Do’s and don’ts of statistics in research

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Universitet\Research\Webpage\everval.github.io\lectures`
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Statistics in research

Statistics in research

Introduction

- Statistics is a branch of mathematics that deals with the collection, analysis, interpretation, and presentation of **data**.
- Data is sampled from a population and used to make **inferences** about the population.
- It is a fundamental tool in research.

Statistics in research

- Statistics is used to summarize data.
- It is used to make inferences about populations.
- It is used to make informed decisions
- It is used to test hypotheses.
- It is conventionally divided into **descriptive** and **inferential** statistics.

(Descriptive) Statistics

(Descriptive) Statistics

- Descriptive statistics is used to summarize data.
- It is used to describe the main features of a dataset.
- It is used to present data in a meaningful way.
- It is used to identify patterns in data.

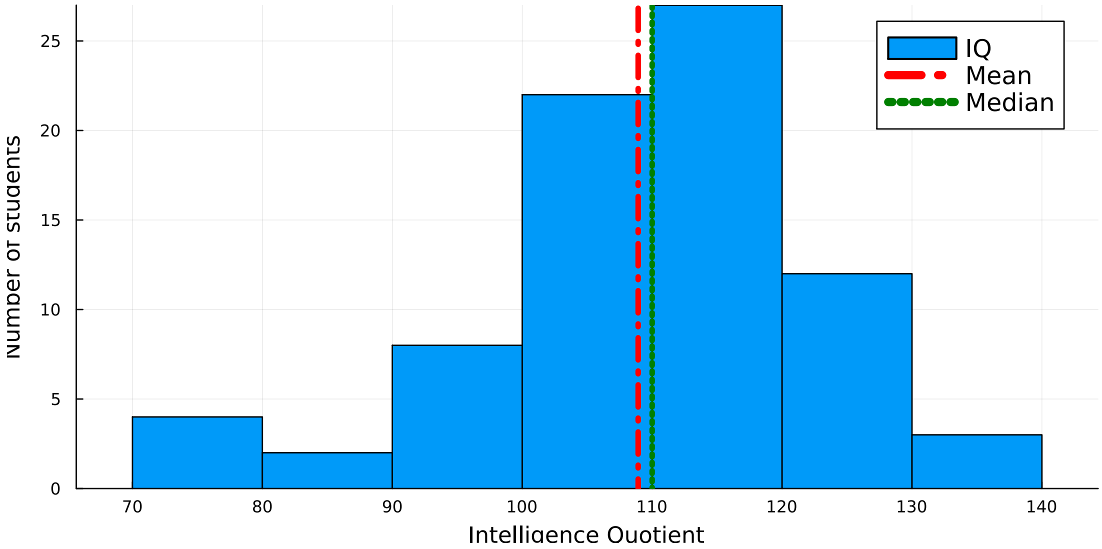
(Descriptive) Statistics

Measures of central tendency

- **Mean**: Average value of a dataset.
- **Median**: Middle value of a dataset.
- **Mode**: Most frequent value in a dataset.

- It is important to choose the right measure of central tendency depending on the data.

Measures of central tendency



- *Half the population has a below average IQ.*
- **Don't** use the mean to report about the median.
- **Do** use the median when the data is skewed or has outliers.
- **Do** label the axes in your plots.

