Lecture 4: Measuring Mortality and Disease Impact

Lecture prepared by Dr. Hailey Banack, PhD

I am sharing this lecture online so it is publicly available to benefit all trainees in epidemiology and public health. However, please be sure to give due credit if you are using this resource:

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Last week

Measuring the **occurrence of disease** in a **population**

- Incidence
- Prevalence
- Risk (= new cases/population)
- Rates (= new cases/person time)

Mortality

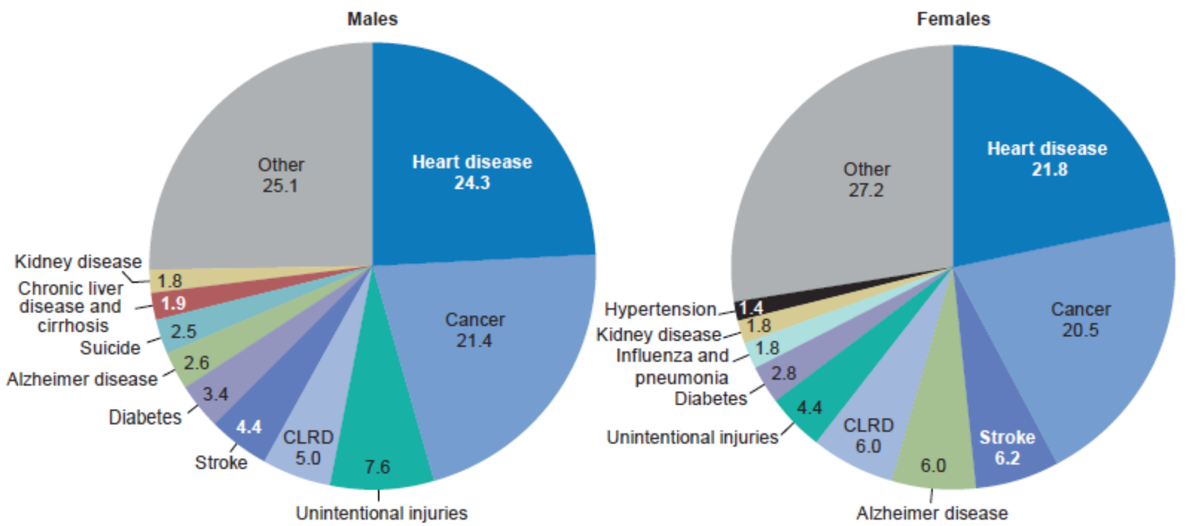
Why do we care about mortality?

- Death is the final outcome of health/disease states
  - Indicator of health of the population
  - “Yard stick” used to evaluate health over time
  - Easily measured because unambiguous (e.g,. compared to cancer staging)
- Vital statistics collected by government agencies
  - National vital statistics system
  - https://www.cdc.gov/nchs/nvss/index.htm

National Death Index

National-level mortality data help **track** the characteristics of those who have died, **monitor and make decisions** about public health challenges, **determine** life expectancy, and **compare** death trends with other countries.

Figure 1. Percent distribution of the 10 leading causes of death, by sex: United States, 2019

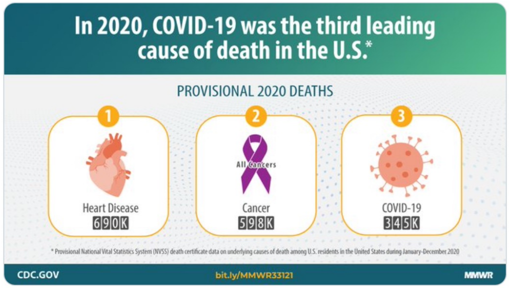


NOTES: CLRD is Chronic lower respiratory diseases. Values show percentage of total deaths. Totals may not add to 100 due to rounding.
SOURCE: National Center for Health Statistics, National Vital Statistics System, Mortality.

COVID-19 as a leading cause of death

CDC @CDCgov

A new @CDCMMWR shows that in 2020, more than 3.3 million deaths occurred in the United States, an 18% increase from 2019. #COVID19 ranked as the 3rd leading cause of death, following heart disease and cancer. Learn more: bit.ly/MMWR33121.



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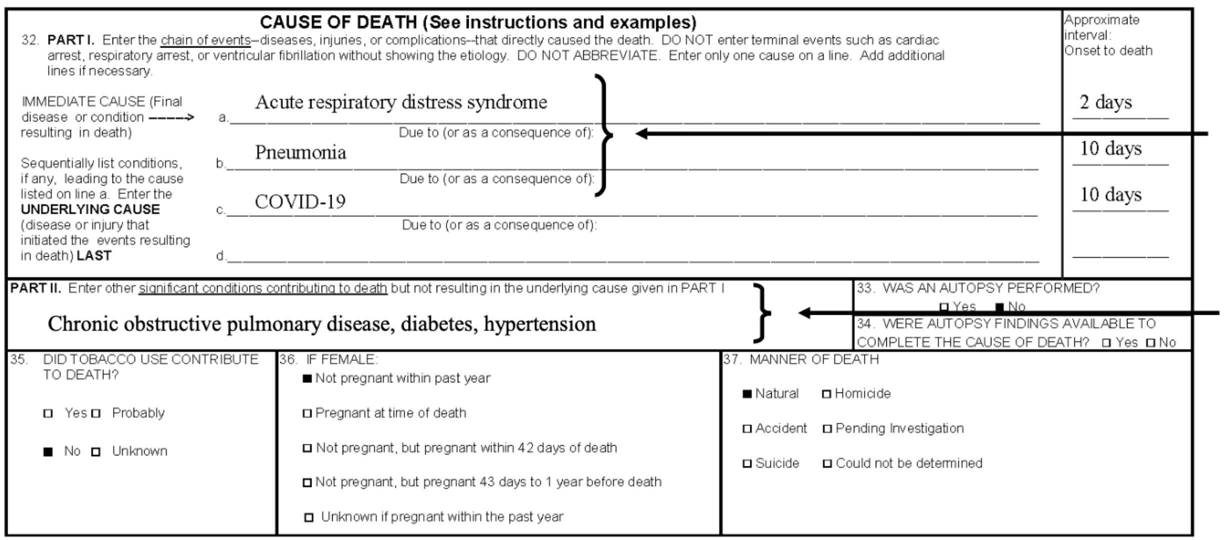
225 See the latest COVID-19 information on Twitter

TABLE 2. Highest-frequency *International Classification of Diseases, Tenth Revision* (ICD-10) codes listed in death certificates with COVID-19 in Part I of death certificate and at least one diagnosis other than COVID-19 (330,198) — National Center for Health Statistics, United States, January–December 2020

Condition (ICD-10 code)	No. (% of 330,198*)
Conditions listed as chain-of-event conditions on ≥1% of death certificates†	
Pneumonia, unspecified (J18.9)	148,530 (45.0)
Acute respiratory failure (J96.0)	66,609 (20.2)
Respiratory failure, unspecified (J96.9)	47,045 (14.2)
Cardiac arrest, unspecified (I46.9)	36,983 (11.2)
Adult respiratory distress syndrome (J80)	36,297 (11.0)
Sepsis, unspecified (A41.9)	20,117 (6.1)
Viral pneumonia, unspecified (J12.9)	12,421 (3.8)
Asphyxia (R09.0)	10,641 (3.2)
Respiratory arrest (R09.2)	7,009 (2.1)

Death certificates

FIGURE. Example Death Certificate with COVID-19 listed as a diagnosis along with chain-of-event and significant contributing conditions


CAUSE OF DEATH (See instructions and examples)

32. **PART I.** Enter the chain of events--diseases, injuries, or complications--that directly caused the death. DO NOT enter terminal events such as cardiac arrest, respiratory arrest, or ventricular fibrillation without showing the etiology. DO NOT ABBREVIATE. Enter only one cause on a line. Add additional lines if necessary.

	Cause	Approximate interval: Onset to death
IMMEDIATE CAUSE (Final disease or condition resulting in death) ---> a.	Acute respiratory distress syndrome	2 days
	Due to (or as a consequence of):	
Sequentially list conditions, if any, leading to the cause listed on line a. Enter the **UNDERLYING CAUSE** (disease or injury that initiated the events resulting in death) **LAST** b.	Pneumonia	10 days
	Due to (or as a consequence of):	
c.	COVID-19	10 days
	Due to (or as a consequence of):	
d.		

