Epidemiology

Measures of Disease Occurrence and Association in Epidemiology

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The objectives

Define Key Measures

Students learn to define and differentiate disease measures.

Apply in Public Health

Students apply measures in public health research.

Real-World Application

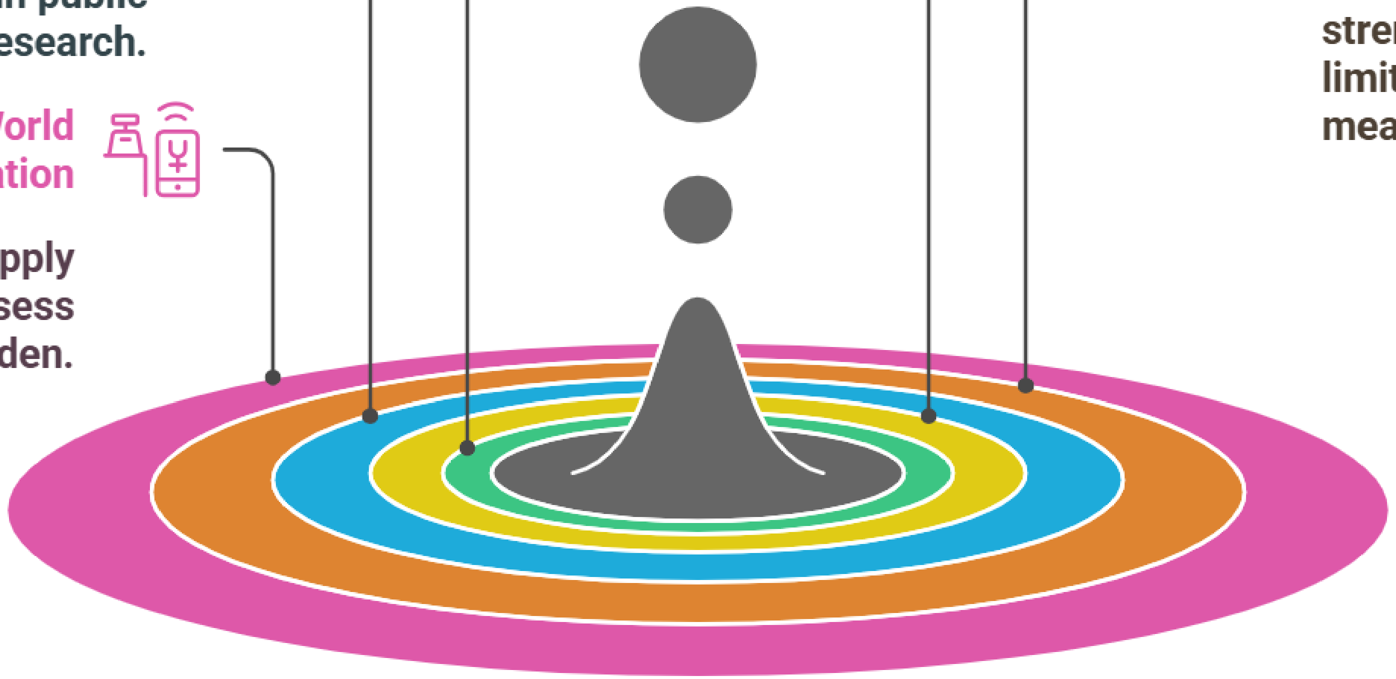
Students apply concepts to assess disease burden.

Calculate Disease Frequency

Students calculate and interpret disease frequency measures.

Recognize Strengths and Limitations

Students recognize strengths and limitations of measures.



Introduction

Determinants

Identifying factors that influence health outcomes.