Measures of central tendency

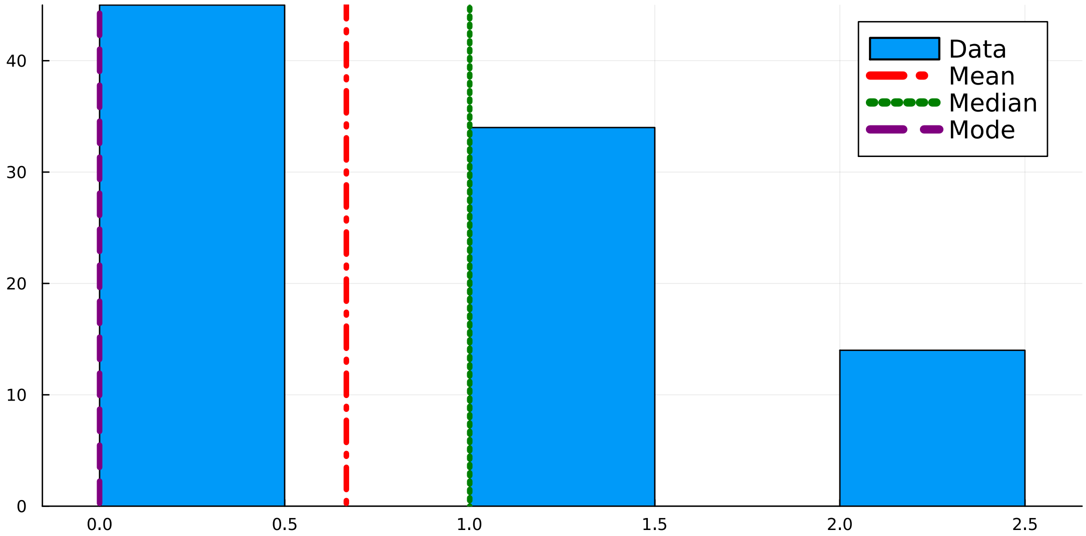


Figure 1: Categorical data: Elementary, Secondary, Higher Education

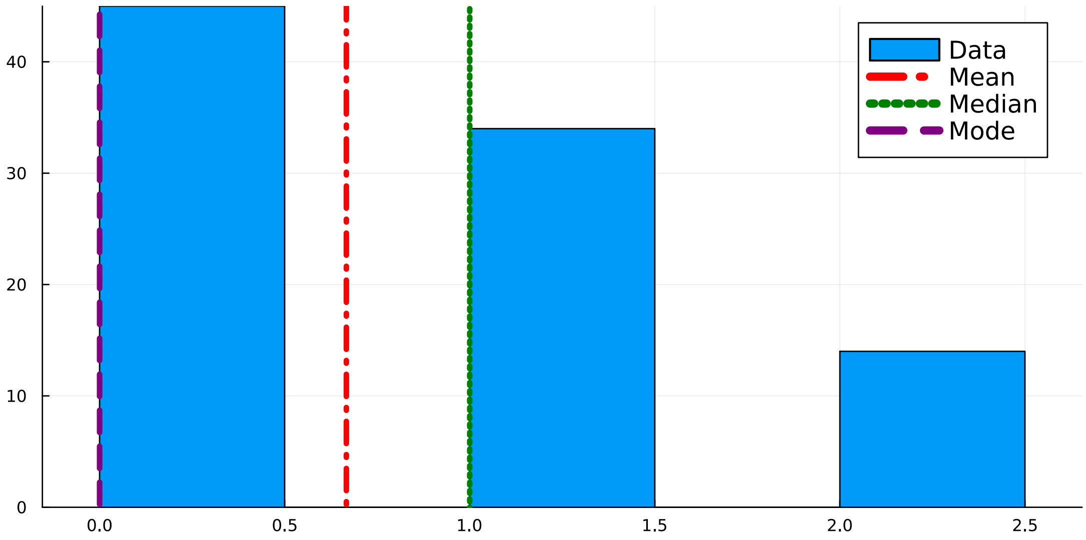
- Mean of categorical data is not meaningful.
- **Don't** use the mean when you have categorical data.
- **Do** use the mode or median instead.

(Descriptive) Statistics

Measures of dispersion

- **Range**: Difference between the maximum and minimum values.
- **Interquartile range**: Difference between the 75th and 25th percentiles.
- **Variance**: Average of the squared differences from the mean.
- **Standard deviation**: Square root of the variance.

Measures of dispersion



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"Range: 2, Interquartile range: 1.0, Variance: 0.5289855072463768"
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- Variance is not meaningful for categorical data.

