Prior Exposure to Disease, and Later Health and Mortality: Evidence from the Civil War Medical Records

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Abstract

This paper examines the effects of socioeconomic factors and local disease environments on the medical experiences of Union army recruits while in service. The results suggest that prior exposure to unfavorable epidemiological environments reduced the chances of contracting and dying from disease while in service. Farmers and rural residents, who were healthier on average prior to enlistment owing to a greater extent of isolation from other people, were more likely to succumb to illness and to be killed by disease than nonfarmers and urban dwellers, respectively. Native recruits were subject to a greater risk of suffering illness than were foreigners who had more chances of exposure to infectious diseases in the course of immigration. More significantly, recruits from a county with a higher child death rate were less likely to contract disease than those from a low-mortality county. A closer examination of cause-specific mortality suggests that the most important link between the extent of prior exposure to disease and later health is the different degree of immunity against pathogens. An alternative explanation is that people who lived in an unhealthy environment were better aware of how to avoid contracting disease than those with little experience of disease. The relationship between the extent of exposure to disease prior to enlistment and health while in service was stronger for the regiments organized in the Midwest and Mid Atlantic and weaker for the regiments from New England and the South, presumably reflecting the regional differences in the severity of military missions, the extent of urbanization, and climate.

1. Introduction

Researchers in various disciples have long tried to understand the interrelations of socioeconomic status, environment, and health. This subject is related with a number of important issues such as the changing relationship between host, agent, and environmental factors, the socioeconomic differences in health, and the long-term decline in mortality. The medical and epidemiological literature provides many examples of the possible links between early-life conditions and chronic disease at older ages. A series of studies by Barker and his colleagues (Barker 1992, 1994) links many of the degenerative conditions of old age to exposure to infectious disease, malnutrition, and other types of biomedical and socioeconomic stress in utero and in the first year of life. Studies have found that infectious diseases affect the chances of suffering chronic disease such as heart, respiratory, and musculoskeletal disorders (Elo and Preston 1992, Costa 2000). These findings provide evidence for the "insult accumulation model," stating that each insult from illness or injury leaves the individual more susceptible to disease in the future (Alter and Riley 1989). However, the relationship between the early-life conditions of a cohort and its later health is not entirely straightforward. Individuals who survive infectious disease may acquire partial or complete immunity and therefore may have lower mortality rates (Lee 1997).

It is well documented that there are considerable variations in health across populations of different socioeconomic backgrounds (United Nations 1973). Inequality in health is an important social problem even in highly wealthy and egalitarian nations today (Kitagawa and Hauser 1973, Notkota et al. 1985, Lehmann et al. 1990, Diderichen 1990, Lawson and Black 1993). Some evidence suggests that the social health gradient has not diminished in spite of rising income during the second half of the twentieth century (Preston et al. 1981, Marmot et al. 1991, Marmot 1999). It is widely accepted that such health differentials by socioeconomic status cannot be fully explained by differences in health behaviors or in access to medical care. A number of hypotheses have been suggested with regard to how social and economic environments alter human biological functioning. Some frequently cited mediating factors between wealth and health include work-related stress, family background, and other social support network. A growing number of studies demonstrate that health at middle and older ages reflects earlier health and may be correlated across and within generations (Barker et al. 1989, Barker 1997, Ravelli et al. 1998, Wadsworth and Kuh 1997). Some studies see the principal impacts of socioeconomic status on health as flowing not from brief episodes but instead from the accumulation of repeated stress over the life course (Seeman et al. 1997). Another line of research focuses on the role of income inequality, maintaining that inequality in relative rank raises the level of psycho-social stress which negatively affects endocrine and immunological processes (Sapolsky 1993, Wilkinson 1996).

The patterns of socioeconomic differences in mortality and morbidity provide important clues to the causes of long-term changes in health. Studies have attributed the long-term improvement in health to a number of factors, including the elimination of chronic malnutrition, advances in public health, improvements in housing, sanitation and food hygiene, and advances in medical technology (Higgs 1973, 1979, Appleby 1975, McKeown 1976, 1983, Condran and Cheney 1982, Livi-Bacci 1982, Kunitz 1983, Fogel 1986, 1991). Recent historical studies have found that health as measured by life expectancy and mean adult height deteriorated through the early nineteenth century in the U.S. and some European nations in spite of the growth in per capita income (Pope 1992, Floud and Steckel 1997). This finding indicates that economic growth and epidemiological conditions are not independent forces, and, more importantly, that under certain circumstances the effects of economic development on the disease environment can be strongly adverse. The possible causes of the downward swings in the trend of health, according to these studies, are rapid urbanization, a decline in the proportion of the population employed in agriculture, increased geographical mobility, more rapid increases in population than in food supply, a rise in the relative food price, an increase in inequality in income distribution, and the turbulence of the Civil War (Rosenberg 1962, Steckel 1983, 1995, Fogel 1986, 1991, Komlos 1987, Floud, Wachter, and Gregory 1990, Cuff 1992, Costa 1993b, Gallman 1995, 1996). Despite the large amount of research on such issues, the relative importance of the potential factors of health remains unclear. Achieving a proper understanding of these matters is not only important from a historical point of view, but, perhaps more significantly, in terms of predicting the impact on health of on-going technological and social changes in developing countries.

The purpose of this article is to deepen our understanding of these issues by exploring the effects of socioeconomic status and local disease environment on later health and mortality of Union army recruits. The Union army sample and supplemental data set containing information on local death rates are ideal for addressing the issues introduced above, possessing the following major advantages over data analyzed in previous research. First, the semi-experimental conditions of the army camps during the war provide a unique chance to determine the relationship between socioeconomic backgrounds and health. The Civil War brought together a large number of men from heterogeneous socioeconomic and ecological backgrounds into an extremely unhealthy environment that caused unusually high rates of contraction of and disease caused mortality. Upon being mustered into the service rural dwellers were suddenly plunged into close contact with impoverished men from cities where diseases and mortality rates were high, but who were nevertheless in good enough health to pass a physical examination. About 12% of all recruits who served in the Union army died while in service (Vinovskis 1990); disease was far more common than wounds as a cause of death or disability. Another unique feature of the army is that recruits were confined to relatively homogeneous living conditions in terms of the quality of diet, housing, and disease environment compared to normal society. Owing to these features of army life, we are able to identify more clearly the effects of socioeconomic and ecological factors, and, in particular, the extent of previous exposure to disease, on the degree of susceptibility or resistance to disease. Furthermore, detailed descriptions of disease diagnoses, and cause and date of death while in service, which are contained in the Union army medical records, make it possible to examine the patterns of cause-specific mortality and timing of wartime deaths.

In an earlier paper, I analyzed the wartime disease experiences of Union army recruits based on a relatively small sample of persons from the state of Ohio (Lee 1997). The relationship between personal characteristics and health among the army recruits was nearly the opposite of the common patterns of socioeconomic differences in health found in the civilian populations in the nineteenth century. Former farmers, rural residents, and natives, who were healthier on average prior to enlistment, were more likely to contract and die from disease than, respectively, non-farmers, urban dwellers and non-natives. The most plausible interpretation of the findings is that the effect of early childhood exposure to disease was particularly important. Despite the negative consequences for net nutritional status, survivors of unhealthy environments developed better immunity to some of the infectious diseases that were rampant in army life. I found suggestive evidence in support of this hypothesis, based on the patterns of disease-specific mortality differentials and of the timing of death. Some diseases are known to have greater potential for the development of immunity. By classifying diseases along this dimension, I found that the "paradoxical" differentials were greater for diseases with greater immunity potential. The difference in the hazard of dying from immunity-sensitive disease was much greater in the earlier stages of military service when enlistees were not seasoned to the unhealthy environment of the army camps.

This article extends and improves my previous study in three major aspects. First, I use a much larger sample of Union army recruits who came from 18 different states in the Northeast, Midwest, and upper South. This larger and geographically more balanced sample will provide a more general picture of wartime medical experiences during the Civil War. Also, we are able to analyze how the effects socioeconomic and ecological factors on health varied across different regions. Secondly, I employ an improved measure of economic status, namely, household wealth per adult male equivalent. This new index will more accurately represent the economic well-being of a person by considering not only the size of economic resources but also the need for spending than does household wealth. Finally, and most significantly, I use a more explicit measure of local disease environment, namely, child death rate of county, which will enrich our understanding of the link between the extent of exposure to disease and later health.

2. Data

This study is based on a sample of the several primary data sources which were collected and linked as part of the project titled *Early Indicators of Later Work Levels, Disease, and Death,* jointly sponsored by the National Institutes of Health, the Center for Population Economics at the University of Chicago, and Brigham Young University. The sample used in this paper is composed of 28,546 recruits who enlisted in the states of Connecticut, Delaware, District of Columbia, Illinois, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New York, Ohio, Pennsylvania, Vermont, and West Virginia.

The service records contain very detailed descriptions of the diseases or wounds which recruits suffered during military service. As soon as a recruit was too ill to report for duty, his condition was noted in morning reports. If his condition required medical attention, it was recorded in the regimental surgeon's report; if he was hospitalized, the diagnosis of the disease was described in the case history together with the ultimate outcome, such as return to service, discharge for disabilities, or death (U.S. Surgeon General's Office, 1870, vol. 1). Information on disease, date and cause of death in service were gathered from these sources. Military service records provide information on demographic and socioeconomic characteristics of recruits, such as age, occupation at enlistment, place of birth, and height, among other variables, as well as on their military career including rank, military duty, company, regiment, change in military status, dates of enlistment and discharge, and so on. Additional information on socioeconomic status, and household structure prior to enlistment can be drawn from manuscript schedules of the 1860 census: it contains information on age, occupation, place of birth, household wealth, place of residence and literacy, not only for recruits but also for their family members.

