Title
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ABSTRACT

Estimates based on official vital statistics underestimate mortality for Italy during the World Wars. This paper uses a modeling strategy to estimate mortality for Italy based on data from both civilian and military authorities. The model uses the same principles as the one used to reconstruct war losses for England/Wales (Jdanov et al. 2005) and can be adapted to other countries even when we lack detailed knowledge of historical events during wartime. The results produce much lower estimates of life expectancy at birth for males during wartime than the previously published estimates that exclude military deaths. For example, in 1917, the former was nearly 15 years lower than the latter (31.0 versus 45.8 years).

Keywords: Italy, First World War, Second World War, population estimates, mortality, military deaths

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1. Introduction

War can have a substantial impact on mortality rates of a population, particularly among young adult males. Yet, official vital statistics data often exclude military deaths that occur abroad. Thus, estimates based on these data may vastly underestimate the true level of mortality during war periods. For example, among French males in 1915, life expectancy at birth was nearly 14 years greater for civilians compared with the overall population (40.8 vs. 27.0, respectively; HMD 2007; Vallin 1973). For males aged 20-24, the mortality rate for the entire population was more than five times greater than that of the civilian population (9.6% vs. 1.8%; HMD, 2007). Similar figures for England and Wales also suggest that civilian mortality substantially underestimates the true mortality level during wartime.

Estimates of civilian mortality may also be biased by failure to account for population movements during wartime. For Italy, official death counts reported by *Istituto Nazionale di Statistica* (ISTAT) exclude the vast majority of military deaths during the First and Second World Wars. Yet, population estimates derived using the intercensal survival method do not account for the mobilization of military troops. Consequently, mortality rates based on these data are plagued by numerator-denominator bias because the numerator represents largely the civilian population whereas the denominator represents the total population. Glei et al. (2005) demonstrates that estimates calculated from official vital statistics and census counts underestimate mortality in Italy in 1911-1921 and 1936-1951.

In this paper, we use a modeling strategy to estimate mortality for Italy based on data from both civilian and military authorities. Our goal is twofold: i) to obtain more accurate estimates of mortality for the population of Italy as a whole, and ii) to employ methods that help ensure comparability with estimates for other countries. To that end, we follow a strategy similar to the one applied to England and Wales by Jdanov et al. (2005), which has already been used for the Human Mortality Database (HMD 2007). One of the guiding principles of the HMD is comparability: to follow a uniform set of procedures for each population. Wartime mortality presents a special challenge because the availability, coverage, and completeness of data can vary considerably across countries. This paper is an attempt to further develop a methodology that can be used across various HMD countries affected by wartime mortality.

2. Previous approaches

Several studies have attempted to estimate wartime mortality for particular countries or evaluate total war-related losses. Urlanis (1971) published aggregate estimates of battle, non-battle, and total human losses for each country involved in both WWI and WWII. Frumkin (1951) also provided data on total demographics losses (including military and civilian deaths, prisoners of war, refugees and displaced persons) during WWII for 25 European countries. These works are based on official sources or indirect estimates and give only aggregate numbers of losses. More detailed data can be found in country-specific studies such as for England & Wales (Winter 1976, 2003; Jdanov et al. 2005), France (Vallin 1973), Italy (Glei et al. 2005) or Germany (Overmans 2000). Below, we review some approaches that have been used to estimate age-specific total mortality (including war-related deaths) for France, England & Wales, and Italy.

2.1. France

For France, some aggregate official data on the total number of deaths during WWI and WWII can be found in special reports by Ministère des Armèes, Institut national de la statistique et des études économiques (INSEE) and Institut national d'études démographiques (INED) (Vallin 1973). Several researchers have also published estimates of military deaths or total population losses (including military and civilian deaths, and emigrations) primarily focusing on the influence of wars on demographic development of France (Huber 1931; Vincent 1946; Boulanger and Moine 1946; cited in Vallin, 1973).

Vallin (1973) adjusted mortality estimates for France during World War I and II taking into account excess war mortality and mobilization of the troops. Using various assumptions, he redistributed military deaths by age, combined those data with civilian deaths to obtain total deaths, and derived January 1st population estimates by age for France as a whole (for details see Vallin 1973:46-67, 69-79 [in French]; for a summary in English see Glei et al. 2004:367-368). Mortality rates and life tables are calculated from these adjusted data. Vallin's general approach relies on estimates of various population movements (i.e., deaths, births, mobilization and demobilization of troops, migration and refugee flows) combined with knowledge of the history during these wartime periods to make plausible assumptions. Such an approach requires a thorough study of the details for that country. Because each country's experience differs and thus may warrant different assumptions, it may be difficult to apply this method uniformly across countries.

2.2. England & Wales

Vital statistics for England & Wales cover only the civilian population, but official counts of total military deaths can be found in special publications by the military authorities and the Central Statistical Office. Other studies also estimate aggregate counts of total war-related deaths by making various adjustments to the official estimates. The data on total and war-related deaths are especially scarce and problematic for the period around WWI. Due to poor military statistics, even total numbers of war-related losses differ widely from source to source, ranging from 550,000 to 1,184,000 casualties (Winter 2003; Urlanis 1971). As for WWII, the Registrar General and Central Statistical Office published more reliable and detailed data on both the total number of casualties and the age-composition of the military population (CSO 1951, reprinted in 1995). In addition, some age- and cause-specific data on combatant mortality have been published by the British Armed Forces (HMSO 1972), but unfortunately, these data cover only selected military branches and hospitals, and thus, cannot be used to estimate total war-related mortality.

