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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

$$\frac{\text{Number of deaths}}{\text{Midyear population}} * 1000$$

Continued

Indicators

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

Continued

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:

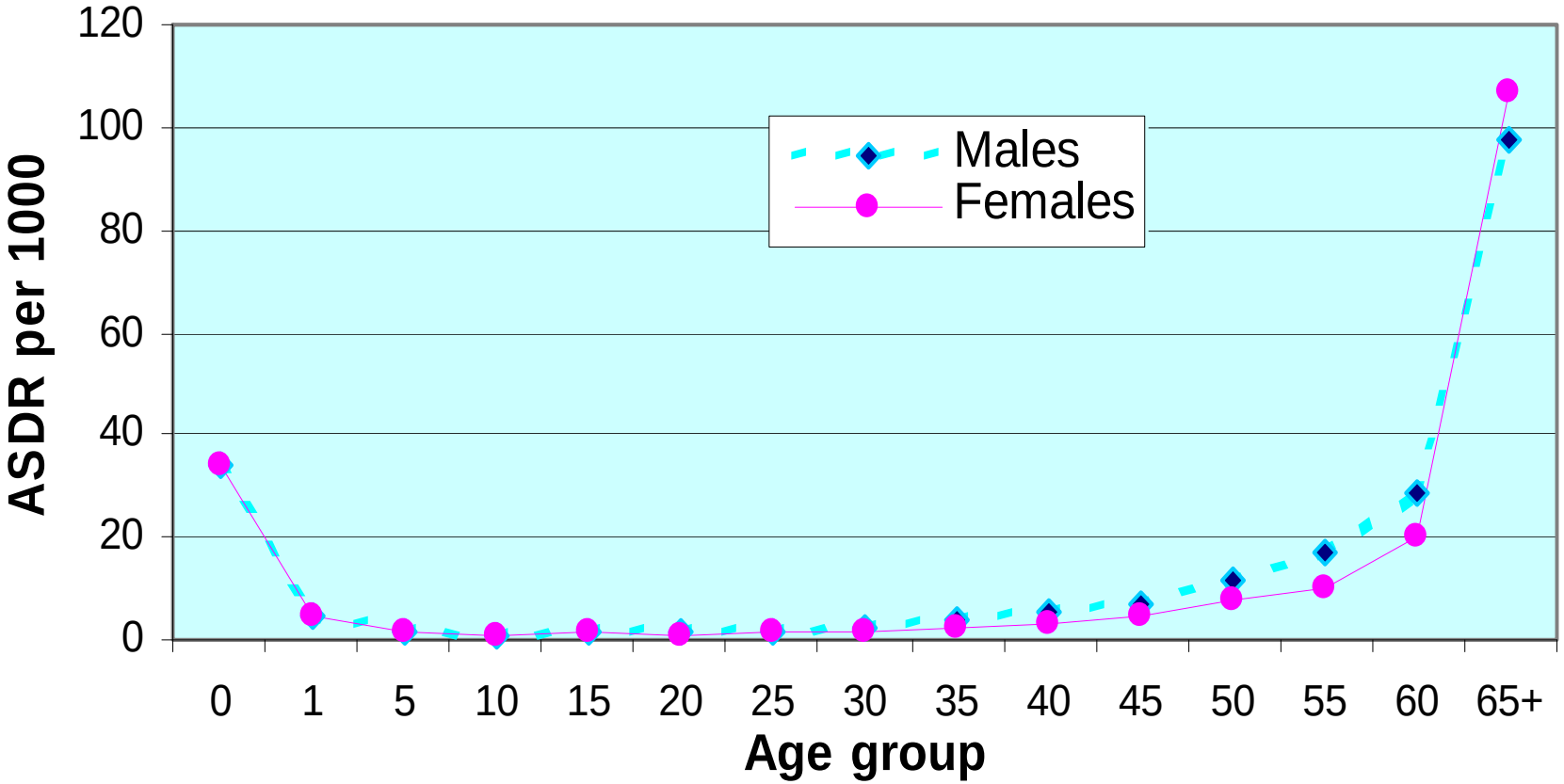
- *Age Specific Death Rate*—Number of deaths per 1,000 persons of a specific age (group)

