NBER WORKING PAPER SERIES

ESTIMATING NEONATAL MORTALITY RATES FROM THE HEIGHTS OF CHILDREN: THE CASE OF AMERICAN SLAVES

Richard H. Steckel

Working Paper No. 1628

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
June 1985

The author has benefitted from comments or discussions with Stanley Engerman, Robert Fogel, Ken Kiple, Robert Margo, J.M. Tanner, Eugene Weinberg, and workshop participants at the University of Chicago. The research reported here is part of the NBER's research program in Development of the American Economy. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

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ABSTRACT

Underenumeration of vital events is a problem familiar to people who work with historical demographic records. This paper proposes a method for recovering information about neonatal mortality. The approach utilizes average heights of young children to predict the birth weight of American slaves. The results suggest that slave newborns weighed on average about 5.1 pounds, which places them among the poorest populations of developing countries in the mid-twentieth century. The birth weight distribution and a schedule of mortality by birth weight suggest that previous estimates of slave infant mortality are too low. The poor health and stature of children and the relatively large size of slave adults is a pattern of growth and development that is unobserved among poor populations of the twentieth century. Thus slavery may have created an unusual pattern of nutritional resource allocation across ages.

Richard H. Steckel
Economics Department
Ohio State University
Columbus, Ohio 43210
(614) 422-5008

INTRODUCTION

The levels and trends in slave mortality have long been part of the debate over slavery. As early as the abolitionist period it was recognized that mortality measures are valuable indicators of the quality of life, and subsequent research established a high correlation between measures such as the infant mortality rate and economic development (United Nations, 1973, 132-142). Although charges and counter-charges about the health and mortality of slaves were part of the campaign against slavery and the defense of slavery, systematic efforts at resolution of controversies raised during the debate have occurred only in the past few decades.

Studies of mortality in the U.S. during the nineteenth century have gone forward using various sources and methods. Death registration began in some localities as early as the 1840s and by 1900 ten states, 134 cities outside these states, and the District of Columbia had established procedures for continuously recording deaths (Thompson and Whelpton, 1933, 228-230; Taeuber and Taeuber, 1958, 269-272). Beginning in 1850 the census included questions on deaths that had occurred during the twelve months preceding the census (Wright, 1900, 98). Genealogies that recorded deaths are an additional source of direct information (Fogel et al., 1978, 79). Census survival techniques, model life tables, and stable population analysis have been used to infer mortality levels and trends (see, for example, Haines, 1979; Farley, 1965; Eblen, 1974; McClelland and Zeckhauser, 1983).

The sources and methods commonly used for questions involving the nineteenth century do not apply or may be unsatisfactory for study of infant, and especially neonatal mortality, among slaves. Death registration, for example, began in southern states after emancipation and underenumeration plagues the retrospective inquiries made by the census. Indirect techniques have been applied to the slave population (Farley, 1965; Eblen, 1974; McClelland and Zeckhauser, 1983), but the results depend heavily on measured patterns of mortality in other populations and the methods cannot identify age patterns of mortality within the first year of life.

Direct information on slave mortality is available from birth and death lists maintained by slaveowners (Postell, 1951; Steckel, 1979b). The number of lists available is small and the data must be interpreted carefully, however. An extensive search of southern archives turned up less than a dozen lists that systematically recorded births and deaths, and that lacked overt instances of underreporting of the date and incidence of death (such as "X" notations). Low values on some lists for the share of infant deaths that occurred within one month after birth suggest that some births and deaths were omitted. Although the record of early mortality on a few lists may be reasonably complete, and these records furnish insights into early mortality (Steckel, 1985a), data limitations substantially constrain our knowledge in the area.

The high rates of loss that ordinarily occur during the first year of life justify the emphasis given to this aspect of mortality (United Nations, 1973, 121-122). Deaths occurring soon after birth frequently arise from genetic defects, from deprivation during gestation, or from trauma during birth, whereas diseases originating from inadequate sanitation, care, and feeding predominate as causes of death in later infancy. The contrast in causes of death has given rise to a classification of causes and to separate measures of mortality. "Endogeneous" factors produce neonatal mortality, which refers to deaths occurring within 28 days after birth, and "exogeneous" factors cause post-neonatal mortality, which refers to deaths occurring during the remainder of the first year.[1] Thus neonatal mortality rates are a measure of the health, nutrition, and work required of pregnant women, of the quality of obstetrical practices, and of the quality of care given to newborns.

