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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):
  - $H_o : \mu_1 = \mu_2 = \ldots \mu_k$
  - $H_A :$ 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 (L/s)	SD FEF (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

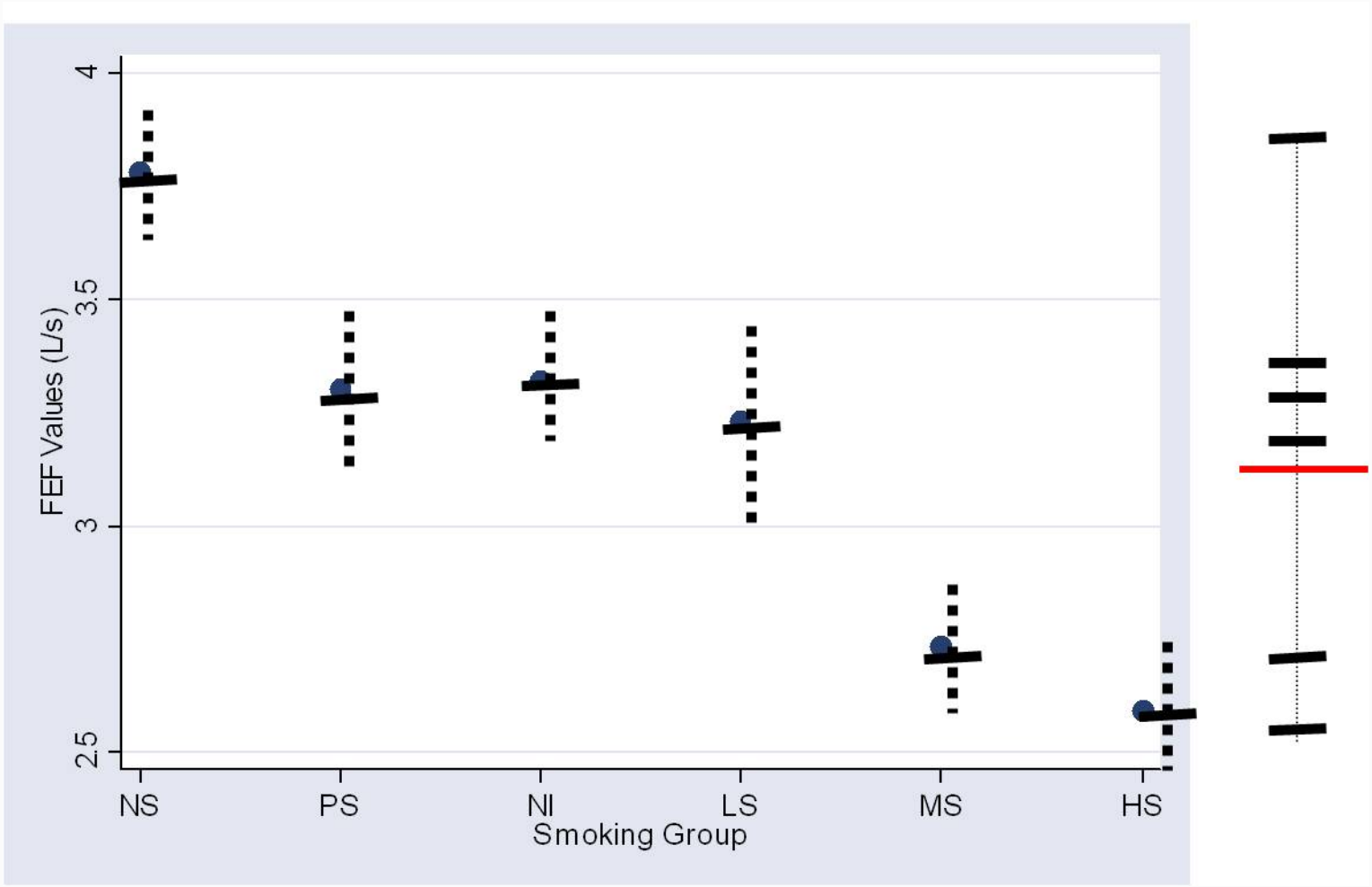
- Based on a one-way analysis of variance, there are statistically significant differences in FEF levels among the six smoking groups ($p < .001$)

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.

