

# Infant Mortality

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## PUBLIC HEALTH IMPORTANCE

Infant mortality is an important indicator of the health of a nation or community because it is associated with a variety of factors such as maternal health, quality and access to medical care, socioeconomic conditions, and public health practices (1–4) (*National Center for Health Statistics [NCHS], unpublished data for 1987, 1992*). The U.S. infant mortality rate has declined approximately tenfold since the beginning of this century, from an estimated 97.3 deaths per 1,000 live births in 1900 (5,6) to 9.2 deaths per 1,000 live births in 1990 (7).

Infant mortality declined rapidly for most of this period; however, rates of decline were slower from 1950 to 1964 and again from 1981 to 1990 (Figure 1). Despite this large decline, the problem of infant mortality remains substantial. In 1990, 38,351 infants died before their first birthday. Each of these deaths represents a tragedy for parents, siblings, and other family members.

Recent declines in infant mortality in the United States have not kept pace with declines in other countries. As a result, the United States' international ranking in infant mortality has fallen from 12th lowest in 1960 to 23rd lowest in 1988 (*NCHS, unpublished data, 1993*). In 1988, the U.S. infant mortality rate of 10 was about twice that of number one-ranked Japan. In addition, large disparities in the risk of infant death between various race and ethnic groups have persisted and even increased in recent years. For example, in 1990, the mortality rate for black infants was 18.0—2.4 times the rate of 7.6 for white infants (7) (see the General Findings section of this chapter).

Infant mortality is defined as the death of an infant before his or her first birthday. The infant mortality rate per 1,000 live births is computed by dividing the number of infant deaths for a given period by the number of live births for the same period and then multiplying by 1,000. Infant mortality rates may be computed either on a period or cohort basis (for additional information about related topics and surveillance activities, see the Behavioral Risk Factors Before and During Pregnancy, Prenatal Care, Preterm Birth, Low Birth Weight and Intrauterine Growth Retardation, Prevalence of Birth Defects, and Neonatal and Postneonatal Mortality chapters).

## HISTORY OF DATA COLLECTION

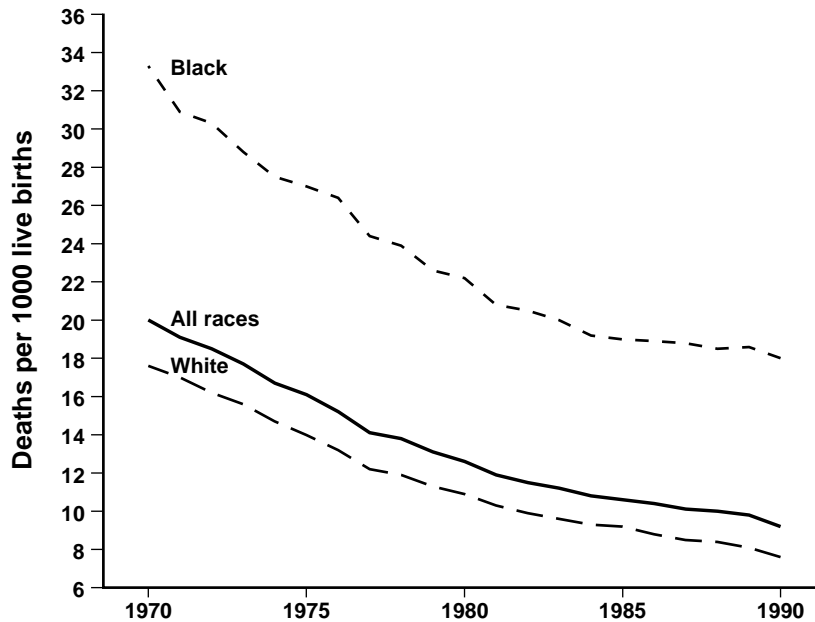
The primary source of infant mortality statistics for the United States is the National Vital Statistics System. Through this system, virtually all vital events (births, deaths, and other events) occurring in the United States each year are registered; the data are then processed and made available to the public. Infant deaths comprise a subset of the approximately 2.2 million deaths registered on death certificates each year.

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**FIGURE 1. Infant mortality rates, by race of mother — United States, 1970–1990**



Periodic estimates of deaths and death rates have long been available, but in 1900, the U.S. Bureau of the Census began collecting mortality statistics annually for a death registration area of 10 states, the District of Columbia, and a number of cities. The death registration area gradually expanded and by 1933 included the entire United States. In 1946, the responsibility for providing vital statistics was given to the Public Health Service (8). This task now rests with CDC's National Center for Health Statistics (NCHS). *Vital Statistics of The United States*, which contains data on general and infant mortality and other vital events, has been published annually since 1937. From 1900 to 1936, the volume was entitled *Mortality Statistics*.

## CDC SURVEILLANCE ACTIVITIES

### National Vital Statistics System

#### MORTALITY DATA

Mortality data from the National Vital Statistics System provide information on the number of infant deaths by various characteristics of the

decedent including age, sex, race and ethnic origin, and cause of death. These data also form the numerator when computing infant mortality rates. Data on the number of live births, used as the denominator for infant mortality rates, are also provided through the National Vital Statistics Program in a manner similar to that described for mortality data (live-birth data are described in more detail in the Prenatal Care and Low Birth Weight and Intrauterine Growth Retardation chapters).

Mortality data from the National Vital Statistics System are cooperatively produced by NCHS and state vital statistics offices under the Vital Statistics Cooperative Program. The basic source of mortality information is the death certificate. U.S. death registration is a state function; death certificates are filed and maintained in state vital statistics offices according to state legal requirements.

The U.S. Standard Certificate of Death, recommended by NCHS for use by states, is revised approximately once every 10 years in collaboration with the states, NCHS, other federal agencies, and subject-matter experts (9). The current certificate, revised in 1989, has been adopted

with minor variations by the states (Figure 2). The information on the death certificate is provided by two groups of persons: 1) the certifying physician, medical examiner, or coroner, and 2) the funeral director. The certifying physician, medical examiner, or coroner certifies the causes of death (10,11). The funeral director provides the demographic information (e.g., age, race, sex) and files the certificate with the state vital statistics office (12). Coverage is universal because state laws require death certificates for disposition of bodies and because the certificates are often needed for legal purposes, including estate settlement.

In addition to making periodic revisions to the U.S. Standard Certificate of Death, NCHS promotes uniformity in the collection and processing of mortality data in a number of ways. NCHS also periodically updates the *Model State Vital Statistics Act and Model State Vital Statistics Regulations* (13) to help states develop and revise their vital statistics laws. In addition, NCHS offers training and technical assistance to state vital statistics offices to enhance their capabilities and provides states with annually updated instruction manuals containing information on standard coding and data processing procedures (14). Most of the mortality data are coded in the state vital statistics offices according to standard NCHS procedures. In 1990, the demographic information for all states and the cause-of-death information for about half of the states were coded by the state vital statistics offices (7). Information not coded in the state offices is coded by NCHS from microfilm copies of the original records.