PART II. Enter other significant conditions contributing to death but not resulting in the underlying cause given in PART I

Chronic obstructive pulmonary disease, diabetes, hypertension

33. WAS AN AUTOPSY PERFORMED? ☐ Yes ■ No

34. WERE AUTOPSY FINDINGS AVAILABLE TO COMPLETE THE CAUSE OF DEATH? ☐ Yes ☐ No

35. DID TOBACCO USE CONTRIBUTE TO DEATH?
☐ Yes ☐ Probably
■ No ☐ Unknown

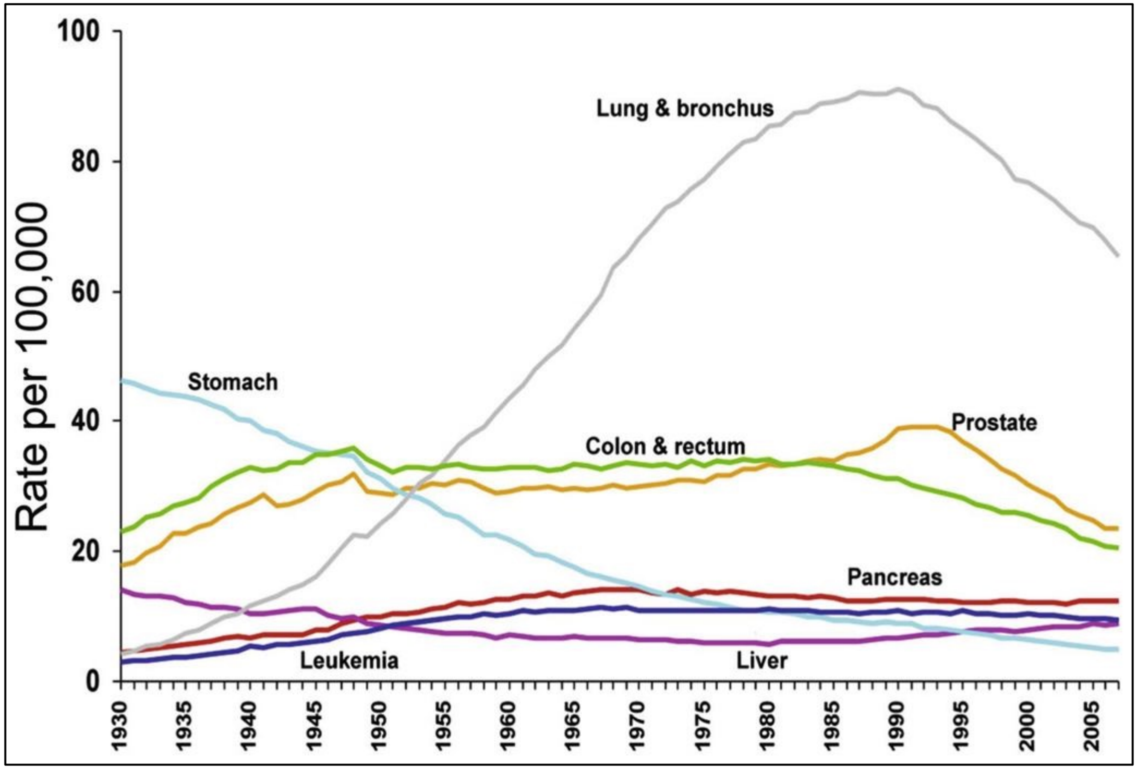
36. IF FEMALE:
■ Not pregnant within past year
☐ Pregnant at time of death
☐ Not pregnant, but pregnant within 42 days of death
☐ Not pregnant, but pregnant 43 days to 1 year before death
☐ Unknown if pregnant within the past year

37. MANNER OF DEATH
■ Natural ☐ Homicide
☐ Accident ☐ Pending Investigation
☐ Suicide ☐ Could not be determined

Chain-of-event condition:
Any ICD-10 code on the same line as or above the COVID-19 listing in Part I (i.e., leading to the cause of death)

Significant contributing condition:
Any ICD-10 code listed in Part II or below the COVID-19 listing in Part I or considered a significant contributing condition (excluding common chain-of-event conditions)

Mortality Surveillance



Cancer death rates for men, 1930-2007

Mortality

Cumulative mortality: incidence proportion (risk), death is the event of interest

=Number of deaths/total population size**

Mortality rate: incidence rate of death

=Number of deaths/person years

Case Fatality= Percentage of people who have the disease of interest that die within a certain time after diagnosis:

$$\frac{\text{(Number of individuals who die during \_\_\_ time after diagnosis)}}{\text{Number of people in population with disease}}$$

Mortality denominators

- Can be challenging to estimate the total population size if the population is changing over time
- For a fixed cohort, or a short time window, can use the total population size
- For an open cohort, or a longer time window, use the mid-year population size as an average
  - This is what we do for annual mortality rates

____-specific mortality

- When interested in understanding the mortality experience of a particular segment of the population (men, women, >65 years)
    - Careful to stratify both the numerator and denominator
- Can also examine cause-specific or disease-specific mortality
- Infant mortality rate is an important metric used to compare health status across different countries

Maternal Mortality

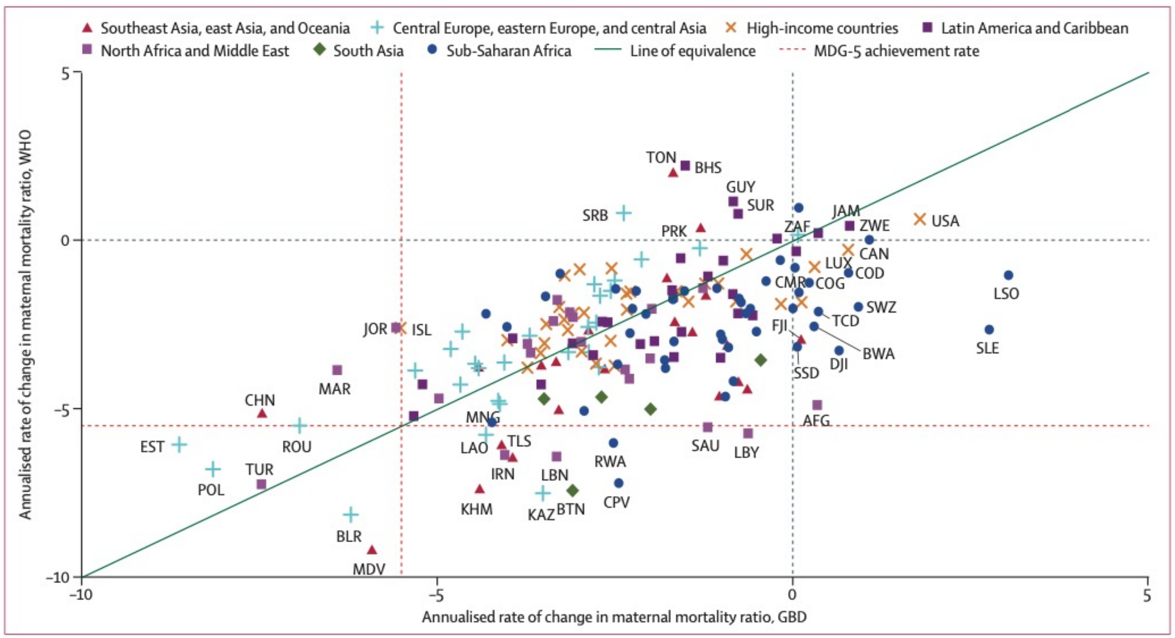


***Figure 9*: Comparison of annualised rate of change (ARC) in maternal mortality ratio (MMR; number of deaths per 100 000 livebirths) from GBD 2015 and MMEIG 2015 for all countries included in both analyses, 1990–2015**

Maternal mortality is defined as a death that occurs to a woman as a direct result of obstetric complications or indirectly as a result of pregnancy-induced exacerbation of pre-existing medical conditions, but not as a result of incidental or accidental causes

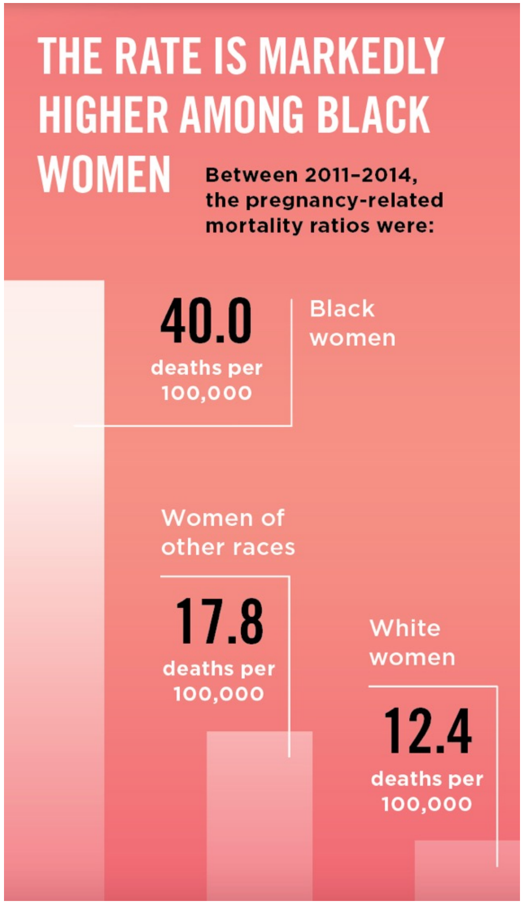
Mortality health disparities

- Measures of mortality are an important indicator of health disparities
  - Health disparities are **preventable differences in the burden of disease or opportunities** to achieve optimal health that are experienced by socially disadvantaged populations
  - Health disparities adversely affect groups of people who have systematically experienced greater obstacles to health
  - Disparities → differences between racial or ethnic groups, but other dimensions as well, such as gender, sexual orientation, age, disability status, socioeconomic status, and geographic location

