs during their growing years were 1.28

times more likely to die at any age after age 45 compared to grandsons whose paternal grandfathers were non-POWs, controlling only for the veteran grandfathers' enlistment characteristics and for the grandsons' birth year, quarter and region of birth, and age when BMI was reported. The hazard ratio fell to 1.25 controlling for the grandsons' overweight and to 1.23 controlling for grandpaternal, paternal, and own socioeconomic characteristics. Male-line grandsons descended from exchange ex-POWs were 1.17 to 1.18 times more likely to die compared to those descended from non-POWs. Controls for overweight lead to respective 9 and 5% decline in the association between non-exchange and exchange ex-POW relative to non-POW descent and the odds of dying at any age after age 45. Additional controls for post-war and contemporary socioeconomic status lead to an additional 6 and 1% decline in the association.

Grandfathers' ex-POW status was not associated with the mortality of female-line grandsons but their own overweight was, increasing the likelihood of dying by 1.18. Among grandsons descended from veterans who were at risk of being non-exchange ex-POWs at age 25 or higher, grandsons descended from non-exchange ex-POWs were as likely to die as grandsons descended from non-POWs (see Appendix Table A.12).

Male-line grandsons were statistically significantly more likely to die if descended from either exchange or non-exchange ex-POWs compared to those descended from non-POWs whereas their BMI and overweight were not statistically significantly different if descended from exchange ex-POWs relative to non-POWs. The findings are not necessarily contradictory. Exchange ex-POWs were partially treated and chronic conditions manifest themselves only at older ages, when mortality was observed. When I expanded the sample to include grandsons for whom I did not have information on BMI and classified the grandfather's ex-POW status as early exchange, non-exchange, and late exchange, I found that that the respective hazard ratios were 1.095 ($\sigma = 0.062$, $p - \text{value} = 0.108$), 1.255 ($\sigma = 0.066$, $p - \text{value} = 0.000$), and 1.173($\sigma = 0.068$, $p - \text{value} = 0.006$) compared to non-POW status. The hazard on the grandfather's non-exchange ex-POW status was statistically significantly different from that on early captivity at the 2% level but was not statistically significantly different from late exchange captivity.

A formal mediation analysis reveals that grandsons' BMI accounts for roughly 14% of the total effect of non-exchange ex-POW status on male-line grandsons' mortality (see Appendix Table A.13), Grandfather's non-exchange ex-POW relative to non-POW status increased mortality risk every year after age 45 by 21.9%. The direct effect was 18.9%. The indirect effect of overweight was 3.0% or14% of the total effect. The total effect of being an exchange ex-POW relative to a non-POW was a 26.9% increase in mortality risk every year after age 45 but the effect was not mediated by BMI.[13]. There was no statistically significant effect of having a grandfather who was a non-exchange relative to an exchange ex-POW and overweight did not intermediate this effect.

[13]A greater magnitude for the association between exchange ex-POW relative to non-POW descent compared to the association non-exchange ex-POW relative to non-POW descent also is seen when I run separate regressions with only two ex-POW categories.

## 7. Conclusion

The transmission of overweight to grandsons descended from ex-POWs malnourished during their late growing years has implications for populations today. Transgenerational inheritance which manifests in overweight suggests that ancestral factors during growing years may play a role in establishing metabolic capacity. Because grandsons' overweight explained at most 14% of the association between grandfathers' ex-POW status and grandsons' longevity, the findings suggest that past famine exposures are likely to manifest themselves in more ways than in overweight and are consistent with the argument in Luke et al. (2021) that metabolic disease in India is not driven by obesity. Although my evidence on the mechanisms driving the association between grandfathers' ex-POW status and grandsons' longevity was circumstantial, my findings of sex-specific transmission, transmission during the grandfather's growing years, and mediation by in-utero conditions are consistent with an epigenetic mechanism and thus with studies demonstrating transgenerational transmission of paternal harvest shocks and famine during the slow growing years in humans to affect their health and longevity (Kaati et al., 2007; Bygren et al., 2001; Bygren, 2013; Vågerö et al., 2018, 2022; van den Berg and Pinger, 2016; Costa, 2021). These studies show that male-line grandsons whose grandfathers were exposed to poor harvests in Sweden circa age 19 faced an elevated mortality risk compared to their unexposed counterparts (Bygren, 2013) but that those whose grandfathers were exposed to poor harvests during the slow growth period prior to puberty faced a lower mortality risk (Kaati et al., 2007; Vågerö et al., 2018, 2022). Bygren et al. (2014) hypothesize that radical change in food availability (common for historical populations in Sweden and for POWs who experienced a rapid deterioration to starvation levels and then a return to good conditions) induces gene expression responses and epigenetic processes. While policy makers cannot undo past fluctuations in food supplies, the mediation of grandfathers' exPOW exposure by fathers' and own season of birth suggests that the benefits of adequate maternal nutrition could compound across generations by mitigating and even reversing the generational reach of ancestral exposures.

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## Additional Analyses and Data Details

ON-LINE APPENDIX

## ON-LINE APPENDIX Appendix

### A.1 Sample Representativeness

Table A.1 demonstrates that linkage rates were comparable by descent from sons or daughters and by the grandfather's ex-POW status.

Table A.2 shows that mean BMI of grandsons, estimated from self-reported height and weight, was similar to BMI estimated from mean measured height and weight of selective service registrants examined for military service. As expected, mean BMI increases with age.

The sample of ex-POWs is biased towards healthy survivors. Men had to survive POW camps. Crowding was the most important determinant of camp survivorship (Costa and Kahn, 2007). More men meant fewer rations per person (and by June 1864 corn bread and cornmeal were the principal staples at Andersonville), more contamination from human excrement and other filth, and more competition for shelter, blankets, and clothing. Although there was trade with the outside world, men who had been prisoners for long had nothing left to trade.

Individual determinants of camp survivorship included age (extreme deprivation was cruel to those above age 30 and the very young), height (the tall needed but did not receive bigger rations), occupation (farmers fared poorly probably because they had few skills within the camp), and rank (commissioned officers received better treatment and sergeants controlled food distribution). Men imprisoned with more comrades were more likely to survive (Costa and Kahn, 2007).

After leaving the camps, men are lost to follow-up until the pension program becomes close to a universal system with the passage of the law of 1890. However, the very ill (disproportionately ex-POWs) were eligible for pensions and they also died prior to 1900. The veterans who had been ex-POWs and who survived to 1900 did not suffer disproportionately from mental health problems (Costa, 2021), perhaps because they found some meaning in their suffering as saviors of the Union who had wiped the sin of slavery from the land, a narrative reinforced by veterans' organizations, former prisoner associations, reunions, and prison memoirs (Gardner, 1998).

Veterans who had children after the war, and thus whose grandsons are in the sample, were more likely to be healthy. Non-exchange ex-POWs were less likely to marry than non-POWs (and thus to be in the sample) but conditional on marriage, they had the same number of children and grandchildren (Costa et al., 2018; Costa, 2021). Veterans' children in turn were more likely to be healthy if they survived to have children.

Grandsons who survived to draft age were more likely to be healthy. There is evidence of excess early childhood mortality among male-line grandsons descended from non-exchange ex-POWs (Costa, 2021).

There is no evidence of selection on socioeconomic status. Neither veterans' socioeconomic status nor veterans' children socioeconomic status was correlated with veterans' ex-POW status, perhaps because socioeconomic status was established prior to health declines (Costa et al., 2018; Costa, 2021). There is evidence of occupational change away from farming but it was not accompanied by declines in socioeconomic status. After the war non-exchange ex-POWs were more likely to be artisans and less likely to be farmers than their non-POW counterparts. Their sons and sons-in-law in turn were more likely to be artisans and less likely to be farmers but the association was much diminished. There is no evidence indicating that a veteran's ex-POW status increased his or his sons or sons-in-laws' probability of being a laborer or of not owning a home (Costa, 2021).

There is no evidence of marriage selection among veterans by ex-POW status. Non-exchange ex-POWs who married after the war did not marry "down" relative to non-POWs: their fathers-in-law had the same wealth in 1860. Their wives also had the same mortality experience. The children of non-exchange ex-POWs did not marry sicker spouses than the children of non-POWs. The mortality experience of children's spouses was the same (Costa, 2021).

Higher mortality after age 45 among male-line but not female-line grandsons descended from non-exchange ex-POWs relative to non-POWs (Costa, 2021) implies that, if BMI is a harbinger of premature mortality, I will underestimate the effect of the veteran's non-POW status on male-line grandsons' overweight among those older than age 45.

## A.2 Sample Means

Tables A.3 and A.4 present sample means for grandsons and their parents and veteran grandfathers, respectively.

Pre-war differences between grandfathers include year of enlistment (which I treat as a dummy variable), occupation at enlistment (farmer, artisan, laborer, and unknown with professional and proprietor as the omitted category), enlistment in a city of 50,000 or more (i.e., one of the 13 largest and thus deadliest cities in the US in 1860), born in the US, and wounded in the war. Ex-POWs were more likely to be urban, less likely to be farmers, and more likely to have enlisted earlier than non-POWs. Exchange ex-POWs had some of the pre-war characteristics of non-exchange ex-POWs (e.g., fraction enlisting in 1861) but more closely resembled non-POWs in other characteristics (e.g., fraction who were laborers). Because there may be unobserved differences between the Union Army sample and the Andersonville sample, I also control for whether the veteran was from the Union Army sample.

My controls for post-war differences between grandfathers are overweight circa 1900 and occupation in 1880 (farmer, professional or proprietor, artisan, laborer, no occupation, and not found in the census). Non-exchange ex-POWs were less likely to be farmers and were more likely to be artisans than non-POWs or exchange ex-POWs. I control for grandchildren's childhood socioeconomic status with years of education of each parent and dummy variables indicating if the father (the veteran's son or son-in-law) was ever a laborer, a farmer, or a property owner. Fathers were slightly less likely to have ever been farmers if their father or father-in-law was a non-exchange ex-POW.

I control for differences between grandchildren with age groups when BMI was measured (18–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, and 40–59), region of birth, the number of siblings, years of education, occupational group in 1940, dummy variables indicating whether the veteran grandfather ever lived in the same household as the grandchild and whether the living veteran grandfather ever was in the same county as the grandchild. The latter two variables could proxy for the grandfather's longevity, socioeconomic status or for a direct influence of the grandfather on the grandchild. As expected from how the sample was constructed, the sample was primarily a Northern sample.

## A.3 Veterans' BMI and Overweight

Table A.5 presents the odds ratios from a logit regression and the coefficients from an OLS regression where the dependent variables are, respectively, a dummy variable equal to one if the veteran was overweight and BMI. I estimate for veteran j

$$BMI_j = \beta_0 + \beta_1 P_{Ej} + \beta_2 P_{Nj} + \beta_3 C_j \tag{A.1}$$

$$\Pr(O_j = 1 \mid X) = \text{logit}^{-1}(\beta_0 + \beta_1 P_{Ej} + \beta_2 P_{Nj} + \beta_3 C_j), \tag{A.2}$$

where $P_{Nj}$ indicates non-exchange captivity, $P_{Ej}$ indicates exchange captivity (non-POW is the omitted category), and C represents a vector of controls. The controls are the veteran's age in 1900, his occupational class at enlistment, his year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are occupation in 1880, a dummy equal to one if the veteran owned less than $100 in personal property in 1870, and population density in 1880 county of residence.

