Measurements of Morbidity and Mortality

By

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Post midterm

- Week 8  Unit 6: Demography and Data
- Week 9  Midterm assessment (Exams.) 15-11-2017
- Week 10 Unit 8  Introduction to Epidemiology.
- Week 11 Unit 9:  Causation, Prevention and Control of Diseases
- Week 12 Unit 10:  Health Education and Communication
- Week 13 Unit 11:  Public Health Surveillance and Screening
- Week 14 Unit 12:  Health Administration and healthcare management
- Week 15 Unit 13:  Revision and Health Research
- Week 16  Final assessment (Exams.)
اليوم يحتفل العالم بذكرى ميلاد بطل من أبطال العلم وهو (يوناس سولك) مخترع اللقاح الذي قضى على شلل الأطفال والذي رفض تسجيل براءة اختراعه حتى يصبح اللقاح في متناول الجميع و خسر أرباح تقدر بحوالي 7 مليار دولار.

يستحق لقب كبار العلماء

28 أكتوبر 1914
TRAVELING HOME FOR THE HOLIDAYS?
Blood clots are a serious risk for long-distance travelers.
Remember to do the following whether you are on a plane, train, bus, or car!

1. Move your legs frequently and walk around every 2-3 hours to avoid developing a blood clot. If you are traveling on the road take advantage of every rest stop to get up and stretch!

2. Know the symptoms of blood clots and when to get help.

3. If you are at risk for blood clots, talk with your doctor to learn more about how to prevent them.

Learn more about blood clots by visiting www.cdc.gov/ncbddd/dvt/travel.html
• **Introduction to Epidemiology.**
  Definition, History of Epidemiology Purpose/Use of Epidemiology
  Concepts in the infectious diseases

• **Measurements of Morbidity and Mortality**
## Presentation outline

<table>
<thead>
<tr>
<th>Measures of Population Health, Rationale for summary measures</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEFINITIONS of Population, Count, Proportion, Ratio And Rate</td>
<td>08:00 to 08:15</td>
</tr>
<tr>
<td>Morbidity Measurements</td>
<td>08:15 to 08:30</td>
</tr>
<tr>
<td>Mortality Measurements</td>
<td>08:30 to 08:45</td>
</tr>
<tr>
<td></td>
<td>08:45 to 09:00</td>
</tr>
<tr>
<td></td>
<td>09:00 to 09:15</td>
</tr>
</tbody>
</table>
INTRODUCTION

• Epidemiology is a quantitative discipline – this lecture defines several of the more common measures of disease frequency employed.

Morbidity and mortality must be measured as accurately as possible:

it forms the foundation for identifying disease etiology, allows epidemiologists to monitor trends, and evaluates public health interventions.
Why do we need measures of population health?

• We wish to monitor health of citizens ...
  – To set priorities for health services & policies
  – To evaluate social and health policies
  – To compare health of different regions
  – To identify pressing health needs
  – To draw attention to inequalities in health
  – Highlight balance between length and quality of life
  – Numerical index desirable: a “GNP of Health”
• Decision making in public health requires evidence (data)
• Summarizing data as ratios, proportions, and rates
• Commonly used rates
• Concept of person-time
• Assessing change in rates
Classifying Population Health Measures by their Purpose

1. **Descriptive measures:**
   i. Current health status (e.g., health surveys)
   ii. *Evaluative* measures (e.g., to assess outcomes of health policies)

2. **Analytic measures** include an implicit time dimension:
   iii. *Predictive* methods (risk assessment; projections of disease burden) look forward;
   iv. *Explanatory* measures (income inequality or social cohesion) look backwards.
Some Introductory Definitions:

– **Burden:**
  • The *amount/frequency of an event or disease* in a population; generally referring to existing events/disease in a defined population at a point in time
  • *Estimated by Prevalence measures.*

– **Risk:**
  • Most simply defined as the *probability* (likelihood/chance) of developing an outcome of interest (event or disease) over a specified amount of time
  • Risk is always expressed as the *proportion of new events* occurring over a *specified time period* in a *defined population at risk* for acquiring the event.