Disease Occurrence Measures

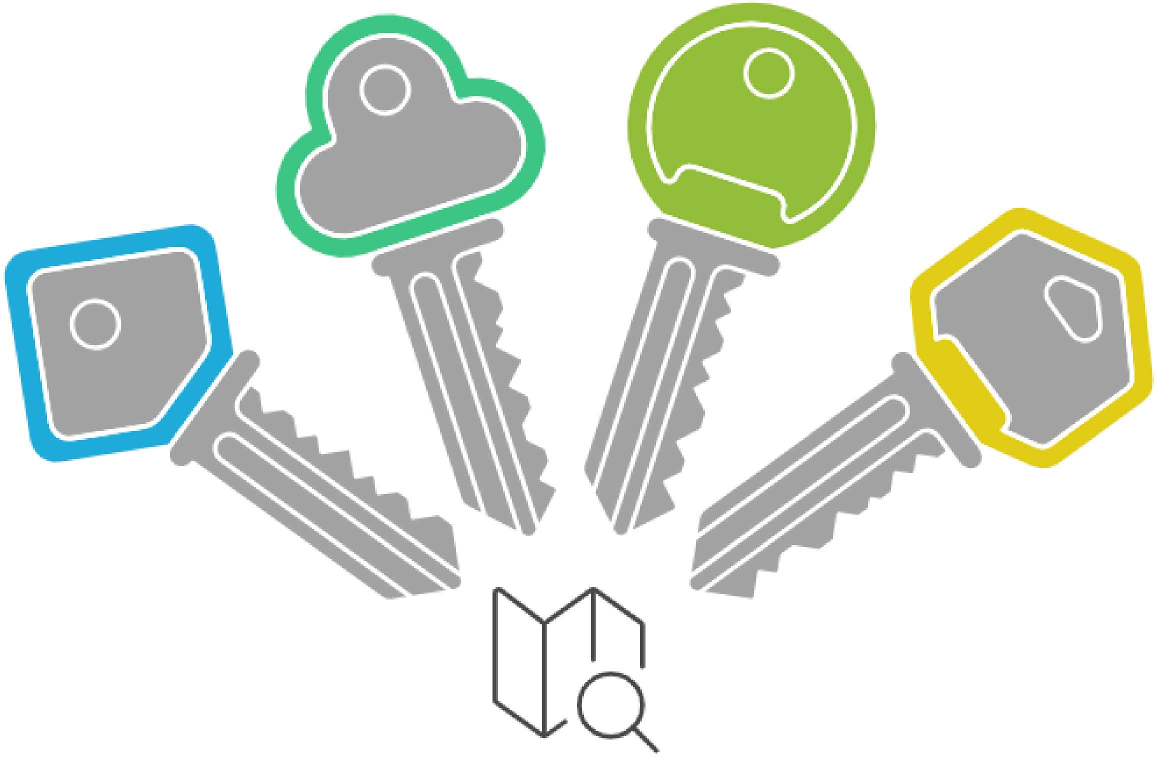
Quantifying how often diseases occur in populations.

Disease Distribution

Understanding how diseases spread across different populations.

