

Biostatistics – Spring 2026

Lecture 05: Rates in Biostatistics (Prevalence, Incidence, Mortality)

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Introduction

In previous lectures, we studied categorical data analysis and association tests. Now we move to an important topic in biostatistics:

How do we measure disease in a population?

In medicine and public health, we do not only test association. We must also measure:

- How common is a disease?
- How fast is a disease spreading?
- How many people are dying?

This lecture introduces the most important epidemiological measures. By the end of this lecture, you should be able to:

- Distinguish between **ratio**, **proportion**, and **rate**.
- Compute **prevalence** and **incidence**.
- Understand the difference between **incidence proportion** and **incidence rate**.
- Compute and interpret **mortality measures**.
- Write correct biomedical conclusions.

1. Ratio, Proportion, and Rate

Students often confuse these three terms. They are not the same.

1.1 Ratio

A ratio compares two quantities.

$$\text{Ratio} = \frac{A}{B}$$

Important:

- Numerator is NOT necessarily part of denominator.
- Example: Male/Female ratio.

Example:

If a hospital has 60 males and 40 females,

$$\text{Male/Female ratio} = \frac{60}{40} = 1.5$$

Interpretation: There are 1.5 males for every 1 female.

1.2 Proportion

A proportion is a special type of ratio.

$$\text{Proportion} = \frac{\text{Part}}{\text{Whole}}$$

Important:

- Numerator IS part of denominator.
- Value is between 0 and 1.

Example:

If 30 out of 100 patients have diabetes,

$$\text{Proportion with diabetes} = \frac{30}{100} = 0.30$$

We can also write 30%.

1.3 Rate

A rate measures how fast something happens.

A rate includes:

- A numerator
- A denominator
- A time component

General form:

$$\text{Rate} = \frac{\text{Number of events}}{\text{Population at risk} \times \text{Time}}$$

Example:

20 new cases per 1000 persons per year.

Time is essential in a rate.

2. Prevalence

Prevalence measures how common a disease is at a specific time.

$$\text{Prevalence} = \frac{\text{All existing cases}}{\text{Total population}}$$

Important:

- Includes old cases + new cases.
- Does NOT measure speed.
- It is a proportion.

2.1 Example

In a city of 10,000 people, 500 people have hypertension today.

$$\text{Prevalence} = \frac{500}{10,000} = 0.05$$

So prevalence = 5%.

Interpretation:

5% of the population currently has hypertension.

2.2 Point vs Period Prevalence (with Examples)

Point prevalence: Disease measured at one specific time.

Example (Point prevalence). On **January 1, 2025** a clinic has **800** registered patients. On that day, **64** patients are currently diagnosed with influenza.

$$\text{Point prevalence on January 1} = \frac{64}{800} = 0.08 = 8\%.$$

Interpretation: On January 1, 8% of patients had influenza.

Period prevalence: Disease measured during a time interval (e.g., during 2025).

Example (Period prevalence). During the year **2025**, the same clinic followed **800** patients. At some time during 2025:

- **64** patients already had influenza on Jan 1 (existing cases),
- **216** more patients were newly diagnosed during 2025.

So, the number of people who had influenza at **any time** during 2025 is:

$$64 + 216 = 280.$$

$$\text{Period prevalence in 2025} = \frac{280}{800} = 0.35 = 35\%.$$

Interpretation: During 2025, 35% of patients had influenza at least once.

Important note (simple rule):

Period prevalence is usually **greater than or equal to** point prevalence, because it counts anyone who was a case at **any time** during the period.

3. Incidence

Incidence measures NEW cases.

It answers:

How many people develop the disease?

3.1 Incidence Proportion (Risk)

$$\text{Incidence proportion} = \frac{\text{New cases during period}}{\text{Population at risk at the beginning of the period}}$$

Important:

- Only new cases.
- People already sick are excluded.
- It is a proportion.

Example:

In 2025, among 1000 healthy people, 50 developed influenza.

$$\text{Incidence proportion} = \frac{50}{1000} = 0.05 = 5\%$$

Interpretation:

5% of healthy individuals developed influenza during 2025.

3.2 Incidence Rate (Density)

Sometimes follow-up times differ between individuals.

We use person-time.

$$\text{Incidence rate} = \frac{\text{New cases}}{\text{Total person-time}}$$

Example:

50 new cases occurred during 5000 person-years.

$$\text{Incidence rate} = \frac{50}{5000} = 0.01$$

= 10 cases per 1000 person-years.

Interpretation:

10 new cases occur per 1000 persons per year.

4. Mortality and Birth Measures

Mortality measures describe death in a population. Some measures describe general deaths, others describe deaths in specific groups.

4.1 Crude Mortality Rate

$$\text{Crude mortality rate} = \frac{\text{Total deaths in a year}}{\text{Mid-year population}} \times 1000$$

We use mid-year population (usually July 1) because population changes during the year.

Example:

Population = 50,000 Deaths in 2025 = 400

$$\frac{400}{50,000} \times 1000 = 8$$

Interpretation: 8 deaths per 1000 population per year.

Important: Crude mortality does NOT consider age or sex differences.

4.2 Cause-Specific Mortality Rate

$$\text{Cause-specific mortality rate} = \frac{\text{Deaths from a specific cause}}{\text{Mid-year population}} \times 1000$$

Example:

100 deaths from heart disease in population 50,000:

$$\frac{100}{50,000} \times 1000 = 2$$

Interpretation: 2 deaths per 1000 population due to heart disease.