Figure A.3 shows results from an OLS regression where the dependent variable is the veteran's BMI circa 1900 and his ex-POW status is interacted with age group when at risk of severe captivity (17–20,21–24, and 25+). That is, for veteran $j$

$$BMI_j = \beta_0 + \beta_1(A_j \times P_{Nj}) + \beta_2(A_j \times P_{Ej}) + \beta_3 C_j . \tag{A.3}$$

where $A_j$ represents the age groups, $P_{Nj}$ indicates non-exchange captivity, $P_{Ej}$ indicates exchange captivity (non-POW is the omitted category), and $C_j$ represents a vector of controls. The controls are the veteran's age in 1900, his occupational class at enlistment, his year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are occupation in 1880, a dummy equal to one if the veteran owned less than $100 in personal property in 1870, and population density in 1880 county of residence.

BMI differences between non-exchange ex-POWs and non-POWs are greatest among veterans at risk of non-exchange captivity between ages 17–24 and lowest among veterans at risk of non-exchange captivity after age 25; however, the differences were not statistically significant. The reductions in BMI differences between non-exchange ex-POWs and non-POWs at age 25+ are largely driven by veterans at risk of a harsh captivity above age 30, perhaps because only the healthiest POWs older than 30 survived the camps (Costa, 2012).

## A.4 Grandsons' BMI and Overweight

Figure A.1 shows that male-line grandsons descended from non-exchange ex-POWs were heavier than those descended from non-POWs but that there were no differences in height by grandpaternal ex-POW status. (Kolmogorov-Smirnov tests, given in the notes to Figure A.1, reveal a marginally statistically significant difference in the distribution of weights of grandsons descended from non-exchange ex-POWs compared to those descended from non-POWs and a statistically significant difference in the distribution of weights of grandsons descended from non-exchange ex-POWs compared to those descended from exchange ex-POWs.) There were no differences in weights by grandfathers' ex-POW status among female-line grandsons (see the figure notes for formal distributional tests).

Table A.6 presents results under different error term assumptions. The estimated BMI equations are

$$BMI_i = \beta_0 + \beta_1 M_i + \beta_2 P_{E,iV} + \beta_3 P_{N,iV} + \beta_4 (M_i \times P_{E,iV}) + \beta_5 (M_i \times P_{N,iV}) + \beta_6 C_{iV} + \beta_7 C_i + \epsilon_i, \tag{A.4}$$

where the individual error term $\epsilon_i$ is clustered on the veteran, and

$$BMI_i = \beta_0 + \beta_1 M_i + \beta_2 P_{E,iV} + \beta_3 P_{N,iV} + \beta_4 (M_i \times P_{E,iV}) + \beta_5 (M_i \times P_{N,iV}) + \beta_6 C_{iV} + \beta_7 C_i + u_{iV} + \epsilon_i, \tag{A.5}$$

where there is a random effect for the veteran but no clustering. Equation A.4 assumes that $u_{iV}$ is uncorrelated with the independent variables and that the $\epsilon_i$ are not iid. Equation A.5 assumes that the $\epsilon_i$ are iid. The estimated probit equations for overweight are

$$\Pr(O_i = 1 \mid X) = \Phi(\beta_0 + \beta_1 M_i + \beta_2 P_{E,iV} + \beta_3 P_{N,iV} + \beta_4 (M_i \times P_{E,iV}) + \beta_5 (M_i \times P_{N,iV}) + \beta_6 C_{iV} + \beta_7 C_i + \beta_8 C_i + u_{iV} + \epsilon_i), \tag{A.6}$$

where there is a random effect for the veteran but no clustering and

$$\Pr(O_i = 1 \mid X) = \Phi(\beta_0 + \beta_1 M_i + \beta_2 P_{E,iV} + \beta_3 P_{N,iV} + \beta_4 (M_i \times P_{E,iV}) + \beta_5 (M_i \times P_{N,iV}) + \beta_6 C_{iV} + \beta_7 C_i + \beta_8 C_i + \epsilon_i), \tag{A.7}$$

where there is no random effect but there is clustering.

Table A.7 presents estimates of Equations A.4, 1 and 2 which include dummies for the veteran's birth year and the grandsons' birth years. The estimates do not include post-war controls for the veterans and the grandsons because of collinearity.

Tables 1, A.6 and A.7 present sampling errors and thus are unrelated to the number of hypotheses which are tested. I do not present errors which are adjusted for multiple hypothesis testing because the number of hypotheses which are tested depends on the identification assumptions. For example, if differences in the female line are a control (as assumed by the differences in differences framework), then the only hypothesis which should be tested is whether the differences in differences (DD) estimate is zero. If the appropriate control group for non-exchange ex-POW descendants consists of non-POW descendants, then there is only one hypothesis. Given that p-values are presented and if acceptance is at the5% level of significance, the reader can adjust for the number of hypotheses of equality to zero by accepting only those hypotheses where the p-value is less than 0.05/(the number of hypotheses).

Table A.8 examines the relationship between grandsons' BMI and the grandfather's ex-POW status at the 25th, 50th, and 75th BMI quantiles. Estimates are from a quantile regression. To ensure convergence at all quantiles, I limit the number of post-war controls to a dummy variable indicating if the veteran was overweight circa 1900, the veteran's occupation in 1880, the number of siblings in the grandson's household, whether the veteran was living in the same county as the grandson, whether the grandson's father was ever a farmer, a laborer, or a property owner, parents' and own years of education, and whether the grandson was in a farm occupation in 1940.

Table A.9 presents results from OLS regressions where for grandson $i$

$$BMI_i = \beta_0 + \beta_1 P_{E,Vi} + \beta_2 P_{N,Vi} + \beta_4 C_i \tag{A.8}$$

$$BMI_i = \beta_0 + \beta_3 O_{Vi} + \beta_4 C_i \tag{A.9}$$

$$BMI_i = \beta_0 + \beta_1 P_{E,Vi} + \beta_2 P_{N,Vi} + \beta_3 O_{Vi} \beta_4 + C_i \tag{A.10}$$

where $O_{Vi}$ is a dummy variable indicating if the veteran was overweight. Estimates are from separate regressions for male- and female-line grandsons.

Figure A.2 plots the increase in BMI by the veteran age group when at risk of severe captivity. I divide veterans ages into those at risk of non-exchange captivity between ages 17–20, 21–24, and age 25+. I estimate OLS regressions for male-line and female-line grandsons, separately, where the dependent variable is BMI,

$$BMI_i = \beta_0 + \beta_1 (A_i \times P_{E,Vi}) + \beta_2 (A_i \times P_{N,Vi}) + \beta_3 C_i \,. \tag{A.11}$$

where $A_i$ represents the age groups, $P_N$ indicates non-exchange captivity, $P_E$ indicates exchange captivity (non-POW is the omitted category), and C represents a vector of controls. The controls are own age group, quarter and region of birth, the veteran grandfather's enlistment characteristics and his occupational class in 1880, the father's socioeconomic status, the parents' education, and own education and occupational class in 1940.

Figure A.2 shows that male-line grandsons were heavier if descended from non-exchange ex-POWs captive at ages 17–24 but not age 25+. Female-line grandsons were heavier only if descended from non-exchange ex-POW grandfathers captive at ages 25 or older. I cannot explain the pattern among female-line grandsons with socioeconomic factors given the full set of controls. The pattern is inconsistent with the absence of an ex-POW mortality effect among grandchildren from either male or female lines descended from veterans age 25 or older (Costa, 2021). Given that grandsons descended from veterans at risk of captivity after their growing years constitute a relatively small proportion of the data, I cannot exclude chance findings.

Table A.10 presents the odds ratios for male-line and female-line grandsons and differences in differences from logit regressions where the dependent variable is overweight. A random effects accounts for veteran effects.

## A.5 Grandsons' Obesity

Table A.11 presents the marginals from two ordered probit models examining BMI categories. The four BMI categories ($C_j$) are underweight ($\text{BMI} < 18.5$), normal ($18.5 \leq \text{BMI} < 25$), overweight ($25 \leq \text{BMI} < 30$), and obese ($\text{BMI} \geq 30$) where $j$ indexes the category. I separately estimate for male-line and female-line grandsons,

$$\Pr(\text{category}_j = i) = \Pr(\kappa_{i-1} < \beta_1 P_{E,iV} + \beta_2 P_{N,iV} + \beta_3 C_{iV} + \beta_4 C_i + \epsilon_i \leq \kappa_i) \quad \text{(A.12)}$$

where $\kappa_i$ represents one of 3 cutpoints and $\epsilon_i$ is assumed to be normally distributed and is clustered on the veteran. Because few grandsons were either underweight or obese, I limit the number of control variables.

Table A.11 shows that the grandfather's POW status affects both overweight and obesity of male-line grandsons but not of female-line grandsons. However, while the regression for male-line grandsons just satisfies the parallel lines assumption the regression for female-line grandsons does not.

## A.6 Grandsons' BMI and Later Mortality

Table A.12 shows that among grandsons descended from veterans at risk of being non-exchange ex-POWs after their growing years, there was no association between a grandfather's mortality and his non-exchange ex-POW relative to non-POW status. Controlling for post-war socioeconomic factors, a unit increase in BMI increased the odds of dying every year after age 45 by 1.03 for both male-line and female-line grandsons.

Table A.13 presents results from a formal mediation analysis using a counterfactual in which I treat whether a grandson was overweight as a mediator for the relationship between grandfather's ex-POW status and the grandson's longevity. I specify the grandson's expected longevity ($Y_i$) given the veteran's ex-POW status (the treatment, $D_i$), the mediator ($M_i$) indicating whether he was overweight, and controls ($C_i$) as

$$E[Y_i \mid D_i, M_i, C_i] = \theta_0 + \theta_1 D_i + \theta_2 M_i + \theta_3 (D_i \times M_i) + \theta_4 C_i \quad \text{(A.13)}$$

where

$$E[M_i \mid D_i, C_i] = \beta_0 + \beta_1 D_i + \beta_2 C_i \quad \text{(A.14)}$$

I estimate Equation A.13 using a Cox proportional hazards model and Equation A.14 using a logistic regression. I run separate equations for three grandfather treatments: 1) non-exchange ex-POW versus non-POW, 2) exchange ex-POW versus non-POW and 3) non-exchange versus exchange ex-POW. I then calculate the proportion of the total effect due to mediation with the grandson's overweight (natural indirect effect) and the mediated interaction, setting the values of the control variables to their means.[14] The identification assumption is that there are no unobserved confounders jointly influencing grandsons' longevity and overweight, i.e. no post-captivity confounders.