Association Measures

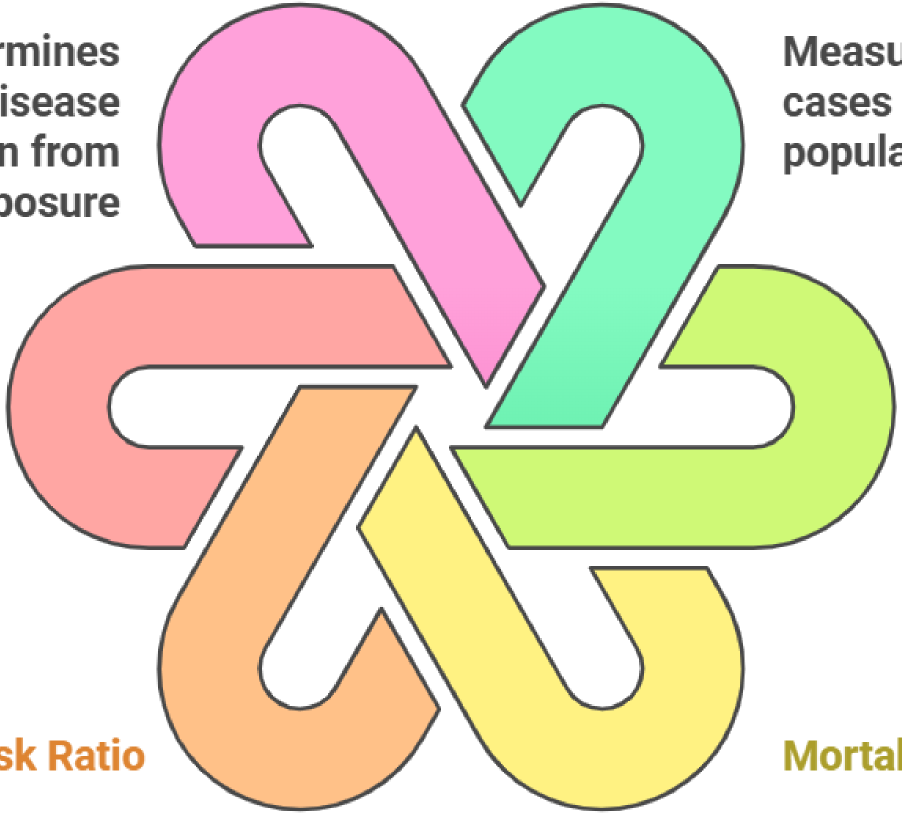
Analyzing the relationship between risk factors and health outcomes.



Epidemiology

Disease metrics

Understanding Disease Metrics



Attributable Risk

Determines disease proportion from exposure

Prevalence

Measures existing cases in a population

Odds Ratio

Evaluates odds in different groups

Incidence

Counts new cases over time

Risk Ratio

Compares disease risk between groups

Mortality Rates

Records deaths in a population

Disease metrics

1. Measures of Disease Occurrence

Measures of disease occurrence describe the frequency of disease in a population. They help us understand the burden of disease and identify trends over time or across populations.

A. Prevalence

Definition: The proportion of individuals in a population who have the disease at a specific point in time.

- Formula:

$$\text{Prevalence} = \frac{\text{Number of existing cases at a given time}}{\text{Total population at that time}} \times K$$

(where K is a constant, e.g., 1,000 or 100,000, for ease of interpretation)

- Types:
  - Point Prevalence: Prevalence at a specific point in time.
  - Period Prevalence: Prevalence over a defined period.
- Use: Useful for resource allocation and planning in public health.
- Limitation: Does not provide information about the risk of developing the disease.

Disease metrics

Problem 1: Prevalence

Scenario: In a town of 20,000 people, a health survey conducted on January 1st, 2023, found that 400 people had diabetes. Over the course of the year, 100 new cases of diabetes were diagnosed, and 50 people with diabetes died.

Questions:

1. Calculate the **point prevalence** of diabetes on January 1st, 2023.
2. Calculate the **period prevalence** of diabetes for the year 2023.

Solution:

1. **Point Prevalence:**

$$\text{Point Prevalence} = \frac{\text{Number of existing cases}}{\text{Total population}} \times K$$

$$\text{Point Prevalence} = \frac{400}{20,000} \times 1000 = 20 \text{ cases per 1,000 population}$$

2. **Period Prevalence:**

- Total cases during the year = Existing cases + New cases = 400 + 100 = 500.

$$\text{Period Prevalence} = \frac{\text{Total cases during the period}}{\text{Total population}} \times K$$

$$\text{Period Prevalence} = \frac{500}{20,000} \times 1000 = 25 \text{ cases per 1,000 population}$$

Disease metrics

B. Incidence

Definition: The number of new cases of a disease that occur in a population during a specified time period.