This paper estimates neonatal mortality rates among U.S. slaves by utilizing data on heights in early childhood. Average heights are a sensitive indicator of past health and nutrition (Eveleth and Tanner, 1976; Tanner, 1978), and this measure has been applied recently to a variety of questions in economic history (see, for example, Trussell and Steckel, 1978; Steckel, 1979a; Sandberg and Steckel, 1980; Fogel et al., 1983).[2] The estimating procedure uses the average height of young slaves relative to modern height standards as a predictor of birth weight. Newborn weight is the major determinant of neonatal mortality. Inevitably this procedure requires assumptions about information that is lacking, and this difficulty is met with sensitivity analysis and a range of plausible results. The findings suggest that slave birth weights were on average about 5.1 pounds, which makes them comparable to those in the poorest populations of developing countries of the mid-twentieth century. The birth weight distribution and a schedule of mortality by birth weight suggests that previous estimates of slave mortality up to the end of the first year are too low.

SLAVE HEIGHTS IN EARLY CHILDHOOD

In 1807 Congress passed legislation that would prevent smuggling of slaves from Africa but permit the interregional transportation of American slaves through the coastal and waterways trade (Wesley, 1942). The law required ship captains involved in the coastwise trade to prepare duplicate manifests that described each slave by name, age, sex, color, and height. The National Archives houses a large number of these manifests under Record Group 36. A collection of 10,562 manifests involving 50,606 slaves comprises the data base for this paper.[3]

Table 1 sets forth the average heights and the corresponding centile of modern heights achieved by young slave children. The heights at ages 1 and 2 are probably biased downward and should be viewed skeptically. The difficulty with the measurements at these ages is that many children aged 1 and some aged 2 could not walk or could not stand very long, and the measurements were probably taken with the children lying down. In this position young children retract or draw up their legs and unless special care is taken the resulting lengths are inaccurate. Modern technique takes this into account, and thus the young slave children appear to be very small by modern standards. In the absence of specific information about actual techniques of measurement used by ship captains, it is difficult to estimate the extent of the bias.

Although the manifests may contain biases as a measure of the health of the entire population of U.S. slaves and there may be distortions in the measurements (such as age and height heaping), as a first approximation it appears to be safe to take the data at ages 3 and above at face value. At ages 3 to 6 slave children on average were 4.5 to 5.8 inches below modern height standards. With the exception of females at age 5 the typical slave fell below the first centile of modern standards. There was a modest trend of improvement between ages 3 and 6; males climbed from centile 0.2 to centile 0.5 and females increased from 0.1 and 0.4.

Why were slave children so small? The origins of poor health can be traced to conditions during the fetal period (Steckel, 1985a). The slave work routine was arduous overall and characterized by seasonal peaks in work effort required of women during planting (March), hoeing (May-June), and especially harvesting (late August-mid December). Modern studies establish the detrimental effect of work, particularly effort that requires standing, by mothers on birth weight (Tafari, et al., 1980; Hytten and Leitch, 1971, 452-454; Naeye and Peters, 1982; Ashworth, 1980, 20; Briend, 1979, 1980; Hytten, 1981).[4] The diet was probably poorest from late winter through early summer and infections such as malaria and gastrointestinal disorders may have contributed to fetal stress during the summer. The health of a child at birth is sensitive to conditions during the first and last trimesters. First trimester deprivation leads to stillbirths and birth deformaties, and low birth weight follows stress during the last trimester. Through luck in the timing of conception some newborns may have escaped the seasonal traps of diet, disease, and work routine and therefore had a good start on life. Substantial numbers were less fortunate, and if born alive, struggled through childhood. Food supplements such as pap, panada, and gruel were ordinarily part of the diet by age 4 to 6 months. Supplementation may have begun within a few weeks after birth for those born during periods of intense work requirements. The poor nutritional content of the supplements and the unsanitary conditions surrounding food preparation and feeding contributed to disease, poor health, and slow growth.