Health disparities and maternal health

- Reasons for health disparities in maternal health are multifactorial
  - Access to care
  - Poor quality care (monitoring)
  - Socioeconomic variables
  - Racism in clinical assessment and evaluation
    - Undervaluing Black women's experiences and voices

"…their odds of surviving childbirth are comparable to those of women in countries such as Mexico and Uzbekistan, where significant proportions of the population live in poverty…" (WHO)



Serena Williams

"She walked out of the hospital room so her mother wouldn't worry and told the nearest nurse, between gasps, that she needed a CT scan with contrast and IV heparin (a blood thinner) right away. The nurse thought her pain medicine might be making her confused. But Serena insisted, and soon enough a doctor was performing an ultrasound of her legs. "I was like, a Doppler? I told you, I need a CT scan and a heparin drip," she remembers telling the team. The ultrasound revealed nothing, so they sent her for the CT, and sure enough, several small blood clots had settled in her lungs. Minutes later she was on the drip."

Further Reading

Pro-publica and NPR have an excellent article on this topic:

"Lost Mothers"

https://www.propublica.org/article/nothing-protects-black-women-from-dying-in-pregnancy-and-childbirth

Dr. Shalon Irving

Case fatality rate*

- Proportion of individuals with a specific disease who die from that disease

*not an actual rate, more appropriate name would be case fatality ratio

- Denominator is different than mortality rate (# individuals with the disease vs. # individuals in population)

- E.g., case fatality rate from Ebola (2014) was ~50%

Proportionate Mortality

- The *proportionate mortality* is defined as the number of deaths due to a particular cause in a given year divided by the total number of deaths in that year
  = deaths from cause D / deaths from all causes

- Must sum to 100%

	Low-and-middle-income countries			High-income countries		
	Cause	Deaths (millions)	% of total deaths	Cause	Deaths (millions)	% of total deaths
1	Ischaemic heart disease	5·70	11·8%	Ischaemic heart disease	1·36	17·3%
2	Cerebrovascular disease	4·61	9·5%	Cerebrovascular disease	0·78	9·9%
3	Lower respiratory infections	3·41	7·0%	Trachea, bronchus, lung cancers	0·46	5·8%
4	HIV/AIDS	2·55	5·3%	Lower respiratory infections	0·34	4·4%
5	Perinatal conditions	2·49	5·1%	Chronic obstructive pulmonary disease	0·30	3·8%
6	Chronic obstructive pulmonary disease	2·38	4·9%	Colon and rectum cancers	0·26	3·3%
7	Diarrhoeal diseases	1·78	3·7%	Alzheimer's disease and other dementias	0·21	2·6%
8	Tuberculosis	1·59	3·3%	Diabetes mellitus	0·20	2·6%
9	Malaria	1·21	2·5%	Breast cancer	0·16	2·0%
10	Road traffic accidents	1·07	2·2%	Stomach cancer	0·15	1·9%

Table 1: **Ten leading causes of death by income group, 2001**

Proportionate mortality ≠ mortality rate

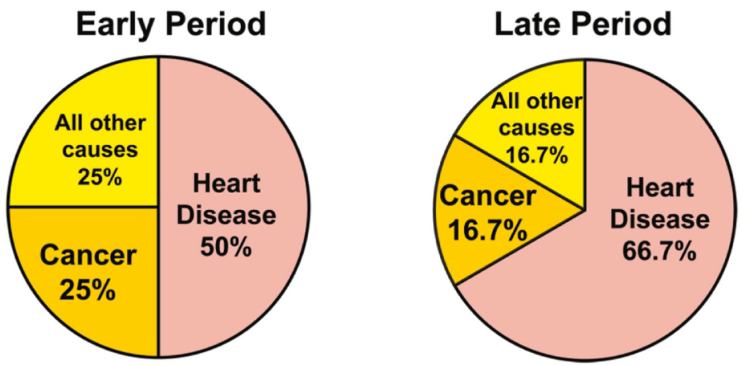
	Community A	Community B
Mortality rate from all causes	30/1,000	15/1,000
Proportionate mortality from heart disease	10%	20%
Mortality rate from heart disease	3/1,000	3/1,000

Is the risk of dying from heart disease in community A 2x higher than in community B?

$=0.10 \times 0.03 = 0.20 \times 0.015$

Factors that affect proportionate mortality

- Changes could be due to increase or decrease in other causes of death
  - Since proportionate mortality sums to 100%



Cause of Death	early period		later period	
	Mortality Rate	Proportionate Mortality	Mortality Rate	Proportionate Mortality
Heart disease	40/1,000	50%	80/1,000	66.7%
Cancer	20/1,000	25%	20/1,000	16.7%
All other causes	20/1,000	25%	20/1,000	16.7%
All deaths	80/1,000	100%	120/1,000	100.0%

Years of Potential Life Lost (YLL)

- Measure of premature mortality used for public health evaluation/policy
- Death occurring in the same person at a younger age involves a greater loss of future productive years than death occurring at an older age

Two step calculation

1. Subtract age of decedent from predetermined benchmark age (in the USA, standard is 75 yrs)
2. Sum the years lost for all members of the population who died from a particular cause

Figure 3: Leading causes of premature death (YLL) and of deaths worldwide, 2001

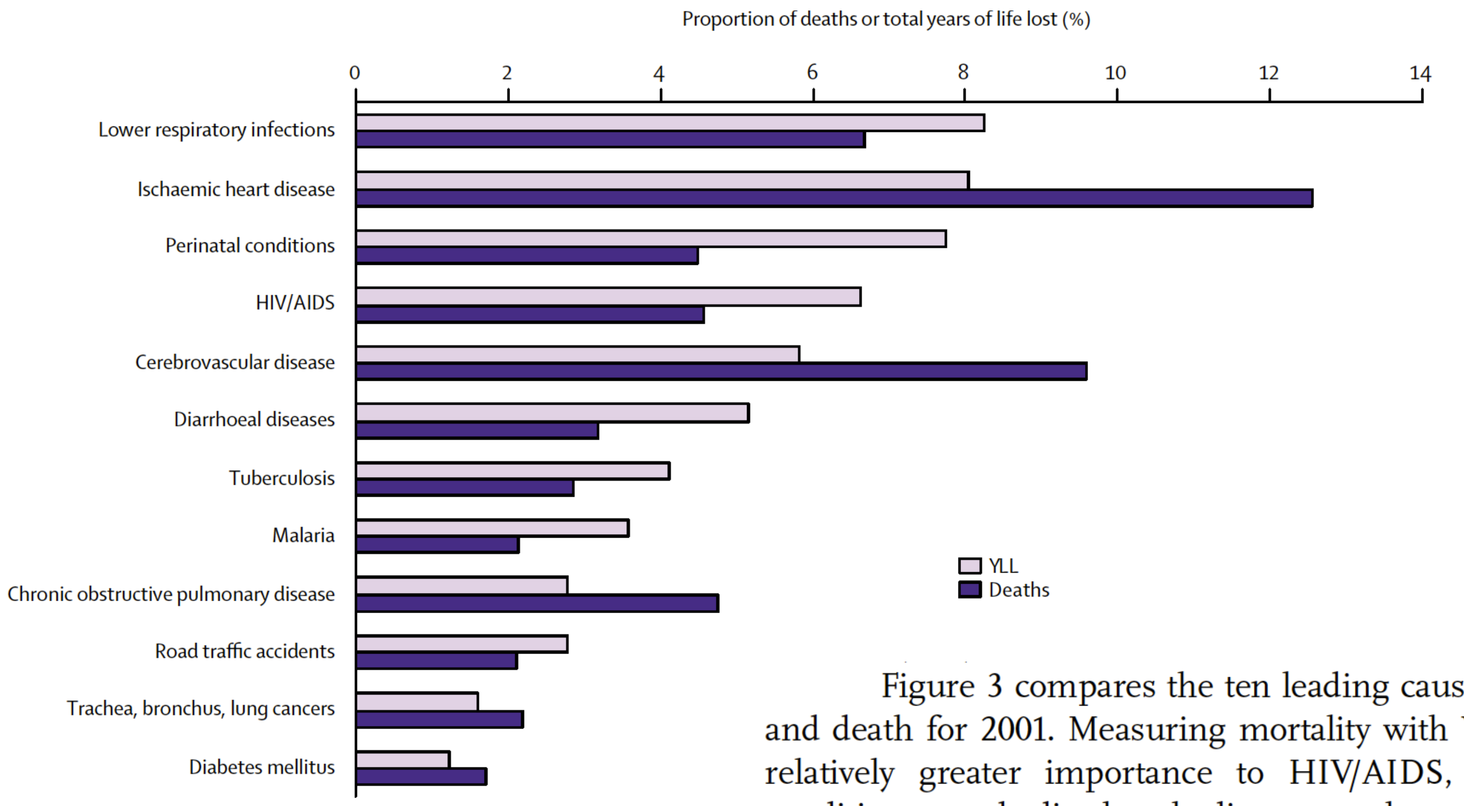


Figure 3 compares the ten leading causes of YLL and death for 2001. Measuring mortality with YLL gives relatively greater importance to HIV/AIDS, perinatal conditions, and diarrhoeal diseases, whereas simple counts of deaths give relatively greater importance to ischaemic heart disease, stroke, and chronic obstructive pulmonary disease, which primarily affect middle-aged and older adults. Sex differences in mortality were also

Purpose of YLL

1. Priority setting – research $ and policies
2. Time trends in premature mortality
3. Program evaluation (decreasing YLL)

FIGURE 1. Years of life lost because of opioid overdose per 100,000 population for Ohio 2010 to 2016. YLL = years of life lost.

