Sickness and Death during the Health Transition: Evidence from the U.S. Army 1905-39

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Abstract: This article uses American army records of the early 20th century to address a controversy over the relationship of mortality to morbidity (sickness). Mortality trends in several disease categories were positively related to the period-prevalence rates of morbidity. Of the two components of the prevalence rate (incidence and duration), the former accounted for the bulk of the reduction in the prevalence for most disease categories. Susceptible to several idiosyncratic influences, sickness duration was weakly connected to prevalence, incidence and mortality, and thus was an inconsistent indicator of underlying health. These findings support the view that sickness and morbidity declined while life expectancy rose during the early stages of the health transition.

Health is central to human well being, but its multifaceted nature requires social scientists to develop an array of measures.[1] Historical demographers, for example, have constructed detailed records of age-specific mortality and life expectancies that extend as far back as the mid-nineteenth century for many industrialized countries. On the other hand, anthropometric historians use stature, body mass index and birth weight to shed light on the net nutritional status of populations over the last two centuries.[2]

While there is consensus on the centrality of health to human well being, scholars continue to debate the substance behind the trends in various health-related variables. Measures of longevity are a case in point. Life expectancy at birth has more than doubled in many industrial countries over the past 150 years. There is lingering doubt, however, whether underlying health improved commensurately because falling mortality rates could have been offset in part by rising morbidity rates. Thus, while people were living longer, they also might have carried a greater burden of sickness.

Despite the importance of the issue, research on the relation of morbidity to mortality has advanced slowly because evidence on morbidity is scarce. Unlike official data on disease-caused deaths, no country has collected morbidity data over the long horizon. Researchers began studying the co-variation only after a series of the National Health Interview Survey (NHIS) results became available over the last few decades.

In the absence of clear evidence, most historical demographers have tacitly assumed that mortality and morbidity moved together (i.e. one was a reasonable substitute for the other). Working separately, the scholars that investigated the NHIS data, on the other hand, found that

[1] Sen (1987); Dasgupta (1993).
[2] Steckel and Floud (1997).

disability rates had increased during the 1970s and early 1980s when life expectancy had been rising, especially among the chronologically older segments of the population.[3]

The possibility of an inverse relation in an historical setting was raised during the 1970s once demographers proposed the framework for the epidemiologic transition. The transition referred to the progress of life expectancy since the nineteenth century as infectious diseases gave way to noninfectious chronic maladies as the main causes of mortality.[4] That type of a framework suggested that high mortality rates from infectious diseases in the past may have prevented the morbidity from chronic noninfectious maladies from surfacing. It was argued that curtailing of the mortality from infectious maladies since the nineteenth century may have produced the unintended result of prolonging the duration of chronic noninfectious maladies and increasing their prevalence.[5] Thus, underlying health may not have improved in tune with life expectancy.

However, researchers studying the prevalence of various maladies over the decades found puzzling, often conflicting, evidence between the 1970s, 80s and the 90s. During the 1970s, it seemed that longer life expectancy coincided with worsening prevalence rates of various maladies, but that relationship seemed to turn around some time during the 1980s.[6] The prevalence rates in these studies, however, were based on the self-reported morbidities and disabilities in the Surveys.[7] The rates could not always be decomposed into the contribution from incidence and from duration of illness. Consequently, it was unclear whether the frequency of illnesses was changing or whether people were suffering longer episodes of illness, or both. The underlying reasons for the puzzling changes in prevalence rates remained hidden.

The varying trends in prevalence rates also proved difficult to interpret because of the periodic revisions in the interview protocols, and because of the changing policy on disability rules from the 1970s through the 1980s.[8] Besides the confounding effects of changing rules, scholars cautioned that it may be unsafe to infer morbidity trends from self-reported illnesses and disabilities because changing cultural norms can reduce people's sickness thresholds and result in greater self-reported morbidity over time.[9]

The limitations of self-reported morbidity, the inability of surveys to chart very long-term trends in prevalence and the growing interest in retirement studies has prompted research on cohort-

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[3] Colvez and Blanchet (1981). Crimmins et al. (1989).
[4] Omran (1971, 1977)
[5] Gruenberg (1977)
[6] Crimmins et al. (1989), Crimmins and Ingegneri (1993), Manton et al (1993, 1995), Verbrugge (1984), Hayward et al (1998)
[7] To monitor disease prevalence, respondents in the National Health Interview Survey are asked about a set of diseases. A list of maladies is presented to one-sixth of the sample. Thus prevalence of all diseases for all individuals cannot be determined. The respondents in the interviews report "ever had," "currently have," or "had in the past twelve months," any of the listed conditions. That information is used to calculate prevalence.
[8] Bawden and Palmer (1984) and Schulz (1995).
[9] Johansson (1991, 1992)

level trends in mortality.[10] Some recent work has tried to identify birth-cohort effects in the prevalence rates during the 1980s and 90s. [11] This research has drawn increasing attention toward health-related conditions during the early twentieth century.

For the early twentieth century, however, morbidity records are even more scarce than the recent times. To shed light on the matter, researchers began looking into morbidity and mortality among select populations. Such populations include members of various insurance schemes in continental Europe during the nineteenth and early-twentieth century, and the Friendly Societies in England and Wales. For the United States, researchers have developed data sets on the medical records of the Civil War and the World War II veterans.[12]

While the new cohort-level research has highlighted the long reach of childhood health during the first half of the twentieth century, not enough is known about the relationship of mortality to the morbidity among the adults during that time. This article tries to narrow the gap by studying such trends in a select population: conscripted troops stationed in the continental United States from 1905 to 1939.

The first four decades of twentieth century provide a compelling backdrop for assessing the relation of morbidity to mortality during the epidemiologic transition. By most accounts, the health of the civilian population in the United States was undergoing a transformation. Overall disease-caused deaths were falling rapidly. Among 15 to 64-year olds, about 76 percent of the total reduction in all disease-caused deaths over 1900–94 was achieved within the first four decades. That proportion was about 90 percent for infectious maladies, and about 65 percent for noninfectious maladies.

Consequently, life expectancy had been rising swiftly. Life expectancy at birth rose from 47 years in 1900 to 64 years in 1940. Life expectancy at age ten advanced from 50 years to 58 years. Moreover, about 57 percent of the total improvement in life expectancy at birth, and about 50 percent of the total improvement in life expectancy at age ten over 1900-94 was attained during 1900–40.[13]

Besides longevity, this period saw rapid improvement in the net nutritional status as well. Adult stature of native-born Americans increased, from 170 cms for the 1900 birth cohort to 176 cms for the 1940s birth cohort. That gain accounted for about 75 percent of the total increase in adult stature over 1890-1970.[14]

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[10] Manton and Myers (1987), Wilmoth et al. (1990), Manton et al. (1997).
[11] Reynolds et al (1998).
[12] See Fogel (1994), Costa and Steckel (1997), Riley (1989, 1997), Murray (2003, 2005), Edwards et al (2003).
[13] Human Mortality Database.
[14] Steckel (1995, 2003).

Such improvements in disease-caused mortality, longevity and in the net nutritional status leave little doubt that a health transition was underway. Conscripted from a population going through that transformation, the troops' experience provides a unique opportunity to study the relation between morbidity and mortality trends during this time. Moreover, unlike the survey data, the annual data for the army allow the construction of variables such as prevalence, incidence, sickness duration and mortality necessary for an assessment of the matter at hand.

The findings from this population, however, only partially agree with the hypothesis that morbidity rates relate inversely to mortality rates. In particular, during the transition, decline in the mortality rates coincided with the fall in period-prevalence rates of most disease categories. The decomposition of the period-prevalence rate into the incidence rate and the sickness duration reveals that the incidence fell in tune with the mortality rates, whereas the sickness duration did not always do so. Moreover, the incidence rate accounted for the bulk of the reduction in the prevalence rate for most disease categories.

Furthermore, the direction of change in the sickness duration varied across disease categories. Its variability suggests that it may be susceptible to idiosyncratic influences that weaken its connection to the underlying trends in health. Moreover, the findings indicate that trends in the prevalence rates and mortality rates could often appear disconnected. However, until the two components of prevalence are separated, the reasons for that apparent disconnect may remain unclear. Besides uncovering the critical role of incidence rates during the transition, the findings of this inquiry caution that what may be true for one place or group may not necessarily be true for another.

Before discussing the data and the results, it helps to briefly view the framework that clarifies the issues.

The Framework

The central issue of the debate is whether the direction of morbidity and mortality rates differs during the epidemiologic transition. Prevalence rates of various diseases are widely used to study the trends in morbidity. The standard expression for disease prevalence is

$$P_{it} = I_{it} \times D_{it} \qquad (1),$$

where, P_{it}, I_{it} and D_{it} are the prevalence, the incidence and the average sickness duration from disease i during a reference period t. The incidence is the number of sickness episodes in a population. The average duration is the time spent sick per episode.

It is important to note that sickness duration has meaning only if there is incidence. It follows that inference about underlying health based largely on sickness duration can be misleading. To infer properly about underlying health, it is necessary to account for the prevalence rate in terms of incidence and duration. That can be done by dividing both sides of equation 1 by the mean strength of the population, N_t, and the number of days during a year to calculate the period-prevalence rate:

$$\frac{P_{it}}{N_t \times 365} = \frac{I_{it}}{N_t \times 365} \times D_{it} \tag{2}$$

Take natural logarithms on both sides and differentiate with respect to time

$$\frac{\hat{p}_{it}}{p_{it}} = \frac{\hat{\varepsilon}_{it}}{\varepsilon_{it}} + \frac{\hat{d}_{it}}{d_{it}} \tag{3},$$

where, p_{it}, ε_{it} and d_{it} are the natural logs of the variables. This equation can be written as

$$g_{it}^{p} = g_{it}^{\varepsilon} + g_{it}^{d} \tag{4},$$

where, g_{it}^{p}, g_{it}^{ε} and g_{it}^{d} denote the percentage changes that can be calculated directly from the data. If average duration remains unchanged, equation 4 implies that the period-prevalence rate would change solely because of the period-incidence rate. A fixed incidence rate implies that the prevalence rate changes entirely because of changing duration. Between those two possibilities, the prevalence rate can change as both incidence and duration rise, fall or differ in direction.

