

Hypothesis testing

INTRODUCTION TO STATISTICS



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Why do we need to know about hypothesis testing?

- Hypothesis testing is used to compare populations
- Hypothesis testing is everywhere!
 - Can a change in price lead to increased revenue?
 - Will changing a website address result in increased traffic?
 - Is a medication effective in the treatment of a health condition?



¹ Image credit: <https://unsplash.com/@towfiqu99999>

The history of hypothesis testing

- Hypothesis testing dates back to the 1700s!
- Human sex ratio
 - More male births than female births



¹ Image credit: <https://unsplash.com/@kellysikkema>

Assume nothing!

- Start by assuming no difference exists
- This is called the *null hypothesis*

Male versus female birth ratio

- **Null hypothesis:**
 - No difference in gender birth ratio between women who do and do not take vitamin C consumption
- **Alternative hypothesis:**
 - A **difference** exists in gender birth ratio between the two populations
 - **More** female births occur among women taking vitamin C supplements

Hypothesis testing workflow

- Define the target populations
 - Adult women taking or not taking vitamin C supplements
- Develop null and alternative hypotheses
 - Births are equally likely to be male or female in both populations
 - More births are female among women taking vitamin C supplements
- Collect or access sample data
- Perform statistical tests on the sample data
- Draw conclusions about the population



How much data do we need?



- Central limit theorem
 - Mean male and female births gets closer to the population means as sample size increases
 - Time and resource intensive
- Look at peer-reviewed research on similar hypothesis tests to decide on the sample size

¹ Image credit: <https://unsplash.com/@jxnsartstudio>

Independent and dependent variables

- **Independent variable:**
 - Unaffected by other data
 - Vitamin C supplementation
 - **Dependent variable:**
 - Affected by other data
 - Birth gender ratio
- Commonly used to describe hypothesis test results



Let's practice!

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Experiments

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Experiments, treatment, and control

- Experiments are a subset of hypothesis testing
 - Experiments are not just conducted in academia



Experiments aim to answer: *What is the effect of the treatment on the response?*

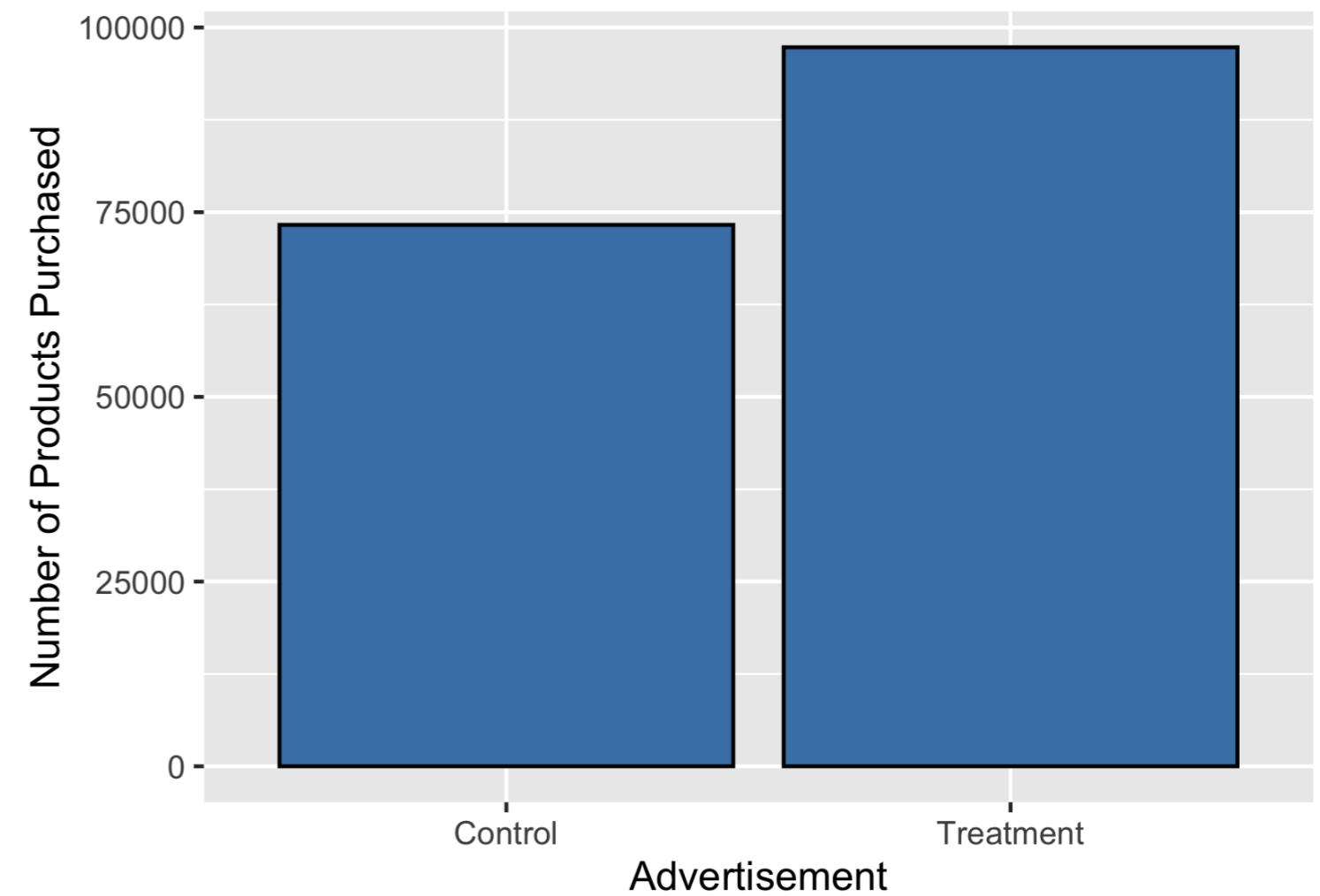
- Treatment: independent variable
- Response: dependent variable

