MEASURES OF DISEASE FREQUENCY

Infectious Disease Epidemiology Bootcamp
Session 3
July 21, 2020
Meghan Warren, PT, MPH, PhD
Infectious Disease Epidemiology Bootcamp Objectives

1. Explain the basics of infectious disease epidemiology, including transmission and conceptual model.
2. Evaluate infectious disease measures (e.g., R-naught, case fatality, incidence)
3. Explain the importance of controlling infectious disease spread through quarantine, vaccination, and other treatment measures
4. Describe the process of testing, case investigation, and contact tracing for infectious diseases
5. Compare sensitivity, specificity, and positive and negative predictive value of screening tests
6. Understand the concepts of database construction and data entry for quality data reporting
7. Interpret data tables and charts related to infectious disease measures

https://nau.edu/sherc/sherc-epidemiology-bootcamp/
**Remember to join us for the last bootcamp!**

- Tuesday, July 28 at 11:30 PDT – Getting the Most Out of Your Data
  - Data interpretation
  - Data visualization
IF YOU HAVE QUESTIONS

• Use the chat function
  – *We want to hear from you 😊*

• Questions will be answered at the end during a discussion period in the order they come in
OBJECTIVES

1. Review math terms associated with measures of disease frequency
2. Define and interpret prevalence, incidence, and incidence rate
3. Explain the relationship between prevalence and incidence
4. Explain and interpret
   1. Mortality
   2. Case fatality
   3. Percent positivity
What we will not cover

- Risk
  - “the probability of an event during a specified period of time”
  - Who is at increased/decreased risk of COVID over time?
Epidemiology

- Epi: on or upon
- Demos: people
- Logos: the study of

- Study of what befalls a population

“Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems.” p.61 (Last JM. Dictionary of Epidemiology, 4th ed. New York: Oxford University Press; 2001.)
DESCRIPTIVE EPIDEMIOLOGY

Figure 1.11 Mortality Rates for Asbestos, by State — United States, 1968-1981 and 1982-2000

Figure 1.15 Infant Mortality Rates for 2002, by Race and Ethnicity of Mother

Figure 1.4 Reported Cases of Salmonellosis per 100,000 Population, by Year — United States, 1972–2002
BOX IT IN! – DISEASE CONTROL

1. Test Widely
2. Isolate All infected people
3. Find Everyone who has been in contact with infected people
4. Quarantine All contacts self-isolate for 14 days

To get us all working again

OUTBREAK INVESTIGATION

• Who has it, why they have it, and what can be done about it

Identify the source of the outbreak

Monitor and track the disease

Study the disease

Develop interventions to slow disease spread & lessen impact

https://www.who.int/news-room/detail/29-06-2020-covidtimeline
Outbreak Investigation: Reality

- Who has it, why they have it, and what can be done about it

Identify the source of the outbreak

Monitor and track the disease

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MEASURES OF DISEASE FREQUENCY
Coronavirus lockdown

Face mask shortage

COVID-19: WHEN WILL THE OUTBREAK END?

Seniors at risk

Coronavirus death toll tops 200,000

Arizona reports record-high number of new COVID-19 cases, hospitalizations

ICU beds in use, ventilators in use and emergency department visits for COVID-19 all reached record levels Monday as well.

U.S. DEATHS NEAR 100,000, AN INCALCULABLE LOSS
**STATE OUTPACES THE BAY AREA**
California had a higher rate of coronavirus cases and deaths than the nine counties in the Bay Area and Santa Cruz County compared to a month ago.

- Total cases: 41,235 (increase of 1,450%)
- Total deaths: 1,612 (increase of 3,006%)

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**Study: Elderly Most At Risk From The Coronavirus**
COVID-19 fatality rate by age (as of February 11, 2020)

- 10-19: 0.2%
- 20-29: 0.2%
- 30-39: 0.2%
- 40-49: 0.4%
- 50-59: 1.3%
- 60-69: 3.6%
- 70-79: 8.0%
- 80+: 14.9%

Note: As of 5 p.m., Thursday.
Source: County Health departments

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**By age group, Hubei, Jan-Feb 2020, %**

- 0-9: 0%
- 10-19: 5%
- 20-29: 0%
- 30-39: 5%
- 40-49: 0%
- 50-59: 5%
- 60-69: 0%
- 70-79: 0%
- 80+: 8%

Source: WHO; Adjusted age-specific case fatality ratio during the COVID-19 epidemic in Hubei, China, January and February 2020 by J. Reu et al.