Mortality data are subject to NCHS quality-control procedures at several processing stages to check for completeness, individual item code validity, and consistency between data items. First, NCHS checks problems or inconsistencies against the original source and corrects them, if possible. When corrections are not possible, lists of coding inconsistencies are returned to the states for information and corrective action. Second, NCHS codes a quality control sample of records and compares the sample with state-coded data to assess the accuracy of state coding. Third, numbers of deaths are compared between the current and the previous year's data for each county in the United States and for 282

cause-of-death categories. States are contacted when large changes are noted, and any data problems are investigated. Counts and percentages of records with impossible or out-of-range codes are also reviewed and compared with the previous year's performance. Finally, according to written procedures, invalid or inconsistent values may be modified or assigned as unknowns. Selected missing items may be imputed.

## FINAL AND PROVISIONAL DATA

Final infant mortality data from the National Vital Statistics System are generally available about 18–24 months after the close of a data year. These data are published annually in the *Advance Report of Final Mortality Statistics* (7) and in *Vital Statistics of the United States* (15), as well as in periodic NCHS reports (16,17). NCHS also produces a number of unpublished worktables each year and public-use data tapes containing individual-record information on all registered deaths occurring since 1968. The tape contents, file characteristics, and cost are described in the *Catalog of Electronic Data Products*, available from NCHS (18).

Each month, NCHS also produces provisional infant mortality data. These data are published 3–4 months after the death certificates are filed in state vital statistics offices and are limited to estimates of the number of infant deaths and infant mortality rates, by state and selected causes of death (19,20). Estimates are derived from 1) counts of the number of deaths and infant deaths registered during the month in state offices and 2) a 10% systematic sample (called the Current Mortality Sample) of death certificates filed in state offices and coded by NCHS. Although not considered as reliable as the final mortality data, provisional data are widely used for surveillance purposes because of their timeliness.

## Role of the World Health Organization

The World Health Organization (WHO) plays a major role in collecting, classifying, and tabulating mortality statistics for the United States and other countries through its publication of the *Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death*

FIGURE 2.

U.S. STANDARD  
CERTIFICATE OF DEATH

TYPE/PRINT  
IN  
PERMANENT  
BLACK INK  
FOR  
INSTRUCTIONS  
SEE OTHER SIDE  
AND HANDBOOK

LOCAL FILE NUMBER STATE FILE NUMBER

1. DECEDENT'S NAME (First, Middle, Last) 2. SEX 3. DATE OF DEATH (Month, Day, Year)

4. SOCIAL SECURITY NUMBER 5a. AGE—Last Birthday (Years) 5b. UNDER 1 YEAR (Months | Days) 5c. UNDER 1 DAY (Hours | Minutes) 6. DATE OF BIRTH (Month, Day, Year) 7. BIRTHPLACE (City and State or Foreign Country)

DECEDENT

8. WAS DECEDENT EVER IN U.S. ARMED FORCES? (Yes or no) 9a. PLACE OF DEATH (Check only one; see instructions on other side)  
HOSPITAL:  Inpatient  ER/Outpatient  DOA OTHER:  Nursing Home  Residence  Other (Specify)

SEE INSTRUCTIONS ON OTHER SIDE

9b. FACILITY NAME (If not institution, give street and number) 9c. CITY, TOWN, OR LOCATION OF DEATH 9d. COUNTY OF DEATH

10. MARITAL STATUS—Married, Never Married, Widowed, Divorced (Specify) 11. SURVIVING SPOUSE (If wife, give maiden name) 12a. DECEDENT'S USUAL OCCUPATION (Give kind of work done during most of working life. Do not use retired.) 12b. KIND OF BUSINESS/INDUSTRY

13a. RESIDENCE—STATE 13b. COUNTY 13c. CITY, TOWN, OR LOCATION 13d. STREET AND NUMBER

13e. INSIDE CITY LIMITS: (Yes or no) 13f. ZIP CODE 14. WAS DECEDENT OF HISPANIC ORIGIN? (Specify No or Yes—If yes, specify Cuban, Mexican, Puerto Rican, etc.)  No  Yes Specify: 15. RACE—American Indian, Black, White, etc. (Specify) 16. DECEDENT'S EDUCATION (Specify only highest grade completed)  
Elementary/Secondary (0-12) College (1-4 or 5+)

PARENTS

17. FATHER'S NAME (First, Middle, Last) 18. MOTHER'S NAME (First, Middle, Maiden Surname)

INFORMANT

19a. INFORMANT'S NAME (Type/Print) 19b. MAILING ADDRESS (Street and Number or Rural Route Number, City or Town, State, Zip Code)

DISPOSITION

20a. METHOD OF DISPOSITION  
 Burial  Cremation  Removal from State  
 Donation  Other (Specify) \_\_\_\_\_ 20b. PLACE OF DISPOSITION (Name of cemetery, crematory, or other place) 20c. LOCATION—City or Town, State

SEE DEFINITION ON OTHER SIDE

21a. SIGNATURE OF FUNERAL SERVICE LICENSEE OR PERSON ACTING AS SUCH 21b. LICENSE NUMBER (of Licensee) 22. NAME AND ADDRESS OF FACILITY

PRONOUNCING PHYSICIAN ONLY

Complete items 23a-c only when certifying physician is not available at time of death to certify cause of death. 23a. To the best of my knowledge, death occurred at the time, date, and place stated. Signature and Title: \_\_\_\_\_ 23b. LICENSE NUMBER 23c. DATE SIGNED (Month, Day, Year)

ITEMS 24-26 MUST BE COMPLETED BY PERSON WHO PRONOUNCES DEATH

24. TIME OF DEATH M 25. DATE PRONOUNCED DEAD (Month, Day, Year) 26. WAS CASE REFERRED TO MEDICAL EXAMINER/CORONER? (Yes or no)

SEE INSTRUCTIONS ON OTHER SIDE

27. PART I. Enter the diseases, injuries, or complications that caused the death. Do not enter the mode of dying, such as cardiac or respiratory arrest, shock, or heart failure. List only one cause on each line. Approximate Interval Between Onset and Death

IMMEDIATE CAUSE (Final disease or condition resulting in death) a. \_\_\_\_\_ DUE TO (OR AS A CONSEQUENCE OF):  
Sequentially list conditions, if any, leading to immediate cause. Enter UNDERLYING CAUSE (Disease or injury that initiated events resulting in death) LAST b. \_\_\_\_\_ DUE TO (OR AS A CONSEQUENCE OF):  
c. \_\_\_\_\_ DUE TO (OR AS A CONSEQUENCE OF):  
d. \_\_\_\_\_

CAUSE OF DEATH

PART II. Other significant conditions contributing to death but not resulting in the underlying cause given in Part I. 28a. WAS AN AUTOPSY PERFORMED? (Yes or no) 28b. WERE AUTOPSY FINDINGS AVAILABLE PRIOR TO COMPLETION OF CAUSE OF DEATH? (Yes or no)

SEE DEFINITION ON OTHER SIDE

29. MANNER OF DEATH  
 Natural  Pending Investigation  
 Accident  Suicide  Could not be Determined  
 Homicide 30a. DATE OF INJURY (Month, Day, Year) 30b. TIME OF INJURY M 30c. INJURY AT WORK? (Yes or no) 30d. DESCRIBE HOW INJURY OCCURRED  
30e. PLACE OF INJURY—At home, farm, street, factory, office building, etc. (Specify) 30f. LOCATION (Street and Number or Rural Route Number, City or Town, State)

CERTIFIER

31a. CERTIFIER (Check only one)  
 CERTIFYING PHYSICIAN (Physician certifying cause of death when another physician has pronounced death and completed Item 23) To the best of my knowledge, death occurred due to the cause(s) and manner as stated.  
 PRONOUNCING AND CERTIFYING PHYSICIAN (Physician both pronouncing death and certifying to cause of death) To the best of my knowledge, death occurred at the time, date, and place, and due to the cause(s) and manner as stated.  
 MEDICAL EXAMINER/CORONER On the basis of examination and/or investigation, in my opinion, death occurred at the time, date, and place, and due to the cause(s) and manner as stated.

