Biostatistics

Week #3 (3/17/2020)

Chapter 4 Rates and Standardization

Introduction

- Two important categories are commonly referred in describing the health status of a population:
  - **Demographic (人口統計學的) data**: size of the population and its composition by gender, race and age.
  - **Vital statistics**: births, deaths, marriages, divorces and **occurrence of disease**.

…including population **density**, **ethnicity (種族)**, **education level**, **health** of the populace (民眾), economic status, religious affiliations and other aspects of the population.

Cont'd

- One case in interpreting those statistics, we may need to compare, for example, the **death count of 1991** vs the **death count in 1992**.
- If there were 100 deaths in 1991, and 110 deaths in 1992, can we say that there were ***more*** deaths in 1992? (These are called the **raw numbers** of death.)
- To be more precise, what would be in your mind when using the phrase "more deaths"?

4.1 Rates

- While rate is normally interpreted as the change of a given physical quantity (e.g., movement along x-axis in kilometer) per unit time (e.g., in one hour), it is also useful in population statistics.
- Here a ***rate*** is defined as the number of cases of a particular outcome of interest (e.g., death) that occur **over a given period of time** divided by **the size of the population** in that time period.

Mortality (or Death) Rate

- The number of deaths that occur during some time period (e.g., a calendar year) divided by the **total population *at risk*** during that period of time.
  - The denominator (分母 or 除數) is "total population **at risk**", not "total population".
  - For example, the mortality rate for one particular cause, such as lung cancer or influenza infection, etc.
- For example, the mortality rate in 1991 in US is 860.3 per 100,000 population.

Mortality vs Morbidity

- **Morbidity** refers to the disease state of an individual, or *the incidence of illness in* a population. [more specific to a given disease]
- **Mortality** refers to the state of being mortal, or *the incidence of death* (number of deaths) in a population.

Infant Mortality Rate

- The other example is the "**infant mortality rate**" – the number of deaths during a calendar year among infants (< 1 yr) divided by the **total number of live births** during that year.
- That is, ***all infants are "at risk"*** of mortality when are less than 1 year old.

Table 4.1 – Infant mortality **rates** for selected countries, 1992

Nation	Mortality Rate per 1,000 Live Births
Australia	7
Brazil	54
Canada	7
China	35
Ethiopia	123
France	7
India	83
Japan	4
USA	9

- While the rates shown in Table 4.1 (called **crude rates**) provide **a summary measure for an entire population**; they disregard differences caused by age, gender, race, and other characteristics.
- More often showing rates based on *specific grouping* will be more useful than simply seeing one crude rate. (See Table 4.2 for example)

TABLE 4.2
Total deaths and death rates by age, race, and sex, United States, 1992

Age	All Races			White		
	Both Sexes	Male	Female	Both Sexes	Male	Female
	Number					
All ages	2,175,613	1,122,336	1,053,277	1,873,781	956,957	916,824
Under 1 year	34,628	19,545	15,083	22,164	12,625	9539
1–4 years	6764	3809	2955	4685	2690	1995
5–9 years	3739	2231	1508	2690	1605	1085
10–14 years	4454	2849	1605	3299	2093	1206
15–19 years	14,411	10,747	3664	10,308	7440	2888
20–24 years	20,137	15,460	4677	14,033	10,696	3337
25–29 years	24,314	18,032	6282	17,051	12,825	4226
30–34 years	34,167	24,863	9304	24,450	18,210	6240
35–39 years	42,089	29,641	12,448	30,127	21,690	8437
40–44 years	49,201	33,354	15,847	35,886	24,726	11,160
45–49 years	56,533	36,622	19,911	43,451	28,343	15,108
50–54 years	68,497	42,649	25,848	53,689	33,681	20,008
55–59 years	94,582	58,083	36,499	75,750	47,042	28,708
60–64 years	146,409	88,797	57,612	122,213	74,994	47,219
65–69 years	211,071	124,228	86,843	180,788	107,427	73,361
70–74 years	266,845	149,937	116,908	234,117	132,273	101,844
75–79 years	301,736	158,257	143,479	270,238	142,422	127,816
80–84 years	308,116	141,640	166,476	279,507	128,484	151,023
85 years and over	487,446	161,236	326,210	448,984	147,419	301,565
Not stated	474	356	118	351	272	79
	Death rate					
All ages	852.9	901.6	806.5	880.0	917.2	844.3
Under 1 year	865.7	956.6	770.8	701.8	780.9	618.7
1–4 years	43.6	48.0	39.0	38.1	42.6	33.3
5–9 years	20.4	23.7	16.8	18.3	21.3	15.2
10–14 years	24.6	30.7	18.2	22.8	28.2	17.2
15–19 years	84.3	122.4	44.0	75.6	106.0	43.3
20–24 years	105.7	159.4	50.1	91.0	135.4	44.3
25–29 years	120.5	178.0	62.5	103.2	153.3	51.9
30–34 years	153.5	224.0	83.3	132.4	195.8	68.1
35–39 years	199.5	282.8	117.2	171.2	245.5	96.3
40–44 years	261.6	359.1	166.5	226.3	312.2	140.6
45–49 years	368.0	485.7	254.6	328.6	432.5	226.5
50–54 years	568.2	728.1	417.1	518.6	663.4	379.3
55–59 years	902.1	1156.5	668.2	835.1	1071.5	613.4
60–64 years	1402.2	1815.2	1038.2	1334.9	1729.7	979.7
65–69 years	2114.8	2775.4	1577.7	2042.6	2688.5	1511.0
70–74 years	3146.8	4109.3	2419.9	3073.0	4012.4	2356.4
75–79 years	4705.9	6202.4	3716.8	4662.2	6148.8	3672.7
80–84 years	7429.1	9726.0	6186.1	7391.0	9700.5	6146.1
85 years and over	14,972.9	17,740.4	13,901.0	15,104.2	17,956.2	14,015.9