  *Risk* is estimated by *Incidence*, calculated as either a Rate or a Proportion
Population

Population:
Definition: A collection of individuals (usually people) sharing a specified characteristic or set of characteristics (usually includes specification of time and geography)
  – Example: All people living in the Amman area on Jan. 1, 2006

• **Population At-Risk:** a specified population of individuals capable of acquiring the condition or event of interest.

• **Sample (estimation)**
  • Because we can never adequately observe all (or all possible) members of a population, we select a sample (smaller group) of individuals from the population to “represent” the population and the characteristics and experiences of that population.

A population can be defined as including all people or items with the characteristic one wishes to understand.

Because there is very rarely enough time or money to gather information from everyone or everything in a population, the goal becomes finding a representative sample (or subset) of that population.
Mathematical Aspects of Epidemiologic Measures:

- **COUNTING** (accurately, precisely, and reliably)
- **NUMERATOR** (those with existing or new condition, i.e. “cases”)
- **DENOMINATOR** (population in which existing or new condition is counted)
- **ESTIMATION** (all measures done in samples are used to estimate some “true” characteristic of the population)
DEFINITIONS OF COUNT, PROPORTION, RATIO AND RATE

• **COUNT**
  • merely refers to the number of cases of a disease or other health phenomenon
  • *not* very important in and of itself – analogous to case-study
  • importance of the number is dependent upon disease being studied/evaluated
DEFINITIONS OF COUNT, PROPORTION, RATIO AND RATE

• **PROPORTION**

• equivalent to count, **but** stated relative to group size (analogous to standardizing the counts)

• - typically presented **as percentages**

• - proportion (A) = \[ \frac{\text{is of}}{\text{whole}} = \% \] or \[ \frac{\text{part}}{\text{whole}} = \% \]

• - denominator is also important; sometimes we want proportions that can be compared across different population groups – we have to figure out a way to do this?
Properties of Proportions

- \( n \) = the number of individuals in a population
- \( x \) = the number of individuals in the same population possess characteristic \( C \)
- \( p = \frac{x}{n} \) = proportion in the population with characteristic \( C \) is equal to \( x/n \)
- \( p \) takes on values between 0 and 1 (\( p \) is a fraction)
- \( p \) has no units
- \( p \) may be multiplied by a constant \( k \) Where \( k \) is a number such as 100, 1,000, or 100,000

Example

- Proportionate mortality
- In 1995, 53% of all deaths in Africa were children under age 5
- \( p = 0.53 = 53\% = 53 \text{ per } 100 = 530 \text{ per } 1,000 \)
DEFINITIONS OF COUNT, PROPORTION, RATIO AND RATE

- **RATIO**

  - a fraction, like proportion — **but** different in that the **numerator and denominator** are not necessarily linked

- ratio =
Properties of Ratios

• R = a/b

• Often a ratio R is rescaled by multiplying by a constant \( k \), Where \( k \) is a number such as 10, 100, 1,000, or 10,000

• R is always > 0

• R may or may not have units
Examples of Ratios

- $R = \frac{\text{number of hospitals}}{(\text{population size})}$
- $R$ may be multiplied by $k = 10,000$
- Units = hospitals per 10,000 people
- Suppose $R = 4 \text{ hospitals}/20,000 \text{ people} = 0.0002 \text{ hospitals per person}$
- $R \times k = 0.0002 \times 10,000 = 2 \text{ hospitals per 10,000 people}$
- Units = hospitals per 10,000 people
DEFINITIONS OF COUNT, PROPORTION, RATIO AND RATE

• **RATE**
  - a fraction, *like proportion* – *but* different in that the denominator *involves a measure of time* (unit size) and the numerator consists of the frequency of disease over a specified period of time; two periods of time – beginning and ending
  - *improve one’s ability to make comparisons*
  - can be reported in any number of convenient forms; typically per 1,000; 100,000 or 1,000,000 cases – also need to take into consideration the denominator
Properties of Rates

- The calendar time period is the same in both the numerator and denominator of a rate.
- A rate expresses the relative frequency of an event per unit time ("risk").

