JOHNS HOPKINS BLOOMBERG SCHOOL of PUBLIC HEALTH

Section G

Comparing Means between More than Two Independent Populations

Motivating Example

- Suppose you are interested in the relationship between smoking and mid-expiratory flow (FEF), a measure of pulmonary health

- Suppose you recruit study subjects and classify them into one of six smoking categories
  - Nonsmokers (NS)
  - Passive smokers (PS)
  - Non-inhaling smokers (NI)
  - Light smokers (LS)
  - Moderate smokers (MS)
  - Heavy smokers (HS)

Motivating Example

- You are interested in whether differences exist in mean FEF amongst the six groups

- Main outcome variable is mid-expiratory flow (FEF) in liters per second

Motivating Example

- One strategy is to perform lots of two-sample t-tests (for each possible two-group comparison)

- In this example, there would be 15 comparisons you would need to do!
  - NS to PS, NS to NI, and so on . . .

Motivating Example

- It would be nice to have one “catch-all” test
  - Something which would tell you whether there were any differences amongst the six groups
  - If so, you could then do group to group comparisons to look for specific group differences

Extension of the Two-Sample t-Test

- Analysis of variance (One-Way ANOVA)
  - The t-test compares means in two populations
  - ANOVA compares means amongst more than two populations with one test

- The p-value from ANOVA helps answer the question
  - "Are there any differences in the means among the populations?"

Extension of the Two-Sample t-Test

- General idea behind ANOVA, comparing means for k-groups (k > 2):
  - $H_o : \mu_1 = \mu_2 = . . . \mu_k$
  - H_A : At least one mean different

Example

- Smoking and FEF (Forced Mid-Expiratory Flow Rate)*
  - A sample of over 3,000 persons was classified into one of six smoking categorizations based on responses to smoking related questions

Source: * White, J.R., Froeb, H.F. (1980). Small-airways dysfunction in non-smokers chronically exposed to tobacco smoke, *New England Journal of Medicine* 302: 13.

Example 1

- Nonsmokers (NS)
- Passive smokers (PS)
- Non-inhaling smokers (NI)
- Light smokers (LS)
- Moderate smokers (MS)
- Heavy smokers (HS)

Example 1

- Smoking and FEF
  - From each smoking group, a random sample of 200 men was drawn (except for the non-inhalers, as there were only 50 male non-inhalers in the entire sample of 3,000)
  - FEF measurements were taken on each of the subjects

Example 1—Table

- Data summary

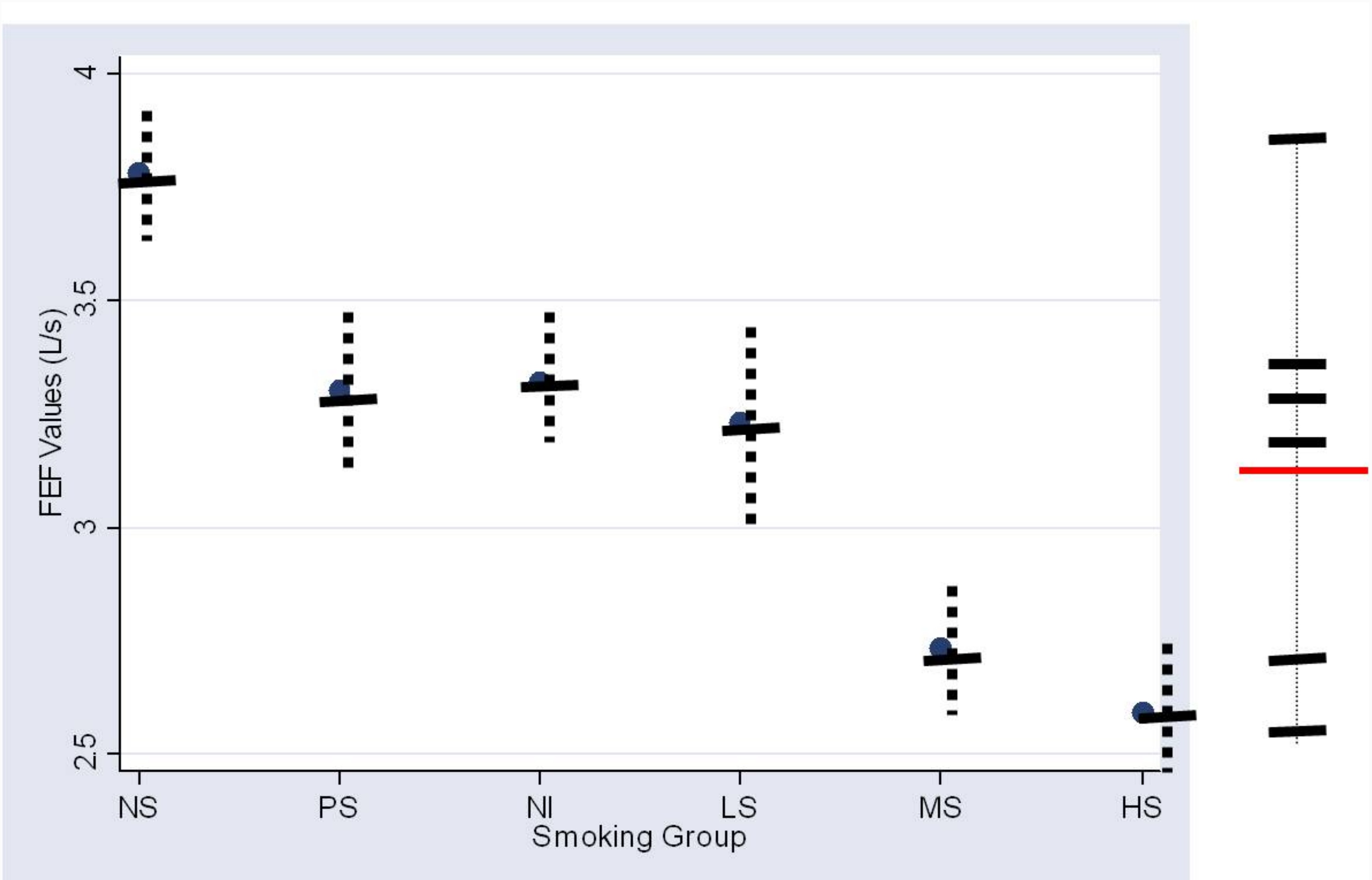
Group	Mean FEF	SD FEF	
	(L/s)	(L/s)	n
NS	3.78	0.79	200
PS	3.30	0.77	200
NI	3.32	0.86	50
LS	3.23	0.78	200
MS	2.73	0.81	200
HS	2.59	0.82	200

