# Research Methods

## *Introduction to Statistics with EXCEL*

Andy Gillett

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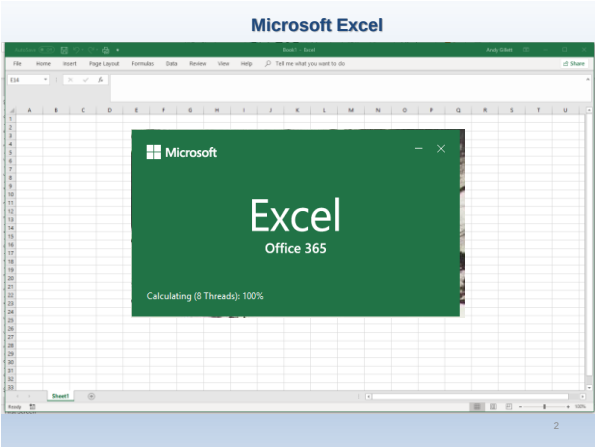


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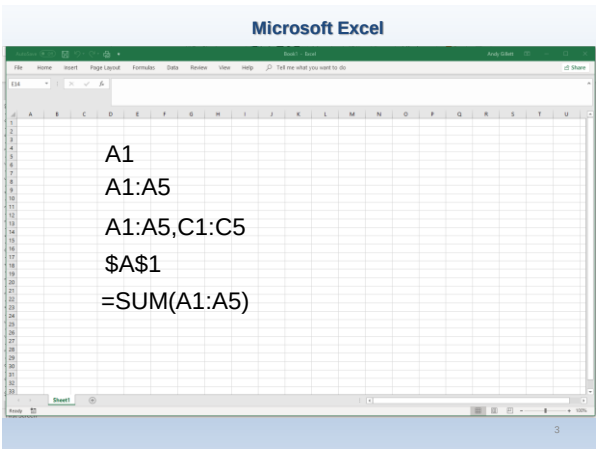


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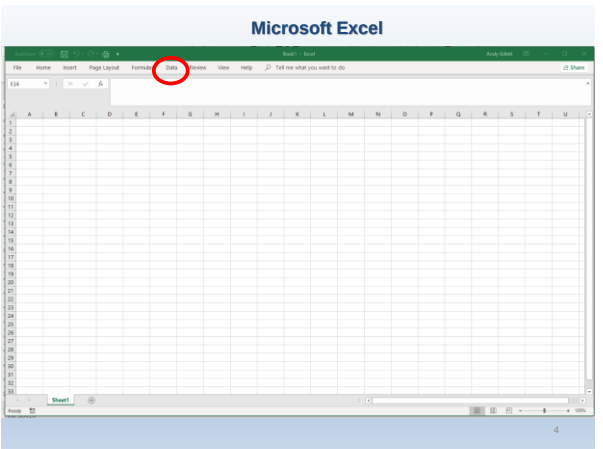


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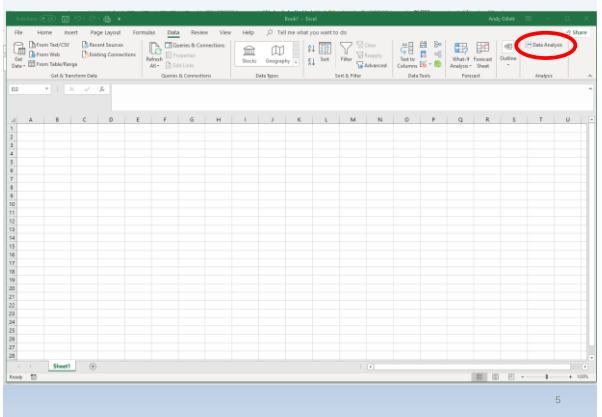

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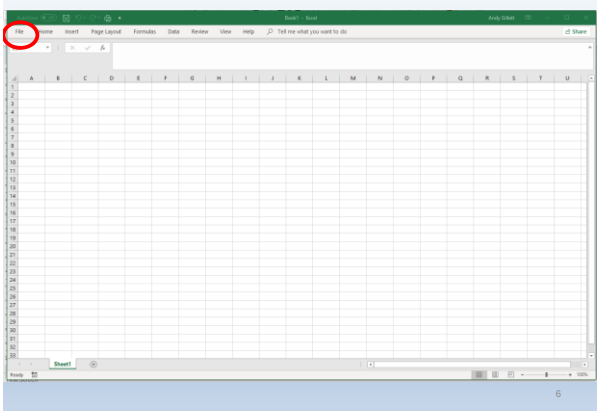

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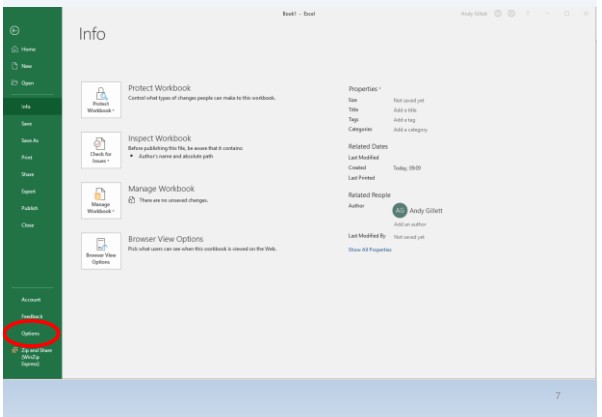


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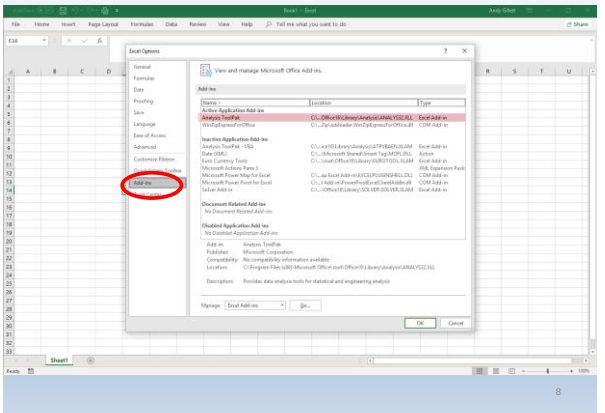


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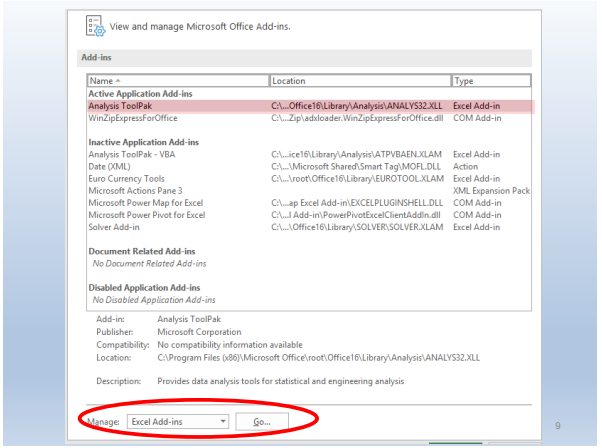


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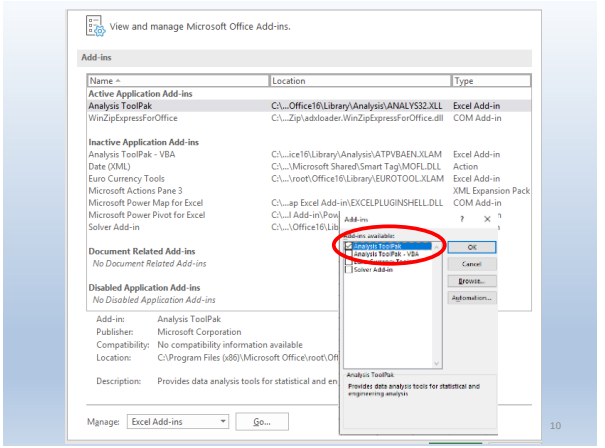


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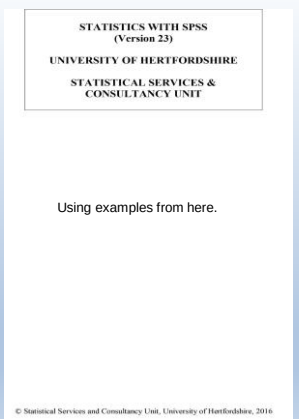
STATISTICS WITH SPSS
(Version 23)

UNIVERSITY OF HERTFORDSHIRE

STATISTICAL SERVICES &
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Using examples from here.



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## Describing Data using Statistics

| Descriptive | Inferential |
|---|---|
| Description | Inference |
| Sample | Population |

"When an individual uses descriptive statistics, he talks about the data he has; but with inferential statistics, he talks about data he does not have."

(Popham & Sirotnik, 1973: 40)

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## Describing Data using Statistics

**Description**

- ❑ Central Tendency
  - Mean, Median, Mode
- ❑ Dispersion
  - Range, Standard Deviation, IQR

**Inference**

- ❑ Exploring Relationships
  - Correlation
  - Regression
- ❑ Comparing Groups
  - t-Test
  - ANOVA

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## Describing Data using Statistics

**Description:**

- The central tendency, which is the common, middle or average value.
- The dispersion, which is how the data values are spread, or dispersed, around the central tendency.

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| Gender | Height (m) |
|---|---|
| Male | 1.89 |
| Female | 1.75 |
| Male | 1.64 |
| Male | 1.81 |
| Female | 1.59 |
| Male | 1.94 |
| Female | 1.88 |
| Female | 1.65 |
| Male | 1.93 |
| Male | 1.74 |
| Female | 1.70 |
| Male | 1.82 |
| Male | 1.91 |
| Female | 1.69 |
| Female | 1.68 |
| Female | 1.80 |

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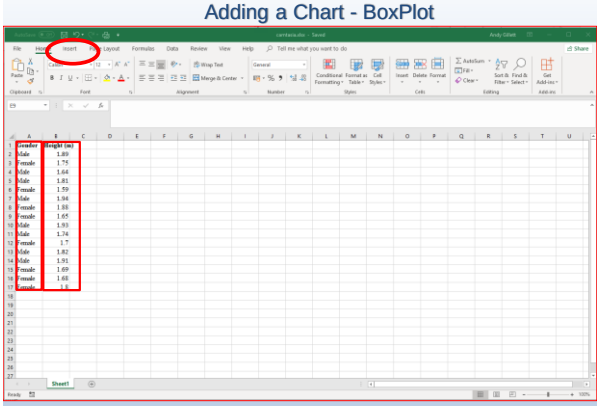
## Adding a Chart - BoxPlot



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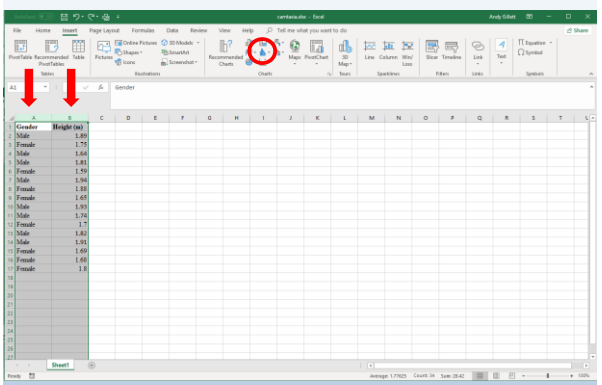

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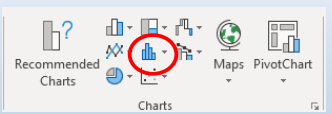


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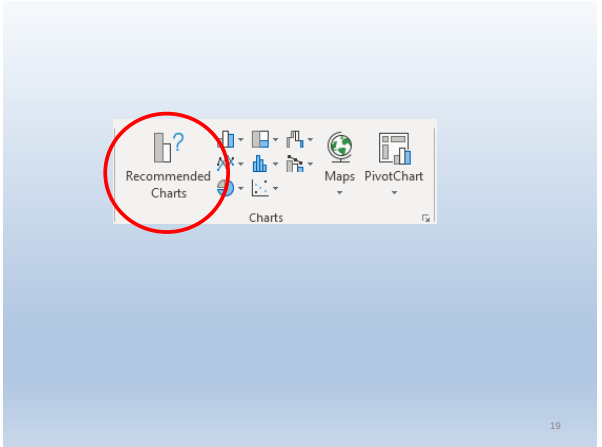


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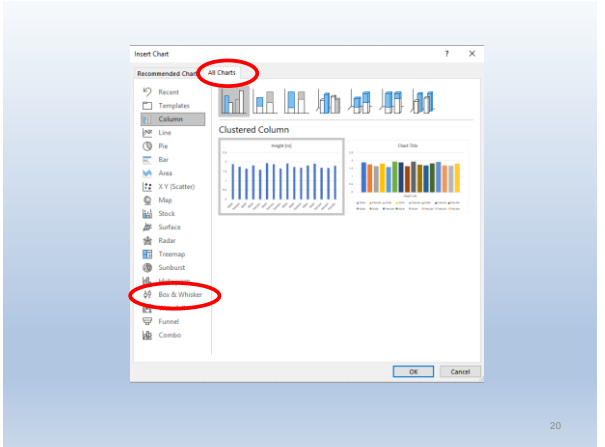