Measures of dispersion

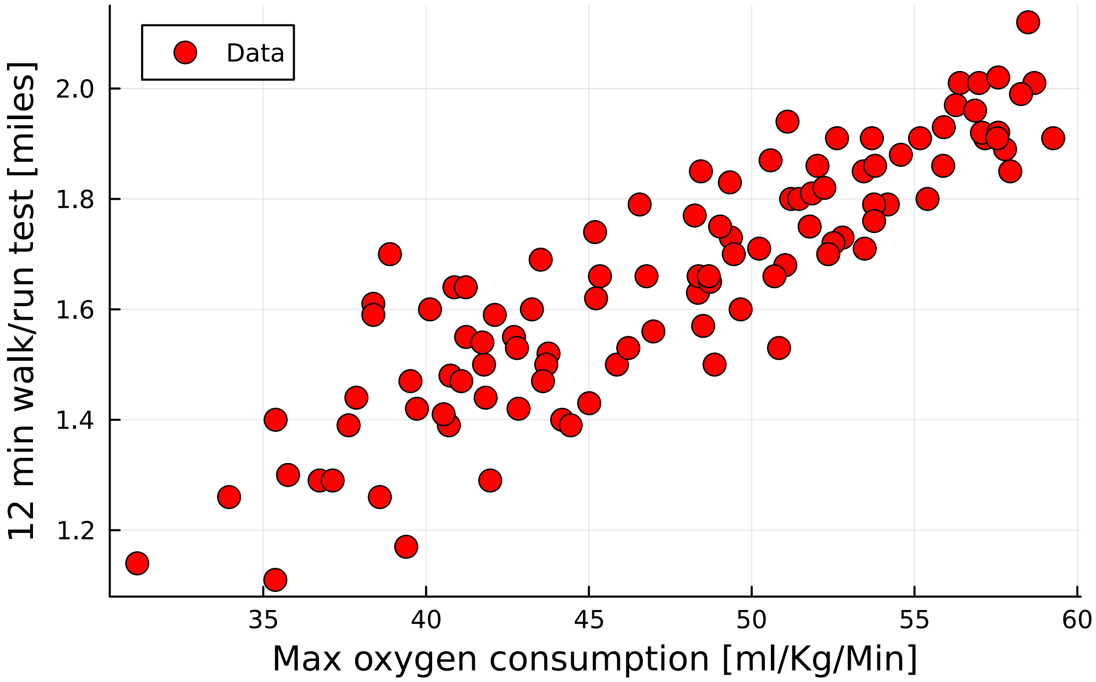
- **Do** use standard deviation to preserve the units of the data.
- **Don't** use the variance when you have outliers.
- **Do** use the right measure of dispersion depending on the data.

(Descriptive) Statistics

Data visualization

- **Scatter plot**: Relationship between two variables.
- **Histogram**: Distribution of a variable.
- **Box plot**: Distribution of a variable, quartiles.
- **Density plot**: Distribution of a variable, smoothed.