In order to construct county-level child death rates, an indicator of local epidemiological environment in the areas in which recruits lived prior to enlistment, I utilize the Jackson collection of mortality data from the 1860 federal population census that was created by genealogist Ronald V. Jackson during the 1980s. Although Jackson's principal interest was in obtaining nominal information to provide to individuals exploring their family history, he collected the full range of data available in the mortality schedules. These records were generated by census marshals in their house-to-house canvass in the 1850 and 1860 Censuses of the United States. The marshals concluded their interview with each household by inquiring whether anyone from the household had died in the twelve months preceding the day of the interview. If affirmative, information on decedents was recorded on a separate mortality schedule. Most of these schedules were returned to state archives earlier in this century, and many have since been microfilmed, and some of these were acquired by Jackson and computerized at his facility in Salt Lake City.

As Jackson was able to computerize only those records that had been microfilmed and made available for loan to the public, the Jackson collection is not a complete compilation of the mortality schedules for 1850 and 1860. The collection contains information on roughly 400,000 decedents in twenty states, with good coverage of Midwestern and Southern states, but less information for the Northeast. For example, the collection contains no records for New York, Massachusetts, or Pennsylvania. Each record reports the state and county in which the death occurred, the date and cause of death, the decedent's age at death, his or her occupation and place of birth.

One obstacle in using these county-level variables on mortality is a potential bias problem. The number of deaths may have been understated in these sources for several reasons. The two most important of these are, first, the retrospective nature of the question (if the interviewee either forgot about a death or was unaware of one, such death would not be reported on these schedules), and second, should an entire household have died, none of their deaths would be reported. If the magnitude of such potential undercounts differed across counties, there will be a bias problem arising from measurement errors, as described in Condran and Crimmins (1979). I do not make any attempt to correct such potential errors in this study.

Since the data have been constructed from a number of different sources with uneven rates of successful linkage, it is unavoidable to use several different samples depending on the variables used in the analysis. Among the socioeconomic variables which are needed for this study, household wealth and county of residence as of 1860 are found only in the census data. Of the 28,546 recruits, 11,056 men (about 39%) were successfully linked to the 1860 census. Therefore, I limit the sample to these 11,056 recruits whenever household wealth is concerned. In addition to these individuals, we have information on county of enlistment for 8264 recruits among those who were not linked to the 1860 census. Assuming that these recruits enlisted in the army in the same counties where they lived in 1860, I use the sample of 19,320 men who were linked to the 1860 census or whose counties of enlistment were known, where the information on the county of residence prior to enlistment is needed. Finally, of 11,056 persons who were linked to the 1860 census, 3864 men lived in counties for which the county death rates are available. I use this sample where the effects of local epidemiological environment indicated by child death rate are analyzed.

Table 1 compares the medical experiences while in service and other personal characteristics of the three major samples that are used in this study. The three samples are generally similar in terms of the number of cases per person and the number of deaths per 1000 cases for all and six major diseases. The number of cases is slightly greater for the recruits who were successfully linked to the 1860 census than for the entire sample, which is expected from the nature of the data collections. The rate of linkage to census records is higher for those who are connected to pension records because pension files provide useful information, especially on place of residence, that helps to locate and identify persons in manuscript schedules of censuses. And army veterans with health problems originating from military service were more likely to apply for and receive pensions because early pension laws required such conditions. Therefore, it is not surprising that recruits who were connected to census records present more severe medical experiences while in service.

Among the personal characteristics, only the percentages of farmers and of immigrants are notably different between the full and census-linked samples. These differences can also be explained by the disparate linkage rates to pension records: immigrants were less likely to be found in pension records because many of the foreigners who died during the early postwar years had no eligible dependents or were used behind the front and so were less likely to incur war-related disabilities (Fogel 1993). Despite the uneven geographical coverage of the Jackson collection of mortality data, the sample linked to mortality census is comparable to the full sample in terms of regional composition. Although we cannot preclude the possibility of sample selection bias based solely on this comparison, the result suggests that such a bias problem is not likely to be serious.

3. Socioeconomic Background, Disease, and Mortality

In this section, I basically replicate my previous study (Lee 1997), using a much larger and more representative sample. Let us begin with a description of the overall features of medical experiences of the recruits in the sample. Nearly 12% of recruits in the sample died while in service, two-thirds from illness and the rest from wound. The total casualties and the fraction of deaths caused by disease are well matched with the statistics for the entire Union army. I identified six most common diseases in army camps, namely, typhoid, smallpox, measles, diarrhea (including dysentery), pneumonia, and malaria.[1] These diseases are responsible for nearly four fifths of all deaths caused by illness and two fifths of all disease cases. Of these diseases, diarrhea is the single most important killer, accounting for 32% of all deaths caused by disease, followed by typhoid that explains 23% of disease-caused deaths.

Table 2 reports the wartime mortality from disease in general (D), the mean number of cases per person-year (C), and the case fatality rates (F) of all diseases for recruits in each of the small cells made

[1]Malaria includes intermittent and remittent fevers; typhoid includes typho-malaria, and continuous fevers.

according to age, occupation, population size of county, household wealth, and nativity.[2] The mean number of cases of disease per person-year reflects how susceptible recruits of a particular socioeconomic background were to disease, while the case fatality rates indicate how robust they were in resisting the disease they contracted.

Before we look at the results, let us explain how the new variable on household wealth per adult male equivalent is constructed. Household wealth is one of the most widely used indicators of economic well-being of individuals. In studying the determinants of health in the nineteenth century, household wealth is often interpreted as a measure of nutritional status because the quality of diet was one of the most important links between economic status and health when medical interventions were limited. In order to construct a more accurate measure of economic well-being (or quality of diet) of a person, it is necessary to consider the size of the needs as well as the material resources possessed by the household. Use of simple per capita household wealth, taking into account of the household size, only partially satisfy this requirement because the demand for consumption goods differs by age, sex, and labor force status. A common method of measuring the needs of a household is to convert the number of household members into a scale of adult male equivalent based on the demographic structure of the household such as the number of householders of particular age and sex. In order to apply this method it is required to determine the scale of a particular type of person based on the relative size of his/her consumption. Here, I consider only food consumption as the basis for determining the scale. I utilize the average caloric consumptions of a typical male and a female at given ages as a proportion of that consumed by a male aged 20 to 39, reported in Fogel (1993, p. 9). For instance, the average caloric consumption of a female aged 5 to 9 is 66.67 percent of an adult male's average consumption. Accordingly, a female aged 5 to 9 is regarded as

[2] The definitions of these figures are as follows: The mean number of cases per person-year of disease k for group *j* is ($\Sigma_p CASE_{pjk}$ / $\Sigma_p SERVICE_{pj}$), and the case fatality rate of disease *k* for group *j*, is ($DEATH_{jk}$ / $\Sigma_p CASE_{pjk}$), where $CASE_{pjk}$ is the number of cases of disease *k* that a recruit *p* in group *j* suffered, $SERVICE_{pj}$ is the length of service in year (measured in days) for a recruit *p* in group *j*, and $DEATH_{jk}$ is the number of the recruits who died from disease *k*.

equivalent to 0.6667 of an adult male.

The results presented in Table 2 confirm the previous finding that the pattern of mortality differentials in the army was nearly the opposite of the relationship between socioeconomic status and health of civilians. On average, former farmers had about a 35% higher case fatality rate, and about 40% more cases of disease per one year of service than non-farmers. As a consequence of a higher susceptibility and case fatality rate combined, farmers were twice as likely to be killed by disease while in service as non-farmers. The nativity composition and the size of household wealth were quite different between farmers and non-farmers. Non-natives were overrepresented among non-farmers, and farmers were wealthier than non-farmers on average. Hence, it is necessary to control for these factors in order to identify the pure effect of occupation. However, such control does not change significantly the pattern of mortality differentials between farmers and non-farmers suggested above. Farmers had markedly higher case fatality and wartime mortality rates in all five categories of household wealth. The results remain unchanged if nativity is controlled for.

To examine the effect of population size of place of residence, I divided the sample into rural and urban residents. I include in urban areas all counties that are classified as metropolitan areas by Integrated Public Use Micro Sample of the 1860 census.[3] A comparison of the recruits from rural and urban areas indicates that rural residents were twice as likely to die from disease while in service as were city dwellers. In particular, recruits from rural areas were much more susceptible to diseases than urban residents, as indicated by the difference the mean number of cases per person-year.

Since most of the farmers lived in rural areas, the effects of occupation and urban residence can be distinguished by comparing rural farmers, rural non-farmers, and urban residents. Farmers who lived

[3]The following counties are classified as metropolitan areas in 1860: Albany, Erie, Kings, New York, Richmond, Rensseaer (NY), Baltimore (MD), Middlesex, Norfolk, Suffolk (MA), Cook (IL), Hamilton, Kenton (Ohio), Jefferson (KY), Clark, Floyd (IN), Orleans (LA), San Francisco (CA), Essex, Hudson, Camden (NJ), Montgomery, Philadelphia, Allegheny (PA), Kent, Providence (RI), and St. Louis (MO).

in rural counties were two and half times as likely to die from disease in service as urban residents. These differences reflect the combined effects of occupation and place of residence. The difference in the number of cases is accounted for almost equally by the effects of urban residence and of occupation, while the difference in the case fatality rate is largely explained by the effect of occupation.