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**The Economist**
• Numerator = top number
• Denominator = bottom number
Ratios → Proportions & Rates

• Ratio: dividing one number by another
  – Does not imply a relationship between the numerator and denominator
  – Example: body mass index (BMI) = weight/height

• Proportion: relates to parts of a whole
  – Often expressed as a percentage
  – Example: 20 cases of the flu in a nursing home of 130 residents
    • 20 cases/130 people = the prevalence of flu in the nursing home is 15%

• Rate: denominator takes into account another dimension
  – Often time
  – Example
    1. Motor vehicle deaths per vehicle-miles
    2. Number of sports injuries per athlete exposures
<table>
<thead>
<tr>
<th>State</th>
<th>Number of cases of COVID (as of July 12) Since 1/21/20</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>320,804</td>
</tr>
<tr>
<td>Arizona</td>
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What is a count good for?
- Identify when there is excess disease
- Identifying distribution of disease
  - Person, place, time
- Resource allocation
  - How many case investigators and contact tracers need to be hired?
  
  [https://preventepidemics.org/covid19/resources/contact-tracing-staffing-calculator/](https://preventepidemics.org/covid19/resources/contact-tracing-staffing-calculator/)

- When the population is stable
- When no comparison is required

Coconino County cases per day, as of July 12

What is a count good for?
- Identify when there is excess disease
- Identifying distribution of disease
  - Person, place, time
- Resource allocation
  - How many case investigators and contact tracers need to be hired?
  https://preventepidemics.org/covid19/resources/contact-tracing-staffing-calculator/
- When the population is stable
- When no comparison is required

What are limitations of a count?
- Comparing different populations
Prevalence

- Proportion of the population that has disease at a particular time
- Overall burden of disease in a population

Prevalence (a proportion)

\[
\text{Prevalence} = \frac{\text{People with disease at a point in time}}{\text{Total People in the study population}}
\]

- Often expressed per 1,000 (or 10,000 or 100,000) people

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https://www.cdc.gov/covid-data-tracker/#cases
INCIDENCE

• Occurrence of **new** cases during a period of time

1. Incidence proportion (cumulative incidence): probability of developing disease over a stated period of time
   - **Estimate of risk**
   - **Must specify a time period**

Cumulative Incidence (a proportion)

\[ \text{Cumulative Incidence} = \frac{\text{People} \times \text{# new cases in a specified period}}{\text{Total People} \times \text{People (at risk) in the study population}} \]
## Incidence of COVID

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**** = caution

**Cumulative Incidence** (a proportion)

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[https://www.cdc.gov/covid-data-tracker/#cases](https://www.cdc.gov/covid-data-tracker/#cases)
**Population at Risk Example**

- Nursing home with 800 residents
- Blood tests for diabetes
  - Fasting glucose
  - A1C

- 50 residents had diabetes

- Prevalence = 50/800
  = 0.63
  = 63/100 people
  = 6.3%

- Incidence of diabetes in the residents over 12 months
  - Going to assume no one moves away or dies in a year

- 25 residents are diagnosed with diabetes in 12 months

- Incidence = 25/750
  = 0.33
  = 33/100 people
  = 3.3%
## Incidence

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**Cumulative Incidence** (a proportion)

\[
\text{Incidence} = \frac{\text{People}}{\text{Total People}} \times \frac{\# \text{new cases in a specified period}}{\# \text{People (at risk) in the study population}}
\]

***** = need population at risk

[https://www.cdc.gov/covid-data-tracker/#cases](https://www.cdc.gov/covid-data-tracker/#cases)
Count

New cases over 7 days

Total Number of COVID-19 Cases in the US Reported to the CDC, by State/Territory

US COVID-19 Cases Reported to the CDC in the Last 7 Days, by State/Territory

https://www.cdc.gov/covid-data-tracker/#cases
INCIDENCE

- Occurrence of **new** cases during a period of time

1. Incidence proportion (cumulative incidence): probability of developing disease over a stated period of time
   - Estimate of risk
   - Must specify a time period

2. Incidence rate: number of new cases per unit of time

**Cumulative Incidence** (a proportion)

\[ \text{Cumulative Incidence} = \frac{\text{People} \ # \text{new cases in a specified period}}{\text{Total People} \ # \text{People (at risk) in the study population}} \]

**Incidence Rate** (a rate)

\[ \text{Incidence Rate} = \frac{\text{number of new cases of disease}}{\text{person-time at risk}} \]
**Incidence rate (AND incidence density)**