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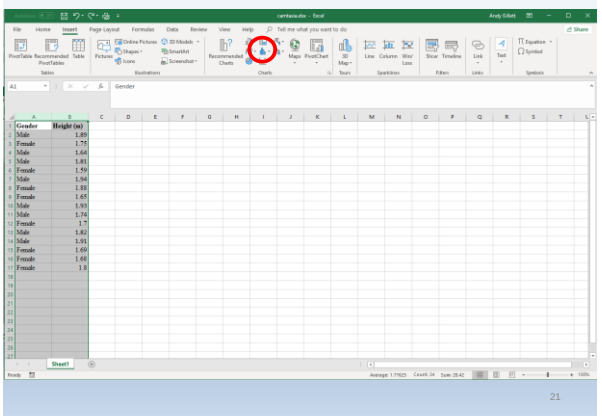

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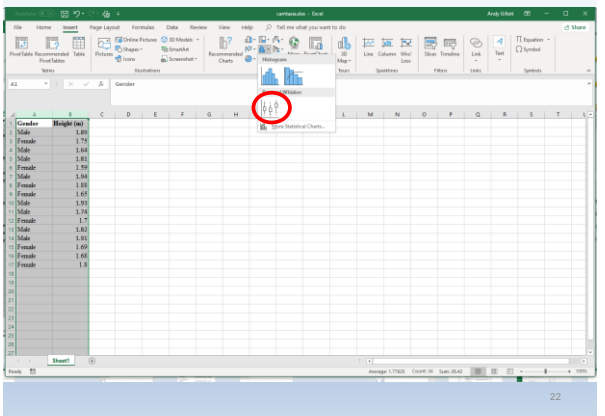

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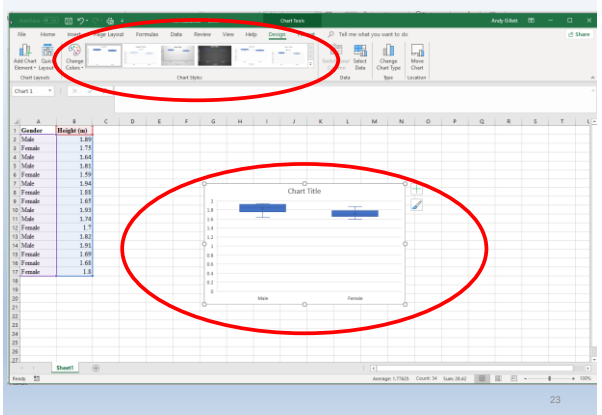


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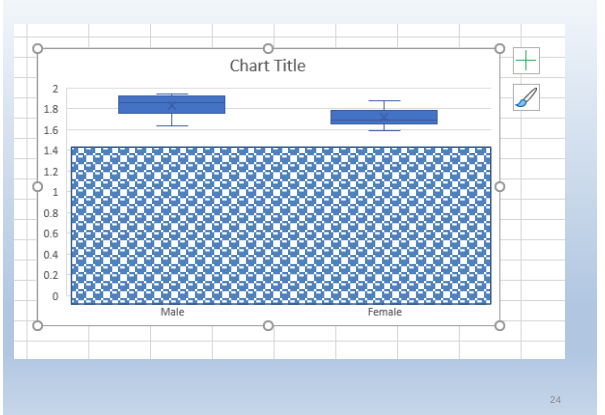


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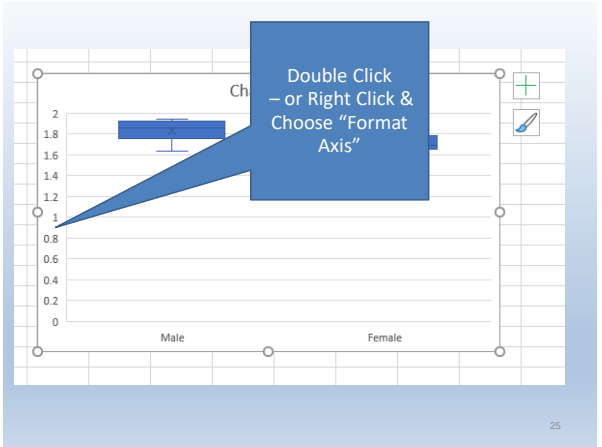


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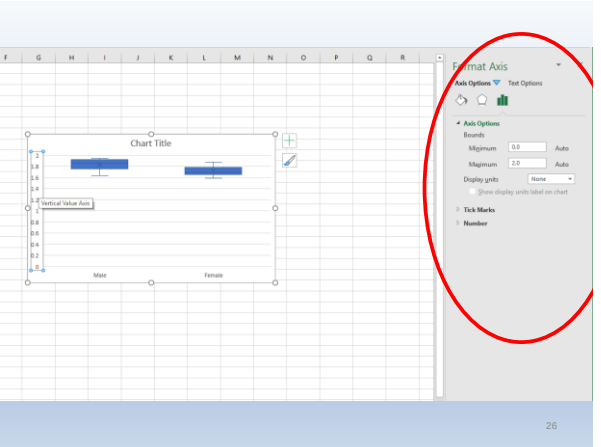


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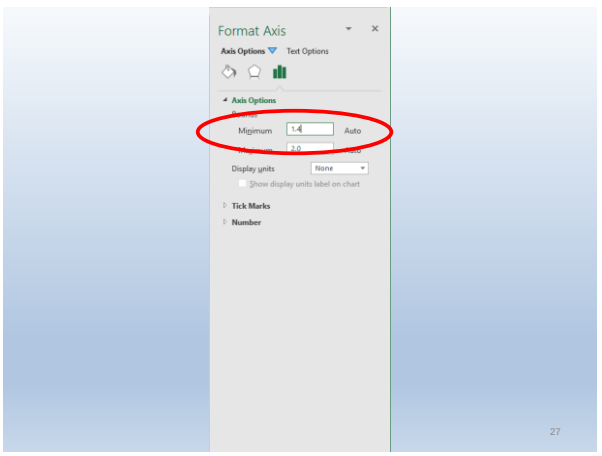


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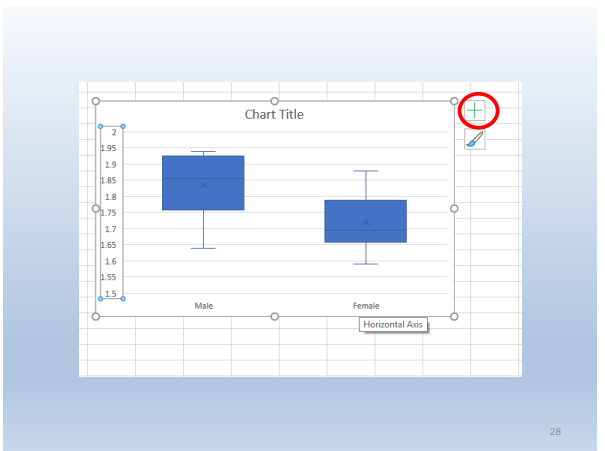


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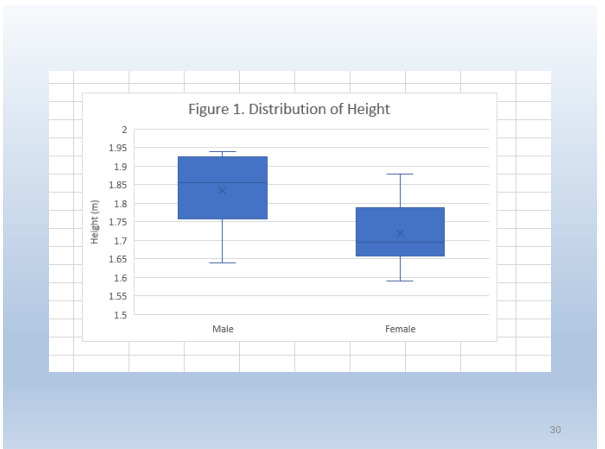


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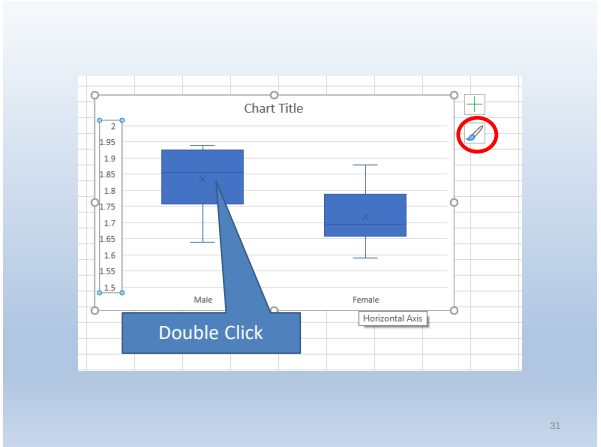


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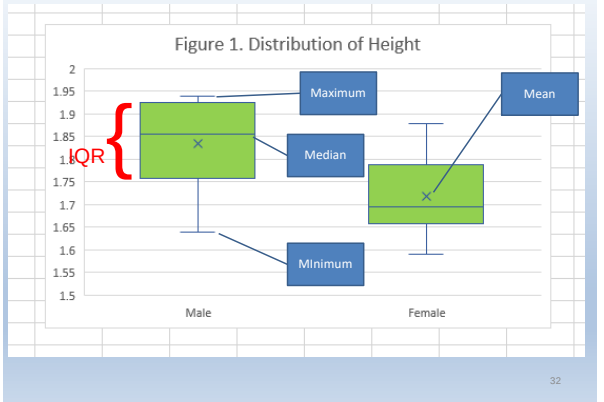


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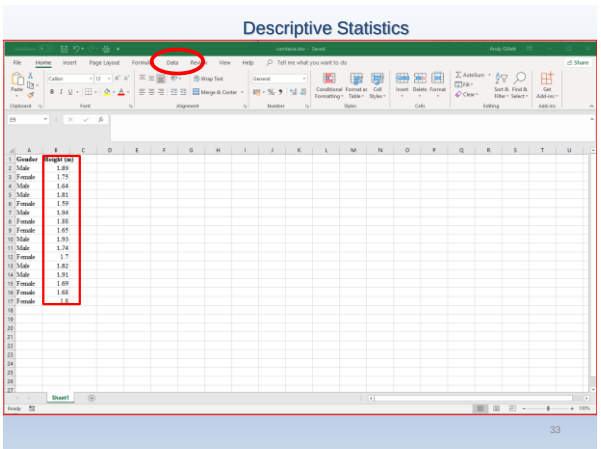


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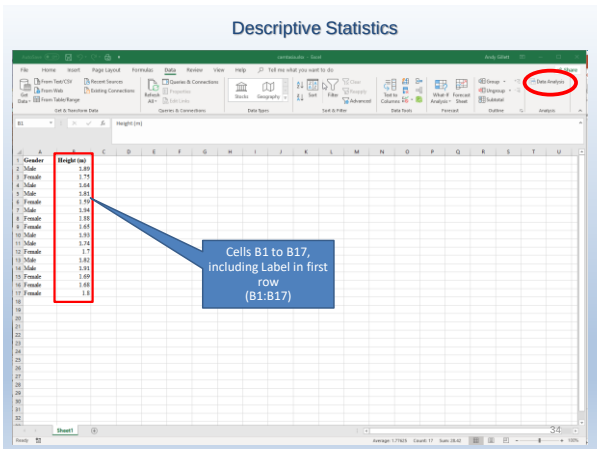


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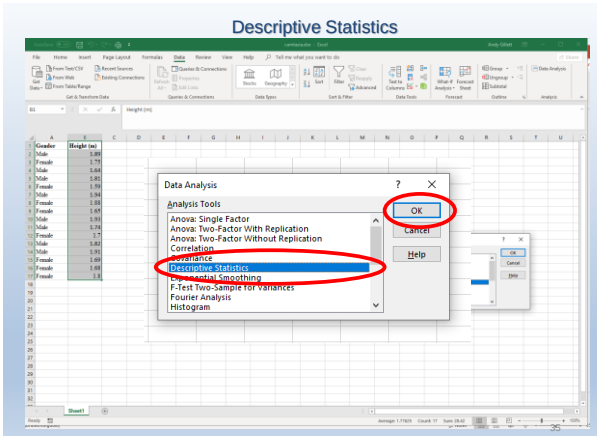


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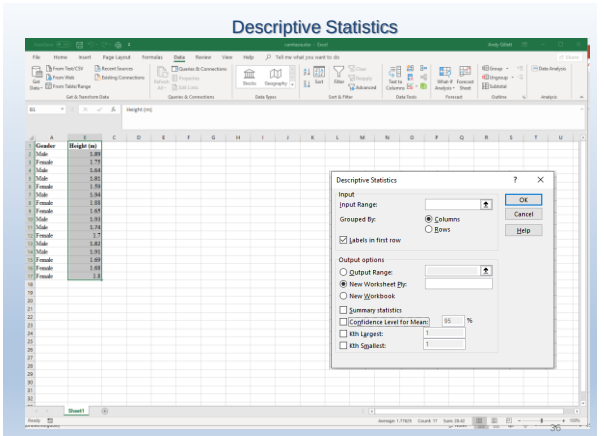


