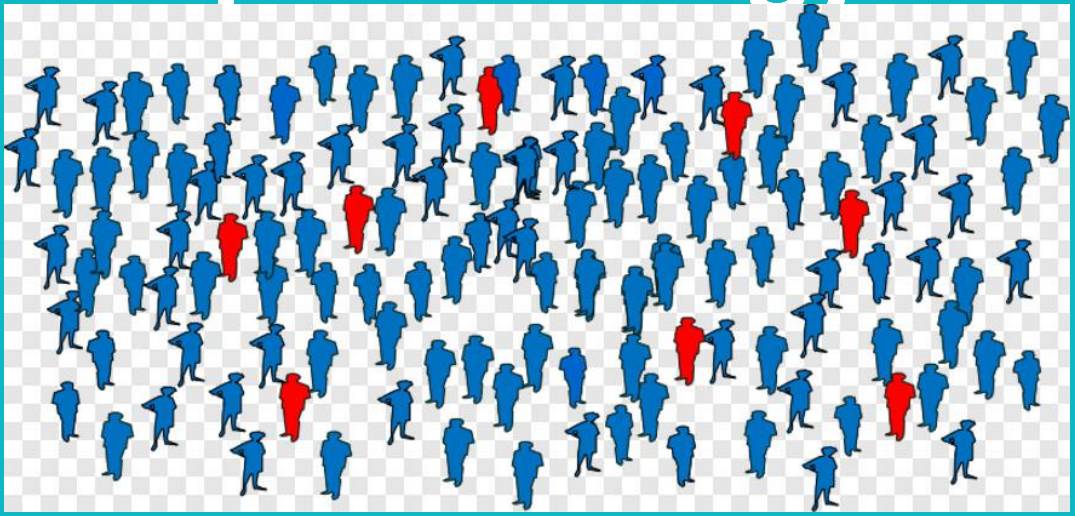
Measures of Disease Occurrence and Frequency in Epidemiology



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- **Learning objectives**

- To understand the various methods used to measure how frequently diseases occur in populations and how they are distributed.#
- To Define and calculate measures of frequency of disease
- Prevalence (point and period prevalence)
- Incidence (risk, rate, odds)

Importance of Measuring Disease

- Measuring disease frequency helps track trends, allocate resources, and plan interventions.
- Allows comparison across populations and assessment of public health interventions.

Reminder - Definition of epidemiology

- The study of the frequency, distribution and determinants of *diseases* and health- related states in populations in order to prevent and control disease.

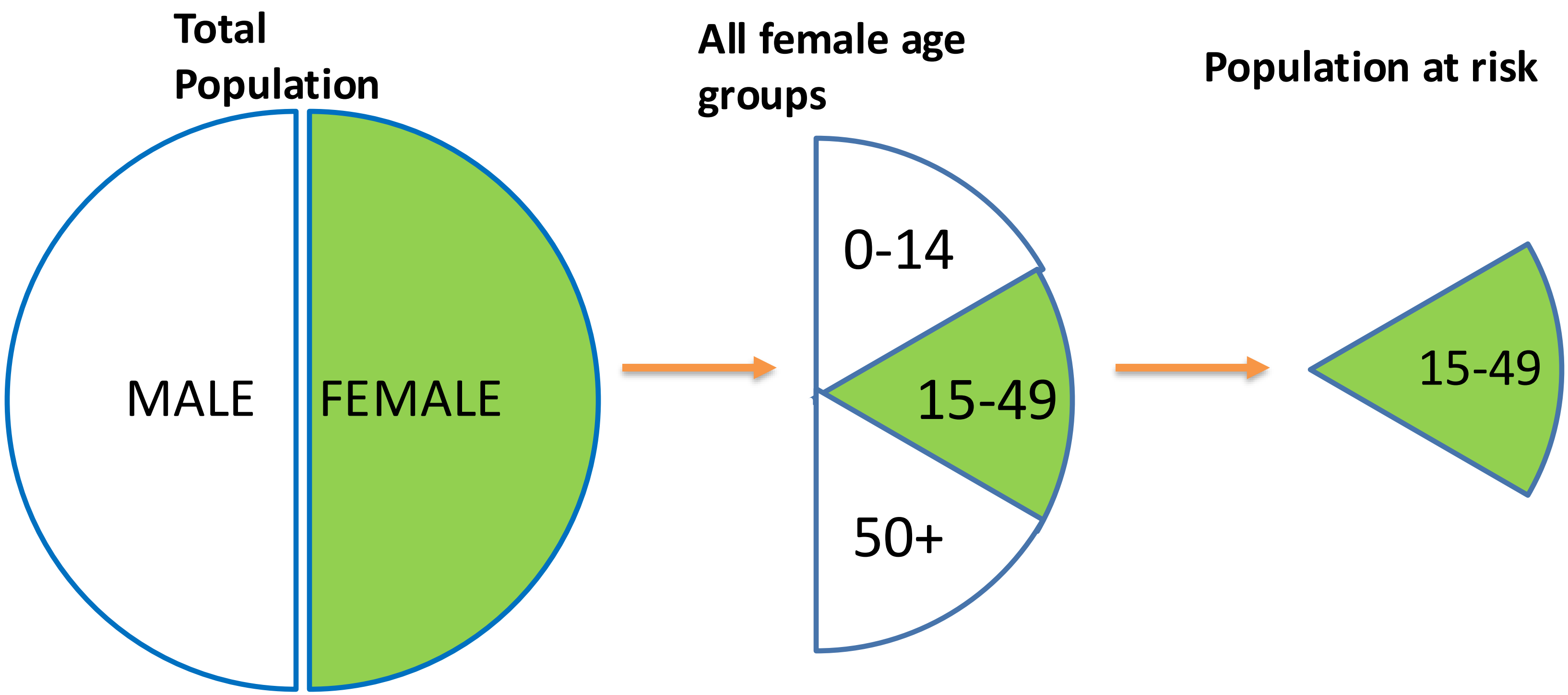
- **A prerequisite for any epidemiologic investigation is to quantify the occurrence of disease.**