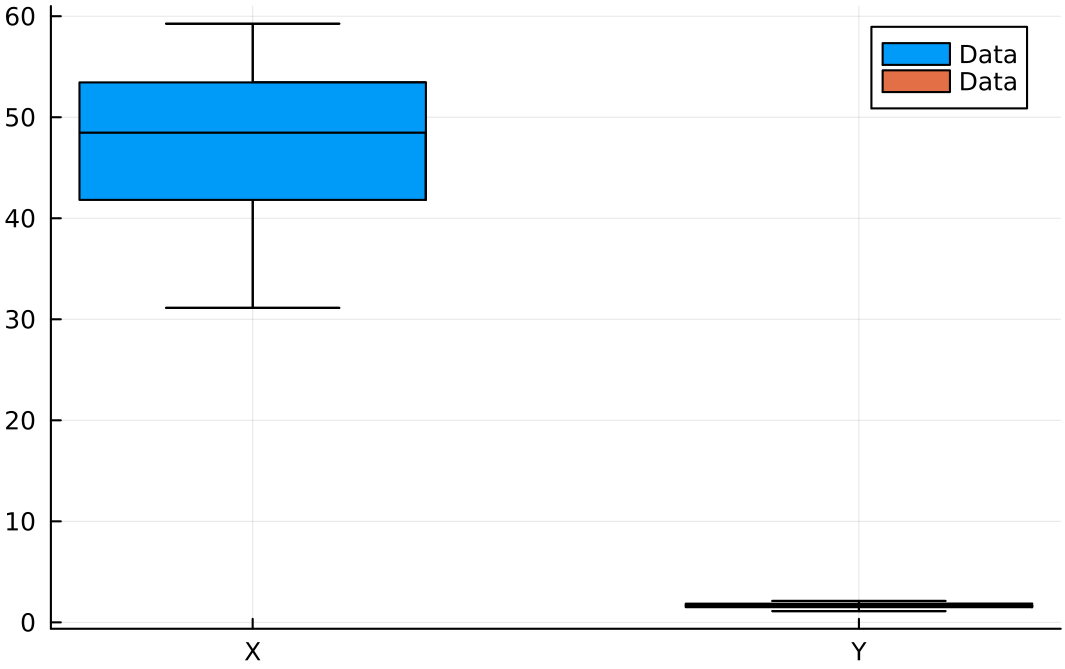
Scatter plot



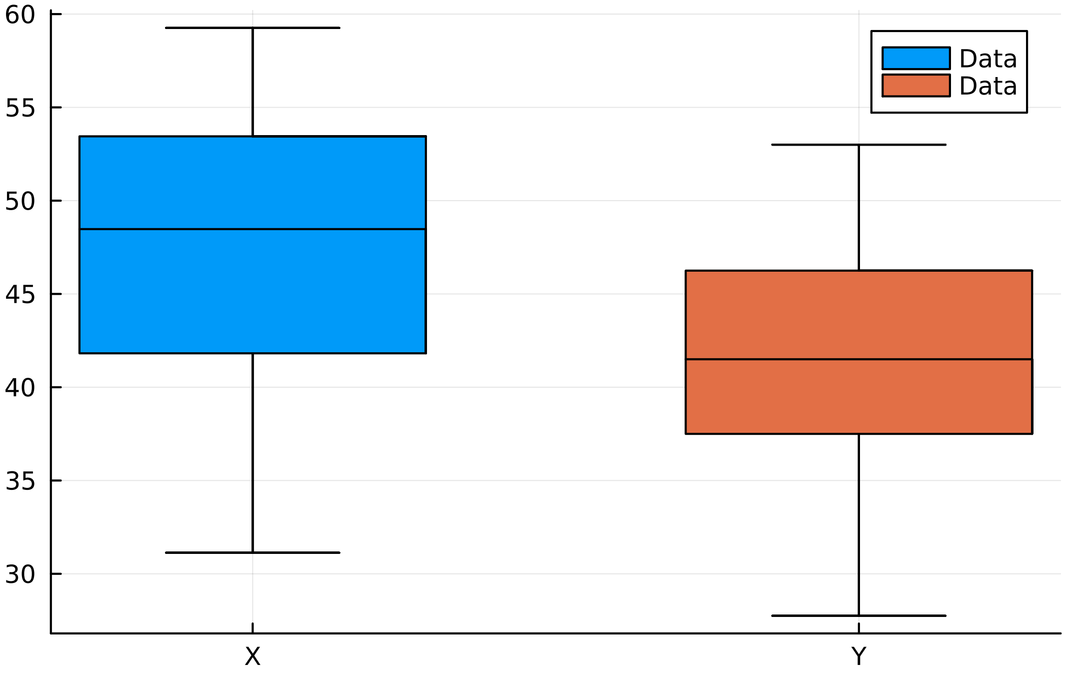
- **Do** think about the units of the variables.
- **Do** summarize the data to make it easier to understand.