Comparing across populations

- What if we want to compare measures of disease occurrence or mortality across populations (or across different time periods?)
- Very common type of question in epidemiologic research
    - Ranking mortality rate for different countries
    - Has the mortality rate in New York State increased or decreased over time?

Direct and Indirect Standardization

Standardization is a set of techniques used to remove the effects of differences when comparing two or more populations.

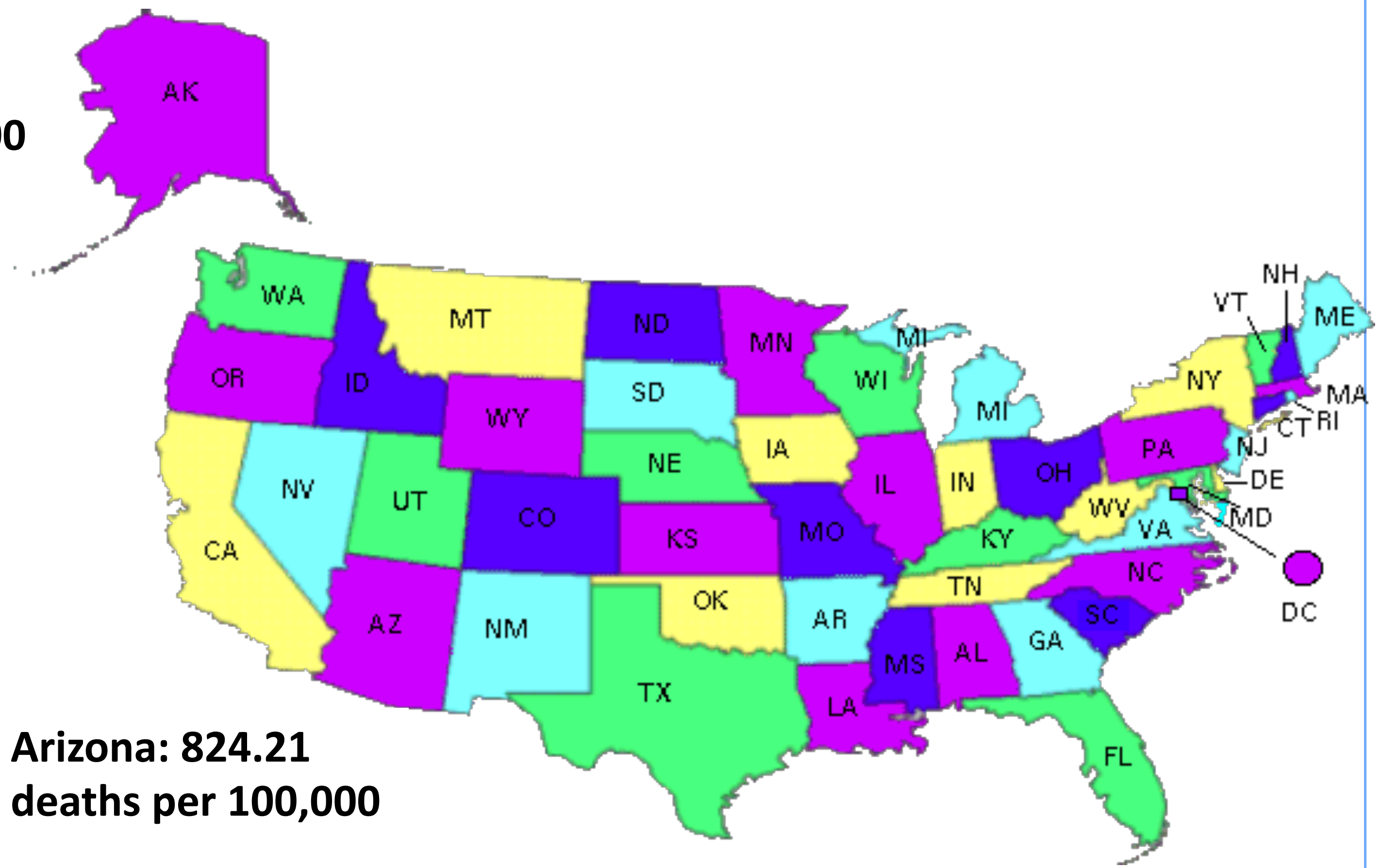
- Will use age as an example for standardization throughout

Direct standardization: Rate of disease/death that would have been observed in the study population if it had the same age distribution as in the standard population

Indirect standardization: Compares the rate of death/disease observed in the population to the expected rate from the standard population

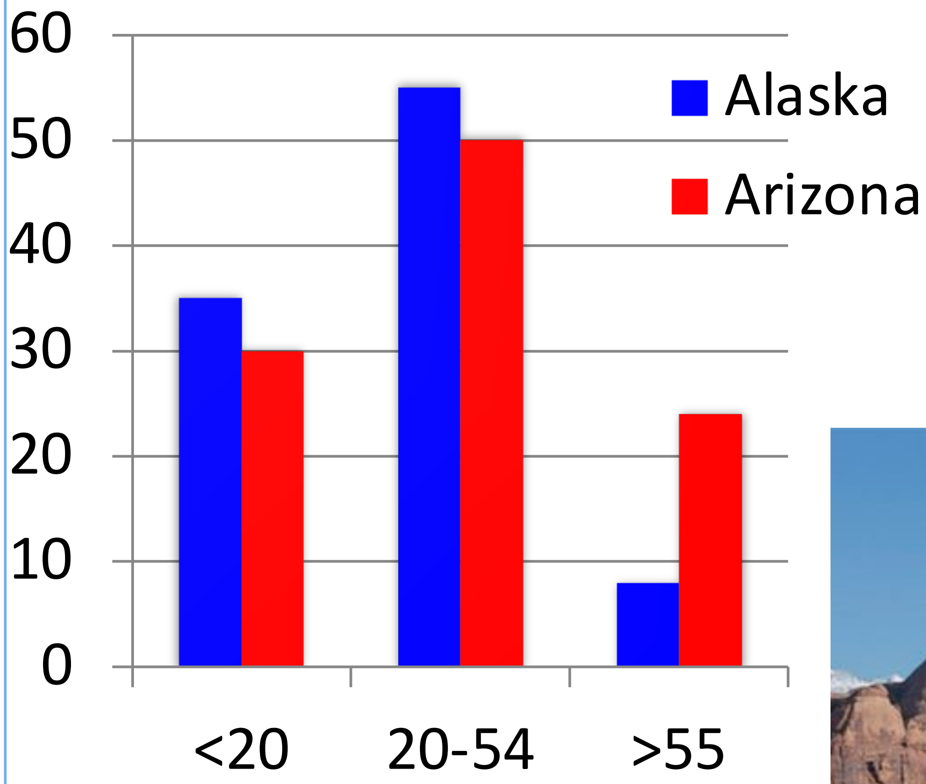
Is it more hazardous to live in Arizona than Alaska?