- In studies or communities, people are often followed for different lengths of time
  - Move away
  - Move away and then come back
  - Drop out
  - Death
  - Births

- Good when there are dynamic populations
  - Or long follow-up times

\[
\text{Incidence Rate} \ (a \ rate) = \frac{\text{number of new cases of disease}}{\text{person-time at risk}}
\]
# HIV in a Brothel: 15 Women Tested; 5 Had HIV

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- Cumulative incidence over 6 years = 4/10 = 0.4 = 4 cases per 10 people = 40%

HIV IN A BROTHEL: 15 WOMEN TESTED; 5 HAD HIV

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</table>

- Incidence rate = 4 cases of HIV/26 person-years = 0.15 = 15/100 person-years
Interrelationship between prevalence and incidence

- Prevalence depends on:
  - New disease during a time period (incidence)
  - Duration of disease

- Incidence is low, but those with it have it for a long time → prevalence high relative to incidence
  - Type 2 diabetes

- Incidence is high, but duration is short → prevalence will be low relative to incidence
  - Chicken pox

A full understanding of COVID is still evolving
**CATEGORY-SPECIFIC MEASURES**

- Categories can be anything (e.g., sex, geographic areas)

**Age and Race/Ethnicity of COVID in Navajo county**

Population = 110,924

Prevalence = 3,860.0/100,000 population

<table>
<thead>
<tr>
<th>Age groups</th>
<th>Number of cases</th>
<th>Population estimates**</th>
<th>Prevalence per 100,000 population</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20 y/o</td>
<td>644</td>
<td>29,173</td>
<td>2,207.5</td>
</tr>
<tr>
<td>20 – 64 y/o</td>
<td>3,151</td>
<td>60,897</td>
<td>5,174.3</td>
</tr>
<tr>
<td>&gt; 64 y/o</td>
<td>549</td>
<td>20,854</td>
<td>2,632.6</td>
</tr>
</tbody>
</table>

Population estimates from https://www.census.gov/quickfacts/navajocountyarizona

MEASURES OF MORTALITY
## MORTALITY ‘RATES’

1. **Mortality**  
   - Overall burden of death

   
   \[
   \text{Mortality Rate} = \frac{\text{# of deaths}}{\text{Population size}}
   \]

   - Typically expressed per 1,000 or 100,000 people
   - Or percent

2. **Case fatality**  
   - Measure of disease severity

   \[
   \text{Case Fatality Rate} = \frac{\text{# of deaths from a specific disease}}{\text{# of people with the disease}}
   \]

   - Typically expressed as a percent
MORTALITY VS. CASE FATALITY RATE

Mortality Rate vs Case Fatality Rate

Mortality Rate = \frac{1 \text{ Deceased}}{100 \text{ People}} = 1\%  

Case Fatality Rate = \frac{1 \text{ Deceased}}{20 \text{ People}} = 5\%  

Graphic courtesy of SAS.

https://newslit.org/updates/case-fatality-rate-vs-mortality-rate/
AZ MORTALITY ‘RATES’

- Population of Arizona = 7,171,459
- Number of COVID cases = 123,824
- Number of COVID deaths = 2,245

- Mortality ‘rate’ = 2,245/7,171,459
  = 0.000313
  = 31.3/100,000

- Case fatality ‘rate’ = 2,245/123,854
  = 0.01812
  = 1.8%

As of July 12, 2020
A CHANGING PANDEMIC

- Since December 2019, case fatality
  - 15%, but in patients who were hospitalized
  - 4.3 – 11.0%, but this was early (China)
  - 0.4% in February (worldwide)
  - 0.99% on Diamond Princess cruise ship


- Case fatality estimated between 0.06% and 18.94%

HOW DOES IT COMPARE?

• Compared to other viral disease
  
  – severe seasonal influenza and 1957 and 1968 influenza (case fatality < 0.1%)
  
  – SARS (2002-3; 9% – 10%) and MERS (2012 – present; 36%)

PERCENT POSITIVE
### Percent Positivity

- **Percentage of tests that were positive**
  
  \[
  \frac{\text{# of positive tests}}{\text{# of completed tests}}
  \]

- Sometimes referred to as positivity rate
  - **But it is not actually a rate**

- Indicator into whether a community is conducting enough testing to find cases
  - **High:** may largely be testing the sickest patients and possibly missing milder or asymptomatic cases
    - Not casting a wide enough net
  - **Low:** including patients with milder or no symptoms
    - Sufficient testing capacity for the size of the outbreak
WHAT IS HIGH PERCENT POSITIVITY?