Alcohol and tobacco consumed by pregnant mothers may have been a factor in low birth weight. Tobacco was grown widely within the South and owners apparently had few if any objections to its use. Some owners forbade liquor on moral grounds and most probably feared its potential for disrupting the labor force; but exceptions were often made at Christmas and other occasions to celebrate the harvest. At other times of the year slaves may have been able to purchase liquor using earnings from the sale of chickens, eggs, and garden produce. Alcohol and tobacco were probably no more than a contributing cause of small stature during childhood, however, because these substances permanently stunt growth and slave adults attained roughly the 28th centile of modern height standards (Steckel, 1985b). Most of the catch-up growth (climb through the centiles of modern standards) occurred after slaves entered the adult labor force at ages 10-12. Ceteris paribus, the additional work requirements of the adult labor force would have retarded growth, but nutritional improvements were sufficient to more than offset the additional claims of physical exertion. Thus working adults were reasonably well-fed, and for this reason it is doubtful that general malnutrition of slave mothers was more than a minor cause of the poor health of young slave children.

ESTIMATING BIRTH WEIGHT

The process of growth in humans is self-stabilizing or "target-seeking" (Tanner, 1978, 154-160). Individuals follow a growth curve in a pattern analogous to a missile directed towards a target. Genetic structure in combination with conditions in utero determine the target or potential for growth. This target can be expressed as a centile on modern height standards. Children can be pushed off the path towards the target by illness or starvation, but if conditions are satisfactory height returns to or approaches the target stature for a particular age through catch-up growth. Although the correlation between birth weight and stature at young ages is only .2 and .3 for individuals, correlations obtained if entire populations are treated as units are much higher because individual differences tend to cancel. Therefore average stature in early childhood may be highly correlated with average birth weight.

Two conditions substantially limit the data available for estimating the relationship between stature in early childhood and birth weight. One is that studies of child growth tend to specialize on infancy or on growth after the first year. Consequently, there are few data available that combine birth weight and stature in early childhood. Second, the average slave child experienced considerable environmental deprivation, and ideally the data for estimating the relationship should be drawn from many examples encompassing the probable range of experience faced by slaves. Developing countries furnish a source of this information, but unfortunately the number of studies having the relevant data is small.

The most comprehensive source of information on growth and development under various conditions is Eveleth and Tanner, Worldwide Variation in Human Growth. Table 2 presents the data from this source on height at ages 3 and 4 and birth weight among poor populations.[5] For convenience in estimation (discussed below), the results are expressed relative to modern standards, which were obtained from Tanner, Whitehouse, and Takaishi (1966). The table shows that the range of experience in the environments for growth is wide. The Lumi of New Guinea are among the very poorest populations in the world for which systematic information is available. In this group birth weights attained 68.6 percent and average heights at age 3 and 4 attained 87.4 percent of modern standards. Casual comparison among other rows in the table reveals a pattern established in other studies; namely, that weight is more sensitive to changes or differences in environmental conditions than is height.

The contention that children tend to follow a target path of growth suggests that relative nutritional status can be expressed (see Cole, 1979) as

$$\text{Height-for-age} = \frac{\text{Actual height}}{\text{Expected (or standard) height}}, \quad (1)$$

and in the case of weight as

$$\text{Weight-for-age} = \frac{\text{Actual weight}}{\text{Expected (or standard) weight}}. \quad (2)$$

The objective is to forecast or predict birth weight from knowledge of relative height. This raises the question of which variable should be the regressand and which variable should be the regressor (Maddala, 1977, 97-102). Since birth obviously occurs before relative height is observed at ages 3 and 4, one can argue that relative birth weight should be the regressor. On the other hand, it is logical to take the variable to be predicted as the regressand.