Case definition

- Case definition is a set of standard criteria for deciding whether or not a person has a particular disease or health related event.
- The probability of getting a disease has a time dimension.

Population at risk

- people who are potentially susceptible to the diseases being studied. can be defined by demographic, geographic or environmental factors.



For example when studying measles, the population at risk used for the calculation should be the children under five years of age, because measles is rare after that age. The population at risk is used as the denominator when calculating proportions or rates

Measures of Disease Occurrence and Frequency

Measures of disease frequency in mathematical quantity:

1. Counts
2. Ratio
3. Proportion
4. Rates

Measures of disease frequency in epidemiology:

1. Incidence/Risk
2. Prevalence

1. COUNTS

Definition: The simplest measure of disease occurrence. Absolute number of persons who have disease or characteristic of interest.

Examples:

-Counting the number of flu cases in a city over a month.

-Total COVID-19 cases in a country from 2020 to 2022.

- 250 severe acute diarrhoea cases reported in village A

But if there are 250 cases of severe acute diarrhea cases in village A and 120 cases in village B, Which one is more infected?

Count of cases gives the numerator . Need to know the size of the denominator (size of population).

Village A : 250/800,000 = 0.3/1,000

Village B: 120/300,000 = 0.4/1,000

1. COUNTS: Applications

Outbreak Investigation:

✓Example: Counts help detect outbreaks, especially for diseases with previously low prevalence.

Public Health Surveillance:

✓Example: Monitoring the number of new tuberculosis cases over the past year.

Health Resource Allocation:

✓Example: Determining how many ventilators are needed during a surge in COVID-19 cases.

1. COUNTS: Limitations

No Population Context:

Counts do not indicate the risk or proportion of affected individuals within a population. They also don't tell whether cases involve long-term residents, whether individuals moved away, or if any died.

Lacks Trend Data:

Counts alone don't show how disease incidence changes over time (whether the number of cases is growing or shrinking over time) additional time-based data is needed.

Not Suitable for Comparing Groups:

Difficult to compare between groups or populations of different sizes. Example: 50 cases of a disease in a small town of 1,000 people is a much higher concern than 50 cases in a city of 1,000,000.

2. Ratio:

- **Definition:** is the relation in: number degree, or quantity **existing between two independent groups.** A fraction in which the numerator is not part of the denominator.

Formula: $Ratio = \frac{a}{b}$ (where a and b are independent of each other)

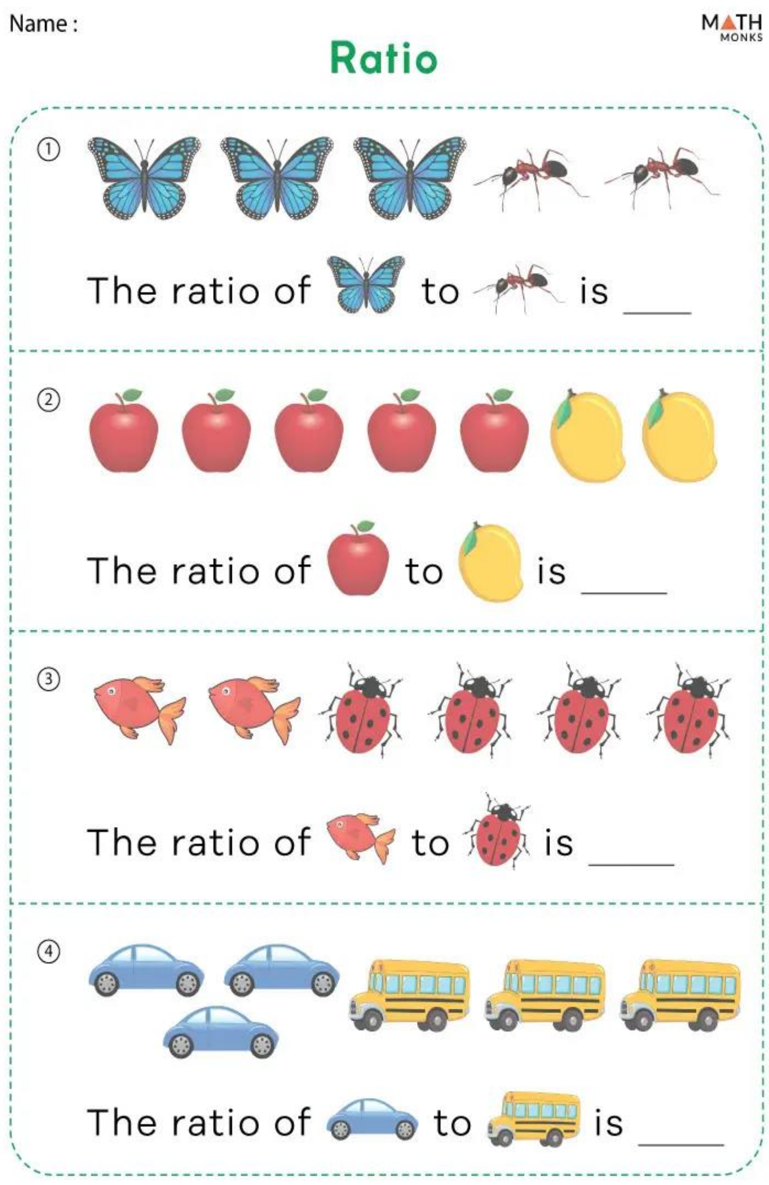
Example:

– Male-to-female ratio in lung cancer cases.

30 male cases and 15 female cases, the ratio would be 30/15, or 2:1, indicating there are twice as many male cases as female.

-- Number of hospital beds per 100,000

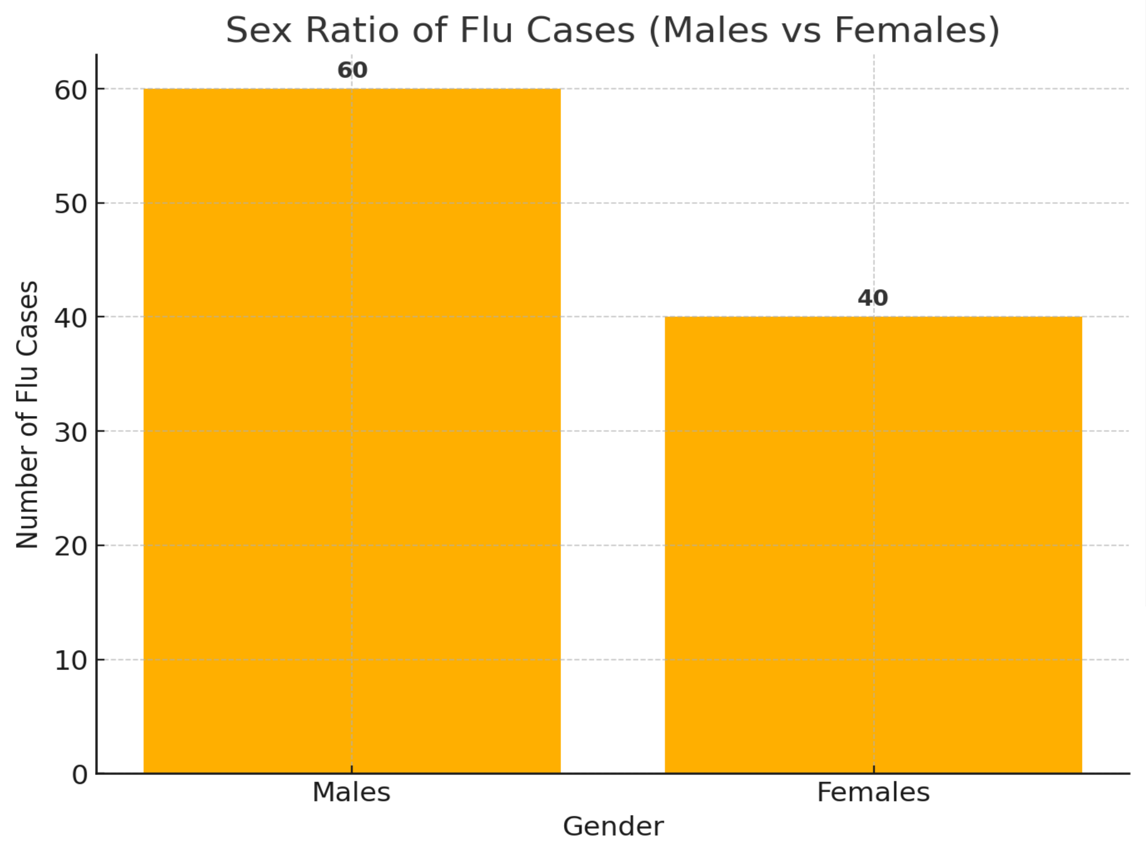
– Fetal death ratio: fetal deaths/live births.



2. Ratio: Use in Epidemiology

- Can compare different groups, such as the risk of disease between exposed and unexposed groups (risk ratio, odds ratio, Sex Ratios..etc.).

EXAMPLE: calculate ratio??