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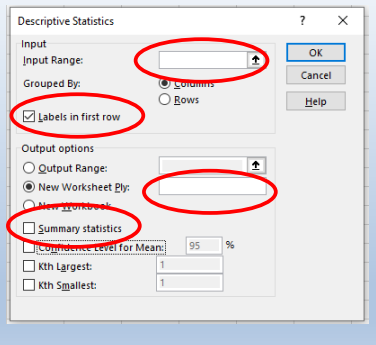
## Descriptive Statistics

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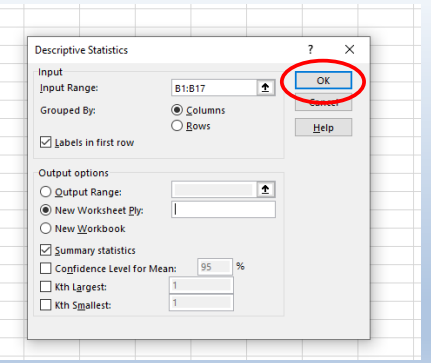
## Descriptive Statistics

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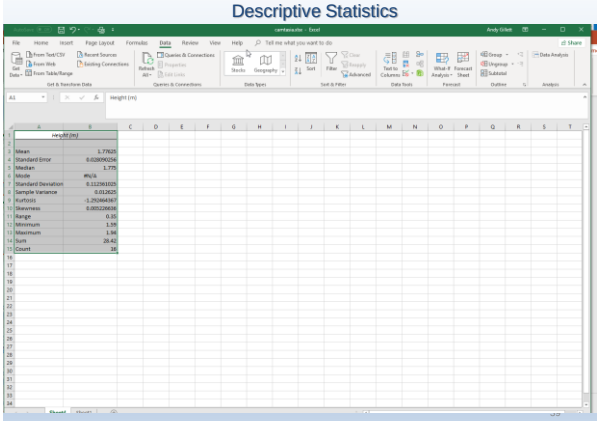
## Descriptive Statistics



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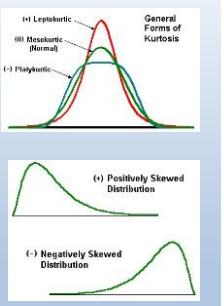
## Descriptive Statistics

| | A | B | C |
|---|---|---|---|
| 1 | *Height (m)* | | |
| 2 | | | |
| 3 | Mean | 1.77625 | |
| 4 | Standard Error | 0.028090256 | |
| 5 | Median | 1.775 | |
| 6 | Mode | #N/A | |
| 7 | Standard Deviation | 0.112361025 | |
| 8 | Sample Variance | 0.012625 | |
| 9 | Kurtosis | -1.292464367 | |
| 10 | Skewness | 0.005226636 | |
| 11 | Range | 0.35 | |
| 12 | Minimum | 1.59 | |
| 13 | Maximum | 1.94 | |
| 14 | Sum | 28.42 | |
| 15 | Count | 16 | |
| 16 | | | |

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## Descriptive Statistics

| Gender | Height (m) | | | | |
|---|---|---|---|---|---|
| Male | 1.89 | | | | |
| Female | 1.75 | | 1st Quartile | =QUARTILE(B2:B17,1) | 1.6875 |
| Male | 1.64 | | 3rd Quartile | =QUARTILE(B2:B17,3) | 1.8825 |
| Male | 1.81 | | IQR | =(F4-F3) | 0.195 |
| Female | 1.59 | | | | |
| Male | 1.94 | | | | |
| Female | 1.88 | | | | |
| Female | 1.65 | | | | |
| Male | 1.93 | | | | |
| Male | 1.74 | | | | |
| Female | 1.7 | | | | |
| Male | 1.82 | | | | |
| Male | 1.91 | | | | |
| Female | 1.69 | | | | |
| Female | 1.68 | | | | |
| Female | 1.8 | | | | |

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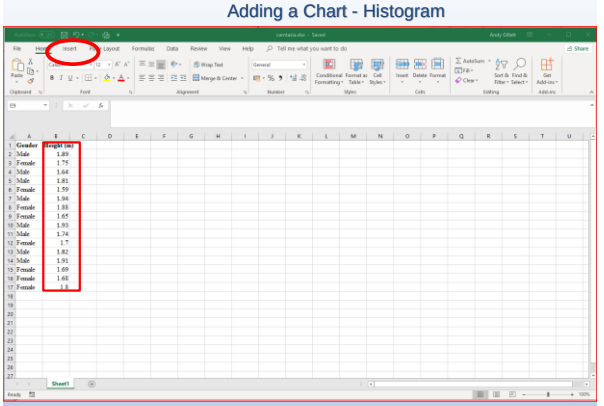
## Adding a Chart - Histogram



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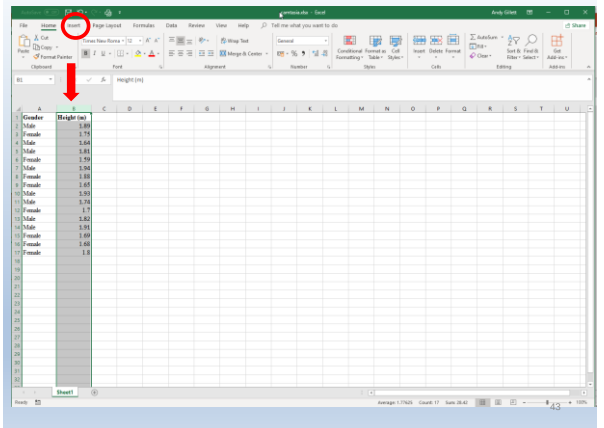


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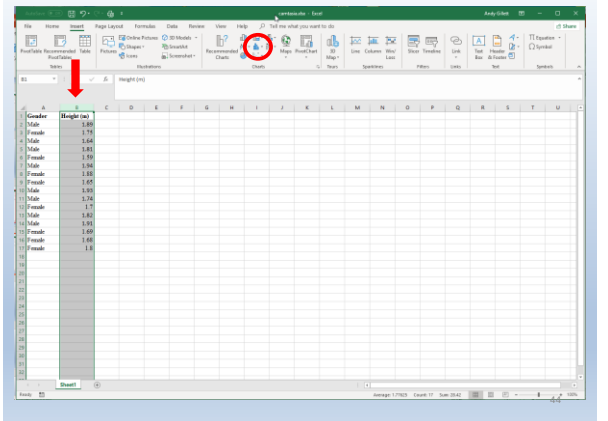


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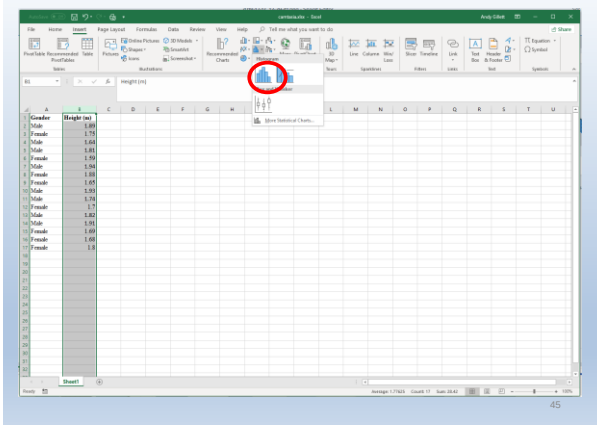


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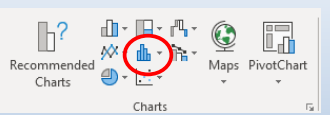


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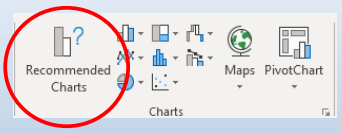


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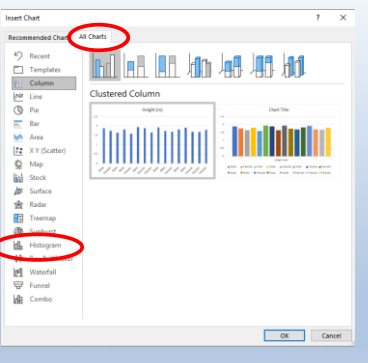


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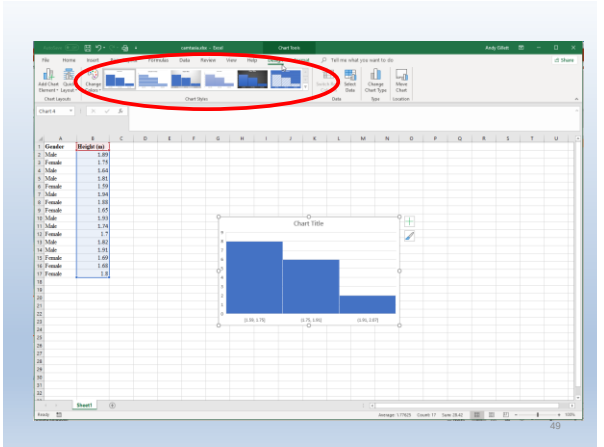


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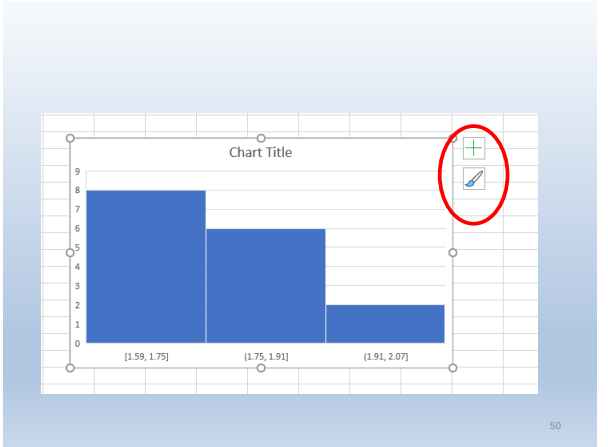


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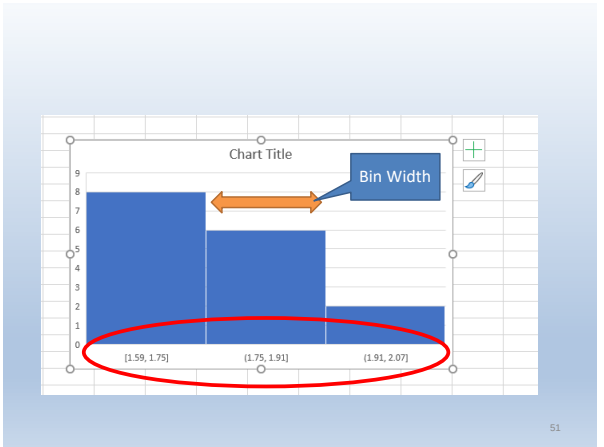


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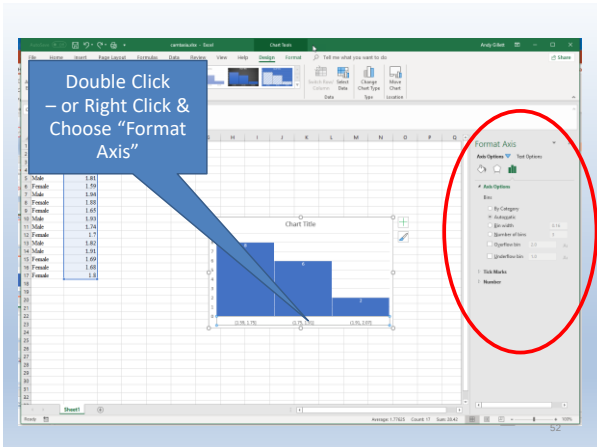


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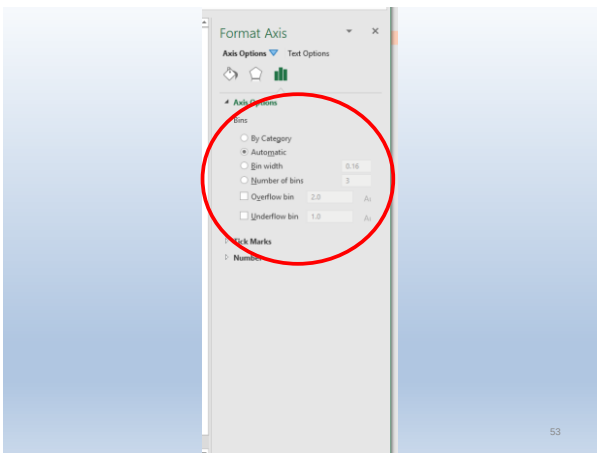


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## Describing Data using Statistics

**Description**

- Central Tendency
- Dispersion

**Inference**

– Exploring Relationships
- Correlation
- Regression

– Comparing Groups
- t-Test
- ANOVA

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## Describing Data using Statistics

**Description**

**Inference**

– Exploring Relationships

– Comparing Groups

"When an individual uses descriptive statistics, he talks about the data he has; but with inferential statistics, he talks about data he does not have."