¹ Image credit: <https://unsplash.com/@nci>

Advertising as a treatment

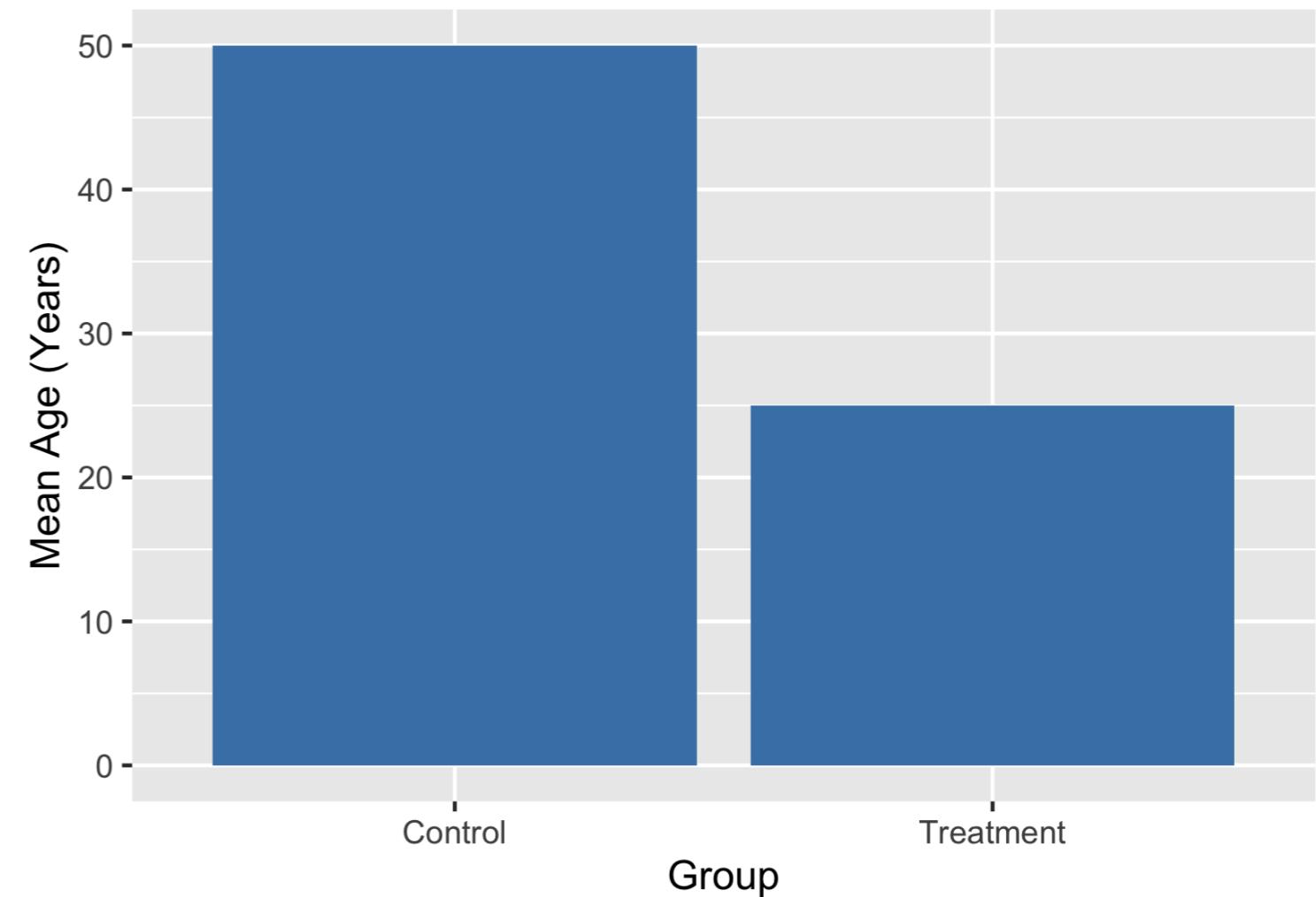
What is the effect of an advertisement on the number of products purchased?