Native recruits were similar to the foreign-born in the risk of dying while in service. Natives suffered more disease per year of service, but had a lower case fatality rate than non-natives. These two different factors of mortality are offset with each other. This result contrasts to the pattern found in Ohio where native recruits were at considerably higher risk of dying from disease while in service than non-natives. A regional comparison of the association between socioeconomic factors and mortality while service indicates that natives recorded a higher mortality than non-natives only in the region of the East North Central (see section 5). Though the pattern of mortality differentials varies considerably across age categories, the above result is generally true for each age group. As in the case of Ohio, the household wealth of recruits prior to enlistment appears to have had no clear effect on the likelihood of contracting diseases or the risk of dying from those diseases.

I conduct logistic regressions to examine the effect of each of the socioeconomic factors controlling for all other factors at the same time (see Table 3). Three different models are employed. The first and second regressions estimate the effect of each independent variable on the probabilities of dying from and contracting a disease while in service, respectively, based on the sample of all recruits linked to the 1860 census. For the third regression, the sample is limited to the recruits who had at least one case of disease while in service. The second regression examines the determinants of the degree of susceptibility to disease while the third is concerned with the fatality in case of contraction. The result of the first regression on mortality shows the combined consequence of the differences in susceptibility and lethality.

The following variables are used as the independent variables. The recruits in the sample are classified into three groups according to occupation and place of residence: rural farmers (control group), rural non-farmers, and residents in urban counties. Variables on personal characteristics such as age, age squared, nativity, and log of household wealth per adult equivalent are included. Variables on height are also added as an index of nutritional status of recruits. The year of enlistment represents variations in the severity of military missions, epidemiological conditions, and the length of service. In a previous study I found that military positions such as rank and duty had very strong effects on the chances of dying while in service (Lee 1999). This study also shows that military positions were selectively assigned to the newly enlisted according to their socioeconomic backgrounds. To control for this potential indirect effect of socioeconomic characteristics on the probability of dying through the assignments of military positions, I include dummy variables on duty (=1 if infantrymen, =0 otherwise) and rank (=1 if private, =0 otherwise).

The results of the regressions are presented in Table 3. The estimated parameters for occupation and urban county confirm the patterns of mortality differentials described above (see Table 2). Farmers in rural areas were much more likely to succumb to disease and be killed by disease in case of contraction than nonfarmers living in a rural county and city dwellers. As suggested by Lee (1997), the most plausible interpretation of these results is that the effect of earlier exposure to disease was particularly important. A number of studies have noted the fragility of isolated populations once they come in contact with different disease pools (McNeill 1976, Curtin 1989, Pritchett and Tunali 1995, Fetter and Kessler 1996, Skold 1997). Despite the negative consequences for net nutritional status, survivors of unhealthy environments developed better immunity to some of the infectious diseases that were rampant in army life.

The results regarding the effects of country of birth reveal two countervailing effects on wartime mortality as observed in Table 2. First, U.S. born recruits were more likely to suffer illness (col. 2) but were less likely than immigrants to die when became sick (col. 3). The advantage of natives over foreigners in terms of fatality dominates the disadvantage in the odds of contracting diseases. As a consequence, native recruits were about 5% less likely to die from disease while in service than immigrants (col. 3). The lower contraction rate of immigrants may be explained by the circumstance that they were more likely to be confined to unhealthy environments. For instance, many immigrants suffered from the overcrowding, bad ventilation, and spoiled foods of ship cabins on the voyage from Europe to America. Moreover, most of the immigrants came to and stayed at first in large cities in the Northeast where communicable diseases were more prevalent than in the countryside. On the other hand, the higher fatality among foreign-born recruits could be attributable to the generally poor health conditions of immigrants compared to natives as indicated by their higher mortality and smaller stature in nineteenth-century America (Haines 1977, Higgs 1979).

Finally, a close relationship between the adjusted household wealth and the odds of contracting disease stands out in the regression result (col. 2). An increase in the log of adjusted household wealth by one standard deviation (2.45) around the sample mean is associated with a decline by 7.4% in the probability of having at least one case of illness while in service. In contrast, the adjusted household wealth is positively associated with the odds of dying from disease for those who suffered illness, though the relationship is statistically insignificant. The effect of the adjusted household wealth on the probability of dying from illness, a combined outcome of the above two countervailing effects, is relatively small in magnitude and statistically insignificant.

I perform similar regression analyses separately for six most common diseases, typhoid, smallpox, measles, diarrhea, pneumonia, and malaria. According to epidemiological studies, the significance of immunity influence differs from one disease to another. For some diseases, such as measles, smallpox, and typhoid, an attack would confer immunity and thus reduce the odds of contracting or dying from those diseases in the future (this type of disease will be called *immunity diseases* below). For other diseases like malaria, diarrhea, dysentery, and pneumonia, on the other hand, a prior contraction has little influence on susceptibility to or resistance against those diseases (this type will be called *non-immunity diseases*).[4] If

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[4]For the epidemiological characteristics of these and other diseases see May (1958), Steiner (1968, pp. 12-26), and Kunitz (1983, pp. 351-353). For more recent documentation of the history of specific diseases, see Fetter and Kessler (1996) for measles, Zurbrigg (1997) for malaria, and Skold (1997) for smallpox.

the *immunity hypothesis* suggested above is true, the difference in mortality between recruits who had come from different environments should be larger for immunity diseases than for non-immunity diseases.

Tables 4 presents the results for the probability of contracting each specific disease. The results are largely consistent with the immunity hypothesis suggested above. The advantages of nonfarmers and urban dwellers over farmers and rural dwellers are generally greater for immunity diseases than for non-immunity diseases. The greater odds of contraction among U.S. born recruits is statistically significant for two of three immunity diseases (typhoid and smallpox), compared to only one non-immunity disease (diarrhea). Meanwhile, the effect of adjusted household wealth is statistically significant for one immunity (measles) and one non-immunity disease (diarrhea).

Table 5 reports the regression results for the probability of dying from each specific disease in case of contraction. The relationship between socioeconomic factors and fatality is less clearly seen for individual than for all diseases. The effect of occupation and urban residence is statistically significant only for typhoid. Natives had a significantly lower fatality than immigrants for an immunity (measles) and two non-immunity diseases (diarrhea and malaria). The wealthier had disadvantages only in case of pneumonia.

The results presented in this section largely confirm the previous findings based on the sample of Ohio regiments (Lee 1997), building a strong circumstantial case for the importance of earlier disease exposure. However, occupation or urban residence is only indirect indicators of local disease environments. Therefore, the interpretations of the results suggested above are subject to reservations. We now turn to a more direct test using an explicit measure of disease environments that will help to establish the above argument more strongly.

4. Local Disease Environment, and Later Health and Mortality

In this section, we analyze the influences of prior exposure to disease using a more explicit measure of local epidemiological environment, namely, the child death rate of each county where recruits resided prior to enlistment. Child or infant mortality is a widely used indicator of the prevalence of infectious diseases. Previous studies have found that infectious diseases increased the chances of suffering chronic diseases at middle and older ages such as heart, respiratory, and musculoskeletal disorders (Barker 1992, 1994, Elo and Preston 1992, Costa 2000). The link between earlier contraction of infectious diseases and later health conditions could be explained in part by the nutritional losses caused by the infections. For example, Haines (1998) found that the crude death rate of the localities where Union army recruits were raised had a strong negative effect on their heights at the time of enlistment. The analysis of this article is distinct from the existing literature in that it is concerned with the relatively short-term influences of infectious diseases when individuals are exposed to highly severe disease conditions in the army.

As explained above, I calculated the number of deaths in each county for children under age 10 and for the population at large from the Jackson collection of the 1860 mortality census. By dividing the number of deaths by the number of the county population, I computed the child and crude death rates for each county. Finally, this county-level data set on death rates was merged to the sample of recruits based on the names of the state and county where the recruits lived in 1860. It turned out that 3864 recruits lived in the counties for which death rates are estimated . Of these recruits 3550 men have non-missing information for all variables used in the analysis. The balance of this section is based on the sample of these 3550 recruits. The sample means of the crude death rate (number of deaths per thousand) and child death rate (number of child deaths per 1000 children) are 2.6 and 4.8, respectively. These death rates fall short of the estimate of the crude death rate for the U.S. circa 1860, 21 deaths per thousand (Poulson 1981, Table 10-2). Even if we consider the fact that the northern death rate was lower than the national average, the estimated county death rates are still much too low, indicating that the number of deaths should be severely undercounted in our mortality data. I use these underestimated county death rates without making any corrections. It should be noted that by doing so I implicitly assume that the extent of undercounting is similar across counties.

Table 6 presents the results of logistic regressions that show the effect of local disease environment indicated by child death rate of county on the probabilities of dying from disease (col. 1), of contracting disease (col. 2), and of dying from disease in case of contraction (col. 3). As predicted by the immunity hypothesis, child death rate is negatively related with the odds of contracting any disease. The magnitude of the effect is considerably large. An increase in child death rate by one standard deviation (3.6) around the sample mean is associated with a 45% decrease in the chances of contracting a disease while in service. However, child death rate has no significant effect on the fatality of those who had one or more disease cases. Largely due to the influence on the odds of contraction, child death rate has a strong effect on the chances of dying from disease. I tried several different specifications, by including instead of child death rate the crude death rate, the log of child death rate, and dummy variables for five categories of counties according to the size of child death rate. The results for these specifications, not reported here, provide practically the same implications.