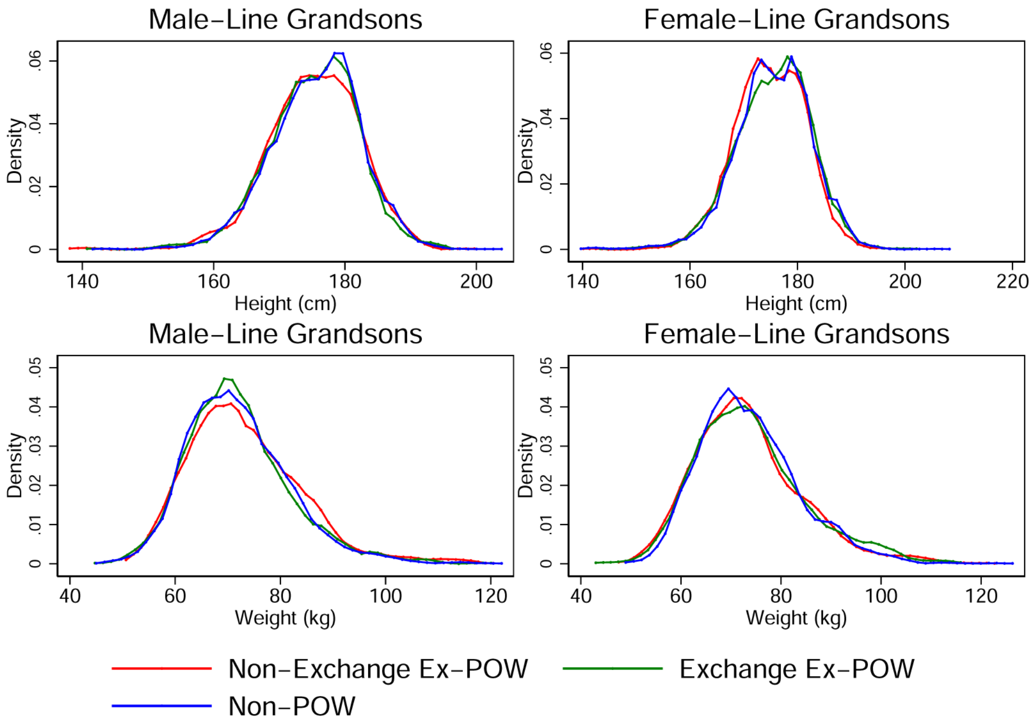


**Figure A.1: Density of Grandsons' Height and Weight by Grandfather's Ex-POW Status and Descent from Sons or Daughters**

The densities are estimated using an Epanechnikov kernel. Among male-line grandsons, the Kolmogorov-Smirnov test for equality of distributions of their heights yielded values of 0.027 ($p = 0.876$) when comparing non-exchange ex-POWs with non-POWs, of 0.038 ($p = 0.665$) when comparing non-exchange with exchange ex-POWs, and of 0.031 ($p = 0.716$) when comparing exchange ex-POWs with non-POWs. The respective tests for the weight distributions were 0.056 ($p = 0.092$), 0.074 ($p = 0.038$), and 0.021 ($p = 0.975$). Among female-line grandsons the respective tests for heights were 0.056 ($p = 0.071$), 0.043 ($p = 0.438$), and 0.033 ($p = 0.620$) and for weights 0.039 ($p = 0.369$), 0.029 ($p = 0.886$), and 0.030 ($p = 0.753$).

[14]See the discussions by Celli (2021) and Belloco (2021).

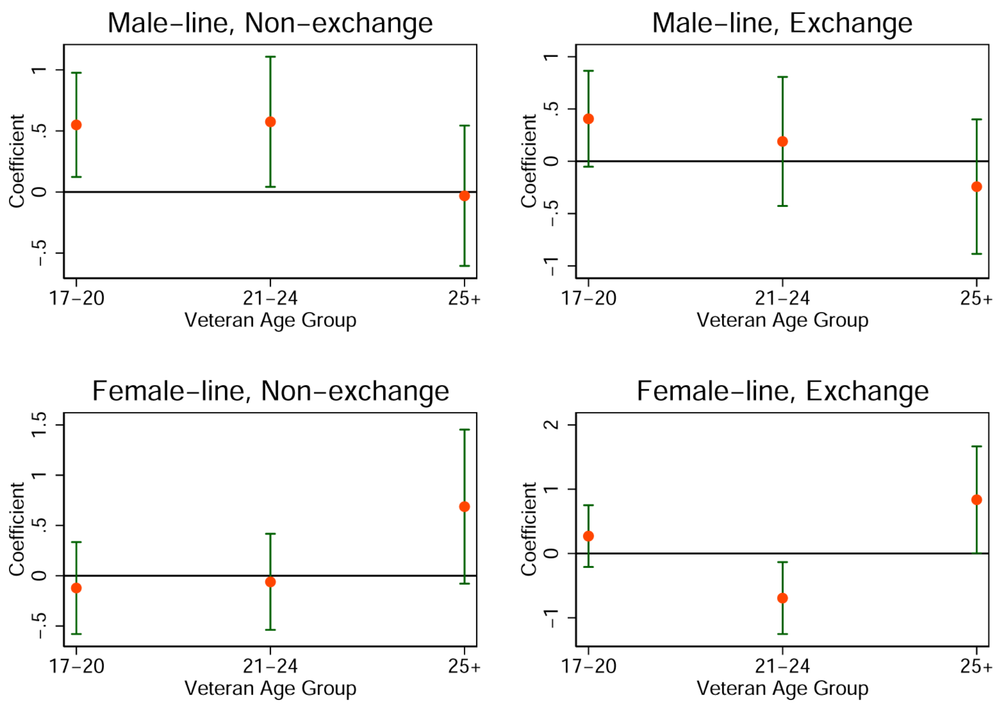


**Figure A.2: Grandfather's Age When at Risk of Non-Exchange Captivity and Male-Line Grandsons' Increase in** BMI

Coefficients are estimated from an OLS regression where the dependent variable is the veteran's BMI (see Equation A.3. The controls are own age group, quarter and region of birth, the veteran grandfather's enlistment characteristics and his occupational class in 1880, the father's socioeconomic status, the parents' education, and own education and occupational class in 1940. Standard errors were clustered on the veteran.

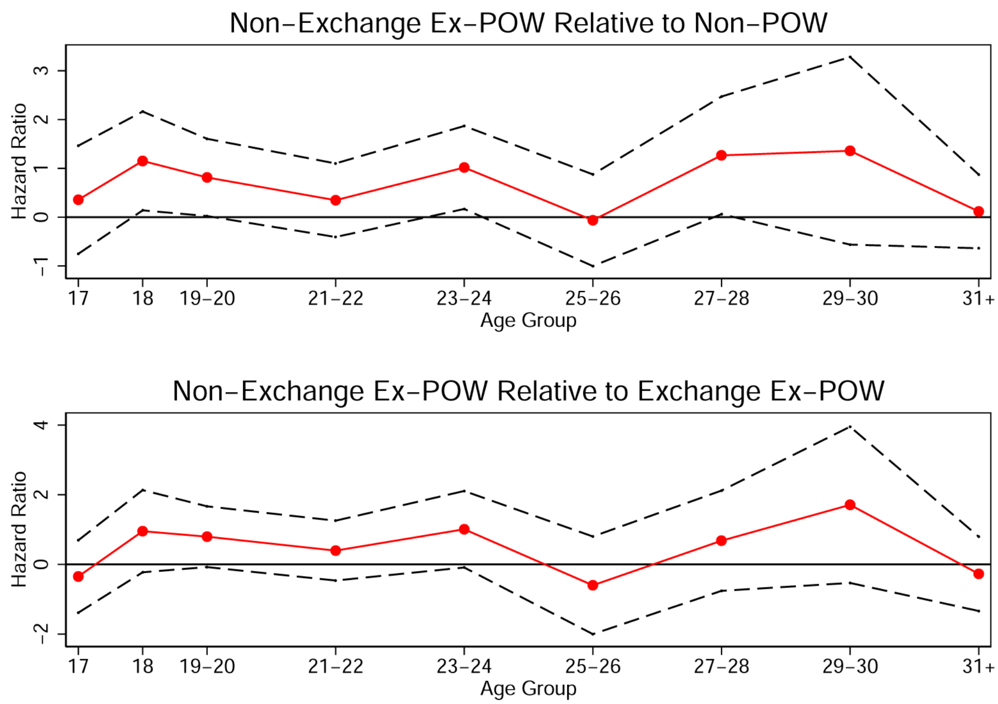


**Figure A.3: Veterans' Ages When at Risk of Non-Exchange Captivity and Their Increase in BMI**

Increases in BMI are estimated from an OLS regression where the dependent variable is the veteran's BMI circa 1900. Controls include the veteran's age in 1900, his occupational class at enlistment, his year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are occupation in 1880, a dummy equal to one if the veteran owned less than$100 in personal property in 1870, and population density in 1880 county of residence.

**Table A.1:**

Linkage Rates by Descent

| | Veteran Grandfather's Status | | | |
|---|---|---|---|---|
| | **Non-POW** | **Exchange Ex-POW** | **Non-Exchange Ex-POW** | **All** |
| Linkage rate to draft cards | | | | |
| Male-line grandsons | 98.7 | 99.1 | 99.1 | 98.9 |
| Female-line grandsons | 98.4 | 99.0 | 98.4 | 98.6 |
| Linkage and useable height and weight information | | | | |
| Male-line grandsons | 97.6 | 98.5 | 98.4 | 98 |
| Female-line grandsons | 97.5 | 97.9 | 97.3 | 97.5 |

All grandsons were alive in 1940 and born between 1877 and 1929 (inclusive).

## Table A.2:

Mean BMI by Age Group

| Age | National Sample | Union Army Grandsons | |
|---|---|---|---|
| | | All | Non-POW Descendant |
| 18–19 | 21.823 | 21.948 | 21.943 |
| 20–24 | 22.595 | 22.646 | 22.636 |
| 25–29 | 23.509 | 23.176 | 23.153 |
| 30–34 | 23.974 | 23.792 | 23.676 |
| 35–37 | 24.216 | 24.008 | 23.788 |
| 38–44 | | 24.510 | 24.478 |
| 45–59 | | 24.977 | 24.982 |

National BMI is calculated from Karpinos (1958) and is for white selective service registrants who were examined and measured. BMI for the grandson sample is calculated from self-reported height and weight.

## Table A.3:

Variable Means, Grandsons

| | All Veterans | | | Veterans at Risk at Ages 17–24 | | |
|---|---|---|---|---|---|---|
| | Veteran Grandfather's Status | | | Veteran Grandfather's Status | | |
| | Non-POW | Exchange Ex-POW | Non-Exchange Ex-POW | Non-POW | Exchange Ex-POW | Non-Exchange Ex-POW |
| Birth year | 1907.40 | 1907.49 | 1907.53 | 1908.10 | 1907.74 | 1907.88 |
| Death year | 1979.56 | 1979.63 | 1979.51 | 1980.37 | 1979.62 | 1979.87 |
| Age height and weight was reported | 33.66 | 33.63 | 33.60 | 32.92 | 33.37 | 33.26 |
| BMI | 23.65 | 23.72 | 23.92 | 23.57 | 23.71 | 23.85 |
| Fraction underweight | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Fraction normal weight | 0.71 | 0.69 | 0.66 | 0.72 | 0.70 | 0.68 |
| Fraction overweight, not obese | 0.25 | 0.26 | 0.28 | 0.24 | 0.25 | 0.28 |
| Fraction obese | 0.03 | 0.04 | 0.05 | 0.03 | 0.04 | 0.04 |
| Height (inches) | 69.15 | 69.07 | 68.94 | 69.19 | 69.03 | 69.01 |
| Weight (pounds) | 160.87 | 161.10 | 161.82 | 160.54 | 160.76 | 161.65 |
| Years of education | 9.49 | 9.49 | 9.69 | 9.59 | 9.40 | 9.68 |
| Years of education of wife | 9.97 | 9.90 | 10.14 | 10.07 | 9.92 | 10.19 |
| Years lived | 72.16 | 72.14 | 71.98 | 72.27 | 71.88 | 71.99 |
| Number of siblings | 4.49 | 4.61 | 4.53 | 4.44 | 4.65 | 4.54 |
| Veteran living in the same county | 0.35 | 0.35 | 0.30 | 0.36 | 0.36 | 0.30 |
| Veteran living in the same household | 0.03 | 0.04 | 0.03 | 0.03 | 0.05 | 0.03 |
| Born in | | | | | | |