31b. SIGNATURE AND TITLE OF CERTIFIER 31c. LICENSE NUMBER 31d. DATE SIGNED (Month, Day, Year)

REGISTRAR

32. NAME AND ADDRESS OF PERSON WHO COMPLETED CAUSE OF DEATH (ITEM 27) (Type/Print)

33. REGISTRAR'S SIGNATURE 34. DATE FILED (Month, Day, Year)

DEPARTMENT OF HEALTH AND HUMAN SERVICES—PUBLIC HEALTH SERVICE—NATIONAL CENTER FOR HEALTH STATISTICS—1989 REVISION

FIGURE 2.-continued

INSTRUCTIONS FOR SELECTED ITEMS

**Item 9.—Place of Death**

If the death was pronounced in a hospital, check the box indicating the decedent's status at the institution (inpatient, emergency room/outpatient, or dead on arrival (DOA)). If death was pronounced elsewhere, check the box indicating whether pronouncement occurred at a nursing home, residence, or other location. If other is checked, specify where death was legally pronounced, such as a physician's office, the place where the accident occurred, or at work.

**Items 13.a-f.—Residence of Decedent**

Residence of the decedent is the place where he or she actually resided. This is not necessarily the same as "home State," or "legal residence." Never enter a temporary residence such as one used during a visit, business trip, or a vacation. Place of residence during a tour of military duty or during attendance at college is not considered as temporary and should be considered as the place of residence.

If a decedent had been living in a facility where an individual usually resides for a long period of time, such as a group home, mental institution, nursing home, penitentiary, or hospital for the chronically ill, report the location of that facility in items 13a through 13f.

If the decedent was an infant who never resided at home, the place of residence is that of the parent(s) or legal guardian. Do not use an acute care hospital's location as the place of residence for any infant.

**Items 23 and 31—Medical Certification**

The PRONOUNCING PHYSICIAN is the person who determines that the decedent is legally dead but who was not in charge of the patient's care for the illness or condition which resulted in death. Items 23a through 23c are to be completed only when the physician responsible for completing the medical certification of cause of death (Item 27) is not available at time of death to certify cause of death. The pronouncing physician is responsible for completing only items 23 through 26.

The CERTIFYING PHYSICIAN is the person who determines the cause of death (Item 27). The box should be checked only in those cases when the person who is completing the medical certification of cause of death is not the person who pronounced death (Item 23). The certifying physician is responsible for completing items 27 through 32.

The PRONOUNCING AND CERTIFYING PHYSICIAN box should be checked when the same person is responsible for completing items 24 through 32, that is, when the same physician has both pronounced death and certified the cause of death. If this box is checked, items 23a through 23c should be left blank.

The MEDICAL EXAMINER/CORONER box should be checked when investigation is required by the Post Mortem Examination Act and the cause of death is completed by a medical examiner or coroner. The Medical Examiner/Coroner is responsible for completing items 24 through 32.

**Item 27.—Cause of Death**

The cause of death means the disease, abnormality, injury, or poisoning that caused the death, not the mode of dying, such as cardiac or respiratory arrest, shock, or heart failure.

In **Part I**, the immediate cause of death is reported on line (a). Antecedent conditions, if any, which gave rise to the cause are reported on lines (b), (c), and (d). The underlying cause, should be reported on the last line used in Part I. No entry is necessary on lines (b), (c), and (d) if the immediate cause of death on line (a) describes completely the train of events. **ONLY ONE CAUSE SHOULD BE ENTERED ON A LINE.** Additional lines may be added if necessary. Provide the best estimate of the interval between the onset of each condition and death. Do not leave the interval blank; if unknown, so specify.

In **Part II**, enter other important diseases or conditions that may have contributed to death but did not result in the underlying cause of death given in Part I.

See examples below.

SEE INSTRUCTIONS ON OTHER SIDE	<b>27. PART I.</b> Enter the diseases, injuries, or complications that caused the death. Do not enter the mode of dying, such as cardiac or respiratory arrest, shock, or heart failure. List only one cause on each line.					Approximate Interval Between Onset and Death
	<b>IMMEDIATE CAUSE</b> (final disease or condition resulting in death)					
SEE INSTRUCTIONS ON OTHER SIDE	Sequentially list conditions, if any, leading to immediate cause. Enter <b>UNDERLYING CAUSE</b> (Disease or injury that initiated events resulting in death) <b>LAST</b>	a	Rupture of myocardium			Mins.
		b	DUE TO (OR AS A CONSEQUENCE OF) Acute myocardial infarction			6 days
		c	DUE TO (OR AS A CONSEQUENCE OF) Chronic ischemic heart disease			5 years
		d	DUE TO (OR AS A CONSEQUENCE OF)			
CAUSE OF DEATH	<b>PART II.</b> Other significant conditions contributing to death but not resulting in the underlying cause given in Part I Diabetes, Chronic obstructive pulmonary disease, smoking					
						<b>28a.</b> WAS AN AUTOPSY PERFORMED? (Yes or no) Yes
<b>29. MANNER OF DEATH</b> <input checked="" type="checkbox"/> Natural <input type="checkbox"/> Pending Investigation <input type="checkbox"/> Accident <input type="checkbox"/> Suicide <input type="checkbox"/> Could not be Determined <input type="checkbox"/> Homicide		<b>30a.</b> DATE OF INJURY (Month, Day, Year)	<b>30b.</b> TIME OF INJURY M	<b>30c.</b> INJURY AT WORK? (Yes or no)	<b>30d.</b> DESCRIBE HOW INJURY OCCURRED	
		<b>30e.</b> PLACE OF INJURY—At home, farm, street, factory, office building, etc. (Specify)		<b>30f.</b> LOCATION (Street and Number or Rural Route Number, City or Town, State)		

