Observational studies

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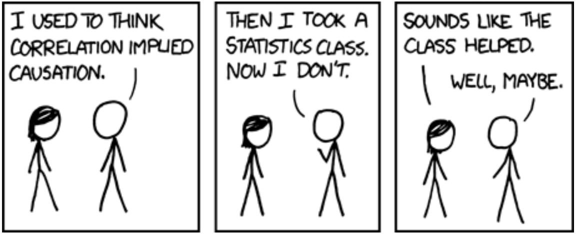
Observational studies

- We have said that randomized controlled experiments are the gold standard for determining cause-and-effect relationships in human health
- However, such experiments are not always possible, ethical, or affordable
- A much simpler, more passive approach is to simply observe people's decisions and the consequences that seem to result from them, then attempt to link the two
- Such studies are called *observational studies*

Smoking

- For example, smoking studies are observational – no one is going to take up smoking for ten years just to please a researcher
- However, the idea of treatment (smokers) and control (nonsmokers) groups is still used, just as it was in controlled experiments
- The essential difference, however, is that the subject assigns themselves to the treatment/control group – the investigators just watch
- Because of this, confounding is possible
- Hundreds of studies have shown that smoking is *associated* with various diseases, but none can prove *causation*

Correlation and causation



http://xkcd.com/552/

Controlling for confounders

- However, just because confounding is possible in such studies does not mean that investigators are powerless to address it
- Instead, well-conducted observational studies make strong efforts to identify confounders and *control for* their effect
- There are many techniques for doing so; the most direct approach is to make comparisons separately for smaller and more homogeneous groups

Controlling for confounders (cont'd)

- For example, studying the association between heart disease and smoking could be misleading, because men are more likely to have heart disease and also more likely to smoke
- A solution is to compare heart disease rates separately: compare male smokers to male nonsmokers, and the same for females
- Age is another common confounding factor that epidemiologists are often concerned with controlling for

The value of observational studies

- Hundreds of very carefully controlled and well-conducted studies of smoking have been conducted in the past several decades
- Most people would agree that these studies make a very strong case that smoking is dangerous, and that alerting the public to this danger has saved thousands of lives
- Observational studies are clearly a very powerful and necessary tool
- Furthermore, observational studies have tremendous value as initial studies to build up support for larger, more resource-intensive controlled experiments
- However, they can be very misleading – identifying confounders is not always easy, and is sometimes more art than science

Racial bias in Florida

- A study of racial bias in the administration of the death penalty was published in the *Florida Law Review*
- The sample consists of 674 defendants convicted of multiple homicides in Florida between 1976 and 1987, classified by the defendant's and the victims' races:

	White defendants		Black defendants	
Victims' race	Total	Death penalty	Total	Death penalty
White	467	53	48	11
Black	16	0	143	4

Evidence for racial bias against whites

- From the table, the overall percentage of white defendants who received the death penalty is

$$\frac{53+0}{467+16} = 11.0\%$$

- And for black defendants,

$$\frac{11+4}{48+143} = 7.9\%$$

- This would seem to be evidence of racial bias against white defendants

Controlling for victim's race

- However, let's control for the potentially confounding effect of victim's race by calculating the percent who received the death penalty separately for white victims and black victims:

	% sentenced to death	
Victims' race	White	Black
White	11.3	22.9
Black	0.0	2.8

- This table indicates racial bias against blacks

What's going on?

- This may seem paradoxical: if blacks are more likely to receive the death penalty for white victims, and also for black victims, how can whites be more likely to receive the death penalty overall?
- The answer is that both races are much more likely to be involved in murders in which the victim is the same race as the defendant (97% of white defendants were on trial for the murder of white victims; 75% of black defendants were on trial for the murder of black victims)
- Furthermore, Florida juries were much more likely to award the death penalty in cases involving white victims (12.5%) than black victims (2.5%)
- Thus, the apparent racial bias against whites could be due to the confounding factor of the victims' race

Numerical summaries

- Seeing all the data is clearly valuable, but for the sake of simplicity, people often want to summarize a comparison with just one (or two) numbers
- The most common such summary is the *average*, or *mean*
- The average of a list of numbers equals their sum divided by how many of them there are:

$$\bar{x} = \frac{x_1 + x_2 + \cdots}{n} = \frac{\sum_{i=1}^{n} x_i}{n}$$

- Thus, the average of 4,5,1, and 9 is:

$$\frac{4+5+1+9}{4} = \frac{19}{4} = 4.75$$

Percentages are averages

- The percentage is a kind of average, in which we are taking the average of whether something happens (in which case it equals 1) or doesn't happen (in which case it equals 0)
- For example, the percentage of whites who received the death penalty is

$$\begin{aligned}\frac{1+1+0+1+0+\cdots}{n} &= \frac{\text{\#who received the death penalty}}{\text{total \# of white defendants}} \\ &= \frac{53}{483} \\ &= 11.0\%\end{aligned}$$