| | All Veterans | | | Veterans at Risk at Ages 17–24 | | |
|---|---|---|---|---|---|---|
| | Veteran Grandfather's Status | | | Veteran Grandfather's Status | | |
| | Non-POW | Exchange Ex-POW | Non-Exchange Ex-POW | Non-POW | Exchange Ex-POW | Non-Exchange Ex-POW |
| New England | 0.02 | 0.02 | 0.06 | 0.03 | 0.02 | 0.05 |
| Mid-Atlantic | 0.15 | 0.11 | 0.23 | 0.15 | 0.11 | 0.24 |
| East North Central | 0.32 | 0.29 | 0.30 | 0.31 | 0.30 | 0.28 |
| West North Central | 0.31 | 0.36 | 0.26 | 0.30 | 0.37 | 0.26 |
| Border | 0.11 | 0.13 | 0.07 | 0.10 | 0.12 | 0.07 |
| Other | 0.10 | 0.09 | 0.08 | 0.11 | 0.07 | 0.09 |
| Occupation in 1940 | | | | | | |
| Professional and technical | 0.04 | 0.05 | 0.05 | 0.04 | 0.04 | 0.05 |
| Farmer | 0.10 | 0.12 | 0.09 | 0.10 | 0.11 | 0.09 |
| Managers, officials and proprietors | 0.05 | 0.06 | 0.06 | 0.05 | 0.06 | 0.06 |
| Clerical and kindred and sales | 0.09 | 0.08 | 0.10 | 0.09 | 0.07 | 0.10 |
| Craftsmen | 0.13 | 0.13 | 0.13 | 0.12 | 0.13 | 0.13 |
| Operatives and service workers | 0.19 | 0.18 | 0.18 | 0.19 | 0.18 | 0.17 |
| Farm laborers | 0.06 | 0.06 | 0.05 | 0.06 | 0.07 | 0.05 |
| Laborers | 0.10 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 |
| Non-occupation or unclassifiable | 0.24 | 0.23 | 0.24 | 0.25 | 0.24 | 0.25 |
| Number of grandsons | 4,333 | 2,108 | 1,922 | 3,154 | 1,531 | 1,540 |

## Table A.4:

Variable Means, Veteran Grandfathers and Parents

| | All Veterans | | | Veterans at Risk at Ages 17–24 | | |
|---|---|---|---|---|---|---|
| | Veteran Grandfather's Status | | | Veteran Grandfather's Status | | |
| | Non-POW | Exchange Ex-POW | Non-Exchange Ex-POW | Non-POW | Exchange Ex-POW | Non-Exchange Ex-POW |
| Veteran grandfathers' characteristics | | | | | | |
| BMI circa 1900 | 22.60 | 22.97 | 23.35 | 22.74 | 22.72 | 23.14 |
| Fraction who were | | | | | | |
| Overweight | 0.23 | 0.27 | 0.29 | 0.24 | 0.24 | 0.28 |
| US-born | 0.86 | 0.85 | 0.83 | 0.86 | 0.85 | 0.86 |
| Enlistees in city with 50,000+ people | 0.03 | 0.04 | 0.04 | 0.03 | 0.05 | 0.04 |
| Wounded | 0.33 | 0.35 | 0.28 | 0.34 | 0.37 | 0.29 |

| | All Veterans | | | Veterans at Risk at Ages 17–24 | | |
|---|---|---|---|---|---|---|
| | Veteran Grandfather's Status | | | Veteran Grandfather's Status | | |
| | Non-POW | Exchange Ex-POW | Non-Exchange Ex-POW | Non-POW | Exchange Ex-POW | Non-Exchange Ex-POW |
| Year of enlistment | 1862.19 | 1861.89 | 1861.73 | 1862.14 | 1861.79 | 1861.73 |
| Veterans' occupations at enlistment | | | | | | |
| Farmer | 0.70 | 0.72 | 0.64 | 0.71 | 0.72 | 0.64 |
| Professional/ proprietor | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 |
| Artisan | 0.11 | 0.11 | 0.11 | 0.10 | 0.09 | 0.11 |
| Laborer | 0.15 | 0.12 | 0.21 | 0.15 | 0.13 | 0.21 |
| Unknown | 0.02 | 0.04 | 0.02 | 0.02 | 0.05 | 0.03 |
| Veterans' occupations in 1880 | | | | | | |
| Farmer | 0.59 | 0.65 | 0.50 | 0.58 | 0.63 | 0.48 |
| Professional/ proprietor | 0.04 | 0.04 | 0.05 | 0.05 | 0.04 | 0.06 |
| Artisan | 0.09 | 0.09 | 0.14 | 0.07 | 0.08 | 0.14 |
| Laborer | 0.21 | 0.18 | 0.26 | 0.23 | 0.21 | 0.27 |
| No occupation | 0.03 | 0.01 | 0.02 | 0.04 | 0.01 | 0.02 |
| Grandsons' fathers were | | | | | | |
| Ever farmers | 0.53 | 0.54 | 0.48 | 0.52 | 0.55 | 0.47 |
| Ever laborers | 0.45 | 0.44 | 0.47 | 0.47 | 0.44 | 0.47 |
| Ever owners | 0.70 | 0.71 | 0.68 | 0.69 | 0.71 | 0.67 |
| Years of education of | | | | | | |
| Grandsons' fathers | 7.35 | 7.71 | 7.73 | 7.49 | 7.67 | 7.73 |
| Grandsons' mothers | 7.86 | 8.01 | 8.04 | 7.95 | 8.15 | 8.07 |
| Number of grandsons | 4,333 | 2,108 | 1,922 | 3,154 | 1,531 | 1,540 |

## Table A.5:

Veterans' Overweight and BMI and Ex-POW Status

| Dependent Variable: | Overweight | | BMI c. 1900 | |
|---|---|---|---|---|
| | Odds Ratio | Odds Ratio | Coeficient | Coeficient |
| Veteran was | | | | |
| Exchange Ex-POW Relative to Non-POW | 1.236 (0.186) [0.159] | 1.238 (0.184) [0.152] | −0.019 (0.216) [0.931] | −0.016 (0.213) [0.942] |
| Non-exchange Ex-POW Relative to Non-POW | 1.774*** (0.268) [0.000] | 1.756*** (0.266) [0.000] | 0.716*** (0.253) [0.005] | 0.695*** (0.251) [0.006] |
| Non-exchange Relative to Exchange Ex-POW | 1.436** (0.234) [0.027] | 1.419** (0.232) [0.033] | 0.735*** (0.240) [0.002] | 0.710*** (0.238) [0.003] |
| Post-war socioeconomic characteristics | N | Y | N | Y |

Estimated from Equations A.1 and A.2. 3,274 observations. Standard errors are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the veteran's age in 1900, his occupational class at enlistment, his year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are occupation in 1880, a dummy equal to one if the veteran owned less than $100 in personal property in 1870, and population density in 1880 county of residence.

**Table A.6:**

Grandsons' BMI and Overweight (Average Marginal Effects) and Ex-POW Status Under Different Error Assumptions

| | Male-line | | | | Female-line | | | |
|---|---|---|---|---|---|---|---|---|
| | BMI | BMI | Over-weight | Over-weight | BMI | BMI | Over-weight | Over-weight |
| Exchange Ex-POW Relative to Non-POW | 0.082<br>(0.171)<br>[0.630] | 0.115<br>(0.170)<br>[0.500] | 0.012<br>(0.042)<br>[0.764] | 0.009<br>(0.042)<br>[0.829] | 0.113<br>(0.178)<br>[0.529] | 0.114<br>(0.169)<br>[0.501] | 0.032<br>(0.044)<br>[0.468] | 0.028<br>(0.044)<br>[0.525] |
| Non-exchange Ex-POW Relative to Non-POW | 0.408**<br>(0.179)<br>[0.023] | 0.433**<br>(0.171)<br>[0.011] | 0.091**<br>(0.045)<br>[0.042] | 0.090**<br>(0.044)<br>[0.042] | 0.015<br>(0.178)<br>[0.931] | −0.007<br>(0.167)<br>[0.966] | 0.035<br>(0.042)<br>[0.405] | 0.028<br>(0.042)<br>[0.503] |
| Non-exchange Relative to Exchange Ex-POW | 0.326*<br>(0.189)<br>[0.085] | 0.318*<br>(0.178)<br>[0.074] | 0.078*<br>(0.045)<br>[0.082] | 0.081*<br>(0.045)<br>[0.074] | −0.097<br>(0.192)<br>[0.614] | −0.121<br>(0.173)<br>[0.485] | 0.003<br>(0.044)<br>[0.942] | 0.000<br>(0.044)<br>[1.000] |
| DD Exchange Ex-POW Relative to Non-POW | −0.030<br>(0.215)<br>[0.889] | 0.001<br>(0.179)<br>[0.996] | 0.017<br>(0.037)<br>[0.646] | 0.019<br>(0.038)<br>[0.625] | | | | |
| DD Non-exchange Ex-POW Relative to Non-POW | 0.393*<br>(0.210)<br>[0.062] | 0.440**<br>(0.178)<br>[0.014] | 0.056*<br>(0.031)<br>[0.070] | 0.062**<br>(0.030)<br>[0.042] | | | | |
| DD Non-exchange Relative to Exchange Ex-POW | 0.423*<br>(0.255)<br>[0.097] | 0.439**<br>(0.208)<br>[0.035] | 0.075**<br>(0.035)<br>[0.033] | 0.081**<br>(0.035)<br>[0.020] | | | | |
| R-squared | | | | | | | | |
| Within | | 0.076 | | | | | | |
| Between | | 0.157 | | | | | | |
| Overall | 0.100 | 0.099 | | | | | | |
| Test var(u)=0, chibar2(01) | | 181.55<br>[0.000] | | | | | | |
| Random effects? | N | Y | N | Y | N | Y | N | Y |
| Clustering? | Y | N | Y | N | Y | N | Y | N |

Estimated using Equations A.4, A.5, A.6, and A.7. DD=double difference. 6,225 observations. Standard errors are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample.

**Table A.7:**

Grandsons' BMI and Overweight (Average Marginal Effects) and Ex-POW Status, Controlling for Birth Year Effects

| | Male-line | | | Female-line | | |
|---|---|---|---|---|---|---|
| | **BMI** | **BMI** | **Overweight** | **BMI** | **BMI** | **Overweight** |
| Exchange Ex-POW Relative to Non-POW | 0.085 (0.174) [0.626] | 0.137 (0.173) [0.430] | 0.003 (0.086) [0.968] | 0.133 (0.179) [0.456] | 0.137 (0.180) [0.445] | 0.064 (0.084) [0.441] |
| Non-exchange Ex-POW Relative to Non-POW | 0.479*** (0.177) [0.007] | 0.511*** (0.180) [0.005] | 0.233*** (0.087) [0.008] | 0.056 (0.177) [0.753] | 0.038 (0.178) [0.829] | 0.003 (0.080) [0.965] |
| Non-exchange Relative to Exchange Ex-POW | 0.395** (0.192) [0.040] | 0.374** (0.190) [0.049] | 0.230** (0.094) [0.015] | −0.077 (0.193) [0.689] | −0.099 (0.192) [0.606] | −0.061 (0.087) [0.484] |
| DD Exchange Ex-POW Relative to Non-POW | −0.049 (0.216) [0.822] | −0.001 (0.217) [0.997] | −0.061 (0.101) [0.545] | | | |
| DD Non-exchange Ex-POW Relative to Non-POW | 0.423** (0.208) [0.043] | 0.473** (0.206) [0.022] | 0.230** (0.100) [0.022] | | | |
| DD Non-exchange Relative to Exchange Ex-POW | 0.472* (0.255) [0.065] | 0.474* (0.251) [0.059] | 0.291** (0.116) [0.012] | | | |
| R-squared | | | | | | |
| Within | | 0.085 | | | | |
| Between | | 0.176 | | | | |
| Overall | 0.111 | 0.110 | | | | |
| Test var(u)=0, chibar2(01) | | 171.92 [0.000] | | | | |
| Random effects? | N | Y | Y | N | Y | Y |

Estimated using Equations A.4, 1, and 2. DD=double difference. 6,225 observations. Standard errors, clustered on the veteran, are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. All equations include dummy variables for the single birth year of the veteran and of the grandson. Additional controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample.

