CHAPTER 3

Epidemiologic Measurements Used to Describe Disease Occurrence

Learning Objectives

By the end of this chapter you will be able to:

- Define three mathematical terms applied to epidemiology and provide examples of each.
- Compare *incidence* and *prevalence* and explain how they are interrelated.
- State one epidemiologic measure of mortality, giving its formula.
- Distinguish between a fertility rate and a birth rate.
- Name the limitations of crude rates and define alternative measures.

Chapter Outline

I. Introduction
II. Mathematical Terms Used in Epidemiology
III. General Information Regarding Epidemiologic Measures
IV. Types of Epidemiologic Measures
V. Epidemiologic Measures Related to Mortality
VI. Specific Rates
VII. Adjusted Rates
VIII. Measures of Natality and Mortality Linked to Natality
IX. Conclusion
X. Study Questions and Exercises

INTRODUCTION

Epidemiologic measurements aid in describing the occurrence of morbidity and mortality in populations. The chapter begins by covering four key mathematical terms that involve the use of fractions and that appear in epidemiologic constructs. You will learn how these terms are applied to fundamental epidemiologic measures of the frequency of diseases in populations and risks associated with exposures to disease agents. This chapter also reveals the different conclusions that can be drawn by examining existing and new cases of disease. Additional topics include basic measures of morbidity and mortality as well as alternative calculations for improving estimates of morbidity and mortality. Finally, you will learn about miscellaneous statistics related to natality and mortality linked to natality. Refer to **Table 3-1** for a list of the major terms and concepts covered in this chapter.

MATHEMATICAL TERMS USED IN EPIDEMIOLOGY

Some important mathematical terms applied to epidemiologic measures are rate, proportion, and percentage; these measures are types of ratios. (Refer to **Figure 3-1**.) The following section defines these terms and gives calculation examples of ratios, proportions, and percentages for mortality from AIDS. The topic of rates will be covered later in the chapter. Data for use in calculating the examples of rates,

TABLE 3-1 List of Important Mathematical and Epidemiologic Terms Used in This Chapter

Mathematical Terms	Epidemiologic Terms: Frequency	Epidemiologic Terms: Risk	Measures Related to Morbidity and Mortality	Measures Related to Natality
Percentage	Count	Attack rate	Case fatality rate	Maternal mortality rate
Proportion	Period prevalence	Incidence rate/ cumulative incidence/ incidence proportion	Crude rate/crude death rate (crude mortality rate)	Infant and perinatal mortality rates/fetal death rate
Rate	Point prevalence	Reference population	Life expectancy	Birth rate
Ratio	Prevalence	Risk factor/population at risk	Specific rate	General fertility rate

proportions, and percentages are given in **Table 3-2**. Following are some data that will be used for the calculations.

Ratio

A **ratio** is defined as "[t]he value obtained by dividing one quantity by another. Rates and proportions (including risk) are ratios…. Ratios are sometimes expressed as percentages."[1] Although a ratio consists of a numerator and a denominator, its most general form does not necessarily have any specified relationship between the numerator and denominator.

A ratio is expressed as follows: ratio = X/Y.

Calculation example of a ratio:

Example 1: With respect to AIDS mortality, the sex ratio of deaths (male to female deaths) = X/Y, where: X = 450,451 and Y = 89,895. The sex ratio = 450,451/89,895 = 5 to 1 (approximately).

FIGURE 3-1 **Definitions of mathematical terms that are used in epidemiology.**

– Ratio (R)	$R = \frac{X}{Y}$	X and Y can be any number, including ratios.
– Rate (r)*	$r = \frac{X}{\Delta t}$	Type of ratio where the numerator is usually a count, and the denominator is a time elapsed.
– Proportion (p)	$P = \frac{A}{A + B}$	Type of ratio where the numerator is part of the denominator.
– Percent (P)	$P = \left(\frac{A}{A + B}\right) \times 100$	A proportion is multiplied by 100.

Modified with permission from Aragón T. *Descriptive Epidemiology: Describing Findings and Generating Hypotheses*. Center for Infectious Disease Preparedness, University of California Berkeley School of Public Health. Available at: http://www.iready.org/slides/feb_descriptive.pdf. Accessed August 16, 2016.

9781284131932_CH03_Pass02.indd 58 13/12/16 5:08 PM

TABLE 3-2 Data for Calculations of Rates, Proportions, and Percentages

Cumulative U.S. AIDS mortality, 2002–2006; deaths among adults and adolescents[2]	Males = 450,541 Females = 89,895
Author's hypothetical survey of clinic patients (n = 20) regarding intravenous drug use (IDU) in a clinic	Number of IDU users = 19 Number of persons who did not use = 1

Example 2: Referring to the data in Table 3-2, you can observe that the ratio of users of intravenous drugs to nonusers is 19 to 1.

Example 3: In demography, the sex ratio refers to the number of males per 100 females. In the United States, the sex ratio in 2005 was 96.5, meaning that there were more women and girls than men and boys.[3] At the same time, there were considerable variations by state; Alaska and Nevada had the highest sex ratios. In 2010, the U.S. sex ratio increased to 96.7.[4] At birth the sex ratio is approximately 105 males to 100 females. Due to higher mortality among males, the sex ratio deceases with age, a trend shown in **Figure 3-2**. However, from 2000 to 2010, the population of males 60 years and older increased in comparison with the population of females in the same age group. According to the U.S. Census Bureau, this change can be attributed to a narrowing of male-female mortality differences.

Proportion

A **proportion** is a type of ratio in which the numerator is part of the denominator. Proportions may be expressed as percentages.

A proportion is expressed as follows: proportion = A/A + B

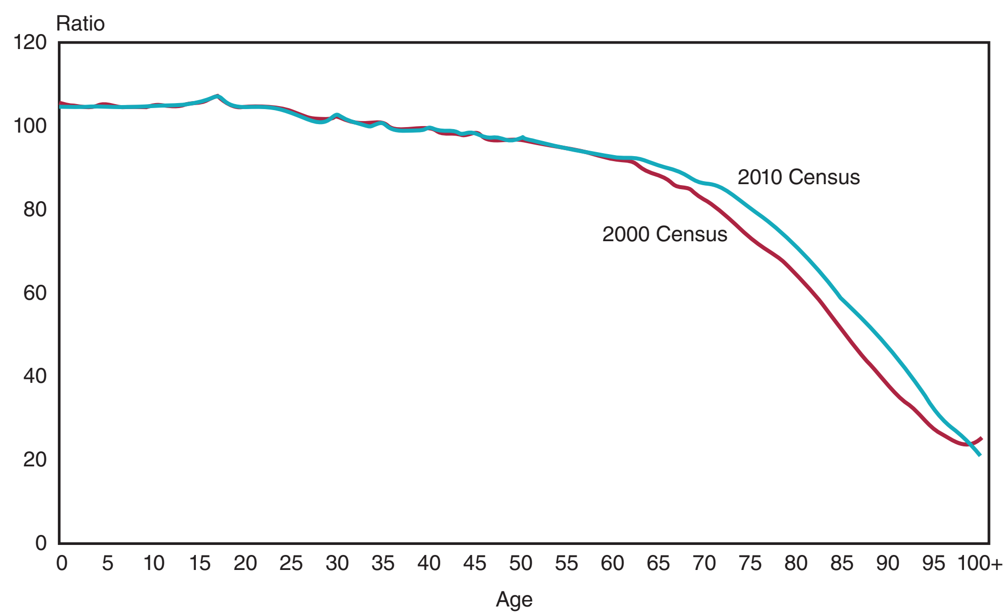
Calculation example of a proportion:

Example 1: Proportion of AIDS deaths

Suppose that A = the number of male deaths from AIDS

A = 450,451

FIGURE 3-2 Sex ratio, by age—2000 and 2010.



Reprinted from U.S. Census Bureau. Age and Sex Composition: 2010. *2010 Census Briefs*. May 2011:5.

B = the number of female deaths from AIDS
B = 89,895
The proportion of deaths that occurred among males = 450,451/(450,451 + 89,895) = 0.83

Example 2: Proportion of IDU users (data from Table 3-2)
Proportion = 19/(19+1) = 0.95

Percentage

A **percentage** is a proportion that has been multiplied by 100. The formula for a percentage is as follows:

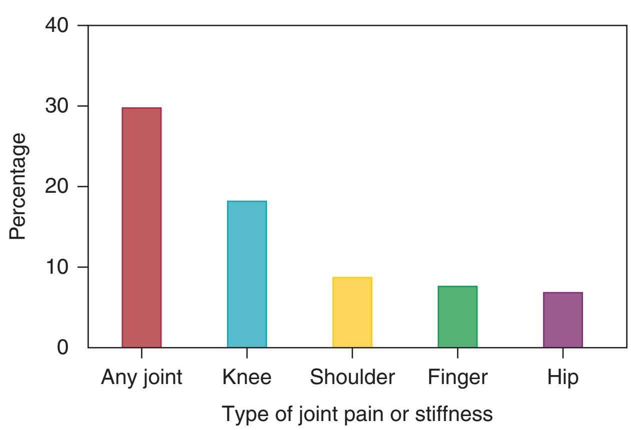
percentage = (A/A + B) × 100

Example 1: The percentage of male deaths from AIDS was (0.83 × 100) = 83%.