Ratio= 1.5:1

2. Ratio: Limitations

- **No Context of Absolute Numbers:** Ratios only show the relative size of one group compared to another (2:1 or 3:1). No information on how large or small each group.
- **Cannot Determine Risk:** a 2:1 ratio between groups doesn't tell us if the disease is rare or common in either group. It just shows that one group is affected more frequently than the other.

$$\frac{a}{a+b}$$

2. Proportion:

- **Definition:** A **proportion** is a type of ratio in which the **numerator** is a subset of the **denominator**, representing a part-to-whole relationship.
- **Formula:** $\text{Proportion} = \frac{\text{Number of cases}}{\text{Total population}}$ (Where the **total population** includes both those with and without the condition)
- **Example:**

From 1000 females aged 16 – 45 y, 675 use modern contraceptive methods. The proportion of those who use modern contraceptive methods $= \frac{675}{1000\ total\ population}$ = 0.675 or 76.5%

It must fall between **0.0 and 1.0** Or **0%-100%**

- **Interpretation:** Expressed as a percentage or a fraction, and indicates what fraction of the population is affected. (used for assessing **prevalence and** understanding the **distribution of diseases, vaccination coverage, proportionate mortality** within populations**).**

Limitations:

- **No Time Dimension:** Proportions do not reflect when the cases occurred, so they cannot be used to determine the speed of disease spread or new case outbreak.
- **Lacks Detail on Dynamics:** It doesn't differentiate between chronic and acute cases (e.g., people may have developed the disease years ago).

4. Rates:

- **Definition:** Is the measure of an event, condition (disease, disability or death) with a *unit population and within a time period*.
- **Formula:** Rate $= \dfrac{\text{Number of events in a population}}{\text{Population at risk during a given time}}$ **x** k

- **Number of events: the occurrences of the health outcome (e.g., new disease cases).**
- **Population at risk: includes only those who are susceptible to the condition.**
- **Time: is included to reflect the period over which the events occur.**
- **k is the constant (e.g., 1,000, 10,000, or 100,000)**

Example:

Incidence rate of heart attacks: $= \dfrac{\textbf{5 heart attacks}}{\textbf{2000 people per year}}$ **x 1000 =**

2.5 cases per 1,000 people per year

✓ There are 3 types of rates

- **Crude Rates**
- **Adjusted Rates**
- **Specific Rates** For subset or subgroup of total population

$$\text{Crude death rate} = \frac{\text{Number of deaths (defined place and time period)}}{\text{Mid-period population (same place and population)}} \times 1000$$

High rates as well as low rates provide useful information

- Spread,
- Transmission.
- Cause,
- Control measurements

Rate= $\frac{\text{№ of TB cases among ♂ in Jordan 2017}}{\text{♂ Population in Jordan in specific time period(2017)}}$ X 100

♂ = 10 / 50X100=20%

Rate= $\frac{\text{№ of TB cases among ♀ in Jordan 2017}}{\text{♀ Population in Jordan in specific time period(2017)}}$ X 100

♀ = 25/200X100= =12.5%

TB is higher in males than females population in the same community

TB occurrence in males may be related to Smoking, HIV ,drug abuse or any other factors

- Ratio is less useful than rates in epidemiology as the time element is missing, making the result more generalized finding

All Rates can be viewed as ratios,

but

ratios are not necessarily Rates

- In Ratio the numerator is not included in the population defined by the denominator

- **Ratio vs proportion: In Ratio the numerator is not part of the denominator population**

Importance:

Monitor disease trends over time: By tracking how rates change year by year (detect increases or decreases in disease occurrence).

Evaluate public health interventions: assess the effectiveness of programs or interventions aimed at reducing disease. For example, a vaccination campaign might lower the incidence rate of measles in a community.

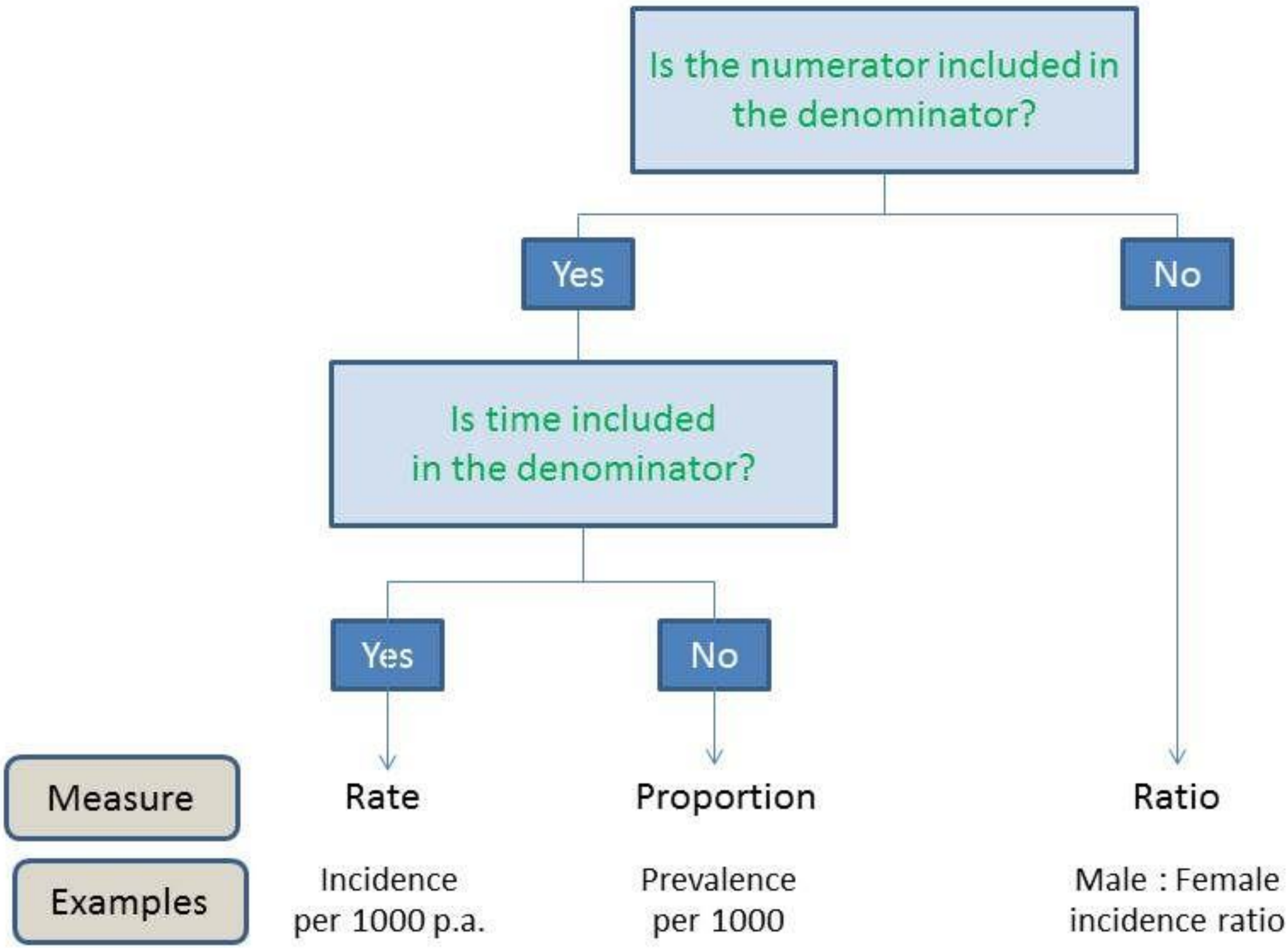
Identify at-risk populations: Rates can be adjusted for different groups (age, sex, region) to identify populations that are at higher risk of disease and require targeted interventions.