The results for other independent variables are generally similar to the results from the previous regressions in which child death rate is not included (Table 3). The only major difference is that the effect of country of birth loses statistical significance. Using the 3550-men sample, I also conducted similar regressions after excluding child death rate. A comparison of the results of these regressions, not presented here, with the original regressions presented in Table 6 shows that the disappearance of the effect of nativity is due mainly to the restriction of the sample, not the inclusion of child death rate in the regressions. The results also indicate that despite the additional control of child death rate in the regressions, the magnitudes of the coefficients for occupation and urban county remain little changed. This implies that the two different measures of exposure to disease, population size of place of residence and child death rate, independently affected the chances of dying while in service.

Tables 7 and 8 offer the results of similar regressions separately conducted for six specific diseases.

The effect of child death rate significantly affects the chances of infection only for two non-immunity diseases, diarrhea and malaria (Table 7). On the other hand, measles is the only disease of which fatality was significantly influenced by child death rate (Table 8). These results suggest that immunity may not be the only link between local disease environment and health. This point is also relevant for the question of why farmers were disadvantaged even for non-immunity type diseases for which their superior nutritional status should have provided an advantage. A possible explanation is that people who lived in an unhealthy environment were more aware of how to avoid contracting disease than those with little experience of disease. According to a qualitative record, for example, Germans ate fewer sweets, cooked their food more carefully, and more actively pursued cleanliness (Hess 1981, pp. 66-67). A number of contemporary account suggest that rural residents and farmers were particularly unhygienic and ignorant of child health (Preston and Haines 1991, pp. 38-39). Alternatively, it could be explained by a population selection caused by differential mortality, that is, individuals who survived an unhealthy environment were on average more robust. Further studies are called for to determine how prior exposure to unfavorable epidemiological environments, if survived, strengthen human resistance to disease.

5. Regional Differences

This section documents how the relationship between socioeconomic factors and wartime mortality differed across regions. Let us begin with a regional comparison of the general features of wartime mortality. Table 9 reports the cause-specific death rates for five regions. The result indicates that recruits who were enlisted into the New England regiments were particularly more vulnerable to wounds, compared to other regions. They were nearly twice as likely to die from wounds as were recruits who enlisted in other regions, largely due to a higher case fatality rate. This indicates that New England regiments were presumably sent to more dangerous missions. On the other hand, mortality from disease was the highest for the West the North Central (12.8%), followed by New England (10.1 %) and the East North Central

(8.5 %). The Mid Atlantic regiments had the lowest mortality from disease (5%). It is notable that, if New England is excluded, there is a clear negative association between disease-influenced mortality and the extent of urbanization. New England regiments may deviate from such a regularity because they went through more severe military missions, as indicated by the greater casualties caused by wounds. The distribution of the specific causes of death from illness, reported in parentheses in Table 9, does not differ much between regions.

Table 10 presents the mortality from all types of diseases (ILL), immunity diseases (IMM), and non-immunity diseases (NIM) for a number of different socioeconomic categories. Though different in the absolute mortality with one another, the Mid Atlantic, East North Central, and West North Central are generally similar in terms of the mortality differentials according to socioeconomic backgrounds. Meanwhile, New England and the South demonstrate remarkably different patterns. Let us first describe the patterns of mortality differentials for the Mid Atlantic, East North Central, and West North Central. In these three regions, farmers were about 1.7 times as likely to be killed by disease as were nonfarmers. The mortality differential between farmers and nonfarmers is much greater (2.5 times greater for farmers than for nonfarmers) for immunity diseases. A comparison between farmers and nonfarmers who lived in rural counties shows similar patterns. Recruits from rural counties were at much greater risks of dying from disease, especially from immunity disease, compared to the enlisted from urban areas. These mortality differentials according to occupation and urban residence remain true if country of birth and household wealth are controlled for.

The association between country of birth and mortality from disease differs between farmers and nonfarmers. For nonfarmers, there is no significant difference in mortality between natives and non-natives. For farmers, on the other hand, the foreign born were considerably less likely to die than natives. This result indicates that the advantages of non-natives over natives found in the Ohio regiments, though not observed for the entire sample, are true not only for Ohio but also for the entire Mid West and Mid

Atlantic regions. As in the case of the full sample, household wealth had no systematic effect on the likelihood of dying from disease. But mortality from non-immunity disease is clearly lower for the top wealth category in all regions but the South.

The advantages that farmers and rural residents had over, respectively, nonfarmers and city dwellers are much less visible for New England. For immunity disease, the difference in mortality between farmers and nonfarmers is comparable to the difference found for the above three regions. But farmers and nonfarmers in New England were no different in likelihood of dying from non-immunity disease. The mortality gap between rural and urban residents is even smaller, only 16%, because the former had higher, not lower, mortality from non-immunity disease than did the latter. In contrast, the mortality differentials by occupation and county of residence were much more pronounced for recruits from the South. Such greater mortality differentials are largely due to the differences in mortality from immunity disease. For example, southern farmers were five times more likely to die from immunity disease than were nonfarmers. Among 192 recruits who lived in urban areas in the South prior to enlistment, not a single person was killed by immunity disease, while 4.1% of rural residents died from this type of disease.

The farm-nonfarm gap in mortality differs considerably between natives and the foreign born for these two regions: The advantages of nonfarmers over farmers are much greater for the foreign born than for natives. In New England, foreign-born farmers were twice as likely to die from illness than were foreign-born nonfarmers, largely due to their lower mortality from immunity disease. In the South, on the other hand, mortality from illness is more than three times greater for foreign-born farmers than for nonfarm immigrants. If household wealth is controlled for, farmers in New England were slightly more likely to die from disease than were nonfarmers, as observed above, for all but one categories of wealth. In the South, on the other hand, the farm-nonfarm difference in mortality depends upon the magnitude of household wealth. That is, among the wealthy, farmers were less likely to die from disease than were nonfarmers, mainly due to their lower mortality from non-immunity disease. Among the poor, in contrast, mortality from disease is greater for farmers than for nonfarmers.

I conduct logit regressions to see how the effects of socioeconomic factors on the probability of dying from disease differed across regions. Table 11 presents the results. The regression results for the Mid Atlantic, East North Central, and West North Central are generally similar to the results for the entire sample. The major difference is that natives are not significantly different from non-natives in terms of the likelihood of dying from disease while in service. The advantages that recruits from urban areas or nonfarmers had over rural farmers are greater in the Mid West than in the Northeast. This result could be explained by the fact that, in a more urbanized region such as the Northeast, the difference in the extent of exposure to disease between rural and urban population was presumably small relative to a more rural region.

The regression results for New England and the South do not support the hypothesis that recruits from healthier environments were more robust in resisting disease because of their superior immunity status. If other socioeconomic factors and military positions are controlled for, occupation and county of residence do not have any significant effects on the probability of dying from disease while in service. In New England, natives were much less likely to be killed by disease than were foreign-born recruits. In the South, the mortality differentials according to occupation and place of residence, clearly seen in Table 10, are no longer present once other variables are controlled for.

These peculiar patterns of New England and the South remain a puzzle to be examined in further studies. A possible explanation for the case of New England is that the effects of socioeconomic backgrounds were relatively weak because New England regiments went through more difficult and dangerous military missions, as indicated by greater casualties caused by wounds. Under the circumstance where people are exposed to common risk factors that are not associated with their socioeconomic backgrounds, it would be more difficult to identify the effects on mortality of socioeconomic factors. In the South, the weak relationship between socioeconomic backgrounds and wartime mortality may be explained as follows: First, since the urban development was relatively retarded in the South, the local environments were not probably much different between urban and rural areas in this region, compared to the North. Second, even the rural populations may have been exposed to relatively unhealthy environments in the South due to the climate that is more favorable to the developments of various infectious diseases.

6. Summary and Implications

The most important result of this study is that prior exposure to unfavorable epidemiological environments reduced the chances of contracting and dying from disease while in service. Farmers and rural residents, who were healthier on average prior to enlistment owing to a greater extent of isolation from other people, were more likely to succumb to illness and to be killed by disease than nonfarmers and urban dwellers, respectively. Native recruits were subject to a greater risk of suffering illness than were foreigners who had more chances of exposure to infectious diseases in the course of immigration. More direct evidence for the relationship between local disease environment prior to enlistment and health while in service comes from the result that recruits from a county with a higher child death rate were less likely to contract disease than those from a low-mortality county.

The different degree of immunity against pathogens is probably the most important link between the extent of prior exposure to disease and later health. That is, despite the negative consequences for net nutritional status, survivors of unhealthy environments developed better immunity to some of the infectious diseases that were rampant in army life. This hypothesis is supported by the result that the mortality differentials by occupation and place of residence are particularly large for diseases that are known to have greater potential for the development of immunity such as typhoid, smallpox, and measles. However, immunity is not the only link between local disease environments and health. The effect of county death rate on the odds of contracting disease is strong for non-immunity diseases such as diarrhea and malaria. Also, farmers were disadvantaged even for non-immunity type diseases for which their superior nutritional status should have provided an advantage. A possible explanation is that people who lived in an unhealthy environment were better aware of how to avoid contracting disease than those with little experience of disease. An alternative account is a population selection caused by differential mortality: individuals who survived an unhealthy environment were on average more robust.