Due to the scarcity of official data, some researchers used alternative data sources and indirect methods to estimate age-specific profiles of war-related and total deaths around both WWI and WWII. Using life tables of the Prudential Life Insurance Company covering five million men of working age, Winter (1976, 2003) calculated total population estimates for 1912-1918 by multiplying the 1911 census population times the corresponding survivor ratios for 1913-1918. He then estimated the total number of deaths for 1914-1918 by applying year- and age-specific death rates from Prudential life tables to the derived total population estimates. War-related deaths by age were obtained as the difference between the total number of deaths and the estimated hypothetical number of deaths "without the effect of war" (Winter 1976, 2003).

Jdanov et al. (2005) applied a different approach to reconstruct the total and war-related mortality across age and time for England & Wales during the periods around WWI and WWII. Their method is based on an extended model of population flows, taking into account the specifics and availability of input data. The model treats all unknown parameters (such as age-specific deaths or migration) as variables in the population balancing equation. The results of this study demonstrated the large impact of the two wars on the age-profile of mortality and the level of life expectancy for the total population in England & Wales.

2.3. Italy

Due to the specifics of war operations in Italy, official data on total and war-related deaths during the two world wars are scarce (Frumkin 1951). Mortara (1925) published estimates of the total number of casualties during WWI, but with only limited information regarding the distribution by age and calendar year (see Section 3 for more details). For WWII, the Milan Institute of Economic Studies attempted to estimate total war-related deaths (Frumkin 1951), and the Istituto Centrale di Statistica (1957) reported the distribution of war-related deaths by calendar year and by age group.

Following a strategy similar to that employed by Vallin (1973) for France, Glei et al. (2005) derived estimates of total mortality for Italy. Using the available estimates from other sources and making multiple assumptions, Glei et al. (2005) estimated the distribution of military deaths across age and time, and then combined them with deaths reported by the civilian authority to obtain death counts for the entire population. Using these adjusted death counts, population estimates were calculated using intercensal survival as described in the HMD Methods Protocol (Wilmoth et al. 2005). Like Vallin's treatment for France, this approach requires numerous assumptions based on detailed historical information.

Cross-national comparability may be better served by a more general approach that requires fewer idiosyncratic assumptions. The model presented here is based on the same principles as the one used to reconstruct war losses for England and Wales (Jdanov et al. 2005) and can be adapted to other countries even when we lack detailed knowledge of historical events during wartime. Nonetheless, the availability of data differs across countries and the model must be modified accordingly. Unlike the case of England and Wales, for Italy we do not have annual population estimates for the civilian population during wartime nor do we have reliable estimates of the strength of the military during World War II. Furthermore, the modeling strategy still requires some assumptions, but they are more general in nature, more similar across countries, and could be applied in other contexts. While no single method for estimating mortality during wartime can be applied uniformly across countries, by following the same general principles we can produce estimates with greater consistency and comparability.

3. Data inputs

The data inputs used in the model are summarized in Table 1. The 1911, 1921, 1936 and 1951 censuses covered the *de facto* population and occurred during peacetime; therefore, we take these counts as representative of the "total" population (civilian and military). Death counts come from two sources: i) vital statistics reported by the civilian authority (Istituto Centrale di Statistica); and ii) figures reported by the military authority. For simplicity, we will hereafter refer to the former as "civilian" deaths and to the latter as "military" deaths. Nonetheless, we acknowledge that these so-called "civilian" deaths may actually include some deaths to (former) military personnel. During 1911-19, deaths reported by the civilian authority included 104,003 such deaths, which comprise 14% of all military deaths (see Mortara 1925, Appendix Table, p. 537); most of these deaths resulted from disease rather than direct combat.

Table 2 shows military deaths by sex and calendar year. For the period from May 24, 1915 through April 30, 1920, the military authority reported 651,010 deaths (all male), but the distribution by calendar year was given only for those who died while on active duty during 1915-18 (378,010; Mortara 1925). For the remaining military deaths during World War I, the distribution by calendar year was estimated (see Glei et al. 2005, p. 372-374). For the World War II period, Istituto Centrale di Statistica (1957) reports a total of 291,340 military deaths including those missing in action. These counts are given by calendar year except for 6,960 deaths where the year of death is unknown; the latter are redistributed based on the distribution of deaths for which year is known (see Glei et al. 2005, p. 378 and Table 5).

Military deaths by sex and age group are presented in Table 3. For World War I, the only information we have regarding the age distribution of military deaths comes from a survey conducted in the province of Bologna that comprises a sample of 10,085 deaths that occurred by the end of 1918 (Mortara 1924:42-45). Mortara argues that these data are of high quality and can be considered representative of all deaths. We apply the age distribution (15, 16…40, 41+) given for this sample of deaths to the total number of military deaths during 1915-20 to obtain the estimates shown in Table 3.

For World War II, Istituto Centrale di Statistica (1957, Table 2-6) reports the distribution by age group (15-19, 20-24…60-64, 65+) for confirmed deaths and persons missing in action (MIA) over the entire war period. They also report deaths (not including MIA) disaggregated into pre-Armistice (10 May 1940 – 8 Sept 1943) and post-Armistice (9 Sept 1943 - 31 Dec 1945) periods (Table 2-5), but with less detailed age groups at older ages (i.e., 50-59, 60+). Within each of these age groups (50-59, 60+), we redistribute deaths during the pre- and post-Armistice periods based on the more detailed age distribution over the entire war period. Age is recorded as unknown for 1,205 pre-Armistice and 1,595 post-Armistice deaths (all males) and 4,033 MIA (sex unspecified). Within each subgroup (MIA; deaths by pre-and post-Armistice period), we redistribute counts of unknown age based on distribution of those where age is known. Because sex is not specified for MIA by age group, we apply the sex distribution based on MIA of all ages. Finally, we sum confirmed deaths and MIA to obtain the total military deaths by sex and age group shown in Table 3.