TABLE 4.2
(Continued)

Age	Black			American Indian			Asian or Pacific Islander		
	Both Sexes	Male	Female	Both Sexes	Male	Female	Both Sexes	Male	Female
	Number								
All ages	269,219	146,630	122,589	8953	5181	3772	23,660	13,568	10,092
Under 1 year	11,348	6298	5050	393	221	172	723	401	322
1–4 years	1799	965	834	127	67	60	153	87	66
5–9 years	894	529	365	54	33	21	101	64	37
10–14 years	982	633	349	61	48	13	112	75	37
15–19 years	3583	2923	660	206	155	51	314	229	85
20–24 years	5399	4246	1153	279	212	67	426	306	120
25–29 years	6559	4695	1864	293	228	65	411	284	127
30–34 years	8836	6083	2753	378	253	125	503	317	186
35–39 years	10,965	7308	3657	403	272	131	594	371	223
40–44 years	12,213	7949	4264	366	246	120	736	433	303
45–49 years	11,753	7493	4260	431	280	151	898	506	392
50–54 years	13,252	8021	5231	487	308	179	1069	639	430
55–59 years	16,727	9824	6903	668	392	276	1437	825	612
60–64 years	21,669	12,380	9289	719	408	311	1808	1015	793
65–69 years	27,011	14,946	12,065	818	454	364	2454	1401	1053
70–74 years	29,124	15,580	13,544	849	457	392	2755	1627	1128
75–79 years	27,875	13,782	14,093	799	422	377	2824	1631	1193
80–84 years	25,260	11,253	14,007	721	354	367	2628	1549	1079
85 years and over	33,856	11,646	22,210	900	370	530	3706	1801	1905
Not stated	114	76	38	1	1	—	8	7	1
	Death rate								
All ages	850.5	977.5	736.2	417.7	487.7	348.9	283.1	332.7	235.8
Under 1 year	1786.0	1957.9	1609.7	939.2	1057.5	821.2	439.8	477.7	400.2
1–4 years	73.2	77.6	68.7	72.0	74.7	69.3	26.9	29.9	23.8
5–9 years	32.1	37.5	26.6	25.1	30.1	19.8	15.4	19.1	11.5
10–14 years	35.3	44.9	25.4	28.3	44.0	*	16.9	22.2	11.3
15–19 years	135.5	218.4	50.5	110.8	163.7	55.9	49.7	70.6	27.6
20–24 years	200.7	321.0	84.3	149.7	218.0	75.2	57.4	80.8	33.1
25–29 years	241.3	361.7	131.3	160.2	245.2	72.4	53.8	75.4	32.8
30–34 years	316.0	464.4	185.2	203.2	275.3	132.8	61.4	79.9	44.1
35–39 years	427.0	609.6	267.1	240.8	334.0	152.4	77.6	101.5	55.8
40–44 years	570.7	803.2	370.7	257.3	355.9	164.1	110.4	139.6	85.0
45–49 years	762.4	1065.7	508.0	391.5	522.4	267.3	184.9	219.6	153.5
50–54 years	1054.9	1419.3	757.0	577.6	759.7	408.9	295.2	366.5	229.0
55–59 years	1579.0	2103.6	1165.4	997.2	1229.3	786.3	500.4	620.6	396.8
60–64 years	2204.1	2924.3	1659.5	1303.7	1574.4	1063.8	729.6	948.4	563.3
65–69 years	3075.9	4029.1	2378.8	1819.9	2219.3	1486.3	1189.4	1576.7	896.4
70–74 years	4278.6	5724.9	3315.3	2541.5	3145.9	2076.5	1872.3	2486.2	1380.5
75–79 years	5596.3	7502.0	4482.7	3434.9	4410.5	2753.2	3001.3	3882.7	2290.5
80–84 years	8400.8	10,969.8	7070.5	5133.1	6753.1	4168.6	5156.3	6461.7	3997.0
85 years and over	14,278.6	16,717.1	13,264.1	7726.0	9381.3	6878.7	10,841.3	12,628.8	9561.8