In particular, rising duration may swamp the reduction in the incidence rate. Consequently, the period-prevalence rate may rise over time. However, the increased prevalence rate would pertain to progressively smaller fractions of the population. Therefore, an upward trend in the prevalence rate, by itself, could portray a grim picture of underlying health, whereas an accounting of the components would reveal otherwise.

To relate the prevalence rate to the mortality rate, consider another epidemiologic term called the fatality ratio that relates mortality to incidence rates. For disease *i*, during period *t*, the fatality ratio, F_{it}, measures deaths, Δ_{it}, per reported case of sickness, I_{it}. Thus,

$$F_{it} = \frac{\Delta_{it}}{I_{it}} \tag{5}$$

Divide the numerator and the denominator of the right-hand-side of equation 5 by the mean strength of the population N_t and the number of days:

$$F_{it} = \frac{\Delta_{it}}{N_t \times 365} \div \frac{I_{it}}{N_t \times 365} \tag{6}.$$

Take natural logarithms on both sides

$$\Omega_{it} = \delta_{it} - \varepsilon_{it} \tag{7},$$

where, Ω_{it}, δ_{it} and ε_{it} are the natural logarithm of the fatality ratio, the death rate per person-year and the period-incidence rate, respectively. Differentiate equation 7 with respect to time

$$\frac{\hat{\Omega}_{it}}{\Omega_{it}} = \frac{\hat{\delta}_{it}}{\delta_{it}} - \frac{\hat{\varepsilon}_{it}}{\varepsilon_{it}} \tag{8},$$

which can be written as

$$g_{it}^{\Omega} = g_{it}^{\delta} - g_{it}^{\varepsilon} \tag{9},$$

where, $g_{it}^{\Omega}, g_{it}^{\delta}$ and g_{it}^{ε} denote the percentage change in the fatality ratio, the death rate and the incidence rate.

Equations 4 and 9 can shed light on the debate's central issue, which, in strict form, can be stated thus: under what conditions would the percentage change in the prevalence rate equal that of the mortality rate?

There are two conditions. First, the left hand side of equation 9 must be zero so that

$$g_{it}^{\delta} = g_{it}^{\varepsilon} \tag{10},$$

which means that the long term fatality ratio must be constant so that the percentage changes in the incidence rate and the mortality rate equal. The second condition is that the second term on the right hand side of equation 4 must be zero so that

$$g_{it}^{p} = g_{it}^{\varepsilon} \quad (11).$$

That requires unchanged sickness duration so that the percentage change in the prevalence rate equals that of the incidence rate. If both of those conditions are met then equations 10 and 11 imply

$$g_{it}^{\delta} = g_{it}^{p} = g_{it}^{\varepsilon} \quad (12)$$

—equality of the percentage changes in the prevalence, incidence and the mortality rates. Though such stringent conditions may not always be satisfied, the broader concern is whether the directions of the prevalence and the mortality rates were similar. That is, does $g_{it}^{\delta} < 0$ over the long-term necessarily imply that $g_{it}^{p} < 0$ had occurred? If their directions diverged during the short-term, did the divergence persist? If not, the logical next step is to find out which component of the period-prevalence rate prevented that from happening.

The data

The data on the troops permit an inquiry into the prevalence rate for the aggregate and for the disease categories that make up the aggregate. They also allow an accounting of the prevalence rate in terms of incidence and duration. According to the received view of the epidemiologic transition, the composition of disease-caused deaths is said to have gradually shifted from infectious maladies to largely noninfectious degenerative maladies. However, it is yet unknown whether the composition of disease prevalence shifted in the same way. If the composition of prevalence rates had shifted that way, it is useful to find out which component of prevalence drove the shift.

It is possible to assess such details because, like the larger populations, the medical records of the army were organized according to the framework outlined in the International Classification of Diseases (ICD). The lists classify hundreds of maladies into broad-groups: diseases of the respiratory system, the nervous system, the circulatory system, the digestive system, cancers, infectious and parasitic diseases, among others. Revised essentially every ten years since the first revision in 1901, the lists were adopted by the army's medical department for compiling its medical records. The relevant ICD-lists (and the year of revision) are ICD–1 (1901), ICD–2 (1909), ICD–3 (1919) and ICD–4 (1929).[15]

However, the ICD-lists can be a potentially useful source only if a large number of diseases are properly assimilated into coherent variables. Samuel H. Preston, among others, has

[15] The year of adoption by the army differs from the year of revision.

recommended that it is prudent to assimilate diseases into broad categories rather than study their trends separately. Aggregating individual causes pertaining to a specific anatomical site can increase the accuracy of measurement.[16] Assigning cause can be subject to potential error, and closely-related maladies that pertain to a specific site are more likely to be mistaken for one another. For example, unspecified hemorrhage can be mistaken for cerebral hemorrhage and that mistake, rather than the incidence per se, may determine the observed trends of each. However, both are maladies of the circulatory system, and grouping them into that broad category reduces the chances of temporal inconsistency. The series can be constructed consistently only by tracking a particular composition of diseases across all ICD-lists, a standard procedure that this article has followed.[17]

To focus on the disease-related experience, external causes such as accidents and homicides were excluded. The remaining aggregate of all diseases was then split into its two main sub-components dubbed as infectious diseases and non-infectious diseases. Noninfectious diseases were then split further into some of its main sub-categories: diseases of the nervous system, the circulatory system, the digestive system, and cancers. The compositions of various disease groups across ICD lists are outlined in the appendix.

For each disease on the ICD-list, the medical department had recorded annually the episodes of sickness among the troops, the days lost to sickness, and the episodes that resulted in deaths. The reported sickness episodes, including new and returning cases, approximate the period-incidence rate. Dividing the days lost to sickness by the reported episodes yields the average sickness duration for each malady. The product of the period-incidence rate and duration then approximates the period-prevalence rate.[18] Furthermore, dividing the mortality rate by the incidence rate yields the fatality ratios.

The present data have several advantages over the data from other select populations. For example, some researchers have used the Friendly Society's records for inferring morbidity trends. In those records, incidence has been inferred indirectly from the number of people filing claims of sickness. The duration has been inferred from the total number of days the claimants received sickness benefits. Furthermore, increasing sickness duration in such records has been viewed as a definite sign of increasing human frailty over time.[19]

However, scholars have argued the data obtained from health insurance schemes are more safely viewed as records of sickness *absences* rather than sickness per se.[20] The duration of

[16] Preston et al (1972), Preston (1976).
[17] See Vallin (1987), D'Espaignet et al (1991); as is standard, the disease composition of various categories in this paper are based on ICD-9; see World Health Organization (1977).
[18] Unfortunately, the data on days lost to sickness from individual diseases do not appear in the annual records until 1904; prevalence rates could not be calculated for the period before that year; thus, the sample period 1905–39.
[19] Riley (1989, 1997).
[20] Murray (2003)

sickness absences are likely to bear as much a relationship to the structure of such schemes as to the level of sicknesses. A comparative study of European insurance schemes has argued that state-supported compulsory-membership schemes reported more episodes of sickness absences than the voluntary-memberships schemes. Unsupported by the state, the voluntary-membership schemes likely policed their claims more strictly than the compulsory-membership schemes.

Thus, the concern about an institution's influence on morbidity, especially about an upwardly trending morbidity, is expressed for two reasons: the claims of sicknesses may not have been medically authenticated, and some of the claimed sickness duration may have been mere absences.

The army was a government-run institution. That institutional set up remained constant during the period. To gauge the influence of the institutional backdrop, one would need to compare the morbidity trends among troops with the morbidities reported from a comparable non-government-run set up. However, such a reference is yet unavailable.

Nevertheless, within the given institutional set up, it is possible that the temporal pattern of rules and criteria for medical admissions could affect the recorded data. The broader criterion for admissions appears to have been that sick troops were sent off for treatment because sickness hindered the nature of the duties involved. Once admitted to the sick list, they stayed there until deemed fit to return to for work by the medical officer. Further, the present data do not pertain to self-reported claims. They pertain to maladies diagnosed, treated and authenticated by the medical officers. Arguably the medical evaluations could have been erroneous, but it is difficult to reexamine the accuracy of decades-old medical decisions.

However, the medical department appears to have been concerned about the veracity of reported sicknesses. They recorded the cases of malingering as a separate category. The rate of malingering, which was reported separately in the data only until 1916, is shown in Figure 1a. Enforcement of rules may have become more lax over time because fewer cases of malingering were caught. However, one can also infer that enforcement became stricter because fewer potential malingerers got away with feigned illnesses.

While the inference can go either way, the very existence of such a category indicates that the medical officers viewed other cases as genuine. Unfortunately, it is unclear from the data source whether malingering stopped altogether after 1916 or was included in ill-defined or unspecified causes since then. For the period it was reported separately, malingering accounted for at most 0.6 percent of the total disease-caused incidence rate and never more than 0.25 percent of the total sickness duration. Both are too small to influence the broader results presented here.

The size of ill-defined causes may shed light on the varying strictness of rule enforcement as well. Stricter rule enforcement may have required that the medical officers specify the cause for the reported sicknesses. Figure 1b shows that the period-incidence rate and the sickness duration for ill-defined causes first diminished, then steeply increased during World War I and the Spanish 1918 flu pandemic, and finally stabilized at a level slightly higher than its level before the War.