Because the causal relationship between the variables is well-established, relative birth weight is chosen as the regressor. The fact that weight tends to be more sensitive to the environment than does height suggests the following functional form:

$$\ln(\text{height-for-age}) = \alpha + \beta \ln(\text{weight-for-age}). \quad (3)$$

Estimation of equation (3) based on the data of Table 2 gives the following results (t-values are given in parenthesis):

$$\alpha = 0.043815 \ (8.11)$$

$$\beta = 0.46864 \ (17.15)$$

$$R^2 = .98.$$

The estimate of β is biased as a measure of the pure effect of relative birth weight on relative height at ages 3 and 4 because nutrition after birth is omitted as an explanatory variable. It is desirable to have an unbiased estimate of β for certain purposes, but the objectives pursued here are modest. It is clear from the results of estimating equation (3) that relative birth weight and relative height at ages 3 and 4 are highly correlated. Thus, if height data are available, knowledge of nutrition after birth is largely redundant for inferring relative birth weight. This is the case despite the fact that nutrition is essential for growth. The results of estimating equation (3) constitute a generalization about resource allocation within poor societies: The conditions of poverty that cause relatively low birth weight endure to keep the children small.

It is conceivable that American slaves did not fit the pattern found in Table 2. Substantial resources could have been invested in prenatal care such that birth weights were high, for example, and then children were neglected such that they ended up small at age 3. However, the pattern of resource allocation that would produce this result makes little sense within an economic regime of slavery. Furthermore, evidence discussed in Steckel (1985a) suggests that the prenatal environment for growth was poor, especially during seasonal peaks in the demand for labor.

On average slave children at ages 3 and 4 attained 86.7 percent of modern height standards.[6] Based on parameter estimates of equation (3) the inferred value of birth weight is 5.10 pounds or 2320 grams. A simple linear form involving weight-for-age and height-for-age yields almost identical results.[7] Using Fieller's method (Maddala, 1977, 101-102) it is possible to obtain a tolerance interval for the inferred value of birth weight. An 80 percent tolerance interval is (4.95, 5.24) in pounds and (2250, 2380) in grams. Values in this range place American slave newborns among the smallest documented for poor populations in developing countries of the mid-twentieth century (Meredith, 1970; WHO, 1980).

FROM BIRTH WEIGHT TO NEONATAL MORTALITY

The method used to estimate neonatal mortality rates draws upon established patterns of the frequency distribution of birth weights and incidence of neonatal mortality by birth weight. The neonatal mortality rate can be calculated by adding (across weight categories) the products of these distributions. This section considers the sources and the limitations of the distributions used for this purpose.

Although the distribution of birth weight is approximately normal, the assumption of normality is inadequate for these calculations. The departure from normality arises primarily because birth weights are skewed to the left. Furthermore, the extent of skewness tends to increase as average birth weight declines. Skewness is important to the calculations because mortality rates are high at low birth weights. Thus the distribution borrowed for calculations should have a mean close to the estimated mean for slaves. Because the estimated mean for slave newborns is so low, however, there are few reasonable choices available in the literature. Among the distributions found readily, the one having the lowest mean derives from a study of birth weights among the poor of Bombay (Jayant, 1964). The mean birth weight of males and females in this group was 2535 grams (N=2,279), which is 215 grams above the estimated mean for U.S. slaves. The distribution for slaves was approximated by shifting the Bombay distribution to the left by 215 grams and by assuming that birth weights were evenly distributed within each weight category. The results are given in the second column of Table 3. To the extent that skewness increases as average birth weight declines below 2535 grams, use of this distribution underestimates neonatal mortality.

The schedule of neonatal mortality rates typically follows a U-shaped pattern (Chase, 1969; Pharoah and Alberman, 1981; North and MacDonald, 1977). Ordinarily the rate reaches a minimum in the neighborhood of 3000 to 4000 grams. The losses usually increase rapidly below 2500 grams, and before technological improvements of the 1960s and 1970s, a majority of newborns weighing less than 1500 grams failed to survive.

Two considerations are important in selecting a neonatal mortality rate schedule that approximates conditions faced by U.S. slaves. One is that losses by birth weight vary between whites and blacks (North and MacDonald, 1977). Compared to whites, nonwhites have lower rates at low birth weights and higher rates at high birth weights. Second, the quality of obstetrical practices and facilities influences the chances of survival, particularily for cases involving complications. The first objective alone is relatively easy to fulfill; many schedules give results for whites and for nonwhites. The second is more elusive because midwives usually attended slave births. By the time that systematic registration procedures for births and deaths were in place in the United States (the registration area was complete in 1933), midwives had diminished considerably in importance. By 1935, for example, midwives delivered only 12.5 percent of all registered births in the United States (U.S. National Office of Vital Statistics, 1954c, 510). The data problem is exacerbated by the fact that many states did not require birth weight information on birth certificates before the 1940s.