(Popham & Sirotnik, 1973: 40)

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## Describing Data using Statistics

**Description**

**Inference**

– Exploring Relationships

– Comparing Groups

"When an individual uses descriptive statistics, he talks about the data he has; but with inferential statistics, he talks about data he does not have."

(Popham & Sirotnik, 1973: 40)

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## Describing Data using Statistics

**Relationships:**

- The association between two variables.
- The correlation between two variables.

Correlation/correlate; Association/associate; Relationship/relate; Covariance/covariation/covary

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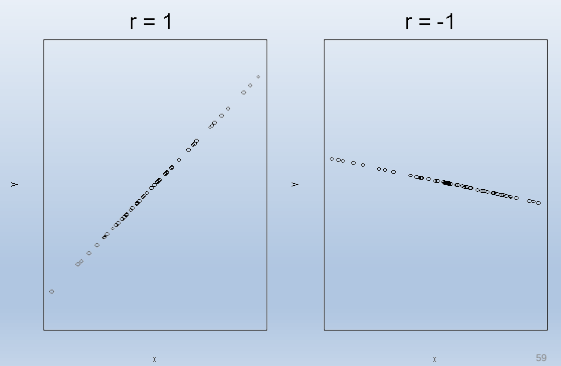
## Correlation Coefficient (r)

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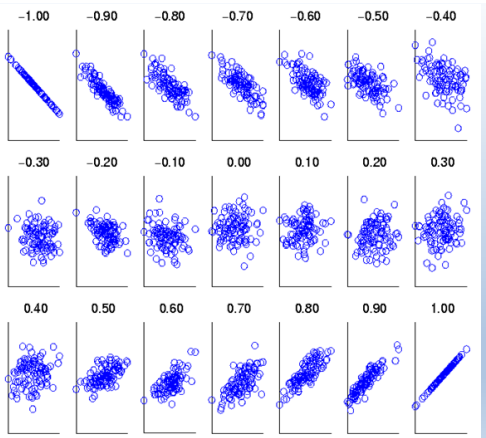


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## Correlation Coefficients

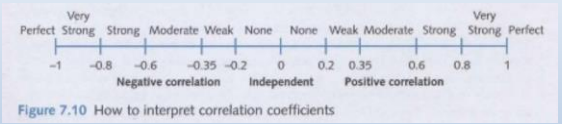


Figure 7.10 How to interpret correlation coefficients

(Saunders & Lewis, 2012: 183)



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## Correlation

There is much interest in whether there is a relationship between pupils' ability at sport and their maths ability. Accordingly a study was carried out in which both sport and maths ability were rated on each of 10 pupils sampled at random from a class of first year pupils in a secondary school. Sport ability was rated on a scale of 1 to 20. Maths ability was measured by a pencil and paper test on a scale from 1 to 30.

Statistical Services and Consultancy Unit (2016: 33-46)



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## Correlation

| Pupil No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Sports score | 15 | 19 | 12 | 14 | 9 | 16 | 20 | 14 | 15 | 19 |
| Maths score | 24 | 29 | 20 | 27 | 16 | 28 | 28 | 23 | 21 | 29 |



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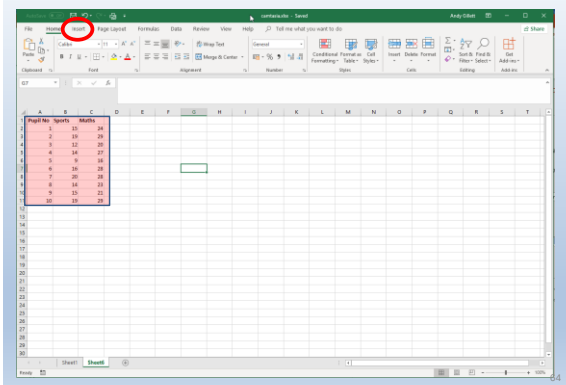



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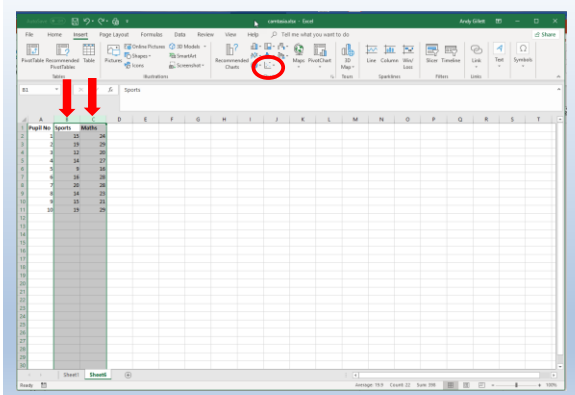



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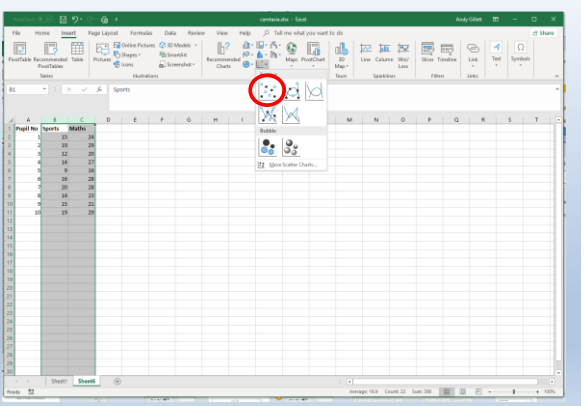



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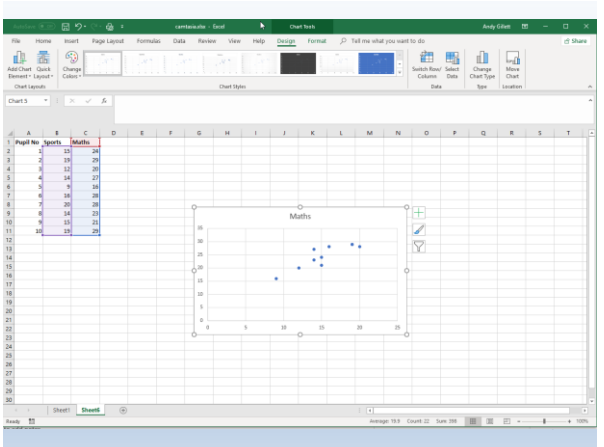


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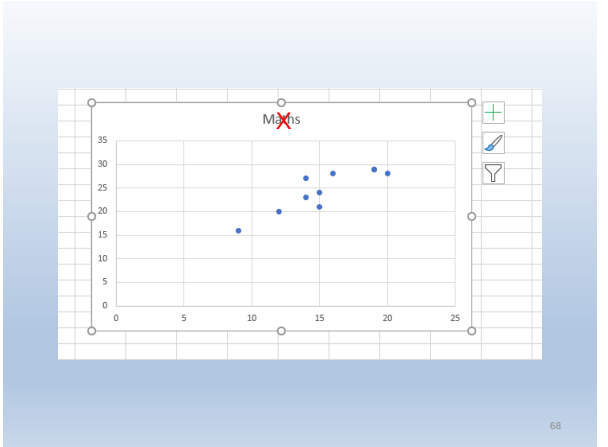


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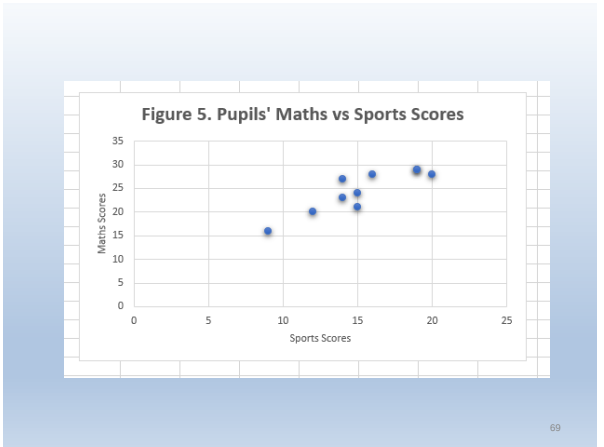


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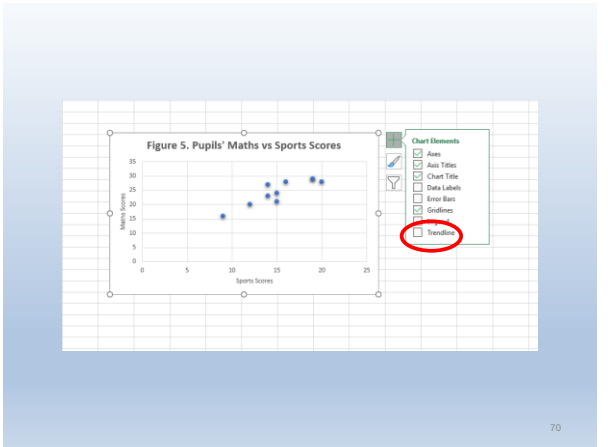


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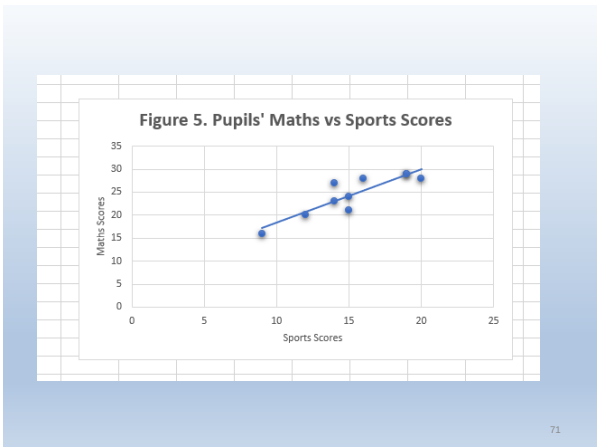


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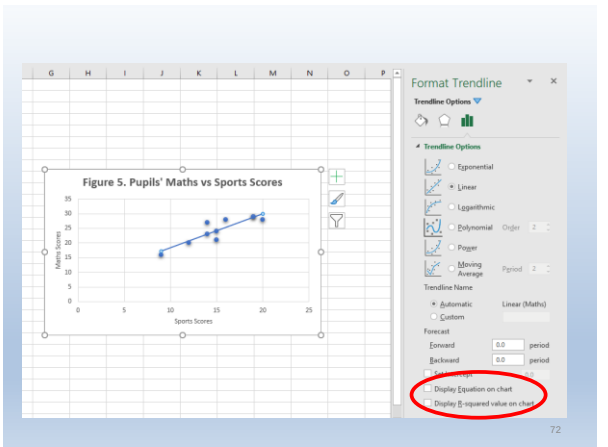


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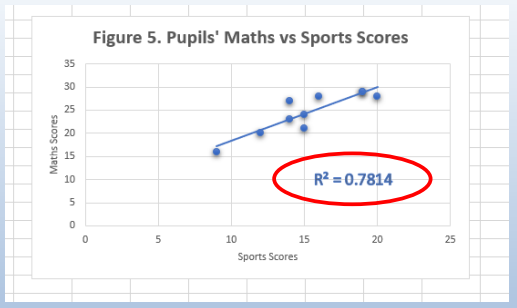


r (Correlation Coefficient) = √0.7814 = 0.884 = Very Strong

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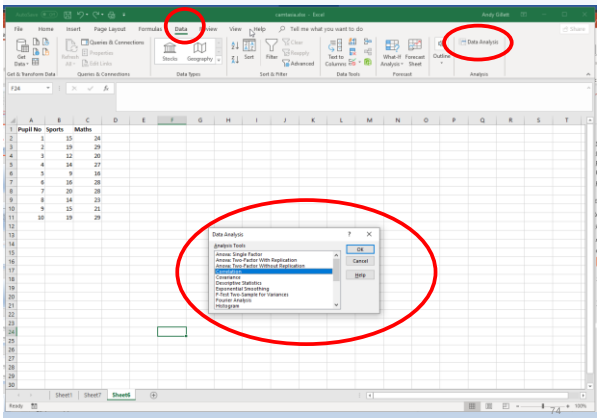


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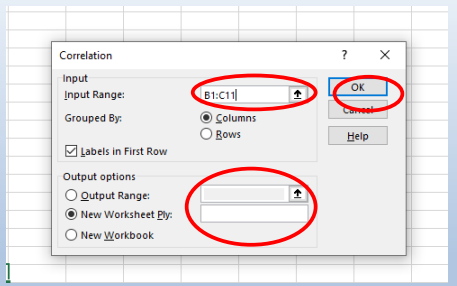


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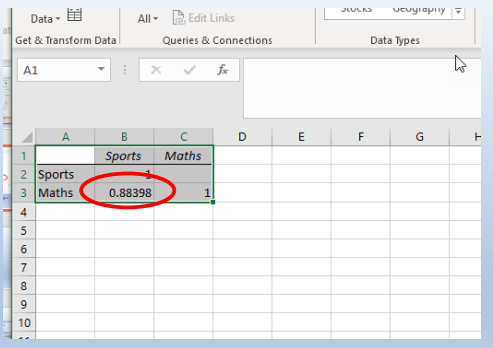


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The correlation, r, has the value 0.884.