- Treatment: advertisement
- Response: number of products purchased



Controlled experiments

- Participants are assigned to *either* the treatment group or the control group
 - **Treatment group** sees the advertisement
 - **Control group** does not see the advertisement
- Groups should be comparable to avoid introducing *bias*
- If groups are not comparable, this could lead to drawing incorrect conclusions



The gold standard of experiments

- **Randomization**
 - Participants are assigned to treatment/control *randomly*, not based on any other characteristics
 - Choosing randomly helps ensure that groups are comparable
 - Known as a **randomized controlled trial**
- **Blinding**
 - Participants will not know which group they're in
 - Participants receive a placebo, which resembles the treatment but has no effect
 - In clinical trials it is common to use a sugar pill

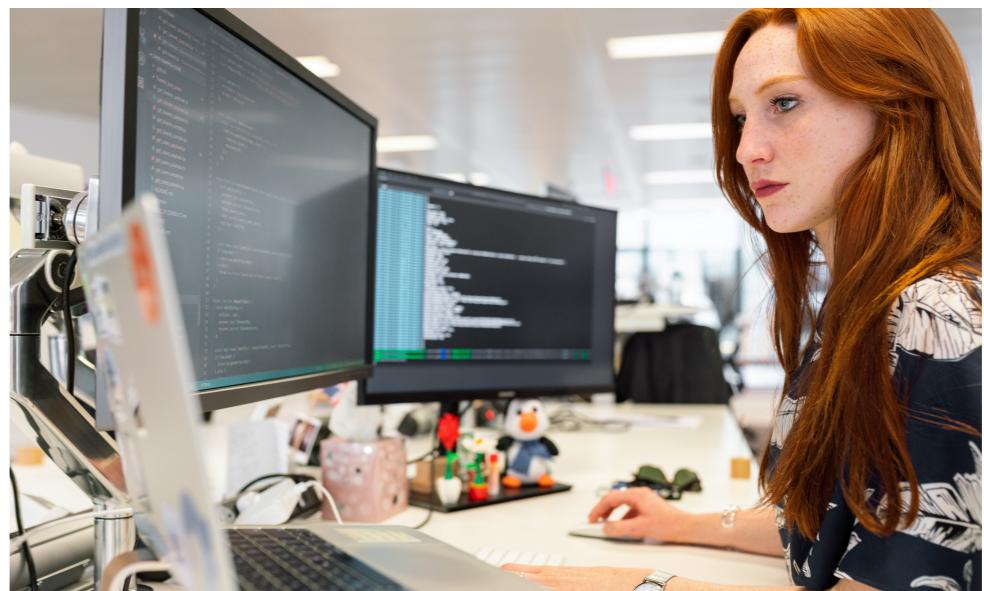
The gold standard of experiments

- Double-blind randomized controlled trial
 - Person administering the treatment/running the study doesn't know whether the treatment is real or a placebo
 - Prevents bias in the response and/or analysis of results

Fewer opportunities for bias = more reliable conclusion about causation

Randomized Controlled Trials vs. A/B testing

- **Randomized controlled trial**
 - Can be multiple treatment groups
 - Popular in science, clinical research
- **A/B testing**
 - Popular in marketing, engineering
 - Only split evenly into two groups



¹ Image credits: <https://unsplash.com/@towfiq99999>; <https://unsplash.com/@thisengineering>

Let's practice!