WHAT IS LOW PERCENT POSITIVITY?
### Percent Positivity for Epidemic Control

<table>
<thead>
<tr>
<th>Epidemiological criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decline of at least 50% of a 3-week period since the latest person and continuous decline in incidences of confirmed and probable cases</td>
</tr>
<tr>
<td><strong>Less than 5% of samples positive for COVID-19, at least for the last 2 weeks (assuming that surveillance for suspected cases is comprehensive)</strong></td>
</tr>
<tr>
<td>At least 80% of cases are from contact list and can be linked to known clusters</td>
</tr>
<tr>
<td>Decline in the number of deaths among confirmed and probable cases at least for the last 3 weeks</td>
</tr>
<tr>
<td>Continuous decline in the number of hospitalizations and ICU admissions of confirmed and probable cases at least for the last 2 weeks</td>
</tr>
<tr>
<td>Among others….</td>
</tr>
</tbody>
</table>

Case positivity comparison

Arizona

Michigan

https://coronavirus.jhu.edu/testing
<table>
<thead>
<tr>
<th>Frequency measure</th>
<th>Numerator</th>
<th>Denominator</th>
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<tbody>
<tr>
<td>Prevalence</td>
<td>Number of people with COVID</td>
<td>Number of people in the population</td>
</tr>
<tr>
<td>Incidence</td>
<td>Number of new cases with COVID</td>
<td>Number of people at risk for COVID</td>
</tr>
<tr>
<td>Incidence rate (density)</td>
<td>Number of new cases with COVID</td>
<td>Follow-up (person-time) or other exposure</td>
</tr>
<tr>
<td>Mortality</td>
<td>Number of people who died from COVID</td>
<td>Number of people in the population</td>
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<tr>
<td>Case fatality</td>
<td>Number of people who died from COVID</td>
<td>Number of people with COVID</td>
</tr>
<tr>
<td>Percent positivity</td>
<td>Number of people with a positive COVID test</td>
<td>Number of people who were tested for COVID</td>
</tr>
</tbody>
</table>

Remember to look at the time period being reported
1. Number of people with COVID (Prevalence, incidence, incidence rate, case fatality, percent positivity)
   - Probably an underestimate
     • Testing capacity/availability
     • Testing policies
     • Asymptomatic people
   - Accuracy of the tests
   - Case definition of ‘with COVID’
     • Confirmed case
     • Probable case
2. Number of people who died from COVID (Mortality and case fatality)
   • Competing conditions
   • Death certificate availability/accuracy
3. Number of people with a positive COVID test (Percent positivity)
   - Accuracy of the tests

But all of these are estimates!
But all of these are estimates!

- Number of people in the population (Prevalence and mortality)
  - May be OK, except for dynamic population
    - # of people in Flagstaff in Feb 2020 vs. July 2020
  - Census population
- Number of people at risk for COVID (Incidence)
  - Who is ‘at risk?’
    - Current disease
    - Immunity after disease
    - Deaths and births
- Number of people tested for COVID
  - Traveling
Future?

- Much has to be done to better understand the epidemiology and science of COVID-19
  - But that does not mean that interventions should not be implemented and continued!!

Identify the source of the outbreak

Monitor and track the disease

Study the disease

Develop interventions to slow disease spread & lessen impact

"I'm actually of the mind right now, I think this [COVID-19] is more like a forest fire. I don't think that this is going to slow down. I'm not sure that the influenza analogy applies anymore. I think that wherever there is wood to burn, this fire is going to burn. And right now we have a lot of susceptible people.” – M. Osterholm, 6/21/20
• Many in slide citations


OBJECTIVES

1. Review terms associated with measures of disease frequency
2. Define and interpret prevalence, incidence, and incidence rate
3. Explain the relationship between prevalence and incidence
4. Explain and interpret
   1. Mortality
   2. Case fatality
   3. Percent positivity
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Thank You!

Questions?

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CASE DEFINITION: CONFIRMED VS. PROBABLE CASES

Confirmed case

- Person who had a confirmatory viral test performed
  - Positive for SARS-CoV-2, which is the virus that causes COVID-19

Probable case

- Meet clinical criteria AND epidemiological evidence
  - NO confirmatory laboratory testing performed
- Meet presumptive laboratory evidence, AND either clinical criteria OR epidemiological evidence
- Vital records criteria
  - No confirmatory laboratory testing performed for COVID-1