Note: This does not prove the cause is preventable or causal. It only describes frequency.

4.3 Infant Mortality Rate (IMR)

$$\text{Infant mortality rate} = \frac{\text{Deaths under age 1 year}}{\text{Live births}} \times 1000$$

Example:

30 infant deaths among 3000 live births:

$$\frac{30}{3000} \times 1000 = 10$$

Interpretation: 10 infant deaths per 1000 live births.

This measure reflects quality of maternal and child health services.

4.4 Neonatal Mortality Rate (NNMR)

$$\text{Neonatal mortality rate} = \frac{\text{Deaths under 28 days}}{\text{Live births}} \times 1000$$

Example:

15 neonatal deaths among 3000 live births:

$$\frac{15}{3000} \times 1000 = 5$$

Important rule:

Neonatal mortality \leq Infant mortality

Because neonatal deaths are part of infant deaths.

4.5 Fetal Mortality Rate (FMR)

$$\text{Fetal mortality rate} = \frac{\text{Fetal deaths}}{\text{Total births (live + stillbirths)}} \times 1000$$

Example:

500 stillbirths and 20,000 total births:

$$\frac{500}{20,000} \times 1000 = 25$$

Interpretation: 25 fetal deaths per 1000 total births.

Note: The denominator includes ALL births (not only live births).

4.6 Maternal Mortality Ratio (MMR)

$$\text{Maternal mortality ratio} = \frac{\text{Maternal deaths}}{\text{Live births}} \times 100,000$$

We multiply by 100,000 because maternal deaths are rare.

Example:

60 maternal deaths and 12,000 live births:

$$\frac{60}{12,000} \times 100,000 = 500$$

Interpretation: 500 maternal deaths per 100,000 live births.

Conceptual note: The ideal denominator would be number of pregnant women, but this is difficult to measure, so live births are used.

4.7 Crude Birth Rate (CBR)

$$\text{Crude birth rate} = \frac{\text{Live births in one year}}{\text{Mid-year population}} \times 1000$$

Example:

12,000 live births in population 500,000:

$$\frac{12,000}{500,000} \times 1000 = 24$$

Interpretation: 24 births per 1000 population per year.

CBR measures population growth but does not consider age structure.

4.8 General Fertility Rate (GFR)

$$\text{GFR} = \frac{\text{Live births in one year}}{\text{Number of women aged 15-49}} \times 1000$$

Example:

12,000 live births 200,000 women aged 15-49:

$$\frac{12,000}{200,000} \times 1000 = 60$$

Interpretation: 60 births per 1000 women of reproductive age.

Important comparison:

GFR is more accurate than crude birth rate because it restricts the denominator to women who can actually give birth.

Homework (HW)

HW1

A city has 20,000 people. 1200 people have diabetes. During 2025, 200 new cases occurred among the 18,800 people who were disease-free at the beginning of 2025.

Compute:

1. Prevalence.
2. Incidence proportion.
3. Interpret both results.

HW2

In a population of 80,000, there were 600 deaths in one year. 150 deaths were due to cancer.

Compute:

1. Crude mortality rate (per 1000).
2. Cancer-specific mortality rate (per 1000).
3. Interpret both.

HW3

In a hospital during 2025: Live births = 8,000, Infant deaths (<1 year) = 120, Neonatal deaths (0-28 days) = 80, Fetal deaths = 200.

Compute:

1. Infant mortality rate.
2. Neonatal mortality rate.
3. Fetal mortality rate.
4. Verify whether neonatal mortality is less than infant mortality.

Multiple Choice Questions (MCQs)

MCQ 1

Which of the following is a proportion?

A) Male/Female ratio B) Prevalence C) Incidence rate per person-year D) Deaths per 1000 population per year

MCQ 2

Which measure includes a time component in its denominator?

A) Prevalence B) Ratio C) Incidence rate D) Proportion

MCQ 3

A disease has high prevalence but low incidence. This most likely means:

A) The disease spreads very quickly B) The disease lasts a long time C) The disease is very fatal D) The disease is rare

MCQ 4

In a population of 10,000 people, 500 have asthma. What is the prevalence?

A) 0.005 B) 5% C) 50% D) 0.5

MCQ 5

During one year, 100 new cases occur among 2,000 disease-free individuals. The incidence proportion is:

A) 0.5% B) 5% C) 50% D) 0.05 per person-year

MCQ 6

The denominator of maternal mortality ratio is:

A) Total women in population B) Total pregnancies C) Live births D) Total population

MCQ 7

Which of the following must always be true?

A) Infant mortality < Neonatal mortality B) Neonatal mortality \leq Infant mortality
C) Fetal mortality < Neonatal mortality D) Crude mortality < Cause-specific mortality

MCQ 8

Crude birth rate uses which denominator?

A) Women aged 15-49 B) Total population C) Total pregnancies D) Married women only

MCQ 9

Incidence rate differs from incidence proportion because it:

- A) Includes old cases B) Uses person-time C) Is not a rate D) Excludes time

MCQ 10

Which measure is most appropriate to evaluate quality of obstetric care?

- A) Crude mortality rate B) Infant mortality rate C) Neonatal mortality rate D) Prevalence