The results of this study provide a counter-example of the "insult accumulation model" stating that each insult from illness or injury leaves the individual more susceptible to disease in the future (Alter and Riley 1989). The medical experiences of recruits suggests that it is possible that a prior insult provides a resistance to disease, especially when a person is suddenly exposed to a severe disease environment as in Civil War army camps. More generally, this study suggests that we need to reconsider the interrelationship between epidemiological environments and the development of human resistance to disease in order to better understand the links between early-life conditions and later health.

This study provides new evidence pertaining to the link between economic status and health in the nineteenth century. A weak association between wealth and mortality has been a puzzling phenomenon in U.S. economic and demographic history. Steckel (1988) has found that wealth conveyed no systematic advantage for the survival of women or children in households matched in the 1850 and 1860 censuses. As late as 1900, economic status appears to have been a much less important correlate of child mortality than place of residence (Preston and Haines, 1991, pp. 150-158). This has led to discussions of egalitarian patterns of death and of relatively small differences in health by social class, perhaps because the poor were better fed in the U.S. than in Europe. I reported in a previous research that there existed a positive effect of wealth on health at least for some diseases on which nutritional influence is great (Lee 1997). I also claimed that the association between wealth and mortality from all causes was weak because the influence of infectious diseases was so strong that it dominated the effect of economic status. This study has found that economic status measured by household wealth per adult equivalent reduced the chances of contracting diseases while in service. However, wealth had no favorable effect on mortality. This result suggests that in spite of a weak wealth-mortality link, economic state may have been an important determinant of health in the nineteenth century, in particular, if morbidity rather than mortality is considered.

This article also strengthens my previous hypothesis that changing human resistance to disease is a potentially important factor of the changes in health in nineteenth-century America. Life-expectancy and mean adult height, major indicators of health, declined through the early nineteenth century (Fogel 1986, Komlos 1987, 1992, 1996, Floud, Watcher and Gregory 1990, Pope 1992, Steckel 1995, Gallman 1995, 1996). A highly plausible explanation for the cycle in health is the epidemiological impact of increased geographical mobility. Higher rates of interregional trade and migration increased morbidity and mortality by spreading communicable diseases and by exposing newcomers to different disease environment. The rise of public schools and changes in labor organization exerted a similar effect by increasing the risk of exposure to infectious diseases (Steckel, 1995, pp. 1929-30). The results of this study provides additional evidence for this hypothesis, highlighting the adverse effect of a contact with a new disease environment caused by geographical migrations.

There was a turnaround in the deterioration in health in the late nineteenth century. Mortality rates started to decline again after the Civil War, and adult height began to increase in the late nineteenth century. Even though a consensus has been reached that the elimination of chronic malnutrition, advances in public health, improvements in housing, sanitation and food hygiene, and advances in medical technology were important factors which contributed to the decline in mortality, the relative importance of those factors is still under debate (Higgs 1973, 1979, Appleby 1975, McKeown, 1976, 1983, Condran and Cheney 1982, Livi-Bacci 1982, Kunitz 1983, Fogel 1986, 1991). The evidence provided in this article suggests that an increase in the degree of resistance, either immunological or social, against infectious diseases could be another potential factor.

Considering the roles of human resistance to disease helps to explain several puzzles in the patterns of the improvements in health since the late nineteenth century, particularly regarding the exact timing of the change. According to pioneering regional studies, the upturn of the trend in the mean height did not occur until the 1880s or 1890s, 20 to 30 years later than the beginning of mortality improvements (Steckel and Haurin, 1994; Wu, 1994; Coclanis and Komlos, 1995). The nutrition hypothesis does not explain why mortality began to decline long before any signs of nutritional improvements showed up. On the other hand, the hypothesis regarding human resistance to disease is at least consistent with the timing of the mortality decline. The proportion of the population in living urban areas substantially increased, and, owing to the developments of canals and railroads, the degree of geographical mobility rose between 1830 and 1860.[5] These changes presumably increased the fraction of the population who were exposed to but survived various infectious diseases. The results of this study suggests that such shifts in the epidemiological experiences of the population would have lowered the mortality from infectious diseases. This explanation is also consistent with the urban-rural difference in the mortality decline. The decline in mortality rates was faster in urban areas than in rural areas between 1870 and 1900. Previous studies have explained this phenomenon largely by the advances in the urban public health system (Haines, 1977; Condran and Crimmins, 1980; Preston, Haines, and Pamuk, 1981). However, the effectiveness of the advances in public health measures such as the provision of central water supplies, sewage system, and inspection of food and milk was at best limited even until the last decade of the nineteenth century (Condran and Crimmins-Gardner 1978; Condran and Cheney, 1982). On the other hand, the proportion of the population with prior experiences with communicable diseases may have increased more rapidly in cities than in the countryside. If this was the case, we would expect a faster mortality decline in urban areas than in rural areas.

[5] In 1830, 4.5% of population were living in large cities with 50,000 residents or more; this percentage rose to 11.0% by 1860, and reached 18.7% by 1890 (U.S. Bureau of the Census, 1965, p. 14). The proportion of the population residing in small cities with 2,500 to 50,000 inhabitants rose from 5.5% in 1830 to 9.9% in 1860 (U.S. Bureau of the Census, 1965, p. 14). The decline in the proportion of the population employed in agriculture could have also contributed to the decline in urban mortality rate, since new migrants to large cities would have been more likely to be non-agricultural workers as the agricultural sector shrank.

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TABLE 1

Medical Experiences in Service and Personal Characteristics: A Comparion of Three Samples

	Full-sample N=28,536	Population Census-Linked Sample N=11,073	Mortality Census-Linked Sample N=3864
Number of cases per one person			
All diseases	2.066	2.338	2.086
Diarrhea	0.431	0.506	0.440
Typhoid	0.061	0.074	0.064
Malaria	0.218	0.228	0.234
Pneumoina	0.034	0.036	0.029
Measles	0.036	0.044	0.042
Smallpox	0.013	0.016	0.013
Number of deaths per 1000 cases			
All diseases	37.6	40.8	37.8
Diarrhea	60.2	60.5	57.7
Typhoid	308.7	324.4	290.3
Malaria	13.5	15.0	14.4
Pneumoina	170.1	186.9	207.2
Measles	81.5	83.5	73.6
Smallpox	229.0	288.9	326.5
Personal characteristics			
Mean age	25.6	26.1	25.9
Mean height	67.5	67.9	68.0
Percentage of farmers	47.6	57.6	57.5
Percentage of the U.S. born	69.3	82.1	86.2
Region of enlistment (percent)			
New England	9.2	10.3	10.4
Mid Atlantic	37.3	31.2	37.4
East North Central	35.8	39.1	34.1
West North Central	11.1	12.5	8.0
South	6.6	6.9	10.1
Military positions			
Percentage of privates	91.8	89.8	88.9
Percentage of infantrymen	67.5	65.1	67.8