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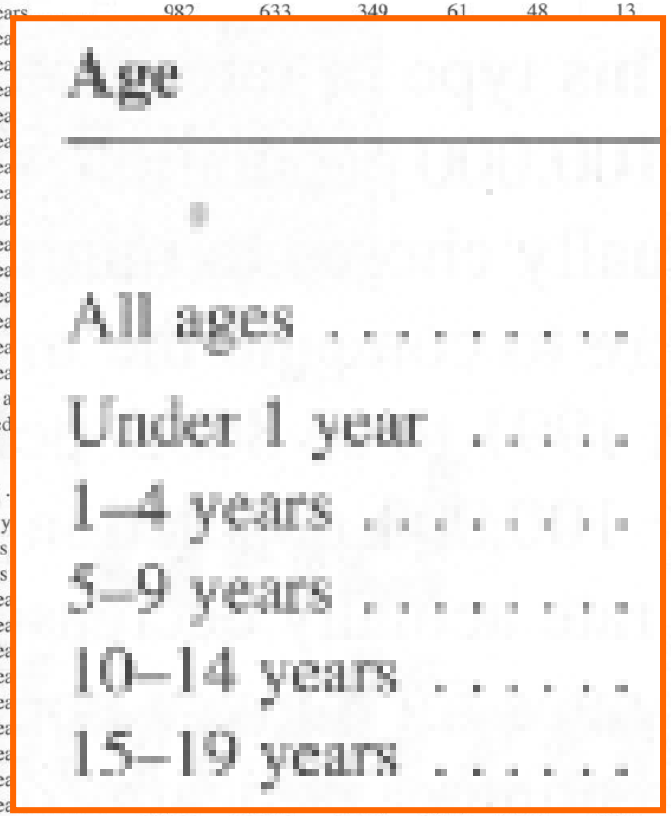
75–79 years							2824	1631	1193
80–84 years							2628	1549	1079
85 years and over							3706	1801	1905
Not stated							8	7	1
All ages							283.1	332.7	235.8
Under 1 year							439.8	477.7	400.2
1–4 years							26.9	29.9	23.8
5–9 years							15.4	19.1	11.5
10–14 years							16.9	22.2	11.3
15–19 years							49.7	70.6	27.6
20–24 years							57.4	80.8	33.1
25–29 years							53.8	75.4	32.8
30–34 years							61.4	79.9	44.1
35–39 years							77.6	101.5	55.8
40–44 years							110.4	139.6	85.0
45–49 years							184.9	219.6	153.5
50–54 years							295.2	366.5	229.0
55–59 years	1579.0	2103.6	1165.4	997.2	1229.3	786.3	500.4	620.6	396.8
60–64 years	2204.1	2924.3	1659.5	1303.7	1574.4	1063.8	729.6	948.4	563.3
65–69 years	3075.9	4029.1	2378.8	1819.9	2219.3	1486.3	1189.4	1576.7	896.4
70–74 years	4278.6	5724.9	3315.3	2541.5	3145.9	2076.5	1872.3	2486.2	1380.5
75–79 years	5596.3	7502.0	4482.7	3434.9	4410.5	2753.2	3001.3	3882.7	2290.5
80–84 years	8400.8	10,969.8	7070.5	5133.1	6753.1	4168.6	5156.3	6461.7	3997.0
85 years and over	14,278.6	16,717.1	13,264.1	7726.0	9381.3	6878.7	10,841.3	12,628.8	9561.8