Example 2: The percentage of IDU users was (0.95 × 100) = 95%.

Example 3: Refer to **Figure 3-3**, which is a graph of the percentage of adults who reported joint pain or stiffness in the United States in 2006. The figure demonstrates that slightly less than one-third of adults had symptoms of joint pain within the preceding 30-day period. The most frequently reported form of pain was knee pain. "During 2006, approximately 30% of adults reported experiencing some type of joint pain during the preceding 30 days. Knee pain was reported by 18% of respondents, followed by pain in the shoulder (9%), finger (7%), and hip (7%). Joint pain can be caused by osteoarthritis, injury, prolonged abnormal posture, or repetitive motion."[5(p467)]

FIGURE 3-3 Percentage of adults reporting joint pain or stiffness, National Health Interview Survey—United States, 2006.



Reprinted from Centers for Disease Control and Prevention. QuickStats: Percentage of adults reporting joint pain or stiffness—National Health Interview Survey, United States, 2006. *MMWR* 2008;57:467.

Let's consider how a proportion (as well as a percentage) can be helpful in describing health conditions. A proportion indicates how important a health outcome is relative to the size of a group. Refer to the following example: suppose there were 10 college dorm residents who had infectious mononucleosis (a virus-caused disease that produces fever, sore throat, and tiredness). How large a problem did these 10 cases represent? To answer this question, one would need to know whether the dormitory housed 20 students or 500 students. If there were only 20 students, then 50% (or 0.50) were ill. Conversely, if there were 500 students in the dormitory, then only 2% (or 0.02) were ill. Clearly, these two scenarios paint a completely different picture of the magnitude of the problem. In this situation, expressing the count as a proportion is indeed helpful. In most situations, it will be informative to have some idea about the size of the denominator. Although the construction of a proportion is straightforward, one of the central concerns of epidemiology is to find and enumerate appropriate denominators to describe and compare groups in a meaningful and useful way.

Rate

Also a type of ratio, a **rate** differs from a proportion because the denominator involves a measure of time. (Refer back to Figure 3-1). The rate measure shown in the figure is the mathematical formula in which elapsed time is denoted in the denominator by the symbol Δt.

Epidemiologic rates are composed of a numerator (the number of events such as health outcomes), a denominator (a population in which the events occur), and a measure of time.[1] This measure of time is the time period during which events in the numerator occur. The denominator consists of the average population in which the events occurred during this same time period.

In epidemiology, rates are used to measure risks associated with exposures and provide information about the speed of development of a disease. Also, rates can be used to make comparisons among populations. More detailed information on rates is provided in the section on crude rates. Medical publications may use the terms ratio, proportion, and rate without strict adherence to the mathematical definitions for these terms. Hence, you must be alert regarding how a measure is defined and calculated.[6]

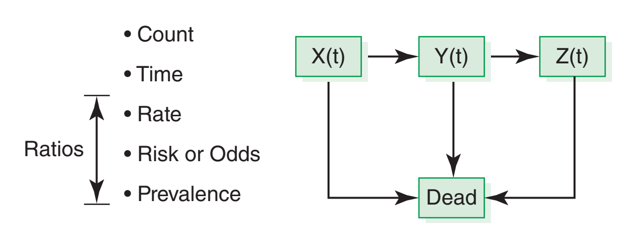
GENERAL INFORMATION REGARDING EPIDEMIOLOGIC MEASURES

As noted previously, epidemiologic measures represent an application of common mathematical terms such as ratio and proportion to the description of the health of the population. Epidemiologic measures provide the following types of information: (1) the frequency of a disease or condition, (2) associations between exposures and health outcomes, and (3) strength of the relationship between an exposure and a health outcome. **Figure 3-4** gives an overview of the principal epidemiologic measures covered in this chapter; these are count, rate (for example, incidence rate and death rate), risk or odds, and prevalence. Keep in mind that time is a component of rates.

The following considerations are important to the expression of epidemiologic measures:

- Defining the numerator.
  - Case definition (condition)—For epidemiologic measures to be valid, the case of disease or other health phenomenon being studied must be defined carefully and in a manner that can be replicated by others.
  - Frequency—How many cases are there?
  - Severity—Some epidemiologic measures employ morbidity as the numerator and others use mortality.
- Defining the denominator—Does the measure make use of the entire population or a subset of the population? Some measures use the **population at risk**, defined as those members of the population who are capable of developing a disease, for example, people who are not immune to an infectious disease.
- Existing (all cases) versus new cases.

FIGURE 3-4 Epidemiologic measures—measures of occurrence.



Reprinted with permission from Aragón T. *Descriptive Epidemiology: Describing Findings and Generating Hypotheses*. Center for Infectious Disease Preparedness, University of California Berkeley School of Public Health. Available at: http://www.idready.org/slides/feb_descriptive.pdf.Accessed August 16, 2016.

The following sections will define the foregoing terms and concepts.

TYPES OF EPIDEMIOLOGIC MEASURES

A number of quantitative terms, useful in epidemiology, have been developed to characterize the occurrence of disease, morbidity, and mortality in populations. Particularly noteworthy are the terms *incidence* and *prevalence*, which can be stated as frequencies or raw numbers of cases. (These terms are defined later.) In order to make comparisons among populations that differ in size, statisticians divide the number of cases by the population size.

Counts

The simplest and most frequently performed quantitative measure in epidemiology is a count. As the term implies, a **count** refers merely to the number of cases of a disease or other health phenomenon being studied. As shown in **Table 3-3**, an example of a count is the number of cases of infrequently reported notifiable diseases per year.

The previous discussion may leave the reader with the impression that counts, because they are simple measures, are of little value in epidemiology; this is not true, however. In fact, case reports of patients with particularly unusual presentations or combinations of symptoms often spur epidemiologic investigations. In addition, for some diseases even a single case is sufficient to be of public health importance. For example, if a case of smallpox (now eradicated) or Ebola virus disease were reported, the size of the denominator would be irrelevant. That is, in these instances a single case, regardless of the size of the population at risk, would stimulate an investigation.

Measures of Incidence

Measures of incidence are measures of risk of acquiring a disease or measures of the rate at which new cases of disease develop in a population. They may also be used to assess other health outcomes in addition to diseases. The terms covered in this section are incidence, incidence rate, cumulative incidence, incidence density, and attack rate. Incidence measures are central to the study of causal mechanisms with regard to how exposures affect health outcomes. Incidence measures such as cumulative incidence are used to describe the risks associated with certain exposures; they can be used to estimate in a

TABLE 3-3 Cases of Selected Infrequently Reported Notifiable Diseases (< 1,000 Cases Reported)—United States, 2011–2015

Total Cases Reported by Year					
Disease	2015*	2014	2013	2012	2011
Botulism, foodborne	37	15	4	27	24
Cholera	2	5	14	17	40
Hansen's disease (leprosy)†	89	88	81	82	82
Rabies, human	1	1	2	1	6

†Not reportable in all states.

*Case counts for 2015 are provisional.

Adapted from data from Centers for Disease Control and Prevention. Notifiable diseases and mortality tables. *MMWR*. 2016;65(24):ND-417.

population "… the probability of someone in that population developing the disease during a specified period, conditional on not dying first from another disease."[7(p23)]

Incidence

The term *incidence* refers to "[t]he number of instances of illness commencing, or of persons falling ill, during a given period in a specified population. More generally, the number of new health-related events in a defined population within a specified period of time."[1] Ways to express incidence include: incidence rate, cumulative incidence, incidence density, and attack rate.

Incidence Rate

The incidence rate is defined as "[t]he RATE at which new events occur in a population."[1] The new events are usually new cases of disease but can be other health outcomes. The incidence rate is a rate because a time period during which the new cases occur is specified and the population at risk is observed. **Figure 3-5** presents the incidence rates for tuberculosis by state in the United States.

The **incidence rate** denotes a rate formed by dividing the number of new cases that occur during a time period by the average number of individuals in the population at risk during the same time period times a multiplier. (Refer to the box, Incidence rate.) The denominator is the average number of persons at risk for the following reason: In most situations, populations are not static because of migration and other influences on the composition of populations. To overcome this challenge, the population at the midpoint of the year is used as the denominator and is considered to be the average population at risk. The formula for the incidence rate shown in the text box is the formula used commonly in public health.