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Correlation

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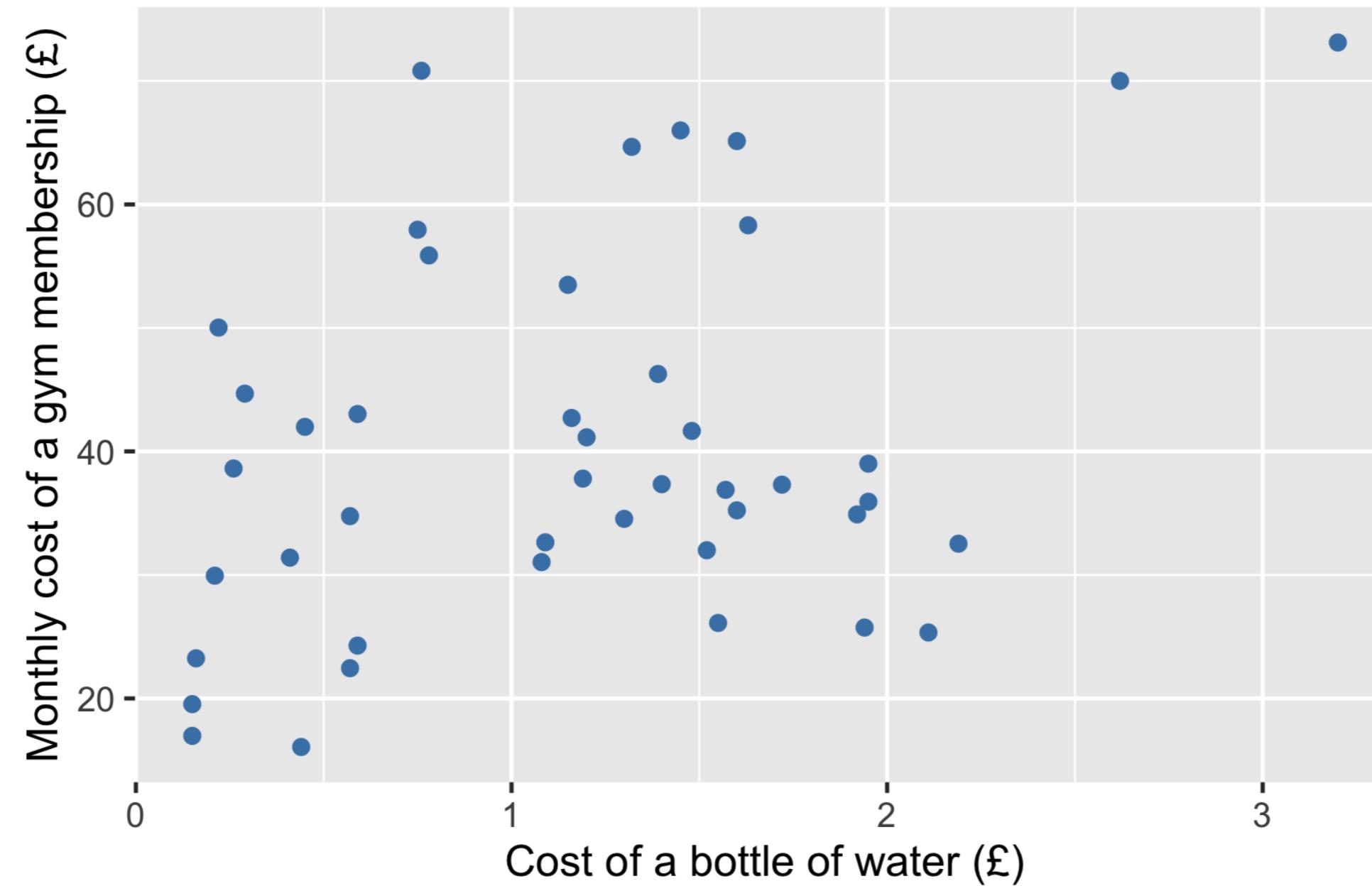


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Relationships between two variables