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45–49 years	762.4	1065.7	508.0	391.5	522.4	267.3	184.9	219.6	153.5
50–54 years	1054.9	1419.3	757.0	577.6	759.7	408.9	295.2	366.5	229.0
55–59 years	1579.0	2103.6	1165.4	997.2	1229.3	786.3	500.4	620.6	396.8
60–64 years	2204.1	2924.3	1659.5	1303.7	1574.4	1063.8	729.6	948.4	563.3
65–69 years	3075.9	4029.1	2378.8	1819.9	2219.3	1486.3	1189.4	1576.7	896.4
70–74 years	4278.6	5724.9	3315.3	2541.5	3145.9	2076.5	1872.3	2486.2	1380.5
75–79 years	5596.3	7502.0	4482.7	3434.9	4410.5	2753.2	3001.3	3882.7	2290.5
80–84 years	8400.8	10,969.8	7070.5	5133.1	6753.1	4168.6	5156.3	6461.7	3997.0
85 years and over	14,278.6	16,717.1	13,264.1	7726.0	9381.3	6878.7	10,841.3	12,628.8	9561.8

All Races
White
Both Sexes
Male
Female
Both Sexes
Male
Female

Total deaths and death rates by age, race and sex in US, 1992

	All Races			White			Black			Am In			As / PI		
Age	Both sexes	Male	Female												
All ages															
Under 1															
1~4 years															
5~9 years															
…															
85 & older															

Am In : American Indian
As & PI: Asian & Pacific Islander

4.2 Standardizing Rates

- We see from Table 4.2 that in some cases rate comparison based on specific grouping can better describe the vital statistics than a crude rate.
- When crude rates are *compared*, however, the difference in underlying populations (age, sex, etc.) may alter the **true relationship** that is displayed from the crude rates themselves. (We will later call these (age, sex, etc.) **confounding variables**, or simply **confounders**.)

Confounding Variables

- **Confounding variables** are two variables that are **confounded**[1] when their effects on a response variable cannot be distinguished from each other.

[1] to confuse and surprise somebody

http://score.kings.k12.ca.us/lessons/wwwstats/confounding.variables.html

- For example, a soccer coach wanted to improve the team's playing ability, so he had them **run** two miles a day.
- At the same time the players decided to **take vitamins**.
- In two weeks the team was playing noticeably better, but the coach and players did not know whether it was from the running or the vitamins.

Example 1

- **Two groups** of performers are each tested for their performance.
- Subjects in one group are tested **in a room** with the heat set at **70** degrees (Fahrenheit).
- Subjects in **another group** are simultaneously tested in **a nearby identical room** with the heat set at **60** degrees.

Cont'd

- The obtained differences in performance could be attributed to any of these factors.
  - It could be due to the **different temperatures** in the two rooms.
  - It could be due to the random assignment of performers (i.e. different **sampling** by chance). This is a confounding factor.

Cont'd

- It could, however, be due to some other confounding factors such as **differences in ambient illumination** that result from unnoticed differences in the orientation of each room with respect to the sun.

Cont'd

- In any experiment, an appropriate **statistical test** can help in the decision as to whether or not **to attribute the results to chance [純屬巧合]**. (We will see a number of these tests in coming lectures.)
- But only the most careful analysis of the actual conditions of the experiment can suggest whether or not the result might be due to a confounding factor.

Example 2

Employment Status	Population	Hearing impaired	Rate per 1,000
(I) Currently employed	98,917	552	**5.58**
(II) Currently unemployed	7,462	27	3.62
(III) Not in the labor force	56,778	368	**6.48**
Total	163,157	947	5.80

Statistics of hearing impairments due to injury for individuals ≥17 years old.
labor force = a region's combined civilian workforce, including both the employed and unemployed.

- Judging from this table, ***can we conclude*** that group (III) individuals (rate=6.48) are at greater risk of hearing impairment due to injury than group (I) individuals (rate=5.58)?
- Are there any confounders involved?