Alaska: 426.57 deaths per 100,000



Arizona: 824.21 deaths per 100,000

Age Distribution

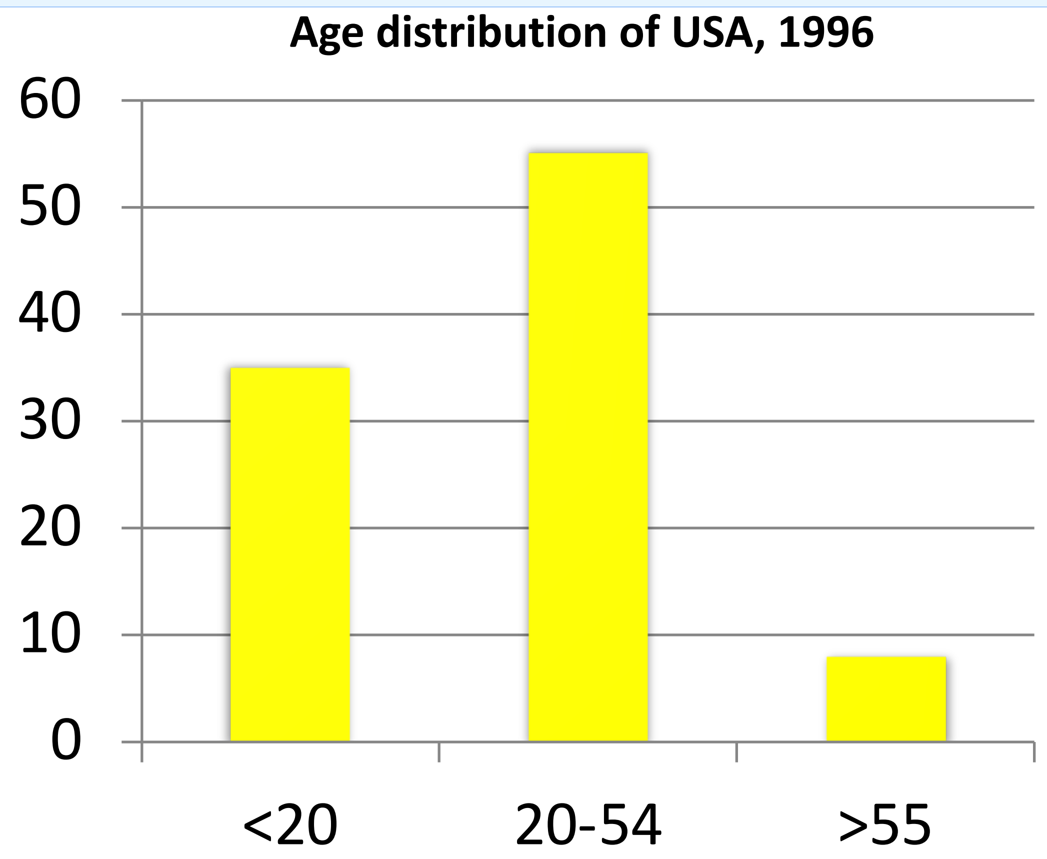


Why standardize?

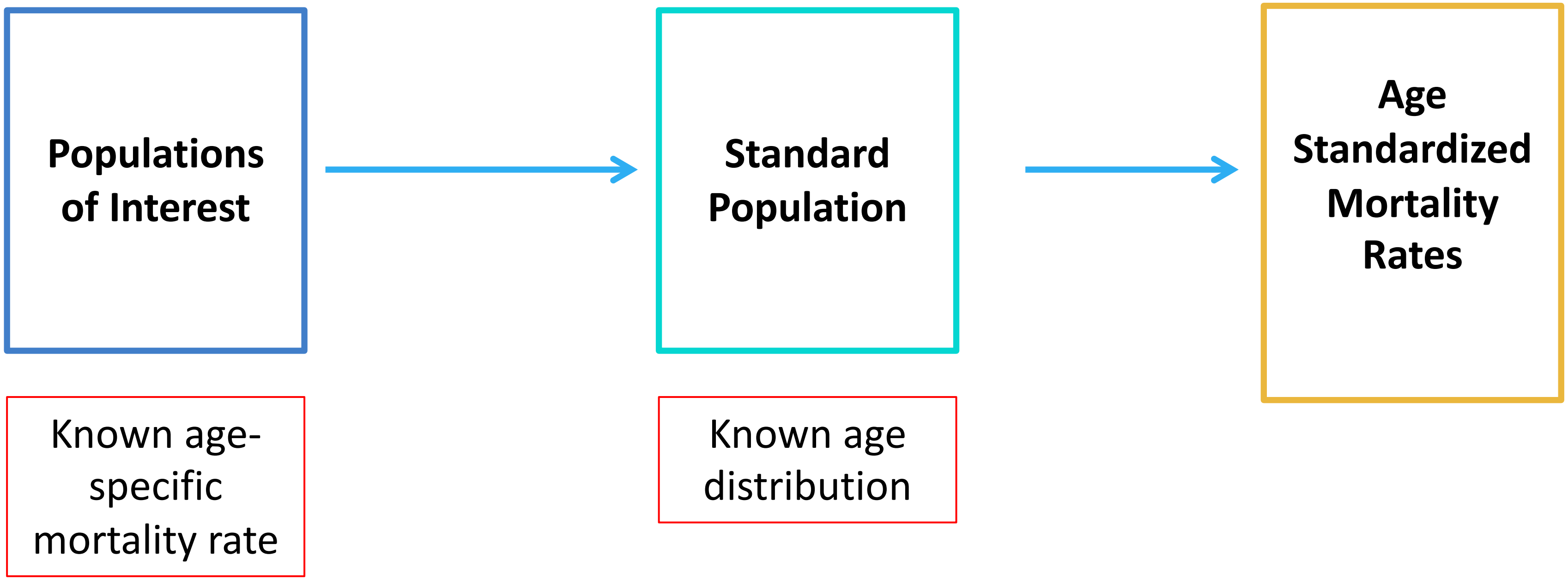
- Age distorts the comparison between populations
- How *can* we compare the death rate in these two populations?
  - Need to use a method to adjust for the effect of age
  - Age-standardization
- Standardization is a general technique that can be used to compare populations that differ (not just for age)

Direct Standardization

- Re-compute rates with a common age distribution
- Use a standard population to remove the effects of any differences in age between the two populations being compared



Direct Standardization



Steps to Direct Standardization

	Population A			Population B		
Age group (years)	Mid-year population	Deaths	Age-specific death rate per 1000	Mid-year population	Deaths	Age-specific death rate per 1000
0-24	18,000	35	1.94	13,000	30	2.31
25-49	11,000	60	5.45	7,000	50	7.14
50-74	9,000	370	41.11	11,000	400	36.36
75 and above	3,000	250	83.33	4,000	380	95.00
Total	41,000	715		35,000	860	
Crude rate per			17.44			24.57

Step 1: Calculate age-specific death rate in both populations for each age group

Population A: Age-specific death rate $_{0\text{-}24yr}$ = (35/18000)= 0.00194

Population B: Age-specific death rate $_{0\text{-}24yr}$ = (30/13000)= 0.00231

(Niang, 2000)

Steps to Direct Standardization

Population A				Population B	
Age group (years)	Reference population per 1000	Age-specific death rate	Expected deaths (Per 1000)	Age-specific death rate per 1000	Expected deaths (Per 1000)
0-24	11,000	1.94	21.34	2.31	25.41
25-49	17,000	5.45	92.65	7.14	121.38
50-74	20,000	41.11	822.20	36.36	727.20
75 and above	3,000	83.33	249.99	95.00	285.00
Total	51,000		1186.18		1158.99

Step 2: Calculate the expected number of deaths per age group

Population A: Expected Deaths $_{0\text{-}24yr}$ = (1.94*11000)= 21,340

Population B: Expected Deaths$_{0\text{-}24yr}$ = (2.31*11000)= 25,410

(Niang, 2000)

Steps to Direct Standardization

Population A				Population B	
Age group (years)	Reference population per 1000	Age-specific death rate	Expected deaths (Per 1000)	Age-specific death rate per 1000	Expected deaths (Per 1000)
0-24	11,000	1.94	21.34	2.31	25.41
25-49	17,000	5.45	92.65	7.14	121.38
50-74	20,000	41.11	822.20	36.36	727.20
75 and above	3,000	83.33	249.99	95.00	285.00
Total	51,000		1186.18		1158.99

Step 3a Add up the expected deaths and divide by standard population size
Population A: 21.34+ 92.65+ 822.20+249.99= 1186.18

Total age adjusted death rate for population A= 1186.18/51,000= 23.3 per 1000

Steps to Direct Standardization

Population A				Population B	
Age group (years)	Reference population per 1000	Age-specific death rate	Expected deaths (Per 1000)	Age-specific death rate per 1000	Expected deaths (Per 1000)
0-24	11,000	1.94	21.34	2.31	25.41
25-49	17,000	5.45	92.65	7.14	121.38
50-74	20,000	41.11	822.20	36.36	727.20
75 and above	3,000	83.33	249.99	95.00	285.00
Total	51,000		1186.18		1158.99