Box plot

Raw data

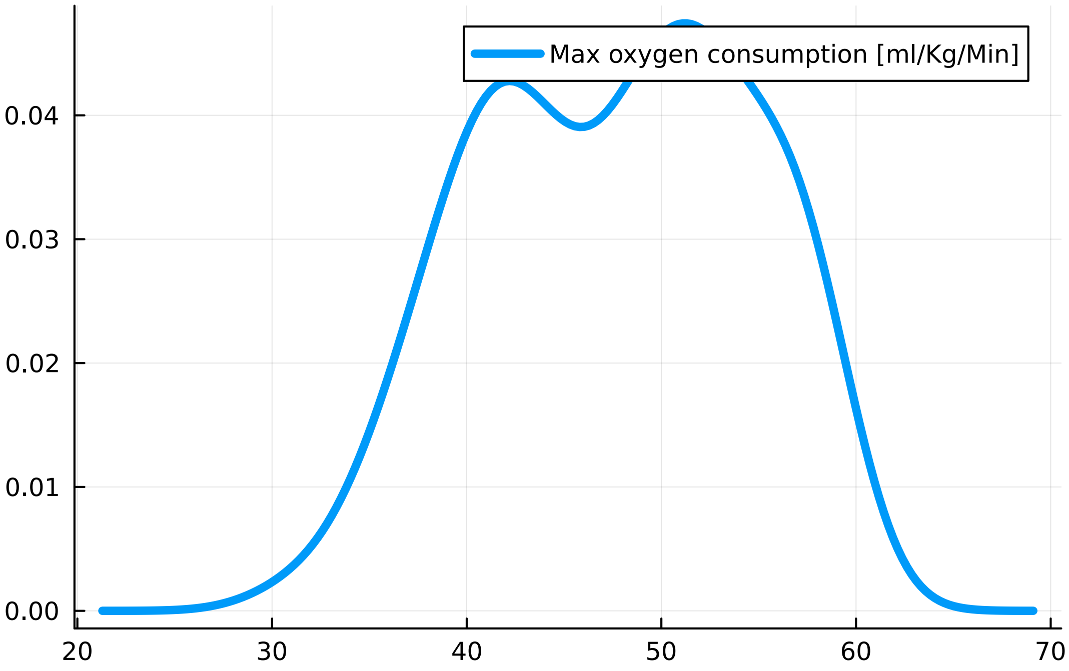


“Standardized” data

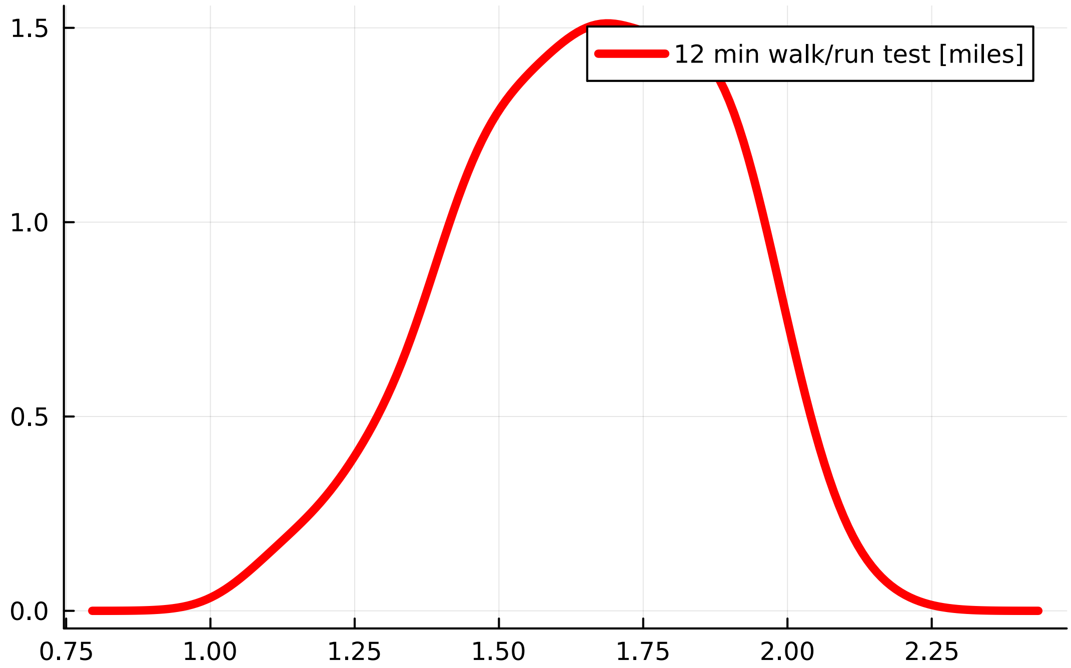


Density plot

X values



Y values



- **Do** think if the data is Normally distributed.

(Inferential) Statistics

(Inferential) Statistics

- Inferential statistics is used to make inferences about populations.
- It is used to test hypotheses.
- It is used to make informed decisions.
- It is used to estimate parameters.

(Inferential) Statistics

Hypothesis testing

- Null and Alternative hypothesis
- Types of error (Type I and Type II)
- P-value
- Confidence interval

Null and Alternative hypothesis

- **Null hypothesis**: No effect or no difference.
- **Alternative hypothesis**: Effect or difference.
- **Example**:
  - Null hypothesis: The vaccine has no effect.