That slight increase after the War might suggest an easing of rules. But it is difficult to be certain about a direct link because the proportion of unidentifiable cases could have increased slightly as well. Some of that slight increase may also be attributable the inclusion of malingering that was reported separately before the War but not afterward. As a fraction of the all disease-caused incidence rate, Ill-defined causes ranged 0.9-2 percent before the War and 3-5 percent afterward. Here, too, the proportions are small to sway the broader trends explored in this article.[21]

In view of the uncertainty about rule enforcement, it might be tempting to say that there is little point in reconstructing the morbidity experience among the troops. However, that may be premature because there are several features in the data that cannot be explained in purely institutional terms. Moreover, even for ill-defined causes it was difficult to clearly establish the influence of rules. Linking rules to the trends in incidence, prevalence and mortality from hundreds of maladies becomes is daunting, and, perhaps, an unproductive exercise, especially if the inferences from such an exercise are to be inconclusive.

The present data have some more advantages over self-reported morbidity that may or may not be medically authenticated. Critics have argued that self-reported morbidities are sensitive to changed in the cultural norms about sickness. Changing norms can alter perceptions of sickness in a way that reduces people's threshold of it. Consequently, reported prevalence rates could trend upward and it may be unsafe to interpret such a trend in strict biological terms.[22]

However, unlike for civilians, the present data may not have been generated by the troops' perception of sickness. It was the medical officers that decided whether a reported case qualified as sickness. While sicknesses would have taken their own natural course, the medical officers and not the troops' perception decided the duration of treatment. Though medical officials, too, may have been influenced by the broader cultural norms, inconsistency in the data because of the evolving expertise of the medical officers may be of greater relevance to the present scenario. Moreover, that expertise itself may have influenced the trends in incidence and duration in this population.

The period under consideration nests between two major biomedical developments: the ascendancy of the germ theory of diseases during the closing decades of the nineteenth century, and

[21] Ill-defined causes and malingering are excluded from the results, even the aggregate-level results, presented below.
[22] Johansson (1991).

the emergence and the widespread use of antibiotics in the 1940s and 50s. Successive annual medical reports refer to the importance of enforcing sanitation standards; the reports also contained special sections on the progress against various infectious diseases and on the measures that led to that progress over time. However, such progress was a sign of the times in the larger population as well; civilian mortality from infectious diseases had been falling rapidly during the first four decades of the twentieth century. That the medical officers may have been instrumental in containing infectious diseases in this population only makes these data more relevant.

Furthermore, as a sign of advancing biomedical knowledge, the ICD-lists used by the medical department changed along similar lines as that of the larger population. As discussed earlier, the data were rearranged along the lines of ICD-9. This standard procedure uses the more recent knowledge to reconstruct the various broad disease categories in the past. It does so by grouping maladies that pertain to specific anatomical sites. Variables based on a group of maladies are less susceptible to spurious trends than the variables pertaining to individual maladies.

That grouping likely smoothes out distortions caused by the changing medical expertise as well. The previously-discussed example of cerebral hemorrhage and unspecified hemorrhage may illustrate. After a change in the medical view, some cases of unspecified hemorrhage may come to be seen as cerebral hemorrhage. This would distort the trends in both unspecified and cerebral hemorrhage before and after the change in the medical view. However, as long as both types of hemorrhage are grouped into circulatory maladies, the likelihood of distortion stemming from the changed medical view is reduced provided all variables—incidence, sickness duration, prevalence and mortality—are constructed by using the same definition.

Furthermore, successive ICD-lists may give the appearance of covering more maladies. However, that does not necessarily mean that newer types of maladies surfaced or that medical officers began identifying newer types of ailments. The expansion in the list could result from more detailed recording of maladies. For example, what was recorded as tuberculosis of "all types" in one list was subsequently recorded as tuberculosis of the lungs, the bones, the meninges, among others, as separate entries.

In sum, the experience of troops stationed in the continental United States provides a reasonable backdrop for evaluating the relationship of morbidity to mortality. Within a given institutional set up, the data pertain to a large number of maladies. Though the influence of varying rule enforcement and cultural factors may not be ruled out, it might be premature to conclude that the entire morbidity experience over the four decades was determined by them.

Period-Incidence rates and Mortality rates

The relation between the trends in the period-incidence and mortality rates can be studied through the fatality ratios. The ratio measures deaths per reported episode of sickness.

Figure 2 shows that the fatality ratio for the broader variables. On the margin, the contour of all diseases appears to mimic the contour for infectious diseases, perhaps reflecting the substantial progress in the control and treatment of such diseases during this period. Moreover, after 1915–19, the level of the fatality ratio for the two disease categories became more distinct. The sharp increase in the middle pertains to World War I and the 1918 Spanish flu pandemic, both special circumstances; as outliers they are excluded from all of the results presented below.

There should be little doubt that the *level* of the incidence rate would be at least as large as the level of the mortality rate from any disease. However, the central issue is not about levels. It is whether the long-term direction of the incidence and the mortality rates were similar. Equation 9, rewritten below as equation 9a, helps assess that matter:

$$g_{it}^{\Omega} = g_{it}^{\delta} - g_{it}^{\varepsilon} \qquad (9a),$$

where, $g_{it}^{\Omega}, g_{it}^{\delta}$ and g_{it}^{ε} denote the percentage change in the fatality ratio, the mortality rate and the incidence rate. There are three possible scenarios for the change in the fatality ratios

$$\begin{aligned} g_{it}^{\Omega} &> 0 \ \text{if} \ g_{it}^{\delta} > g_{it}^{\varepsilon} \\ g_{it}^{\Omega} &= 0 \ \text{if} \ g_{it}^{\delta} = g_{it}^{\varepsilon} \\ g_{it}^{\Omega} &< 0 \ \text{if} \ g_{it}^{\delta} < g_{it}^{\varepsilon} \end{aligned} \qquad (13)$$

Figure 3 shows that there was considerable variability and no clear time trend in the g_{it}^{Ω} s for various disease categories. Though the changes in the incidence and mortality rates may not always have been identical at each point in time, the sharp saw-toothed pattern indicates they might not have diverged systematically either. The Figures also suggest that the sharp swings in the data can potentially sway inference in studies on the short term relation of deaths to incidence. However, inference based solely on the first and the last datum of a period might be misleading as well because it would skip all the variability in the middle. Therefore, for the numerical results, it is prudent to account for the fatality ratios through the shorter five-year intervals and then average the annual changes to obtain the results for the entire period.[23]

[23] 1905–09, 1910–14, 1915–19, 1920–24, 1925–29, 1930–34, 1935–39.

Excluding the data for the interval 1915–19, Table 1 shows an accounting for the fatality ratio in terms of the change in the incidence and the mortality rates. The fatality ratio diminished at an average annualized rate of about one percent per annum for all diseases and at about 3.3 percent per annum for infectious diseases. However, it increased at approximately 3.8 percent per annum for non-infectious diseases. Excepting cancers, both the incidence rate and the mortality rate diminished for all disease groups; for cancers, both rates increased. The decompositions suggest that the direction of the incidence and the mortality rates for various disease categories were similar during the epidemiologic transition of this population.

The fatality ratio-profile during the transition shifted gradually toward the non-infectious diseases with higher fatality ratios. However, that shift does not necessarily imply that the underlying health of this population had worsened or that the population became any frailer over time. Note that in equation 9a, the fatality ratio can increase even as the mortality rate or the incidence rate or both reduce.

As Table 1 shows, the fatality ratio had increased for most categories of the non-infectious group. However, that increase occurred because the incidence rate had reduced along with the mortality rate. Since incidence usually precedes disease-caused mortality, it is reasonable to infer that the mortality rate fell because incidence of sickness had reduced; progressively, more people were able to escape sickness as well as death. Thus, in this population, the long-term incidence and mortality rates trended in the same direction, although the two might have diverged temporarily over the shorter time intervals.

The second section of this paper outlined that the percentage change in the prevalence and mortality rates would equal provided two conditions were satisfied. One condition required the percentage change in the fatality ratio to be zero over time. For that to happen, the change in the incidence and the mortality rate should equal (equation 10). Numerically, these data do not satisfy that strict condition. A reason for that shortfall is that the numerical results are averages over the shorter time intervals.

The main point, however, is that the percentage change in the fatality ratio should not trend permanently, upward or downward. It would not trend if the percentage changes in the incidence and the mortality rates do not diverge permanently. Figure 3, therefore, provides a much better perspective of that condition than the numerical results.

That lack of permanent trend then prompts the question: is there something special about the troops' experience? In other words, for some other population, or the entire civilian population, could the g_{it}^{Ω} have trended upward or downward permanently?

Under the scenario of declining mortality rates, equation 9a says that g_{it}^{Ω} would trend upward permanently only if the reduction in the incidence rate is always larger than the reduction in the mortality rate. But that kind of a dynamic may not persist. If it were to persist there would come a point where the *level* of mortality from a disease would exceed the level of the incidence rate, and would continue to so indefinitely. That outcome seems implausible. For example, deaths rates from—say, the flu—cannot indefinitely exceed the rate at which people fall sick from it. So g_{it}^{Ω} cannot trend upward indefinitely during the mortality decline.

Can g_{it}^{Ω} trend downward indefinitely? When mortality rates are declining, equation 9a says that there are two possible scenarios. First, the incidence rate continues to increase, while the mortality rate diminishes. However, that dynamic limited too. Continuously diminishing mortality from a disease should eventually lead to no deaths. At that point, the fatality ratio will become zero and remain there as long as there are no deaths. The second case is that incidence rate reduces, but the reduction in incidence remains smaller than the reduction in the mortality rate. But this dynamic is unsustainable over the long term for the same reason. So g_{it}^{Ω} may not indefinitely trend downward at a constant rate either.[24]

During the mortality decline, if g_{it}^{Ω} can neither trend permanently upward nor downward, it must either fluctuate around a stationary value or become zero. The lack of a trend in g_{it}^{Ω} reveals the importance of the incidence rate for studying the long term trends in morbidity in relation to mortality. Even when there is no mortality from a disease, the incidence rate provides important information about the progress in morbidity rates.