- **Types:**
  1. **Incidence Risk (Cumulative Incidence):**
     - Proportion of individuals who develop the disease during a specified period.
     - **Formula:**

$$\text{Incidence Risk} = \frac{\text{Number of new cases during a time period}}{\text{Population at risk at the start of the period}} \times K$$

  2. **Incidence Rate (Incidence Density):**
     - Rate at which new cases occur in a population, accounting for the time each person is observed.
     - **Formula:**

$$\text{Incidence Rate} = \frac{\text{Number of new cases during a time period}}{\text{Total person-time at risk}} \times K$$

Disease metrics

Problem 2: Incidence Risk (Cumulative Incidence)

Scenario: A study follows 1,000 healthy individuals for 5 years to determine the incidence of hypertension. By the end of the study, 150 individuals developed hypertension.

Question:

Calculate the **incidence risk** of hypertension over the 5-year period.

Solution:

$$\text{Incidence Risk} = \frac{\text{Number of new cases}}{\text{Population at risk at the start}} \times K$$

$$\text{Incidence Risk} = \frac{150}{1,000} \times 1000 = 150 \text{ cases per 1,000 population over 5 years}$$

Disease metrics

Problem 3: Incidence Rate (Incidence Density)

Scenario: A study follows 500 individuals for 2 years to track the development of asthma. During the study, 20 new cases of asthma are diagnosed. The total person-time observed is 900 person-years.

Question:

Calculate the **incidence rate** of asthma.

Solution:

$$\text{Incidence Rate} = \frac{\text{Number of new cases}}{\text{Total person-time at risk}} \times K$$

$$\text{Incidence Rate} = \frac{20}{900} \times 1000 = 22.2 \text{ cases per } 1{,}000 \text{ person-years}$$

Disease metrics

- Use: Helps identify risk factors and evaluate interventions.
- Limitation: Requires accurate follow-up of the population at risk.

C. Mortality Rates

- Definition: Measures the frequency of deaths in a population.
- Types:
  - Crude Mortality Rate: Total deaths in a population during a time period.
  - Cause-Specific Mortality Rate: Deaths due to a specific cause.
  - Case Fatality Rate: Proportion of individuals with a disease who die from it.
- Use: Important for understanding the severity of diseases and public health priorities.

Disease metrics

Problem 4: Mortality Rate

Scenario: In a population of 50,000 people, there were 200 deaths from all causes in a year. Of these, 50 deaths were due to cardiovascular disease (CVD).

Questions:

1. Calculate the **crude mortality rate**.
2. Calculate the **cause-specific mortality rate** for CVD.

Solution:

1. **Crude Mortality Rate:**

$$\text{Crude Mortality Rate} = \frac{\text{Total deaths}}{\text{Total population}} \times K$$

$$\text{Crude Mortality Rate} = \frac{200}{50,000} \times 1000 = 4 \text{ deaths per 1,000 population per year}$$

2. **Cause-Specific Mortality Rate for CVD:**

$$\text{Cause-Specific Mortality Rate} = \frac{\text{Deaths due to CVD}}{\text{Total population}} \times K$$

$$\text{Cause-Specific Mortality Rate} = \frac{50}{50,000} \times 1000 = 1 \text{ death per 1,000 population per}$$ year

Disease metrics

2. Measures of Association

Measures of association quantify the relationship between an exposure and a disease. They help us understand whether and to what extent a factor increases or decreases the risk of disease.

A. Risk Ratio (Relative Risk, RR)

- Definition: The ratio of the risk of disease in the exposed group to the risk in the unexposed group.
- Formula:

$$RR = \frac{\text{Risk in exposed group}}{\text{Risk in unexposed group}}$$

- Interpretation:
  - RR = 1: No association.
  - RR > 1: Positive association (exposure increases risk).
  - RR < 1: Negative association (exposure decreases risk).
- Use: Commonly used in cohort studies.