  - Alternative hypothesis: The vaccine has an effect.
- **Do** state the null and alternative hypothesis.
- **Do** make sure that the null hypothesis is the status quo.
- **Do** make sure that the null and alternative hypothesis are mutually exclusive.

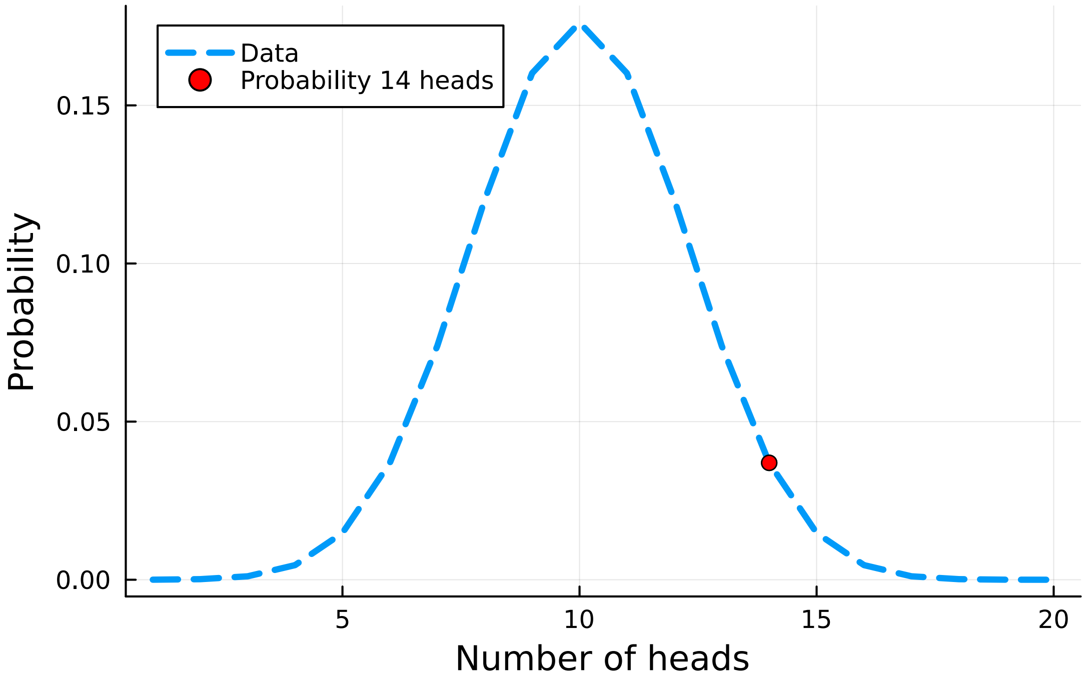
Types of error

- **Type I error**: Rejecting the null hypothesis when it is true.
- **Type II error**: Failing to reject the null hypothesis when it is false.
- **Example**:
  - Type I error: Jail an innocent person.
  - Type II error: Free a guilty person.

P-value

- The probability of observing the data given that the null hypothesis is true.
- It is used to test hypotheses.
- (For historical reasons) It is compared to a threshold, usually 0.05 or 0.01.