Example

- Infant mortality rate (IMR) = number of infant deaths per 1,000 live births during a calendar year.
- The IMR is a ratio.
- The IMR is not a proportion because the numerator is not necessarily part of the denominator (some infants may have been born during the previous calendar year).
The FIVE elements (or components) of a rate

Rate = \frac{Number\ of\ events\ in\ a\ specified\ population\ during\ a\ specified\ period}{Average\ population\ during\ the\ period} \times 10^n
Rate is often a better measure

• Denominator of a risk = the population at risk at the beginning of a study.
• What if this “population at risk” changes?
• Eg. death (without having had the disease in question)
• loss of follow-up (due to migration or other reasons)
• The denominator for a rate is a precise measure: units are person-years.
Ratios, Proportions, and Rates

• A proportion is **always** a ratio
• A rate is **always** a ratio
• A rate **may or may not be** a proportion
Summary

• A **ratio** can be written as one number divided by another (a fraction) of the form \( \frac{a}{b} \). Both \( a \) and \( b \) refer to the frequency of some event or occurrence.

• A **proportion** is a ratio in which the numerator is a subset (or part) of the denominator and can be written as \( \frac{a}{a+b} \). A relative frequency.

• A **rate** is a ratio of the form \( \frac{a^*}{(a+b)a^*} = \) the frequency of events during a **certain time period**.
  • \( a+b = \) the number at risk of the event **during that time period**.

• **A rate may or may not be a proportion**.
Measures of Disease Frequency

- Prevalence
- Incidence
- Risk
- Rate

Measures of Disease Frequency

- Rates, Ratios, and Proportions
- Incidence versus Prevalence
- Risk
- Rate
- Risk versus Rate
- Mortality
- Risk/Rate Adjustment
Mortality and Morbidity as Indicators of Health Status of a Population

• **Death is a unique and universal** event, and as a final event, **clearly defined**.

• **Age at death** and cause provide an instant **depiction of health status**

• In high mortality settings, information on trends of death (by causes) substantiate the progress of health programs
Mortality and Morbidity as Indicators of Health Status of a Population

• As survival improves with modernization and populations age, mortality measures do not give an adequate picture of a population’s health status

• Indicators of morbidity such as the prevalence of chronic diseases and disabilities become more important
Measures of Mortality

- **Crude Death Rates**
- Age-Specific Death Rates
- Life Table Estimates
  - Life expectancy
    - Survivorship (by age)
- Cause-Specific Death Rates
- Special Indicators
  - Infant and maternal mortality rates
Crude Mortality Indicators

Crude Death Rate (CDR)

- Number of deaths in a given year per 1000 mid-year population

\[
\frac{\text{Number of deaths/year}}{\text{Mid-year population}} \times 1000
\]
Crude Death Rate : Example

\[
\frac{\text{Number of deaths/ year}}{\text{Mid - year population}} \times 1000
\]

- In Jordan

- \( \text{---} \times 1000 = \)

- **3.84** (\textit{deaths per 1,000 population}) in 2015

- which indicates that there were about...... deaths per 1000 inhabitants in the year 2015
Crude birth and death rates will continue to fall

Source: UN, World Population Prospects, 2008
Crude Death Rate in MENA
Jordan - Crude death rate

3.8

(per 1,000 people)
in 2014

Crude death rate indicates the number of deaths occurring during the year, per 1,000 population estimated at midyear. Subtracting the crude death rate from the crude birth rate provides the rate of natural increase, which is equal to the rate of population change in the absence of migration.

https://knoema.com/atlas/Jordan/Death-rate
Jordan - Mortality - Infant mortality rate

15.87

(infant deaths per 1,000 live births)
in 2015

Infant deaths per 1,000 live births. Both sexes combined. Probability of dying between birth and exact age 1. It is expressed as deaths per 1,000 births.