Incidence rate =

$$\frac{\text{Number of new cases over a time period}}{\text{Average population at risk during the same time period}} \times \text{multiplier (e.g., 100,000)}$$

The choice of the multiplier is arbitrary; any convenient multiplier can be chosen.

Population at risk: those members of the population who are capable of developing a disease, e.g., nonimmune persons.

Time period: various time periods can be chosen, e.g., a week, month, year, or other time period; annual incidence rates are often reported in government statistics.

Calculation example (incidence rate of pertussis [whooping cough], 2013):

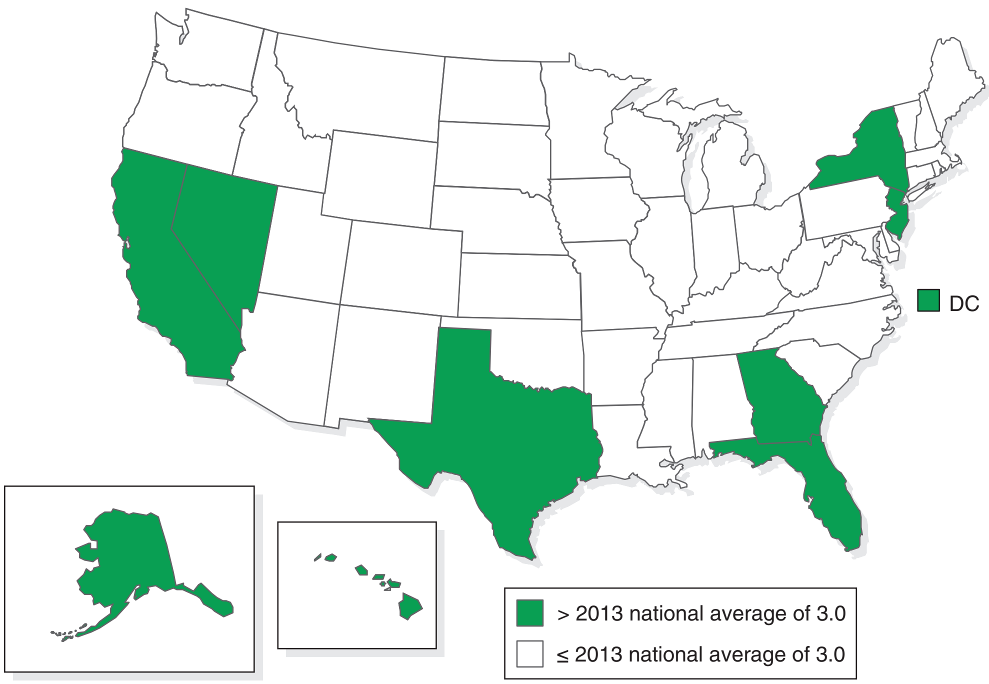
Number of new cases of pertussis, 2013 = 28,639

Average population of the U.S. (estimated population, July 1, 2013) = 316,128,839

$$\text{Incidence rate} = \left(\frac{28{,}639}{316{,}128{,}839}\right) \times 100{,}000$$

$$= 9.1 \text{ per } 100{,}000 \text{ (rounded)}$$

FIGURE 3-5 Rate of tuberculosis cases per 100,000, by state/area—United States, 2013.



Reproduced from: Centers for Disease Control and Prevention. Trends in tuberculosis—United States, 2013. *MMWR*. 2014;63:230.

An incidence rate is called **cumulative incidence (incidence proportion)** when *all* individuals in the population are at risk throughout the time period during which they were observed. (Refer to the box, Cumulative incidence.) An example of a population in which all members of the population are at risk is a fixed or closed population (such as the participants in a cohort study) in which no new members are allowed to enter the study after it begins.

Here is a hypothetical calculation example for cumulative incidence: An epidemiologist studies cardiovascular disease among 23,502 male middle-aged alumni of an Ivy League university. Initial medical examinations certify that the alumni have never had a heart attack in the past. During the first year of the research, 111 alums have heart attacks.

$$\text{Cumulative incidence} = \frac{111}{23{,}502} = .005\ (0.5\%)$$

In this example the cumulative incidence (incidence proportion) is .005, or 0.5% when expressed as a percentage.

$$\text{Cumulative incidence (incidence proportion)} = \frac{\text{Number of new cases over a time period}}{\text{Total population at risk during the same time period}}$$

Incidence Density

Incidence density is a variation of an incidence rate that is used when the time periods of observation of the members of a population vary from person to person. During a study that takes place over an extended period of time (for example, a cohort study, which is described later in the text), participants may be observed for varying periods of time because some drop out before the study is completed. In order to make use of all participants' data, we calculate incidence density according to the formula shown in the box. The numerator is the number of new cases during the time period and the denominator is the total person-time of observation. Person-time is the total period of time that each individual at risk has been observed. For example, one person-year means that one subject has been observed for one year. For a further discussion of person-time of observation and incidence density, refer to Friis and Sellers.[8]

> Incidence density =
>
> $$\frac{\text{Number of new cases during the time period}}{\text{Total person} - \text{Time of observation}}$$
>
> Note: Person-years of observation are often used as the denominator.

Attack Rate

An **attack rate** is a type of incidence rate used when the occurrence of disease among a population at risk increases greatly over a short period of time; attack rate is often related to a specific exposure. The attack rate is frequently used to describe the occurrence of foodborne illness, infectious diseases, and other acute epidemics. An attack rate is not a true rate because the time dimension is often uncertain. The formula for an attack rate is:

> Attack rate =
>
> $$\text{Ill} / (\text{Ill} + \text{Well}) \times 100 \text{ during a time period}$$
>
> *Calculation example*: Fifty-nine people ate roast beef suspected of causing a *Salmonella* outbreak. Thirty-four people fell ill; 25 remained well.
>
> Number ill = 34
> Number well = 25
> Attack rate = 34/(34 + 25) × 100 = 57.6%

Prevalence

The term **prevalence** (expressed as a proportion) refers to the number of existing cases of a disease or health condition, or deaths in a population at some designated time divided by the number of persons in that population. The two forms of prevalence are point prevalence and period prevalence. **Point** prevalence refers to all cases of a disease, health condition, or deaths that exist at a particular point in time relative to a specific population from which the cases are derived. For example, if we are referring to illness (morbidity) in a group of people, the formula for point prevalence is shown in the following box.

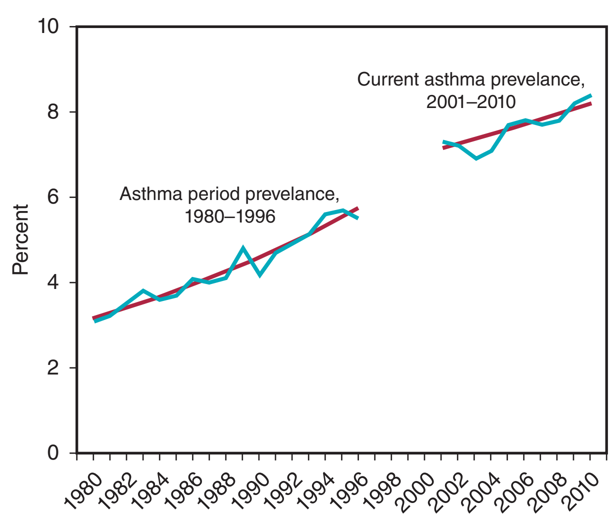
$$\text{Point prevalence} = \frac{\text{Number of persons ill}}{\text{Total number in the group}} \text{ at a point in time}$$

Point prevalence may be expressed as a proportion formed by dividing the number of cases that occur in a population by the size of the population in which the cases occurred times a multiplier. Note that point prevalence is a proportion and not a rate. If the value of 100 is used as the multiplier, prevalence becomes a percentage.

Figure 3-6 presents information on asthma period prevalence (defined below) and current (point) asthma prevalence in the United States. Data are from the National Health Interview Survey. Current asthma prevalence was based on the questions "Has a doctor or other health professional ever told you that (you/your child) had asthma? AND (Do you/does your child) still have asthma?"[9(p57)] The second question corresponds to point prevalence because the point of assessment refers to having asthma at the time when the question was asked. See Figure 3-6.

The second variety of prevalence is **period prevalence**, which denotes the total number of cases of a disease that

FIGURE 3-6 Asthma period prevalence and current (point) asthma prevalence: United States, 1980–2010.



Adapted from Moorman JE, Akinbami LJ, Bailey CM, et al. National Surveillance of Asthma: United States, 2001–2010. National Center for Health Statistics. *Vital Health Stat.* 2012;3(35)23.