Step 3b: Add up the expected deaths and divide by standard population size

Population B: 25.41+ 121.38+ 727.20+285.00= 1158.99

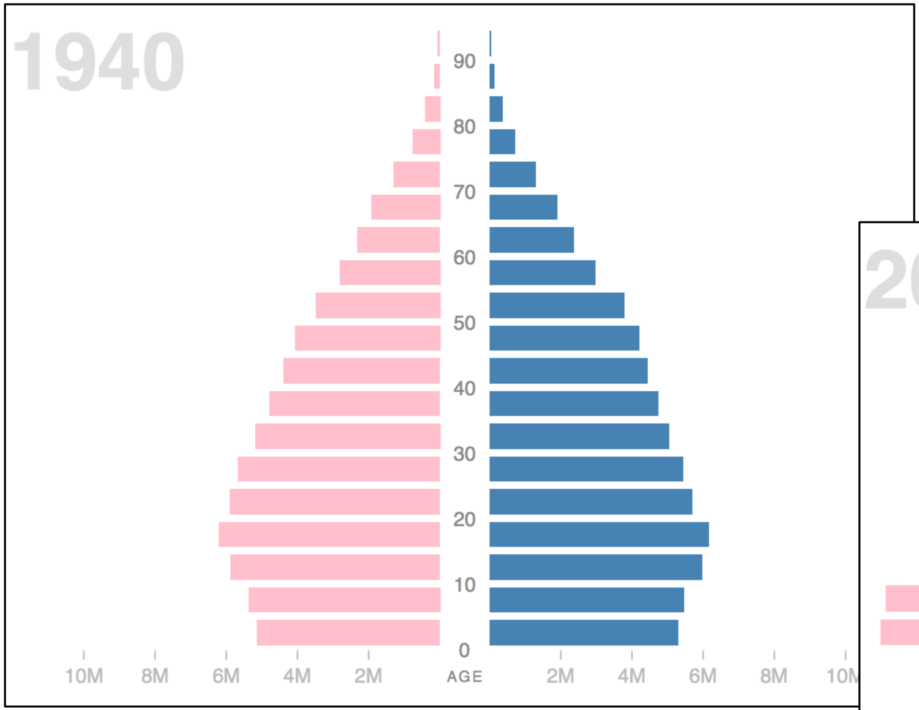
Total age adjusted death rate for population B= 1158.99/51,000= 22.7 per 1000

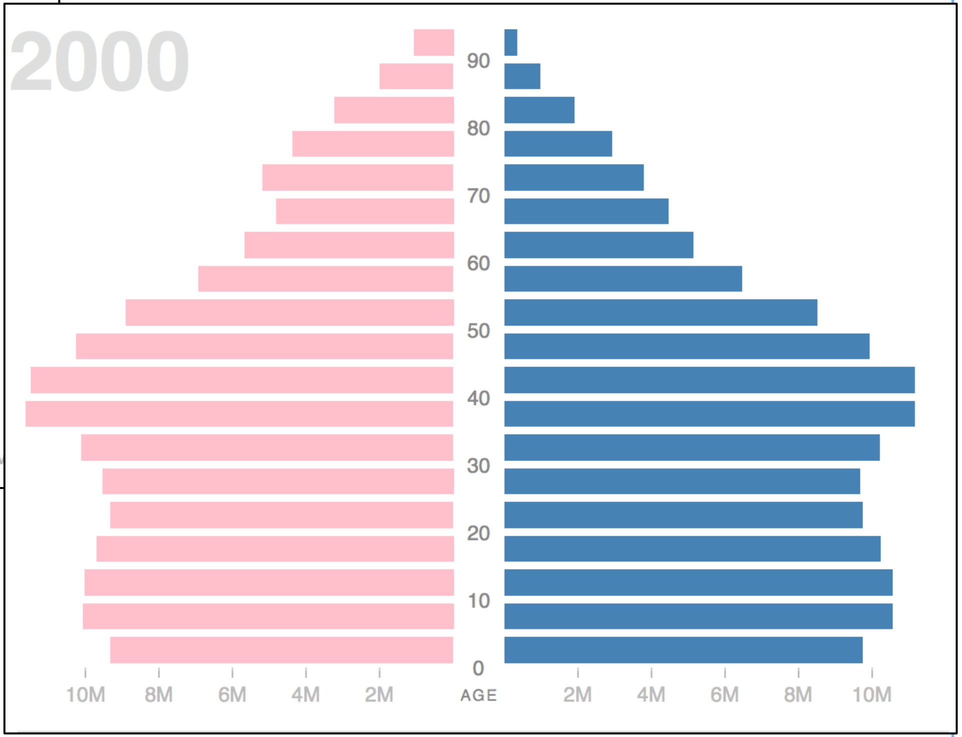
Crude vs. Standardized

Just looking at crude rates can be very misleading!

	Population A (per 1000)	Population B (per 1000)
Crude	17.44	24.57
Standardized	23.30	22.70

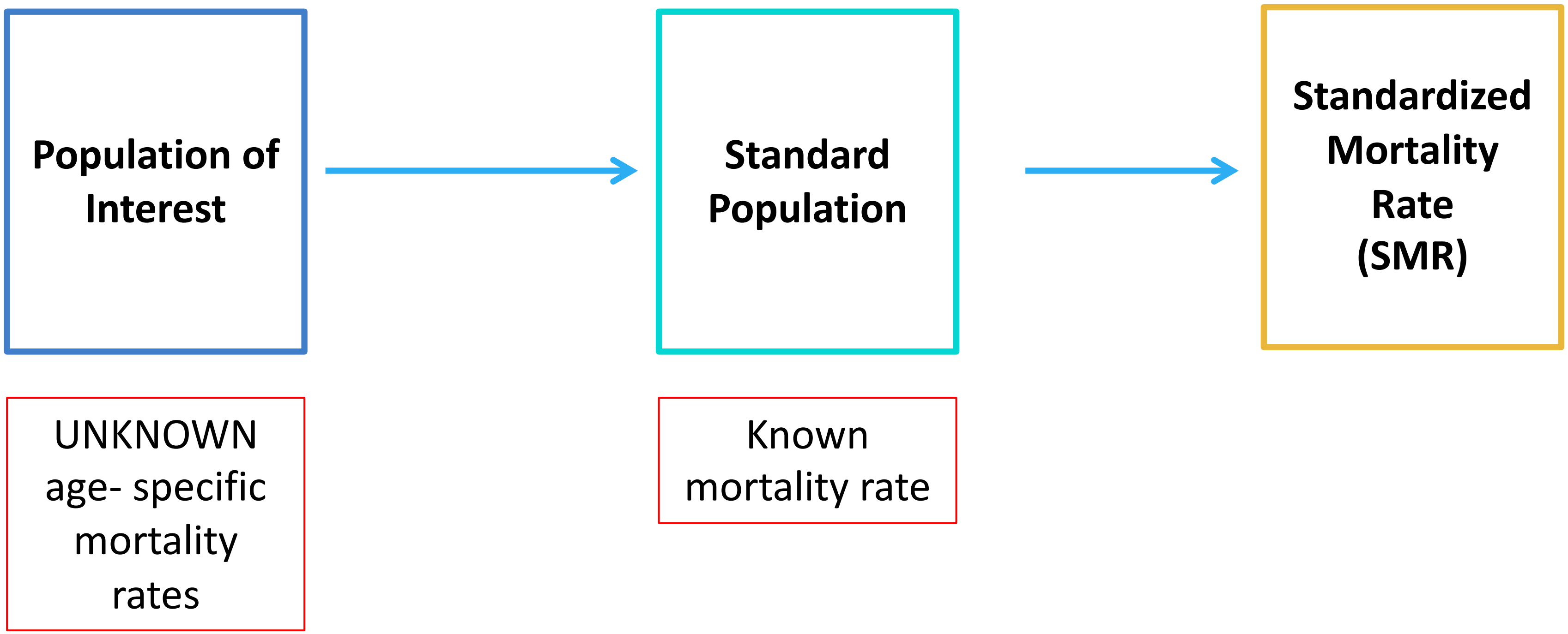
Choosing a Standard Population





Population pyramids by age group and gender

Indirect Standardization



Indirect Standardization

- Used when the age-specific death rates are not known:
  - Do men who work in automobile factories have a higher mortality rate than men in the general population?
  - Do people who were affected by Hurricane Katrina have a higher mortality rate than the general population of Louisiana?