TABLE 2

Socioeconomic Background and Wartime Mortality from All Types of Disease

Category	All ages				Age 19 and younger				Age 20-24				Age 25 - 29				Age 30 and older			
	N	D	C	F	N	D	C	F	N	D	C	F	N	D	C	F	N	D	C	F
Farmer	13595	103.5	1.27	42.4	4402	93.6	1.27	37.3	4209	106.2	1.17	43.1	2030	111.8	1.24	46.2	2954	108.7	1.47	47.0
Non-farmer	14951	54.3	0.90	31.4	3514	45.0	0.92	23.5	4408	45.6	0.81	28.4	2740	46.7	0.83	29.1	4289	75.8	1.06	42.2
Rural county	15521	91.5	1.22	38.1	4472	85.2	1.21	34.2	4618	88.8	1.12	37.2	2485	85.7	1.18	36.6	3946	105.4	1.40	45.8
Urban county	3799	45.3	0.72	30.7	847	29.5	0.79	16.7	1073	36.3	0.59	28.5	682	48.4	0.63	36.8	1197	62.7	0.84	40.8
Rural farmer	9153	109.8	1.31	42.5	2891	102.4	1.31	38.4	2840	109.2	1.20	41.8	1362	114.5	1.29	44.3	2060	118.0	1.53	48.1
Rural non-farmer	6368	65.2	1.09	30.9	1581	53.8	1.05	24.6	1778	56.2	0.99	27.6	1123	50.8	1.05	24.8	1886	91.7	1.26	42.9
U.S. born	19709	80.8	1.18	35.9	6322	72.9	1.17	31.4	6100	76.4	1.08	34.1	3096	82.0	1.17	36.5	4272	98.1	1.39	44.9
Farmer	11215	100.9	1.32	40.2	3812	91.3	1.32	35.8	3533	99.3	1.21	39.2	1655	110.6	1.32	43.7	2215	112.9	1.58	47.2
Non-farmer	8575	54.6	1.00	28.4	2510	45.0	0.97	22.9	2567	44.8	0.89	24.5	1441	49.3	1.01	25.5	2057	82.2	1.19	41.9
Foreign born	8756	70.7	0.85	42.9	1594	68.4	0.87	35.4	2517	72.3	0.76	47.9	1674	60.3	0.70	43.0	2971	76.4	1.01	43.7
Farmer	2380	115.5	1.02	55.2	590	108.5	1.02	48.8	676	142.0	0.93	67.8	375	117.3	0.90	60.8	739	96.1	1.18	46.3
Non-farmer	6376	54.0	0.78	36.4	1004	44.8	0.79	25.5	1841	46.7	0.68	36.1	1299	43.9	0.64	35.0	2232	69.9	0.95	42.5
Farmer																				
Wealth $ 0-14	903	106.3	1.39	38.9	261	107.3	1.34	38.2	226	119.5	1.25	45.7	158	94.9	1.44	31.7	258	100.7	1.55	38.6
Wealth $15-143	1117	123.5	1.37	47.1	303	108.9	1.37	41.7	276	126.8	1.18	48.5	182	164.8	1.36	60.0	356	112.4	1.58	43.7
Wealth $144-325	1305	123.4	1.37	47.1	428	144.9	1.35	54.2	395	106.3	1.27	38.0	174	97.7	1.44	37.4	308	129.9	1.56	55.5
Wealth $326-809	1514	111.6	1.32	45.0	506	122.5	1.35	45.5	475	105.3	1.19	43.5	187	117.6	1.12	51.4	346	101.2	1.65	43.6
Wealth $ 810-	1512	108.5	1.32	44.1	489	81.8	1.31	31.8	576	102.4	1.32	39.4	201	129.4	1.21	62.2	246	158.5	1.47	72.2
Non-farmer																				
Wealth $ 0-14	1235	76.1	1.04	36.4	279	60.9	1.15	25.0	262	61.1	0.90	29.4	198	30.3	0.93	15.8	496	110.9	1.11	56.3
Wealth $15-143	1120	54.5	1.07	27.2	248	40.3	0.92	19.3	223	26.9	1.10	13.2	210	61.9	1.04	28.9	439	72.9	1.25	38.7
Wealth $144-325	937	79.0	1.03	40.4	234	68.4	0.94	35.2	242	70.2	1.06	32.9	154	32.5	0.95	18.4	307	117.3	1.14	61.1
Wealth $326-809	723	66.4	1.06	33.4	207	72.5	1.10	33.7	213	51.6	0.88	28.3	108	55.6	0.98	30.2	195	82.1	1.30	39.8
Wealth $ 810-	655	64.1	1.02	33.4	195	46.2	1.12	21.1	225	93.3	0.87	55.0	102	58.8	0.95	32.8	133	45.1	1.18	22.6

N: Number of recruits. D: Number of deaths per 1000 men. C: Number of cases per person-year. F: Number of deaths per 1000 cases. Wealth: Adjusted household wealth.

TABLE 3

Result of Logistic Regressions: Correlates of Probability of Dying from Disease

Independent variables	All recruits linked to the 1860 census					Recruits who contracted disease		
	Mean	(1) Dying from disease (Mean = 0.098)		(2) Contracting disease (Mean = 0.700)		Mean	(3) Dying from disease (Mean=0.139)	
		Parameter	MP/ MX_i	Parameter	MP/ MX_i		parameter	MP/ MX_i
Intercept		3.104		-5.549			6.410	
Age	26.039	-0.011	-0.050	-0.100 ***	-0.451	25.932	0.006	0.028
Age squared *10^{-1}	74.480	0.004	0.107	0.017 ***	0.470	74.117	0.001	0.026
Height	67.923	-0.179	-0.267	0.246	0.366	67.957	-0.277	-0.411
Height squared *10^{-1}	461.923	0.014	0.275	-0.018	-0.362	462.543	0.021	0.418
Farmers, rural county	0.573	NI	NI	NI	NI	0.609	NI	NI
Nonfarmers, rural county	0.349	-0.497 ***	-0.131	-0.432 ***	-0.113	0.327	-0.380 ***	-0.098
Urban county	0.078	-0.932 ***	-0.138	-0.959 ***	-0.142	0.064	-0.599 ***	-0.081
Born in the U.S.	0.820	-0.251 ***	-0.053	0.187 ***	0.040	0.831	-0.310 ***	-0.064
Log of adjusted wealth	4.674	0.009	0.012	-0.030 ***	-0.041	4.675	0.014	0.019
Duty=Infantrymen	0.649	1.093 ***	0.288	-0.308 ***	-0.081	0.621	1.215 ***	0.325
Rank=Private	0.899	0.420 ***	0.070	0.192 **	0.032	0.901	0.385 ***	0.063
Enlisted in 1861	0.247	NI	NI	NI	NI	0.273	NI	NI
Enlisted in 1862	0.392	0.053	0.014	-0.125	-0.034	0.422	0.075	0.020
Enlisted in 1863	0.045	0.144	0.016	-0.033	-0.004	0.049	0.161	0.019
Enlisted in 1864	0.231	-0.968 ***	-0.225	-1.033 ***	-0.240	0.184	-0.656 ***	0-140
Enlisted in 1865	0.084	-1.131 ***	-0.173	-0.874 ***	-0.134	0.072	-0.890 ***	-0.127

Note. The number of observations is 10124 for regressions (1) and (2), and 7152 for (3). Dependant variables are dummy variables which are one if a person died from a disease for (1) and (3), and if a person contracted a disease for (2), and zero otherwise. NI refers to the omitted variables. Significance level: *** (1%), ** (5%), * (10%).

TABLE 4

Result of Logistic Regressions: Personal Characteristics and Probability of Contracting Particular Disease (MP/ MX_i)

	(1) Typhoid Mean=0.065	(2) Smallpox Mean=0.013	(3) Measles Mean=0.038	(4) Diarrhea Mean=0.277	(5) Pneumonia Mean=0.031	(6) Malaria Mean=0.151
Age	0.091	-0.268	-0.549 *	-0.040	-0.076	-0.116
Age squared $*10^{-1}$	-0.160	0.211	0.030	0.035	0.083	0.048
Height	-0.070	-0.128	1.552	0.516	0.565	-0.224
Height squared $*10^{-1}$	0.049	0.117	-1.539	-0.509	-0.448	0.236
Farmers, rural county	NI	NI	NI	NI	NI	NI
Nonfarmers, rural county	-0.068 ***	-0.254 ***	-0.216 ***	-0.061 ***	-0.159 ***	-0.053 ***
Urban county	-0.175 ***	-2.127	-0.254 ***	-0.109 ***	-0.238 ***	-0.086 ***
Born in the U.S.	0.043 *	0.057	0.066 *	0.072 ***	-0.001	0.022
Log of adjusted wealth	0.022	-0.058	-0.053 *	-0.028 **	-0.049	-0.003
Duty=Infantrymen	0.102	-0.049	0.006	-0.041 ***	0.039	-0.110 ***
Rank=Private	0.031 ***	0.036	0.023	0.023 *	-0.007	0.032 **
Enlisted in 1861	NI	NI	NI	NI	NI	NI
Enlisted in 1862	0.019	-0.002	-0.037	0.036 **	0.027	0.017
Enlisted in 1863	-0.021	-0.073	0.046 *	0.025 **	-0.039	0.005
Enlisted in 1864	-0.141 ***	-0.127 **	0.002	-0.112 ***	-0.146 ***	-0.096
Enlisted in 1865	-0.175 ***	-0.165 **	0.029	-0.055 ***	-0.048	0.019

Note. The number of observations is 10124 for all regressions. Dependant variables are dummy variables which are one if a person contracted a particular disease, and zero otherwise. NI refers to the omitted variables. Significance level: *** (1%), ** (5%), * (10%).

TABLE 5

Result of Logistic Regressions: Personal Characteristics and Probability of Dying from Particular Diseasess in Case of Contraction (MP/MX_i)

	(1) Typhoid Mean=0.321 N=654	(2) Smallpox Mean=0.319 N=135	(3) Measles Mean=0.083 N=387	(4) Diarrhea Mean=0.100 N=2808	(5) Pneumonia Mean=0.171 N=315	(6) Malaria Mean=0.016 N=1528
Age	-0.395	-0.057	0.806	0.206	-0.064	-0.580
Age squared $*10^{-1}$	0.430	0.392	-0.973	-0.078	0.392	0.703
Height	-1.370	-1.789	3.267	-1.545 +	4.119	-0.661
Height squared $*10^{-1}$	1.361	1.864	-3.049	1.544 +	-4.071	0.929
Farmers, rural county	NI	NI	NI	NI	NI	NI
Nonfarmers, rural county	-0.144 ***	-0.038	-0.231	-0.045	0.014	0.137
Urban county	-0.157 **	NI	0.009	-0.005	-0.074	0.144 +
Born in the U.S.	-0.051	0.077	-0.349 ***	-0.072 **	-0.058	-0.213 **
Log of adjusted wealth	0.037	0.014	-0.127	0.037	0.194 *	0.089
Duty=Infantrymen	0.400 ***	0.134	0.319 **	0.243 ***	0.499 ***	0.352 **
Rank=Private	0.062	0.204	0.043	0.024	0.138	0.008
Enlisted in 1861	NI	NI	NI	NI	NI	NI
Enlisted in 1862	-0.059	-0.112	0.335 **	0.022	-0.188	0.063
Enlisted in 1863	0.009	0.012	-1.686	0.057 *	0.067	-1.461
Enlisted in 1864	-0.153 ***	-0.244 *	0.173	-0.114 **	-0.055	-0.080
Enlisted in 1865	-0.080	-0.125	0.173	-0.178 ***	-0.009	-0.113

Note. N denotes the number of observations for each regression. Dependant variables are dummy variables which are one if a person died from a particular disease, and zero otherwise. NI refers to the omitted variables. Significance level: *** (1%), ** (5%), * (10%).