SEE INSTRUCTIONS ON OTHER SIDE	<b>27. PART I.</b> Enter the diseases, injuries, or complications that caused the death. Do not enter the mode of dying, such as cardiac or respiratory arrest, shock, or heart failure. List only one cause on each line.					Approximate Interval Between Onset and Death
	<b>IMMEDIATE CAUSE</b> (final disease or condition resulting in death)					
SEE INSTRUCTIONS ON OTHER SIDE	Sequentially list conditions, if any, leading to immediate cause. Enter <b>UNDERLYING CAUSE</b> (Disease or injury that initiated events resulting in death) <b>LAST</b>	a	Cerebral laceration			10 Mins.
		b	DUE TO (OR AS A CONSEQUENCE OF) Open skull fracture			10 Mins.
		c	DUE TO (OR AS A CONSEQUENCE OF) Automobile accident			10 Mins.
		d	DUE TO (OR AS A CONSEQUENCE OF)			
CAUSE OF DEATH	<b>PART II.</b> Other significant conditions contributing to death but not resulting in the underlying cause given in Part I					
						<b>28a.</b> WAS AN AUTOPSY PERFORMED? (Yes or no) No
<b>29. MANNER OF DEATH</b> <input type="checkbox"/> Natural <input type="checkbox"/> Pending Investigation <input checked="" type="checkbox"/> Accident <input type="checkbox"/> Suicide <input type="checkbox"/> Could not be Determined <input type="checkbox"/> Homicide		<b>30a.</b> DATE OF INJURY (Month, Day, Year) 11/15/85	<b>30b.</b> TIME OF INJURY 1p. M	<b>30c.</b> INJURY AT WORK? (Yes or no) No	<b>30d.</b> DESCRIBE HOW INJURY OCCURRED 2-car collision driver	
		<b>30e.</b> PLACE OF INJURY—At home, farm, street, factory, office building, etc. (Specify) Street		<b>30f.</b> LOCATION (Street and Number or Rural Route Number, City or Town, State) Route 4, Raleigh, North Carolina		

(*ICD*) (21). The *ICD* specifies the detailed title for >5,000 categories to which medical entities and circumstances of death may be assigned. The *ICD* also recommends broad categories to be used for tabulating and ranking mortality data and provides information on standard definitions and reporting requirements. The *ICD* has been revised about once each decade since the beginning of this century to take into account advances in medical knowledge. The ninth revision of the *ICD* (*ICD-9*) was implemented in 1979 and is currently used in the United States (21). The 10th revision should be implemented in the United States in the mid- to late-1990s.

Cause of death in the United States and other countries is traditionally presented in terms of the underlying cause of death, defined as “(a) the disease or injury which initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury” (21). The underlying cause of death is selected from the several possible morbid conditions listed on the death certificate, according to rules specified in the *ICD*. However, underlying-cause data can be augmented with additional information on other conditions reported as contributing to death on the death certificate (22). For this reason, NCHS also produces reports and a public-use data tape on multiple causes of death (18,23).

### **The National Linked Birth and Infant Death Data Set**

Another important source of data on infant mortality is NCHS's linked birth and infant death data set. In this data set, the death certificate is linked with the corresponding birth certificate for each infant who dies in the United States. The purpose of this linkage is to use the many additional variables available from the birth certificate in infant mortality analysis and to use the more accurate race data from the birth certificate in calculating race-specific infant mortality rates (see the Interpretation Issues section of this chapter). Information on all of the approximately 4 million live births in the United States each year is also included in the data set to enable researchers to compare deaths with survivors and to facilitate the computation of rates. The most recent of an annual series of

national linked files is the 1987 birth cohort file, which includes infants born in 1987 who died in 1987 or 1988 before their first birthday (24).

The linked birth and infant death data set (linked file) is constructed as a cohort file, with a one-to-one match of birth and death records from the NCHS's annual Natality and Mortality Vital Statistics Files. The linked file itself consists of two separate files. The first, the numerator file, is made up of the matched birth and death records of all deceased infants from a given cohort; the second, the denominator file, consists of the natality file for a given year plus any birth records from that cohort filed after the closing date of that year's natality file. Approximately 2% of each cohort's certificates cannot be linked, resulting in an underestimate of infant mortality of about 2% compared with the annual files.

The national linked file is processed in two stages. In the first stage, NCHS creates an initial file. NCHS takes advantage of the fact that most states routinely link infant death certificates to their corresponding birth certificates for their own linked files to obtain a list of birth and death certificate numbers from state vital statistics offices. Using these identifiers, NCHS selects birth and death records from the final, edited NCHS natality and mortality statistical files and creates a single record containing information from both.

In the second stage, NCHS works with states to correct problems identified during the processing of the initial file; unlinked death certificates are identified and records with inconsistent data are reviewed. To link unlinked death certificates, NCHS provides a list of unlinked certificates to the states in which the infant deaths occurred. If the state of death is different from the state of birth, the state of death is responsible for contacting the state of birth identified on the death certificate to obtain the original birth certificate number. If a third state is identified as the state of residence at the time of birth or death, that state is also sent a copy of the appropriate certificate.

If the birth certificate had been filed after the close of the NCHS statistical files, the state provides NCHS with a copy of the late-filed birth

certificate. Because the linked file includes late filed certificates, it differs slightly from the natality file, and rates may differ from those that have been computed by using data from the mortality and natality files.

Four items common to the birth and death certificates are used to link the files and assess the validity of the match: date of birth, sex, state of birth, and race. A link is rejected if two or more items are inconsistent, if the date of birth is inconsistent by >1 day, if the date of death is earlier than the date of birth, or if the infant's sex is inconsistent between the birth and death records. NCHS provides states with certificate numbers of records in need of review to confirm that both the data and the link are correct.

The follow-up process confirms that questionable matches are correct and improves the overall match rate. For 1987, the overall match rate increased from 94.5% in the initial file to 97.8% in the final file. For infants whose births and deaths occurred in the same state, matching increased from 95.7% to 98.3%; for infants whose births and deaths occurred in different states, matching increased from 66.5% to 87.3%.

Both its construction as a cohort and the processing procedure add to the linked file's processing time. Two years of mortality data are necessary if all infant deaths to a cohort are to be included. The multiple steps taken to ensure correct matching also add to the processing time. As a result, linked files are available later than annual mortality data from the vital statistics system. The linked birth and infant death data sets for the 1983–1987 birth cohorts are available for public use in magnetic tape format.

## National Maternal and Infant Health Survey

In addition to the data sources mentioned above, periodic sample surveys can provide a wealth of more detailed data on infant mortality in the United States. The most recent of these is the 1988 National Maternal and Infant Health Survey (NMIHS) (25). The NMIHS is a vital records follow-back survey (the sample is drawn by using vital records, and then supplementary information is collected through mail or telephone sur-

veys). NCHS conducted the 1988 NMIHS in collaboration with state vital records offices and 17 additional federal or state organizations. The objective of the NMIHS was to collect data needed by the research community to study factors related to pregnancy and the health of infants up to 6 months of age. Black infants and low-birth-weight infants were oversampled because of their higher risk of adverse outcomes.

Questionnaires were sent out for a sample of 9,953 live births, 5,332 infant deaths, and 3,309 fetal deaths. A stratified random probability sample design was used. Surveys were sent to the sampled mother, hospitals where she and her infant received care, and her prenatal-care providers. The mother's questionnaire included questions on sociodemographic characteristics, barriers to prenatal care, smoking, alcohol and drug use, infant immunizations, and participation in the Special Supplemental Food Program for Women, Infants, and Children. The hospital questionnaire included questions on diagnoses and procedures, maternal and infant hospitalization, fetal monitoring, and charges for care. The prenatal-care provider questionnaire included questions on patient education, advice and referral, sonograms, x-rays, medications, and vitamins. In addition, information on weight, blood pressure, hematocrit, urine glucose, urine protein, and hemoglobin was collected for each prenatal visit.