$$= \frac{D_a}{P_a} * 1000$$

- 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

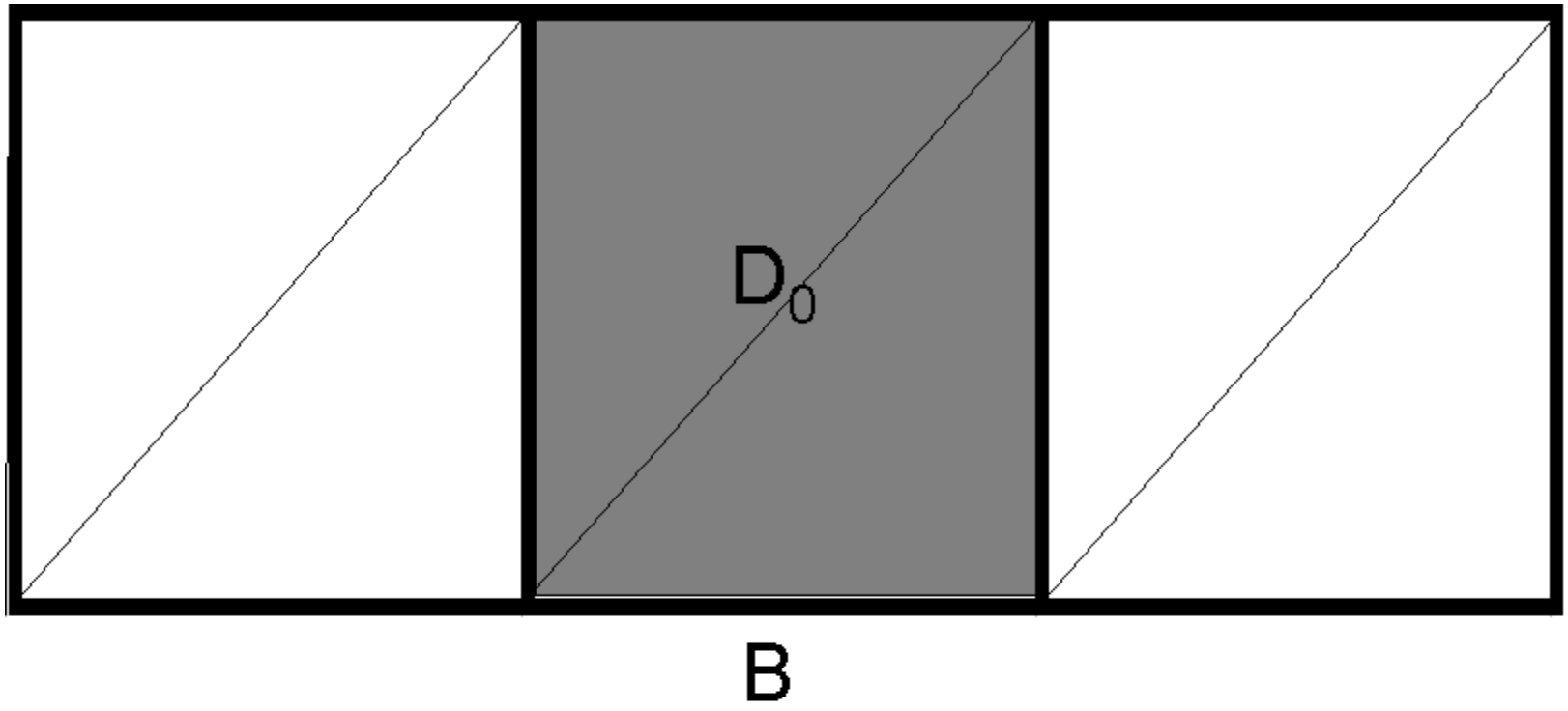
$$IMR = \frac{D_0}{B} * 1000$$

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

  B = Number of births

Continued

Infant Mortality “Rate”



IMR is a Period Measure

Exercise

Infant Mortality "Rate"

- Calculate the conventional infant mortality rate for the U.S. (1990), based on the following data

United States

Year	Birth Cohort	Births	Deaths	Infant Deaths
1989	1989	4,040,958	39,655	33,645
1990	1989	--		5,861
1990	1990	4,158,212	38,351	32,490
1991	1990	--		5,657
1991	1991	4,110,907	36,766	31,109

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

Source: Vital Statistics of the United States *1989-1991*

Exercise Answer

Infant Mortality "Rate"

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

United States

Year	Birth Cohort	Births	Deaths	Infant Deaths
1989	1989	4,040,958	39,655	33,645
1990	1989	--		5,861
1990	1990	4,158,212	38,351	32,490
1991	1990	--		5,657
1991	1991	4,110,907	36,766	31,109

Infant Mortality "Rate"

