# Analysis of Variance (ANOVA)

Math 122

| Observed | Athlete | Non-athlete |
|---|---|---|
| Male | | |
| Female | | |

Is whether or not a student is an athlete dependent on that student's gender?

| Expected | Athlete | Non-athlete |
|---|---|---|
| Male | | |
| Female | | |

H0: Rows and columns dependent.
H1: Rows and columns independent.

Df=

P-value:

Formal Conclusion:

# Claims about means

To test a claim about two means $\mu_1$ and $\mu_2$ we use a $t$-test or a $z$-test.

To test claims about three or more means $\mu_1, \mu_2, \mu_3$, … we use ANALYSIS OF VARIANCE or ANOVA.

# ANOVA claims

Suppose we have means $\mu_1, \mu_2, \mu_3, \ldots$

We address claims which result in these $H_0$ and $H_1$:

$H_0$: All of the means are equal.

$(\mu_1, \mu_2, \mu_3, \ldots)$

$H_1$: Not all of the means are equal.

($m_1 \neq m_2$ or $m_1 \neq m_3$ or $m_2 \neq m_3$ or …)

# ANOVA Test Statistic

$$F = \frac{variance\ of\ sample\ means}{variance\ of\ all\ samples\ pooled\ together}$$

This has an $F$ distribution

If the means are the same or very close, this fraction will be small.

If one of the means is different from the others, this fraction will be large.

# ANOVA on the TI

Enter your sample data into lists $L_1$, $L_2$, $L_3$,…

Use ANOVA($L_1$, $L_2$, $L_3$,…)

Make the usual decision based on a $P$-value.

# ANOVA on the online calculator

Enter your data into lists List0, List1, List2,…

Select the ANOVA function.

Enter your first list and last list.

Calculate.

# Emissions

Listed below are measured amounts of greenhouse gas emissions from cars in three different categories. Use a .05 significance level to test the claim that the different categories have the same mean amount of greenhouse gas emissions.

- 4 Cyl: 7.2, 7.9, 6.8, 7.4, 6.5, 6.6, 6.7, 6.5, 7.1, 6.7, 7.3
- 6 Cyl: 8.7, 7.7, 8.7, 8.2, 9.0, 9.3, 7.4, 7.0, 7.2, 7.2, 8.2
- 8 Cyl: 9.3, 9.3, 9.3, 8.6, 8.7, 9.3, 9.3

- 4 Cyl: 7.2, 7.9, 6.8, 7.4, 6.5, 6.6, 6.7, 6.5, 7.1, 6.7, 7.3
- 6 Cyl: 8.7, 7.7, 8.7, 8.2, 9.0, 9.3, 7.4, 7.0, 7.2, 7.2, 8.2
- 8 Cyl: 9.3, 9.3, 9.3, 8.6, 8.7, 9.3, 9.3

Claim: The different categories have the same mean amount of greenhouse gas emissions.

$H_0$: All of the means are equal.

$H_1$: Not all of the means are equal.

$P =$

Formal conclusion:

Final Conclusion:

Do the different classes have the same amount of greenhouse gas emissions?

# Skull Breadths

Below are skull breadths of Egyptian male skulls from three different time periods. Use a .05 significance level to test the claim that the different time periods have the same mean skull breadth.

- 400 BC: 131, 138, 125, 129, 132, 135, 132, 134, 138
- 1850 BC: 129, 134, 136, 137, 137, 129, 136, 138, 134
- 150 AD: 128, 138, 136, 139, 141, 142, 137, 145, 137

- 400 BC: 131, 138, 125, 129, 132, 135, 132, 134, 138
- 1850 BC: 129, 134, 136, 137, 137, 129, 136, 138, 134
- 150 AD: 128, 138, 136, 139, 141, 142, 137, 145, 137

Claim: The different time periods have the same mean skull breadth.

$H_0$: All of the means are equal.

$H_1$: Not all of the means are equal.

$P =$

Formal conclusion:

Final Conclusion:

Do the different periods have the same mean skull breadth?

# Weight Loss

A clinical trial is run to compare weight loss programs. Participants follow assigned programs for 8 weeks. The outcome of interest is weight loss, defined as the difference in weight measured at the start of the study (baseline) and weight measured at the end of the study (8 weeks), measured in pounds.

Weights are measured at the beginning of the study. After 8 weeks, each patient's weight is again measured and the difference in weights is computed by subtracting the 8 week weight from the baseline weight.

# Weight Loss

Test the claim that there is a difference in mean weight loss between the programs.

| Low Calorie | Low Fat | Low Carbohydrate |
|---|---|---|
| 8 | 2 | 3 |
| 9 | 4 | 5 |
| 6 | 3 | 4 |
| 7 | 5 | 2 |
| 3 | 1 | 3 |

| Low Calorie | Low Fat | Low Carbohydrate |
|---|---|---|
| 8 | 2 | 3 |
| 9 | 4 | 5 |
| 6 | 3 | 4 |
| 7 | 5 | 2 |
| 3 | 1 | 3 |

Claim: There is a difference in mean weight loss between the programs.

$H_0$: All of the means are equal.

$H_1$: Not all of the means are equal.

$P =$

Formal conclusion:

Final Conclusion:

Is there a difference in weight loss between the programs?