The possibility of a zero fatality ratio, however, brings up some important caveats. The analysis presented above has a significant shortcoming that stems from the grouping of maladies into broad categories. Not all maladies reported in the data resulted in deaths consistently. For such maladies the annual fatality ratio could be zero even as the period-incidence rate remains positive. That amounts to a clear divergence between the mortality rate and the incidence rate. However, isolating each malady is not recommended for various reasons outlined earlier. Disaggregating the data any further must wait for a consensus on the maladies whose medical diagnosis may have remained uniform over the period under consideration.

Nevertheless, consider a case where the fatality ratio is zero but the incidence is positive. For given incidence, could one conclude that human well being had reduced compared to the past

[24] It can trend downward permanently only under one case. The case involves rising mortality and requires that the percentage increase in the incidence rate exceed that of the mortality rate. While this may be relevant to a small segment of maladies, the debate about health is pertinent when mortality is decreasing. The case of long-term rise in mortality, by itself, would be alarming. The concern about underlying health in such a scenario would be indisputable anyway.

when the fatality ratio might have been positive? If deaths have been prevented over time, the gut response is that human well being had improved compared to the past.

However, that normative assessment can be questioned. An example may illustrate the quandary:

> "…the introduction of insulin in 1920s began to allow diabetics to control the disease, deferring its effects on health. Insulin did not lead diabetics to recovery, however, so that the prevalence of the disease in the population increased. More people survived with the disease, meaning that they died later in life (hence mortality declined), while the average duration of an episode of diabetes increased."[25]

Suppose that no deaths from diabetes ensued for about ten years after insulin was introduced. The fatality ratio over those ten years would be zero. Deaths were prevented, which, normatively, is an improvement. But more time was spent sick because the duration of diabetes had increased. Does that mean that overall health had worsened compared to the past? The answer is uncertain.

It is uncertain because more information is necessary. For instance, one may ask: did the age of onset of diabetes change? Suppose that after insulin was introduced the new age of death—say, 65 years—is held constant. If the age of onset of diabetes had remained constant at, say, 40 years, the total (and the average) duration must have increased because the preexisting cases began living longer with diabetes and so did every new case that initiated diabetes at age 40.[26]

On the other hand, if the age of onset had been deferred, it is unclear whether the introduction of insulin had increased the average duration of diabetes episodes. Holding the new age of death constant at 65, if the age of onset for every new case had been deferred from age 40 to 55, average duration may not have increased.

Now if the age of death shifts as well, the answer depends on the relative percentage shifts in the age of onset and in the age of death. Therefore, without additional information, it is difficult to say whether the duration prolonged, shrank or remained constant.

Such complications make measures of current sickness duration ambiguous indicators of underlying trends in health. At the aggregate-level, and especially without precise measurement of additional parameters, normative judgments based on current duration are likely to be inconclusive. To understand more such problems, it helps to look further into sickness duration.

Duration of Sickness

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[25]Riley (1999), p., 120.
[26] The crucial insight on the age of onset is discussed in Manton (1982).

There is little doubt that duration should be integral to the study of disease prevalence. However, some researchers have emphasized duration as the more relevant gauge of morbidity.[27] But there appears no a priori basis for that emphasis because duration cannot exist on its own. For duration to be observed at all there must be some incidence.

The emphasis on duration also likely stems from a distinction between sicknesses and deaths. While they may be distinct in a general way, for normative analysis and for measurement the distinction is less clear.

Amartya Sen has cautioned that disease-caused deaths usually signal serious sickness. The seriousness of the sickness may not be dismissed merely because, on death, there remains no more sickness duration that requires medical attention.[28]

Further, the separation of sickness from death perhaps overlooks that the sickness incidence includes the episodes that resulted in death. The level of disease-caused deaths, when they occur, must be a subset of the incidence during any reference period.

Moreover, people who die from disease may have suffered some duration of sickness as well. Consequently, the observed sickness duration includes the duration of those who continue to remain ill and of those whose illness had resulted in death. It is unclear why the observed duration would then be pertinent to only one group (sick, but alive) but not to the other (dead, *after* sickness). If the sick and the dead are to be considered as two separate categories, then their sickness durations need to be separated as well. The average duration conflates them.

Furthermore, the epidemiologic transition of mortality is studied in terms of the frequency of deaths in the population. In parallel terms, it seems more appropriate to examine the transition of morbidity in terms of the frequency of morbidity—the incidence rate.

Besides the conceptual problems, accurate measurement of duration is difficult as well. The current time spent while sick can be gauged in at least two (crude) ways. The first gauge, average duration (D_{it}), indicates whether the sickness episodes over time are prolonging or shrinking on average. The reference group for this measure is the people who fall sick.

However, if the incidence rate diminishes over time, average duration becomes relevant to a diminishing fraction of the total population. Consequently, the percentage change in the time-loss among the sick does not necessarily represent the rate of time loss suffered by the entire population. For temporal welfare comparisons, therefore, a broader measure might be relevant. It is gauged by an index called the non-effective ratio (η_{it}) that measures the fraction of total person-days lost to sickness from each disease *i*:

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[27] Riley (1989, 1997)
[28] Sen (1998).

$$\eta_{it} = \frac{S_{it}}{N_t \times 365} \times 100000 \qquad (14),$$

where, S_{it} is the number of days lost to sicknesses and N_t is the mean strength of the entire population.

For all disease categories, Table 2 shows average annual rate of change in the mortality rates and in the two measures of time loss. Excepting cancer, the non-effective ratio had diminished along with the death rates for all categories. Further, among the disease categories for which the time loss diminished, the non-effective ratio had reduced more rapidly than the average duration. However, for maladies of the respiratory system, the circulatory system and the digestive system, the sickness duration had increased, a nuance that remains hidden in the aggregate (all diseases). Thus, unlike the incidence rates, sickness duration across diseases portrays a mixed picture of underlying health.

Besides that ambiguity, there are more reasons why duration might be an unreliable indicator. The duration could be subject to several idiosyncratic factors such as the effectiveness of medical therapies and the severity of the medical condition. For a given level of incidence, the duration may diminish as medical technology becomes more effective. Or, as the discussion earlier on the medical technology for diabetes revealed, the duration may increase, stay constant or decrease depending on several other parameters. For chronic conditions such as diabetes, the duration in the annual records may not reflect the *true* sickness duration as well. In this population, at least, it is difficult to say whether duration can be relied upon consistently as a metric of the underlying trends in morbidity. Episodes of sickness may prolong or shorten depending upon the many factors.

This is not to say that sickness duration provides no relevant information about the state of human well being. Just that the information it provides may not be consistent over time. The issue here is not relevance, but consistency. It is whether duration can be interpreted consistently as the primary indicator of morbidity trends, and morbidity trends only, during the health transition.

Furthermore, life spans increased during the epidemiologic transition. None of the presented estimates calculate duration as the fraction of the lengthening life span. Over 1900–40, life expectancy at age 15 in the civilian population had increased from 46 years to 53 years, a 15 percent increase. That increase by itself may significantly diminish the sickness time as a *fraction* of the total lifetime available, to those who were sick, and to the entire population. But even so, unless the shifts in the age of onset and the age of death are ascertained, it is difficult to be conclusive about duration. Ascertaining those shifts requires age-specific data and is beyond the

scope of this article. However, it is worth pointing out that despite the adjustments to the numerical estimates, interpretation is likely to remain confounded by a host of other factors.

That uncertainty about sickness duration, however, brings up a major problem. In the second section, equality of the change in the prevalence, incidence and mortality rates required sickness duration to remain unchanged over the long haul. The analysis so far is inconclusive about whether that condition was met during this period.

Nevertheless, it is still informative to find out the importance of duration to the overall change in the prevalence rates from various diseases.

Decomposition of the Period-Prevalence rates

It helps to first briefly view the likely broader relation of prevalence and mortality rates across disease categories. Panel A of Figure 4 shows the positive association between the arithmetic means of annual death rates and prevalence rates across disease categories; the correlation is 0.83. Though not perfect, the correlation indicates that the diseases that caused more deaths were on an average more prevalent as well.

Over short periods, sickness from maladies such as the flu may suddenly strike a large fraction of the population. Unexpected outbreaks of contagious maladies may make their trends more volatile than the trends of chronic maladies. The variance of prevalence and of mortality rates from various diseases may gauge their volatility. Panel B shows that the variances of the period-prevalence and mortality rates relate positively; the correlation is 0.95.

This preliminary broader evidence appears unsupportive of the hypothesis that the prevalence rates relate inversely with mortality rates. However, we need to find out which component of the period-prevalence rate was responsible for that positive relation.

Table 3 shows the average annual percentage change in the prevalence rates over shorter time intervals. The second-to-last column is the average of the percentage changes in the preceding columns, and the last column is the average percentage change excluding the interval 1915-19.

At the peak of the pandemic, prevalence rate from respiratory diseases had increased by 223.4 percent from the previous year. The period-prevalence rate had increased by 121.3 percent for all diseases, by 97.1 for infectious diseases, and by 106.8 for non-infectious diseases. For most disease categories**,** the sharp increases during that interval had interrupted the reductions in the prevalence rates during the prior years. The prevalence rates diminished during 1920-24 for all disease categories, but increased during 1925-30. Excepting maladies of the circulatory system, the digestive system and cancers, the prevalence rates diminished during the early 1930s, after which the pattern across disease categories was mixed.

To account for the prevalence rate reconsider equation 4 rewritten below as equation 4a

$$g_{it}^{p} = g_{it}^{\varepsilon} + g_{it}^{d} \qquad (4a),$$

where, g_{it}^{p}, g_{it}^{ε} and g_{it}^{d} denote the percentage changes in the prevalence rate, incidence rate and the sickness duration.

For all disease categories, the second and third columns of Table 4 show the g_{it}^{ε} and g_{it}^{d}, and the fourth column shows their sum, g_{it}^{p}. Excepting cancers, the prevalence rate and the incidence rate diminished for all disease groups. However, the sickness duration did not always follow suit.