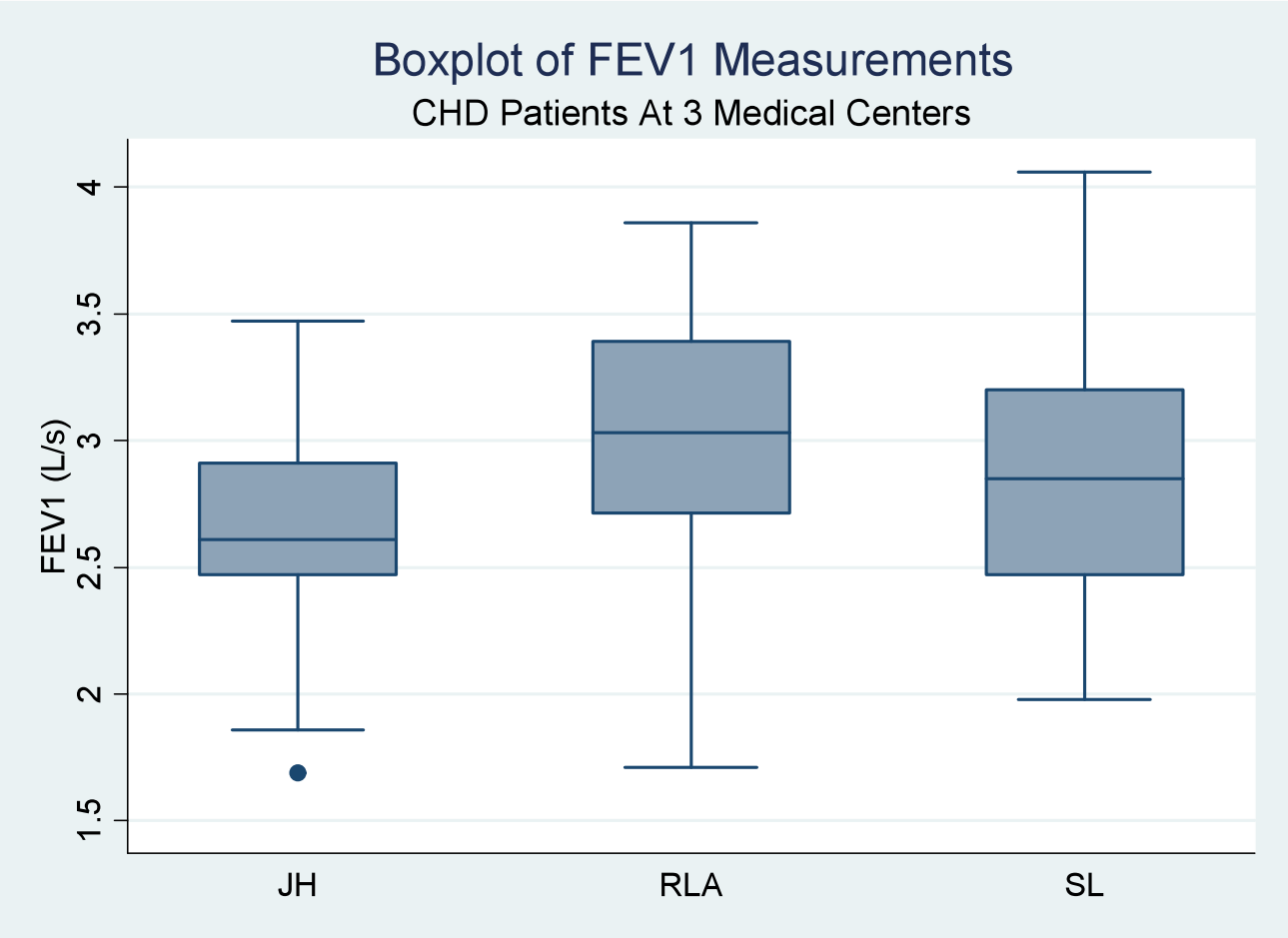
Example 2

- 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
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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
```