<table>
<thead>
<tr>
<th>Date</th>
<th>Value</th>
<th>Change, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>15.87</td>
<td>-2.89 %</td>
</tr>
<tr>
<td>2014</td>
<td>16.34</td>
<td>-2.88 %</td>
</tr>
<tr>
<td>2013</td>
<td>16.83</td>
<td>-2.87 %</td>
</tr>
<tr>
<td>2012</td>
<td>17.32</td>
<td>-2.85 %</td>
</tr>
<tr>
<td>2011</td>
<td>17.83</td>
<td>-2.82 %</td>
</tr>
<tr>
<td>2010</td>
<td>18.35</td>
<td>-2.77 %</td>
</tr>
<tr>
<td>2009</td>
<td>18.87</td>
<td>-2.72 %</td>
</tr>
<tr>
<td>2008</td>
<td>19.40</td>
<td>-2.65 %</td>
</tr>
<tr>
<td>2007</td>
<td>19.93</td>
<td>-2.61 %</td>
</tr>
<tr>
<td>2006</td>
<td>20.46</td>
<td>-2.57 %</td>
</tr>
<tr>
<td>2005</td>
<td>21.00</td>
<td>-2.56 %</td>
</tr>
<tr>
<td>2004</td>
<td>21.55</td>
<td></td>
</tr>
</tbody>
</table>
Crude Death Rates
Points to Note

• Risks of death change by age, so CDR is affected by population age structure
• Aging populations can have rising CDRs, even as the health conditions are improving
• Therefore mortality comparisons across countries should always use mortality indicators that are adjusted for differences in age composition
Age Specific Death Rates (ASDR)

Number of deaths per year in a specific age (group) per 1000 persons in the age group

\[ \frac{D_a}{P_a} \times 1000 \]

Where \( D_a \) = Number of deaths in age group a
\( P_a \) = Midyear population in age group a
Why Age Specific Death Rates?

• Can compare mortality at different ages
• Can compare mortality in the same age groups over time and/or between countries and areas
• Can be used to calculate life tables to create an age-independent measure of mortality (life-expectancy)
Matlab, Bangladesh
Percent distribution of population and deaths, 1987

Source: ICDDR,B
Cause Specific Death Rates

- Number of deaths attributable to a particular cause $c$ divided by population at risk, usually expressed in deaths per 100,000

$$\frac{D}{P} \times 100000$$
Cause Specific Death Rate: Examples

- The cause specific death rate per 100,000 for tuberculosis in South Africa in 1993 was:

\[
\frac{\text{Deaths from TB}}{\text{Total Population}} \times k = \frac{7474}{39,544,974} \times 100,000 = 18.9
\]

- Cause specific death rates for TB in Philippines, Mexico and Sweden were 36.7, 5.1, and 0.4 respectively

(UN Demographic year book, 1997)
Mortality and Morbidity
Special Mortality Indicators

Maternal Mortality Ratio

- Number of women who die as a result of complications of pregnancy or childbearing in a given year per 100,000 live births in that year

\[
\text{Maternal Mortality Ratio} = \frac{\text{# of maternal deaths}}{\text{# of live births}} \times 100,000
\]

- Represents the risk associated with each pregnancy, i.e., the obstetric risk
Maternal Mortality Rate

• Number of women who die as a result of complications of pregnancy or childbearing in a given year per 100,000 women of childbearing age in the population

\[
= \frac{\text{# of maternal deaths}}{\text{# of women ages 15 - 49}} \times 100,000
\]

• Represents both the obstetric risk and the frequency with which women are exposed to this risk
# Women’s Lifetime Risk of Death from Pregnancy, 1990

<table>
<thead>
<tr>
<th>Region</th>
<th>Risk of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>1 in 16</td>
</tr>
<tr>
<td>Asia</td>
<td>1 in 65</td>
</tr>
<tr>
<td>Latin America and Caribbean</td>
<td>1 in 130</td>
</tr>
<tr>
<td>Europe</td>
<td>1 in 1400</td>
</tr>
<tr>
<td>North America</td>
<td>1 in 3700</td>
</tr>
<tr>
<td>All developing countries</td>
<td>1 in 48</td>
</tr>
<tr>
<td>All developed countries</td>
<td>1 in 1800</td>
</tr>
</tbody>
</table>

*Source: Adapted from Family Care International, 1998*
Mortality and Morbidity

• Data Sources and

• Indicators for Measuring Morbidity
Morbidity

• Morbidity refers to the diseases and illness, injuries, and disabilities in a population

• Data on frequency and distribution of a illness can aid in controlling its spread and, in some cases, may lead to the identification of its causes
Morbidity

- The major methods for gathering morbidity data are through *surveillance systems and sample surveys*.
- These are both costly procedures and therefore are used only selectively in developing country setting to gather data on health problems of major importance.
Morbidity – Indicators

Incidence Rate

• Number of persons contracting a disease during a given time period per 1000 population at risk
• Refers only to new cases during a defined period
  – **INCIDENCE**:
    • **General Definition**: the occurrence of *new* events or cases that develop in a *population at risk* during a *specified time interval*.