P-value



P-value

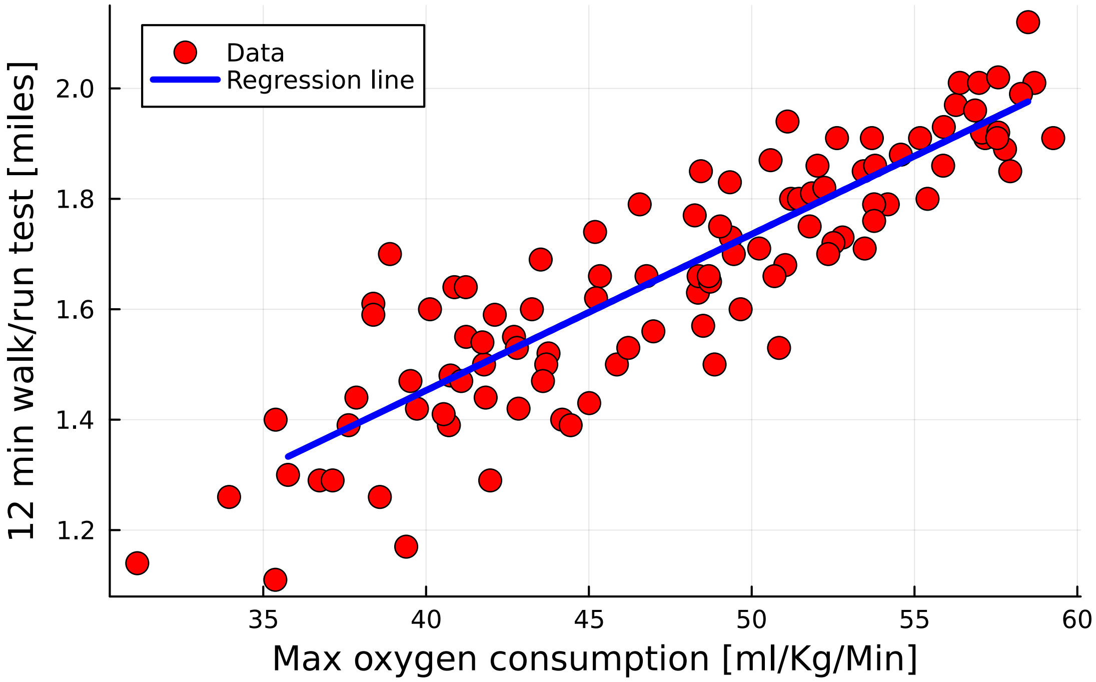
- **Do** report the p-value.
- **Do** state the p-value threshold before the test.
- **Do** use the p-value to make informed decisions.

- **Don't** use the p-value to make binary decisions.
- **Don't** change the model to get a p-value below the threshold.

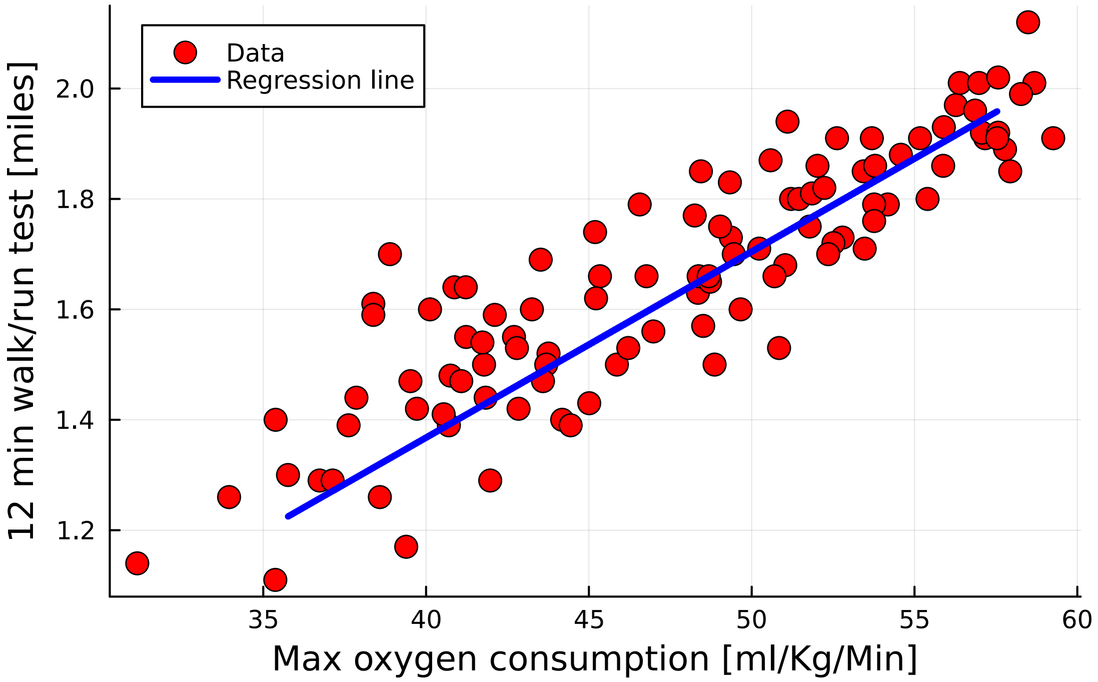
Confidence interval

- A range of values that is likely to contain the true value of a parameter.
- It is constructed from the data, hence we cannot guarantee that it contains the true value.
- (For historical reasons) It is usually set at 95%.