Limitations:

Requires Accurate Time Data: Incomplete or inaccurate time data can result in misleading rates, affecting the understanding of disease trends. Example: If some cases of a disease are not properly dated, it might appear that the disease is spreading more slowly or quickly than it actually is.

Complex Calculations: Calculating rates often requires adjustments to account for differences in age, gender, or other population characteristics, which can complicate the interpretation. Example: If comparing two populations with different age distributions, the age-adjusted mortality rate must be calculated to avoid overestimating the risk in an older population, where death rates naturally tend to be higher.

Distinguishing Proportions, Rates and Ratios



Measures of disease Frequency in epidemiology

- **Two main measures of disease frequency:**
- **Prevalence**

– Point prevalence

– Period prevalence

- **Incidence**

– Cumulative incidence (risk)

– Incidence odds

– Incidence rate

Point prevalence

Prevalence means ALL. (Pre existing + New)

Is a proportion (dimensionless i.e. has no units) But useful to specify the point in time to which it refers.

Measure of existing cases

$$\text{Point prevalence} = \frac{\text{Number of cases of disease at a point in time}}{\text{Total number of people in the defined population at the same point in time}}$$

Example prevalence:

- 10000 population.
- We found 50 with T1DM.
- Prevalence= 50/10000

= 0.005 → 0.5%

Period prevalence

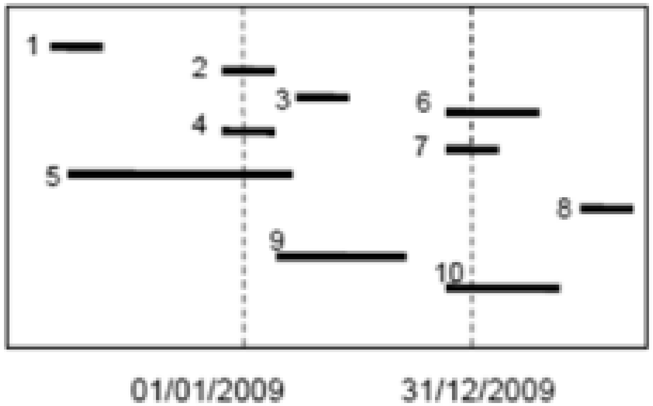
$$\text{Period prevalenc} = \frac{\text{Number of cases of disease at any time during a specified (usually short) period}}{\text{Total number of people in that defined population}}$$

•**Point prevalence** represents a single moment in time (e.g., how many people have a disease on January 1st). Pre-existing+New cases present at the specific time point

•**Period prevalence** covers a time frame (e.g., how many people had the disease at any point during 2023). Pre-existing+New cases during the period. E.g. annual prevalence rate.

When the type of prevalence rate is not specified, It is usually point prevalence.