**Table A.8:**

Grandsons' BMI and Grandfathers' Ex-POW Status at Different Quantiles

| | Male-line Quantile | | | Female-line Quantile | | |
|---|---|---|---|---|---|---|
| | **25** | **50** | **75** | **25** | **50** | **75** |
| Grandfather was | | | | | | |
| Exchange Ex-POW Relative to Non-POW | 0.169 (0.168) [0.316] | 0.340* (0.195) [0.081] | 0.524** (0.257) [0.042] | −0.088 (0.190) [0.645] | −0.072 (0.223) [0.746] | −0.016 (0.026) [0.541] |
| Non-exchange Ex-POW Relative to Non-POW | 0.287* (0.152) [0.060] | 0.287 (0.187) [0.124] | 0.685** (0.253) [0.007] | −0.183 (0.177) [0.302] | −0.173 (0.187) [0.355] | 0.004 (0.024) [0.857] |

| | Male-line Quantile | | | Female-line Quantile | | |
|---|---|---|---|---|---|---|
| | 25 | 50 | 75 | 25 | 50 | 75 |
| DD Exchange Ex-POW Relative to Non-POW | 0.264 (0.235) [0.262] | 0.441 (0.300) [0.142] | 0.369 (0.364) [0.311] | | | |
| DD Non-exchange Ex-POW Relative to Non-POW | 0.470** (0.208) [0.024] | 0.460** (0.225) [0.041] | 0.540** (0.275) [0.049] | | | |

Estimated using quantile regressions. DD=double difference. 6,225 observations. Standard errors, clustered on the veteran, are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are a dummy variable indicating if the veteran was overweight circa 1900, the veteran's occupation in 1880, the number of siblings in the grandson's household, whether the veteran was living in the same county as the grandson, whether the grandson's father was ever a farmer, a laborer, or a property owner, parents' and own years of education, and whether the grandson was in a farm occupation in 1940.

## Table A.9:

Grandsons' BMI and Grandfathers' Overweight and Ex-POW Status

| | Male-line Grandsons | | | | Female-line Grandsons | | | |
|---|---|---|---|---|---|---|---|---|
| Grandfather was | | | | | | | | |
| Exchange Ex-POW Relative to Non-POW | 0.169 (0.190) [0.373] | | 0.165 (0.186) [0.375] | 0.161 (0.178) [0.366] | 0.051 (0.192) [0.790] | | 0.002 (0.191) [0.990] | 0.012 (0.192) [0.952] |
| Non-exchange Ex-POW Relative to Non-POW | 0.496** (0.193) [0.010] | | 0.477** (0.188) [0.011] | 0.490*** (0.186) [0.009] | −0.054 (0.197) [0.784] | | −0.128 (0.191) [0.503] | −0.144 (0.190) [0.448] |
| Veteran was overweight | | 0.558*** (0.168) [0.001] | 0.542*** (0.167) [0.001] | 0.534*** (0.163) [0.001] | | 0.680*** (0.178) [0.000] | 0.692*** (0.178) [0.000] | 0.692*** (0.180) [0.000] |
| Post-war controls | N | N | N | Y | N | N | N | Y |

3,048 male-line grandsons and 3,177 female-line grandsons. Estimates were done separately for male-line and female-line grandsons using Equation A.8. Standard errors, clustered on the veteran, are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are the veteran's occupation in 1880, the number of siblings in the grandson's household, whether the veteran was living in the same county as the grandson, whether the veteran was in the same household as the grandson, whether the grandson's father was ever a farmer, a laborer, or a property owner, parents' and own years of education, and occupational class in 1940.

## Table A.10:

Male-line Grandsons' Overweight and Grandfathers' Ex-POW Status, Odds Ratios

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Grandfather was | | | | |

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Exchange Ex-POW Relative to Non-POW | 0.987 (0.146) [0.931] | 1.007 (0.143) [0.961] | 1.101 (0.154) [0.490] | 1.075 (0.150) [0.603] |
| Non-exchange Ex-POW Relative to Non-POW | 1.436** (0.212) [0.014] | 1.423** (0.205) [0.014] | 0.990 (0.132) [0.942] | 0.944 (0.127) [0.668] |
| Non-exchange Relative to Exchange Ex-POW | 1.454** (0.228) [0.017] | 1.413** (0.216) [0.024] | 0.899 (0.129) [0.460] | 0.878 (0.125) [0.362] |
| DD Exchange Ex-POW Relative to Non-POW | 0.896 (0.152) [0.519] | 0.937 (0.158) [0.698] | | |
| DD Non-exchange Ex-POW Relative to Non-POW | 1.450** (0.245) [0.028] | 1.508** (0.254) [0.015] | | |
| DD Non-exchange Relative to Exchange Ex-POW | 1.617** (0.314) [0.013] | 1.610** (0.310) [0.013] | | |
| Post-War Controls | N | Y | N | N |

Random effects estimates. 6,225 observations. Standard errors, clustered on the veteran, are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are a dummy variable indicating if the veteran was overweight circa 1900, the veteran's occupation in 1880, the number of siblings in the grandson's household, whether the veteran was living in the same county as the grandson, whether the veteran was in the same household as the grandson, whether the grandson's father was ever a farmer, a laborer, or a property owner, parents' and own years of education, and occupational class in 1940.

## Table A.11:

Grandsons' BMI Categories (Average Marginal Effects) and Grandfathers' Ex-POW Status

| | Male-line Grandsons | | | | Female-line Grandsons | | | |
|---|---|---|---|---|---|---|---|---|
| | Underweight | Normal Weight | Overweight | Obese | Underweight | Normal Weight | Overweight | Obese |
| Veteran grandfather was | | | | | | | | |
| Exchange Ex-POW relative to Non-POW | −0.003 (0.003) [0.293] | −0.022 (0.021) [0.301] | 0.020 (0.019) [0.298] | 0.005 (0.005) [0.306] | 0.000 (0.001) [0.804] | 0.006 (0.026) [0.801] | −0.005 (0.020) [0.801] | −0.002 (0.006) [0.801] |
| Non-exchange Ex-POW relative to Non-POW | −0.008*** (0.003) [0.002] | −0.073*** (0.023) [0.002] | 0.062*** (0.019) [0.001] | 0.019*** (0.006) [0.003] | 0.000 (0.001) [0.840] | 0.005 (0.025) [0.839] | −0.004 (0.020) [0.839] | −0.001 (0.006) [0.838] |
| Non-exchange Ex-POW relative to Exchange Ex-POW | −0.005** (0.002) [0.035] | −0.051** (0.023) [0.026] | 0.042** (0.019) [0.026] | 0.013** (0.006) [0.030] | −0.000 (0.001) [0.957] | −0.001 (0.025) [0.957] | 0.001 (0.020) [0.957] | −0.000 (0.006) [0.957] |
| LR test equality of coefficients | | | | | | | | |
| chi2(40) | 50.65 | | | | 85.4 | | | |
| Prob ¿ chi2 | [0.121] | | | | [0.000] | | | |

| | Male-line Grandsons | | | | Female-line Grandsons | | | |
|---|---|---|---|---|---|---|---|---|
| | **Underweight** | **Normal Weight** | **Overweight** | **Obese** | **Underweight** | **Normal Weight** | **Overweight** | **Obese** |
| Observations | 3,048 | 3,048 | 3,048 | 3,048 | 3,177 | 3,177 | 3,177 | 3,177 |

Estimated using ordered probits (see Equation A.12). Standard errors, clustered on the veteran, are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include birth year, the age group when height and weight were reported, quarter of birth, whether the veteran was a farmer at enlistment, and whether the veteran was US-born. The respective definitions of underweight, normal weight, overweight, and obese are: BMI < 18.5, 18.5 ≤ BMI < 25, 25 ≤ BMI < 30, and BMI ≥ 30.

## Table A.12:

Grandsons' Mortality After Age 45 (Hazard Ratios) and Their Overweight and Grandfathers' Ex-POW Status, Descendants of Grandfathers at Risk After Their Growing Years

| | **Male-line Grandsons** | | | | **Female-line Grandsons** | | | |
|---|---|---|---|---|---|---|---|---|
| Grandfather was | | | | | | | | |
| Non-POW | | 1.000 | 1.000 | 1.000 | | 1.000 | 1.000 | 1.000 |
| Exchange Ex-POW | | 0.805** <br> (0.082) <br> [0.033] | 0.796** <br> (0.082) <br> [0.027] | 0.759*** <br> (0.073) <br> [0.004] | | 1.063 <br> (0.115) <br> [0.574] | 1.066 <br> (0.116) <br> [0.553] | 1.016 <br> (0.118) <br> [0.893] |
| Non-exchange Ex-POW | | 0.940 <br> (0.097) <br> [0.552] | 0.936 <br> (0.096) <br> [0.519] | 1.005 <br> (0.101) <br> [0.964] | | 1.095 <br> (0.139) <br> [0.476] | 1.070 <br> (0.138) <br> [0.601] | 1.066 <br> (0.152) <br> [0.656] |
| Non-exchange Ex-POW relative to Exchange Ex-POW | | 1.168 <br> (0.134) <br> [0.175] | 1.176 <br> (0.136) <br> [0.162] | 1.324** <br> (0.152) <br> [0.014] | | 1.030 <br> (0.124) <br> [0.807] | 1.003 <br> (0.123) <br> [0.981] | 1.049 <br> (0.141) <br> [0.807] |
| Grandson's BMI | 1.019 <br> (0.013) <br> [0.143] | | 1.021 <br> (0.013) <br> [0.107] | 1.030** <br> (0.014) <br> [0.025] | 1.025* <br> (0.015) <br> [0.085] | | 1.025* <br> (0.015) <br> [0.094] | 1.027* <br> (0.016) <br> [0.093] |
| Test of proportional hazards | 37.18 | 32.68 | 33.30 | 62.96 | 38.16 | 39.98 | 40.53 | 81.86 |
| assumption, df= | 30 [0.172] | 31 [0.385] | 32 [0.404] | 60 [0.372] | 30 [0.146] | 31 [0.129] | 32 [0.143] | 60 [0.032] |
| Post-war controls | N | N | N | Y | N | N | N | Y |

Estimated using Equation 5. 794 male-line grandsons and 685 female-line grandsons. Standard errors, clustered on the veteran, are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are a dummy variable indicating if the veteran was overweight circa 1900, the veteran's occupation in 1880, the number of siblings in the grandson's household, whether the veteran was living in the same county as the grandson, whether the veteran was in the same household as the grandson, whether the grandson's father was ever a farmer, a laborer, or a property owner, parents' and own years of education, and occupational class in 1940.