Disease metrics

Problem 5: Risk Ratio (Relative Risk, RR)

Scenario: A cohort study is conducted to investigate the association between smoking and the development of lung cancer. The study follows two groups of individuals over 10 years:

Group 1 (Smokers): 1,000 smokers.

Group 2 (Non-Smokers): 2,000 non-smokers.

By the end of the study, the following outcomes are observed:

Smokers: 100 cases of lung cancer.

Non-Smokers: 20 cases of lung cancer.

Questions:

1. Calculate the **risk of lung cancer** in smokers and non-smokers.
2. Calculate the **Risk Ratio (Relative Risk, RR)** for lung cancer among smokers compared to non-smokers.
3. Interpret the Risk Ratio in terms of the association between smoking and lung cancer.

Solution:

1. **Calculate the Risk of Lung Cancer:**
   - **Risk in Smokers:**

$$\text{Risk in Smokers} = \frac{\text{Number of lung cancer cases in smokers}}{\text{Total number of smokers}} = \frac{100}{1,000} = 0.10$$

Disease metrics

- **Risk in Non-Smokers:**

$$\text{Risk in Non-Smokers} = \frac{\text{Number of lung cancer cases in non-smokers}}{\text{Total number of non-smokers}} = \frac{20}{2,000} = 0.01$$

2. **Calculate the Risk Ratio (RR):**

$$\text{Risk Ratio (RR)} = \frac{\text{Risk in Smokers}}{\text{Risk in Non-Smokers}} = \frac{0.10}{0.01} = 10$$

3. **Interpret the Risk Ratio:**
   - The Risk Ratio (RR) of **10** indicates that smokers are **10 times more likely** to develop lung cancer compared to non-smokers.
   - This suggests a **strong positive association** between smoking and lung cancer.

Disease metrics

Summary of Results:

- **Risk in Smokers**: 10%.
- **Risk in Non-Smokers**: 1%.
- **Risk Ratio (RR)**: 10.

Interpretation in Public Health Context:

- The findings suggest that smoking is a significant risk factor for lung cancer.
- Public health interventions aimed at reducing smoking rates could substantially lower the incidence of lung cancer in the population.

Additional Notes:

- A Risk Ratio (RR) of 1 indicates no association between the exposure and the outcome.
- An RR > 1 suggests a positive association (increased risk).
- An RR < 1 suggests a negative association (protective effect).

Disease metrics

B. Odds Ratio (OR)

- Definition: The ratio of the odds of disease in the exposed group to the odds in the unexposed group.
- Formula: $$\text{OR} = \frac{\text{Odds of disease in exposed group}}{\text{Odds of disease in unexposed group}}$$
- Interpretation: Similar to RR
- Use: Commonly used in case-control studies.

B. Attributable Risk (AR)

- Definition: The difference in risk between the exposed and unexposed groups.
- Formula:

$$\text{AR} = \text{Risk in exposed group} - \text{Risk in unexposed group}$$

- Interpretation: The proportion of disease in the exposed group that can be attributed to the exposure.
- Use: Helps assess the public health impact of an exposure.

Disease metrics

Problem 6: Odds Ratio (OR)

Scenario: A case-control study is conducted to investigate the association between alcohol consumption and the risk of liver cirrhosis. The study includes:

Cases: 200 individuals diagnosed with liver cirrhosis.

Controls: 400 individuals without liver cirrhosis.

The exposure (alcohol consumption) is assessed in both groups, and the following data is obtained:

Cases (Liver Cirrhosis):

Exposed to alcohol: 120.

Not exposed to alcohol: 80.

Controls (No Liver Cirrhosis):

Exposed to alcohol: 100.

Not exposed to alcohol: 300.

Questions:

1. Construct a **2x2 table** to summarize the data.
2. Calculate the **Odds Ratio (OR)** for the association between alcohol consumption and liver cirrhosis.
3. Interpret the Odds Ratio in terms of the strength and direction of the association.

