Mortality and Its Measurement

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Section A

Definitions and Indicators
De Jure vs. De Facto

- De jure
  - Death is registered at place of residence

- De facto
  - Death is registered at place of occurrence
Year of Registration vs. Year of Occurrence

- **Year of registration**
  - Death is tabulated according to the time of its registration

- **Year of occurrence**
  - Death is tabulated according to the time it occurs
Indicators

- **Basic indicator**
  - *Crude death rate*—Number of deaths per 1,000 population

\[
\text{Number of deaths} \div \text{Midyear population} \times 1000
\]
Indicators

- Midyear population is an approximation of the average population exposed to risk
- Total person-years lived is a better denominator if available
Indicators

- Typically computed for calendar year so as to eliminate the effect of seasonal or monthly variations on the comparability of the rates.
- There is a problem if the mid-point of the time reference for the numerator does not correspond to the time of the midpoint population.
Age Specific Death Rate:

- **Age Specific Death Rate**—Number of deaths per 1,000 persons of a specific age (group)

\[
\text{Age Specific Death Rate} = \frac{D_a}{P_a} \times 1000
\]

- Where
  - \(D_a\) = Number of deaths in age (group) \(a\)
  - \(P_a\) = Midyear population in age (group) \(a\)
Egypt ASDR Graph 1990

Source: UN, Demographic year book 1990
Infant Mortality “Rate”

- **Infant Mortality Rate**—Number of infant deaths per 1000 births

\[
\text{IMR} = \frac{D_0}{B} \times 1000
\]

- Where \( D_0 \) = Number of infant (< 1 year) deaths
  
  \( B \) = Number of births

Continued
Infant Mortality “Rate”

IMR is a Period Measure
Calculate the conventional infant mortality rate for the U.S. (1990), based on the following data.

<table>
<thead>
<tr>
<th>Year</th>
<th>Birth Cohort</th>
<th>Births</th>
<th>Deaths</th>
<th>Infant Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>1989</td>
<td>4,040,958</td>
<td>39,655</td>
<td>33,645</td>
</tr>
<tr>
<td>1990</td>
<td>1989</td>
<td>--</td>
<td></td>
<td>5,861</td>
</tr>
<tr>
<td>1990</td>
<td>1990</td>
<td>4,158,212</td>
<td>38,351</td>
<td>32,490</td>
</tr>
<tr>
<td>1991</td>
<td>1990</td>
<td>--</td>
<td></td>
<td>5,657</td>
</tr>
</tbody>
</table>

You have 15 seconds to calculate the answer. You may pause the presentation if you need more time.

Exercise Answer

Infant Mortality “Rate”

♦ The correct IMR for 1990 is as follows:
  - **9.22 infant deaths per 1,000 births**

<table>
<thead>
<tr>
<th>Year</th>
<th>Birth Cohort</th>
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</table>
Infant Mortality “Rate”

- Good index of child mortality in low mortality populations; less good in high mortality populations
- Because of the very high level of mortality in the first hours, days, and weeks of life, IMR is broken down into even more specific rates
- Not a true rate
Adjusted Infant Mortality Rate

- To be used when the number of births fluctuates sharply between years and within a year.
- Infant deaths in a year occur to births of that year and also to births of the previous year.

Continued
Adjusted Infant Mortality Rate

\[ D''_y \]

\[ D'_{y+1} \]

\[ B_y \]

\[ B_{y+1} \]
Three Techniques for Adjusting Infant Mortality Rate

- Cohort probability
- Data by year and cohort
- Separation factors
Adjusted Infant Mortality Rate

Cohort Probability

- The portion of deaths under one in year $y$ and the portion of deaths under one in year $y+1$ occurring to births in year $y$ are combined and divided by the births in year $y$

$$IMR_C = \frac{D'_y + D''_{y+1}}{B_y} \times 1000$$
Adjusted Infant Mortality Rate

Cohort Probability

\[
\begin{align*}
D''_y &= D'_y \\
D''_{y+1} &= D'_{y+1}
\end{align*}
\]
Calculate the cohort probability of infant death for the U.S. (1990)