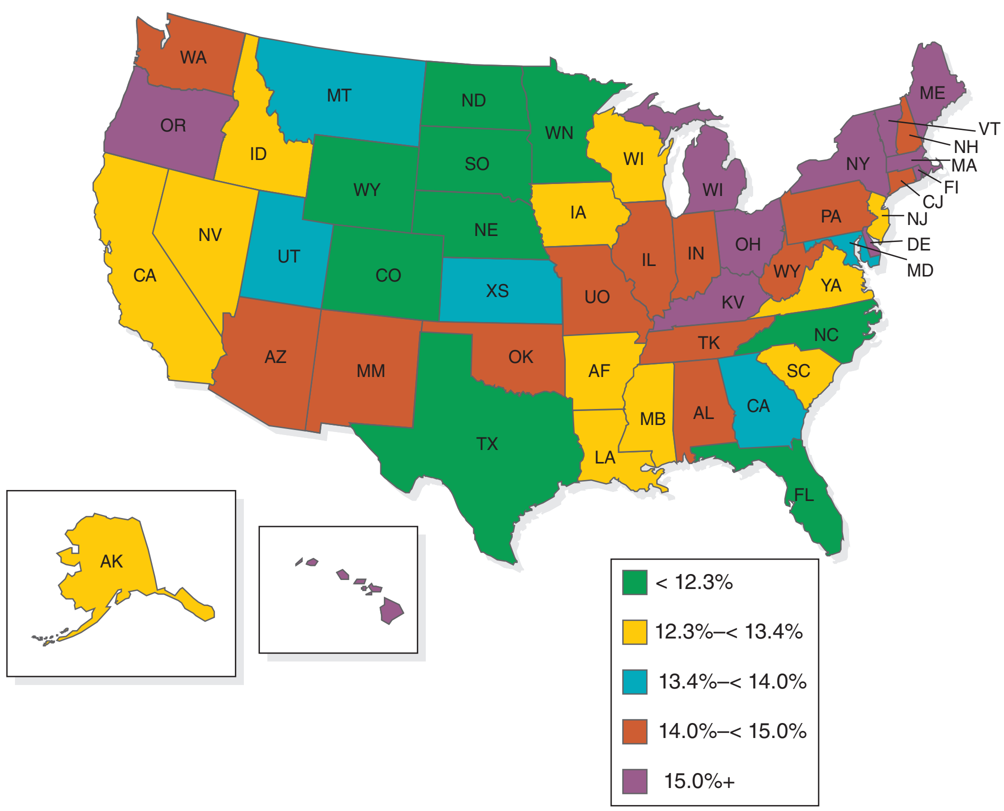
exist during a specified period of time (e.g., a week, month, year, or other interval). An example of period prevalence is asthma period prevalence. The numerator for asthma period prevalence reflects whether a respondent answered affirmatively to the question "[d]uring the past 12 months, did anyone in the family have asthma?"[9(p57)] The time period for this measure is the past year. Figure 3-6 also shows asthma period prevalence.

Lifetime prevalence denotes cases of disease diagnosed at any time during the person's lifetime. Refer to **Figure 3-7** for an illustration of the geographic distribution of lifetime prevalence of asthma in the United States. The data are from the Behavioral Risk Factor Surveillance System. Lifetime asthma prevalence was assessed by asking whether the respondent was ever told by a health professional that they had asthma. The time period was a lifetime.

Prevalence measures are used to describe the scope and distribution of health outcomes in the population. The scope or amount of disease is called the burden of disease in the population. By offering a snapshot of disease occurrence, prevalence data contribute to the accomplishment of two of the primary functions of descriptive epidemiology: to assess variations in the occurrence of disease and to aid in the development of hypotheses that can be followed up by analytic studies.

Populations that differ in size cannot be compared directly by using frequency data, i.e., just the numbers of cases. In order to make such comparisons, prevalence proportions need to be calculated. Then it is possible to compare the proportions of health outcomes among different geographic areas. For example, Figure 3-7 shows how asthma lifetime prevalence (%) varies from state to state.

FIGURE 3-7 Adult self-reported lifetime asthma prevalence.



Reprinted from Centers for Disease Control and Prevention. 2014 Adult asthma data: prevalence tables and maps. Available at: http://www.cdc.gov/asthma/brfss/2014/mapL1.htm. Accessed September 21, 2016.

Interrelationships Between Incidence and Prevalence

Incidence and prevalence are interrelated concepts, as demonstrated by **Figure 3-8**. The relationship among incidence, prevalence, and duration of a disease is expressed by the following formula:

$$P \cong ID$$

The prevalence (P) of a disease is proportional to the incidence of the disease times the duration of the disease. Consequently, when the incidence of a disease increases, the prevalence also increases. Other factors that cause the prevalence of a disease to increase are its duration, in-migration of new cases, and development of treatments for the disease, including methods for extending the lives of patients who may not actually be cured. An example of how the duration of a disease affects its prevalence would be two diseases (A—long duration and B—short duration) that have similar incidence rates; we would expect disease A to have a higher prevalence than disease B. In the United States, the incidence of HIV infections has tended to remain constant over time and is much lower than HIV prevalence. Because more people with HIV infection are surviving for longer time periods, the prevalence of HIV is much greater than its incidence.

FIGURE 3-8 **Factors influencing observed prevalence.**

FPO

Reprinted with permission from Beaglehole R, Kjellström T. *Basic Epidemiology*. Geneva, Switzerland: World Health Organization; 1993:17.

EPIDEMIOLOGIC MEASURES RELATED TO MORTALITY

Mortality rates (death rates) have trended downward over time in this country. Increasing life expectancy has accompanied this decline in mortality rates. The term **life expectancy** refers to the number of years that a person is expected to live, at any particular year. "Life expectancy at birth represents the average number of years that a group of infants would live if the group was to experience throughout life the age-specific death rates present in the year of birth."[10(p8)] In 2013, life expectancy for the population of the United States was 78.8 years overall, 81.2 years for females, and 76.4 years for males.

Crude Rates/Crude Death Rate

The basic concept of a rate can be broken down into three general categories: crude rates, specific rates, and adjusted rates. A **crude rate** is a type of rate that has not been modified to take into account any of the factors, such as the demographic makeup of the population, that may affect the observed rate. Remember that rates include a time period during which an event occurred. Crude rates are summary rates based on the actual number of events in a population over a given time period. The numerator consists of the frequency of a disease (or other health-related outcome) over a specified period of time, and the denominator is a unit size of population (**Exhibit 3-1**). An example is the crude death rate, which approximates the portion of a population that dies during a time period of interest.[1]

In the formula shown in Exhibit 3-1, the denominator is also termed the **reference population**, which is defined as the population from which cases of a disease have been taken. For example, in calculating the annual **crude death rate** (crude mortality rate) in the United States, one would count all the deaths that occurred in the country during a certain year and assign this value to the numerator. The value for the denominator would be the size of the population of the country during that year. The best estimate of the size of a population is often taken as the size of the population around the midpoint of the year, if such information can be obtained. Referring to Exhibit 3-1, one calculates the U.S. crude mortality rate as 821.5 per 100,000 persons for 2013 (the most recently available data as of this writing).

Rates improve our ability to make comparisons, although they also have limitations. For example, rates of mortality for a specific disease (see the section on cause-specific mortality rates later in this chapter) reduce the standard of comparison to a common denominator, the unit size of population. To illustrate, the U.S. crude death rate for diseases of the heart in 2013 was 193.3 per 100,000. One also might calculate the

9781284131932_CH03_Pass02.indd 66 13/12/16 5:08 PM

EXHIBIT 3-1 Rate Calculation

Rate: A ratio that consists of a numerator and a denominator and in which time forms part of the denominator.

Epidemiologic rates contain the following elements:

- Disease frequency (or frequency of other health outcome)
- Unit size of population
- Time period during which an event occurs

Example (crude death rate, 2013):

Crude death rate =

$$\frac{\text{Number of deaths in a given year}}{\text{Reference population (during midpoint of the year)}} \times 100{,}000$$

(Either rate per 1,000 or 100,000 is used as the multiplier.)

Sample calculation problem (crude death rate in the United States):

Number of deaths in the United States during 2013 = 2,596,993

Population of the United States as of July 1, 2013 = 316,128,839

Crude death rate = (2,596,993/316,128,839) × 100,000 = 821.5 per 100,000

Adapted and reprinted from Friis RH, Sellers TA. *Epidemiology for Public Health Practice*. 5th ed. Burlington, MA: Jones & Bartlett Publishers; 2014:112.

heart disease death rate for geographic subdivisions of the country (also expressed as frequency per 100,000 individuals). These rates then could be compared with one another and with the rate for the United States for judging whether the rates found in each geographic area are higher or lower. For example, the crude death rates in 2013 for diseases of the heart in New York and Texas were 224.1 and 152.0 per 100,000, respectively.[10] On the basis of the crude death rates, it would appear that the death rate was much higher in New York than in Texas or the United States as a whole. This may be a specious conclusion, however, because there may be important differences in population composition (e.g., age differences between populations) that would affect mortality experience. Later in this chapter, the procedure to adjust for age differences or other factors is discussed.