Disease metrics

Solution:

1. **Construct a 2×2 Table:**

	Exposed to Alcohol	Not Exposed to Alcohol	Total
Cases (Liver Cirrhosis)	120	80	200
Controls (No Liver Cirrhosis)	100	300	400
Total	220	380	600

Disease metrics

2. **Calculate the Odds Ratio (OR):**

- The formula for Odds Ratio is:

$$\text{OR} = \frac{\text{Odds of exposure in cases}}{\text{Odds of exposure in controls}}$$

- Calculate the odds of exposure in cases:

$$\text{Odds in Cases} = \frac{\text{Exposed Cases}}{\text{Unexposed Cases}} = \frac{120}{80} = 1.5$$

- Calculate the odds of exposure in controls:

$$\text{Odds in Controls} = \frac{\text{Exposed Controls}}{\text{Unexposed Controls}} = \frac{100}{300} = 0.333$$

- Calculate the Odds Ratio:

$$\text{OR} = \frac{1.5}{0.333} = 4.5$$

Disease metrics

3. **Interpret the Odds Ratio:**
   - The Odds Ratio (OR) of **4.5** indicates that individuals with liver cirrhosis are **4.5 times more likely** to have been exposed to alcohol compared to individuals without liver cirrhosis.
   - This suggests a **strong positive association** between alcohol consumption and liver cirrhosis.

Summary of Results:

- **Odds of Exposure in Cases:** 1.5.
- **Odds of Exposure in Controls:** 0.333.
- **Odds Ratio (OR):** 4.5.

Interpretation in Public Health Context:

- The findings suggest that alcohol consumption is a significant risk factor for liver cirrhosis.
- Public health interventions aimed at reducing alcohol consumption could help lower the incidence of liver cirrhosis in the population.

Additional Notes:

- An Odds Ratio (OR) of 1 indicates no association between the exposure and the outcome.
- An OR > 1 suggests a positive association (increased risk).
- An OR < 1 suggests a negative association (protective effect).

Disease metrics

Problem 7: Attributable Risk (AR)

Scenario: A cohort study is conducted to investigate the association between smoking and the risk of developing cardiovascular disease (CVD). The study follows two groups of individuals over 10 years:

- **Group 1 (Smokers)**: 2,000 smokers.
- **Group 2 (Non-Smokers)**: 3,000 non-smokers.

By the end of the study, the following outcomes are observed:

- **Smokers**: 200 cases of CVD.
- **Non-Smokers**: 90 cases of CVD.

Questions:

1. Calculate the **risk of CVD** in smokers and non-smokers.
2. Calculate the **Attributable Risk (AR)** for CVD among smokers compared to non-smokers.
3. Interpret the Attributable Risk in terms of the impact of smoking on CVD.

Disease metrics

Solution:

1. **Calculate the Risk of CVD:**
   - **Risk in Smokers:**

$$\text{Risk in Smokers} = \frac{\text{Number of CVD cases in smokers}}{\text{Total number of smokers}} = \frac{200}{2,000} = 0.10$$

   - **Risk in Non-Smokers:**

$$\text{Risk in Non-Smokers} = \frac{\text{Number of CVD cases in non-smokers}}{\text{Total number of non-smokers}} = \frac{90}{3,000} = 0.03$$

2. **Calculate the Attributable Risk (AR):**
   - The formula for Attributable Risk is:

$$\text{AR} = \text{Risk in Exposed Group} - \text{Risk in Unexposed Group}$$

   - Substituting the values:

$$\text{AR} = 0.10 - 0.03 = 0.07$$

Disease metrics

Interpret the Attributable Risk:

1. The Attributable Risk (AR) of **7%** indicates that **7% of the CVD cases among smokers can be attributed to smoking**.
2. In other words, if smoking were eliminated, the risk of CVD among smokers would decrease by 7 percentage points (from 10% to 3%).

Summary of Results:

- Risk in Smokers: 10%.
- Risk in Non-Smokers: 3%.
- Attributable Risk (AR): 7%.