### United States

<table>
<thead>
<tr>
<th>Year</th>
<th>Birth Cohort</th>
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<th>Deaths</th>
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</tr>
</tbody>
</table>
The correct IMRC for 1990 is as follows:

- **9.17 infant deaths per 1,000 births**

<table>
<thead>
<tr>
<th>Year</th>
<th>Birth Cohort</th>
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</table>
Adjusted Infant Mortality Rate

*Data by Year and Cohort*

- Each portion of the infant deaths occurring in a given year is related to the births in the appropriate year and cohort

\[
IMR_B = \left( \frac{D''_y}{B_{y-1}} + \frac{D'_y}{B_y} \right) \times 1000
\]
Adjusted Infant Mortality Rate

Data by Year and Cohort
**Exercise**

*Data by Year and Cohort*

- Calculate the adjusted infant mortality rate using data by year and cohort for the U.S. (1990)

<table>
<thead>
<tr>
<th>Year</th>
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The correct IMR_B for 1990 is as follows:
- 9.26 infant deaths per 1,000 infant births

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1989</td>
<td>4 040 958</td>
<td>39 655</td>
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<tr>
<td>1990</td>
<td>4 158 212</td>
<td>38 351</td>
</tr>
<tr>
<td>1991</td>
<td>4 040 958</td>
<td>36 766</td>
</tr>
</tbody>
</table>
Adjusted Infant Mortality Rate

Separation Factors

- Infant deaths in year $y$ are divided by a weighted average of births in years $y$ and $y-1$
- The weights are called separation factors

\[
\text{IMR}_w = \left( \frac{D_y}{f'' B_{y-1} + f' B_y} \right) \times 1000
\]

\[
f' = \frac{D'_y}{D_y} \quad \text{and} \quad f'' = 1 - f'
\]

Continued
Adjusted Infant Mortality Rate

Separation Factors

\[ B_{y-1} \quad D_y \]

\[ B_y \]

\[ D_y \]

\[ = \]

\[ D''_y \quad D_y' \]

28
Exercise
Separation Factors

- Calculate the adjusted infant mortality rate using the separation factors technique for the U.S. (1990)

United States

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You have 15 seconds to calculate the answer. You may pause the presentation if you need more time.

Exercise Answer

Separation Factors

The correct IMR\textsubscript{w} for 1990 is as follows:

- **9.26 infant deaths per 1,000 births**

### United States

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Summary

- Mortality is one of the demographic phenomena most commonly studied.
- It is important to take into consideration the definitions in the data collection systems when interpreting and comparing different rates.
- There are several ways of calculating infant mortality rates; the results can be somewhat different.
Section B

Events Occurring During Pregnancy or Around the Time of Birth
Neonatal Mortality Rate

- *Neonatal Mortality Rate*—Number of deaths of newborns in the first month of life per 1,000 births

\[
\text{Neonatal Mortality Rate} = \frac{D_{0-3\text{ weeks}}}{B} \times 1000 \quad \text{or} \quad \frac{D_{<1\text{ month}}}{B} \times 1000
\]
Post-Neonatal Mortality Rate

*Post-Neonatal Mortality Rate*—Number of deaths of babies between the 1st and 12th month of life per 1,000 births

\[
= \frac{D_{4-51 \text{ weeks}}}{B} \times 1000 \quad \text{or} \quad \frac{D_{1-11 \text{ months}}}{B} \times 1000
\]
Infant Mortality Rate (IMR)

- Note:
  - IMR = Neonatal mortality rate + Post-neonatal mortality rate
Fetal Death

- Early fetal loss: < 20 weeks
- Intermediate: 20–27 weeks
- Late: 28+ weeks
Fetal Death

- Let $D_f = \text{Number of fetal deaths}$
  - $B = \text{Number of births}$

1) Fetal death ratio

$$\frac{D_f}{B}$$

2) Fetal death rate

$$\frac{D_f}{B + D_f}$$
Perinatal Mortality Rate

- *Perinatal Mortality Rate*—Number of stillbirths and deaths of babies up to one week old per 1,000 births

\[
\text{Rate} = \frac{\text{(late fetal deaths} + \text{ early neonatal deaths)}}{\text{Live births}} \times 1000
\]
Maternal Mortality