Furthermore, bulk of the reduction in the prevalence rate came from the reduction in the incidence rate. The diminishing incidence rate accounted for about 82 percent of the reduction in the prevalence rate of all diseases; about 60 percent of the reduction in infectious diseases, and about 95 percent of the reduction in non-infectious diseases. It was only for cancers that the duration accounted for a larger fraction of the total change in the prevalence rate. The prevalence rate of cancers had increased, and the sickness duration accounted for about 80 percent of it. Thus, for the aggregate and for most disease categories, the incidence rate was the heftier component of the prevalence rate.

This result differs from some of the results from the data on the Friendly Societies in Britain during the nineteenth and the early twentieth centuries. The results for the Societies showed that increasing duration had swamped the effect of diminishing incidence rate so that the prevalence rate had increased during the mortality decline.

All told, it is difficult to infer from the results that the underlying health of this population worsened during the epidemiologic transition. Further, it was the incidence rate that related more consistently with the direction of the prevalence rate. The direction of the incidence rate and the mortality rate were similar as well. For most disease categories, those two results suggest that the positive relation of the prevalence rate and the mortality rate may have been driven by the direction of the incidence rate.

Moreover, several features of this population's transition appear to have been different from the received view of the transition proposed during the 1970s. According to that view, high rates of mortality from infectious diseases ought to have coincided with low rates of morbidity from chronic noninfectious maladies. However, in this population, high rates of infectious disease-caused mortality early during this period had coincided with high rates of prevalence rates from most noninfectious chronic maladies.

According to the received view, the declining rates of mortality from infectious disease should have coincided with increasing prevalence rate of chronic noninfectious maladies. However, the reverse appears to have occurred in this population: prevalence rates of most noninfectious disease categories fell along with the declining mortality rates from infectious diseases.

Further, in the received view, increasing prevalence rate of noninfectious maladies should have been characterized by prolonging sickness durations. Though there are many caveats about the trends in sickness duration, it is worth noting that the prevalence from most noninfectious disease categories reduced even as the conventional measure of duration had increased for some of them. The trends in prevalence of most noninfectious categories appeared to have been driven by incidence and not duration.

In sum, there are four significant differences from the received view. First, the early segments of the period witnessed high rates of prevalence and deaths from both infectious diseases and noninfectious diseases. Second, the trend in the mortality rates from infectious diseases related positively with that of most noninfectious diseases, as if they were being driven by a common set of underlying factors. Third, the prevalence rates from infectious maladies and most noninfectious maladies trended downward, which, too, is indicative of an underlying synergy Fourth, the prevalence rate of most chronic noninfectious maladies reduced during the transition and it did so despite the increasing duration for some of them.

One reason for the differences with the received view could be that the age-composition of this population may have been much younger than that of the general population. While an inquiry into the age-specific prevalence and mortality is beyond the scope of this article, the evidence seems to indicate that the received view may have under-emphasized the extent of chronic conditions prevalent among the chronologically young during the early stages of the transition. If etiologies of infectious and noninfectious diseases had overlapped—such as the effects of childhood infections on chronic conditions during adulthood—it is possible for high prevalence and death rates from both infectious and noninfectious maladies to coincide.

Curbing the etiology of one category of maladies could, in turn, have had a salutary effect on the prevalence and mortality from the other category, though not necessarily at the same time. That type of a process could underpin the positive relation between the prevalence rates of infectious and noninfectious maladies. It could also underpin the observed positive relation between the mortality rates of the two disease categories.

A growing body of evidence has been suggesting that chronic and degenerative maladies may have been at least as significant as infectious diseases during the early stages of the transition. The coincidence of high rates of chronic, degenerative maladies with relatively shorter life spans

during the late nineteenth and early twentieth century suggests such conditions surfaced much earlier in life.[29] Indeed, for the United States, the Union Army data reveal the ubiquity of chronic conditions during the mid-nineteenth century. Such conditions afflicted even the teens and the young adults to a much greater extent than today.[30]

Further, the received view proposed that increasing longevity would have resulted in longer durations of chronic maladies. However, that proposition assumed that there would be no delay in the age of onset of such maladies during the transition. Helmchen (2003) has found that the average age of onset for heart disease among men born 1830-45 was about 55.9 years; that age had shifted to 65.4 years for men born during 1918-27. Between the two cohorts, the average age of onset of arthritis had shifted from 53.7 years to 64.7 years; for neoplasms, from 59 years to 66.6 years; for chronic respiratory maladies, from 53.8 years to 65 years.

That evidence appears consistent with the declining incidence of chronic maladies among the troops. Along with the troops' improving net nutritional status, incidence rates from a broad spectrum of maladies fell, suggesting that the age of onset was being deferred. Consequently, mortality rates fell, an indication that the age of death was being deferred as well. As a result, the average life span in this population may have lengthened.

Another reason for the inverse morbidity-mortality relation in the received view is that it does not take into account cohort effects. During the transition, successive birth cohorts are likely to have been raised under progressively more salutary conditions. The effects of early-age health related factors are likely to surface when the cohort is younger before doing so when the cohort becomes chronologically older. The first four decades of the twentieth century may have been the time when the cohort effects began surfacing among the younger segments of the population. That could have shaped the downward period-trend in the incidence of various chronic conditions among the troops. If this development bears any relation to the larger population, this long-term development could also have continued into the post-World War II period, perhaps surfacing among the chronologically older segments of the population then. [31]

All told, many aspects of the epidemiologic transition in this select population differ from the received view.

This paper began with the proposition that if morbidity rates related inversely with the mortality rates, underlying health may not have improved in tune with life expectancy. As a result, life expectancy and mortality rates could over-state the well being achieved during the transition.

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[29] Arora (2005).
[30] Lee (2001).
[31] Costa (2000), Costa and Steckel (1997).

However, the data revealed that the directions of prevalence and mortality rates were similar. Progressively smaller fractions of this population fell ill and the well being of this population improved over time.

But was that improvement commensurate? For the aggregate "all diseases," the incidence rate decreased at an average annual rate of 3.63 percent, while the mortality rate fell at the rate of 4.64 percent, and those changes are not commensurate.

However, the aggregate result hides the variation across disease categories. For infectious and parasitic maladies, the incidence fell more steeply than the mortality rate. Whereas, for respiratory infections, the mortality rate fell at a faster pace. It is for noninfectious maladies that sizable improvements in the incidence rates occurred. The incidence rates for most noninfectious chronic disease categories fell rapidly and did so at a much faster pace than the mortality rate. Some of the numerical results may appear unsustainable, but that is because the sample period does not extend long enough for the data to show subsequent corrections. The absence of a permanent trend in the changing fatality ratios suggested that the percentage changes in the incidence rate and the mortality rate may not have diverged permanently.

As far as the duration of sickness is concerned, the analysis is yet inconclusive. Suffice it to mention, for all disease categories, the duration pertained to progressively smaller fractions of the population because of falling incidence. Further, it is likely that once the lengthening life spans are taken into account, sickness duration may have diminished significantly more than the results presented here.

But suppose for the time being that the information on incidence and duration were unavailable, and prevalence rates were all that could be observed. Mortality rates in aggregate fell at an average annual rate of about 4.64 percent; the prevalence rate did so at 4.43 percent. Give or take, that is a commensurate change.

However the details across disease categories vary. For infectious and parasitic maladies, the prevalence rate fell at a faster pace than the mortality rate, suggesting that the underlying health of this population, as far as infections are concerned, had improved faster than what the mortality rates would have indicated. The case for the aggregate of noninfectious and chronic maladies is similar. Excepting cancers, the subcategories of noninfectious diseases, too, suggest that health was improving more than what the trend in the mortality rate was indicating. While this seems counter-intuitive, note that the results pertain to the rates of change and not to levels. Over the short horizon of this study, the pace of reduction in the prevalence rates can exceed that of mortality rates. However, that discrepancy could not have persisted because it implies the implausible scenario

where the final level disease-caused mortality exceeds level of sickness. Therefore, some correction must have followed after this period.

Conclusions

This article has used American army records of the early 20th century to address a controversy over the relationship of mortality to morbidity. In the absence of clear evidence, most historical demographers have tacitly assumed that mortality and morbidity moved together (i.e. one was a reasonable substitute for the other). That assumption was being increasingly questioned since the 1970s when some evidence to the contrary became available.

However, among the army troops, the prevalence rate and the mortality rates from most disease categories related positively (including maladies such as cancer that had caused increasing mortality). Moreover, of the two components of the prevalence rate (incidence and duration), the former accounted for the bulk of the reduction in the prevalence for most disease categories. The trends in mortality, incidence and prevalence rates across disease categories were similar. However, the trend in the sickness duration often differed from them. The duration also appears to have been weakly connected with the other variables and, most likely, with the underlying health.

The findings suggest that the relation between prevalence and mortality rates over the long term may have been shaped by the trends in the incidence rate. Besides being the heftier component of the declining disease prevalence over time, the incidence rate tracked the mortality rate closely. These findings support the view that sickness and morbidity declined as life expectancy rose during the early stages of the health transition.

APPENDIX

Data Sources

All data come from various years of the Annual Report of the Surgeon-General of the Army to the Secretary of War published by the Government Printing Office. The data for 1914 is the average of 1913 and 1915 because the records for 1914 were inaccessible. For each disease-related variable, whenever the total of all diseases did not coincide with the one reported in the records, I used the total based on my calculations instead of the reported totals.

Composition of Variables

The composition listed in the Table below is based on the ninth revision of the International Classification of Diseases. The columns titled "No." indicate serial number and not the ICD-list number. Not all diseases mentioned under each category were recorded originally as a part of that category.