Table 1 is about here

Table 2 is about here

Table 3 is about here

4. Methods

During the periods of World Wars I and II, we estimate total mortality by taking into account military as well as civilian mortality. Italy entered WWI on May 24, 1915; although the armistice to end the war was signed on November 11, 1918, the Italian military authority recorded war-related deaths (including prisoners of war and those dying of war injuries) thru April 30, 1920. Italy entered WWII on June 10, 1940, and surrendered on September 8, 1943, but the war in Europe did not officially end until "V.E. day" (May 8, 1945). Therefore, we define the WWI and WWII periods to include years 1915-1920 and 1940-1945, respectively. We use t_{begin} to refer to the year in which war began and t_{end} to indicate the last year of the war period.

Figure 1 summarizes the process by which we derive mortality estimates for the total population based on the data inputs described in Section 3. Our first step is to estimate population age structure on January 1st of the year war began. Starting with the pre-war census count and civilian deaths, we use standard Human Mortality Database (HMD) methods (Wilmoth et al. 2005) to: i) redistribute counts of unknown age, ii) split deaths and population counts by birth cohort, and iii) calculate post-censal estimates $P(z, t_{\text{begin}})$, representing the population size of cohort z on January 1st of year t_{begin}.[1]

The aim of the second step is to distribute military deaths by cohort for each year of the war period:

$$\pi(z,t) = \frac{D^{\text{m}}(z,t)}{\tilde{D}^{\text{m}}(t)} \quad , \tag{1}$$

where $\tilde{D}^{\text{m}}(t)$ represents a known quantity: total military deaths for year t (Table 2). With regard to notation, we use a tilde (~) above a variable to denote input data; other quantities remain unknown and must be estimated. The procedures described below are performed separately for each sex. We assume the military population is restricted to ages 18-60 (i.e., cohorts $t-60$ to $t-18+1$) for WWI and ages 18-70 for WWII. The proportion $\pi(z,t)$ depends on the relative size of the cohort and the probability of military death:

[1] $P(z,t)$ is the same as $P(x,t)$, where x represents age on January 1st and $x = t - z - 1$.

$$\pi(z,t) = \frac{q^{\mathrm{m}}(z,t)\cdot P(z,t)}{\sum_{i=t-60}^{t-18} q^{\mathrm{m}}(i,t)\cdot P(i,t)} \quad , \tag{2}$$

where $q^{\mathrm{m}}(z,t)$ represents the probability of military death (among the total population) for cohort z during year t, and $P(z,t)$ is the size of the total population of cohort z on January 1st of year t. The probability $q^{\mathrm{m}}(z,t)$ is further defined as:

$$q^{\mathrm{m}}(z,t) = D^{\mathrm{m}}(z,t) / P(z,t) \ . \tag{3}$$

At this point, we have estimates of the population for the year the war began $P(z,t_{\mathrm{begin}})$ (obtained in Step 1), but $q^{\mathrm{m}}(z,t)$ and $D^{\mathrm{m}}(z,t)$ remain unknown. To estimate these quantities, we assume that $q^{\mathrm{m}}(z,t)$ follows a gamma p.d.f.[2] with a maximum between ages 18 ($t-z=18$) and 24 (see example for France in Vallin, 1973, and for England & Wales in Winter, 1976). Thus, $q^{\mathrm{m}}(z,t)$ is described by parameterized function with parameters $a(t)$ and $b(t)$. We fit parameters $a(t)$ and $b(t)$ for $t = t_{\mathrm{begin}},...,t_{\mathrm{end}}$ by minimizing differences between the input data and the resulting estimates of military deaths:

$$\sum_{x}\left(\frac{\sum_{t=t_{\mathrm{begin}}}^{t_{\mathrm{end}}}\hat{D}^{\mathrm{m}}(x:x+n,t)-\tilde{D}^{\mathrm{m}}(x:x+n)}{\tilde{D}^{\mathrm{m}}(x:x+n)}\right)^{2} \to \min_{a(t_{\mathrm{begin}}),b(t_{\mathrm{begin}}),...,a(t_{\mathrm{end}}),b(t_{\mathrm{end}})} , \tag{4}$$

where $\tilde{D}^{\mathrm{m}}(x:x+n)$ represents input data consisting of military deaths at ages x to $x+n$ during the entire war period (t_{begin} to t_{end}), and $\hat{D}^{\mathrm{m}}(x:x+n,t)$ is the estimate fitted by the model for that age group during year t. The format of age groups varies across periods (see Table 3 for details). For example, military deaths during WWII are available by 5-year age groups (15-19,…60-64, 65+); so, we fit Eq. 4 for $x = 15,20...,65$ and $n = 5,5,...5,\infty$. In order to constrain the military population to ages 18-70, we assume all deaths in the youngest age group occurred at ages 18-19 and all deaths at ages 65 and older occurred at ages 65-70.