*Maternal Mortality*—Death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration or site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental causes (WHO)
Maternal Mortality

- Let $D_{mc}$ = Number of deaths due to maternal causes
- $W_{15-49}$ = Number of women of reproductive age
- $B$ = Total live births
Maternal Mortality Ratio

- *Maternal Mortality Ratio*—Number of deaths due to maternal causes per 100,000 births

\[
\begin{align*}
&D \cdot \frac{mc}{B} \times 100000
\end{align*}
\]
Maternal Mortality Rate

- *Maternal Mortality Rate*—Number of deaths due to maternal causes per 1,000 women of reproductive ages

\[
D_{mc} = \frac{W_{15-49}}{1000}
\]

- Note: Maternal mortality ratio is more widely used
Exercise
Maternal Mortality Ratio and Rate

Calculate the maternal mortality ratio and rate for the U.S. (1990), based on the following data:

United States, 1990

<table>
<thead>
<tr>
<th>Births</th>
<th>4158212</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal deaths</td>
<td>343</td>
</tr>
<tr>
<td>W_{15-49}</td>
<td>65 624</td>
</tr>
</tbody>
</table>


You have 15 seconds to calculate the answer. You may pause the presentation if you need more time.
The correct answer for the maternal mortality indicator is as follows:

**Ratio:**
8.25 per 100,000

**Rate:**
5.23 per 1,000

**United States, 1990**

<table>
<thead>
<tr>
<th>Births</th>
<th>4158212</th>
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<td>65 624</td>
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</tbody>
</table>
Cause-Specific Morbidity and Mortality

Let $D_c = \text{Number of deaths from cause (disease) } c$

$C_c = \text{Number of cases of cause } c$

$N_c = \text{Number of new cases of cause (disease) } c$

$D = \text{Total number of deaths}$

$P = \text{Mid-point population}$
Cause-Specific Death Ratio

- *Cause-Specific Death Ratio*—Proportion of all deaths attributable to cause $c$

\[
\frac{D_c}{D} \times 100
\]
Cause-Specific Death Rate

• *Cause-Specific Death Rate*—Number of deaths attributable to cause c per 100,000 population

\[
= \frac{D_c}{P} \times 100000
\]
<table>
<thead>
<tr>
<th>Causes</th>
<th>Egypt 1987</th>
<th>U.S. 1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>950.4</td>
<td>874.4</td>
</tr>
<tr>
<td>Cholera</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>Typhoid fever</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Other intestinal infectious diseases</td>
<td>82.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>2.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Tetanus</td>
<td>7.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Septicemia</td>
<td>0.7</td>
<td>8.2</td>
</tr>
<tr>
<td>Malignant neoplasm of stomach</td>
<td>0.9</td>
<td>5.7</td>
</tr>
<tr>
<td>Malignant neoplasm of colon</td>
<td>0.2</td>
<td>19.9</td>
</tr>
<tr>
<td>Malignant neoplasm of rectum,</td>
<td>0.6</td>
<td>3.3</td>
</tr>
<tr>
<td>rectosigmoid junction and anus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malignant neoplasm of trachea, bronchus and lung</td>
<td>1.7</td>
<td>53.5</td>
</tr>
<tr>
<td>Malignant neoplasm of female breast</td>
<td>-</td>
<td>41.2</td>
</tr>
<tr>
<td>Malignant neoplasm of cervix uteri</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td>All other malignant neoplasms</td>
<td>14.6</td>
<td>88.2</td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>0.2</td>
<td>104.4</td>
</tr>
</tbody>
</table>

Source: UN, Demographic Year book 1996
Table: Selected CSDR in Egypt and U.S. 1987