The *p*-value is the probability that the correlation found between the two variables could be a chance result. As *p* here is less than 0.05 the correlation is unlikely to be a chance result.

The conclusion is that there is a relationship between SPORT scores and MATHS scores in the wider population of first year secondary school pupils. The results can be generalised.

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## Regression

A study looked at the possibility of predicting students' future reading ability (READING) from their intelligence score (IQ).
Ten children were included in the investigation, selected at random from a primary school class. The children's IQ scores were obtained when they entered the school and the corresponding reading score was obtained at the end of the first year. The reading score was the result out of 100 on a test.

Statistical Services and Consultancy Unit (2016: 36-42)

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## Regression

| Pupil No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| IQ Score | 98 | 115 | 124 | 97 | 135 | 105 | 117 | 101 | 110 | 127 |
| Reading | 54 | 74 | 81 | 59 | 88 | 70 | 78 | 73 | 84 | 86 |

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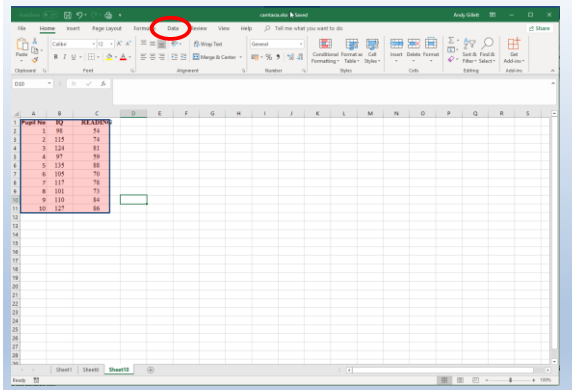

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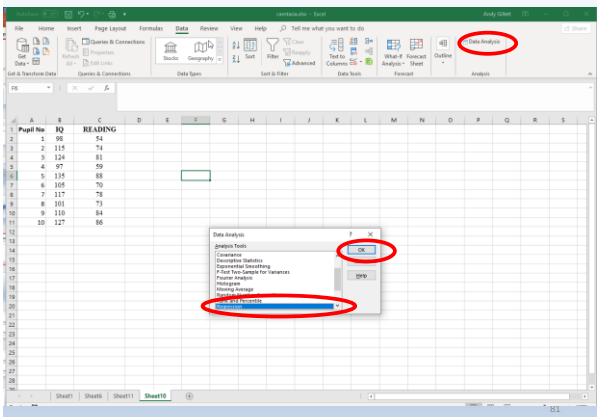

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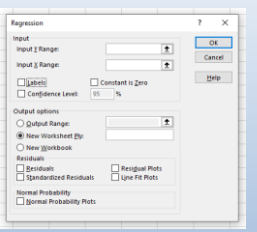

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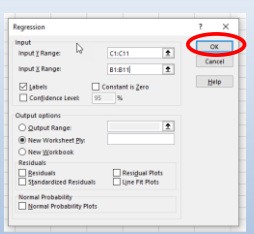

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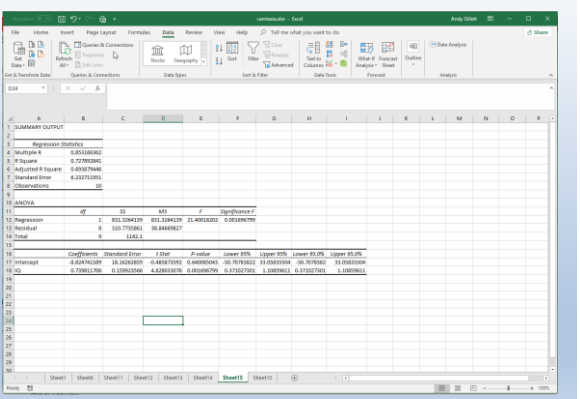

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SUMMARY OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.853166362 |
| R Square | 0.727892841 |
| Adjusted R Square | 0.693879446 |
| Standard Error | 6.232711951 |
| Observations | 10 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 831.3264139 | 831.3264139 | 21.40018202 | 0.001696799 |
| Residual | 8 | 310.7735861 | 38.84669827 | | |
| Total | 9 | 1142.1 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* |
|---|---|---|---|---|---|
| Intercept | -8.824741589 | 18.16262859 | -0.485873592 | 0.640085043 | -50.70783822 |
| IQ | 0.739811706 | 0.159923566 | 4.626033076 | 0.001696799 | 0.371027301 |

Very Strong Correlation (0.85)

0.0016 < 0.05 therefore significant

Reading = -8.82 + 0.74 x IQ

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## Regression

The regression equation

"READING = −8.82 + 0.740 × IQ"

can be obtained by equating the dependent variable **Reading** to the *CONSTANT* value −8.825, plus the independent variable **IQ** multiplied by its coefficient 0.740.

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## Example

Since $p$ is very small, below 0.05, the relationship is unlikely to be a chance result. Hence it is concluded that there is a relationship between IQ and reading score for primary school children. Hence, we can reject $H_0$ in favour of $H_1$. For every primary school child whose IQ is known the reading score can be predicted.

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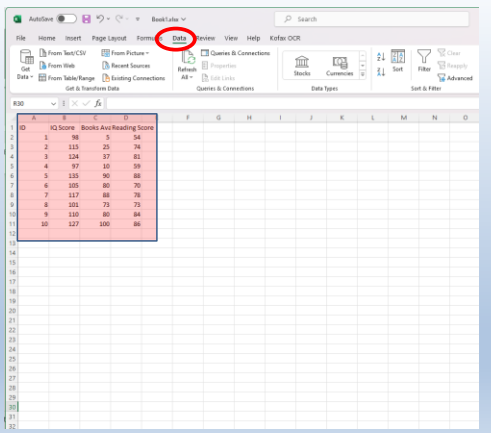

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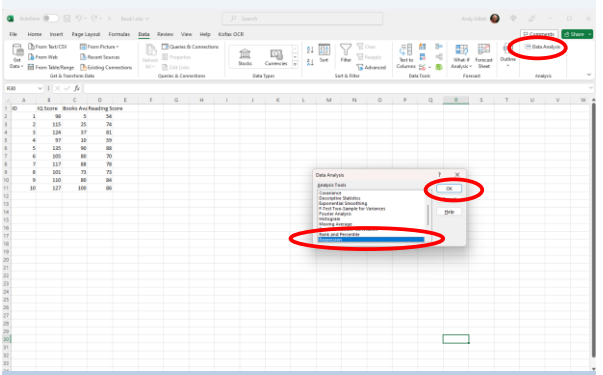

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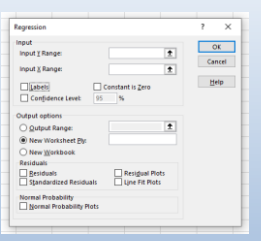


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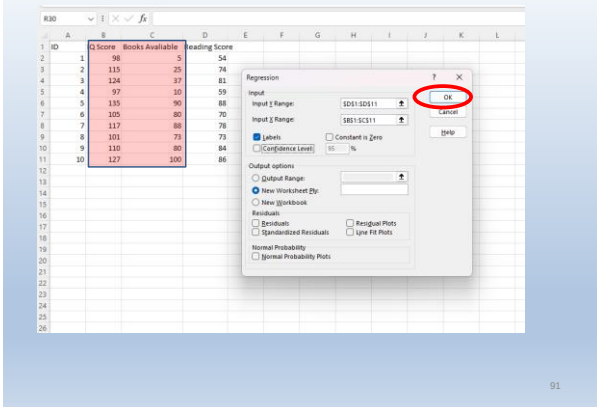


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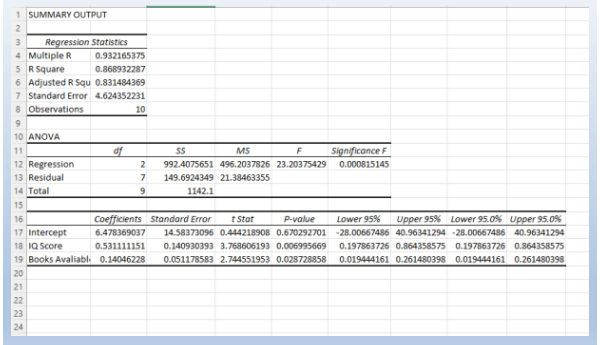
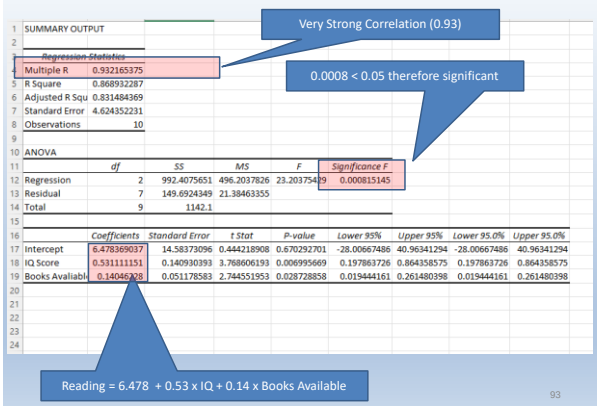


| | | | | | |
|---|---|---|---|---|---|
| SUMMARY OUTPUT | | | | | |
| *Regression Statistics* | | | | | |
| Multiple R | 0.932165375 | | | | |
| R Square | 0.868932287 | | | | |
| Adjusted R Squ | 0.831484369 | | | | |
| Standard Error | 4.624352231 | | | | |
| Observations | 10 | | | | |
| ANOVA | | | | | |
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 2 | 992.4075651 | 496.2037826 | 23.20375429 | 0.000815145 |
| Residual | 7 | 149.6924349 | 21.38463355 | | |
| Total | 9 | 1142.1 | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
| Intercept | 6.478369037 | 14.58373096 | 0.444218908 | 0.670292701 | -28.00667486 | 40.96341294 | -28.00667486 | 40.96341294 |
| IQ Score | 0.531111151 | 0.140930393 | 3.768606193 | 0.006995669 | 0.197863726 | 0.864358575 | 0.197863726 | 0.864358575 |
| Books Avaliabl | 0.14046228 | 0.051178583 | 2.744551953 | 0.028728858 | 0.019444161 | 0.261480398 | 0.019444161 | 0.261480398 |

92

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## Multiple Regression

The regression equation

"READING = 6.478 + .140 × Books + .531 x IQ "

can be obtained by equating the dependent variable **Reading** to the *CONSTANT* value 6.478, plus the independent variable **IQ** multiplied by its coefficient .531 and the **Number of Books** multiplied by .140.

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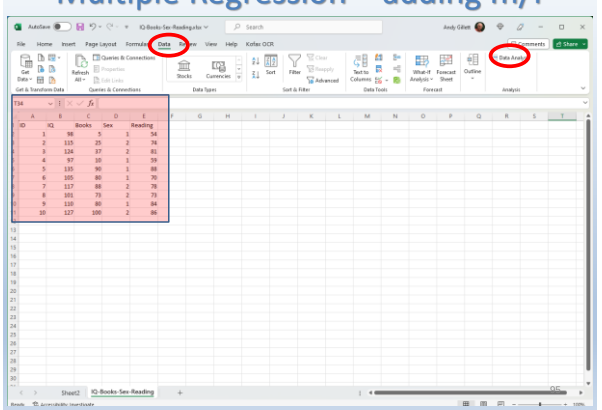
## Multiple Regression – adding m/f



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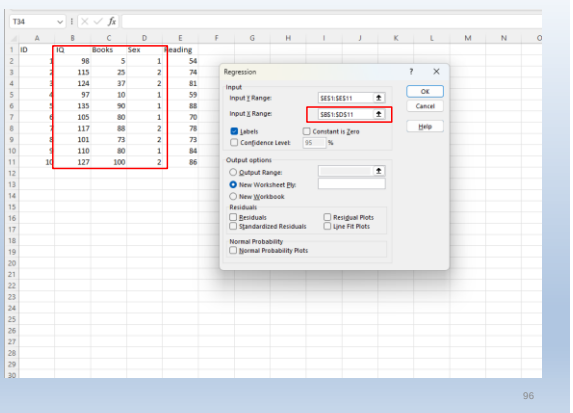