- Based on a one-way analysis of variance, there are statistically significant differences in FEF levels among the six smoking groups ($p < .001$)

What's the Rationale behind Analysis of Variance?

- The variation in the sample means between groups is compared to the variation within a group
- If the between group variation is a lot bigger than the within group variation, that suggests there are some differences among the populations

Analysis of Variance



Summary: Smoking and FEF

- **Statistical methods**
  - 200 men were randomly selected from each of five smoking classification groups (non-smoker, passive smokers, light smokers, moderate smokers, and heavy smokers), as well as 50 men classified as non-inhaling smokers for a study designed to analyze the relationship between smoking and respiratory function

Summary: Smoking and FEF

- **Statistical Methods**
  - Analysis of variance was used to test for any differences in FEF levels amongst the six groups of men
  - Individual group comparisons were performed with a series of two sample t-tests, and 95% confidence intervals were constructed for the mean difference in FEF between each combination of groups
  - Analysis of variance showed statistically significant ($p < .001$) differences in FEF between the six groups of smokers
  - Non-smokers had the highest mean FEF value, 3.78 L/s, and this was statistically significantly larger than the five other smoking-classification groups

Summary: Smoking and FEF

- **Results**
  - Analysis of variance showed statistically significant ($p < .001$) differences in FEF between the six groups of smokers
  - Non-smokers had the highest mean FEF value, 3.78 L/s, and this was statistically significantly larger than the five other smoking-classification groups
  - The mean FEF value for non-smokers was 1.19 L/s higher than the mean FEF for heavy smokers (95% CI 1.03–1.35 L/s), the largest mean difference between any two smoking groups
  - Confidence intervals for all smoking group FEF comparisons are in Table 1

Example 2

- FEV1 and three medical centers*
  - Data was collected on 63 patients with coronary artery disease at 3 difference medical centers (Johns Hopkins, Ranchos Los Amigos Medical Center, St. Louis University School of Medicine)
  - Purpose of study to investigate effects of carbon monoxide exposure on these patients
  - Prior to analyzing CO effects data, researchers wished to compare the respiratory health of these patients across the three medical centers

Source: * Pagano, M., Gauvreau, K. (2000). *Principles of biostatistics*. Duxbury Press.