Fortunately, usable data are available from the Public Health Service, but they must be interpreted with caution. As part of an effort to assess the extent of underregistration of births, the National Office of Vital Statistics linked a sample of birth and death certificates for persons born in January-

March of 1950. These records have been the data source for special reports on birth weight and survival published by the Public Health Service during the 1950s. These data are useful for this paper because midwives delivered a large absolute number of births as late as 1950 and their services were concentrated among blacks who lived in the South. In 1950, for example, midwives (or other nonphysicians) working outside hospitals and other institutions attended approximately 38.7 percent of the nonwhite births registered in the South Atlantic region (U.S. National Office of Vital Statistics, 1954c, 517).

The last column of Table 3 presents the neonatal mortality schedule for nonwhite births attended by nonphysicians in metropolitan (SMSA) counties.[8] The authors of the specical report caution readers about the potential for understatement in the measured mortality rates relevant to midwives (U.S. National Office of Vital Statistics, 1954a, 18-19). Specifically, the data fail to take into account subsequent hospitilization of some infants delivered at home or the physician's care given to others soon after delivery by a nonphysician. Perhaps more important is the possible selection of obstetrical cases involving complications for referral to hospitals and the calling in of physicians by some midwives to handle difficult deliveries. Furthermore, in home births there was probably a greater tendency to underreport infants who died shortly after birth or to misreport them as fetal deaths. To these sources of downward bias in the mortality rates as a measure of the experience for slaves can be added the midwives' lack of knowledge about antiseptic procedures during the early and mid-nineteenth century compared to the mid-twentieth century. Relative levels of mortality imply that obstetrical services were important to survival in the weight range of 1501 to 3500 grams. Among nonwhite births in this weight group born in metropolitan counties, the loss rate for physicians in hospitals was less than half of that for nonphysicians working outside hospitals (U.S. National Office of Vital Statistics, 1957, 217-218).

The expected rated of neonatal mortality calculated from the data in Table 3 is 152.2 per thousand live births. In view of previous remarks this figure should be regarded as a lower bound. Sensitivity analysis establishes a cluster of values for the loss rate. Substituting a birth weight distribution from Barua (1973) that also had a mean of 2535 grams produces an estimated loss rate of 156.1 per thousand. The distribution from Jayant (1964) is preferred for calculations on the grounds of a larger sample size (2,279 vs. 1,086). Shifts of the birth weight distribution given in Table 3 corresponding to values of the 80 percent tolerance interval for mean birth weight of (2250, 2380) imply a loss rate interval of (168.7, 136.8).

WERE LOW BIRTH WEIGHTS "OPTIMAL"?

The laws and institutions of the antebellum South establish that slaveowners had firm control of their chattel. It is clear that these arrangements facilitated the allocation of slave resources within the plantation and within the South. Owners and overseers, as representatives of owners, for example, controlled the daily routine of slaves and could, and did, use force to extract work.

Given this setting it may be instinctive for economists to conclude that all major aspects of slave life were shaped by the owner to fulfill the objective of long-run profit maximization. Accordingly, owners would have systematically collected information about the costs and benefits of alternative deployments of resources and then reached a decision that established plantation policy. Plantation documents such as diaries, ledgers, inventories, and birth and death lists, and the records of market evaluation of slaves are strong evidence of optimizing behavior.

Given the evidence for optimizing behavior in many aspects of plantation life, it is natural to ask whether low birth weights were optimal. Should low birth weights be taken as evidence that Simon Legree was a typical slaveowner? In discussing this question it is important to distinguish between optimal and deliberate. The term "deliberate" implies a full or nearly full command of the facts essential for a decision. In constrast, decision-makers can optimize despite the lack of considerable information. Thus the question can be rephrased in terms of what slaveowners might have known about determinants and consequences of birth weight.