Appendix Table 1: Composition of Diseases-variables Across ICD Lists

No.	*ICD–1(1901)*	*No.*	*ICD–2(1909)*	*No.*	*ICD–3(1920)*	*No.*	*ICD–4(1929)*
			Infectious and Parasitic Diseases				
1	Typhoid fever	1	Typhoid fever	1	Typhoid fever	1	Typhoid fever
2	Undetermined fevers	2	Paratyphoid fever	2	Paratyphoid fever	2	Paratyphoid fever
3	Malarial fevers	3	Malaria (all types)	3	Typhus fever	3	Typhus fever
	Malarial cachexia	4	Smallpox and variole	4	Relapsing fever (all)	4	Relapsing fever
	Non-malignant infections	5	Vaccinia	5	Malta fever	5	Undulant fever
4	Scarlet fever	6	Measles	6	Malaria (all)	6	Smallpox
5	Smallpox	7	Scarlet fever	7	Smallpox	7	Measles
6	Measles	8	Diphtheria & croup	8	Measles (all)	8	Scarlet fever
7	Other eruptive fevers	9	Cholera nostras	9	Scarlet fever	9	Whooping cough
8	Diphtheria	10	Asiatic cholera	10	Whooping cough	10	Diphtheria
9	Cholera nostras	11	Dysentery (all types)	12	Diphtheria	12	Cholera (all types)
10	Asiatic cholera	12	Plague (all types)	13	Miliary fever	13	Dysentery (all types)
11	Dysentery (all types)	13	Erysipelas	14	Mumps	14	Plague (all types)
12	Leprosy	14	Dengue fever	15	Asiatic cholera	15	Erysipelas
13	Erysipelas	15	German measles	16	Cholera nostras	16	Acute poliomyelitis &
14	Dengue fever	16	Mumps	17	Dysentery (all types)		acute polioencephalitis
15	Mumps	17	Purulent infection &	18	Plague (all types)	17	Epidemic encephalitis
16	Epidemic cerebrospinal		septicemia	19	Yellow fever	18	Epidemic cerebrospinal
	meningitis	18	Whooping cough	20	Spirochetal hemorrhagic		meningitis
17	Acute infectious jaundice	19	Chicken pox		jaundice	19	Glanders
18	Other epidemic diseases	20	Mycoses	21	Leprosy	20	Anthrax, malignant pustule
19	Purulent infc.& septicemia	21	Respiratory TB	22	Erysipelas	21	Rabies

No.	*ICD–1(1901)*	*No.*	*ICD–2(1909)*	*No.*	*ICD–3(1920)*	*No.*	*ICD–4(1929)*
20	Trichinosis	22	Miliary TB	23	Acute anterior polio	22	Tetanus
21	Pulmonary TB	23	TB, other organs	24	Lethargic encephalitis	23	TB: Respiratory
22	TB, other organs	24	Syphilis	25	Meningococcus meningitis	24	TB: Others
23	Syphilis	25	Soft Chancre	26	Other epidemic diseases	25	Leprosy
24	Canchroid	26	Gonococcal infections	27	Chicken pox	26	Syphilis
25	Gonorrhea	27	Tuberculous meningitis	28	Measles	27	Gonococcal infections &
26	Other VD	28	Epidemic cerebrospinal	29	Dengue fever		other venereal diseases
27	Tetanus		meningitis	30	Glanders	28	Purulent infections &
28	Anthrax	29	Glanders	31	Anthrax		septicemia
29	Glanders	30	Tetanus	32	Rabies	29	Yellow fever
30	Rabies	31	Rabies	33	Tetanus	30	Malaria (all types)
31	Plague (all)	32	Yellow fever	34	Mycoses	31	Other protozoal parasites
32	Yellow fever	33	Anthrax	35	TB: Respiratory	32	Ankylostomiasis
33	Filariasis	34	Locomotor ataxia	36	TB: other organs	33	Hydatid cysts
34	Diarrhea and enteritis	35	General paralysis of insane	37	Syphilis	34	Other helminthes
35	Intestinal parasites (all)	37	Diarrhea & enteritis	38	Soft chancre	35	Mycoses
36	Pemphigus contagiosus	38	Ankylostomiasis	39	Gonococcus infections	36	Other infectious &
37	Dhobi itch	39	Intestinal parasites	40	Purulent infection & septi.		parasitic diseases
38	Other parasitic skin disease	40	Hydatid tumor of liver	41	Other infectious diseases	37	Epidemic cerebrospinal
39	Food poisoning	41	Poisoning by food	42	Cerebrospinal meningitis		meningitis
40	General paralysis of insane	42	Diarrhea & enteritis	43	General paralysis of insane	38	Locomotor ataxia
41	Locomotor ataxy	43	Furuncle and carbuncle	44	Diarrhea & enteritis	39	General paralysis of insane
		44	Other skin infections	45	Ankylostomiasis	40	Diarrhea & enteritis
				46	Intestinal parasites	41	Poisoning food
				47	Hydatid tumor of the liver	42	Carbuncle
				48	Poisoning by food		
			Respiratory System				
38	Influenza	40	Influenza	51	Influenza	43	Influenza
39	Bronchopneumonia	41	Diseases of the nasal fossae	52	Diseases of nasal fossae	44	Diseases of the nasal fossae
40	Pneumonia, other	42	Diseases of the larynx	53	Disease of larynx	45	Diseases of larynx
41	Bronchitis	43	Diseases of thyroid body	54	Bronchitis	46	Bronchitis
42	Diseases of nasal fossae	44	Bronchitis	55	Bronchopneumonia	47	Bronchopneumonia
43	Pleurisy	45	Pneumonia	56	Pneumonia: lobar	48	Lobar pneumonia
44	Asthma	46	Bronchopneumonia	57	Pneumonia, other	49	Pleurisy
45	Diseases of larynx	47	Pleurisy	58	Pleurisy	50	Congestion, edema of lung
46	Emphysema	48	Pulmonary congestion	59	Pulmonary emphysema	51	Asthma
47	Diseases of pharynx	49	Gangrene of lung	60	Other respiratory diseases	52	Pulmonary emphysema
48	Diseases of thyroid body	50	Asthma	61	Disease of pharynx, tonsils	53	Other respiratory diseases

No.	*ICD–1(1901)*	*No.*	*ICD–2(1909)*	*No.*	*ICD–3(1920)*	*No.*	*ICD–4(1929)*
48	Others	51	Pulmonary emphysema	62	Gangrene of lung	54	Disease of pharynx, tonsils
		52	Other respiratory diseases				
		53	Diseases of pharynx				
				Nervous System			
49	Encephalitis	54	Encephalitis(brain abscess)	63	Encephalitis(non-epidemic)	55	Encephalitis(intra-cranial
50	Meningitis	55	Encephalitis (other)	64	Encephalitis (other)		abscesses
51	Other spinal chord diseases	56	Simple meningitis	65	Simple meningitis	56	Encephalitis (other)
52	Paralysis without cause	57	Other spinal chord disease	66	Other spinal chord disease	57	Simple meningitis
53	Epilepsy	58	Paralysis unspecified cause	67	Hemiplegia & other -	58	Other spinal chord disease
54	Neuralgia & Neuritis		Hemiplegia, others		unspecified paralysis	59	Hemiplegia & other -
55	Others	59	Epilepsy	68	Facial paralysis		unspecified paralysis
56	Diseases of eye & annexa	60	Neuralgia & neuritis	69	Epilepsy	60	Epilepsy
57	Diseases of ears & annexa	61	Others	70	Neuralgia & neuritis	64	Neuritis
		62	Diseases of eye & annexa	71	Neurastenia	62	Paralysis agitans
		63	Diseases of ears & mastoid	72	Neuro-circulatory astehnia	63	Disseminated sclerosis
				73	Others	64	Others
				74	Diseases of organs vision	65	Diseases of organs vision
				75	Diseases of ears & mastoid	66	Diseases of ears & mastoid
				Circulatory System			
58	Acute articular rheumatism	64	Acute rheumatic fever	76	Acute rheumatic fever	67	Acute rheumatic pericard -
59	Rheumatic fever	65	Cerebral hemorrhage	77	Cerebral hemorrhage		itis
60	Cerebral hemorrhage &	66	Apoplexy	78	Cerebral embolism &	68	Cerebral hemorrhage
	Apoplexy	67	Chorea		Thrombosis	69	Cerebral embolism &
61	Softening of the brain	68	Softening of brain	79	Softening of brain		Thrombosis
62	Chorea	69	Pericarditis	80	Valvular heart diseases	70	Softening of brain
63	Pericarditis	70	Endocarditis, Myocarditis	81	Cardiac hypertrophy	71	Chorea
64	Acute endocarditis	71	Angina pectoris		& dilation	72	Pericarditis
65	Organic diseases of heart	72	Organic diseases of heart	82	Pericarditis	73	Acute endocarditis
66	Diseases of arteries	73	Diseases of arteries	83	Acute endocarditis	74	Chronic affections of the
67	Embolism & Thrombosis	74	Embolism & thrombosis	84	Cardiac arrythmias	75	valves of endocardium
68	Diseases of lymphatic -	75	Cardiac murmurs	85	Functional cardiac disorder	76	Diseases of myocardium
	System	76	Cardiac disorders, others	86	Diseases of myocardium	77	Diseses of coronary
69	Hemorrhage	77	Cardiac arrythmias	87	Diseases of coronary		arteries
70	Others	78	Variocele		arteries	78	Angina pectoris
71	Variocele	79	Other diseases of veins	88	Angina pectoris	79	Other diseases of heart
		80	Diseases of lymphatic	89	Other diseases of heart	80	Aneurysm
			system	90	Diseases of veins	81	Arteriosclerosis
		81	Hemorrhage, unspecified	91	Aneurysm	82	Other diseases of arteries
		82	Others	92	Arteriosclerosis	83	Diseases of veins