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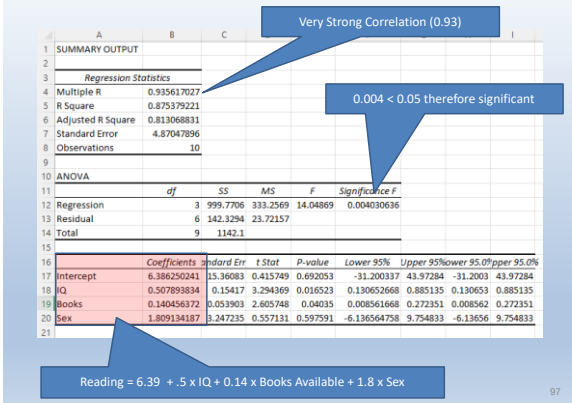


| SUMMARY OUTPUT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Regression Statistics* | | | | | | | | |
| Multiple R | 0.935617027 | | | | | | | |
| R Square | 0.875379221 | | | | | | | |
| Adjusted R Square | 0.813068831 | | | | | | | |
| Standard Error | 4.87047896 | | | | | | | |
| Observations | 10 | | | | | | | |
| ANOVA | | | | | | | | |
| | *df* | *SS* | *MS* | *F* | *Significance F* | | | |
| Regression | 3 | 999.7706 | 333.2569 | 14.04869 | 0.004030636 | | | |
| Residual | 6 | 142.3294 | 23.72157 | | | | | |
| Total | 9 | 1142.1 | | | | | | |
| | *Coefficients* | *Standard Err* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
| Intercept | 6.386250241 | 15.36083 | 0.415749 | 0.692053 | -31.200337 | 43.97284 | -31.2003 | 43.97284 |
| IQ | 0.507893834 | 0.15417 | 3.294369 | 0.016523 | 0.130652668 | 0.885135 | 0.130653 | 0.885135 |
| Books | 0.140456372 | 0.053903 | 2.605748 | 0.04035 | 0.008561668 | 0.272351 | 0.008562 | 0.272351 |
| Sex | 1.809134187 | 3.247235 | 0.557131 | 0.597591 | -6.136564758 | 9.754833 | -6.13656 | 9.754833 |



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## Multiple Regression

The regression equation

Reading = 6.39 + .5 x IQ + 0.14 x Books Available + 1.8 x Sex

Note that Sex is a categorical variable with two levels (Males = 1 & Females = 2).

In this case the regression weighting (1.8) is added to the predicted Reading value. So for females 1.8 (1.8 x 1) would be added and for males 3.6 (1.8 x 2) would be added.



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## Multiple Regression: Relative Importance

Which variables are important?

| | *Coefficients* | *Standard Err* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 6.386250241 | 15.36083 | 0.415749 | 0.692053 | -31.2003 | 43.97284 | -31.2003 | 43.97284 |
| IQ | 0.507893834 | 0.15417 | 3.294369 | 0.016523 | 0.130653 | 0.885135 | 0.130653 | 0.885135 |
| Books | 0.140456372 | 0.053903 | 2.605748 | 0.04035 | 0.008562 | 0.272351 | 0.008562 | 0.272351 |
| Sex | 1.809134187 | 3.247235 | 0.557131 | 0.597591 | -6.13656 | 9.754833 | -6.13656 | 9.754833 |

We cannot compare these coefficients as they use different scales. We need to standardize them – put them on the same scale. We will then have the standardised regression coefficients, which we can compare.



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## Multiple Regression: Relative Importance

Which variables are important?

=STANDARDIZE(B2:B11,AVERAGE(B2:B11),STDEV(B2:B11))

| ID | IQ | Books | Sex | Reading | IQ Standardised | Books Standardised | Sex Standardised | Reading Standardised |
|---|---|---|---|---|---|---|---|---|
| 1 | 98 | 5 | 1 | 54 | -1.146945897 | -1.503912381 | -0.948683298 | -1.837551562 |
| 2 | 115 | 25 | 2 | 74 | 0.161650093 | -0.944837146 | 0.948683298 | -0.062139425 |
| 3 | 124 | 37 | 2 | 83 | 0.854436205 | -0.609392006 | 0.948683298 | 0.559254823 |
| 4 | 97 | 10 | 1 | 59 | -1.223922132 | -1.364143572 | -0.948683298 | -1.393698528 |
| 5 | 135 | 90 | 1 | 88 | 1.701174787 | 0.872157366 | -0.948683298 | 1.180649072 |
| 6 | 105 | 80 | 1 | 70 | -0.608112254 | 0.592619748 | -0.948683298 | -0.417221852 |
| 7 | 117 | 88 | 2 | 78 | 0.315602562 | 0.816249842 | 0.948683298 | 0.292943003 |
| 8 | 101 | 73 | 2 | 73 | -0.916071193 | 0.396943416 | 0.948683298 | -0.150910032 |
| 9 | 110 | 80 | 1 | 84 | -0.223231081 | 0.592619748 | -0.948683298 | 0.825566644 |
| 10 | 127 | 100 | 2 | 86 | 1.085364909 | 1.151694983 | 0.948683298 | 1.003107858 |

Run the regression function as before.



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## Multiple Regression: Relative Importance

Which variables are important?

| SUMMARY OUTPUT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Regression Statistics* | | | | | | | | |
| Multiple R | 0.935617027 | | | | | | | |
| R Square | 0.875379221 | | | | | | | |
| Adjusted R Square | 0.813068831 | | | | | | | |
| Standard Error | 0.432355373 | | | | | | | |
| Observations | 10 | | | | | | | |
| ANOVA | | | | | | | | |
| | *df* | *SS* | *MS* | *F* | *gnificance F* | | | |
| Regression | 3 | 7.878413 | 2.626138 | 14.04869 | 0.004031 | | | |
| Residual | 6 | 1.121587 | 0.186931 | | | | | |
| Total | 9 | 9 | | | | | | |
| | *Coefficients* | *Standard Err* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
| Intercept | -1.38519E-17 | 0.136723 | -1E-16 | 1 | -0.33455 | 0.334549 | -0.33455 | 0.334549 |
| IQ Standardised | 0.585713812 | 0.177792 | 3.294369 | 0.016523 | 0.150671 | 1.020756 | 0.150671 | 1.020756 |
| Books Standardised | 0.446036475 | 0.171174 | 2.605748 | 0.04035 | 0.027189 | 0.864884 | 0.027189 | 0.864884 |
| Sex Standardised | 0.084642546 | 0.151926 | 0.557131 | 0.597591 | -0.28711 | 0.456392 | -0.28711 | 0.456392 |



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## Multiple Regression: Relative Importance

Which variables are important?

| | *Coefficients* |
|---|---|
| Intercept | -1.38519E-17 |
| IQ Standardised | 0.585713812 |
| Books Standardised | 0.446036475 |
| Sex Standardised | 0.084642546 |

You now have the standardised regression coefficients, and can now compare them.

IQ: 0.586
Sex: 0.085
Books Available: 0.446

And you can see that the most important predictor is **IQ**, followed closely by **Books Available**. **Sex** is not contributing very much.



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## Describing Data using Statistics

**Description**

**Inference**

- Exploring Relationships
- Comparing Groups

"When an individual uses descriptive statistics, he talks about the data he has; but with inferential statistics, he talks about data he does not have."

(Popham & Sirotnik, 1973: 40)

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## Comparing Groups (2 groups)

An experiment is carried out to see if announcing the items on a conveyor belt as they pass helps children remember the items better. Twenty-two children, all aged 12 years, were randomly allocated; 10 to the announcement group, and the remaining 12 to the no-announcement group. The children were shown the items on the conveyor belt with or without announcing each item as they passed. The number of items recalled out of each of the ten letters in the list was recorded for each child:

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## Comparing Groups

The researchers wanted to find out if the announcement had any impact on the number of items recalled.

| | Items Recalled | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Announcement:** | 5 | 7 | 8 | 9 | 5 | 4 | 9 | 8 | 7 | 4 | | |
| **No announcement:** | 3 | 8 | 5 | 6 | 3 | 5 | 9 | 3 | 3 | 4 | 7 | 4 |

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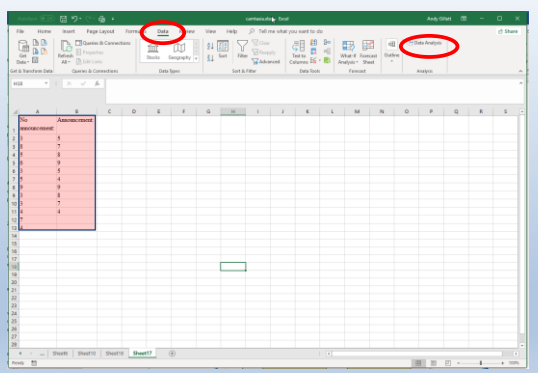
## t-Test



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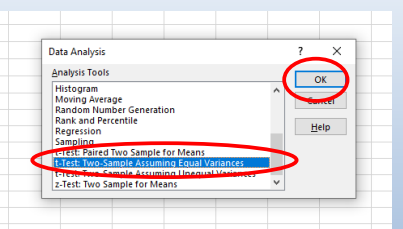


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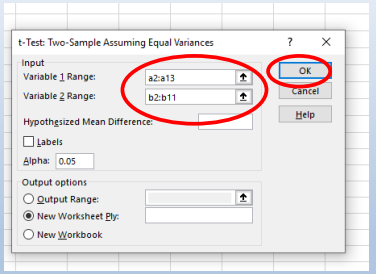


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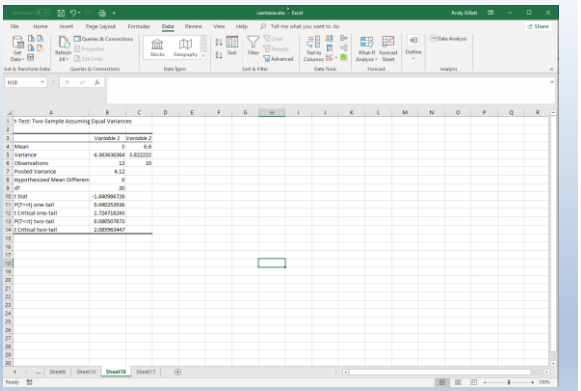

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| t-Test: Two-Sample Assuming Equal Variances | | |
|---|---|---|
| | *Variable 1* | *Variable 2* |
| Mean | 5 | 6.6 |
| Variance | 4.363636364 | 3.822222222 |
| Observations | 12 | 10 |
| Pooled Variance | 4.12 | |
| Hypothesized Me | 0 | |
| df | 20 | |
| t Stat | -1.840986726 | |
| P(T<=t) one-tail | 0.040253936 | |
| t Critical one-tail | 1.724718243 | |
| P(T<=t) two-tail | 0.080507873 | |
| t Critical two-tail | 2.085963447 | |

P = 0.08 > 0.05 Therefore not significant

The conclusion is that there is no benefit to the wider population from the use of announcements.

111

111

## Comparing Groups (3 groups or more)

An experiment was carried out in which a sample of adults was selected and randomly allocated to four groups. All were asked to consume amounts of alcohol as follows:

Group 1: NO ALCOHOL
Group 2: ONE UNIT OF ALCOHOL
Group 3: TWO UNITS OF ALCOHOL
Group 4: THREE UNITS OF ALCOHOL

after which they were asked drive a car simulator and perform an emergency stop at 40 miles per hour. The distance to stopping the simulator in metres by each group member is shown below.