<table>
<thead>
<tr>
<th>Causes</th>
<th>Egypt 1987</th>
<th>U.S. 1987</th>
</tr>
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<tbody>
<tr>
<td>Other ischaemic heart diseases</td>
<td>16.0</td>
<td>106.5</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>18.9</td>
<td>61.7</td>
</tr>
<tr>
<td>Other diseases of circulatory system</td>
<td>243.9</td>
<td>101.4</td>
</tr>
<tr>
<td>Bronchitis, emphysema and asthma</td>
<td>29.5</td>
<td>9.2</td>
</tr>
<tr>
<td>Abortion</td>
<td>12.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Direct obstetric causes</td>
<td>46.8</td>
<td>5.0</td>
</tr>
<tr>
<td>Indirect obstetric causes</td>
<td>5.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Congenital anomalies</td>
<td>9.0</td>
<td>5.1</td>
</tr>
<tr>
<td>Birth trauma</td>
<td>0.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Other conditions originating in the perinatal period</td>
<td>639.5</td>
<td>471.5</td>
</tr>
<tr>
<td>Motor vehicle traffic accidents</td>
<td>6.6</td>
<td>19.5</td>
</tr>
<tr>
<td>Suicide and self-inflicted injury</td>
<td>0.0</td>
<td>12.7</td>
</tr>
<tr>
<td>Homicide and injury purposely inflicted by other persons</td>
<td>0.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Other violence</td>
<td>20.4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Source: UN, Demographic Year Book 1996
**Incidence of Cause (Disease) c**

- $I(c)$—Proportion of new cases of cause (disease) c in a population

\[
\text{Number of new cases of cause (disease) } c \text{ in time } (t, t+1) = \frac{N_c}{P}
\]

Mid-point population

\[
= \frac{N_c}{P}
\]
Case Fatality Rate Due to Cause (Disease) $c$

- *Case Fatality Rate Due to Cause (Disease) $c$*—Proportion of persons with cause (disease) $c$ who die from it

\[
= \frac{D_c}{C_c}
\]
Acute Causes (Diseases)

- Note: For acute causes (diseases), case fatality = \[ \frac{D_C}{N_C} \]

- So \[ \frac{D_C}{P} = \frac{N_C}{P} \ast \frac{D_C}{N_C} \]
Cause-Specific Death Rate

Therefore:

\[
\text{cause specific death rate} = \text{incidence} \times \text{case fatality}
\]

This relationship works well for acute diseases but not for chronic ones.
Person Years of Life Lost From Cause c (PYLL\(_{(c)}\))

\[
\text{PYLL}\,(c) = \sum_{a=0}^{70} (70 - a) m_{ac} \times 1000
\]

- Where \(c\) = Cause of death
- \(a\) = Age at death
- \(m_{ac}\) = Age-cause specific death rate
Calculation of potential years of life lost between ages 1 and 70 (PYLL), Rate and Age-Adjusted Rate, Ontario, Ischemic Heart Disease, Males 1974 (Source: Hetzel BS. In: New Developments in the Analysis of Mortality and Cause of Death. 1986)