**Table A.13:**

Mediation of Grandfathers' Ex-POW Status and Male-line Grandsons' Mortality by Grandsons' BMI

| — | Coefficient | Std. Err. | P-value |
|---|---|---|---|
| Grandfather was non-exchange ex-POW relative to non-POW | | | |
| Total effect | 0.219** | 0.088 | 0.013 |
| Controlled direct effect | 0.189** | 0.088 | 0.032 |
| Interaction only | −0.005 | 0.013 | 0.718 |
| Mediated interaction only | 0.005 | 0.019 | 0.773 |
| Pure indirect effect | 0.030** | 0.013 | 0.019 |
| Grandfather was exchange ex-POW relative to non-POW | | | |
| Total effect | 0.269*** | 0.092 | 0.003 |
| Controlled direct effect | 0.254*** | 0.093 | 0.006 |
| Interaction only | 0.010 | 0.014 | 0.472 |
| Mediated interaction only | −0.005 | 0.007 | 0.474 |
| Pure indirect effect | 0.010 | 0.008 | 0.207 |
| Grandfather was non-exchange relative to exchange ex-POW | | | |
| Total effect | 0.083 | 0.070 | 0.235 |
| Controlled direct effect | 0.089 | 0.070 | 0.206 |
| Interaction only | −0.021 | 0.016 | 0.185 |
| Mediated interaction only | 0.014 | 0.012 | 0.231 |
| Pure indirect effect | 0.000 | 0.007 | 0.944 |

Estimated from Equations A.13 and A.14. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are a dummy variable indicating if the veteran was overweight circa 1900, the veteran's occupation in 1880, the number of siblings in the grandson's household, whether the veteran was living in the same county as the grandson, whether the veteran was in the same household as the grandson, whether the grandson's father was ever a farmer, a laborer, or a property owner, parents' and own years of education, and occupational class in 1940.

## References

Abeelen Annet F.M. van, Elias Sjoerd G., Roseboom Tessa J., Bossuyt Patrick M.M., van der Schouw Yvonne T., Grobbee Diederick E., and Uiterwaal Cuno S.P.M. (2012) "Postnatal Acute Famine and Risk of Overweight: The Dutch Hungerwinter Study," International Journal of Pediatrics, doi:10.1155/2012/936509.

Almond Douglas (2006) "Is the 1918 influenza pandemic over? Long-term effects of in utero influenza exposure in the post-1940 US population," Journal of Political Economy, 114 (4), 672–712.

Baker Samuel, Biroli Pietro, von Kippersluis Hans, and von Hinke Kessler Scholder Stephanie (2022) "Beyond Barker: Infant Mortality at Birth and Ischaemic Heart Disease in Older Age," IZA Discussion Paper no. 15291.

Barker DJP (1992) Fetal and Infant Origins of Adult Disease, London: British Medical Publishing Group

—— (1994) Mothers, Babies, and Disease in Later Life, London: British Medical Publishing Group.

Baxter Faye A. and Drake Amanda J. (2019) "Non-genetic inheritance via the male germline in mammals," Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 374, 20180118. [PubMed: 30966887]

Behrman Jere R. and Rosenzweig Mark (2001) "The Returns to Increasing Body Weight," SSRN Working Paper No. 297919, Febuary, Available at SSRN: https://ssrn.com/abstract=297919.

Belloco Rino (2021) "Mediation analysis in Stata: a short look at med4way," https:/www.stata.com/symposiums/biostatistics-and-epidemiology21/slides/Bio21_Bellocco.pdf.

van den Berg Gerard J., von Hinke Stephanie, and Wang R. Adele H. (2022) "Prenatal Sugar Consumption and Late-Life Human Capital and Health: Analyses Based on Postwar Rationing and Polygenic Scores," IZA Discussion Paper no. 15544.

van den Berg GJ and Pinger PR (2016) "Transgenerational effects of childhood conditions on third generation health and education outcomes," Economics and Human Biology, 23 (Dec), 219–229.

Bernal AJ, Dolinoy DC, Huang D, Skaar DA, Weinhouse C, and Jirtle RL (2013) "Adaptive radiation-induced epigenetic alterations mitigated by antioxidants," FASEB J, 27 (2), 665–71. [PubMed: 23118028]

Bygren Lars Olav, Kaati G, and Edvinsson S (2001) "Longevity determined by paternal ancestors' nutrition during their slow growth period," Acta Biotheor, 49 (1), 53–9. [PubMed: 11368478]

Bygren Lars Olov (2013) "Intergenerational Health Responses to Adverse and Enriched Environments," Annual Review of Public Health, 34 (1), 49–60.

Bygren Lars Olov, Tinghöf Petter, Carstensen John, Edvinsson Sören, Kaati Gunnar, Pembrey Marcus, and Sjöström Michael (2014) "Change in paternal grandmothers' early food supply influenced cardiovascular mortality of the female grandchildren," BMC Genomic Data, 15 (12).

Cawley John and Chad Meyerhoefer (2012) "The medical care costs of obesity: An instrumental variables approach," Journal of Health Economics, 31 (1), 219–30. [PubMed: 22094013]

Celli Viviana (2021) "Causal mediation analysis in economics: Objectives, assumptions, models," Journal of Economic Surveys, https:/onlinelibrary.wiley.com/doi/abs/10.1111/joes.12452.

Conti Gabriella, Poupakis Stavros, Ekamper Peter, Bijwaard Govert, and Lumey Lambert H. (2021) "Severe Prenatal Shocks and Adolescent Health: Evidence from the Dutch Hunger Winter," IZA Institute of Labor Studies Discussion Paper No. 14789, October.

Cook C. Justin, Fletcher Jason M., and Forgues Angela (2019) "Multigenerational Effects of Early-Life Health Shocks," Demography, 56 (5), 1855–1874. [PubMed: 31359286]

Corsi Daniel J. and Subramanian SV (2019) "Socioeconomic Gradients and Distribution of Diabetes, Hypertension, and Obesity in India," JAMA Network Open, 2.

Costa Dora (2015) "Health and the Economy in the United States from 1750 to the Present," Journal of Economic Literature, 53 (3), 503–70. [PubMed: 26401057]

Costa Dora and Kahn Matthew (2008) Heroes and Cowards: The Social Face of War, Princeton, NJ and Oxford, UK: Princeton University Press, 120–159.

Costa Dora L. (1996) "Health and Labor Force Participation of Older Men, 1900–1991," Journal of Economic History, 56 (1), 62–89.

Costa Dora L (2012) "Scarring and mortality selection among Civil War POWs: A long-term mortality, morbidity and socioeconomic follow-Up," Demography, 49 (4), 1185206.

—— (2021) "Health Shocks of the Father and Longevity of the Children's Children," National Bureau of Economic Research Working Paper No. 29553, DOI 10.3386/w29553.

Costa Dora L and Kahn Matthew E (2007) "Surviving Andersonville: The benefits of social networks in POW Camps," American Economic Review, 97 (4), 1467–487.

Costa Dora L., Yetter Noelle, and DeSomer Heather (2018) "Intergenerational transmission of paternal trauma among US Civil War ex-POWs," Proceedings of the National Academy of Sciences, 115 (44), 11215–11220, https:/www.pnas.org/content/115/44/11215.

Currie Janet and Vogl Tom (2013) "Early-Life Health and Adult Circumstance in Developing Countries," Annual Review of Economics, 5, 1–36.

Cutler David M., Glaeser Edward L., and Shapiro Jesse M. (2003) "Why Have Americans Become so Obese?" Journal of Economic Perspectives, 17 (3), 93–118.

Doblhammer G and Vaupel JW (2001) “Lifespan depends in month of birth,” Proc Natl Acad Sci USA, 98 (5), 2934–39. [PubMed: 11226344]

Dolinoy DC, Huang D, and Jirtle RL (2007) “Maternal nutrient supplementation counteracts bisphenol A-induced DNA hypomethylation in early development,” Proc Natl Acad Sci USA, 104 (32), 13056–61. [PubMed: 17670942]

Fund Naama, Ash Nachman, Porath Avi, Shalev Varda, and Koren Gideon (2019) “Comparison of Mortality and Comorbidity Rates Between Holocaust Survivors and Individuals in the General Population in Israel,” JAMA Network Open, 2 (1).

Gardner Douglas Gibson (1998) Andersonville and American Memory: Civil War Prisoners and Narratives of Suffering and Redemption Ph.D. dissertation, Miami University.

Gruber Jonathan and Kubik Jeffrey D. (1997) “Disability insurance rejection rates and the labor supply of older workers,” Journal of Public Economics, 64, 1–23.

Heard Edith and Martienssen Robert A (2014) “Transgenerational epigenetic inheritance: myths and mechanisms,” Cell, 157 (1), 95–109. [PubMed: 24679529]

Heijmans BT, Tobi EW, Stein AD, Putter H, Blauw GJ, Susser ES, Slagboom PE, and Lumey LH (2008) “Persistent epigenetic differences associated with prenatal exposure to famine in humans,” Proc Natl Acad Sci USA, 104 (44), 17046–9.

Kaati Gunnar, Bygren Lars Olov, Pembrey Marcus, and Sjöström Michael (2007) “Trans-generational response to nutrition, early life circumstances and longevity,” Eur J Hum Genet, 15 (7), 784–90. [PubMed: 17457370]

Karpinos Bernard D. (1958) “Height and Weight of Selective Service Registrants Processed for Miliary Service During World War II,” Human Biology, 30, 292–321. [PubMed: 13620295]

Kaspar Daniela, Hastreiter Sieglinde, Irmler Martin, de Angelis Martin Hrabé, and Beckers Johannes(2020) “Nutrition and its role in epigenetic inheritance of obesity and diabetes across generations,” Mammalian Genome, 31, 119–133. [PubMed: 32350605]

Lakdawalla Darius and Philipson Tomas (2009) “The growth of obesity and technological change,” Economics and Human Biology, 7 (3), 283–93. [PubMed: 19748839]

Ling Charlotte and Rönn Tina (2019) “Epigenetics in Human Obesity and Type 2 Diabetes,” Cell Metabolism, 29 (5), 1028–1044. [PubMed: 30982733]

Luke Nancy, Munshi Kaivan, Oomen Anu, and Singh Swapnil (2021) “Economic Development, the Nutrition Trap, and Metabolic Disease,” National Bureau of Economic Research Working Paper Series (29132).

Lumey LH, Ekamper Peter, Bijwaard Govert, Conti Gabriella, and Poppel Frans (2021) “Overweight and obesity at age 19 after prenatal famine exposure,” International Journal of Obesity, 45, 1668–1676. [PubMed: 33967270]

Lumey LH and van Poppel FWA (2013) “The Dutch Famine of 1944–45 as a Human Laboratory: Changes in the Early Life Environment and Adult Health,” in Lumey LH and Vaiserman Alexander eds. Early Life Nutrition and Adult Health and Development, 59–76, Hauppage, New York: Nova Science Publishers.

MacKay Harry, Gunasekara Chathura, Yam Kit-Yi et al. (2022) “Sex-specific epigenetic development in the mouse hypothalamic arcuate nucleus pinpoints human genomic regions associated with body mass index,” Science Advances, 8.