Cont'd

- To check whether group (I) and (III) have **similar underlying demographic structures**, we may (empirically) break each group down according to **age**.
  - 17-44 years old
  - 45-64 years old
  - 65+ years old

Employment Status	Population	Hearing impaired	Rate per 1,000
(I) Currently employed	**98,917**	552	**5.58**
(II) Currently unemployed	7,462	27	3.62
(III) Not in the labor force	**56,778**	368	**6.48**
Total	163,157	947	5.80

Age	(I) Currently employed		(III) Not in the labor force	
	Population	%	Population	%
17-44	67,987	68.7	20,760	36.6
45-64	27,592	27.9	15,108	26.6
65+	3,338	3.4	20,910	**36.8**
total	**98,917**	100.0	**56,778**	100.0

Considerably older than group (I) individuals (3.4%).

Cont'd

- We next consider the **age-specific impairment rates** as a whole (groups (I)+(II)+(III)):

Age	Population	Impairments	Rate per 1000
17-44	94,930	441	4.65
45-64	43,857	308	7.02
65+	24,370	198	8.12
Total	163,157	947	**5.80**

Increase with age

$$\frac{(94930)(4.65)+(43857)(7.02)+(24370)(8.12)}{163157}=5.80$$

A **weighted** average of the age-specific rates

A brief summary

- **Age** seems to be a confounder between hearing impairment (impaired or not impaired) and employment status (groups I, II or III).
- As a result, we cannot be sure whether the higher hearing-impairing rate of group (III) is of some inherent characteristic of the members of that group, or whether it is simply the effect of age.

Cont'd

- According to what we have seen so far, it appears:
  - Older people seem to be more susceptible to hearing impairment
  - Group III seems to have significantly more older people
  - This may explain why group III has overall higher impairment rate

Using age-specific rates instead of their overall rates

	Age	Currently Employed (I)			Not in Labor Force (III)		
		Population	Impair-ments	Rate per 1000	Populati on	Impair-ments	Rate per 1000
1	17-44	67,987	346	**5.09**	20,760	80	3.85
2	45-64	27,592	179	6.49	15,108	117	**7.74**
3	65+	3,338	27	8.09	20,910	171	**8.18**
4	Total	98,917	552	5.58	56,778	368	**6.48**

- Row #4 is what we have seen in the beginning, representing the overall rate that suggested group (III) contains more hearing-impaired individuals.
- Although rows #2 and #3 also favored group (III), row #1 (age 17-44) indicates otherwise.

Conclusion

- Although subgroup-specific rates provide a more accurate comparison, the task may be overwhelming if there are too many subgroups to compare.
- Instead, we may compute a number for each subpopulation, that can be used in **adjusting** the summary according to differences in **population composition**.
- This is called **rate standardization**, that can be often accomplished by either a **direct** and an **indirect** method.