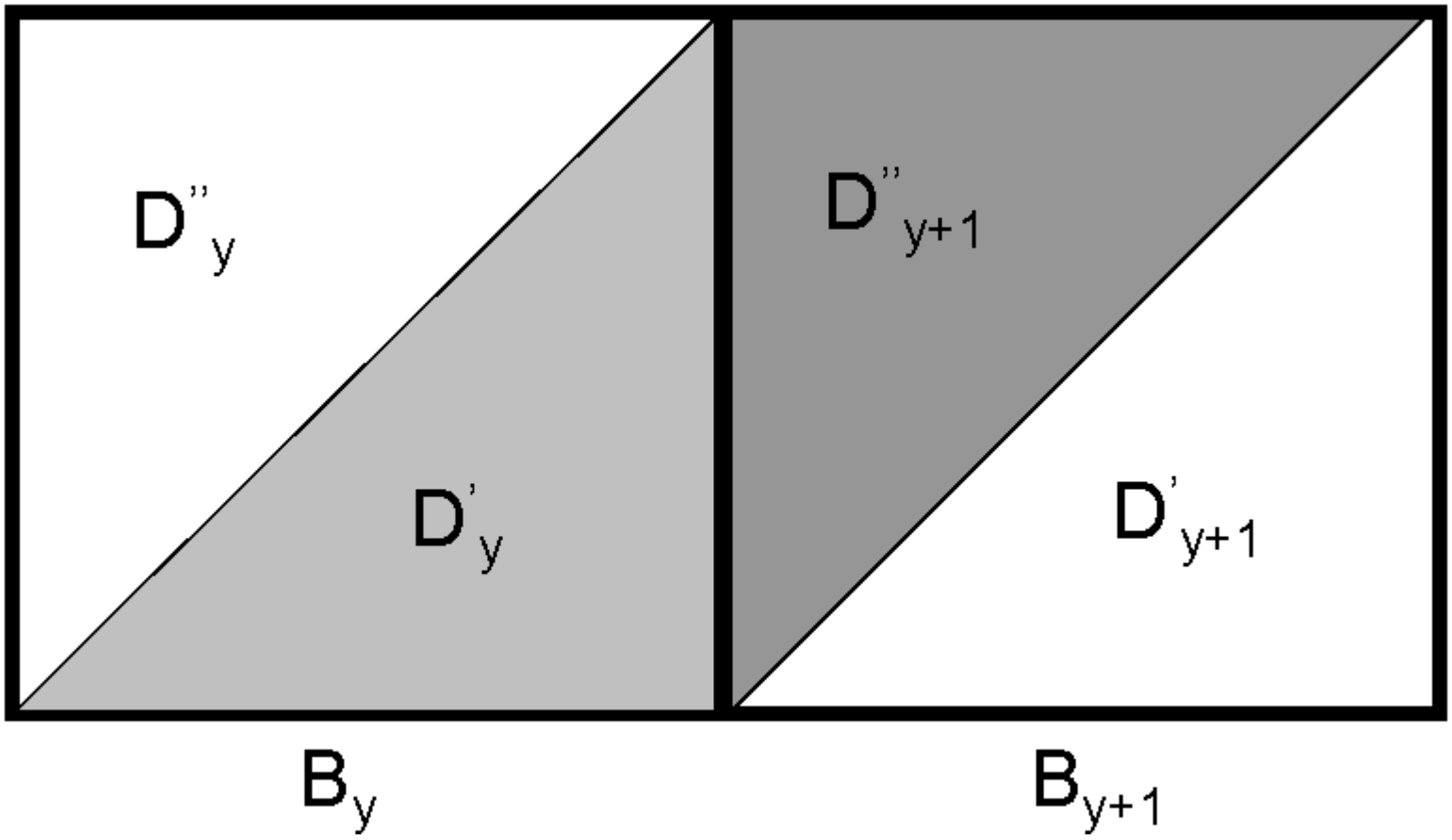
- Good index of child mortality in low mortality populations; less good in high mortality populations
- Because of the very high level of mortality in the first hours, days, and weeks of life, IMR is broken down into even more specific rates
- Not a true rate