Weighted averages

- Due to the threat of confounding in observational studies, it is often useful to obtain an overall average that has been adjusted for the confounding factor
- One such method is to calculate a *weighted average*
- In a regular average, every observation gets an equal weight of $1/n$ – an equivalent way of writing the average is

$$\bar{x} = \sum_{i=1}^{n} \frac{1}{n} x_i$$

- In a weighted average, every observation gets its own weight w_i:

$$\bar{x}_w = \sum_{i=1}^{n} w_i x_i$$

where the weights must add up to 1

Example

- So, for example, the percent of whites who received the death penalty could also be written as

$$\begin{aligned}
&\text{(Proportion of WD on trial for murder of WV)} \\
&\cdot \text{(\% Death penalty for WD on trial for murder of WV)} \\
&+ \text{(Proportion of WD on trial for murder of BV)} \\
&\cdot \text{(\% Death penalty for WD on trial for murder of BV)} \\
&\quad = (.967)11.3 + (.033)0 \\
&\quad = 11.0,
\end{aligned}$$

  the same answer as we obtained before

Where WD = white defendants, WV = white victims, BV = black victims, etc.

Comparison of averages

- Comparing the two averages:

$$\begin{aligned} \text{Whites:} \quad & (.967)11.3 + (.033)0 = 11.0 \\ \text{Blacks:} \quad & (.251)22.9 + (.749)2.8 = 7.9 \end{aligned}$$

  we see directly the effect of confounding: the white-victim death penalty percentage gets 97% of the weight for white defendants, but only 25% of the weight for black defendants

- What would happen if these weights were the same (*i.e.* if victims' race was not a confounding factor and both races were equally likely to be on trial for the murder of a white victim)?

Average controlled for victims' race

- Overall, 76.4% (515/674) of the victims were white and 23.6% were black; using these as weights,

$$\begin{aligned} \text{Whites:} \quad & (.764)11.3 + (.236)0 = 8.6 \\ \text{Blacks:} \quad & (.764)22.9 + (.236)2.8 = 18.2 \end{aligned}$$

- By artificially forcing the distribution of victims' race to be the same for both groups, we obtain an average that is adjusted for the confounding factor of victim's race
- This allows us to isolate the effect of defendant's race upon his/her likelihood of receiving the death penalty, in the absence of the confounding effect of victim's race

Procedure for weighted averages

- To summarize these ideas into a step by step procedure for calculating the weighted average for a single group:
  - #1 Calculate $w_1, w_2, \ldots, w_n$, the overall proportion of observations that belong to each level of the confounder that you are controlling for
  - #2 Calculate $\bar{x}_1, \bar{x}_2, \ldots, \bar{x}_n$, the average (or percentage) for that group at each level of the confounder
  - #3 Calculate the weighted average: $\bar{x} = \sum_i w_i \bar{x}_i$
- To calculate the weighted averages for additional groups, repeat steps 2 and 3 for that group – step 1 remains the same

Example: Death penalty by victim race

- Earlier we saw that Florida juries awarded the death penalty in 12% of cases involving white victims and 3% of cases involving black victims
- However, this also could be skewed by confounding (here, the race of the defendant)
- Calculate weighted averages of death penalty rates for white victims and for black victims, controlling for the effect of defendant's race

Example: Death penalty by victim race (cont'd)

- First, we calculate the overall percent of white defendants (w_1) and black defendants (w_2):

$$w_1 = \frac{16 + 467}{674} = 0.7166$$
$$w_2 = \frac{48 + 143}{674} = 0.2834$$

- Then we can calculate the weighted averages:

$$\bar{x}_1 = 0.7166 \left(\frac{53}{467} \right) + 0.2834 \left(\frac{11}{48} \right) = 15\%$$
$$\bar{x}_2 = 0.7166 \left(\frac{0}{16} \right) + 0.2834 \left(\frac{4}{143} \right) = 1\%$$

- This calculation indicates a rather extreme bias in the administration of the death penalty in Florida juries of 1976–1987 with respect to the victims' race

Summary

- Randomized controlled trials are not always possible or practical; for these reasons observational studies also play an important role in science
- Observational studies are always limited by confounding, although known confounders can be accounted for, either through design or statistical calculations
- We have focused on the weighted average; more sophisticated approaches to adjusting for confounders are discussed in Design and Analysis of Biomedical Studies (171:162)