Example 3

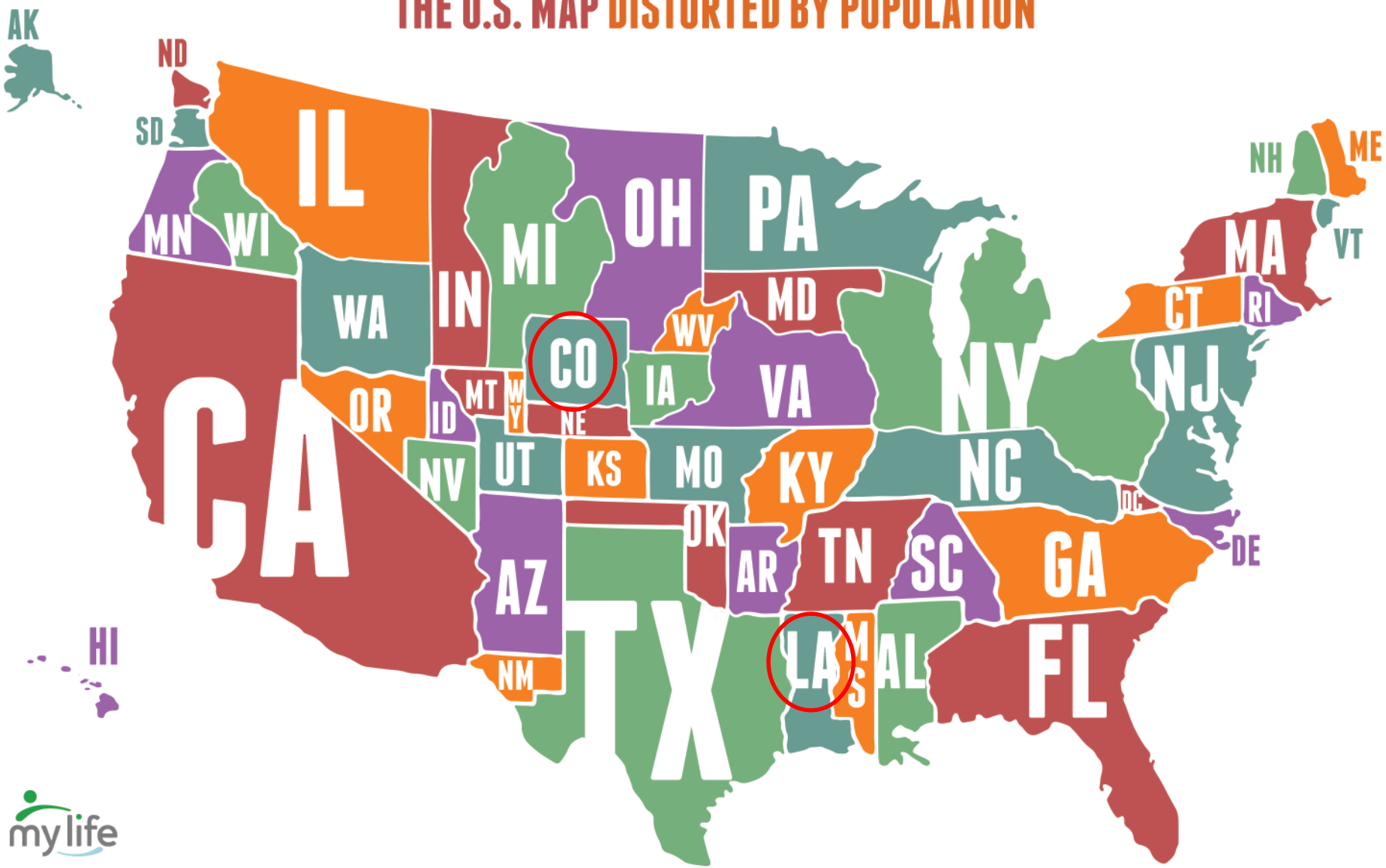
- Given the following table describing the data collected from the two states in the US in 1987.

State	Live Births	Infant Deaths	Rate per 1000
Colorado	53,808	527	9.8
Louisiana	73,967	872	**11.8**

- **☑ Can we conclude that the infants born in Louisiana are more likely to die before they reach 1 yr of age?**

http://www.emapstore.com/usa_map2.jpg

THE U.S. MAP DISTORTED BY POPULATION



https://images.app.goo.gl/wJrmaAMWzcQLYrSg6

On a Second Thought…

- Louisiana is a southern state that contains a good portion of black population, while in Colorado they are mostly white.
- It is suspicious that **race** is a confounder in the relationship between **state (independent variable)** and **infant mortality rate (dependent variable)**.

Cont'd

- That is, high rate (11.8 per 1,000) of Louisiana could be overestimated. (Because of black babies are at a higher risk?)
- As a result, we should explore the underlying distributions of race on two populations (population from either state).

A more accurate comparison between the two states by examining the race-specific infant mortality rates rather than the crude rates

	Colorado			Louisiana		
Race	**Live birth**	**Infant deaths**	**Rate per 1000**	**Live birth**	**Infant deaths**	**Rate per 1000**
total	**53,808**	**527**	**9.8**	**73,967**	**872**	勝出 **11.8**

Here is what we have seen earlier…

A more accurate comparison between the two states by examining the race-specific infant mortality rates rather than the crude rates

	Colorado			Louisiana		
Race	Live birth	Infant deaths	Rate per 1000	Live birth	Infant deaths	Rate per 1000
Black	3,166	52	16.4	29,670	525	勝出 17.7
White	48,805	469	勝出 9.6	42,749	344	8.0
Other	1,837	6	勝出 3.3	1,548	3	1.9
total	53,808	527	9.8	73,967	872	勝出 11.8

It is clear that the Louisiana black infants have a higher death rate than Colorado black infants, while the Colorado white infants have a higher death rate than Louisiana black infants. The latter is also true for other racial groups.