Prevalence divided into two types:



- Point prevalence

  01/01/2009: case No. 2, 4, 5

  31/12/2009: case No. 6, 7, 10

- Period prevalence between 01/01-31/12/2009:

Case No. 2, 3, 4, 5, 6, 7, 9, 10

Factors influencing prevalence

Increased by:	Decreased by:
Longer duration of the disease	Shorter duration of the disease
Prolongation of life of patients without cure	High case-fatality rate from disease
Increase in new cases (increase in incidence)	Decrease in new cases (decrease in incidence)
In-migration of cases	In-migration of healthy people
Out-migration of healthy people	Out-migration of cases
In-migration of susceptible people	Improved cure rate of cases
Improved diagnostic facilities (better reporting)	

Incidence

- Measure of new cases of disease
  – or other events (e.g. injury, death)
  In a specified time period
  In a defined group or population

– Cumulative incidence (risk)

– Incidence rate (Density)

cumulative incidence (risk)

- The **cumulative incidence (CI)** is a measure of the probability that a particular event (the development of a disease), will occur within a defined period in a specified population.
- Risk is defined as the number of new cases divided by the total population-at-risk at the beginning of the follow-up period (cumulative incidence).
- $Risk = \frac{\#new\ cases}{total\ \#\ of\ individuals\ at\ risk}$x10^n

cumulative incidence (risk)

- The denominator of "disease- free people" is the "population at risk"
- is a proportion
- the time period must be clearly stated (can be of any length→ several years, or even lifetime.
- Cumulative incidence may increase over a longer time period

Example Incidence:

- 10000 population.
- 50 have T1DM.
- Observed for 5 years.
- 10 cases occurred. Incidence??
- Incidence: 10000-50= 9950
- 10/9950= 0.001= 0.1%

- A person has a 25% risk of getting the disease within the next 10 years it does not mean that he/she will be 25% diseased.
- It means that among (1,000) people with same characteristics we expect about 250 to develop the disease.

Attack rate:

The **attack rate** is a type of **cumulative incidence**. It represents the proportion of individuals in a population who develop a disease over a specific period following exposure to a risk factor, such as during an outbreak.

$$\text{Attack Rate} = \frac{\text{Number of new cases in a specific period}}{\text{Population at risk at the start of the period}}$$

Secondary attack rate: Number of new cases of a disease among contacts divided by number of contacts. measures the spread of disease from primary cases to secondary cases within a specific group or setting, such as a household, school, or community.

$$\text{Secondary Attack Rate} = \frac{\text{Number of new cases among contacts}}{\text{Number of susceptible contacts exposed to primary case}} \times 100$$

Open and closed populations

- Cumulative incidence (or risk) require that all the population at risk are followed up to the end of the time period – also called a closed population or cohort
- But in a dynamic or open population, people enter and exit the population at risk at different points and therefore may have been followed up for different lengths of time

If we count all new cases of flu among students occurring from 1st September 2023 to 31st August 2024.
- Cumulative incidence: new cases of flu/ all students enrolled in September 2023
- Incidence rate: the denominator will differ because of:
Students who left university during the year
Students Who died
Students who had flu once and will not have it again during that period
Students who entered university later that year
We need to add up the period of time each individual was present in the population and was at risk of becoming a new case.----**person-time at risk**

Incidence rate = incidence density

- Measures the rapidity with which new cases are occurring in a population.
- A way of taking into account time in the study i.e. person- time at risk
- Unlike cumulative incidence, which considers new cases over a fixed period, incidence rate accounts for the exact time each individual is observed (useful when follow-up times vary).
- **The rate at which new cases of a disease arise**

Incidence rate = incidence density

$$\text{Incidence Rate (IR)} = \frac{\text{Number of new cases during the study period}}{\text{Total person−time at risk}}$$

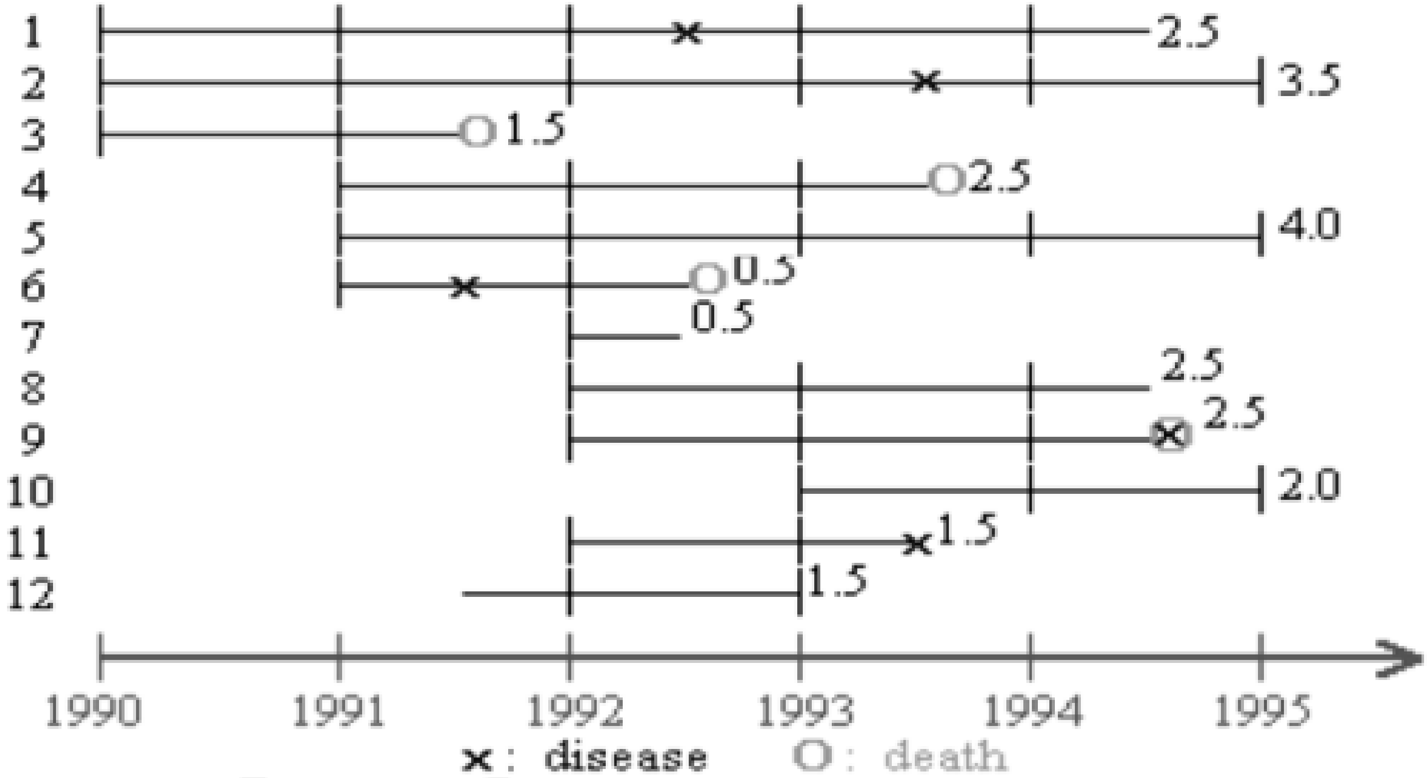
The sum of the time each individual was observed and at risk of developing the disease (measured in person-years, person-months, etc., depending on the study).