TABLE 6

Result of Logistic Regressions: County Child Death Rate and Probabilities of Contracting and Dying from Diseases

Independent variables	All recruits linked to the 1860 census					Recruits who contracted diseases		
	Mean	(1) Dying from disease (Mean = 0.098)		(2) Contracting disease (Mean = 0.663)		Mean	(3) Dying from disease (Mean=0.120)	
		Parameter	MP/ MX_i	Parameter	MP/ MX_i		parameter	MP/ MX_i
Intercept		-31.445		-12.586			-24.320	
Child Death Rate	4.771	-0.041 **	-0.083	-0.062 ***	-0.125	4.574	-0.019	-0.035
Age	25.842	-0.035	-0.148	-0.107 ***	-0.461	25.636	-0.005	-0.022
Age squared $*10^{-1}$	72.881	0.006	0.166	0.017 ***	0.433	71.910	-0.002	0.050
Height	68.022	0.824	1.154	0.454	0.635	68.109	0.610	0.853
Height squared $*10^{-1}$	463.34	-0.057	-1.093	-0.032	-0.607	464.520	-0.042	-0.800
Farmers, rural county	0.572	NI	NI	NI	NI	0.611	NI	NI
Nonfarmers, rural county	0.358	-0.496 ***	-0.131	-0.353 ***	-0.093	0.328	-0.392 ***	-0.101
Urban county	0.070	-1.464 ***	-0.206	-0.850 ***	-0.120	0.061	-1.227 ***	-0.162
Born in the U.S.	0.863	-0.184	-0.035	-0.056	-0.011	0.860	-0.193	-0.037
Log of adjusted wealth	4.871	-0.046	-0.054	-0.056 ***	-0.066	4.831	-0.032	-0.038
Rank=Private	0.888	0.137	0.024	0.076	0.013	0.886	0.115	0.020
Duty=Infantrymen	0.678	1.066 ***	0.275	-0.271 ***	-0.070	0.648	1.179 ***	0.310
Enlisted in 1861	0.250	NI	NI	NI	NI	0.283	NI	NI
Enlisted in 1862	0.374	-0.177	-0.047	-0.067	-0.018	0.407	-0.196	-0.053
Enlisted in 1863	0.043	-0.070	-0.008	0.036	0.004	0.051	-0.109	-0.013
Enlisted in 1864	0.241	-0.939 ***	-0.221	-1.119 ***	-0.264	0.180	-0.506 **	-0.107
Enlisted in 1865	0.091	-1.070 ***	-0.170	-0.826 ***	-0.131	0.079	-0.866 ***	-0.128

Note. The number of observations is 3550 for regressions (1) and (2), and 2355 for (3). Dependant variables are dummy variables which are one if a person died from a disease for (1) and (3), and if a person contracted a disease for (2), and zero otherwise. NI refers to the omitted variables. Significance level: *** (1%), ** (5%), * (10%).

TABLE 7

Result of Logistic Regressions: County Child Death Rates and Probability of Contracting Particular Disease (MP/MX_i)

	(1) Typhoid Mean=0.054	(2) Smallpox Mean=0.011	(3) Measles Mean=0.036	(4) Diarrhea Mean=0.245	(5) Pneumonia Mean=0.025	(6) Malaria Mean=0.146
Child death rate	0.002	-0.046	0.018	-0.116 ***	0.068	-0.113 ***
Age	0.159	-0.511	0.169	-0.120	-0.079	-0.281
Age squared $*10^{-1}$	-0.205	0.460	-0.590	0.115	0.069	0.240
Height	2.041	-0.371	7.276 ***	0.425	1.311	0.515
Height squared $*10^{-1}$	-1.999	0.298	-7.310 ***	-0.396	-1.181	-0.514
Farmers, rural county	NI	NI	NI	NI	NI	NI
Nonfarmers, rural county	0.010	-0.379 ***	-0.206 ***	-0.083 ***	-0.193 ***	-0.064 **
Urban county	-0.063	-1.892	-0.345 **	-0.084 ***	-2.020	-0.124 ***
Born in the U.S.	0.082 *	0.108	0.040	0.018	-0.011	-0.032
Log of adjusted wealth	0.003	-0.110	-0.082	-0.067 ***	-0.054	-0.050 *
Rank=Private	0.055	-0.016	0.074	0.032	-0.039	0.009
Duty=Infantrymen	0.078 *	-0.138	-0.018	-0.036	0.046	-0.103 ***
Enlisted in 1861	NI	NI	NI	NI	NI	NI
Enlisted in 1862	0.004	-0.064	0.001	0.081 ***	0.089	0.060 *
Enlisted in 1863	-0.029	0.010	0.040	0.015	0.041	0.007
Enlisted in 1864	-0.224 ***	-0.195	-0.070	-0.106 ***	-0.147	-0.134 ***
Enlisted in 1865	-0.133 **	-0.257	0.001	-0.011	-0.014	-0.030

Note. The number of observations is 3550 for all regressions. Dependant variables are dummy variables which are one if a person contracted a particular disease, and zero otherwise. NI refers to the omitted variables. Significance level: *** (1%), ** (5%), * (10%).

TABLE 8

Result of Logistic Regressions: County Death Rates and Probability of Dying from Particular Disease in Case of Contraction (MP/MX_i)

	(1) All diseases Mean=0.120 N=2355	(2) Typhoid Mean=0.333 N=201	(3) Smallpox Mean=0.040 N=40	(4) Measles Mean=0.084 N=131	(5) Diarrhea Mean=0.101 N=878	(6) Pneumonia Mean=0.237 N=93	(7) Malaria Mean=0.023 N=522
Child death rate	-0.035	-0.092	-0.488	-0.693 *	-0.080	-0.242	0.160
Age	-0.022	-0.461	5.763	8.939 *	0.185	0.582	-1.660
Age squared $*10^{-1}$	0.050	0.552	-5.213	-9.414 *	-0.101	-0.430	1.853 *
Height	0.853	-2.137	36.202	90.255 **	-1.349	8.398	-9.882 *
Height squared $*10^{-1}$	-0.800	2.259	-35.468	-90.959 **	1.371	-8.451	10.047 *
Farmers, rural county	NI	NI	NI	NI	NI	NI	NI
Nonfarmers, rural county	-0.101 ***	-0.055	2.044 *	-0.117	-0.066	-0.195	-0.206
Urban county	-0.162 ***	-1.592	NI	0.467	-0.068	NI	-1.337
Born in the U.S.	-0.037	-0.042	0.956	-0.274	0.017	0.120	-0.359 ***
Log of adjusted wealth	-0.038	0.127	-1.818 *	-0.276	0.006	-0.076	0.069
Rank=Private	0.020	-0.142	0.565	2.289	-0.027	0.272	0.157
Duty=Infantrymen	0.310 ***	0.554 ***	1.757	0.878 **	0.223 ***	0.162	-0.008
Enlisted in 1861	NI	NI	NI	NI	NI	NI	NI
Enlisted in 1862	-0.053	-0.102	1.321	0.239	-0.108	0.008	-0.053
Enlisted in 1863	-0.013	0.034	1.056 *	-1.195	0.010	0.216	-1.380
Enlisted in 1864	-0.107 ***	-0.045	0.321	0.267	-0.030	0.143	-0.114
Enlisted in 1865	-0.128 ***	-0.040	-1.201	-0.068	-0.148 *	-0.072	0.052

Note. N denotes the number of observations for each regression. Dependant variables are dummy variables which are one if a person died from a particular disease, and zero otherwise. NI refers to the omitted variables. Significance level: *** (1%), ** (5%), * (10%).

TABLE 9

Number of Cases and Deaths from Specific Causes by Region

	All	New England	Mid Atlantic	East North Central	West North Central	South
Number	28546	2623	10643	10227	3167	1886
Cases per person-year						
Wounds	0.29	0.35	0.38	0.25	0.20	0.20
Illness	1.07	0.86	0.91	1.28	1.30	0.91
Deaths per 1000 men						
Wound	38.5	72.4	39.3	30.3	37.3	33.9
Illness	77.7 (100.0)	100.6 (100.0)	50.0 (100.0)	85.0 (100.0)	127.6 (100.0)	79.5 (100.0)
Immunity diseases	24.5 (30.5)	34.3 (34.1)	15.5 (31.0)	27.3 (32.1)	36.6 (28.7)	25.4
Typhoid	18.7 (23.2)	29.7 (28.9)	14.1 (26.7)	18.9 (21.3)	23.7 (18.2)	20.1 (25.0)
Smallpox	2.9 (3.6)	1.1 (1.1)	0.9 (1.8)	4.1 (4.6)	6.9 (5.3)	2.7 (3.3)
Measles	2.9 (3.6)	3.4 (3.3)	0.5 (0.9)	4.4 (5.0)	6.0 (4.6)	2.7 (3.3)
Nonimmunity	37.1 (47.7)	44.6 (44.3)	23.5 (47.0)	41.2 (48.5)	64.7 (50.7)	35.5
diseases	26.0 (32.2)	31.3 (30.4)	18.0 (34.2)	28.3 (31.9)	44.8 (34.4)	19.1 (23.7)
Diarrhea	5.8 (7.2)	4.2 (4.1)	2.1 (3.9)	7.8 (8.8)	11.1 (8.5)	9.0 (11.2)
Pneumonia	2.9 (3.7)	5.3 (5.2)	2.3 (4.3)	2.2 (2.5)	4.7 (3.6)	4.2 (5.3)
Malaria	2.5 (3.0)	3.8 (3.7)	1.1 (2.1)	2.8 (3.2)	4.1 (3.1)	3.2 (3.9)
Tuberculosis	1.5 (1.9)	0.4 (0.4)	1.5 (2.9)	2.0 (2.2)	0.9 (0.7)	1.6 (2.0)
Scurvy	17.5 (21.7)	23.6 (23.0)	12.2 (23.2)	18.0 (20.3)	28.1 (21.5)	18.0 (22.4)
All other diseases						