- Although the race-specific rates provide the most detailed information, it would be convenient to be able to summarize the entire situation with a pair of numbers – one for each state – that adjust for differences in racial composition.
- That is, both the “Colorado 9.8” and “Louisiana 11.8” rates are to be adjusted.
- They can be adjusted by **standardization method** to give a better comparison.

(1) By Direct Method

- Pretending that, instead of having different distribution in both states, we assume **a single standard** of the same composition.
- The first thing is to choose a standard distribution to use. Here we use *the stat from the US population in the same year*.

Race	Live Births	Infant Deaths	Rate per 1000
Black	641,567	11,461	17.9
White	2,992,488	25,810	8.6
Other	175,339	1,137	6.5
Total	3,809,394	38,408	10.1

	Colorado			Louisiana		
Race	**Live birth**	**Infant deaths**	**Rate per 1000**	**Live birth**	**Infant deaths**	**Rate per 1000**
Black	3,166	52	**16.4**	29,670	525	**17.7**
White	48,805	469	**9.6**	42,749	344	**8.0**
Other	1,837	6	**3.3**	1,548	3	**1.9**
total	53,808	527	9.8	73,967	872	11.8

Race	Live Births	Infant Deaths	Rate per 1000
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Other	**175,339**	1,137	6.5
Total	**3,809,394**	38,408	10.1

From page 37
From page 39

We want to compute the "expected" death from either state's rate using the US population composition. (To 'merge' these two tables.)

U.S.		Colorado		Louisiana	
Race	Live Births	Rate per 1000	Expected Deaths	Rate per 1000	Expected Deaths
Black	641,567	16.4	10,521.7 (641,567×16.4/1000)	17.7	11,355.7
White	2,992,488	9.6	28,727.9	8.0	23,939.9
Other	175,339	3.3	578.6	1.9	333.1
Total	3,809,394		39,828.2		35,628.7

$$\text{Colorado}: \frac{39828.2}{3809394} = 10.5 \text{ per } 1000$$

(was 9.8)

$$\text{Louisiana}: \frac{35628.7}{3809394} = 9.4 \text{ per } 1000$$

(was 11.8)

The **adjusted** Colorado infant death rate is actually higher.

(2) By Indirect Method

- Similar to a direct method, an indirect method also uses a standard composition to re-compute the death rates for both states.
- Instead of **using the US population and individual state's rates (direct method)**, we now **use US rates with individual state's population (indirect method)** to get the expected death counts.

	Colorado			Louisiana		
Race	**Live birth**	**Infant deaths**	**Rate per 1000**	**Live birth**	**Infant deaths**	**Rate per 1000**
Black	**3,166**	52	16.4	**29,670**	525	17.7
White	**48,805**	469	9.6	**42,749**	344	8.0
Other	**1,837**	6	3.3	**1,548**	3	1.9
total	**53,808**	527	9.8	**73,967**	872	11.8

Race	Live Births	Infant Deaths	Rate per 1000
Black	641,567	11,461	**17.9**
White	2,992,488	25,810	**8.6**
Other	175,339	1,137	**6.5**
Total	3,809,394	38,408	**10.1**

From page 37
From page 39

Use US rates with individual state's population (columns filled in black).

U.S.		Colorado		Louisiana	
Race	Rate per 1000	Live Births	Expected Deaths	Live Births	Expected Deaths
Black	17.9	3,166	56.7 (3,166×17.9/1000)	29,670	531.1
White	8.6	48,805	419.7	42,749	367.6
Other	6.5	1,837	11.9	1,548	10.1
Total	10.1	53,808	488.3	73,967	908.8

Both adjusted from **the same US rate 10.1**:

$$\text{Colorado}: 10.1 \times \frac{527}{488.3} = 10.1 \times 1.08 = 10.9 \text{ per } 1000$$

(was 9.8)

$$\text{Louisiana}: 10.1 \times \frac{872}{908.8} = 10.1 \times 0.96 = 9.7 \text{ per } 1000$$

(was 11.8)

Recall that **527** and **872** are the actual death counts from either state.

Conclusion

- It can be seen, by either way of adjusting these rates, the State of Colorado does have higher infant death rate than the State of Louisiana does, regardless that the ‘raw’ rates show that infants in Louisiana are more vulnerable.