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



Three Techniques for Adjusting Infant Mortality Rate

- Cohort probability
- Data by year and cohort
- Separation factors

Adjusted Infant Mortality Rate

Cohort Probability

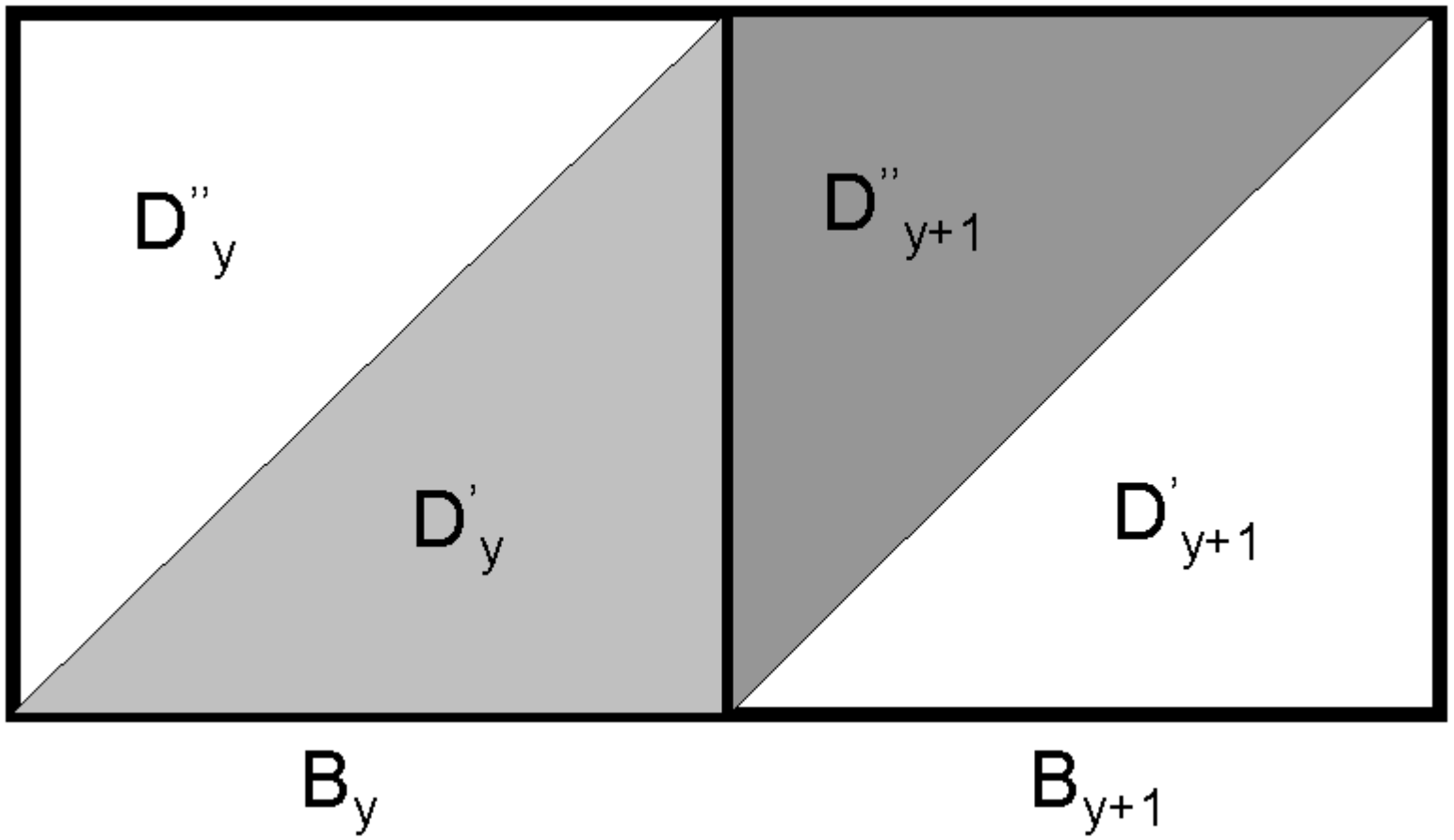
- The portion of deaths under one in year y and the portion of deaths under one in year y+1 occurring to births in year y are combined and divided by the births in year y

$$IMR_C = \frac{D_y^{'} + D_{y+1}^{''}}{B_y} * 1000$$

Continued

Adjusted Infant Mortality Rate

Cohort Probability



Exercise

Cohort Probability

- Calculate the cohort probability of infant death for the U.S. (1990)

United States

Year	Birth Cohort	Births	Deaths	Infant Deaths
1989	1989	4,040,958	39,655	33,645
1990	1989	--		5,861
1990	1990	4,158,212	38,351	32,490
1991	1990	--		5,657
1991	1991	4,110,907	36,766	31,109

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

Source: Vital Statistics of the United States *1989-1991*

Exercise Answer

Cohort Probability

- The correct IMR_C for 1990 is as follows:
  - **9.17 infant deaths per 1,000 births**

United States

Year	Birth Cohort	Births	Deaths	Infant Deaths
1989	1989	4,040,958	39,655	33,645
1990	1989	--		5,861
1990	1990	4,158,212	38,351	32,490
1991	1990	--		5,657
1991	1991	4,110,907	36,766	31,109