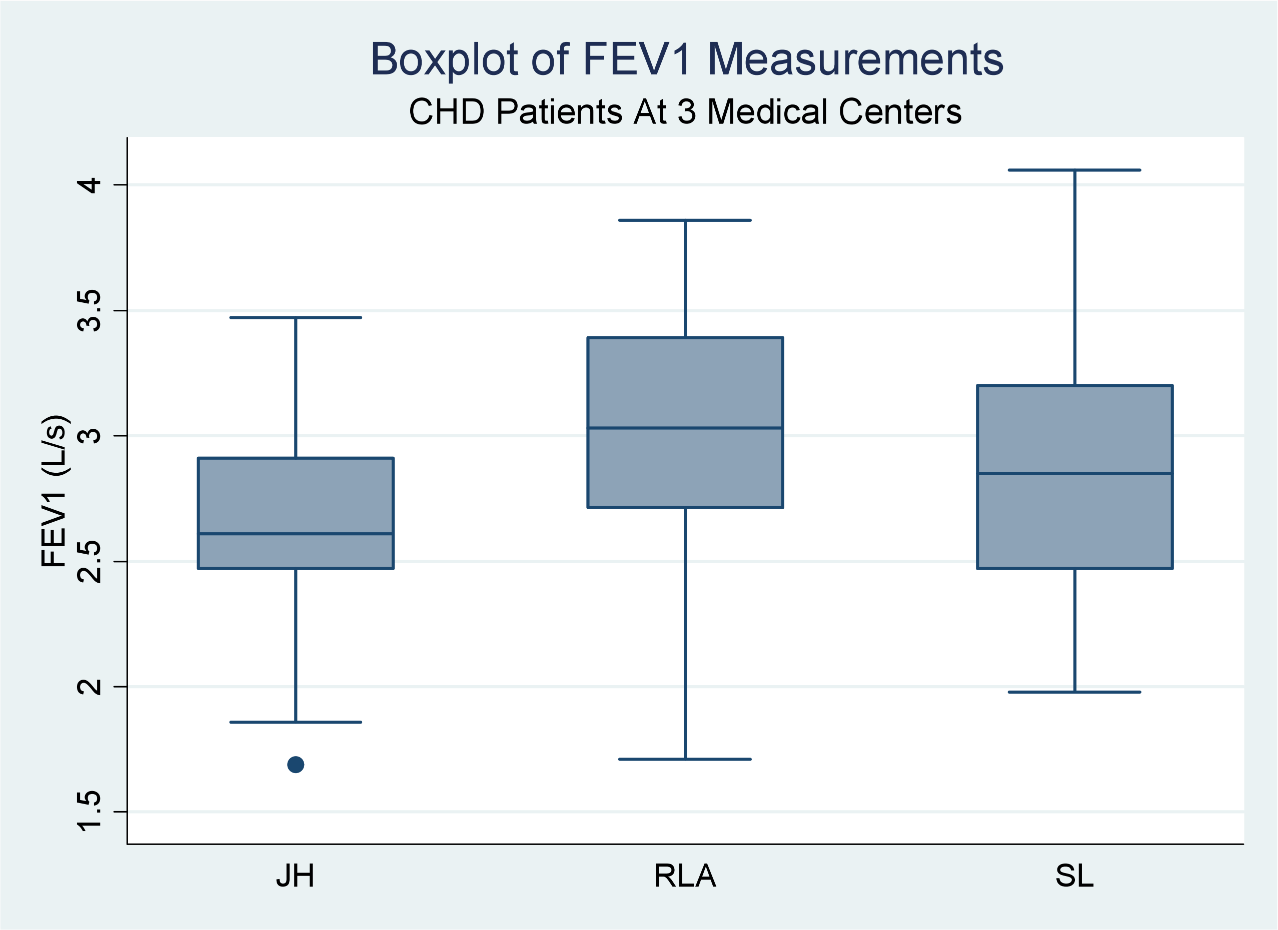
Example 2

- Snippet of data in Stata

```
     +---------------+
     | center   fev1 |
     |---------------|
 20. |     JH   2.63 |
 21. |     JH   2.53 |
 22. |    RLA   3.22 |
 23. |    RLA   2.88 |
 24. |    RLA   1.71 |
     |---------------|
 25. |    RLA   2.89 |
 26. |    RLA   3.77 |
 27. |    RLA   3.29 |
 28. |    RLA   3.39 |
 29. |    RLA   3.86 |
     |---------------|
 30. |    RLA   2.64 |
     +---------------+
```

Boxplots

- FEV1 values by center



Example 2

- ANOVA with Stata
  - syntax oneway outcome_var group_var

```
oneway  fev1 center

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      1.58283723      2   .791418613      3.12     0.0520
 Within groups      14.4802561     57   .254039581
------------------------------------------------------------------------
    Total           16.0630933     59   .272255819

Bartlett's test for equal variances:  chi2(2) =   0.0583  Prob>chi2 = 0.971
```

Example 2

- ANOVA with Stata
  - syntax oneway outcome_var group_var

```
oneway  fev1 center

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      1.58283723      2   .791418613      3.12     0.0520
 Within groups      14.4802561     57   .254039581
------------------------------------------------------------------------
    Total           16.0630933     59   .272255819

Bartlett's test for equal variances:  chi2(2) =   0.0583  Prob>chi2 = 0.971
```

Example 2

- FEV and 3 medical centers 95% CIs for FEV1 by medical center

```
. bys center: ci fev1

-------------------------------------------------------------------------------------
-> center = JH

    Variable |        Obs        Mean    Std. Err.       [95% Conf. Interval]
-------------+---------------------------------------------------------------
        fev1 |         21     2.62619    .1082732        2.400337    2.852044

-------------------------------------------------------------------------------------
-> center = RLA

    Variable |        Obs        Mean    Std. Err.       [95% Conf. Interval]
-------------+---------------------------------------------------------------
        fev1 |         16      3.0325      .13081        2.753685    3.311315

-------------------------------------------------------------------------------------
-> center = SL

    Variable |        Obs        Mean    Std. Err.       [95% Conf. Interval]
-------------+---------------------------------------------------------------
        fev1 |         23    2.878696    .1037809        2.663467    3.093924
```