TABLE 10

Socioeconomic Background and Wartime Mortality by Region (Number of Deaths per 1000)

Category	New England				Mid Atlantic				East North Central				West North Central				South			
	N	ILL	IMM	NIM	N	ILL	IMM	NIM	N	ILL	IMM	NIM	N	ILL	IMM	NIM	N	ILL	IMM	NIM
Farmer	897	121.5	55.7	43.5	3094	70.5	26.5	31.4	6212	100.8	36.4	46.2	2375	143.1	42.9	74.5	1017	112.1	40.3	47.2
Non-farmer	1726	89.8	23.2	45.2	7549	41.6	11.0	20.3	4015	60.5	13.4	33.4	792	80.8	17.7	35.4	869	41.4	8.1	21.9
Rural county	1306	117.2	39.8	49.0	4893	62.9	23.1	28.0	6526	91.9	31.1	44.0	1833	138.6	42.0	69.8	963	109.0	40.5	44.7
Urban county	228	100.9	30.7	61.4	2732	41.4	5.5	24.5	646	44.9	7.7	27.9	1	0.0	0.0	0.0	192	36.4	0.0	36.5
Rural farmer	569	123.0	52.7	43.9	2137	81.0	30.9	34.6	4307	105.4	38.1	48.1	1441	152.6	47.2	80.5	699	125.9	50.1	47.2
Rural non-farmer	737	112.6	29.9	52.9	2756	49.0	17.1	22.9	2219	65.8	17.6	36.1	392	86.7	23.0	30.6	264	64.4	15.2	37.9
U.S. born	1394	89.0	30.1	38.0	6618	56.1	20.1	25.4	8172	90.8	30.8	43.3	2269	116.8	41.4	54.2	1337	73.3	26.2	35.9
Farmer	541	83.2	33.3	31.4	2548	76.5	30.2	34.1	5477	106.1	39.1	48.6	1814	128.4	46.3	60.6	835	93.4	37.1	41.9
Non-farmer	853	92.6	28.1	42.2	4070	43.2	13.8	19.9	2695	59.7	14.1	32.7	455	70.3	22.0	28.6	502	39.8	8.0	25.9
Foreign born	1229	113.9	39.1	52.1	4025	40.0	8.0	20.4	2055	61.8	13.6	32.6	898	154.8	24.5	91.3	549	94.7	23.7	34.6
Farmer	356	179.8	89.9	61.8	546	42.1	9.2	18.3	735	61.2	16.3	28.6	561	190.7	32.1	119.4	182	197.8	54.9	71.4
Non-farmer	878	87.1	18.3	48.1	3479	39.7	7.8	20.7	1320	62.1	12.1	34.8	337	95.0	11.9	44.5	367	43.6	8.2	16.3
Farmer																				
Wealth $ 0-100	82	134.1	85.4	0.0	273	102.6	44.0	40.3	555	99.1	41.4	45.0	131	122.1	38.2	68.7	138	159.4	50.7	72.5
Wealth $ 101-500	53	56.6	18.9	75.5	200	105.0	50.0	45.0	439	97.9	25.1	47.8	182	148.4	65.9	65.9	98	132.7	30.6	61.2
Wealth $ 501-1500	128	156.3	39.1	78.1	281	81.9	32.0	28.5	517	127.7	46.4	63.8	320	162.5	43.8	96.9	136	117.6	51.5	44.1
Wealth $ 1501-5000	180	127.8	61.1	33.3	411	85.2	29.2	36.5	808	99.0	43.3	43.3	376	175.5	63.8	87.8	129	108.5	62.0	31.0
Wealth $ 5001-	62	129.0	64.5	48.4	222	90.1	40.5	40.5	506	98.8	33.6	25.7	102	147.1	49.0	98.0	41	24.4	0.0	24.4
Non-farmer																				
Wealth $ 0-100	194	128.9	30.9	56.7	827	68.9	14.5	33.9	480	66.7	18.8	29.2	54	148.1	74.1	37.0	91	33.0	0.0	33.0
Wealth $ 101-500	123	97.6	8.1	56.9	447	42.5	6.7	26.8	256	54.7	11.7	39.1	61	82.0	16.4	32.8	42	47.6	23.8	23.8
Wealth $ 501-1500	137	116.8	43.8	51.1	338	44.4	11.8	32.5	314	54.1	19.1	22.3	68	73.5	29.4	29.4	44	90.9	22.7	68.2
Wealth $ 1501-5000	127	110.2	15.7	86.6	299	63.5	16.7	23.4	273	69.6	22.0	44.0	60	116.7	0.0	50.0	26	153.8	38.5	115.4
Wealth $ 5001-	56	107.1	71.4	17.8	152	32.9	6.8	19.7	168	29.8	11.9	6.0	26	76.9	38.5	0.0	23	173.9	0.0	87.0

N: Number of recruits. ILL: All types of disease. IMM: Immunity disease. NIM: Non-immunity disease. Wealth: Unadjusted household wealth.

TABLE 11

Result of Logistic Regressions: Correlates of Probability of Dying from Any Disease by Region

Independent Variables	New England		Mid Atlantic		East North Central		West North Central		South	
	Dept. Mean = 0.125 N = 1091		Dept. Mean = 0.073 N = 3139		Dept. Mean = 0.090 N = 3927		Dept. Mean = 0.155 N = 1269		Dept. Mean = 0.115 N = 707	
	Mean	Parameter	Mean	Parameter	Mean	Parameter	Mean	Parameter	Mean	Parameter
Intercept		-0.059		26.228		-15.141		3.797		8.803
Age under 20	0.254	NI	0.224	NI	0.284	NI	0.269	NI	0.276	NI
Age 20-24	0.309	-0.227	0.301	-0.182	0.291	-0.254	0.273	-0.146	0.287	-0.082
Age 25-29	0.160	-0.015	0.160	-0.462 *	0.160	-0.045	0.139	-0.089	0.161	0.140
Age 30 and older	0.277	0.309	0.315	0.359 **	0.266	0.109	0.318	-0.278	0.276	0.158
Height	67.7	-0.089	67.3	-0.863	68.1	0.341	68.5	-0.199	68.3	-0.366
Height squared $*10^{-1}$	459.7	0.007	454.2	0.062	465.1	-0.024	470.2	0.016	467.1	0.030
Born in the U.S.	0.616	-0.657 ***	0.806	0.165	0.884	0.278	0.813	-0.317	0.850	-0.472
Farmers, rural county	0.438	NI	0.397	NI	0.651	NI	0.805	NI	0.710	NI
Nonfarmers, rural county	0.474	-0.028	0.440	-0.375 **	0.309	-0.493 ***	0.195	-0.453 *	0.252	-0.253
Urban county	0.088	-0.197	0.163	-0.630 ***	0.040	-1.044 **	0.000	NI	0.038	-0.183
Wealth $ 0-100	0.242	-0.204	0.315	0.364 *	0.234	-0.217	0.127	-0.204	0.297	-0.205
Wealth $ 101-500	0.158	-0.759 **	0.187	0.106	0.163	-0.201	0.175	-0.017	0.192	-0.220
Wealth $ 501-1500	0.225	NI	0.183	NI	0.192	NI	0.279	NI	0.240	NI
Wealth $ 1501-5000	0.271	-0.081	0.209	0.132	0.254	-0.169	0.325	0.024	0.188	-0.021
Wealth Over $ 5000	0.104	-0.018	0.107	0.028	0.157	-0.284	0.095	-0.187	0.082	-0.407
Enlisted in 1861	0.281	NI	0.231	NI	0.221	NI	0.248	NI	0.403	NI
Enlisted in 1862	0.544	-0.303	0.359	0.329 *	0.385	0.130	0.470	0.212	0.209	-0.649 *
Enlisted in 1863	0.077	0.487	0.050	0.366	0.024	0.390	0.052	-1.361 **	0.076	-0.282
Enlisted in 1864	0.091	-0.674 *	0.303	-0.690 ***	0.224	-1.302 ***	0.204	-0.804 ***	0.216	-0.796 **
Enlisted in 1865	0.006	-14.30	0.057	-2.874 ***	0.144	-0.702 ***	0.026	-1.515 ***	0.095	-13.895
Duty=Infantrymen	0.659	1.371 ***	0.673	0.912 ***	0.667	1.262 ***	0.534	1.154 ***	0.631	1.363 ***
Rank=Private	0.883	0.513	0.925	0.727 **	0.885	0.266	0.892	0.511 *	0.898	0.181

Note. Dependant variable is dummy variable which is one if a person died from a disease, and zero otherwise. NI refers to the omitted variables. Significance level: *** (1%), ** (5%), * (10%).