<table>
<thead>
<tr>
<th>Age</th>
<th>Remaining yrs</th>
<th>No. of deaths</th>
<th>PYLL</th>
<th>Correcting factor</th>
<th>Age-adjusted PYLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 4</td>
<td>67</td>
<td>0</td>
<td>0</td>
<td>1.08</td>
<td>0</td>
</tr>
<tr>
<td>5 to 9</td>
<td>62.5</td>
<td>0</td>
<td>0</td>
<td>1.02</td>
<td>0</td>
</tr>
<tr>
<td>10 to 14</td>
<td>57.5</td>
<td>1</td>
<td>57.5</td>
<td>1.03</td>
<td>59.2</td>
</tr>
<tr>
<td>15 to 19</td>
<td>52.5</td>
<td>1</td>
<td>52.5</td>
<td>1.05</td>
<td>55.1</td>
</tr>
<tr>
<td>20 to 24</td>
<td>47.5</td>
<td>3</td>
<td>142.5</td>
<td>1.03</td>
<td>146.8</td>
</tr>
<tr>
<td>25 to 29</td>
<td>42.5</td>
<td>9</td>
<td>382.5</td>
<td>0.97</td>
<td>371</td>
</tr>
<tr>
<td>30 to 34</td>
<td>37.5</td>
<td>26</td>
<td>975</td>
<td>0.96</td>
<td>936</td>
</tr>
<tr>
<td>35 to 39</td>
<td>32.5</td>
<td>89</td>
<td>2,892.5</td>
<td>0.96</td>
<td>2,776.8</td>
</tr>
<tr>
<td>40 to 44</td>
<td>27.5</td>
<td>198</td>
<td>5,445</td>
<td>0.95</td>
<td>5,172.8</td>
</tr>
<tr>
<td>45 to 49</td>
<td>22.5</td>
<td>489</td>
<td>11,002.5</td>
<td>0.94</td>
<td>10,342.4</td>
</tr>
<tr>
<td>50 to 54</td>
<td>17.5</td>
<td>772</td>
<td>13,510</td>
<td>0.95</td>
<td>12,834.5</td>
</tr>
<tr>
<td>55 to 59</td>
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<td>Total (1 to 70)</td>
<td>5,652</td>
<td>61,865</td>
<td>60,140.4</td>
<td>3,791,600</td>
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</tbody>
</table>

\[
\frac{61,865}{3,791,600} \times 1,000 = 16.3 \text{ per 1,000}
\]

\[
\frac{60,140.4}{3,791,600} \times 1,000 = 15.9 \text{ per 1,000}
\]
Summary

- Several indicators have been developed to measure fetal/newborn mortality
- Maternal mortality can be measured as a rate or as a ratio; the two indicators give different perspectives on the problem
- Cause-specific indicators are important in singling out the contribution of a particular disease or cause of death in a population
Section C

Relationships of Death Rates and Probability of Death, and Differential in Mortality Between Populations
Death Rate and Probability of Death

- Deriving probability of dying ($q_x$) from observed mortality rate ($M_x$), using the actuarial method

Let $D_x^t = D =$ Deaths in age group $(x, x+n)$ in year $t$

$n P_x^t = P =$ Mid-point population in age group $(x, x+n)$ in year $t$

$n M_x^t = M =$ Mortality rate in age group $(x, x+n)$ in year $t$

$n M_x^t = n D_x^t / n P_x^t$

Continued
Death Rate and Probability of Death

- Also assume that
  - $n D^x_t$ are constant over the years
  - Deaths are linearly distributed throughout the year
Death Rate and Probability of Death

Continued
Death Rate and Probability of Death

\[ nq_x = \frac{n \times D}{P + \frac{n}{2}D} \]

and

\[ \frac{1}{nq_x} = \frac{P + \frac{n}{2}D}{n \times D} = \frac{1}{nM} + \frac{1}{2} = \frac{2 + nM}{2nM} = \frac{1 + \frac{n}{2}M}{nM} \]

so

\[ nq_x = \frac{n \times M}{1 + \frac{n}{2}M} \]
### Percentage of Error in a Ratio for Given Levels of Under and Overcount in Numerator and Denominator

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<th>10</th>
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</tbody>
</table>

*Source: Stan Becker, University of Dacca, August, 1978 (Not published)*
Differentials in Mortality

Important variations in mortality are associated with a number of socio-economic characteristics:

- Ethnicity / race
  - Blacks versus whites in the U.S.
- Marital status
  - Single versus married
Differentials in Mortality

- Educational attainment
  - Higher education consistently associated with better health outcomes
- Occupation
  - Miner versus a white collar
- Income
  - Rich versus poor

Continued
Differentials in Mortality

- Important for understanding the physical and sociological factors in health and for program planning
The life table probability of dying ($nq_x$) can be calculated from the observed mortality rates ($nM_x$).

One of the most common methods used to derive $nq_x$ from $nM_x$ is the actuarial method which assumes that deaths are linearly distributed throughout the year.

Important variations in mortality are associated with a number of socio-economic characteristics.