The process for fitting $q^{\mathrm{m}}(z,t)$ proceeds as follows. We begin by choosing initial values for $a(t)$ and $b(t)$ (e.g., all parameters set to one), and based on the gamma p.d.f.[2], we derive $q^{\mathrm{m}}(z,t)$ for $t_{\mathrm{begin}} \le t \le t_{\mathrm{end}}$ (Steps 2a & 2b of Figure 1). Next, using $q^{\mathrm{m}}(z,t_{begin})$ and $P(z,t_{begin})$ from Step 1c, we solve Eq. 3 for $D^{m}(z,t_{begin})$ (Step 2c-i). With this information and civilian death counts (from Step 1a), we calculate the population size of cohort z on January 1st of year $t_{begin}+1$ (Step 2c-ii):

$$P(z,t_{begin}+1) = P(z,t_{begin}) - \hat{D}^{\mathrm{c}}(z,t_{begin}) - D^{\mathrm{m}}(z,t_{begin}) \ . \tag{5}$$

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[2] The gamma probability density function is defined for each cohort z aged $x = t - z$ on January 1st as:

$$G(x;a,b) = \frac{1}{b^{a}\Gamma(a)} x^{a-1} e^{\frac{x}{b}} ,$$

where a and b are parameters and $\Gamma(a)$ is a standard gamma function.

Fig. 1 is about here

We repeat steps 2c-i and 2c-ii, iterating year by year through t_{end}, until we have obtained $D^{\text{m}}(z,t)$ for all years during the war period.

In Step 2d, we split these estimates of military deaths by birth cohort into Lexis triangles, $\hat{D}^{\text{m}}(x,z,t)$, where $x = t - z$ for deaths occurring in the lower triangle and $x = t - z - 1$ for deaths occurring in the upper triangle. For the first and last year of each war period, we use the proportions corresponding to the area of the two triangles for the war period portion of the year.[3] For all other years, we allocate 50 percent of deaths to each of the two triangles according to standard HMD methods (Wilmoth et al. 2005). The estimates of military deaths by Lexis triangle can then be aggregated into the same *n*-year age groups as the input data, $\tilde{D}^{\text{m}}(x:x+n)$, and plugged into Eq. 4 (Step 2e).

Iteratively, we repeat Steps 2a-2e (with different values for $a(t)$ and $b(t)$) using the gradient method to find fitted values of $\hat{a}(t)$ and $\hat{b}(t)$ that minimize the functional shown in Eq. 4. From $\hat{a}(t)$ and $\hat{b}(t)$, we obtain fitted values of $\hat{q}^{\text{m}}(z,t)$.

To conclude step 2, we first substitute these fitted values and $P(z,t)$ (from Step 2c) into Eq. 2 to derive $\hat{\pi}(z,t)$ (Step 2f). Then, using these estimates along with the input data, $\tilde{D}^{\text{m}}(t)$, we solve Eq. 1 to obtain $\hat{D}^{\text{m}}(z,t)$ for the entire war period (Step 2g).

In Step 3, we split these estimates of annual military deaths by cohort into Lexis triangles using the same method described in Step 2d. Next, deaths for the total population (by age, birth cohort, and calendar year) are derived by summing deaths for civilian and military populations (Step 4). The final step involves calculating all the estimates needed to produce complete life tables for the total population. As we did with pre-war census counts, we use standard HMD methods to split post-war census counts into birth cohorts (Step 5a). Then, using the pre- and post-war census counts and deaths for the total population, we apply the intercensal survival method to derive annual (January 1st) population estimates (Step 5b). The method is the same as that described in the HMD Methods Protocol (Wilmoth et al. 2005) except that we assume no migration (except mobilization and demobilization of military troops) during 1915-18 and 1940-45. Finally, we estimate exposure-to-risk, death rates, and complete period life tables using standard HMD methods (Step 5c).

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[3] For example, Italy entered World War I on May 24, 1915. For the portion (0.61) of the year after that date, simple geometry shows that the upper triangle occupies 30% the total area. Thus, we allocate 30% of military deaths in 1915 to the upper triangle and 70% to the lower triangle.

5. Results

5.1. Validating the modeling approach

5.1.1. Estimated Military Deaths compared with Input Data

Comparing the estimated distribution of deaths by age for each of the two war periods to the age distribution of the input data, we see that the modeling procedure tends to smooth out the irregular patterns (Figure 2). By definition, our estimates of total war losses (for each year and for the entire war period) are equivalent to the input data. Thus, the differences across age compensate for one another. Whereas the input data show a sharp peak at age 20 during WWI, the estimates redistribute some of those deaths to ages 18-19 and ages 22-24.

Fig. 2 is about here

5.1.2. Estimates based on current modeling strategy versus previous approach

In Figure 3, we compare our estimates of the probability of dying (q_x) by age x among the total (civilian + military) population to the comparable figures obtained using an earlier approach (Glei et al., 2005). During WWI, the biggest differences between these estimates occurred in 1917: the current estimates concentrate mortality risk more heavily at younger ages (< 25) than the earlier approach. In contrast, in 1943 (the year with the biggest differences during WWII), we find the opposite pattern: the current approach tends to shift more risk to older ages than the earlier estimates. Again, the modeling procedure tends to smooth out the irregular patterns.

Fig. 3 is about here

Despite these differences, the estimates of e0 produced by the two approaches are quite similar—in most cases the differences are less than 0.25 years (Figure 4). The largest difference is for 1919: our estimate of e0 for males is 39.2 years compared with 39.8 years using the previous approach. This difference probably results from the fact that the earlier approach subtracted 8,146 deaths (2% of all male deaths) to non-Italians (e.g., POWs) that were included in the vital statistics. We have not subtracted these deaths because during this period the death counts and census counts covered the *de facto* population. Nonetheless, some numerator-denominator bias may remain because this population of non-Italians may not have been in Italy during the census years (1911 & 1921). Because our population estimates are derived from the census counts, they may underestimate the true population at risk during war years (if some people entered Italy during the war and died before leaving).