The available information suggests that owners were largely ignorant of the causes and effects of low birth weight. Owners were substantially more confused than in command of the determinants of health and mortality, especially those aspects involving delays or incubation periods between cause and effect. Fetal growth illustrates the difficulties of medical inquiry because development occurs over several months and little is observed until the final product is delivered. Indeed, many important aspects of fetal development remain conjecture as late as the mid to late twentieth century (Tanner, 1978).

The practice of taking measurements of newborns originated in Germany during the 1750s, but was not common in clinics until the mid 1800s (Tanner, 1981, 254-261). Studies published in the late 1700s and early 1800s attempted to link the dimensions of newborns to the chances of survival. Particular attention was given to dimensions of the head because it was of major importance in difficult deliveries. It is possible, but doubtful that planters were generally aware of the results of these studies. Discussions of the substance of these studies by slaveowners were notably absent from the major agricultural journals that circulated within the antebellum South (Breeden, 1980). If owners were aware of these issues, their interest may have focused on large births as an obstacle to the health and survival of the mother. After all, the typical mother may have been worth 15 times as much as the typical newborn (Fogel and Engerman, 1974, 76).

Even though slaveowners had little scientific understanding of the determinants and consequences of low birth weight, knowledge about desirable prenatal practices could have accumulated in the form of traditional patterns. Through a long process of trial, error, observation, and adjustment, traditional societies may gravitate towards practices that scientific analysis could show were desirable. Did slaveowners compell slaves to follow substantially different patterns of prenatal care than were practiced by the free population? The limited information examined on nineteenth century birth weights suggests that important differences in prenatal care may have existed. During the early 1800s the newborns of the poor in Paris had average weights of 2,940 grams (Tanner, 1981, 256-257), and during the mid 1800s the poor of Philadelphia had newborns weighing on average above 3,200 grams.[9] A poor diet associated with poverty probably contributed to reduce these weights below modern standards of about 3,450 grams. Yet an enormous difference existed between slaves and the poor of Paris and Philadelphia. It is possible but doubtful that differences in diet alone could explain the relatively low birth weights of slaves. The height data suggest that slaves were reasonably well-fed for the work effort required of them. The major culprit may have been the detrimental effects of work, especially effort that required standing, on blood flow to the placenta. Slaveowners were probably unaware of these effects, however, because the earliest studies suggesting that rest during pregnancy was beneficial to fetal development were not conducted until the late 1800s (Briend, 1980, 1159). Additional research on birth weights of nineteenth century populations would help to clarify the role of work effort and other factors on low birth weight.

It is reasonable to conclude that low birth weights were not deliberate in the sense that owners compelled hard work and rations insufficient for normal fetal development based upon well-established calculations that the value of the extra output and savings in food costs more than offset the costs of higher infant mortality that would result. The term "optimize" suggests that decision-makers have command of some important facts. The facts best known to slaveowners were the benefits of extra work effort in terms of output produced. This knowledge alone may qualify slaveowners as optimizing agents in the production of slave health, but the limited sense in which it was true should be emphasized.

CONCLUDING REMARKS

Underenumeration of vital events is a problem familiar to people who work with historical demographic records. The difficulties are acute for study of mortality because a large share of deaths are concentrated soon after birth. The rare compulsive recordkeeper aside, ordinarily sources are riddled with births and deaths that were never recorded. Family histories and genealogies, for example, clearly demonstrate this problem (Fogel _et al_., 1978). In the case of slave birth and death lists, the potential for underenumeration is clear from entries that died unnamed. In a world of high mortality rates parents were reluctant to name or otherwise invest psychic attachment in a child that had little chance of survival. Yet it is the survival or nonsurvival of these children that is useful for an assessment of living standards and other aspects of the quality of life in the past.

This paper proposes a method for recovering information about mortality that occurred soon after birth. The method requires height data for young children, which are abundant for slaves and which are available for other historical populations.[10] In principle the method could be extended for use with older children and with adults. The results may not be as precise as those based on the heights of young children, however, because the older the child the greater are the chances that environmental conditions different from those surrounding pregnancy had an influence on stature. Furthermore, the lack of studies that link birth weight with heights of older children may force a two step procedure: estimating relative height at age 1 from relative height of older children or adults and then estimating birth weight from estimated relative height at age 1.