Rates can be expressed in terms of any unit size of population that is convenient (e.g., per 1,000, per 100,000, or per 1,000,000). Many of the rates that are published and routinely used as indicators of public health are expressed according to a particular convention. For example, cancer rates are typically expressed per 100,000 population, and infant mortality is expressed per 1,000 live births. One of the determinants of the size of the denominator is whether the numerator is large enough to permit the rate to be expressed as an integer or an integer plus a trailing decimal (e.g., 4 or 4.2). For example, it would be preferable to describe the occurrence of disease as 4 per 100,000 rather than 0.04 per 1,000, even though both are perfectly correct. Throughout this chapter, the multiplier for a given morbidity or mortality statistic is provided.

Case Fatality Rate

An additional measure covered in this section is the case fatality rate (CFR). The **case fatality rate** refers to the number of deaths due to a disease that occur among people who are afflicted with that disease. The CFR(%), which provides a measure of the lethality of a disease, is defined as the number of deaths due to a specific disease within a specified time period divided by the number of cases of that disease during the same time period multiplied by 100. The formula is expressed as follows:

$$\text{CFR}(\%) = \frac{\text{Number of deaths due to disease "X"}}{\text{Number of cases of disease "X"}} \times 100 \text{ during a time period}$$

The numerator and denominator refer to the same time period. For example, suppose that 45 cases of hantavirus infection occurred in a western U.S. state during a year of interest. Of these cases, 22 were fatal. The CFR would be:

$$\text{CFR}(\%) = \frac{22}{45} \times 100 = 48.9\%$$

An example of an infectious disease that has a high case fatality rate is primary amebic meningoencephalitis, which is extremely rare and nearly always fatal. The causative organism is a type of amoeba (*Naegleria fowleri*) found in bodies of fresh water such as hot springs. This uncommon infection occurs when amoeba-contaminated water enters the nose and the parasites migrate to the brain via the optic nerve.[11]

Proportional Mortality Ratio

The National Vital Statistics Reports (for example, Deaths: Final Data for 2013)[10] provide data on the mortality experience of the United States. From these data, one can compute the crude death rate for the U.S. population as demonstrated previously. In comparison with the crude rate, the proportional mortality ratio (PMR) is used to express the proportion of all deaths that can be attributed to a given cause, for example, diseases of the heart. In 2013, the three leading causes of death were heart disease, cancer, and chronic lower respiratory diseases.

The *proportional mortality ratio PMR(%)* is the number of deaths within a population due to a specific disease or cause divided by the total number of deaths in the population (and multiplied by 100).

Proportional mortality ratio PMR(%) =

$$\frac{\text{Mortality due to a specific cause during a period of time}}{\text{Mortality due to all causes during the same time period}} \times 100$$

Sample calculation: Refer to Table 3-4 for data used in this calculation. In the United States, there were 611,105 deaths due to diseases of the heart in 2013 and 2,596,993 deaths due to all causes in that year. The PMR is (611,105/2,596,993) × 100 = 23.5%.

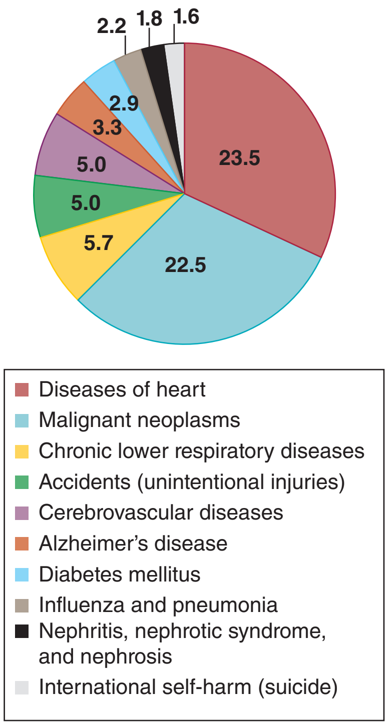
Table 3-4 presents mortality data for 2013 for the 10 leading causes of death in the United States. In **Figure 3-9** a pie chart illustrates the percentage of total deaths for each of the 10 leading causes of death listed in Table 3-4.

TABLE 3-4 Number and Percentage of Deaths for the 10 Leading Causes of Death in the United States, 2013

Rank	Cause of Death	Number	Percentage of Total Deaths	2013 Crude Death Rate
...	All causes	2,596,993	100.0	821.5
1	Diseases of heart	611,105	23.5	193.3
2	Malignant neoplasms	548,881	22.5	185.0
3	Chronic lower respiratory diseases	149,205	5.7	47.2
4	Accidents (unintentional injuries)	130,557	5.0	41.3
5	Cerebrovascular diseases	128,978	5.0	40.8
6	Alzheimer's disease	84,767	3.3	26.8
7	Diabetes mellitus	75,578	2.9	23.9
8	Influenza and pneumonia	56,979	2.2	18.0
9	Nephritis, nephrotic syndrome, and nephrosis	47,112	1.8	14.9
10	Intentional self-harm (suicide)	41,149	1.6	13.0

Data from Xu JQ, Murphy SL, Kochanek KD, Bastian BA. Deaths: final data for 2013. *National Vital Statistics Reports*. 2016;64(2):5. Hyattsville, MD: National Center for Health Statistics.

FIGURE 3-9 Proportional mortality ratios for 10 major causes of death in the United States, 2013.



Data from Xu JQ, Murphy SL, Kochanek KD, Bastian BA. Deaths: Final data for 2013. *National vital statistics reports;* vol 64 no 2. Hyattsville, MD: National Center for Health Statistics. 2016, p. 5.

SPECIFIC RATES

A **specific rate** is a statistic referring to a particular subgroup of the population defined in terms of race, age, or sex. A specific rate also may refer to the entire population but is specific for some single cause of death or illness. The three examples of specific rates discussed in this chapter are cause-specific rates, age-specific rates, and sex-specific rates. You will learn how they can be applied in various situations.

Cause-Specific Rate

The *cause-specific rate* is a measure that refers to mortality (or frequency of a given disease) divided by the population size at the midpoint of a time period times a multiplier. An example of a cause-specific rate is the cause-specific mortality rate, which, as the name implies, is the rate associated with a specific cause of death. The formula for a cause-specific rate (cause-specific mortality rate) is shown in the text box.

Cause-specific rate (e.g., cause-specific mortality rate) =

$$\frac{\text{Mortality (or frequency of a given disease)}}{\text{Population size at midpoint of time period}} \times 100{,}000$$

Refer back to Table 3-4 for data used in the following sample calculation of the cause-specific mortality rate for accidents (unintentional injuries) for 2013. In the United States, the number of deaths for accidents (unintentional injuries) was 130,557, whereas the population total on July 1, 2013 was estimated to be 316,128,839. The crude cause-specific mortality rate due to accidents (unintentional injuries) per 100,000 was 130,557/316,128,839 × 100,000 or 41.3 per 100,000.

Age-Specific Rates

An *age-specific rate* refers to the number of cases of disease per age group of the population during a specified time period. Age-specific rates help in making comparisons regarding a cause of morbidity or mortality across age groups. A more precise definition of an age-specific rate is the frequency of a disease (or health condition) in a particular age stratum divided by the total number of persons within that age stratum during a time period. The formula for an age-specific rate is shown in the text box.

AGE-SPECIFIC RATE (R)

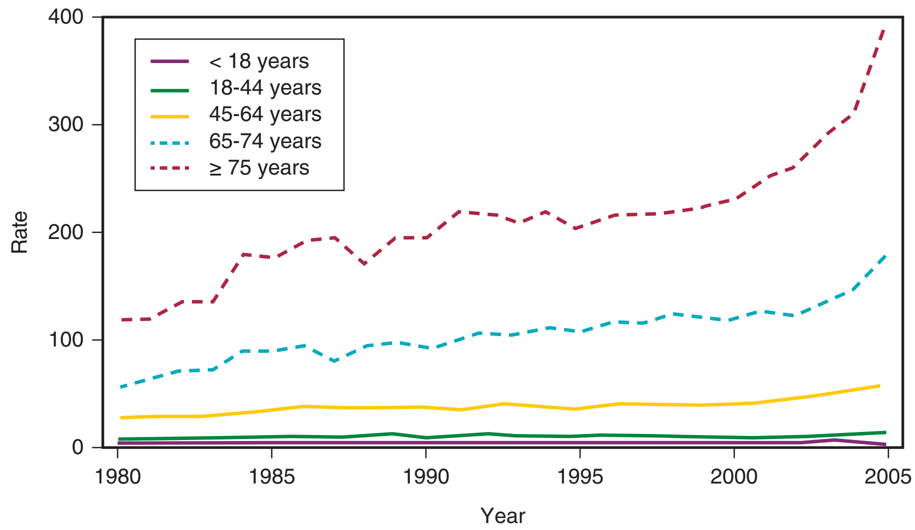
Age-specific rate: the number of cases per age group of population (during a specified time period such as a calendar year). The following example pertains to the group age 15 to 24 years, although some other convenient age group could be chosen.