The data collected from the mother, her prenatal-care providers, the hospital, and vital records are linked to produce a single data tape that can be linked to other sources of information for additional analyses on other topic areas.

## GENERAL FINDINGS

### Trends

The infant mortality rate in the United States has declined rapidly during much of this century. In 1900, about 1 in 10 infants died within the first year of life (5,6), whereas in 1990, <1 in 100 infants died within their first year (26). The infant mortality rate declined rapidly from 1900 to 1950; by 1950, the rate of 29.2 infant deaths per 1,000 live births was less than one third the rate in

1900. However, from 1950 to 1964, the decline in the infant mortality rate slowed markedly to average only 1% per year. From 1965 to 1981, the infant mortality rate again declined rapidly, by an average of 4.5% per year from 24.7 to 11.9. However, from 1981 to 1989, the rate of decline again slowed markedly to average 2.5% per year. Between 1989 and 1990, the infant mortality rate decreased 6% to 9.2 per 1,000. A 24% decline in deaths caused by respiratory distress syndrome was a major contributor to the

rapid reduction in the infant mortality rate from 1989 to 1990 (26).

### Leading Causes of Infant Death

In 1990, the four leading causes of infant death were congenital anomalies, sudden infant death syndrome, disorders relating to short gestation and unspecified low birth weight, and respiratory distress syndrome (Table 1). Together, these four causes accounted for about half (48.8%) of all

**TABLE 1. Number of infant deaths, mortality rate,\* and percentage of deaths for each cause of death, by race of mother — United States, 1990**

Race/rank order	Cause of death (ICD-9 codes)	No.	Rate	Distribution (%)
<b>Total†</b>				
<b>All Causes</b>		<b>38,351</b>	<b>922.3</b>	<b>100.0</b>
1	Congenital anomalies (740–759)	8,239	198.1	21.5
2	Sudden infant death syndrome (798.0)	5,417	130.3	14.1
3	Disorders relating to short gestation and unspecified low birth weight (765)	4,013	96.5	10.5
4	Respiratory distress syndrome (769)	2,850	68.5	7.4
5	Newborn affected by maternal complications of pregnancy (761)	1,655	39.8	4.3
6	Newborn affected by complications of placenta, cord, and membranes (762)	975	23.4	2.5
7	Accidents and adverse effects (E800–E949)	930	22.4	2.4
8	Infections specific to the perinatal period (771)	875	21.0	2.3
9	Intrauterine hypoxia and birth asphyxia (768)	762	18.3	2.0
10	Pneumonia and influenza (480–487)	634	15.2	1.7
All other causes (residual)		12,001	288.6	31.3
<b>White</b>				
<b>All Causes</b>		<b>24,883</b>	<b>756.3</b>	<b>100.0</b>
1	Congenital anomalies (740–759)	6,418	195.1	25.8
2	Sudden infant death syndrome (798.0)	3,643	110.7	14.6
3	Disorders relating to short gestation and unspecified low birth weight (765)	2,004	60.9	8.1
4	Respiratory distress syndrome (769)	1,798	54.6	7.2
5	Newborn affected by maternal complications of pregnancy (761)	1,044	31.7	4.2
6	Newborn affected by complications of placenta, cord, and membranes (762)	657	20.0	2.6
7	Accidents and adverse effects (E800–E949)	609	18.5	2.4
8	Infections specific to the perinatal period (771)	569	17.3	2.3
9	Intrauterine hypoxia and birth asphyxia (768)	505	15.3	2.0
10	Pneumonia and influenza (480–487)	375	11.4	1.5
All other causes (residual)		7,261	220.7	29.2

**TABLE 1. Number of infant deaths, mortality rate,\* and percentage of deaths for each cause of death, by race of mother — United States, 1990 — continued**

Race/rank order	Cause of death (ICD-9 codes)	No.	Rate	Distribution (%)
<b>Black</b>				
<b>All Causes</b>		<b>12,290</b>	<b>1,795.9</b>	<b>100.0</b>
1	Disorders relating to short gestation and unspecified low birth weight (765)	1,912	279.4	15.6
2	Sudden infant death syndrome (798.0)	1,578	230.6	12.8
3	Congenital anomalies (740–759)	1,530	223.6	12.4
4	Respiratory distress syndrome (769)	984	143.8	8.0
5	Newborn affected by maternal complications of pregnancy (761)	571	83.4	4.6
6	Infections specific to the perinatal period (771)	291	42.5	2.4
7	Newborn affected by complications of placenta, cord, and membranes (762)	291	42.5	2.4
8	Accidents and adverse effects (E800–E949)	289	42.2	2.4
9	Pneumonia and influenza (480–487)	235	34.3	1.9
10	Intrauterine hypoxia and birth asphyxia (768)	231	33.8	1.9
	All other causes (residual)	4,378	639.7	35.6

\* Rate per 100,000 live births in specified group.  
† Includes infants of races other than black or white.

infant deaths. The first four leading causes of death were the same for black and white infants, although their rank order differed. The leading cause of death for black infants was disorders relating to short gestation and unspecified low birth weight.

### Low Birth Weight

Overall, the percentage of infants with low birth weight has declined by only 8% since 1950, whereas the 1990 infant mortality rate of 9.2 is less than one third the rate of 29.2 in 1950. So, the vast majority of the decline in the infant mortality rate since 1950 has been the result of declines in birth-weight-specific infant mortality rates, rather than a decline in the percentage of infants with low birth weight. Linked infant death and birth certificate data can be used to make a more accurate estimate of how improvements in birth-weight-specific mortality and in birth-weight distribution have contributed to the decline in infant mortality (27,28). The statistical methods that have been used in such analyses of time trends are a straightforward

extension of direct standardization of rates and are discussed in detail elsewhere (29).

In the most recently published analysis of national time trends that used this statistical approach, infant mortality rates in 1983 were compared with those in 1960 (28). Among white infants, 90% of the decline in mortality for single delivery infants was attributed to lower birth-weight-specific mortality and 10% was attributed to an improved birth-weight distribution. Among black infants, all of the decrease in mortality was attributed to lower birth-weight-specific rates because the incidence of low birth weight actually **increased** among blacks during this 23-year period.

These results clearly show that birth-weight-specific mortality rates have declined drastically but birth-weight distributions have improved very little. Thus, most of the progress in improving infant survival has resulted from improved obstetric and neonatal care, and very little has resulted from the prevention of low birth weight (27,28).

When we review national data on birth-weight-specific infant mortality for the 1987 birth cohort, comparing infant death rates in three weight categories for the 1960 and 1987 birth cohorts, we see that the declines are quite striking (Table 2). Because very little change occurred in the weight distributions of U.S. births between 1983 and 1987 (the percentage of infants with low birth weight was 6.8% in 1983 and 6.9% in 1987 [30]), the conclusions of the Kleinman et al. study (28) remain valid: improvement in perinatal medical care is the major contributor to the infant mortality decline, whereas efforts to prevent low birth weight have had little impact on infant mortality.