  (# New Events observed over time)

• Incidence = ---------------------------------------------
  (Population at Risk observed over time)
Cumulative Incidence

• **Incidence Proportion** (or **Cumulative Incidence**) – the *proportion* of individuals in an *at-risk population* who develop a condition or event over a *specific period of time*.

  – This measure of incidence can only be calculated when of all individuals have complete follow-up throughout the observation period or are followed for the same amount of time, i.e. only with *closed populations*.

• $(\# \text{ new events in a specified period}) / (\text{population at risk at onset of that period})$

  • (expressed as $\# \text{ events}/10^x$ over a year)
Cumulative Incidence of GI side effects for Rofecoxib (VIOXX) vs. Naproxen - The VIGOR Trial (Bombardier NEJM 2000)

![Cumulative Incidence Graph](image)
Other terms often used......

Cumulative Incidence

• **Proportion of people who become diseased during a specified period of time**
• **Provides an estimate of the probability or risk that an individual will develop a disease during a specified period of time.**
• **Assumes that entire population at risk has been followed for the entire specified period of time.**

\[
\text{number of new cases of a disease during a given period of time} = \frac{\text{total population at risk}}{\text{total population at risk}}
\]
Morbidity

- **Incidence Rate – Example**
- Incidence for malaria will be given by:

\[
\frac{\text{# of persons developing malaria during a given time period}}{\text{Population at risk}} \times k
\]
Incidence Density

- Can take into account differing periods of follow up.
- Also called Incidence rate/force of morbidity or mortality.

\[
\text{number of new cases of a disease} \quad \frac{\text{during a given period of time}}{\text{total person-time of observation}}
\]
PREVALENCE

• Point Prevalence: the proportion in a population with a particular existing condition (prevalent cases) at a specific point in time.
  – “Point in time”
    » Usually refers to a general or specific temporal point (e.g. a short survey period – December, 2004; or a specified date – December 31, 2004)
    » May also refer to a “point” in the life cycle (e.g. birth, entry into graduate school, retirement)
PREVALENCE

Calculation:

(# Existing cases at a point in time) / (total specified population at that point)

– Interpretation

  » The amount (“status” or “burden”) of existing condition in the population at a given point in time.

– Example: A study in metropolitan Atlanta in 1996 identified 577 children (ages 3-10) with autism in a population of 169,710 white children, yielding a prevalence of 3.4/1,000.

•
Concept of the Prevalence “Pool”

New cases (Incidence)

Recovery rate

Death rate
Prevalence Rate - Example

- Prevalence of HIV/AIDS among *adults at a given point in time will be*

\[
\frac{\text{# of persons ages 15 - 49 with HIV/AIDS}}{\text{Total population ages 15 - 49}} \times k
\]
PREVALENCE

• **Period Prevalence:** the proportion in a population with a particular *existing condition* at *any time during a specified time-period.*

  – This mixes prevalent (existing) and incident (new) cases

    » New cases that develop during the period become “existing cases” and are added to the cases present at the beginning of the period

    » Any cases “existing” at any time during the observation period will be included even if the condition resolves during that period.
Period Prevalence

- (# Existing cases at any time during a time period) / (total specified population)

- Example: In a sample of U.S. adults (ages 18-44 years), 7.7% reported having had a serious mental health disorder at some point during the prior 12 months
### Estimated Worldwide Incidence, Prevalence and Deaths For Selected Infectious Diseases, 1990