Formula (age-specific death rate [R])

$$R = \frac{\text{Number of deaths among those age 15 to 24 years}}{\text{Number of persons who are age 15 to 24 years}} \times 100{,}000$$

Sample calculation (deaths from malignant neoplasms): In the United States during 2013, there were 1,496 deaths due to malignant neoplasms among the group age 15 to 24 years, and there were 43,954,402 persons in that age group. The age-specific malignant neoplasm death rate in this age group is 1,496/43,954,402 × 100,000 = 3.4 per 100,000.

FIGURE 3-10 **Age-specific hospitalization rates per 10,000 for kidney disease, by age group—National Hospital Discharge Survey, United States, 1980–2005.**



Reprinted from Centers for Disease Control and Prevention. Hospitalization discharge diagnoses for kidney disease—United States, 1980–2005. MMWR. March 2008; 57:311.

Figure 3-10 illustrates data for age-specific rates of hospitalization for kidney disease. For people 45 years of age and older, the age-specific hospitalization rates have shown an increasing trend. The highest rates of hospitalization and the sharpest increase in rates occurred among people age 75 years and older.

Sex-Specific Rates

A sex-specific rate refers to the frequency of a disease in a sex group divided by the total number of persons within that sex group during a time period times a multiplier. The formula for a sex-specific rate is shown in the following text box.

Sex-specific rate (e.g., sex-specific death rate) =

$$\frac{\text{Number of deaths in a sex group}}{\text{Total number of persons in the sex group}} \times 100{,}000$$

Sample calculation: In 2013, the following information was recorded about mortality and the population size:

- Number of deaths among males: 1,306,034
- Number of deaths among females: 1,290,959
- Estimated number of males in the population as of July 1, 2013: 155,651,602
- Estimated number of females in the population as of July 1, 2013: 160,477,237

The sex-specific crude death rate for males in 2013 per 100,000 was 1,306,034/155,651,602 × 100,000 = 839.1 per 100,000.

The sex-specific crude death rate for females in 2013 per 100,000 was 1,290,959/160,477,237 × 100,000 = 804.4 per 100,000.

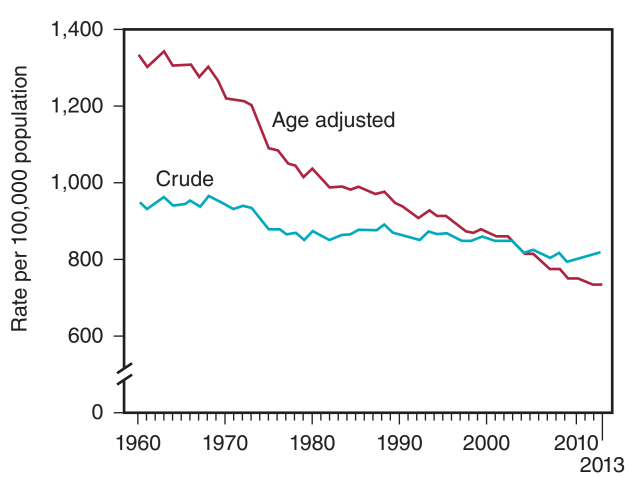
Thus, in 2013, the sex-specific crude death rate for males was 839.1 per 100,000 population versus 804.4 per 100,000 population for females.

ADJUSTED RATES

An *adjusted rate* is a rate of morbidity or mortality in a population in which statistical procedures have been applied to permit fair comparisons across populations by removing the effect of differences in the composition of various populations. A factor in rate adjustment is age adjustment. Calculation of age-adjusted rates is a much more involved procedure than that required for crude rates. A weighting process entails the use of detailed information about the age structure of the population for which the rates are being age adjusted. For example, "age-adjusted death rates are constructs that show what the level of mortality would be if no changes occurred in the age composition of the population from year to year."[12(p3)] The direct method of age adjustment involves multiplying the age-specific rates for each subgroup of a population to be standardized by the number in a comparable subgroup of a standard population.

To age adjust the crude mortality rate in the United States, we would use the standard population, which for the United States is the year 2000 population. For example, suppose you wanted to standardize the crude mortality data for the United States for 2003. You would multiply the age-specific death rate for the population under age 1 (700.0 per 100,000) in 2003 by the number in the year 2000 standard population under age 1 (3,794,301). This calculation would need to be repeated for each age stratum. The results for each stratum would then be summed to create a weighted average—the age-adjusted death rate. For additional information regarding the computations involved in age adjustment, refer to *Epidemiology for Public Health Practice*, 5th edition.[8]

FIGURE 3-11 Crude and age-adjusted death rates: United States, 1960–2013.



Reproduced From: Xu JQ, Murphy SL, Kochanek KD, Bastian BA. Deaths: final data for 2013. *National Vital Statistics Reports*. 2016;64(2):4. Hyattsville, MD: National Center for Health Statistics.

According to the National Center for Health Statistics, the age-adjusted death rate in the United States in 2013 was 731.9 deaths per 100,000 U.S. standard population. This figure compares with a crude rate of 821.5 per 100,000 population. In most years since 1980 (with the exception of 1983, 1985, 1988, 1993, 1999, 2005, 2008, and 2013), the age-adjusted death rate in the United States has declined.[10] Refer to **Figure 3-11** for information on trends in age-adjusted and crude mortality rates over time.

Returning to the example in which we compared mortality in New York and Texas, the crude mortality rate for diseases of the heart in 2013 was 224.1 per 100,000 in New York; in Texas, the rate was 152.0 per 100,000. The corresponding age-adjusted rates were 184.8 per 100,000 and 170.7 per 100,000, respectively. The higher crude mortality rate observed in New York in comparison with Texas was due largely to differences in the age structures of the two states. You can see that when the rates were age adjusted, the differences in mortality for diseases of the heart diminished substantially. Consequently, age-adjusted rates permitted a more realistic comparison between the two states than crude rates.

MEASURES OF NATALITY AND MORTALITY LINKED TO NATALITY

Data about natality pertain to birth-related phenomena.[13] Measures of natality include the **crude birth rate** and the fertility rate. Additionally, statisticians compute measures that describe mortality linked to natality. These indices are the maternal mortality rate, fetal mortality rate, and infant mortality rate. This section covers several measures that pertain to the number of births in a population (birth rate) and the fertility of women of childbearing age (fertility rate). Note that by statistical convention, one definition of the childbearing age is 15 to 44 years of age. Related to giving birth is maternal mortality, which occurs during a small number of births in this country. Another fatal outcome is death of the fetus during gestation; such deaths are called fetal mortality. Still another measure tracks death of the newborn during the first year of life. Consult **Table 3-5** for measures presented in this section as well as some of their applications.

Maternal Mortality

Maternal mortality encompasses maternal deaths that result from causes associated with pregnancy. Among the factors related to maternal mortality are race, insufficient healthcare

TABLE 3-5 Examples of Measures of Natality and Mortality Linked to Natality

Measure	How Used
Maternal mortality rate	Reflects health disparities such as healthcare access
Infant mortality rate	For international comparisons to identify countries with high rates
Fetal death rate/late fetal death rate	Measures risk of death of the fetus
General fertility rate	Compares populations and subgroups regarding their fertility
Crude birth rate	To project population changes
Perinatal mortality rate	Assesses events that occur during late pregnancy and soon after birth

access, and social disadvantage. The **maternal mortality rate** is the number of maternal deaths ascribed to childbirth divided by the number of live births times 100,000 live births during a year. In 2005, the maternal mortality rate was 15.1 deaths per 100,000 live births (623 total deaths in 2005). The respective maternal mortality rates per 100,000 live births for black and white women were 36.5 and 11.1; the rate for black women was about 3.3 times that for white women.[12]

Maternal mortality rate =

$$\frac{\text{Number of deaths assigned to causes related to childbirth}}{\text{Number of live births}} \times 100{,}000 \text{ live births (during a year)}$$

Note: Live births include multiple births.

Infant Mortality Rate

The **infant mortality rate** is defined as the number of infant deaths among infants age 0 to 365 days during a year divided by the number of live births during the same year (expressed as the rate per 1,000 live births). Refer to the text box, Infant mortality rate.