112

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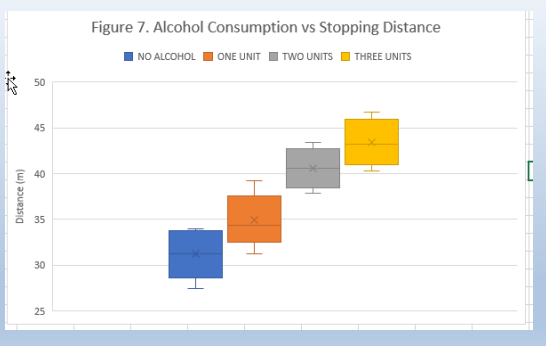
## Comparing Groups (3 groups or more)

The results were as follow.

| | | | | | |
|---|---|---|---|---|---|
| NO ALCOHOL | 31.2 | 27.4 | 29.8 | 33.5 | 34.0 |
| ONE UNIT | 31.2 | 33.7 | 34.3 | 39.2 | 36.0 |
| TWO UNITS | 42.1 | 40.6 | 43.4 | 37.9 | 39.0 |
| THREE UNITS | 46.7 | 45.1 | 43.2 | 41.7 | 40.3 |

113

113




114

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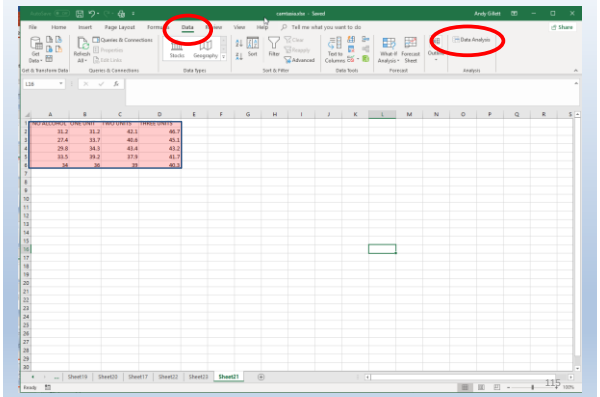
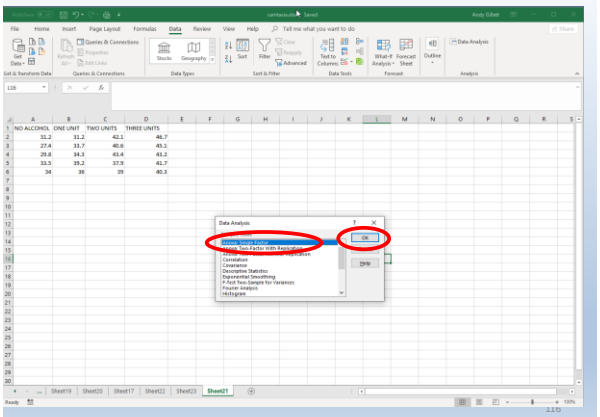
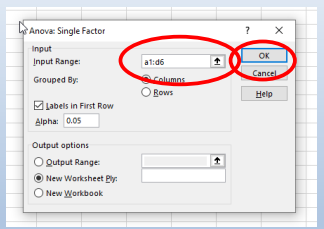
## ANOVA



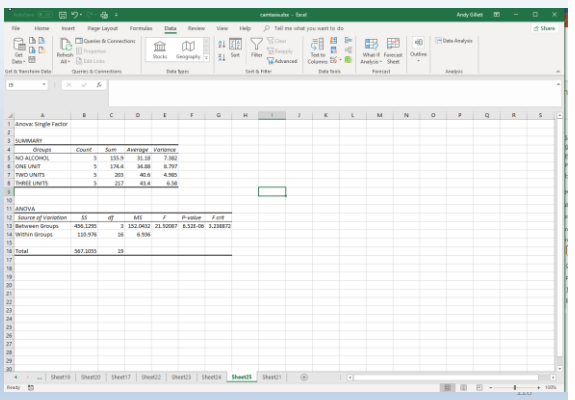
115



116




117



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Anova: Single Factor

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| NO ALCOHOL | 5 | 155.9 | 31.18 | 7.382 |
| ONE UNIT | 5 | 174.4 | 34.88 | 8.797 |
| TWO UNITS | 5 | 203 | 40.6 | 4.985 |
| THREE UNITS | 5 | 217 | 43.4 | 6.58 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 456.1295 | 3 | 152.0432 | 21.92087 | 6.52E-06 | 3.238872 |
| Within Groups | 110.976 | 16 | 6.936 | | | |
| Total | 567.1055 | 19 | | | | |

$p = 6.52E\text{-}06 = 6.52 \times 10^{-6} = 0.00000652 < 0.05$
Therefore significant

The conclusion is that there is a significant difference between the distance it takes to stop a car simulator according to the amount of alcohol consumed.

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## Comparing Groups

An experiment was carried out in which a sample of adults was selected and randomly allocated to four groups. All were asked to consume amounts of alcohol as follows:

Group 1: NO ALCOHOL
Group 2: ONE UNIT OF ALCOHOL
Group 3: TWO UNITS OF ALCOHOL
Group 4: THREE UNITS OF ALCOHOL

after which they were asked drive a car simulator and perform an emergency stop at 40 miles per hour. The distance to stopping the simulator in metres by each group member is shown below.

Is this the same for both males and females?

120

120

## Comparing Groups (4 groups and M/F)

The results were as follows.

| | | | | | | |
|---|---|---|---|---|---|---|
| MALES | NO ALCOHOL | 31.2 | 27.4 | 29.8 | 33.5 | 34.0 |
| | ONE UNIT | 31.2 | 33.7 | 34.3 | 39.2 | 36.0 |
| | TWO UNITS | 42.1 | 40.6 | 43.4 | 37.9 | 39.0 |
| | THREE UNITS | 46.7 | 45.1 | 43.2 | 41.7 | 40.3 |
| FEMALES | NO ALCOHOL | 35.1 | 32.3 | 35.4 | 38.1 | 35.9 |
| | ONE UNIT | 32.8 | 35.9 | 36.1 | 40.9 | 38.2 |
| | TWO UNITS | 38.1 | 35.9 | 40.2 | 39.8 | 37.6 |
| | THREE UNITS | 39.8 | 31.7 | 41.2 | 39.1 | 37.9 |

Stopping Distance in Metres

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## Three Questions

1. Is there a difference in the stopping distance according to the amount of alcohol consumed?
2. Is there a difference in the stopping distance between male and females?
3. Is the effect of amount of alcohol consumed on stopping distance different for males and females?

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## EXCEL - Data

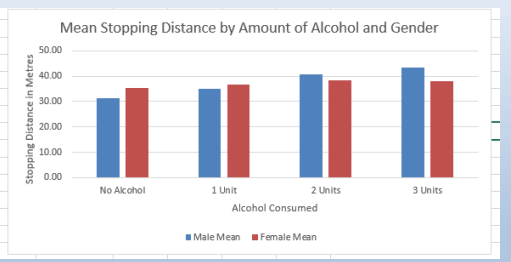
B16

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Gender | No Alcohol | 1 Unit | 2 Units | 3 Units | | |
| 2 | Male | 31.20 | 31.20 | 42.10 | 46.70 | | |
| 3 | Male | 27.40 | 33.70 | 40.60 | 45.10 | | |
| 4 | Male | 29.80 | 34.30 | 43.40 | 43.20 | | |
| 5 | Male | 33.50 | 39.20 | 37.90 | 41.70 | | |
| 6 | Male | 34.00 | 36.00 | 39.00 | 40.30 | | |
| 7 | Female | 35.10 | 32.80 | 38.10 | 39.80 | | |
| 8 | Female | 32.30 | 35.90 | 35.90 | 31.70 | | |
| 9 | Female | 35.40 | 36.10 | 40.20 | 41.20 | | |
| 10 | Female | 38.10 | 40.90 | 39.80 | 39.10 | | |
| 11 | Female | 35.90 | 38.20 | 37.60 | 37.90 | | |
| 12 | | | | | | | |
| 13 | | | | | | | |

123

123

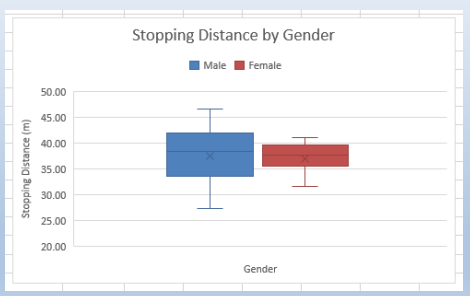
## Descriptive Statistics




124

124

## Total (M&F) Means




125

125

## Descriptive Statistics

| *Male* | | *Female* | |
|---|---|---|---|
| Mean | 37.515 | Mean | 37.1 |
| Standard Error | 1.221631243 | Standard Error | 0.620780493 |
| Median | 38.45 | Median | 37.75 |
| Mode | 31.2 | Mode | 35.9 |
| Standard Deviation | 5.463301007 | Standard Deviation | 2.776214765 |
| Sample Variance | 29.84765789 | Sample Variance | 7.707368421 |
| Kurtosis | -0.984023157 | Kurtosis | -0.542471441 |
| Skewness | -0.132899632 | Skewness | -0.442046056 |
| Range | 19.3 | Range | 9.5 |
| Minimum | 27.4 | Minimum | 31.7 |
| Maximum | 46.7 | Maximum | 41.2 |
| Sum | 750.3 | Sum | 742 |
| Count | 20 | Count | 20 |
| Confidence Level(95. | 2.556903578 | Confidence Level(95 | 1.299308505 |

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## Descriptive Statistics

| | No Alcohol | 1 Unit | 2 Units | 3 Units |
|---|---|---|---|---|
| Mean | 33.27 | 35.83 | 39.46 | 40.67 |
| Standard Error | 1.00244701 | 0.944463 | 0.707766 | 1.31327 |
| Median | 33.75 | 35.95 | 39.4 | 40.75 |
| Mode | #N/A | #N/A | #N/A | #N/A |
| Standard Deviation | 3.17001577 | 2.986656 | 2.238154 | 4.152924 |
| Sample Variance | 10.049 | 8.920111 | 5.009333 | 17.24678 |
| Kurtosis | -0.06924912 | -0.52334 | -0.22062 | 1.742686 |
| Skewness | -0.46548337 | 0.216964 | 0.291447 | -0.82207 |
| Range | 10.7 | 9.7 | 7.5 | 15 |
| Minimum | 27.4 | 31.2 | 35.9 | 31.7 |
| Maximum | 38.1 | 40.9 | 43.4 | 46.7 |
| Sum | 332.7 | 358.3 | 394.6 | 406.7 |
| Count | 10 | 10 | 10 | 10 |
| Confidence Level(95. | 2.26769268 | 2.136525 | 1.601079 | 2.970823 |



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## ANOVA

One-Way Between-Groups ANOVA
Single independent variable.

Two-Way Between-Groups ANOVA
Factorial/Multifactorial ANOVA
2 independent variables - two factors
Two factor design: A & B
Each factor can have different values - levels of the factor



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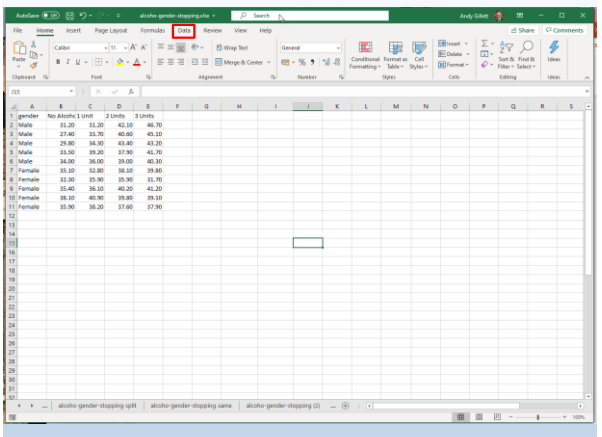

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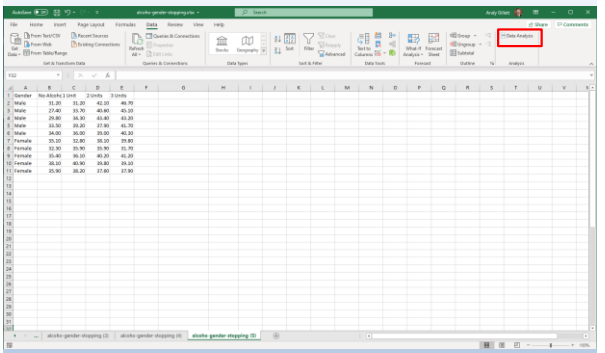



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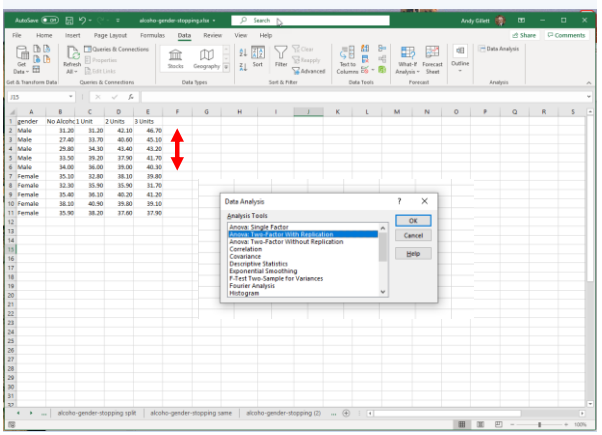


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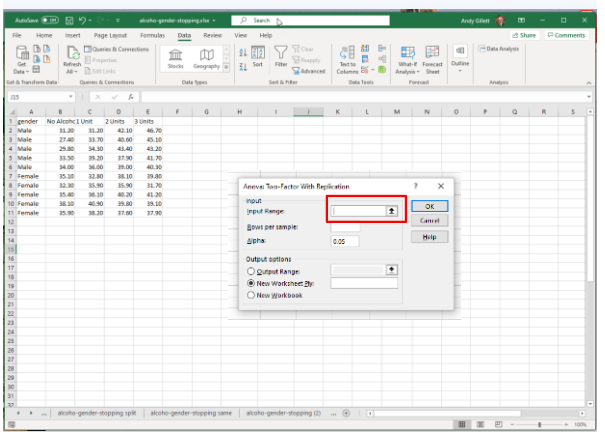
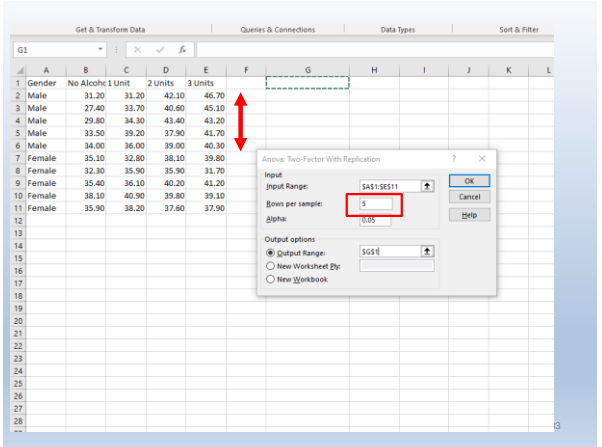