Steps to Indirect Standardization

Observed deaths in population A: 120

Observed deaths in population B: 30

Population A				Population B		
Age group	Population	Age-specific mortality rate deaths per1000	Expected	Population	Age-specific mortality rate per1000	Expected deaths
0-24	2000	4.0	8.0	1000	4.0	4.0
25-49	2500	7.0	17.5	1500	7.0	10.5
50-74	3500	10.0	35.0	2500	10.0	25.0
75+	4500	30.0	135.0	1000	30.0	30.0
Total			195.5			69.5

These age-specific mortality rates are from the standard population

(Niang, 2000)

Steps to Indirect Standardization

Population A				Population B		
Age group	Population	Age-specific mortality rate deaths per1000	Expected	Population	Age-specific mortality rate per1000	Expected deaths
0-24	2000	4.0	8.0	1000	4.0	4.0
25-49	2500	7.0	17.5	1500	7.0	10.5
50-74	3500	10.0	35.0	2500	10.0	25.0
75+	4500	30.0	135.0	1000	30.0	30.0
Total			195.5			69.5

Step 1: Calculate expected deaths in each age group

Population A: Expected deaths $_{0\text{-}24yr}$ = (2000*4.0)= 8,000

Population B: Expected deaths $_{0\text{-}24yr}$ = (1000*4.0)= 4,000

Steps to Indirect Standardization

Population A				Population B		
Age group	Population	Age-specific mortality rate per1000	Expected deaths	Population	Age-specific mortality rate per1000	Expected deaths
0-24	2000	4.0	8.0	1000	4.0	4.0
25-49	2500	7.0	17.5	1500	7.0	10.5
50-74	3500	10.0	35.0	2500	10.0	25.0
75+	4500	30.0	135.0	1000	30.0	30.0
Total			195.5			69.5

Step 2: Sum the expected number of deaths in each population

Population A: Expected deaths= 8.0+ 17.5 + 35.0+ 135.0= 195.5

Population B: Expected deaths= 4.0 + 10.5 + 25.0+ 30.0= 69.5

Steps to Indirect Standardization

Step 3: Calculate the standardized mortality ratio (SMR)

$$SMR = \frac{\text{Total number of deaths in the population}}{\text{Sum of all expected deaths}}$$

Population A:
Observed deaths= 120
Expected deaths= 195.5

SMR= 120/ 195.5 = 0.61

Population B:
Observed deaths = 30
Expected deaths= 69.5

SMR= 30/ 69.5 = 0.43

Life table analysis

- Form of survival analysis where survival times are grouped into intervals (most often age group)
  - Measure of the health of a population - used to calculate life expectancy
  - What is the probability of dying for individuals in a particular age group for a particular interval
- Can be used to calculate:
  - Incidence rates or survival
  - Life expectancy
  - Proportion of individuals still alive

Sample Life Table

Table 1 Life tables of Dutch men of 1900–1910 and 1990–1994. The values are taken from the unabridged life table.[2] Values are in percentages

	1900			1990			
Age	qx	dx	ex	qx	dx	ex	Risk ratio
0	14.0	14.0	50.5	0.7	0.7	74.1	20.4
1–4	6.6	5.7	58.2	0.2	0.2	73.7	35.5
5–14	2.8	2.2	58.3	0.2	0.2	69.8	14.2
15–44	14.7	11.5	49.8	3.0	2.9	59.9	5.3
45–64	30.4	20.2	25.6	15.7	15.1	31.2	2.1
65–74	44.3	20.5	11.6	31.0	25.0	14.5	1.6
75+	100.0	25.8	6.7	100.0	55.8	8.6	1.4

"q_x" is the probability of dying in the age interval. "d_x" is the proportion of deaths in that age interval in the synthetic cohort. "e_x" is the residual life expectancy at the beginning of the age interval. The risk ratio compares the age adjusted risk of dying in 1990, compared with 1900.

No migration, constant birthrate and deathrate

Sample Life Table 1

Table 7-1
Example of an Abridged Life Table

Age Interval Column 1	$_nQ_x$ Column 2	l_x Column 3	$_nd_x$ Column 4	L_x Column 5	T_x Column 6	e Column 7
00-01	0.02592	100000	2592	97408	6892855	68.93
1-5	0.0042	97408	409	387996	6795447	69.76
5-10	0.00232	96999	225	483869	6407451	66.06
10-15	0.00201	96774	195	482897	5923582	61.21
15-20	0.00443	96579	428	480757	5440686	56.33
20-25	0.00611	96151	587	477820	4959928	51.58
25-30	0.00632	95564	604	474800	4482108	46.90
30-35	0.00654	94960	621	471695	4007308	42.20
35-40	0.01098	94339	1036	466516	3535613	37.48
40-45	0.01765	93303	1647	458282	3069097	32.89
45-50	0.02765	91656	2534	445610	2610815	28.48
50-55	0.04387	89122	3910	426061	2165205	24.29
55-60	0.05987	85212	5102	400553	1739144	20.41
60-65	0.09654	80111	7734	361884	1338591	16.71
65-70	0.13654	72377	9882	312472	976707	13.49
70-75	0.18765	62494	11727	253837	664235	10.63
75-80	0.25439	50767	12915	189263	410399	8.08
80-85	0.37887	37853	14341	117557	221135	5.84
85-90	0.47898	23511	11261	61250	103578	4.41
90-95	0.57908	12250	7094	25781	42329	3.46
95+	1	5156	5156	16548	16548	3.21

1. Age interval, x to x+n: Age interval between exact ages for each row of the life table

2. $_nQ_x$: The proportion of the population in each age interval that are alive at the beginning of the interval, and dead before reaching the end of the interval.

--Computed from the observed mortality rates of an actual population.

Sample Life Table 2

Table 7-1
Example of an Abridged Life Table

Age Interval Column 1	$_nQ_x$ Column 2	l_x Column 3	$_nd_x$ Column 4	L_x Column 5	T_x Column 6	e Column 7
00-01	0.02592	100000	2592	97408	6892855	68.93
1-5	0.0042	97408	409	387996	6795447	69.76
5-10	0.00232	96999	225	483869	6407451	66.06
10-15	0.00201	96774	195	482897	5923582	61.21
15-20	0.00443	96579	428	480757	5440686	56.33
20-25	0.00611	96151	587	477820	4959928	51.58
25-30	0.00632	95564	604	474800	4482108	46.90
30-35	0.00654	94960	621	471695	4007308	42.20
35-40	0.01098	94339	1036	466516	3535613	37.48
40-45	0.01765	93303	1647	458282	3069097	32.89
45-50	0.02765	91656	2534	445610	2610815	28.48
50-55	0.04387	89122	3910	426061	2165205	24.29
55-60	0.05987	85212	5102	400553	1739144	20.41
60-65	0.09654	80111	7734	361884	1338591	16.71
65-70	0.13654	72377	9882	312472	976707	13.49
70-75	0.18765	62494	11727	253837	664235	10.63
75-80	0.25439	50767	12915	189263	410399	8.08
80-85	0.37887	37853	14341	117557	221135	5.84
85-90	0.47898	23511	11261	61250	103578	4.41
90-95	0.57908	12250	7094	25781	42329	3.46
95+	1	5156	5156	16548	16548	3.21

3. l_x: The number of persons alive at the beginning of the age interval

4. $_nd_x$: The number of persons dying during the age interval

5. L_x: The total number of person-years in the stationary population for each age interval. It can be viewed as the average midyear population size

Sample Life Table 3

Table 7-1
Example of an Abridged Life Table

Age Interval Column 1	$_nQ_x$ Column 2	l_x Column 3	$_nd_x$ Column 4	L_x Column 5	T_x Column 6	e Column 7
00-01	0.02592	100000	2592	97408	6892855	68.93
1-5	0.0042	97408	409	387996	6795447	69.76
5-10	0.00232	96999	225	483869	6407451	66.06
10-15	0.00201	96774	195	482897	5923582	61.21
15-20	0.00443	96579	428	480757	5440686	56.33
20-25	0.00611	96151	587	477820	4959928	51.58
25-30	0.00632	95564	604	474800	4482108	46.90
30-35	0.00654	94960	621	471695	4007308	42.20
35-40	0.01098	94339	1036	466516	3535613	37.48
40-45	0.01765	93303	1647	458282	3069097	32.89
45-50	0.02765	91656	2534	445610	2610815	28.48
50-55	0.04387	89122	3910	426061	2165205	24.29
55-60	0.05987	85212	5102	400553	1739144	20.41
60-65	0.09654	80111	7734	361884	1338591	16.71
65-70	0.13654	72377	9882	312472	976707	13.49
70-75	0.18765	62494	11727	253837	664235	10.63
75-80	0.25439	50767	12915	189263	410399	8.08
80-85	0.37887	37853	14341	117557	221135	5.84
85-90	0.47898	23511	11261	61250	103578	4.41
90-95	0.57908	12250	7094	25781	42329	3.46
95+	1	5156	5156	16548	16548	3.21

6. T_x: The total number of person-years that would be lived for a particular age cohort if the cohort were to progress through the remainder of the life table. It is the cumulative sum of the $_nL_x$ values.