<table>
<thead>
<tr>
<th>Disease</th>
<th>Incidence</th>
<th>Prevalence</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New cases (1000s)</td>
<td>Rate/100,000</td>
<td>Cases (1000s)</td>
</tr>
<tr>
<td>Malaria</td>
<td>213,743</td>
<td>4,058</td>
<td>2,777</td>
</tr>
<tr>
<td>Measles</td>
<td>44,334</td>
<td>842</td>
<td>1,739</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>6,346</td>
<td>121</td>
<td>12,739</td>
</tr>
<tr>
<td>HIV and AIDS</td>
<td>2,153</td>
<td>41</td>
<td>8,823</td>
</tr>
<tr>
<td>Poliomyelitis</td>
<td>215</td>
<td>4</td>
<td>10,648</td>
</tr>
</tbody>
</table>

Critical Issues related to all Incidence measures

– Always need a clear indication of the relevant time period of observation and how it will be incorporated into the measure (extrinsically in the IP, intrinsically in the IR).

– Need a clear definition and means of identifying the numerator – as new “cases” of a specified event, disease or condition.

– Need a clear definition and means of identifying the denominator – as specifically relating to the population at risk for the event, disease or condition.
Relationship among Prevalence and Incidence measures

Prevalence depends upon both Incidence (the rate at which disease or events occur in the population) and Average Duration of disease/events:

$$\text{Prevalence} \approx (\text{Incidence Rate}) \times (\text{Average Duration})$$

• This relationship explains why....
  – Arthritis is common (“prevalent”) in the elderly
  – Rabies is rare.
  – Influenza is only common during epidemics

• This approximation works well only when the disease prevalence is low (<10%) and it assumes that the population dynamics are in a “steady state”, i.e. that the incidence rate and disease duration are constant.
Why bother to distinguish between prevalent and incident cases?

- When you measure prevalent cases you are measuring *BOTH cases that have been around for ages AND new cases*!
- The old cases and the new cases may behave very differently!
- Old cases are survivors and may differ from the „usual disease“
Incidence measured by: Risk and Rate

Risk

• the probability of a disease occurring in a disease free population during a specified time period

• risk (over a defined period) = n/P
  • n = new P= population initially at risk
  • cases in a defined period

Rate

• number/frequency of events that occur in a defined time period, in relation to the average population at risk.

rate = n/person-time (Y) at risk
Risk an example

- the probability of a disease occurring in a disease free population during a specified time period

- risk (over a defined period) = \( n/P \)
  - \( n \) = new
  - \( P \) = population initially at risk
  - cases in a defined period

eg If 3 cases of lung cancer develop in 1,000 adult men in 2001

we say:
Risk = \( 3/1000 \) per annum for adult males
### Examples

<table>
<thead>
<tr>
<th>Interview question</th>
<th>Type of Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Do you currently have asthma?’</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>‘Have you had asthma during the last (n) years?’</td>
<td>Period prevalence</td>
</tr>
<tr>
<td>‘Have you ever had asthma?’</td>
<td>Cumulative or lifetime incidence</td>
</tr>
<tr>
<td>‘Have you developed asthma in the last 12 months?’</td>
<td>Incidence density/rate</td>
</tr>
</tbody>
</table>
Summary Terms Related to Morbidity

• **Morbidity**
  – The extent of illness, injury or disability in a defined population

• **Incidence** of a disease (Incidence rate)
  – The number of new cases of a disease that occur during a specified time period (numerator) in a population at risk for developing the disease (denominator)

• **Prevalence** of a disease (Prevalence rate)
  – The number of total cases of disease present at a particular time (numerator) in a specific population (denominator)

• **Risk**
  – The likelihood that an individual will contract a disease
### Characteristics

<table>
<thead>
<tr>
<th>RISK</th>
<th>PREVALENCE</th>
<th>INCIDENCE RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of disease</td>
<td>% of pop. with the disease</td>
<td>Rapidity of disease occurrence</td>
</tr>
<tr>
<td>No units</td>
<td>No units</td>
<td>Cases per person-time</td>
</tr>
<tr>
<td>Newly diagnosed</td>
<td>Existing</td>
<td>Newly diagnosed</td>
</tr>
<tr>
<td>“Cumulative incidence”</td>
<td></td>
<td>“Incidence density”</td>
</tr>
</tbody>
</table>