With regard to the underenumeration of slave deaths that follow from this analysis, comparisons are possible with mortality estimates derived from plantation records. A collection of birth and death lists from eleven large plantations that contain information on the period from 1786 to 1865, and which among them grew cotton, rice, and sugar, has been assembled for study (Steckel, 1979b). In selecting these records from southern archives, care was taken to avoid lists that had overt instances of underreporting such as "X" or "dead" notations. In this sample the measured neonatal mortality rate was 57.8 per thousand (N=1,989),[11] which is about 38 percent of the rate of 152.2 implied by the data in Table 3.

The postneonatal mortality rate in the plantation record sample (Steckel, 1979b) was 162.2 per thousand. Assuming a lack of underenumeration in this figure and that the distributions in Table 3 accurately portray the neonatal period, then the implied level of infant mortality is 30 percent. Given the potential for understatement in the neonatal mortality schedule, the possibility that the lower tail of the estimated weight distribution is too small, and the possibility of underreporting in the the calculated postneonatal mortality rate, infant mortality could easily have been several percentage points above 30.

Although it is difficult to estimate the extent of possible downward bias, numbers in the range of 30 to 35 percent, and possibly higher, are reasonable conjectures for slave infant mortality. Figures in this range are considerably above previous estimates. The raw data of the eleven plantations discussed above have a rate of 233 per thousand (Steckel, 1979b, 92); based on a different set of plantation records, Postell (1951, 158) found a rate of 152.6; Evans (1962, 212) estimated a rate of 182.7; Farley (1970) argues for 288; and Eblen's estimates (1972; 1974) range from 246 to 275.

The low estimates based on plantation records are easily understood; even diligent recordkeepers fail to record some vital events, especially if death occurred soon after birth. The estimates of Evans, Farley, and Eblen are based fundamentally on borrowing age patterns of mortality observed in other, presumably similar, populations. The technique of estimating model life tables is widely employed in demographic work. One of the conclusions of this paper is that borrowing age patterns of mortality should be undertaken cautiously, especially if the application involves historical populations for which information about the determinants of health is lacking. Specifically, the level of mortality at young ages among American slaves appears to have been above those in populations once thought to have been similar.

The estimated birth weight distribution substantially drives the estimates of neonatal mortality. This distribution also has important implications for the share of pregnancies lost through fetal deaths. Table 4 shows the ratios of fetal losses to live births by birth weight for nonwhites in 1950. The schedule is similar to that for neonatal mortality. If the birth weight distribution of Table 3 and the data of Table 4 are combined, the implied rate of loss is 114.2 per thousand live births. If the birth weight distributions corresponding to the 80 percent tolerance interval of estimated birth weight are used, the implied interval for stillbirth loss is (126.3, 102.8). The extent to which the schedule of loss in Table 4 applies to slaves is unknown. Because of the great potential for stress during the first trimester among slave pregnancies and the relevance of this stress for stillbirths, however, the calculations using the schedule of Table 4 should be viewed as lower bounds.

The analysis discussed in this paper can be extended to study of regional differences and time profiles of health and mortality. Sufficient height data are available in the National Archives for these purposes, and efforts to assemble additional data are in progress. One of the major questions involving time trends concerns possible cycles. Previous work in this area (Steckel, 1979a) discovered declines in the heights of children during the 1830s and early 1840s. Additional data will enhance study of this question by region and perhaps by individual years.

A final point worth making concerns estimates of slave fertility. If previous mortality estimates are too low, then previous fertility estimates are low as well. At the level of family reconstitution, higher infant mortality estimates imply that intervals between live births were shorter and the number of children ever born per woman were higher than previously thought. New estimates of birth intervals and children ever born could be made based on a life table revised in light of this paper.