132

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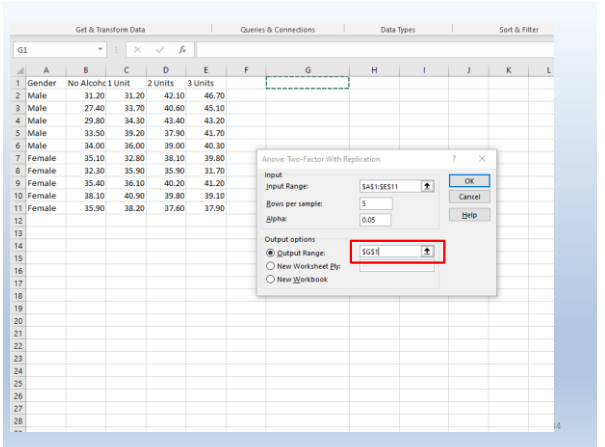
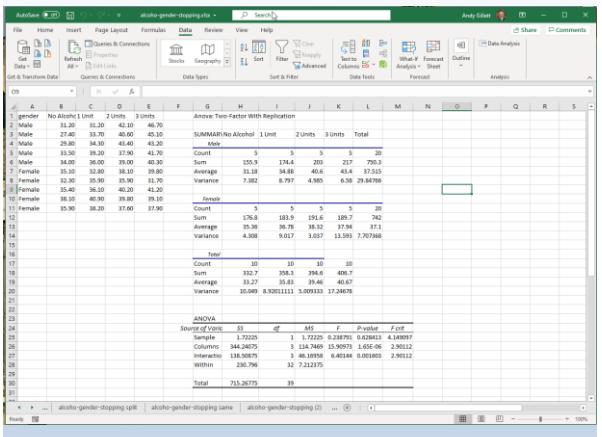



134



135

Variance = $SD^2$

Anova: Two-Factor With Replication

| SUMMARY | No Alcohol | 1 Unit | 2 Units | 3 Units | Total | |
|---|---|---|---|---|---|---|
| *Male* | | | | | | |
| Count | 5 | 5 | 5 | 5 | 20 | |
| Sum | 155.9 | 174.4 | 203 | 217 | 750.3 | |
| Average | 31.18 | 34.88 | 40.6 | 43.4 | 37.515 | |
| Variance | 7.382 | 8.797 | 4.985 | 6.58 | 29.84766 | SD = 5.5 |
| *Female* | | | | | | |
| Count | 5 | 5 | 5 | 5 | 20 | |
| Sum | 176.8 | 183.9 | 191.6 | 189.7 | 742 | |
| Average | 35.36 | 36.78 | 38.32 | 37.94 | 37.1 | |
| Variance | 4.308 | 9.017 | 3.037 | 13.593 | 7.707368 | SD = 2.8 |
| *Total* | | | | | | |
| Count | 10 | 10 | 10 | 10 | | |
| Sum | 332.7 | 358.3 | 394.6 | 406.7 | | |
| Average | 33.27 | 35.83 | 39.46 | 40.67 | | |
| Variance | 10.049 | 8.92011111 | 5.009333 | 17.24678 | | |

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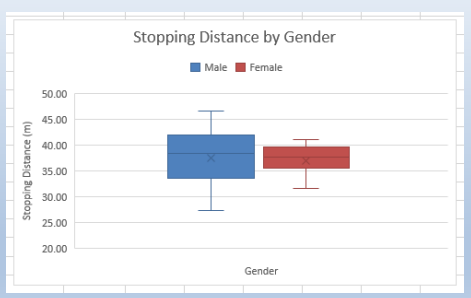
## Total Means (SD)

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Anova: Two-Factor With Replication

| SUMMARY | No Alcohol | 1 Unit | 2 Units | 3 Units | Total |
|---|---|---|---|---|---|
| *Male* | | | | | |
| Count | 5 | 5 | 5 | 5 | 20 |
| Sum | 155.9 | 174.4 | 203 | 217 | 750.3 |
| Average | 31.18 | 34.88 | 40.6 | 43.4 | 37.515 |
| Variance | 7.382 | 8.797 | 4.985 | 6.58 | 29.84766 |
| *Female* | | | | | |
| Count | 5 | 5 | 5 | 5 | 20 |
| Sum | 176.8 | 183.9 | 191.6 | 189.7 | 742 |
| Average | 35.36 | 36.78 | 38.32 | 37.94 | 37.1 |
| Variance | 4.308 | 9.017 | 3.037 | 13.593 | 7.707368 |
| *Total* | | | | | |
| Count | 10 | 10 | 10 | 10 | |
| Sum | 332.7 | 358.3 | 394.6 | 406.7 | |
| Average | 33.27 | 35.83 | 39.46 | 40.67 | |
| Variance | 10.049 | 8.92011111 | 5.009333 | 17.24678 | |

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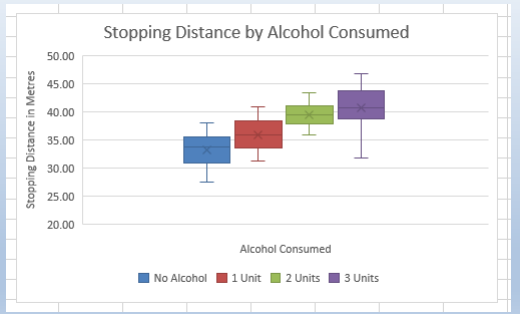
## Total – Means (SD)

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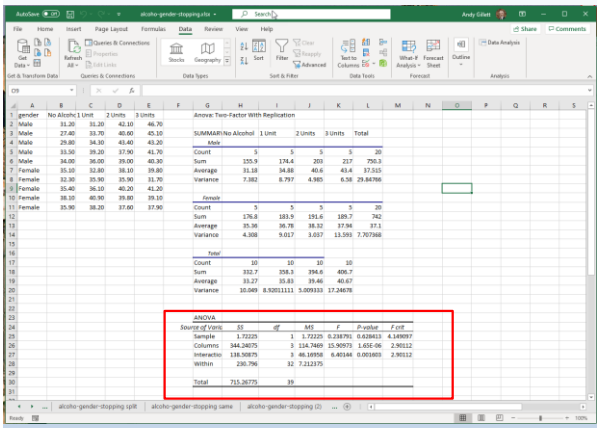

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## Main Effects

ANOVA

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Sample | 1.72225 | 1 | 1.72225 | 0.238791 | 0.628413 | 4.149097 |
| Columns | 344.24075 | 3 | 114.7469 | 15.90973 | 0.000002 | 2.90112 |
| Interaction | 138.50875 | 3 | 46.16958 | 6.40144 | 0.001603 | 2.90112 |
| Within | 230.796 | 32 | 7.212375 | | | |
| | | | | | | |
| Total | 715.26775 | 39 | | | | |

Sample = Gender – not significant (p=0.63)

Columns = Amount of Alcohol Consumed – significant (p=0.000002 <0.05)

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## Interaction

ANOVA

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Sample | 1.72225 | 1 | 1.72225 | 0.238791 | 0.628413 | 4.149097 |
| Columns | 344.24075 | 3 | 114.7469 | 15.90973 | 0.000002 | 2.90112 |
| Interaction | 138.50875 | 3 | 46.16958 | 6.40144 | 0.001603 | 2.90112 |
| Within | 230.796 | 32 | 7.212375 | | | |
| | | | | | | |
| Total | 715.26775 | 39 | | | | |

Interaction = whether the influence of alcohol on stopping distance depends on whether you are male or female – significant (p=0.0016)

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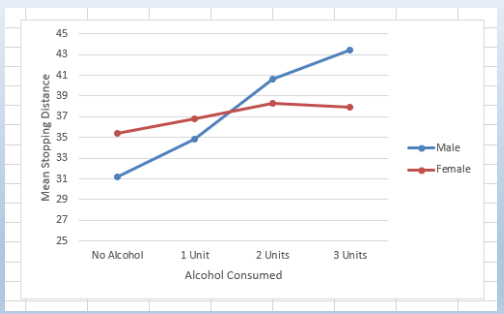
## Means Plots

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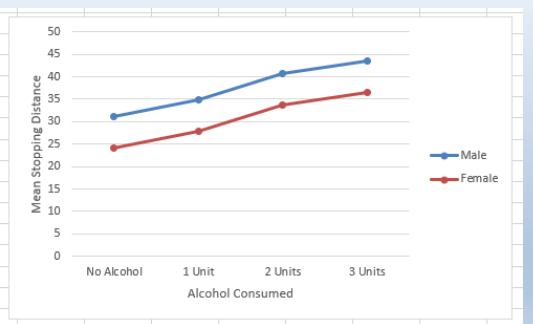
## Means Plots – No Interaction




144

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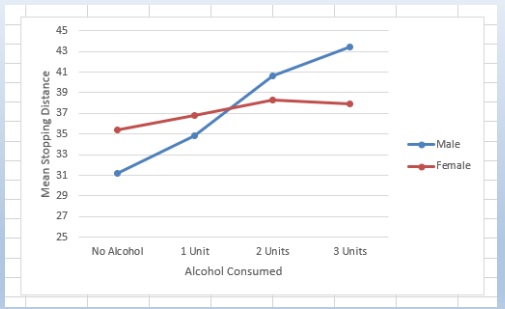
## Means Plots - Interaction

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## M/F Differences per Treatment Group

| | | | | | |
|---|---|---|---|---|---|
| 30 | t-Test: Two-Sample Assuming Equal Variances | | | | |
| 31 | | | | | |
| 32 | | No Alcohol | One Unit | Two Units | Three Units |
| 33 | Mean | 31.18 | 34.88 | 40.6 | 43.4 |
| 34 | Variance | 7.382 | 8.797 | 4.985 | 6.58 |
| 35 | Observations | 5 | 5 | 5 | 5 |
| 36 | Pooled Variance | 5.845 | 8.907 | 4.011 | 10.0865 |
| 37 | Hypothesized Mea | 0 | 0 | 0 | 0 |
| 38 | df | 8 | 8 | 8 | 8 |
| 39 | t Stat | -2.73 | -1.01 | 1.80 | 2.72 |
| 40 | P(T<=t) one-tail | 0.01 | 0.17 | 0.05 | 0.01 |
| 41 | t Critical one-tail | 1.86 | 1.86 | 1.86 | 1.86 |
| 42 | P(T<=t) two-tail | 0.03 | 0.34 | 0.11 | 0.03 |
| 43 | t Critical two-tail | 2.31 | 2.31 | 2.31 | 2.31 |
| 44 | | | | | |

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**Anova: Single Factor**

**Males**

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 456.1295 | 3 | 152.0432 | 21.92087 | 0.000007 | 3.238872 |
| Within Groups | 110.976 | 16 | 6.936 | | | |
| | | | | | | |
| Total | 567.1055 | 19 | | | | |

**Females**

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 26.62 | 3 | 8.873333 | 1.184888 | 0.346793 | 3.238872 |
| Within Groups | 119.82 | 16 | 7.48875 | | | |
| | | | | | | |
| Total | 146.44 | 19 | | | | |

Males:
p = < 0.05
Therefore significant

The conclusion is that for males there is a significant difference between the distance it takes to stop a car simulator according to the amount of alcohol consumed.

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## Interaction

The conclusion is that the effect of alcohol on car stopping distance was different for male subjects than for females.

*A two-way between-groups analysis of variance was conducted to explore the impact of gender and amount of alcohol consumed on a car stopping distance. There was a significant interaction effect between the amount of alcohol consumed and the gender of the person driving the car on the distance needed to stop the car (F3, 32) = 6.4, p<0.05).*

148

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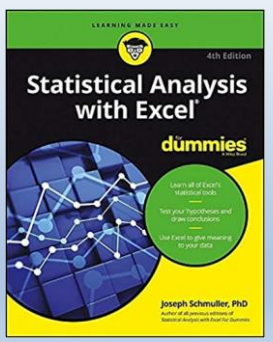
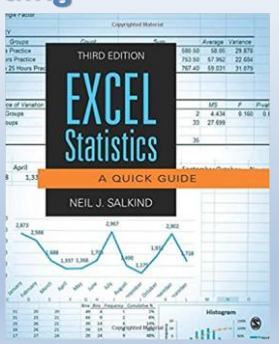
## Reading

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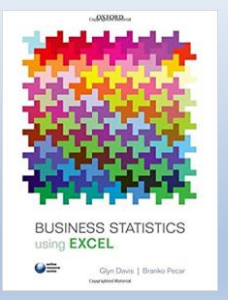
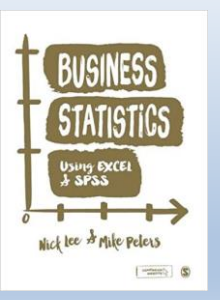
## Reading




150

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