### Racial and Ethnic Differences

Infant mortality rates vary substantially by race and ethnicity (Table 3). Mortality rates are highest for the infants of black, Native American, and Puerto Rican mothers, and they are lowest for the infants of Asian mothers. We must use caution, however, when interpreting race and ethnic data from different data sources. Some data sources have measurement problems, whereas others do not have sufficient socioeconomic covariates available in the data set to allow researchers to control for confounding factors (see the Interpretation Issues of this chapter).

Although Puerto Rican and Native American infants also experience elevated mortality rates, the highest mortality rates are for black infants. In 1990, the mortality rate for black infants was 18.0—2.4 times the rate of 7.6 for white infants. A number of interrelated factors may help to explain the high mortality rates for black infants. In 1990, nearly three times as many black infants (56%) as white infants (20%) were members of families with incomes below the poverty level (*U.S. Bureau of the Census, unpublished data for 1990, 1993*). Infants of families of low-socioeconomic status are at an increased risk of death (1,31). In addition, largely because of income differentials, black women are less likely to have health insurance that covers the cost of care for pregnancy and childbirth (32) and therefore are less likely to obtain adequate prenatal care (30).

**TABLE 2. Infant mortality rates, by birth weight and race of mother — United States, 1960 and 1987 birth cohorts**

Birth weight and race of mother	Birth cohort		
	1960	1987	% change
<b>All birth weights, all races</b>	25.1	9.8	-61.0
White	22.2	8.2	-63.1
Black	42.1	17.8	-57.7
<b>&lt;1,500 g</b>	752.6	351.4	-53.3
White	769.4	354.8	-53.9
Black	706.4	346.5	-51.0
<b>1,500–2,499 g</b>	91.9	25.5	-72.3
White	93.9	26.2	-72.1
Black	85.1	23.6	-72.3
<b>≥2,500 g</b>	11.2	4.0	-64.3
White	9.7	3.6	-62.9
Black	20.2	5.9	-70.8

### Risk Factors

Although all infants born in the United States are at some risk of death, the probability of death varies markedly according to the risk factors of the mother, the baby, and the pregnancy. Maternal and family characteristics that influence infant mortality include age, education, marital status, family income, access to medical care, and the use of cigarettes, alcohol, and other drugs during pregnancy. Infant and pregnancy-related variables include birth order, previous history of infant or fetal loss, adequacy of prenatal care, period of gestation, birth weight, Apgar scores, sex, and plurality.

As we discuss the relationships between some of the most important of these variables and infant mortality, please keep in mind that these results show differentials in infant mortality rates for each variable **unadjusted for the possible effects of other variables**. In the real world, women

**TABLE 3. Infant mortality rates, by race and Hispanic origin of mother — United States, 1987 birth cohort**

Race and Hispanic origin of mother	Birth cohort 1987
All mothers	9.8
White	8.2
Black	17.8
American Indian or Alaska Native	13.0
Asian or Pacific Islander	7.3
Chinese	6.2
Japanese	6.6
Filipino	6.6
Other Asian or Pacific Islander	7.9
Hispanic origin*	8.2
Mexican American	8.0
Puerto Rican	9.9
Cuban	7.1
Central and South American	7.8
Other and unknown Hispanic	8.7
Non-Hispanic White	8.1
Non-Hispanic Black	17.4

\* Includes mothers of all races. Data are shown only for states with a Hispanic origin item on their birth certificates. In 1987, 23 states and the District of Columbia included this item.

with one risk factor often have other risk factors as well. Thus, teenaged mothers are more likely to also be unmarried and of a low-income status. Mothers who do not receive prenatal care are more likely to be of a low-income status and uninsured. The preferred method for disentangling the multiple interrelationships between risk factors is multivariate analysis; however, an understanding of the basic relationships between risk factors and infant mortality is a necessary precursor to more sophisticated types of analysis.

Infant mortality rates exhibit a curvilinear relationship with the age of the mother, with infants of teenaged mothers and mothers  $\geq 40$  years of age having a substantially higher risk of death than mothers aged 20–39 years. For the 1987 birth cohort, the infant mortality rate was 14.5 for teenaged mothers, compared with 8.4 for mothers aged 25–29 years and 8.1 for mothers

aged 30–34 years. For mothers aged  $\geq 40$  years, the rate was 12.6 (NCHS, unpublished data for 1987, 1992). Both biological and sociological factors may contribute to the elevated mortality risks for infants born to teenaged and older mothers (33–35).

Infant mortality rates were also higher for mothers with fewer years of education. For the 1987 birth cohort, the infant mortality rate was 14.6 for infants whose mothers did not complete high school compared with 6.3 for infants whose mothers were college graduates. These differentials may reflect actual differences in knowledge as well as socioeconomic differences because women with more education tend to have higher family income levels (35).

Infants born to unmarried mothers are also at an elevated risk of death. For the 1987 birth cohort, mortality rates for the infants of unmarried white mothers (12.5) were 1.7 times those for the infants of married white mothers (7.3); rates for the infants of unmarried black mothers (19.6) were 1.3 times those for the infants of married black mothers (14.8). Altogether, 17% of white infants and 63% of black infants were born to unmarried mothers.

Infants born from multiple pregnancies are also at an elevated risk of death. For the 1987 birth cohort, the infant mortality rate was 8.9 for single births compared with 50.0 for multiple births. Multiple pregnancies can lead to an accentuation of maternal risks and complications associated with pregnancy (36). Infants from multiple pregnancies are also much more likely to be born with low birth weights or at preterm gestational ages. Other specific biological risks associated with multiple births are described in detail elsewhere (28,36,37)

The timing and quality of prenatal care received by the mother during pregnancy are also important to the infant's subsequent health and survival (see the Prenatal Care chapter) (38). For the 1987 birth cohort, the mortality rate for infants whose mothers began prenatal care during the first trimester of pregnancy was 8.4 compared with 41.5 for infants whose mothers received no prenatal care.

One preventable maternal behavior that consistently has been associated with an increased risk of infant mortality is cigarette smoking. Several studies have used linked birth and infant death files from states that include maternal smoking as an item on the birth certificate (39–41). In the 1988 NMIHS, the estimated risk of mortality was 46% higher among infants of mothers who smoked during pregnancy (13.1 per 1,000 live births) than among infants of mothers who did not smoke (9.9 per 1,000 live births) (NCHS, unpublished data, 1993).

### Geographic Variations

Substantial geographic variation in infant mortality has been observed in the United States. A twofold to threefold difference exists between the highest and the lowest state-specific infant mortality rates (15,42,43). Similarly, data for 1985–1989 for cities with a population of >100,000 (1980 census) showed that the highest city-specific infant mortality rate was three times that of the lowest rate (44). Some of these differences relate to differences in race and ethnic composition and income distribution between geographic areas. However, significant geographic variations persist even after race differences and birth weight are taken into account. When the comparison is limited to normal-birth-weight infants born to low-risk women (those with ≥13 years of education who are ≥20 years of age and who initiated prenatal care in the first trimester), substantial differences still exist between states (45). These findings suggest that differences in access to high-quality prenatal and perinatal care may be important contributors to the geographic variation in infant mortality.