FOOTNOTES

1. Because "endogenous" factors also cause mortality during the late prenatal period, stillbirths and early neonatal deaths are combined into a separate measure called perinatal mortality. This measure includes deaths from the 28th week of gestation to the seventh day after birth, and has the advantage of eliminating some of the measurement problems associated with various definitions of stillbirths.
2. See the references cited in the sentence and references therein, for discussions of the methodology of using height as a measure of nutrition, health, and living standards.
3. See Steckel (1979a; 1985b) for descriptions of the data and discussions of possible biases.
4. The effects of mother's work on fetal growth may be the consequence of maladaptation by humans to an upright posture. See Briend (1979; 1980) and Hytten (1981).
5. In this context poor populations are defined as having average birth weights under 3.20 kilograms (7.0 pounds). The modern standard for birth weight is 3.45 kilograms (average for males and females).
6. In calculating this figure it is important to remember that the average age of children age 3 at last birthday, for example, is 3.5 years.
7. A simple linear form involving weight-for-age and height-for-age gives an inferred value of 5.07 pounds. The coefficient of a dummy variable for sex is statistically insignificant (t=0.19) if it is included in equation (3).
8. The sample for metropolitan counties is preferred on grounds that registration was more complete in metropolitan as opposed to nonmetropolitan areas (U.S. National Office of Vital Statistics, 1954b, 59).

9. The results for Philadelphia are based on preliminary analysis by Claudia Goldin and Robert Margo.

10. John Komlos, for example, has recently assembled height data for young children who lived in Eastern Europe during the eighteenth century.

11. Based on observations for which month, day, and year of the event is available.

Table 1

Mean, Standard Deviation, and Centile of Modern Height Standards Achieved by Young Slave Children.

	MALES				FEMALES			
Age	Mean	s.d.	N	Centile of Modern	Mean	s.d.	N	Centile of Modern
1	23.88[a]	4.65	96	0.00003[a]	23.64[a]	5.58	91	0.0002[a]
2	29.17[a]	5.35	136	0.01[a]	29.50[a]	5.42	148	0.06[a]
3	33.35	5.20	187	0.2	32.65	4.93	168	0.1
4	35.91	5.53	195	0.3	35.92	5.46	206	0.5
5	38.25	5.29	169	0.3	38.98	5.19	200	1.6
6	40.63	5.31	218	0.5	40.01	5.76	262	0.4

Source: Slave manifests and calculated from Tanner Whitehouse and Takaishi (1966). Steckel (1985a) discusses calculation methods.

a. The means and centiles at these ages are probably biased downward due to measurement error. See the text for additional discussion.

Table 2

Birth Weight and Height at ages 3 and 4 Relative to Modern Standards Among Poor Populations

Region or Country	People or Place	Sex	Birth Weight Relative to Standard	Height at Ages 3 and 4 Relatve to Standard
Brazil	São Paulo	F	.909	.988
Thailand	Bangkok	M	.891	.991
Thailand	Bangkok	F	.885	.993
Australia	Aborigine	F	.853	.975
Australia	Aborigine	M	.829	.962
Nigeria	Imesi	M	.829	.954
Nigeria	Imesi	F	.824	.952
New Guinea	Lumi	M	.686	.874

Source: Eveleth and Tanner (1976) and Tanner, Whitehouse and Takaishi (1966).

Table 3

Estimated Distribution of Slave Birth Weights and Neonatal Mortality Rates

Weight (grams)	Birth Weight Distribution	Neonatal Mortality Rate per Thousand[a]
Under 1501	.0805	744.1
1501-2000	.1740	298.5
2001-2500	.3457	88.4
2501-3000	.2894	27.8
3001-3500	.0968	16.9
3501+	.0137	9.2

Source: Calculated from Jayant (1964) and U.S. National Office of Vital Statistics (1957, 211, 215, and 218).

a. Nonwhite births delivered by nonphysicians outside of hospitals and institutions in metropolitan counties.

Table 4

Stillbirths as a Share of Live Births by Birth Weight, Nonwhites, 1950

Birth Weight (grams)	Stillbirths as a Share of Live Births
Under 1500	.6085
1501-2000	.2028
2001-2500	.0652
2501-3000	.0199
3001-3500	.0138
3500+	.0184

Source: Calculated from U.S. National Office of Vital Statistics (1953).

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