Martorell Reynaldo, Stein Aryeh D., and Schroeder Dirk G. (2001) “Early Nutrition and Later Adiposity,” The Journal of Nutrition, 131 (3), 8745–8805.

Marvel William (1994) Andersonville: The Last Depot, Chapel Hill, NC and London: The University of North Carolina Press.

McPherson NO, Lane M, Sandeman L, Owens JA, and Fullston T (2017) “An Exercise-Only Intervention in Obese Fathers Restores Glucose and Insulin Regulation in Conjunction with the Rescue of Pancreatic Islet Cell Morphology and MicroRNA Expression in Male Offspring,” Nutrients, 9 (2), 122. [PubMed: 28208792]

NCD Risk Factor Collaboration, (NCD-RisC) (2016) “Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants,” The Lancet, 387, P1377–1386.

—— (2017) "Worldwide trandes in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults," The Lancet, 390, P2627–2642.

Pembrey Marcus, Saffery Richard Saffery, and Bygren Lars Olov (2014) "Human transgenerational responses to early-life experience: potential impact on development, health and biomedical research," J Med Genet, 51 (9), 563–72. [PubMed: 25062846]

Philipson Tomas (2001) "The world-wide growth in obesity: an economic research agenda," Health Economics, 10 (1), 1–7. [PubMed: 11180565]

Ravelli Gian-Paolo, Stein Zena A., and Susser Mervyn W. (1976) "Obesity in Young Men After Famine Exposure in Utero and Early Infancy," The New England Journal of Medicine, 295, 349–53. [PubMed: 934222]

Rosenquist James Niels, Lehrer Steven F., O'Malley A. James, Zaslavsky Alan M., Smoller Jordan W., and Christakis Nicholas A. (2015) "Cohort of birth modifies the association between FTO genotype and BMI," Proceedings of the National Academy of Sciences, 112 (2), 354–359, https:/www.pnas.org/content/112/2/354.

Strauss John and Thomas Duncan (2008) "Health over the life course," in Schultz T. Paul and Strauss John eds. Handbook of Development Economics, Volume 4, 3375–3474, Netherlands: North-Holland, Elselvier.

Vågerö Denny, Cederström Agneta, and van den Berg Gerard J. (2022) "Food abundance in men before puberty predicts a range of cancers in grandsons," Nature Communications, 13 (7507).

Vågerö Denny, Pia R Pinger Vanda Aronsson, and van den Berg Gerard J. (2018) "Paternal grandfather's access to food predicts all-cause and cancer mortality in grandsons," Nature Communications, 9 (5124).

Veenendaal MVE, Painter RC, de Rooij SR, Bossuyt PMM, van den Post JAM, Hanson MA, and Roseboom TJ (2013) "Transgenerational effects of prenatal exposure to the 1944–45 Dutch famine," BJOG: An international journal of obstetrics and gynaecology, 120 (5), 548–53. [PubMed: 23346894]

Wilson Sven E and Pope Clayne L (2003) "The Height of Union Army Recruits," in Costa Dora L ed. Health and Labor Force Participation Over the Life Cycle, 113–145, Chicago: University of Chicago Press.

Zhou Jielin, Zhang Liangjian, Xuan Peng et al. (2018) "The relationship between famine exposure during early life and body mass index in adulthood: A systematic review and meta-analysis," PLos ONE, 13 (2).

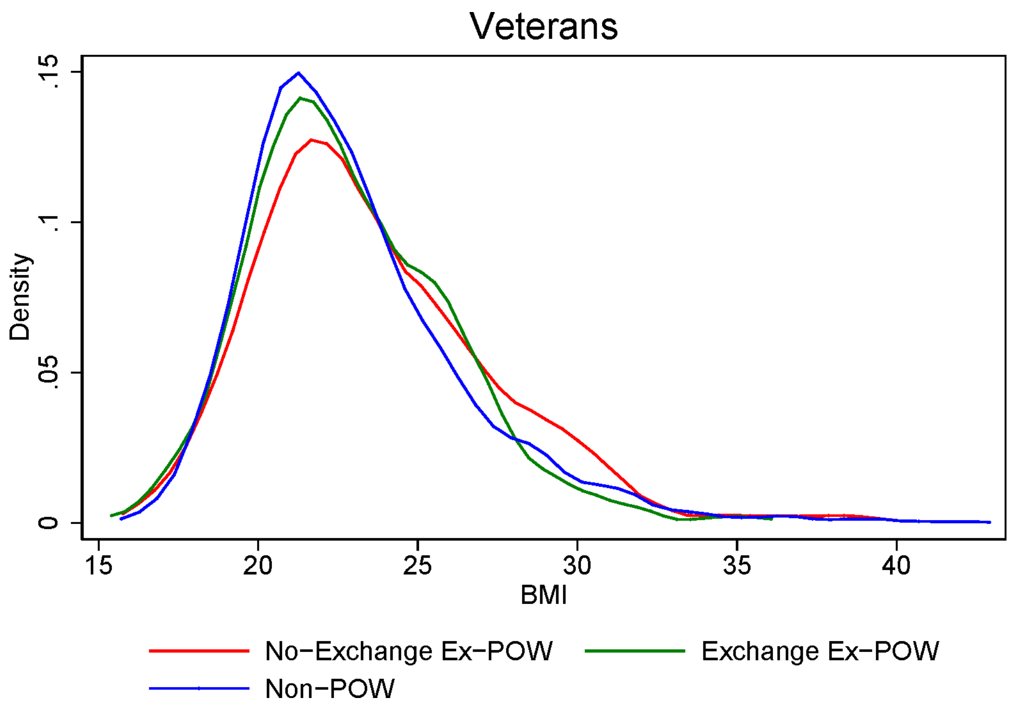


**Figure 1: Density of Veterans' BMI by their Ex-POW Status**

The density is estimated using an Epanechnikov kernel. The Kolmogorov-Smirnov test for equality of the BMI distributions yielded values of 0.098 (p=0.002) when comparing non-exchange ex-POWs with nonPOWs, of 0.088 (p=0.093) when comparing non-exchange with exchange ex-POWs, and o0.039 (p=0.692) when comparing exchange ex-POWs with non-POWs.

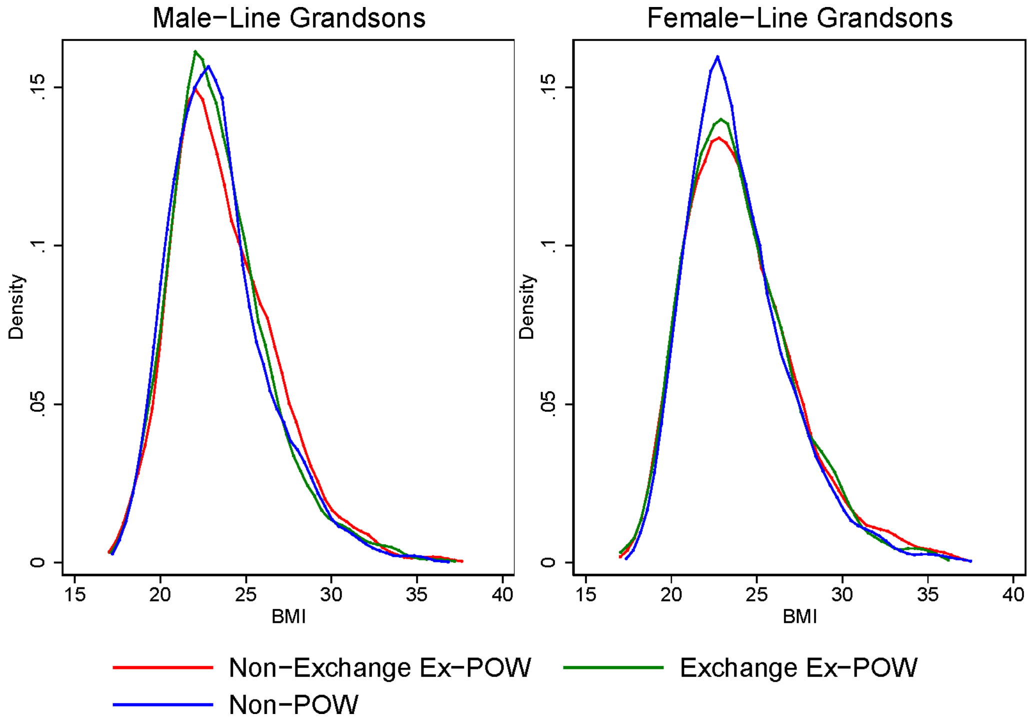


**Figure 2: Density of Male-Line Grandsons BMI by Grandfather's Ex-POW Status**

The density is estimated using an Epanechnikov kernel. The Kolmogorov-Smirnov test for equality of BMI distributions among male-line grandsons yielded values of 0.079 (p=0.004) when comparing non-exchange ex-POWs with non-POWs, of 0.068 (p=0.070) when comparing non-exchange with exchange ex-POWs, and of 0.038 (p=0.437) when comparing exchange ex-POWs with non-POWs. Among female-line grandsons, the respective values were 0.029 (p=0.749), 0.031 (p=0.834), and 0.045 (p=0.248).

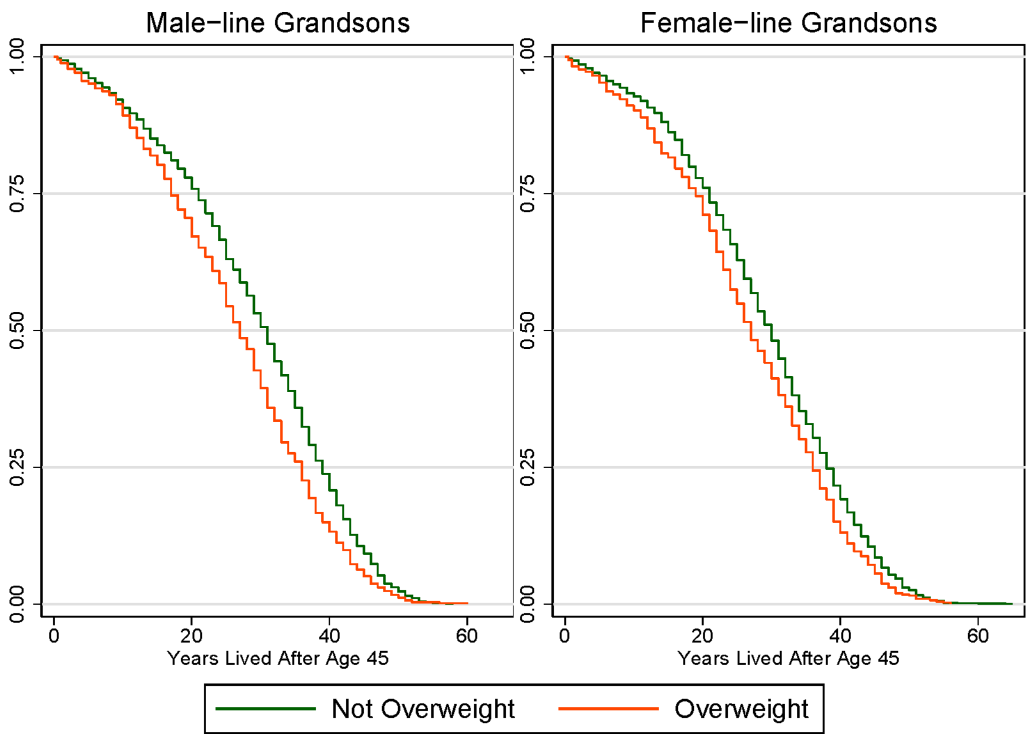


**Figure 3: Kaplan-Meier Survival Curves, Survival and Overweight for Male-Line and Female-Line Grandsons**

2,484 male-line grandsons and 2,390 female-line grandsons. All grandsons survived to age 45, reported height and weight prior to age 45 and have a cousin from an opposite sex line. Survival is measured in years lived after age 45.