Interpretation in Public Health Context:

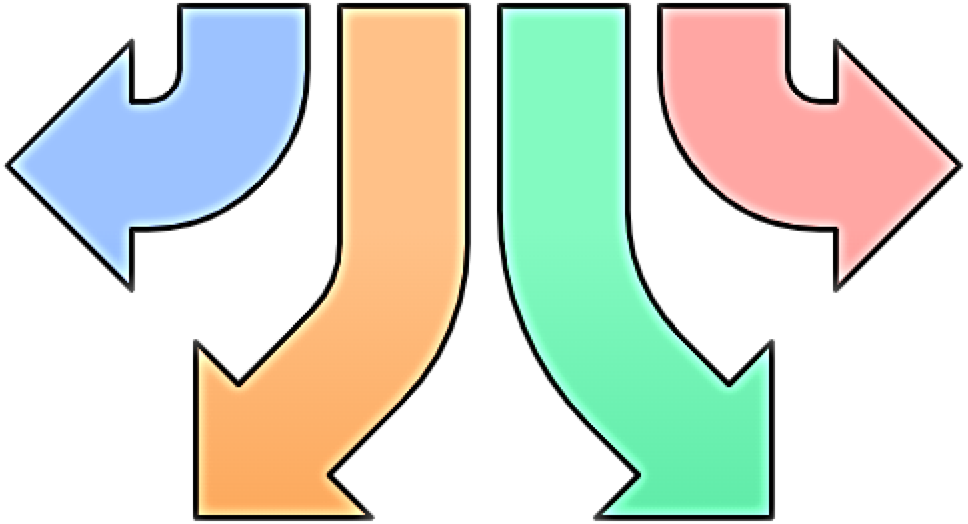
- The findings suggest that smoking is a significant contributor to the development of CVD.
- Public health interventions aimed at reducing smoking rates could prevent a substantial proportion of CVD cases in the population.

Additional Notes:

- Attributable Risk (AR) quantifies the excess risk of disease in the exposed group that can be attributed to the exposure.
- AR is useful for assessing the public health impact of an exposure and guiding interventions.

Applications in Public Health

Which epidemiological measure should be used for specific health scenarios?



Prevalence

Estimate the burden of chronic diseases like diabetes or hypertension.

Incidence

Track outbreaks of infectious diseases like COVID-19.

Risk/Odds Ratio

Evaluate intervention effectiveness or risk factor impact (e.g., smoking and lung cancer).

Attributable Risk

Guide public health policies by identifying preventable disease causes.

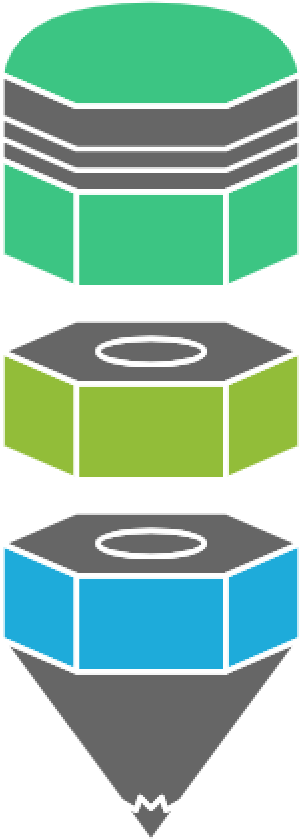
Strengths and Limitations

Which epidemiological measure should be used for analysis?

- **Prevalence**: Easy to measure but not causal
- **Incidence**: Insight into risk but requires longitudinal data
- **Risk/Odds Ratio**: Powerful for causal inference but confounded
- **Attributable Risk**: Highlights preventable cases but assumes causality

Conclusion

Key Components of Epidemiology



Measures of Disease Occurrence

Quantifies disease burden

Measures of Association

Identifies risk factors

Public Health Applications

Evaluates interventions

Comprehensive Questions

Definitions and Concepts

1. Define prevalence and incidence. How do they differ in terms of what they measure?
2. Explain the difference between point prevalence and period prevalence. Provide an example of when each might be used.
3. What is the difference between incidence risk (cumulative incidence) and incidence rate (incidence density)? When would you use each measure?