The terms neonatal mortality and postneonatal mortality also are used to describe mortality during the first year of life. The **neonatal mortality rate** is the number of infant deaths under 28 days of age divided by the number of live births during a year. The **postneonatal mortality rate** refers to the number of infant deaths from 28 days to 365 days after birth divided by the number of live births minus neonatal deaths during a year (expressed as rate per 1,000 live births).

Infant mortality (IM) rate =

$$\frac{\text{Number of infant deaths among infants age 0–365 days during the year}}{\text{Number of live births during the year}} \times 1{,}000 \text{ live births}$$

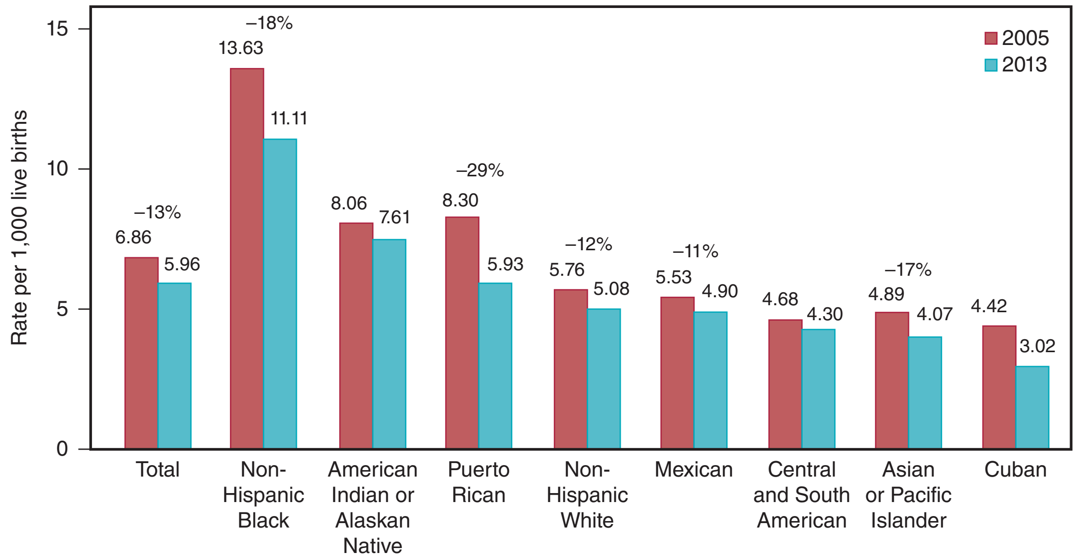
Sample calculation: In the United States during 2013, there were 23,440 deaths among infants under 1 year of age and 3,932,181 live births. The infant mortality rate was (23,440/3,932,181) × 1,000 = 5.96 per 1,000 live births.

From 2005 to 2013, the infant mortality rate in the United States declined by 13% (6.86 versus 5.96). Infant mortality is related to inadequate health care and poor environmental conditions. There are substantial racial/ethnic variations. (See **Figure 3-12**.)

Fetal Mortality

Fetal mortality is defined as the death of the fetus when it is in the uterus and before it has been delivered. Two measures of fetal mortality are the **fetal death rate** and the **late fetal death rate**. The formulas for these terms are shown in the text box.

FIGURE 3-12 Infant mortality rates, by race and Hispanic origin of mother—United States, 2005 and 2013.



Reproduced from Mathews TJ, MacDorman MF, Thoma ME. Infant mortality statistics from the 2013 period linked birth/infant death data set. *National Vital Statistics Reports*. 2015;64(9):5. Hyattsville, MD: National Center for Health Statistics.

Fetal Death Rate and Late Fetal Death Rate

Fetal death rate (per 1,000 live births plus fetal deaths) =

$$\frac{\text{Number of fetal deaths after 20 weeks or more gestation}}{\text{Number of live births + number of fetal deaths after 20 weeks or more gestation}} \times 1{,}000$$

Late fetal death rate (per 1,000 live births plus late fetal deaths) =

$$\frac{\text{Number of fetal deaths after 28 weeks or more gestation}}{\text{Number of live births + number of fetal deaths after 28 weeks or more gestation}} \times 1{,}000$$

Birth Rates

This section defines the terms *crude birth rate* and *general fertility rate*. The **crude birth rate** refers to the number of live births during a specified period such as a year per the resident population at the midpoint of the year. The birth rate affects the total size of the population.

Crude birth rate =

$$\frac{\text{Number of live births within a given period}}{\text{Population size at the middle of that period}} \times 1{,}000 \text{ population}$$

Sample calculation: 3,932,181 babies were born in the United States during 2013, when the U.S. population was 316,128,839. The crude birth rate was 3,932,181/316,128,839 = 12.4 per 1,000.

General Fertility Rate (Fertility Rate)

Related to birth rates is the **general fertility rate**, which refers to the number of live births reported in an area during a given time interval divided by the number of women age 15 to 44 years in the area (expressed as rate per 1,000 women age 15 to 44 years). The general fertility rate is referred to more broadly as the fertility rate.

General fertility rate =

$$\frac{\text{Number of live births with in a year}}{\text{Number of women age 15 to 44 years}^{*}} \times 1{,}000 \text{ women age 15 to 44 years}$$

*Number of women in this age group at the midpoint of the year

Sample calculation: During 2013 there were 62,939,772 women age 15 to 44 years in the United States. There were 3,932,181 live births. The general fertility rate was 3,932,181/62,939,772 = 62.5 per 1,000 women age 15 to 44 years.

Perinatal Mortality

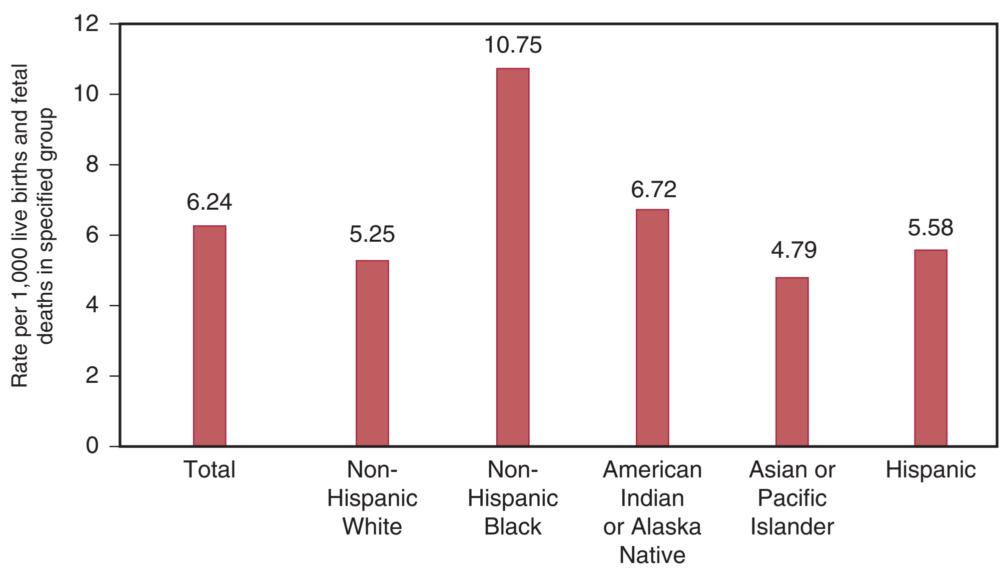
Perinatal mortality (known as definition I from the National Center for Health Statistics) takes into account both late fetal deaths and deaths among newborns. The **perinatal mortality rate** is defined as the number of late fetal deaths (after 28 weeks or more gestation) plus infant deaths within 7 days of birth divided by the number of live births plus the number of late fetal deaths during a year (expressed as rate per 1,000 live births and fetal deaths).

Figure 3-13 compares perinatal mortality rates by race in the United States for 2013.

Perinatal mortality rate =

$$\frac{\text{Number of late fetal deaths (after 28 weeks or more gestation)} + \text{infant deaths within 7 days of birth}}{\text{Number of live births} + \text{number of late fetal deaths}} \times 1{,}000 \text{ live births and fetal deaths}$$

FIGURE 3-13 Perinatal mortality rate, definition I, by race and Hispanic origin of mother—United States, 2013.



Reproduced from MacDorman MF, Gregory ECW. Fetal and perinatal mortality: United States, 2013. *National Vital Statistics Reports*. 2015;64(8):6. Hyattsville, MD: National Center for Health Statistics.