7. e: Average number of years of life remaining for a person alive at the beginning of age interval x

Sample life table calculations

Table 3.2.1: Life Table Construction: 1960 Costa Rican Males

(1)	Age-specific death rate	(2)	(3)	(4)	(5)	(6)	(7)
Age Interval	$_nm_x$	$_nq_x$	l_x	$_nd_x$	$_nL_x$	T_x	e_x^0
<1 year	0.07505	0.07230	100,000	7,230	96,340	6,297,331	62.97331
1-4	0.00701	0.02765	92,770	2,566	365,924	6,200,991	66.84287
5-9	0.00171	0.00851	90,204	768	449,098	5,835,067	64.68736
10-14	0.00128	0.00636	89,436	569	445,757	5,385,970	60.22141
15-19	0.00129	0.00641	88,867	570	442,912	4,940,212	55.59081

Steps:

1. Calculate $_nq_x$ (proportion dying in the age interval)

For age interval 0-1:
n = 1
Age-specific death rate ($_1m_0$) = .07505

$_1q_0 = 1 - e^{-.07505}$ = 0.072303

For age interval 1-4:
n = 4
Age-specific death rate ($_4m_1$) = 0.00701

$_4q_1 = 1 - e^{-4*0.00701}$ = 0.027651

Sample life table calculations

Table 3.2.1: Life Table Construction: 1960 Costa Rican Males

(1)	Age-specific death rate (2)	(2)	(3)	(4)	(5)	(6)	(7)
Age Interval	$_nm_x$	$_nq_x$	l_x	$_nd_x$	$_nL_x$	T_x	e_x^0
<1 year	0.07505	0.07230	100,000	7,230	96,340	6,297,331	62.97331
1-4	0.00701	0.02765	92,770	2,566	365,924	6,200,991	66.84287
5-9	0.00171	0.00851	90,204	768	449,098	5,835,067	64.68736
10-14	0.00128	0.00636	89,436	569	445,757	5,385,970	60.22141
15-19	0.00129	0.00641	88,867	570	442,912	4,940,212	55.59081

Steps:

2. Use $_nq_x$ to compute l_x

(The number of persons alive at the beginning of the age interval)

First set $l_0 = 100{,}000$

Then $l_1 = l_0 * (1 - {}_1q_0)$

$$l_1 = l_0 * (1 - {}_1q_0) = 100000 * (1 - .072303) = 92770$$

3. Calculate the number of deaths in age intervals ($_nd_x$) in Column 4 as:

$$_nd_x = l_x * {}_nq_x \text{ (Column 3 * Column 2)}$$

$$_1d_0 = l_0 * {}_1q_0 = 100000 * .072303 = 7230$$

Sample life table calculations

Table 3.2.1: Life Table Construction: 1960 Costa Rican Males

(1) Age Interval	(2) Age-specific death rate $_nm_x$	(2) $_nq_x$	(3) l_x	(4) $_nd_x$	(5) $_nL_x$	(6) T_x	(7) e_x^0
<1 year	0.07505	0.07230	100,000	7,230	96,340	6,297,331	62.97331
1-4	0.00701	0.02765	92,770	2,566	365,924	6,200,991	66.84287
5-9	0.00171	0.00851	90,204	768	449,098	5,835,067	64.68736
10-14	0.00128	0.00636	89,436	569	445,757	5,385,970	60.22141
15-19	0.00129	0.00641	88,867	570	442,912	4,940,212	55.59081

Steps:

4. Compute the person-years of life in the indicated age interval ($_nL_x$)

$$_nL_x = \frac{_nd_x}{_nm_x}$$ (Column 4 / age-specific death rate)

$$_1L_0 = \frac{_1d_0}{_1m_0} = \frac{7230}{.07505} = 96340$$

Sample life table calculations

Table 3.2.1: Life Table Construction: 1960 Costa Rican Males						
(1)	Age-specific death rate	(2)	(3)	(4)	(5)	(6)	(7)
Age Interval	$_nm_x$	$_nq_x$	l_x	$_nd_x$	$_nL_x$	T_x	e_x^0
<1 year	0.07505	0.07230	100,000	7,230	96,340	6,297,331	62.97331
1-4	0.00701	0.02765	92,770	2,566	365,924	6,200,991	66.84287
5-9	0.00171	0.00851	90,204	768	449,098	5,835,067	64.68736
10-14	0.00128	0.00636	89,436	569	445,757	5,385,970	60.22141
15-19	0.00129	0.00641	88,867	570	442,912	4,940,212	55.59081

5. In Column 6, compute the cumulative person-years of life after a specified age (T_x):

$$T_x = \sum_{x}^{\text{End of table}} {}_nL_n$$

(Sum values in Column 6 from a specified age to the end of the table.)

Sample life table calculations

Table 3.2.1: Life Table Construction: 1960 Costa Rican Males

(1)	Age-specific death rate	(2)	(3)	(4)	(5)	(6)	(7)
Age Interval	$_nm_x$	$_nq_x$	l_x	$_nd_x$	$_nL_x$	T_x	e_x^0
<1 year	0.07505	0.07230	100,000	7,230	96,340	6,297,331	62.97331
1-4	0.00701	0.02765	92,770	2,566	365,924	6,200,991	66.84287
5-9	0.00171	0.00851	90,204	768	449,098	5,835,067	64.68736
10-14	0.00128	0.00636	89,436	569	445,757	5,385,970	60.22141
15-19	0.00129	0.00641	88,867	570	442,912	4,940,212	55.59081

6. The final column of the life table (Column 7) is the expectation of life at specified ages

$$e_x^0 = \frac{T_x}{l_x}$$ (Column 6 / Column 3)

$$e_0^0 = \frac{T_0}{l_0} = \frac{6297007}{100000} = 62.97$$

Other calculations

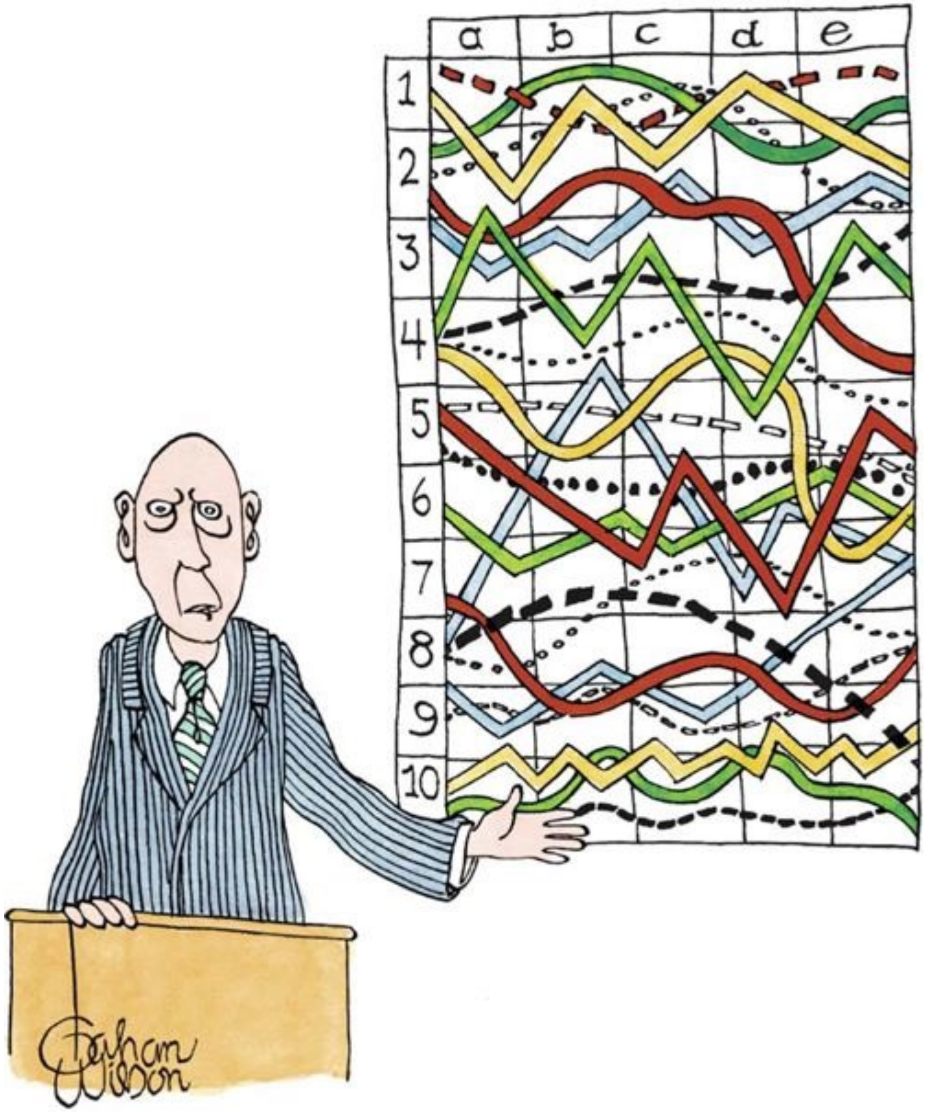
- Life tables can also be used to calculate:
  - Risk = # deaths in an interval/ # individuals at risk
  - Survival (p_t) = 1-risk
  - Cumulative survival (P_t) = product of survival probabilities for each age interval

$P_1 = 1.0$
$P_2 = p_1 * P_1$
$P_3 = p_2 * P_2$
$P_4 = p_3 * P_3$

$0.9 \times 1.0 = 0.9$

$0.83 \times 0.9 = 0.747$

Interval	l_t	d_t	q_t	p_t	P_t
1	200	20	0.1	0.9	1.0
2	180	30	0.17	0.83	0.9
3	150	40	0.27	0.73	0.747
	0.73 x 0.747 = 0.545				0.545



"I'll pause for a moment so you can let this information sink in."

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