- **Example:**

A study tracking a disease in 100 people, with follow-up times that vary:

- 60 people are observed for 1 year, 30 people for 2 years, and 10 people for 3 years.
- The total person-time would be (60×1)+(30×2)+(10×3)=60+60+30=150 person-years.
- If there are 15 new cases during this period, the **incidence rate** would be:
- $\text{Incidence Rate (IR)} = \frac{\text{15 cases}}{150\, person\ years}$ = 0.1 cases per person-year

Hypothetical cohort of 12 initially disease-free subjects followed over a 5-year period from 1990 to 1995.



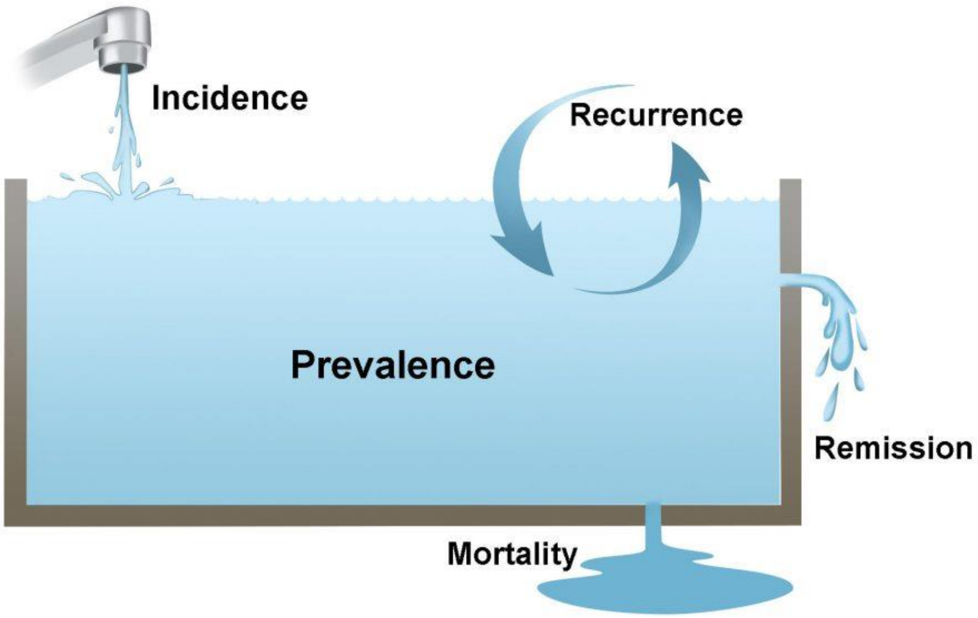
Calculate Incidence Rate?

Nominator: New cases: **5**

Denominator: Time person: 2.5+3.5+1.5+2.5+4+0.5+0.5+2.5+2.5+2+1.5+1.5= **25**

IR= 5/25= 0.20 (20 NEW CASES PER 100 PERSON YEARS).

Relationship Between Incidence and Prevalence



Incidence is **all new** cases of the disease.

They enter the prevalence bathtub.

If no cases leave the bathtub, it continues to Fill, adding to the number of cases **unless** some cases either **recover** or **die** **reducing the prevalence**.