CONCLUSION

This chapter provided information on measures that are used in epidemiology; these were derived from ratios, such as rates, proportions, and percentages. Types of epidemiologic measures included counts and crude rates as well as case fatality rates, proportional mortality ratios, specific rates, and adjusted rates. These measures are helpful in making descriptive statements about the occurrence of morbidity and mortality and demonstrating risks of adverse health outcomes associated with particular exposures. Two important measures used in epidemiology are prevalence and incidence, which are interrelated terms. Rates are measures that specify a time period during which health events have occurred. A common epidemiologic rate is a crude rate, which allows comparisons of populations that differ in size but not in demographic composition. Specific rates and adjusted rates may be used to overcome some of the problems inherent in crude rates and thus can be used to make comparisons among populations.

© McIek/Shutterstock

Study Questions and Exercises

1. Define the following terms and give an example of how each one is used in public health:
   a. Maternal mortality rate
   b. Infant mortality
   c. Fetal mortality
   d. Crude birth rate
   e. General fertility rate
   f. Perinatal mortality rate
2. Suppose that an immunization becomes available for an incurable highly fatal disease. A successful immunization campaign has resulted in the immunization of persons who are at risk of the disease. Which of the following measures is likely to be affected? The case-fatality rate, the mortality rate, or, no change in either would occur.
3. Describe what is meant by the term *ratio*. Compare and contrast rates, proportions, and percentages. Give an example of each one.
4. An epidemiologist presented information regarding the annual prevalence (number of cases per 1,000) of adolescent pregnancy to a local health planning board. The epidemiologist compared data for the local county with data for the United States as a whole. One of the members of the planning board objected that this comparison was not valid because the county is much smaller than the entire country. Do you agree with the objection?
5. How does a prevalence proportion (expressed as number of cases per unit size of population) differ from an incidence rate?
6. Distinguish between period prevalence and incidence. What is the definition of lifetime prevalence? Explain the meaning of the formula, $P \cong ID$.
7. Define the term *crude rate*, giving an example. What are the advantages of using crude rates instead of frequency data such as counts?
8. Define the term *adjusted rate*. What is one of the main purposes of adjusted rates? Compare the advantages and disadvantages of crude and adjusted rates. What is meant by age adjustment? Describe the applications of age-adjusted rates.
9. What types of information are found by using specific rates, such as cause-specific, age-specific, and sex-specific rates, instead of crude rates?
10. Many communities and jurisdictions throughout the United States have legalized recreational use of marijuana. Suppose you are asked to conduct a questionnaire study of the prevalence of marijuana use in a community where use of marijuana is legal. Propose interview questions to assess the following measures of prevalence: point prevalence, period prevalence (one-year time period), and lifetime prevalence.
11. Explain the following measures of incidence and compare their applications: incidence rate, cumulative incidence rate, incidence density, and attack rate.
12. In 2010, the sex ratio among the age group 70-79 years was 81.0. The sex ratio among the age group 100 years and older was 20.7. How might one account for this decline in the sex ratio?
13. Refer back to Table 3-3. What quantitative measure is shown in the table? Describe the annual trends in the cases of infrequently reported notifiable diseases.
14. Calculate the incidence rate (per 100,000 population) of primary and secondary syphilis (combined) in 2013 from the following data:

    Number of reported cases in 2013: 17,357

    Estimated population of the United States as of July 1, 2013: 316,128,839

15. **Table 3-6** provides hypothetical data regarding the prevalence of diabetes in two counties in the United States.

    Based on 2020 prevalence (percentage), which of the two counties had a higher burden of disease from diabetes?

16. Refer to Exhibit 3-1. Calculate the crude death rate (per 100,000) from the following data:

    Number of deaths in the United States during 1990 = 2,148,463

    Population of the United States as of July 1, 1990 = 248,709,873

    How did the crude death rate in 2013 compare with the crude death rate in 1990?

17. Calculate the infant mortality rate (per 1,000 live births) from the following data:

    Number of infant deaths under 1 year in the United States during 1991 = 36,766

    Number of live births during 1991 = 4,111,000

    How did the infant mortality rate in 2013 compare with the infant mortality rate in 1991? (Note: refer to the text for 2013 data.)

18. Calculate the crude birth rate (per 1,000 population) from the following data:

    Number of live births during 1991 = 4,111,000

    Population of the United States as of July 1, 1991 = 252,688,000

    How did the crude birth rate in 2013 compare with the crude birth rate in 1991? (Note: refer to text for 2013 data.)

19. Calculate the general fertility rate (per 1,000 women aged 15-44) from the following data:

    Number of live births during 1991 = 4,111,000

    Number of women (15 to 44 years of age) in the United States as of July 1, 1991 = 59,139,000

    How did the general fertility rate in 2013 compare with the general fertility rate in 1991? (Note: refer to text for 2013 data.)

    Questions 20 through 22 refer to **Table 3-7**.

20. What is the sex ratio for total injuries?
21. What is the crude mortality rate per 100,000 population?
22. What is (a) the cause-specific mortality rate for injuries, and (b) the case fatality rate (%) for injuries?

TABLE 3-6 Hypothetical Data for Diabetes

	Estimated Total Population on July 1, 2020	Total Number of Cases of Diabetes in 2020
County A	11,020,000	356,289
County B	3,900,000	253,612

TABLE 3-7 Hypothetical Data for Unintentional Injuries

	Total Injuries	Fatal Injuries	Nonfatal Injuries	Number in Population	Total Deaths from All Causes
Men	73	3	70	2,856	9
Women	41	2	39	2,981	8

Answers to calculation problems

14. 5.5 per 100,000
15. County B (6.5% versus 3.2%)
16. The crude death rate declined from 863.8 per 100,000 to 821.5 per 100,000.
17. The infant mortality rate decreased from 8.95 to 5.86.
18. The crude birth rate declined from 16.3 per 1,000 to 12.4 per 1,000.
19. The general fertility rate declined from 69.5 per 1,000 to 62.5 per 1,000.
20. 1.78 to 1, male to female
21. 291.2 per 100,000
22. (a) 85.7 per 100,000; (b) 4.4%

Young Epidemiology Scholars (YES) Exercises

The Young Epidemiology Scholars: Competitions website provides links to teaching units and exercises that support instruction in epidemiology. The YES program, discontinued in 2011, was administered by the College Board and supported by the Robert Wood Johnson Foundation. The exercises continue to be available at the following website: http://yes-competition.org/yes/teaching-units/title.html. The following exercises relate to topics discussed in this chapter and can be found on the YES competitions website.

1. Bayona M, Olsen C. Measures in Epidemiology
2. Huang FI, Baumgarten M. Adolescent Suicide: The Role of Epidemiology in Public Health
3. McCrary F, St. George DMM. Mortality and the Trans-Atlantic Slave Trade

REFERENCES

1. Porta M, ed. *A Dictionary of Epidemiology*. 6th ed. New York, NY: Oxford University Press; 2014.
2. Centers for Disease Control and Prevention. HIV/AIDS surveillance report, 2006. Vol. 18. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2008:1–55.
3. U.S. Census Bureau. Age and sex distribution in 2005. Population profile of the United States: dynamic version. Available at: http://www.census.gov/population/pop-profile/dynamic/AgeSex.pdf. Accessed September 30, 2016.
4. U.S. Census Bureau. Age and sex composition: 2010. *2010 Census Briefs*; May 2011.
5. Centers for Disease Control and Prevention. QuickStats: Percentage of adults reporting joint pain or stiffness—National Health Interview Survey, United States, 2006. *MMWR*. 2008;57:467.
6. Hennekens CH, Buring JE. *Epidemiology in Medicine*. Boston, MA: Little, Brown; 1987.
7. Morgenstern H, Thomas D. Principles of study design in environmental epidemiology. *Environ Health Perspect*. 1993;101(Suppl 4):23–38.
8. Friis RH, Sellers TA. *Epidemiology for Public Health Practice*. 5th ed. Burlington, MA: Jones & Bartlett Learning; 2014.
9. Moorman JE, Akinbami LJ, Bailey CM, et al. National Surveillance of Asthma: United States, 2001–2010. *National Center for Health Statistics*. Vital Health Stat 3(35).
10. Xu JQ, Murphy SL, Kochanek KD, Bastian BA. Deaths: final data for 2013. *National Vital Statistics Reports*. 2016;64(2). Hyattsville, MD: National Center for Health Statistics.
11. Centers for Disease Control and Prevention. Primary amebic meningoencephalitis—Arizona, Florida, and Texas, 2007. *MMWR*. 2008;57:573–577.
12. Kung HC, Hoyert DL, Xu JQ, Murphy SL.Deaths: final data for 2005. *National Vital Statistics Reports*. 2008;56(10). Hyattsville, MD: National Center for Health Statistics.
13. Schneider D, Lilienfeld DE. *Lillienfeld's Foundations of Epidemiology*. 4th ed. New York, NY: Oxford University Press; 2015.