Adjusted Infant Mortality Rate

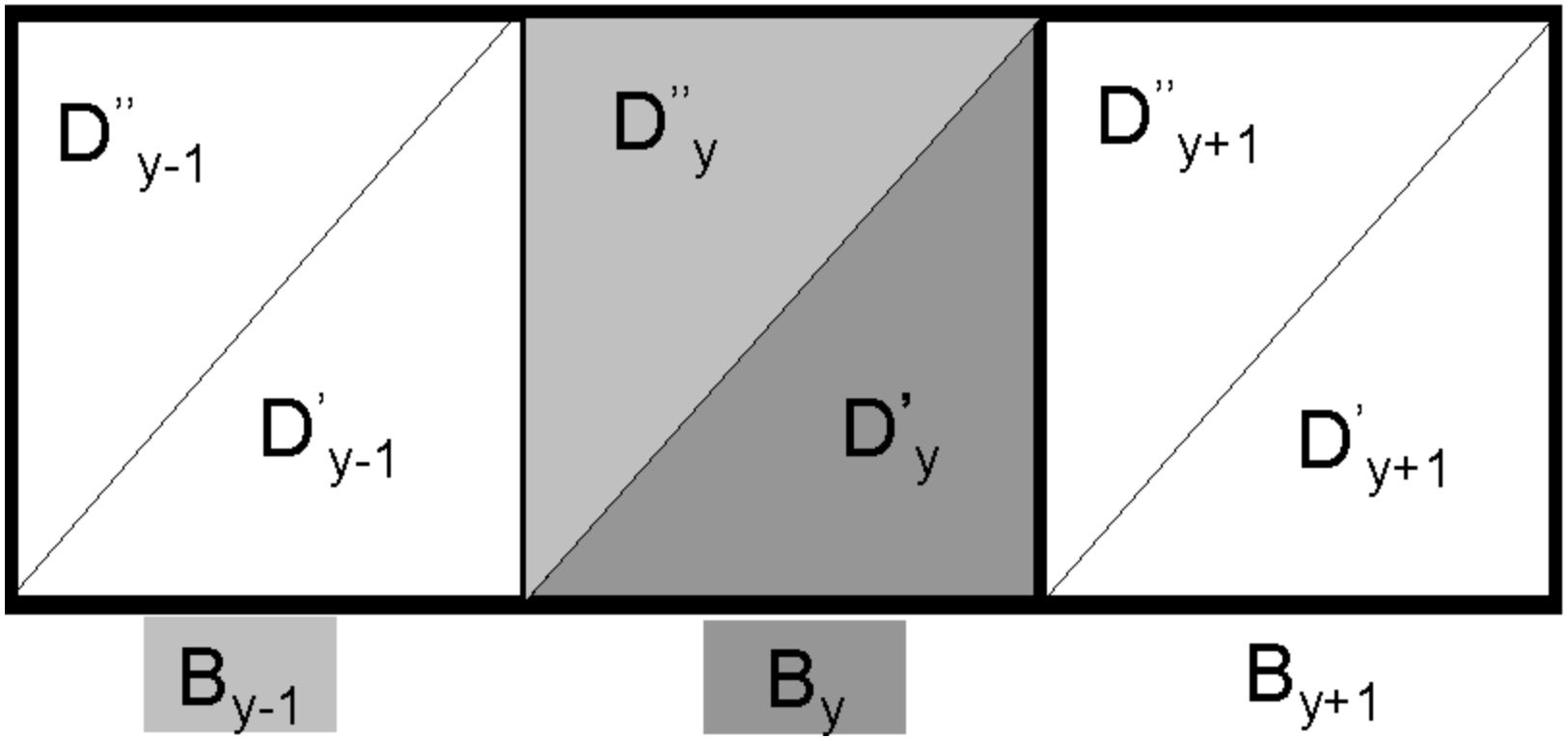
Data by Year and Cohort

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

$$IMR_B = \left(\frac{D_y^{''}}{B_{y-1}} + \frac{D_y^{'}}{B_y} \right) * 1000$$

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)

United States

Year	Birth Cohort	Births	Deaths	Infant Deaths
1989	1989	4,040,958	39,655	33,645
1990	1989	--		5,861
1990	1990	4,158,212	38,351	32,490
1991	1990	--		5,657
1991	1991	4,110,907	36,766	31,109

Source: Vital Statistics of the United States *1989-1991*

Exercise

Data by Year and Cohort

- The correct IMR_B for 1990 is as follows:
  - **9.26 infant deaths per 1,000 infant births**

United States

Year	Births	Infant Deaths
1989	4 040 958	39 655
1990	4 158 212	38 351
1991	4 040 958	36 766

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

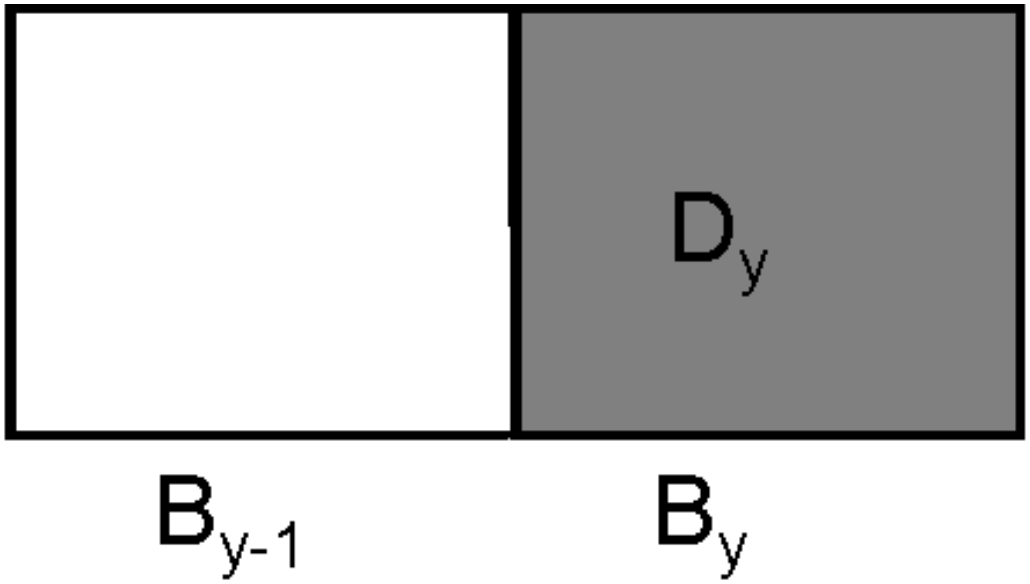
$$IMR_W = \left(\frac{D_y}{f''B_{y-1} + f'B_y} \right) * 1000$$