No. *ICD–1(1901)*	*No.* *ICD–2(1909)*	*No.* *ICD–3(1920)*	*No.* *ICD–4(1929)*
		93 Other diseases of arteries	84 Diseases of Lymphatic
		94 Diseases of veins	System
		95 Diseases of lymphatic	85 High blood pressure,
		system	idiopathic
		96 Idiopathic anomalies of	
		blood pressure	
Digestive System			
72 Dis. of mouth & annexa	83 Dis. of mouth & annexa	97 Diseases of buccal cavity	86 Diseases of buccal cavity
73 Diseases of esophagus	84 Diseases of esophagus	& annexa	87 & annexa
74 Ulcer of stomach	85 Ulcer of stomach and	98 Diseases of esophagus	88 Diseases of esophagus
85 Other diseases of stomach	duodenum	99 Ulcer of stomach and	89 Ulcer of stomach and
76 Appendicitis & Typhilitis	86 Other diseases of stomach	duodenum	90 duodenum
77 Hernia and intestinal	87 Appendicitis & Typhilitis	100 Other diseases of stomach	91 Other diseases of stomach
obstruction	88 Hernia and intestinal	101 Appendicitis	92 Appendicitis
78 Other diseases of intestines	obstruction	102 Hernia and intestinal	93 Hernia and intestinal
79 Acute Yellow liver atrophy	89 Other diseases of intestines	obstruction	obstruction
80 Cirrhosis of liver	90 Acute Yellow liver atrophy	103 Other diseases of intestines	94 Other diseases of intestines
81 Biliary calculi	91 Cirrhosis of liver	104 Cirrhosis of liver	95 Cirrhosis of liver
82 Other diseases of liver	92 Biliary calculi	105 Other diseases of liver	96 Other diseases of liver
83 Simple peritonitis	93 Other diseases of liver	Yellow atrophy, others	Yellow atrophy, others
84 Others	94 Diseases of pancreas	106 Biliary calculi	97 Biliary calculi
	95 Peritonitis unspecified	107 Other diseases of gall	98 Other diseases of gall
	96 Others	bladder & biliary passage	bladder & biliary passage
		108 Diseases of pancreas	99 Diseases of pancreas
		109 Unspecified peritonitis	100 Unspecified peritonitis
Cancers and Malignant Tumors			
85 Cancers & other malignant	97 Cancers & other malignant	110 Cancers & other malignant	101 Cancers & other malignant
86 Other tumors	98 Other tumors	111 Non-malignant tumors	102 Other malignant tumors
87 Leukemia	99 Leukemia	112 Unspecified tumors	103 Non-malignant tumors
	100 Hodgkin's disease	113 True leukemia	104 Unspecified tumors
		114 Pseudoleukemias –	105 True leukemia
		(Hodgkin's disease)	106 Aleukemias –
			(Hodgkin's disease)

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Figure 1a
Period-incidence Rate of Malingering per 100000 mean strength per year,
and days lost to Malingering per year

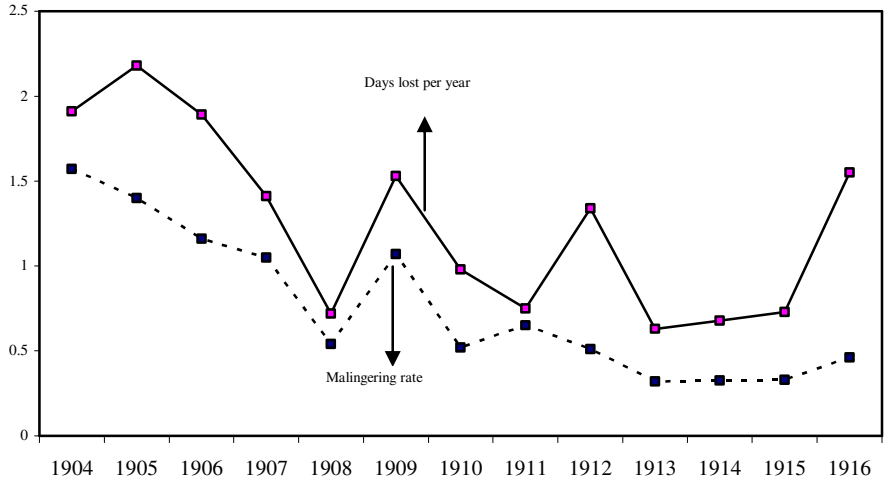
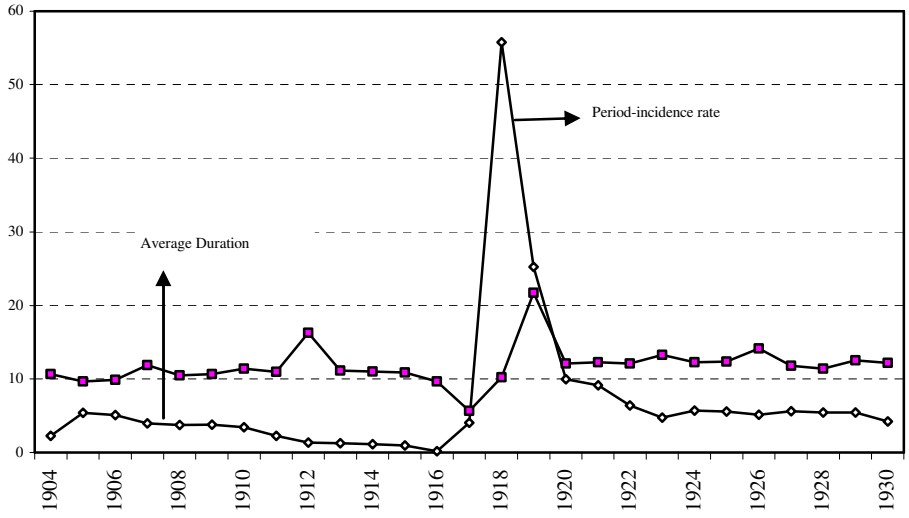


Figure 1b: Ill-defined Causes
Period-Incidence rate per 100000 mean strength per year
and average Sickness Duration (days per episode)