- A study followed a population of 150 smoker persons for one year, and 25 had a lung cancer at the start of follow-up and another 15 new cases developed during the year.
- 1) What is the period prevalence for the year?
  - pp = (25+15)/150 = 0.27 or 27%
- 2) What is the point prevalence at the start of the period?
  - p = 25/150 = 0.17 = 17%
- 3) What is the cumulative incidence for the one year period?
  - CI = 15/125 = 0.12 = 12%

Uses of frequency measures

- Prevalence:

– Useful in health care settings e.g. estimate services required, study of the burden of chronic diseases and implication for health services

– Not used for investigating causal relationships

– Cannot distinguish between factors that cause disease and factors that cause the disease to persist in a population

– Cannot study cases that have got better or died

- May not require duration
- Unit of analysis is the person

P=I x D

- Incidence:

– Useful for investigating causal relationships (etiology)

–Useful in health care settings

- The main measure of acute diseases or conditions, but also used for chronic diseases
- Always Requires duration
- Unit of analysis is the event

Case fatality

- Case fatality is a measure of disease severity and is defined as the proportion of cases with a specified disease or condition who die within a specified time. It is usually expressed as a percentage.

$$\textbf{Case fatality \%} = \frac{\textbf{Number of deaths from diagnosed cases in a given period}}{\textbf{Number of diagnosed cases of the disease in the same period}} \textbf{x100}$$

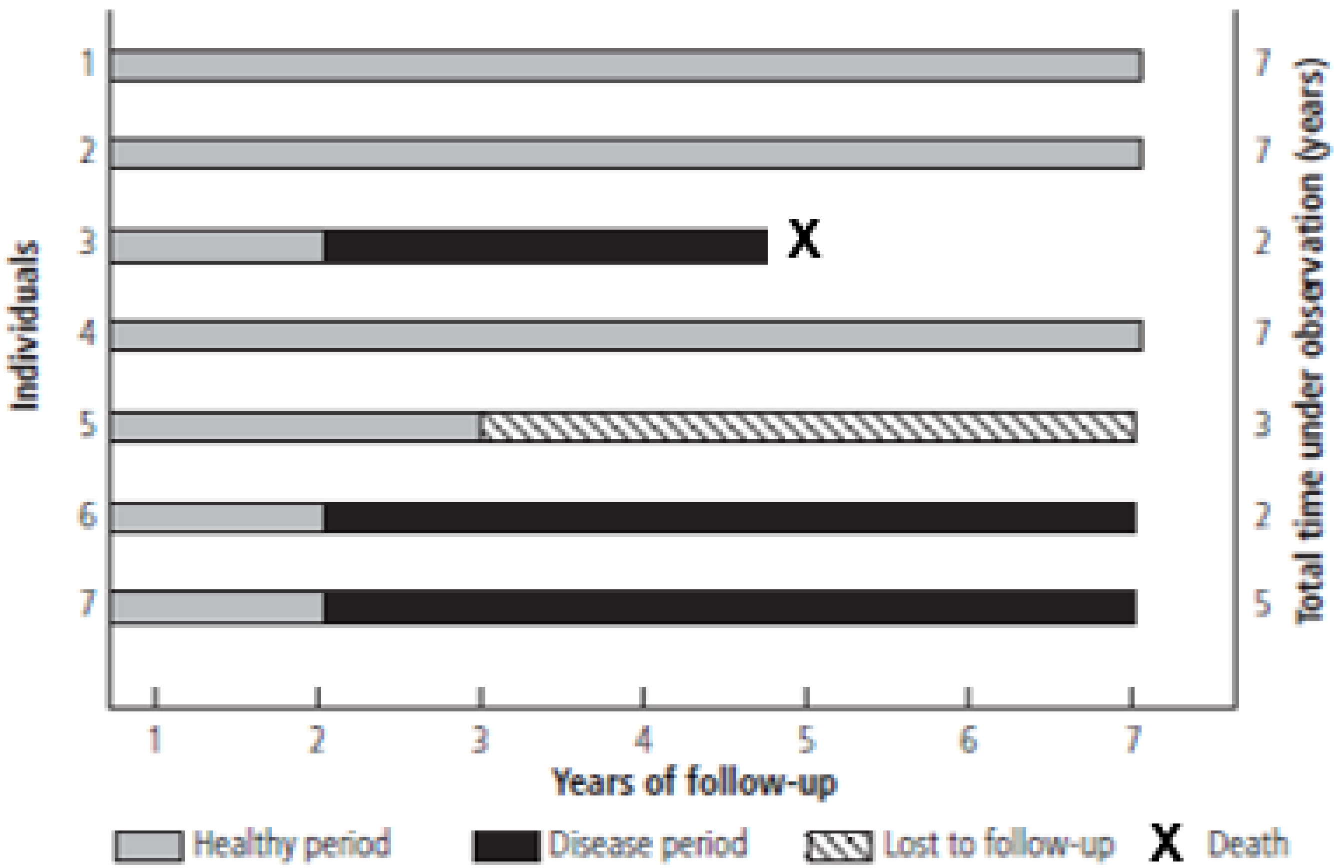
Case fatality rate :

❖ The case fatality rate is **used to link** mortality to morbidity.

❖ One function of the case fatality rate is to measure various aspects or properties of a disease such as its pathogenicity, severity or virulence .

It can also be used in poisonings, chemical exposures or other short-term non-disease cause of death.

Exercise:



Individuals
1
2
3
4
5
6
7
X
Total time under observation (years)
7
7
2
7
3
2
5
1
2
3
4
5
6
7
Years of follow-up
Healthy period
Disease period
Lost to follow-up
X Death

Calculate:

- The average duration of disease.
- The prevalence at the start of year 4,
- Case fatality
- The cumulative incidence
- Incidence rate of the disease.

- # Thank you