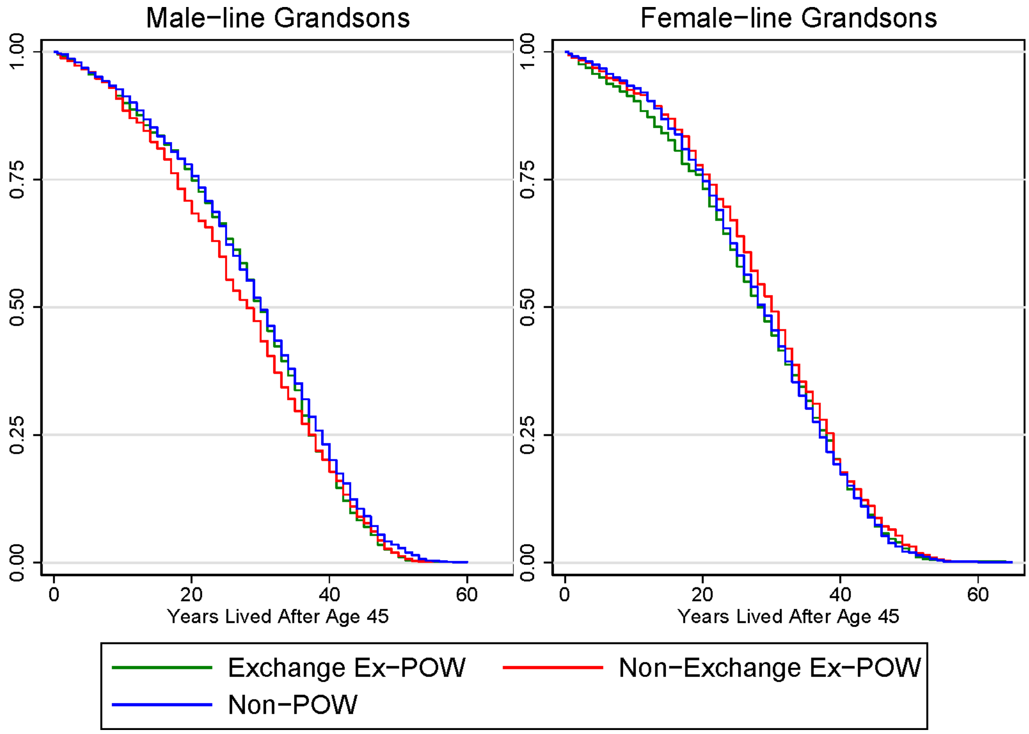


**Figure 4: Kaplan-Meier Survival Curves, Survival and Grandfather's Ex-POW Status for Male-Line and Female-Line Grandsons**

2,484 male-line grandsons and 2,390 female-line grandsons. All grandsons survived to age 45, reported height and weight prior to age 45 and have a cousin from an opposite sex line. Survival is measured in years lived after age 45.

**Table 1:**

Grandsons' BMI and Overweight (Average Marginal Effects) and Grandfathers' Ex-POW Status

| | Male-line | | | | Female-line | | | |
|---|---|---|---|---|---|---|---|---|
| | **BMI** | **Overweight** | **BMI** | **Overweight** | **BMI** | **Overweight** | **BMI** | **Overweight** |
| Grandfather was | | | | | | | | |
| Exchange Ex-POW Relative to Non-POW | 0.115 (0.172) [0.504] | 0.009 (0.042) [0.829] | 0.123 (0.165) [0.458] | 0.012 (0.040) [0.770] | 0.114 (0.179) [0.526] | 0.028 (0.044) [0.525] | 0.077 (0.178) [0.668] | 0.022 (0.043) [0.614] |
| Non-exchange Ex-POW Relative to Non-POW | 0.433** (0.182) [0.017] | 0.090** (0.044) [0.042] | 0.431** (0.179) [0.016] | 0.083* (0.043) [0.052] | −0.007 (0.179) [0.969] | 0.028 (0.042) [0.503] | −0.055 (0.177) [0.756] | 0.014 (0.041) [0.739] |
| Non-exchange Relative to Exchange Ex-POW | 0.318* (0.188) [0.091] | 0.081* (0.045) [0.074] | 0.308* (0.186) [0.098] | 0.071 (0.044) [0.103] | −0.121 (0.191) [0.528] | 0.000 (0.044) [1.000] | −0.132 (0.189) [0.485] | −0.008 (0.043) [0.852] |
| DD Exchange Ex-POW Relative to Non-POW | 0.001 (0.215) [0.996] | 0.019 (0.038) [0.625] | 0.046 (0.216) [0.830] | 0.026 (0.037) [0.479] | | | | |
| DD Non-exchange Ex-POW Relative to Non-POW | 0.440** (0.207) [0.033] | 0.062** (0.030) [0.042] | 0.486** (0.206) [0.018] | 0.069** (0.030) [0.021] | | | | |
| DD Non-exchange Relative to Exchange Ex-POW | 0.439* (0.250) [0.079] | 0.081** (0.035) [0.020] | 0.440* (0.247) [0.075] | 0.079** (0.034) [0.020] | | | | |
| $R^2$ | | | | | | | | |
| Within | 0.076 | | 0.081 | | | | | |
| Between | 0.157 | | 0.190 | | | | | |
| Overall | 0.099 | | 0.114 | | | | | |
| Test $var(u) = 0,\ \bar{\chi}^2(1)$ | 181.55 [0.000] | | 123.18 [0.000] | | | | | |
| Post-war controls | N | N | Y | Y | N | N | Y | Y |

Estimated using the random effects specifications in Equations 1 and 2. DD=double difference. 6,225 observations. Standard errors, clustered on the veteran, are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are a dummy variable indicating if the veteran was overweight circa 1900, the veteran's occupation in 1880, the number of siblings in the grandson's household, whether the veteran was living in the same county as the grandson, whether the veteran was in the same household as the grandson, whether the grandson's father was ever a farmer, a laborer, or a property owner, parents' and own years of education, and occupational class in 1940. The Breusch and Pagan Lagrangian multiplier test was used for random effects ($var(u) = 0$).

**Table 2:**

Male-line Grandsons' BMI, Own and Fathers' Season of Birth and Grandfathers' Ex-POW Status

| Row | | Born in Winter? Grandson | Father | Coefficient | Std Err | P-Value |
|---|---|---|---|---|---|---|
| | Grandfather was | | | | | |
| 1 | Non-exchange ex-POW relative to non-POW | Y | Y | 1.121 *** | 0.291 | 0.000 |
| 2 | | Y | N | 0.252 | 0.379 | 0.506 |
| 3 | | N | Y | 0.608 * | 0.311 | 0.051 |
| 4 | | N | N | 0.311 | 0.341 | 0.361 |
| 5 | Exchange ex-POW relative to non-POW | Y | Y | 0.477 | 0.305 | 0.118 |
| 6 | | Y | N | −0.253 | 0.321 | 0.430 |
| 7 | | N | Y | 0.643 ** | 0.312 | 0.039 |
| 8 | | N | N | 0.049 | 0.337 | 0.884 |
| 9 | Non-exchange relative to exchange ex-POW | Y | Y | 0.644 ** | 0.324 | 0.047 |
| 10 | | Y | N | 0.506 | 0.403 | 0.210 |
| 11 | | N | Y | −0.035 | 0.370 | 0.925 |
| 12 | | N | N | 0.262 | 0.363 | 0.471 |
| 13 | Row 1 - Row 4 | | | 0.810 ** | 0.409 | 0.048 |
| 14 | Row 1 - Row 2 | | | 0.869 * | 0.464 | 0.061 |
| 15 | Row 1 - Row 3 | | | 0.513 | 0.367 | 0.163 |

Estimated using Equation 3. 2,660 observations. Male-line grandsons born during WWI or the Influenza Pandemic are excluded. Standard errors are clustered on the veteran. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are a dummy variable indicating if the veteran was overweight circa 1900, the veteran's occupation in 1880, the number of siblings in the grandson's household, whether the veteran was living in the same county as the grandson, whether the veteran was in the same household as the grandson, whether the grandson's father was ever a farmer, a laborer, or a property owner, parents' and own years of education, and occupational class in 1940.

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**Table 3:**

Grandsons' Mortality After Age 45 (Hazard Ratios) and Their Overweight and Grandfathers' Ex-POW Status

| | **Male-line Grandsons** | | | | **Female-line Grandsons** | | | |
|---|---|---|---|---|---|---|---|---|
| Grandfather was | | | | | | | | |
| Non-POW | | 1.000 | 1.000 | 1.000 | | 1.000 | 1.000 | 1.000 |
| Exchange Ex-POW | | 1.182*** (0.071) [0.006] | 1.173*** (0.071) [0.008] | 1.171*** (0.069) [0.007] | | 1.037 (0.069) [0.580] | 1.039 (0.069) [0.563] | 1.041 (0.069) [0.543] |
| Non-exchange Ex-POW | | 1.275*** (0.083) [0.000] | 1.251*** (0.082) [0.001] | 1.234*** (0.079) [0.001] | | 0.953 (0.060) [0.443] | 0.959 (0.061) [0.508] | 0.969 (0.063) [0.628] |
| Non-exchange Ex-POW relative to Exchange Ex-POW | | 1.079 (0.064) [0.201] | 1.067 (0.063) [0.275] | 1.054 (0.060) [0.359] | | 0.919 (0.061) [0.202] | 0.923 (0.062) [0.234] | 0.931 (0.063) [0.287] |
| Grandson was overweight | 1.225*** (0.061) [0.000] | | 1.208*** (0.060) [0.000] | 1.205*** (0.059) [0.000] | 1.184*** (0.055) [0.000] | | 1.183*** (0.055) [0.000] | 1.183*** (0.055) [0.000] |
| Test of proportional hazards | 37.94 | 35.96 | 37.76 | 64.01 | 58.31 | 59.36 | 59.22 | 71.63 |
| assumption, df= | 30 [0.151] | 31 [0.2474] | 32 [0.223] | 60 [0.338] | 30 [0.002] | 31 [0.002] | 32 [0.002] | 60 [0.145] |
| Post-war controls | N | N | N | Y | N | N | N | Y |

Estimated using Equation 5. 2,484 male-line grandsons and 2,390 female-line grandsons. Standard errors, clustered on the veteran, are in parentheses and p-values are in square brackets. The symbols *, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively. Controls include the age group when height and weight were reported, quarter of birth, region of birth, and the veteran's occupational class at enlistment, year of enlistment, whether he was wounded in the war, enlistment in a city with population of 50,000 or more, born in the US, wounded in the war, and in the original Union Army sample. Post-war controls are a dummy variable indicating if the veteran was overweight circa 1900, the veteran's occupation in 1880, the number of siblings in the grandson's household, whether the veteran was living in the same county as the grandson, whether the veteran was in the same household as the grandson, whether the grandson's father was ever a farmer, a laborer, or a property owner, parents' and own years of education, and occupational class in 1940.