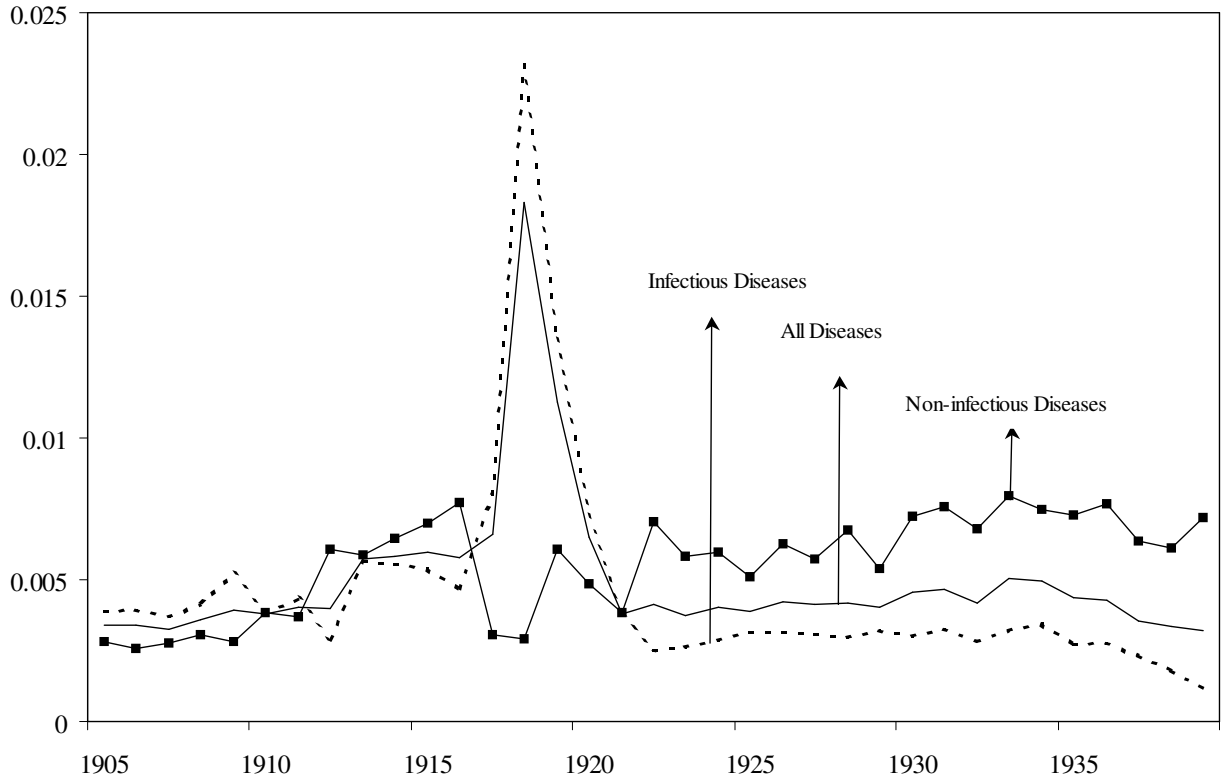


Figure 2: Fatality Ratios

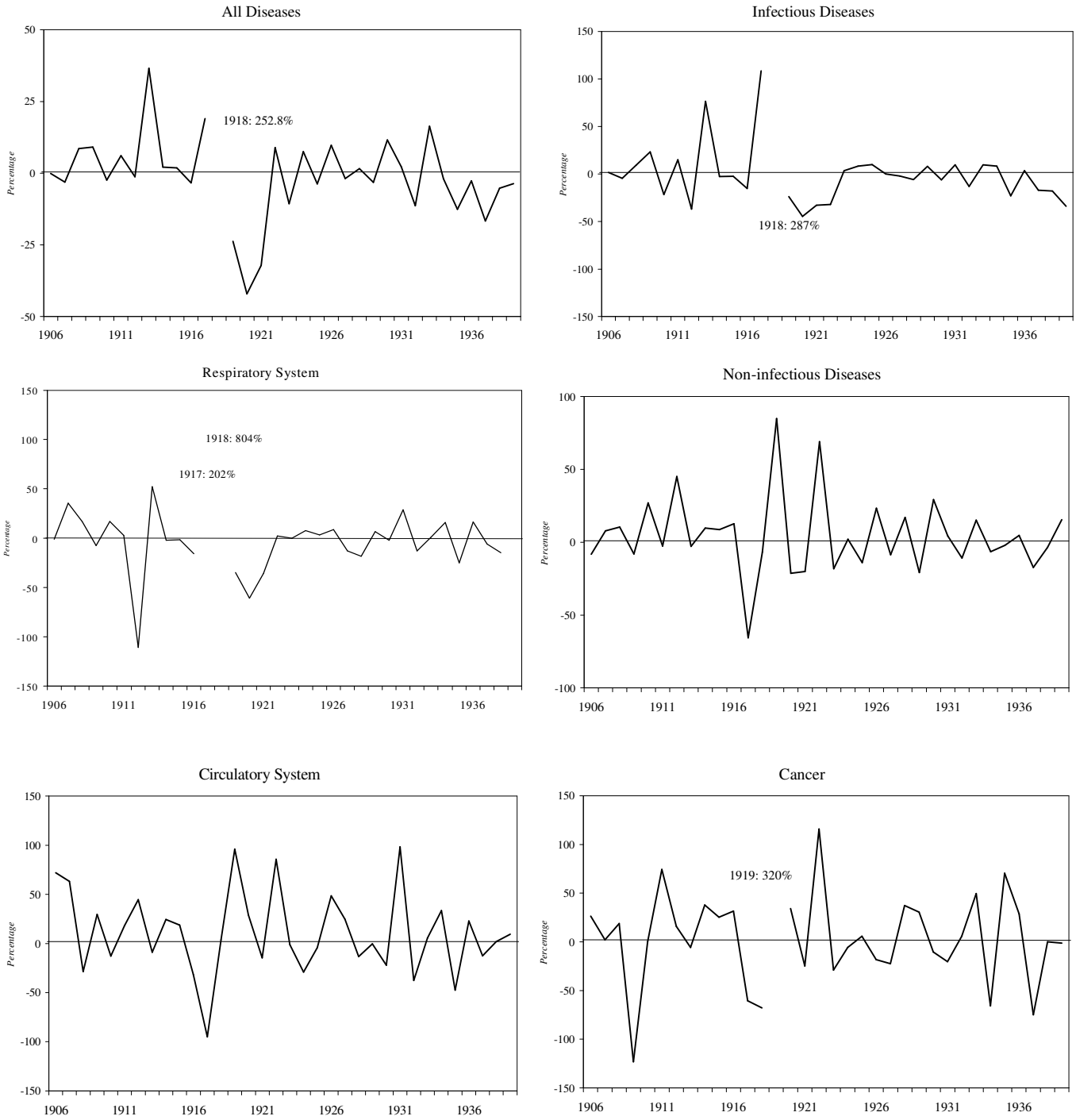


Figure 3: Percentage Changes in the Fatality Ratios of various Diseases Categories

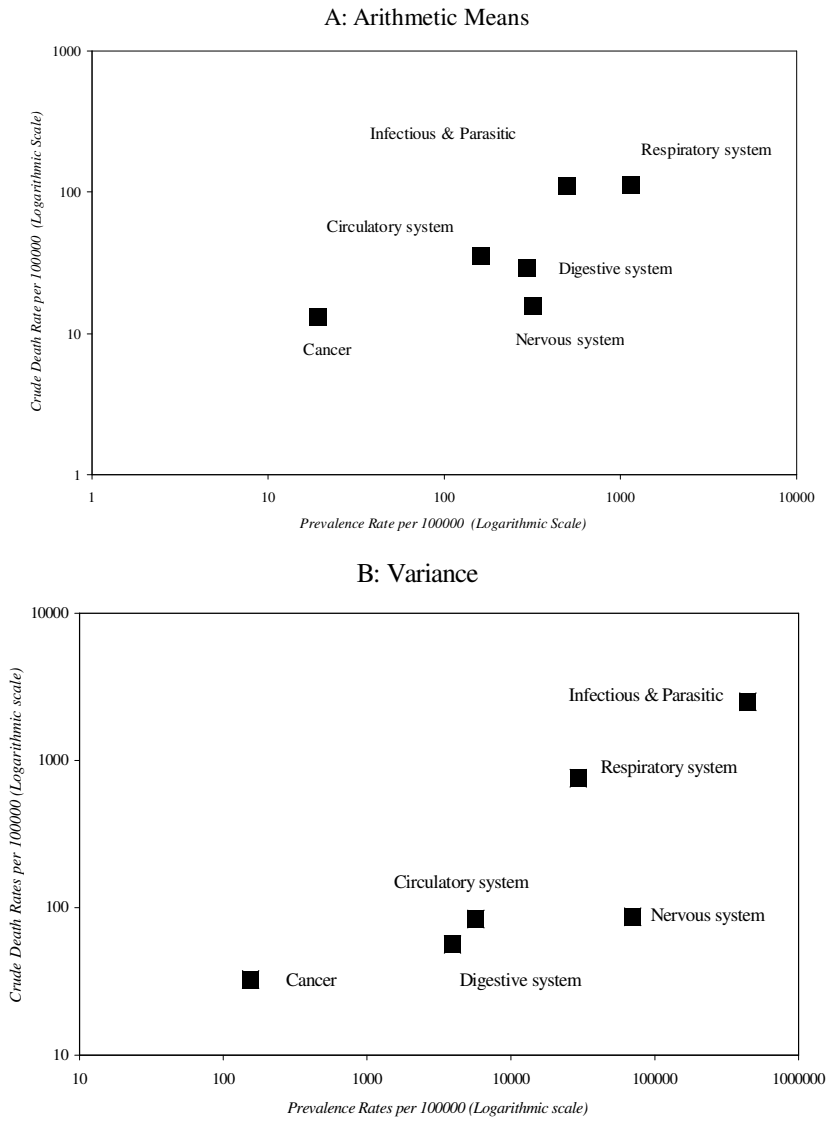


Figure 4: Correlation of Mortality and Period-Prevalence Rates across Disease Categories

Table 1: Decomposition of the Fatality Ratio

(*Average annual percentage change*)

Disease-Category	g_{it}^{δ}	g_{it}^{ε}	$g_{it}^{\Omega} = g_{it}^{\delta} - g_{it}^{\varepsilon}$
All Diseases	–4.64	–3.63	–1.02
Infectious Diseases	–5.96	–2.64	–3.32
Infectious and Parasitic	–3.69	–4.05	0.36
Respiratory System	–2.38	–1.03	–1.35
Non-infectious Diseases	–0.22	–4.06	3.83
Nervous System	–3.46	–4.06	0.59
Circulatory System	–0.07	–5.99	5.92
Digestive System	–1.92	–3.61	1.70
Cancers	2.00	1.99	0.01

Note: Besides the interval 1915–19, the following outliers for g_{it}^{δ} were excluded from the calculations reported in this table: Respiratory system (1912: 82.3%), nervous system (1933: –100%, 1935: 466.12%), circulatory system (1907: 140%, 1922: 75.3%, 1931: 94.2%), digestive system (1908: 88%), cancers (1910: 209%, 1922: 151%, 1938: 102.4%).

Table 2: Measures of Time Lost to Sickness, and Mortality Rates

(*Average annual percentage change*)

Disease Category	g_{it}^{D}	g_{it}^{η}	g_{it}^{δ}
All Diseases	–0.81	–4.46	–4.64
Infectious Diseases	–1.73	–4.69	–5.96
Infectious and Parasitic	–0.82	–4.79	–3.69
Respiratory Infections	0.41	–2.54	–2.38
Non-infectious Diseases	–0.19	–4.97	–0.22
Nervous System	–0.10	–6.22	–3.46
Circulatory System	0.62	–2.72	–0.07
Digestive System	0.77	–4.40	–1.92
Cancers	9.22	3.55	2.00

.

Table 3: Period-Prevalence Rates

(Average annual percentage change)

Disease Category	*1905-09*	*1910-14*	*1915-19*	*1920-24*	*1925-29*	*1930-34*	*1935-39*	*Average*	*Average ex. 1915–19*
All Diseases	–3.1	–9.9	34.2	–13.5	3.6	–2.4	–1.3	1.1	–4.43
Infectious Diseases	–1.4	–9.7	40.3	–17.4	4.3	–1.3	–0.7	2.0	–4.37
Infectious and Parasitic	0.0	–12.7	47.6	–17.0	2.7	–1.4	–0.8	2.6	–4.87
Respiratory System	–1.9	6.6	53.6	–14.6	5.8	–0.44	0.7	7.1	–0.64
Non-infectious Diseases	–3.7	–6.3	25.2	–13.8	3.5	–3.5	–1.7	–0.04	–4.25
Nervous System	–9.5	1.0	21.4	–13.6	7.0	–10.8	1.0	–0.50	–4.15
Circulatory System	–9.2	–14.6	85.8	–14.7	0.44	4.6	1.3	7.65	–5.37
Digestive System	–2.3	–15.6	30.8	–3.0	2.0	3.9	–2.1	1.96	–2.85
Cancers	36.9	14.2	27.0	– 1.8	5.7	10.4	1.9	13.5	11.21

Table 4: Decomposition of the Period-Prevalence Rate

(*Average annual percentage change*)

Disease-Category	g_{it}^{ε}	g_{it}^{d}	$g_{it}^{p} = g_{it}^{\varepsilon} + g_{it}^{d}$
All Diseases	–3.63	–0.81	–4.43
Infectious Diseases	–2.64	–1.73	–4.37
Infectious and Parasitic	–4.05	–0.82	–4.87
Respiratory System	–1.03	0.41	–0.62
Non-infectious Diseases	–4.06	–0.19	–4.25
Nervous System	–4.06	–0.10	–4.16
Circulatory System	–5.99	0.62	–5.37
Digestive System	–3.61	0.77	–2.84
Cancers	1.99	9.22	11.21

Note: Besides the interval 1915–19, the following outliers were excluded from the calculations: For g_{it}^{ε}, Respiratory system (1912: 82.3%), Circulatory system (1907: 76%), Cancer (1910: 1122%, 1938: 84.3%). For g_{it}^{d}, Nervous system (1920: 352.4%), Digestive system (1912: 95.5%).