Calculations

1. In a population of 10,000 people, 500 have diabetes on January 1st. By December 31st, 200 new cases of diabetes are diagnosed. Calculate the point prevalence on January 1st and the incidence risk for the year.
2. A study follows 1,000 individuals for 5 years. During this period, 50 develop the disease. Calculate the incidence rate, assuming no loss to follow-up.

Interpretation and Application

1. Why is prevalence more useful for chronic diseases like arthritis, while incidence is more useful for infectious diseases like influenza?
2. A country reports a high prevalence of malaria but a low incidence. What could explain this pattern?
3. How might changes in diagnostic techniques affect the prevalence and incidence of a disease?

Mortality Rates

1. Define case fatality rate (CFR). How is it different from cause-specific mortality rate?
2. In a population of 100,000, there are 200 deaths from lung cancer in a year. Calculate the cause-specific mortality rate for lung cancer.

Comprehensive Questions

Definitions and Concepts

1. Define risk ratio (RR) and odds ratio (OR). What is the key difference between them?
2. When would you use a risk ratio instead of an odds ratio? Provide an example.
3. What does an attributable risk (AR) measure, and how is it useful in public health?

Calculations

1. In a cohort study, 100 out of 1,000 smokers develop lung cancer, while 20 out of 2,000 non-smokers develop lung cancer. Calculate the risk ratio and interpret the result.
2. In a case-control study, 80 out of 100 cases were exposed to a risk factor, while 40 out of 200 controls were exposed. Calculate the odds ratio and interpret the result.
3. Using the same data from the cohort study above, calculate the attributable risk and interpret its public health significance.

Interpretation and Application

1. A study finds that the risk ratio for developing heart disease among smokers is 2.5. What does this mean in terms of the association between smoking and heart disease?
2. If the odds ratio for a disease is 0.5, what does this suggest about the exposure and the disease?
3. How can attributable risk help policymakers decide which public health interventions to prioritize?

Comprehensive Questions

Real-World Applications

1. A public health official wants to determine whether a new vaccine is effective. Which measure of disease occurrence would you recommend they use, and why?
2. How would you use measures of association to evaluate the impact of a smoking cessation program on lung cancer rates?

Strengths and Limitations

1. What are the strengths and limitations of using prevalence as a measure of disease burden?
2. Why might an odds ratio overestimate the risk ratio in a study with a high prevalence of the outcome?
3. Discuss the limitations of attributable risk in determining causality.

Scenario-Based Questions

1. In a population of 50,000, the prevalence of hypertension is 20%. A new screening program identifies an additional 1,000 cases. How does this affect the prevalence and incidence of hypertension?
2. A study finds that the risk ratio for obesity and type 2 diabetes is 3.0, while the attributable risk is 15%. Explain what these results mean for public health interventions targeting obesity.

Comprehensive Questions

Epidemiological Study Design

1. How would you design a study to measure the incidence of a rare disease? Which measure of association would be most appropriate, and why?
2. In a case-control study, why is it not possible to calculate incidence risk or risk ratio directly?

Confounding and Bias

1. How might confounding affect the interpretation of a risk ratio or odds ratio? Provide an example.
2. A study finds a strong association between coffee consumption and lung cancer, but it does not adjust for smoking. What potential issue does this raise, and how could it be addressed?

Public Health Policy

1. If the attributable risk of lung cancer due to smoking is 80%, what does this imply for public health policies aimed at reducing smoking rates?
2. How would you explain the concept of population attributable risk to a policymaker, and why is it important?


THANK YOU!