### INTERPRETATION ISSUES

#### Period versus Cohort Rates of Infant Mortality

In the conventional definition used in most reports of vital statistics, the **period infant mortality rate** (per 1,000 live births) is calculated as follows:

$$\frac{\text{Number of infant deaths during a year}}{\text{Number of live births during the same year}} \times 1000^*$$

Because this rate is calculated by comparing infant deaths with live births during the same period instead of following the birth cohort† to determine its mortality experience, the numerator and denominator may relate to different populations. For example, an urban renewal project may result in a rapid, sudden change in the characteristics of an area's population. In this case, the infant deaths during the year would be compared with a very different population of births for that year, and the rate would be misleading. Keep in mind these types of population shifts when analyzing mortality rates for small areas.

This problem does not occur, however, in analyses of linked birth and infant death files because these files allow us to analyze the infant mortality experience of birth cohorts. A **cohort infant mortality rate** is calculated as follows:

$$\frac{\text{Number of infant deaths that occurred among live births during a year}}{\text{Number of live births during a year}} \times 1000$$

An important difference exists between this rate and the **period infant mortality rate** defined previously. Two years of data on infant deaths are needed to calculate the cohort rate for a given year. For example, the numerator of the cohort infant mortality rate for 1987 would include deaths in both 1987 and 1988 among infants born in 1987.

\* Course-specific infant mortality rates are generally calculated per 100,000.

† A cohort consists of "a group of individuals who experienced the same significant demographic event during a specified brief period of time, usually a year, and who may be identified as a group at successive later dates on the basis of this common demographic experience. Examples are a birth cohort, persons born during the same year or years. . ." (46).

An additional problem with analyses using period infant mortality rates is that the source of information for the numerator is the death certificate whereas the source for the denominator is the birth certificate. Lack of comparability in certain items has been noted by researchers who have compared birth and death certificates for the same infant (47). The problem does not occur in analyses of linked birth and infant death files because these files use the more accurate data on race and other socioeconomic characteristics from the birth certificate, regardless of whether the infant died.

### Data on Race and Ethnicity

Surveillance of infant mortality outcome by race and ethnicity is useful in monitoring the success of the national year 2000 goal of reducing the disparity in health outcomes (48). We must recognize, however, that surveillance reports have some limitations, including potential problems in the classification of race and ethnicity in vital records. In addition, potential socioeconomic and cultural factors that may underlie differences in health status by race and ethnicity are often not available in surveillance data. Also, misinterpretation of racial and ethnic information can lead to stigmatization and racism.

Inconsistencies in the classification of race and ethnicity on birth and death certificates can lead to problems in the accurate estimation of race-specific infant mortality rates. A study comparing the race assigned on the birth certificate to the race assigned on the death certificate for the same infant found that 3.7% of infant deaths in the 1983–1985 birth cohorts were classified to different races on birth and death certificates (47). Discrepancies in race classification were greatest for infants of races other than black or white, with 43.2% assigned to different races on birth and death certificates. Substantial differences were also found for Hispanic origin subgroups (47). In part to address these problems, NCHS created the linked birth and infant death data set that allows researchers to use more accurate race data from birth certificates in tabulating infant mortality statistics.

In 1989, to further improve the quality of race data on vital records, NCHS changed the

method of tabulating race for live births to the race of the mother as reported directly on the birth certificate. Before 1989, birth tabulations were by race of child as determined by an algorithm based on information reported for the mother and father. Briefly, children of mixed-race parentage with one white parent were assigned the other parent's race. When neither parent was white, the child was assigned the father's race (30). The change to tabulating live births by race of the mother affects infant mortality data because live births comprise the denominator of infant mortality rates. The method of tabulating mortality data by race has not changed; race is that of the decedent as reported on the death certificate. The change to tabulating live births by race of the mother provides a more consistent indicator of race and helps to reduce the magnitude of differences between race-specific infant mortality rates from vital statistics data and the linked file (49). Unless otherwise specified, all infant mortality rates shown in this chapter are based on live births tabulated by race of the mother.

Surveillance program staff who include information on race and ethnicity should exercise caution when using race as a substitute for socioeconomic status (if the race is black, it is usually interpreted to mean low-socioeconomic status). The validity of routinely adjusting for race as a method for controlling for missing socioeconomic data has been questioned (50).

Race and ethnicity should not be used as an etiologic risk factor for infant mortality. Race sometimes has been used as a genetic marker, and therefore, assumed to be a risk factor. Race has not been demonstrated to directly increase physiologic risk for disease, except for a few genetic diseases. Specific racial or ethnic populations may be socially, culturally, environmentally, or economically exposed to risk factors that put them at a higher or lower risk for death (51,52). Ideally, potential intervening variables such as socioeconomic status and environmental exposures should be collected and analyzed in relation to race and ethnicity data because misinterpretation of the meaning of reporting of race or ethnicity may sometimes impede prevention research activities (53).

## Birth-Weight-Specific Rates

In nonexperimental evaluations of medical care, the need to adjust for differences in disease severity between groups receiving different therapies has long been recognized. For example, in comparisons of postoperative mortality in different hospitals, elaborate statistical techniques have been developed for case-mix adjustment.

In the surveillance and monitoring of infant mortality rates, the need for some sort of case-mix adjustment has also been acknowledged, but the situation is simplified by the overwhelming importance of birth weight as a predictor of infant death. Therefore, when comparing infant mortality rates between geographic areas, time periods, or hospitals, the common practice is to look separately at two components of these rates: 1) the **birth-weight distribution** and 2) the mortality within each birth-weight category or **birth-weight-specific mortality**. The first component is generally considered to be strongly affected by the socioeconomic and demographic circumstances of the mother. The second component is often used as a measure of the quality of perinatal care (54).

In analyses of birth-weight-specific mortality, the use of 500-g categories has been commonly used. However, in small areas, the number of infants falling into many of the 500-g categories are quite small. Therefore, a more practical option may be to use the following categories: <1,500 g, 1,500–2,499 g, and ≥2,500 g.

For each birth-weight category, the **birth-weight-specific mortality rate** is calculated by using the following formula:

$$\frac{\text{Number of deaths in the birth-weight category}}{\text{Number of births in the birth-weight category}} \times 1000$$

Because birth-weight-specific infant mortality rates may not always be a direct measure of the effect of perinatal medical care, factors such as these must be considered: 1) female infants usually have lower birth-weight-specific mortality rates than males; 2) black infants usually have

lower mortality rates at low birth weights and higher rates at normal and high birth weights; and 3) postneonatal mortality has several causes—such as intestinal infections, pneumonia, influenza, sudden infant death syndrome, and unintentional injuries—that have little association with obstetric or neonatal care. For this reason, postneonatal deaths are often excluded from evaluations of perinatal care, and birth-weight-specific **neonatal** mortality rates are compared.