Fig. 4 is about here

5.1.3. Differences in modeling strategy from that applied to England & Wales

As noted earlier, this modeling strategy is similar to the one developed by Jdanov et al. (2005) for England and Wales. Differences between that model and the one presented here result from the fact that more detailed input data were available for England and Wales than for Italy. For the former, the following data were available as inputs: 1) civilian death counts by 5-year age groups and calendar year, 2) the number of (non-civilian) war-related deaths by calendar year, 3) civilian population estimates by 5-year age groups and calendar year, and 4) rough estimates of the size of the combatant population for each year of the war.

For Italy, we have complete data only for the first two of these four inputs, although we use one set of input data that were not used for England and Wales: military deaths by age group over the entire war period. Because we do not have civilian and military population estimates for each war year, the model presented here is fitted for the entire war period, whereas the model for England and Wales was fitted for each year separately. Furthermore, we are not able to estimate mortality separately for the civilian and military population as was done for England and Wales; we work directly with the total population for Italy.

In order to assess how these differences in modeling strategy might affect the resulting estimates, we use input data for England & Wales that are in the same format as those used for Italy, apply the model described in Section 4, and compare the estimated deaths to those obtained by Jdanov et al. (2005). We further compare these figures to estimates derived by Winter (2003) based on Prudential Insurance Company life tables for the total (including military) male population during this period; the latter are based on insured men, although Winter (2003) reports them to be nationally representative. As shown in Figure 5, the estimated deaths by age using this model are very similar to those derived by Jdanov et al. (2005), although they differ somewhat from comparable estimates published by Winter (2003). At many young adult ages, Winter (2003) estimates fewer deaths than those derived here; such difference may result from differences in population coverage (i.e., the insured population may be at lower risk).

Fig. 5. is about here

5.2. Effects of incorporating war mortality

Figure 6 demonstrates that the addition of military deaths during the World Wars has a sizeable impact on the total death count among males. The effect is even more dramatic among young men aged 20-25 (data not shown): for example, in 1917 there were about ten times as many military deaths (≈110,000) as civilian deaths (≈11,000) among this group.

Fig. 6 is about here

The exclusion of military deaths would vastly underestimate mortality among young men during wartime. When military deaths are excluded, the death rate among men aged 20-24 was less than 1% in 1917 versus more than 8% after accounting for military deaths. Similarly, the estimate of e0 (among males) is considerably diminished after accounting for war mortality. In 1917, the difference between the unadjusted (45.8) and adjusted (31.0) estimate of e0 was nearly 15 years.

5.3. Cross-national comparisons

Figure 7 presents the total death rate among young males in Italy compared with two other populations that suffered heavy war losses: France and England/Wales. France entered each of the World Wars much earlier than Italy, and thus suffered a higher death rate than Italy during the early part of the wars. In contrast, Italy experienced a heavier causality rate during the middle of both wars. Through most of both wars, England & Wales had lower death rates among young men than either of the other two countries. Similar inter-country differences are reflected in estimates of e0 (Figure 7).

Fig. 7 is about here

6. Conclusions

These results demonstrate the importance of adjusting for war losses for countries that sustain combat-related mortality. Failure to do so risks vastly underestimating mortality among males in particular. In order to make meaningful inter-country comparisons, it is also important that the methods used to make such adjustments follow a similar strategy across countries. The modeling strategy described here has been applied to Italy and England/Wales, but could easily be adapted to other countries.

At a detailed level (i.e., death rates by 5-year age groups), the estimates produced by the model differ somewhat from those obtained in an earlier estimation strategy (Glei et al. 2005). The current model provides more smoothed patterns, but it is difficult to judge which set of estimates are more accurate because the true values are unknown. Nonetheless, the estimates of e0 obtained from the two approaches are very similar. For example, our current estimate of e0 among males in 1917 is 31.0 years compared with the earlier estimate of 31.4 years. This difference (0.4 years) is dwarfed when you consider how much these estimates differ from the estimate of e0 before making any adjustment for war mortality (45.8 years; a difference of nearly 15 years).

The mortality data for some of the countries currently included in the HMD take into account war mortality (i.e., England/Wales, France, Finland), but others do not. We argue that the estimates presented here for Italy would be a great improvement over the data currently provided in the HMD. Furthermore, the HMD data for the USA could probably be improved by applying similar methods to correct for war mortality. The data series for several other countries (e.g., Austria, Germany, Hungary, Japan, Russia) begin after WWII; further work to correct for war mortality would be needed to extend those series backwards. Nonetheless, finding appropriate data to make such adjustments is a challenge. Although this modeling strategy allows one to estimate the mortality surface based on relatively limited input data, it still requires credible estimates of military deaths and the distribution of those losses across age and time. In some cases (e.g., Germany, Japan, Russia), those data may be difficult if not impossible to obtain.