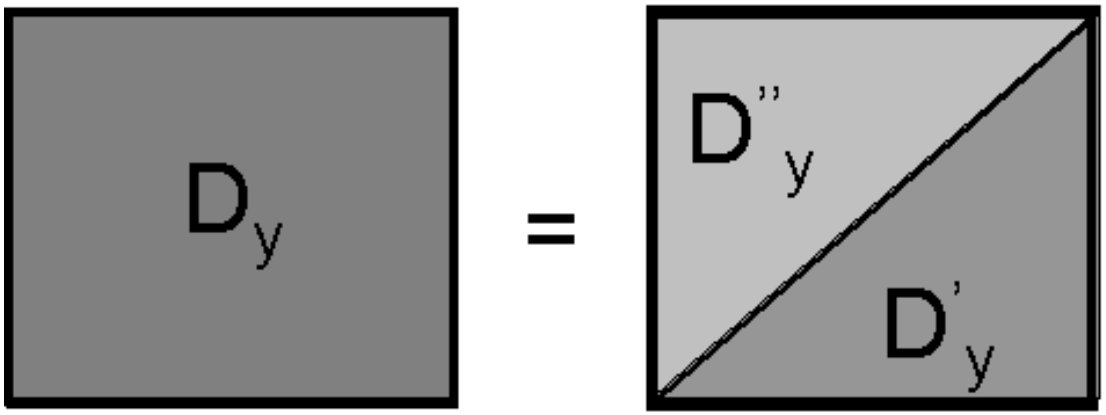
$$f' = \frac{D'_y}{D_y} \quad \text{and} \quad f'' = 1 - f'$$

Continued

Adjusted Infant Mortality Rate

Separation Factors





Exercise

Separation Factors

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

United States

Year	Birth Cohort	Births	Deaths	Infant Deaths
1989	1989	4,040,958	39,655	33,645
1990	1989	--		5,861
1990	1990	4,158,212	38,351	32,490
1991	1990	--		5,657
1991	1991	4,110,907	36,766	31,109

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

Source: Vital Statistics of the United States *1989-1991*

Exercise Answer

Separation Factors

- The correct IMR_W for 1990 is as follows:
  - **9.26 infant deaths per 1,000 births**

United States

Year	Birth Cohort	Births	Deaths	Infant Deaths
1989	1989	4,040,958	39,655	33,645
1990	1989	--		5,861
1990	1990	4,158,212	38,351	32,490
1991	1990	--		5,657
1991	1991	4,110,907	36,766	31,109

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

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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

$$= \frac{D_{0-3\ \text{weeks}}}{B} * 1000 \quad \text{or}$$

$$= \frac{D_{<1\,\text{month}}}{B} * 1000$$

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

$$= \frac{D_{4\text{-}51\,\text{weeks}}}{B} * 1000 \quad \text{or}$$

$$= \frac{D_{1\text{-}11\,\text{months}}}{B} * 1000$$

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

Continued

Fetal Death

- Let D_f = Number of fetal deaths
  B = 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

$$= \frac{(\text{late fetal deaths} + \text{early neonatal deaths})}{\text{Live births}} * 1000$$

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)

Continued

Maternal Mortality

- Let D_{mc} = Number of deaths due to maternal causes

  $W_{15\text{-}49}$ = 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

$$= \frac{D_{mc}}{B} * 100000$$

Maternal Mortality Rate

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

$$= \frac{D_{mc}}{W_{15-49}} * 1000$$

- 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	
Births	4158212
Maternal deaths	343
$W_{15\text{-}49}$	65 624

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

Source: Vital Statistics of the United States *1989-1991*

Exercise Answer

Maternal Mortality Ratio and Rate

- The correct answer for the maternal mortality indicator is as follows:

Ratio: **Rate**:

8.25 per 100,000 5.23 per 1,000

United States, 1990	
Births	4158212
Maternal deaths	343
$W_{15\text{-}49}$	65 624