## Quality of Cause-of-Death Data

Identifying the cause of death among infants presents particular challenges to the physician, medical examiner, or coroner certifying the death. More than half of all infant deaths occur during the first 7 days of life (15). For these deaths, the certifier does not have access to a medical history of illness that would help him or her in identifying the underlying cause of death. Therefore, he or she is much more likely to rely on postmortem examination in determining the cause of death. In 1989, 44.1% of infant deaths resulted in autopsies, compared with 11.5% of deaths at all ages (55). Few studies focus on the validity of cause-of-death information for infants. However, because of the high autopsy rate, the quality of cause-of-death certification for infants is believed to be at least as good as that for persons at all ages. The validity of cause-of-death data for deaths at all ages has been discussed extensively elsewhere (56,57).

## Stability of Rates

An area's observed infant mortality rate should be considered an estimate of the true underlying mortality rate.<sup>§</sup> As is the case with any estimate, the infant mortality rate is subject to chance variation. If the area has very few births, the observed infant mortality rate may be very different from the true rate. Thus, if rates for two areas are compared in a given year and one (or both) of the area's rates is based on a small number of

<sup>§</sup> The number of infant deaths in an area varies by chance, depending on the number of births and the probability of infant death (the *true* infant mortality rate). As the number of births increases, the chance component becomes less important, and the observed infant mortality rate becomes a better estimate of the true rate.

births, it would not be unusual for the findings to be reversed the following year.

Therefore, a method is needed to assess the adequacy of the observed infant mortality rate as an estimate of its true value. The most common method is the use of confidence intervals. Calculation of confidence intervals is explained in detail elsewhere (58–60). Basically, a **95% confidence interval** is defined so that the probability is 95% that the true rate is included in the interval. If the interval is very wide, the true rate is not estimated with much precision. The interval generally becomes narrower as the number of births on which the rate is based increases. Two common methods of increasing the numbers of births are to combine years and to combine smaller areas into larger ones.

Although aggregation over years and areas permits us to compute stable rates, loss of information occurs. Combining heterogeneous areas to obtain a stable rate may be more misleading than helpful. Combining years involves the assumption that in each of the years, the ranking of the areas is the same—that is, annual changes in the rates are the same for all areas.

The stability issue is especially important when comparing areas or determining whether real changes have occurred over time within an area. In these situations, confidence limits should be used to assess the magnitude of the differences. Two areas (or two time periods for one area) can be compared by using the absolute difference in their rates or by using the ratio of their rates. The ratio of rates (or relative risk as it is sometimes called) is usually preferred because it allows for comparison of areas or time over a wide range of rates.

### Multivariate Analysis

When investigating factors that may affect infant mortality, researchers must always consider the possibility of confounding variables. An apparent association between a factor and infant mortality may be related to the effect of other variables. This is especially true in studies of social and demographic factors because the effects of such variables are often relatively small, and the addition of a confounding variable into the analysis

could easily reduce relative risks to 1. By social and demographic factors, we mean such variables as the parents' income, occupation, race, ethnicity, and education as well as the mother's age, parity, and gravidity. This is in contrast to biological variables such as very low birth weight, abruptio placentae, and prolapsed umbilical cord, whose associations with mortality are so strong that it is unlikely that the control of any confounder could reduce their effects to the null.

In investigations of infant mortality, one of the most common solutions to the problem of confounders has been to perform **multivariate analyses**. Detailed discussions of dealing with confounding, and of the problems of carrying out a careful multivariate analysis, can be found elsewhere (61–63). Several examples of multivariate analyses of infant mortality have been published in the epidemiologic (64–66), sociological (67), and demographic (68) literature.

### EXAMPLES OF DATA USE

Vital statistics data on infant mortality are used extensively by state and local health departments to track numbers of infant deaths and infant mortality rates for states, cities, counties, and other geographic areas. Major changes in numbers of deaths, in rates, or in the cause-of-death profile of a region can provide a strong indication of improvements in medical care, or conversely, problems that the health department needs to address. Some causes of death, such as whooping cough, serve as red flags to health departments for follow-up activities.

One example of state use of linked birth and infant death data is Mississippi's program for high-risk infant follow-up (69). The purpose of this program is to prevent postneonatal deaths of infants born at high risk of death. In the original system, birth certificates were marked if they contained one or more risk factors and were sent to county nurses for follow-up. The problem with the initial system was that it identified about one fourth of all births as high risk—too many births for the county nurses to effectively follow.

Mississippi's goal was to design a new system that would reduce the number of infants identified without running the risk of missing infants

who needed follow-up. To redesign the system, the state used logistic regression on its linked files to calculate relative risk scores for a variety of risk factors relating to maternal age and education, race, prenatal care, pregnancy history, birth weight, Apgar score, and the presence of congenital anomalies. Because the risk scores were multiplicative, a total risk score could then be generated for each infant on the basis of its unique risk profile. Currently, risk scores are generated monthly, and information on high-risk infants is sent to county health nurses. The nurses follow up through letters, telephone calls, and/or home visits to provide information on the need for and availability of well-baby care and immunizations and to address parents' concerns. By using this system, the state reduced the number of infants identified for follow-up by almost two thirds, allowing county health nurses to concentrate their follow-up activities on the infants most in need of their help (69).

## FUTURE ISSUES

The national health objectives for the year 2000 relating to infant mortality are to reduce the infant mortality rate to 7 for the total population, 11 for black infants, 8.5 for Native American infants, and 8 for Puerto Rican infants (48). The objective for the total population is the rate that we can expect to achieve if the average annual decline in infant mortality rates observed from 1981–1986 (2.8%) persists through the 1990s. To achieve the goal for black infants, we must accelerate the average annual decline in infant mortality from 2.2% per year from 1981–1986 to 3.5% (48).

As previously stated, most of the decline in infant mortality over the past three decades can be attributed to improvements in perinatal medical care rather than improvements in prevention. In 1990, as in 1980, only 76% percent of mothers began prenatal care in the first trimester (70). Even for those women who did get prenatal care, serious questions persist about the quality of that care, particularly for socioeconomically disadvantaged groups (71). Similarly, the percentage of infants born with low birth weights has not declined during the 1980s and has actually increased for black infants (70).

Future research must focus on some of the fundamental issues, such as low birth weight, that affect infant mortality. To address this need, the linked birth and infant death data set is being expanded to provide more detailed information on specific risk factors for infant death. Beginning with the 1989 birth cohort, the linked file contains the many additional variables available from the 1989 revision of the birth certificate. Included are items on smoking, alcohol use, and weight gain during pregnancy as well as checkbox items on specific medical risk factors of the pregnancy, complications of labor and delivery, method of delivery, obstetric procedures, abnormal conditions of the newborn, and congenital anomalies of the child.

Although these research issues are important, we have an even greater need to apply what we already know to solve the fundamental problems surrounding infant mortality in the United States. For example, much of what is already known about preventing low birth weight—such as the need for universal access to quality prenatal care and substance abuse counseling—is not being applied in this country. Although improvements in perinatal medicine have lowered the mortality rate for low-birth-weight infants, these infants are at a substantially increased risk of morbidity, mental retardation, and neurological disorders that require increased levels of medical and parental care (72–74). If our goal is not merely to reduce the infant mortality rate but to improve the quality of life for infants and children, we must prevent preterm and low-birth-weight births and increase prenatal care use. Future efforts should focus on making basic prevention and public health services available to all pregnant women.

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