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Table 1. Data inputs used for the model

Year(s)	Description	Age Format	Source(s)
1911 (June 10)	Census count of *de facto* population by sex and age group	0,1…20,21-24,25-29… 95-99,100+,unk	Istituto Centrale di Statistica (1914)
1921 (December 1)	Census count of *de facto* population by sex and age group[1]	0,1…20,21-24,25-29… 95-99,100+,unk	Istituto Centrale di Statistica (1928); Ministero dell'Economia Nazionale (1925)
1936 (April 21)	Census count of *de facto* population by sex and age group	0,1…99,100+,unk	Istituto Centrale di Statistica (1937)
1951 (November 4)	Census count of *de facto* population by sex and age group[2]	0,1…79,80-84,…95-99, 100+	Istituto Centrale di Statistica (1956, 1958)
1911, 1912…1921, 1936, 1937…1951	Deaths reported by the civilian authority, by sex, calendar year, and age group	Varies across years (for details see Glei, 2006, Appendix 2)	Istituto Centrale di Statistica Della Republica Italiana (1910-11, 1912-14, 1915-1918, 1919-23, 1936, 1938-39, 1940, 1941-42, 1943-48, 1949-50); Istituto Centrale di Statistica del Regno D'Italia (1939); Istituto Centrale di Statistica (1962)
1915, 1916…1920, 1940, 1941…1945	Deaths reported by the military authority, by sex and calendar year	n/a	Derived by Glei et al. (2005) based on data from Mortara (1925), and Istituto Centrale di Statistica (1957); see Table 2.
1915-1920	Deaths reported by the military authority for World War I, by sex and age group	18,19…40,41+	Derived based on Mortara (1925); see Table 3.
1940-1945	Deaths reported by the military authority for World War I, by sex and age group	15-19,20-24…60-64,65+	Derived based on Istituto Centrale di Statistica (1957); see Table 3.

unk = unknown age; n/a = not applicable

Notes

1. Census counts for 1921 have been adjusted to exclude the regions of Venezia Tridentina and Venezia Giulia, which were not included in death counts until 1924 (for details see Glei, 2006, Appendix 2).
2. Census counts for 1951 have been adjusted to exclude Trieste, which was not included in death counts until 1955 (for details see Glei, 2006, Appendix 2).

Table 2. Military-reported deaths by sex and calendar year, World War I and II

	Male		Total	Female	Male
World War I		**World War II**			
1915	84,413	1940	12,776	-	12,776
1916	146,792	1941	40,928	-	40,929
1917	208,407	1942	63,999	-	63,999
1918	149,104	1943	106,994	5	106,989
1919	56,065	1944	41,771	14	41,757
1920	6,229	1945	24,908	17	24,890
1915-20	651,010	1940-45	291,376	36	291,340

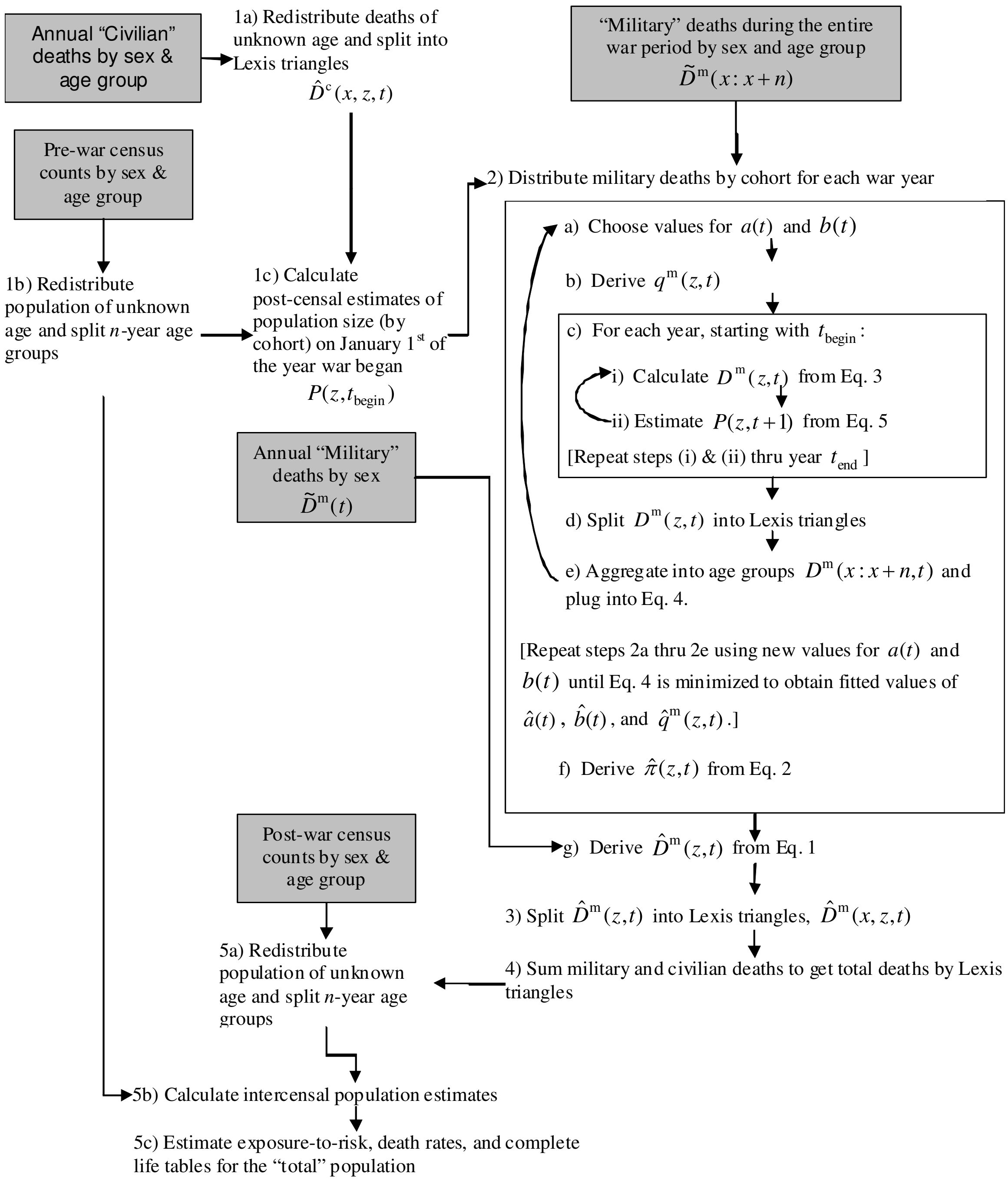
Sources: Data for World War I were derived by Glei et al. (2005, pp. 372-374 and Table 1) based on data from Mortara (1925). Data for World War II were derived by Glei et al. (2005, p. 378 and Table 5) based on data from Istituto Centrale di Statistica (1957, Table 1-1).