Cause- Specific Morbidity and Mortality

- Let D_c = Number of deaths from cause (disease) c

  C_c = Number of cases of cause c

  N_c = Number of new cases of cause (disease) c

  D = Total number of deaths

  P = Mid-point population

Cause-Specific Death Ratio

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

$$= \frac{D_c}{D} * 100$$

Cause-Specific Death Rate

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

$$= \frac{D_c}{P} * 100000$$

Table: Selected CSDR in Egypt and U.S. 1987

Causes	Egypt 1987	U.S. 1987
Total	950.4	874.4
Cholera	-	0.0
Typhoid fever	0.2	0.0
Other intestinal infectious diseases	82.1	0.2
Tuberculosis	2.6	0.7
Tetanus	7.2	0.0
Septicemia	0.7	8.2
Malignant neoplasm of stomach	0.9	5.7
Malignant neoplasm of colon	0.2	19.9
Malignant neoplasm of rectum, rectosigmoid junction and anus	0.6	3.3
Malignant neoplasm of trachea, bronchus and lung	1.7	53.5
Malignant neoplasm of female breast	-	41.2
Malignant neoplasm of cervix uteri	-	4.5
All other malignant neoplasms	14.6	88.2
Acute myocardial infarction	0.2	104.4

Source: UN, Demographic Year book 1996

Continued

Table: Selected CSDR in Egypt and U.S. 1987

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

Source: UN, Demographic Year book 1996

Incidence of Cause (Disease) c

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

$$= \frac{\text{Number of new cases of cause (disease) c in time (t, t+1)}}{\text{Mid-point population}}$$

$$= \frac{N_c}{P}$$

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 $\frac{D_c}{P} = \frac{N_c}{P} * \frac{D_c}{N_c}$

Cause-Specific Death Rate

- Therefore:

  cause specific death rate =

  incidence * case fatality

- This relationship works well for acute diseases but not for chronic ones

Person Years of Life Lost From Cause c ($PYLL_{(c)}$)

$$PYLL_{(c)} = \sum_{a=0}^{70} (70 - a) m_{ac} * 1000$$

- 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

	PYLL and Rate			Standardized PYLL and Rage	
Age	Remaining yrs	No. of deaths	PYLL	Correcting factor	Age-adjusted PYLL
1 to 4	67	0	0	1.08	0
5 to 9	62.5	0	0	1.02	0
10 to 14	57.5	1	57.5	1.03	59.2
15 to 19	52.5	1	52.5	1.05	55.1
20 to 024	47.5	3	142.5	1.03	146.8
25 to 29	42.5	9	382.5	0.97	371
30 to 34	37.5	26	975	0.96	936
35 to 39	32.5	89	2,892.5	0.96	2,776.8
40 to 44	27.5	198	5,445	0.95	5,172.8
45 to 49	22.5	489	11,002.5	0.94	10,342.4
50 to 54	17.5	772	13,510	0.95	12,834.5
55 to 59	12.5	1,015	12,687.5	1	12,687.5
60 to 64	7.5	1,419	10,642.5	1	10,642.5
65 to 69	2.5	1,630	4,075	1.01	4,115.8
Total (1 to 70)		5,652	61,865		60,140.4

61,865 / 3,791,600 X 1,000

= 16.3 per 1,000

60,140.4 / 3,791,600 X 1,000

= 15.9 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

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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 (${}_nq_x$) from observed mortality rate (${}_nM_x$), using the actuarial method