Confidence interval



Confidence interval



Confidence interval

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Universitet\Research\Webpage\everval.github.io\lectures\regression.gif
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\Research\\Webpage\\everval.github.io\\lectures\\regression.gif")
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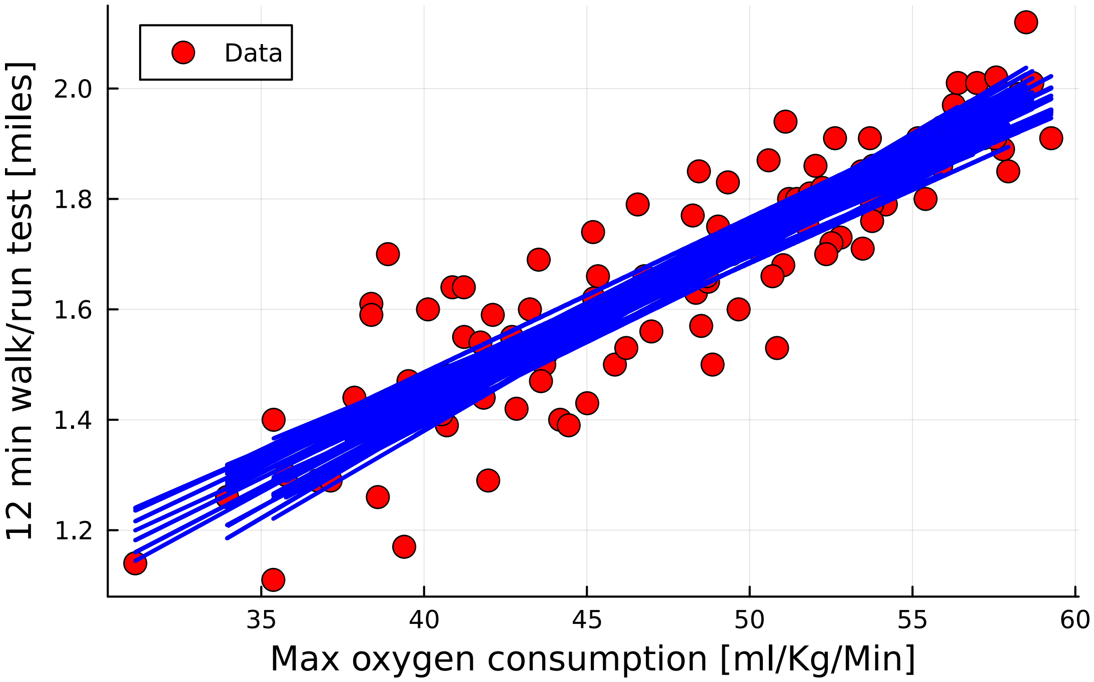
Confidence interval



Do and don’ts of statistics in research

Do and don’ts of statistics in research

- **Do** use the right measure of central tendency.
- **Don’t** use the mean when the data is skewed or has outliers.
- **Do** use the right measure of dispersion.
- **Don’t** use the variance when you have outliers.
- **Do** use standard deviation to preserve the units of the data.

Do and don’ts of statistics in research

- **Don’t** say we *proved* the hypothesis.
- **Do** say the data *supports* the hypothesis.
- **Don’t** say we *accept* the null hypothesis.
- **Do** say we *fail to reject* the null hypothesis.
- **Do** report confidence intervals.
- **Don’t** confuse improbability with impossibility.

Biases in statistics

- **Selection bias**: When the sample is not representative of the population.
- **Confirmation bias**: When we look for evidence that confirms our beliefs.
- **Publication bias**: When only significant results are published.

- **Extrapolation bias**: When we extrapolate beyond the data.
- **Causation bias**: When we confuse correlation with causation.

Conclusion

Conclusion

- Ask questions, use PhD consult: https://www.math.aau.dk/research/phd-consult
- More questions? eduardo@math.aau.dk
- Thank you.