Table 3. Military-reported deaths by sex and age group, World Wars I and II

	Male		Total	Female	Male
World War I		**World War II**			
Age 18	9,747	Age 15-19	12,322	6	12,316
19	26,208	20-24	132,774	15	132,759
20	66,037	25-29	79,178	5	79,173
21	55,128	30-34	42,362	6	42,357
22	46,349	35-39	12,387	1	12,386
23	41,959	40-44	5,433	3	5,430
24	41,830	45-49	3,379	-	3,379
25	41,830	50-54	2,098	-	2,098
26	37,634	55-59	943	-	943
27	34,665	60-64	323	-	323
28	28,080	65+	175	-	175
29	28,661	Total	291,376	36	291,340
30	28,919				
31	23,755				
32	23,497				
33	21,496				
34	16,913				
35	17,558				
36	13,298				
37	11,232				
38	10,522				
39	6,649				
40	4,583				
41+	14,460				
Total	651,010				

Sources: Estimates derived based on data from Mortara (1925) for World War I and Istituto Centrale di Statistica (1957, Tables 2-5 and 2-6) for World II. See the text for details.

Fig. 1. Flowchart showing procedures for estimating total mortality



Note: Data inputs are shown in shaded boxes.

Fig. 2. Military-reported deaths, estimated age distribution versus input data

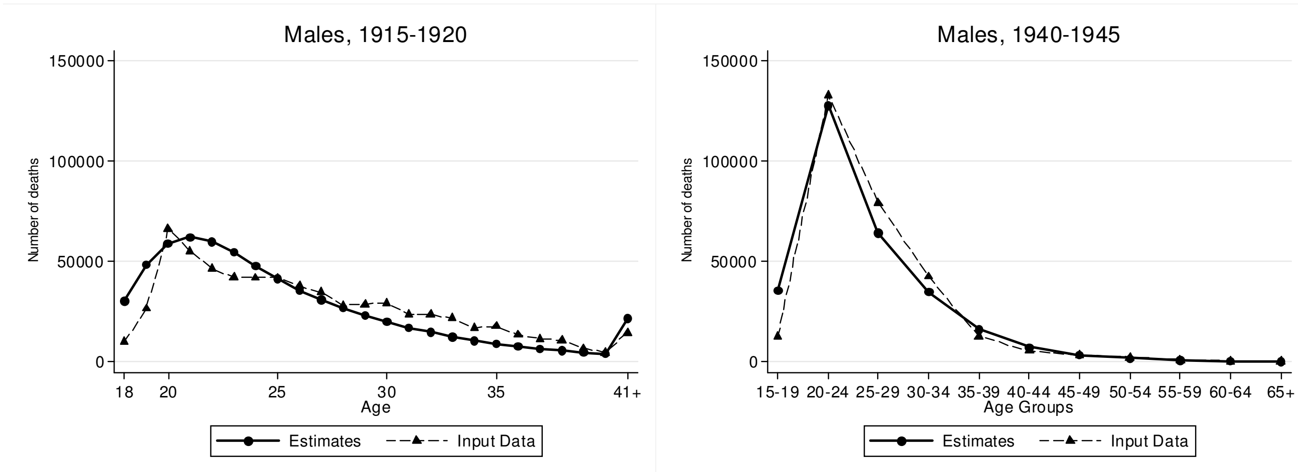


Fig. 3. Estimated probability of dying (q_x) by age, males, 1917 & 1943

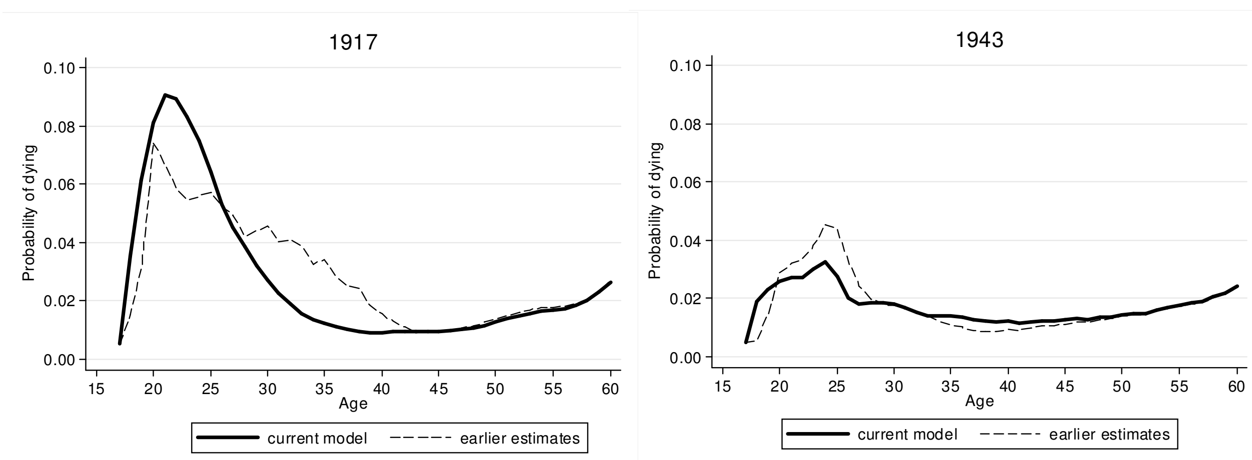


Fig. 4. Difference in life expectancy at birth among males, current vs. previous approach

Fig. 5. Estimated deaths by age, England & Wales Total Population, Model (solid lines with filled markers) vs. Jdanov et al. (2005) (dotted lines with hollow markers, left panel) and Winter (2003) (dotted lines with hollow markers, right panel)

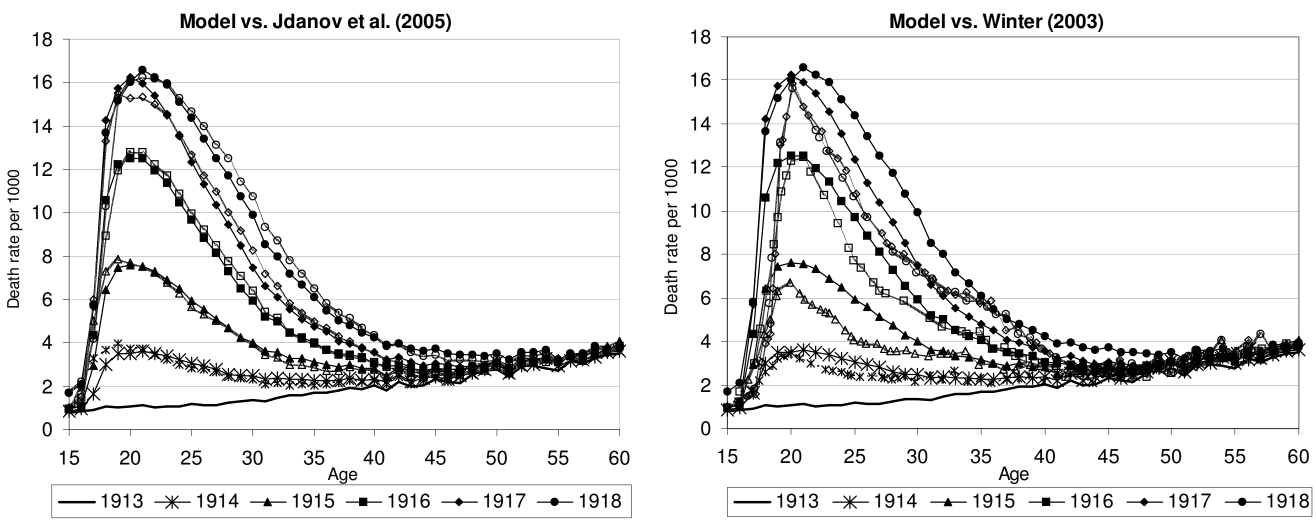


Fig. 6. Civilian and military deaths during WWI & WWII, males of all ages

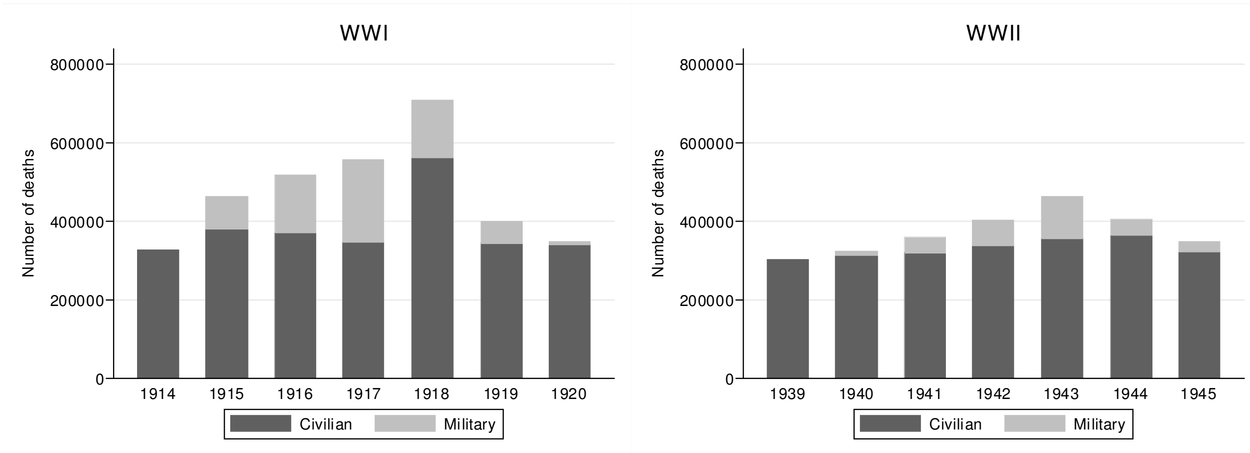


Fig. 7. Estimated death rate among males aged 20-25 and male life expectancy at birth in Italy, France and England/Wales