Let ${}_nD^x_t$ = D = Deaths in age group (x, x+n) in year t

${}_nP^x_t$ = P = Mid-point population in age group (x, x+n) in year t

${}_nM^x_t$ = M = Mortality rate in age group (x, x+n) in year t

$${}_nM^x_t = {}_nD^x_t \,/\, {}_nP^x_t$$

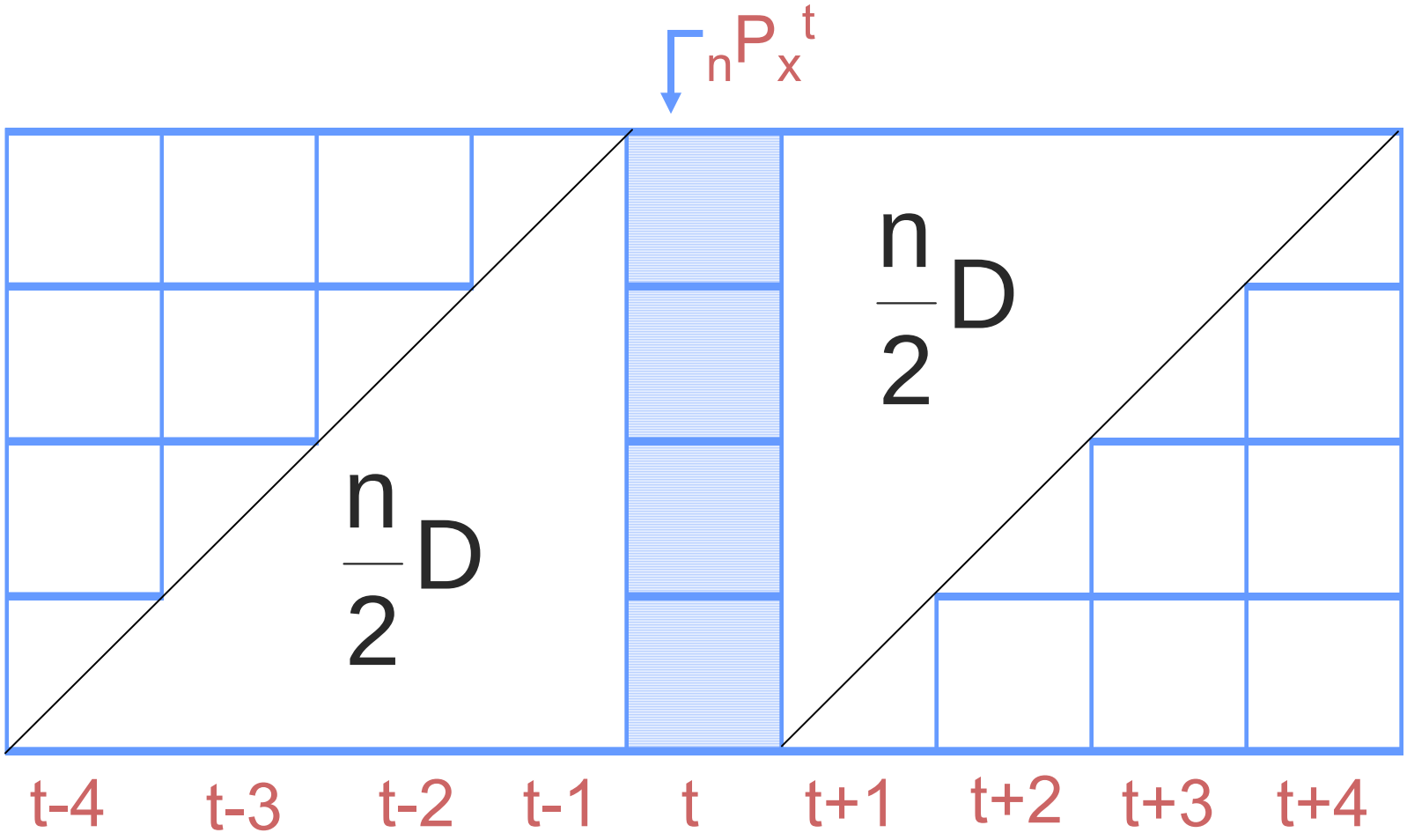
Continued

Death Rate and Probability of Death

- Also assume that
  - ${}_nD^x_t$ are constant over the years
  - Deaths are linearly distributed throughout the year

Continued

Death Rate and Probability of Death



Continued

Death Rate and Probability of Death

$$ {}_nq_x = \frac{n * D}{P + \frac{n}{2} D} $$

and

$$ \frac{1}{{}_nq_x} = \frac{P + \frac{n}{2} D}{n * D} = \frac{1}{nM} + \frac{1}{2} = \frac{2 + nM}{2nM} = \frac{1 + \frac{n}{2} M}{nM} $$

so

$$ {}_nq_x = \frac{n * M}{1 + \frac{n}{2} M} $$

Percentage of Error in a Ratio for Given Levels of Under and Overcount in Numerator and Denominator

Numerator: Percent Undercount	Denominator: Percent Undercount 30	25	20	15	10	5	0	Denominator: Percent Overcount 5	10	15	20	25	30
30	0	- 7	-13	-18	-22	-26	-30	-33	36	-39	-42	-44	-46
25	7	0	- 6	-12	-17	-21	-25	-29	-32	-35	-38	-40	-42
20	14	7	0	- 6	-11	-16	-20	-24	-27	-30	-33	-36	-38
15	21	13	6	0	- 6	-11	-15	-19	-23	-26	-29	-32	-35
10	29	20	13	6	0	- 5	-10	-14	-18	-22	-25	-28	-31
5	36	27	19	12	6	0	- 5	-10	-14	-17	-21	-24	-27
0	43	33	25	18	11	5	0	- 5	- 9	-13	-17	-20	-23
Numerator: Percent Overcount 5	50	40	31	24	17	11	5	0	- 5	- 9	-13	-16	-19
10	51	47	38	29	22	16	10	5	0	- 4	- 8	-12	-15
15	64	53	44	35	28	21	15	10	5	0	- 4	- 8	-12
20	71	60	50	41	33	26	20	14	9	4	0	- 4	- 8
25	79	67	56	47	39	32	25	19	14	9	4	0	- 4
30	86	73	63	53	44	37	30	24	18	13	8	4	0

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

Continued

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

Summary

- 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