Costs for monthly gym membership vs. a bottle of water



Pearson correlation coefficient

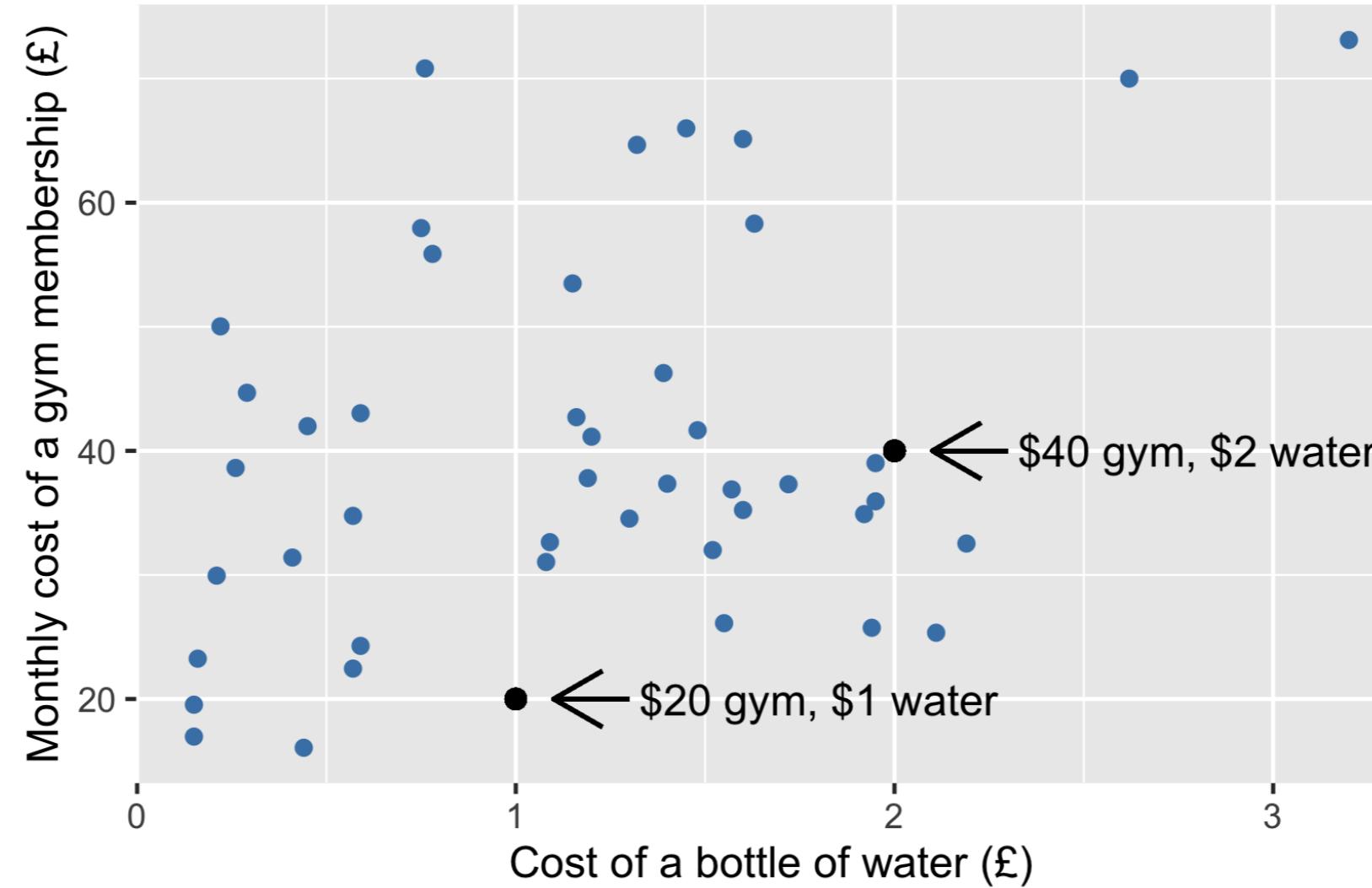
- Published by Karl Pearson in 1896¹
- Quantifies the strength of a relationship between two variables
- Number between **minus one** and **one**
- Magnitude corresponds to strength of relationship
- Sign (+ or -) corresponds to direction of relationship

¹ <https://royalsocietypublishing.org/doi/10.1098/rsta.1896.0007>

Linear relationships

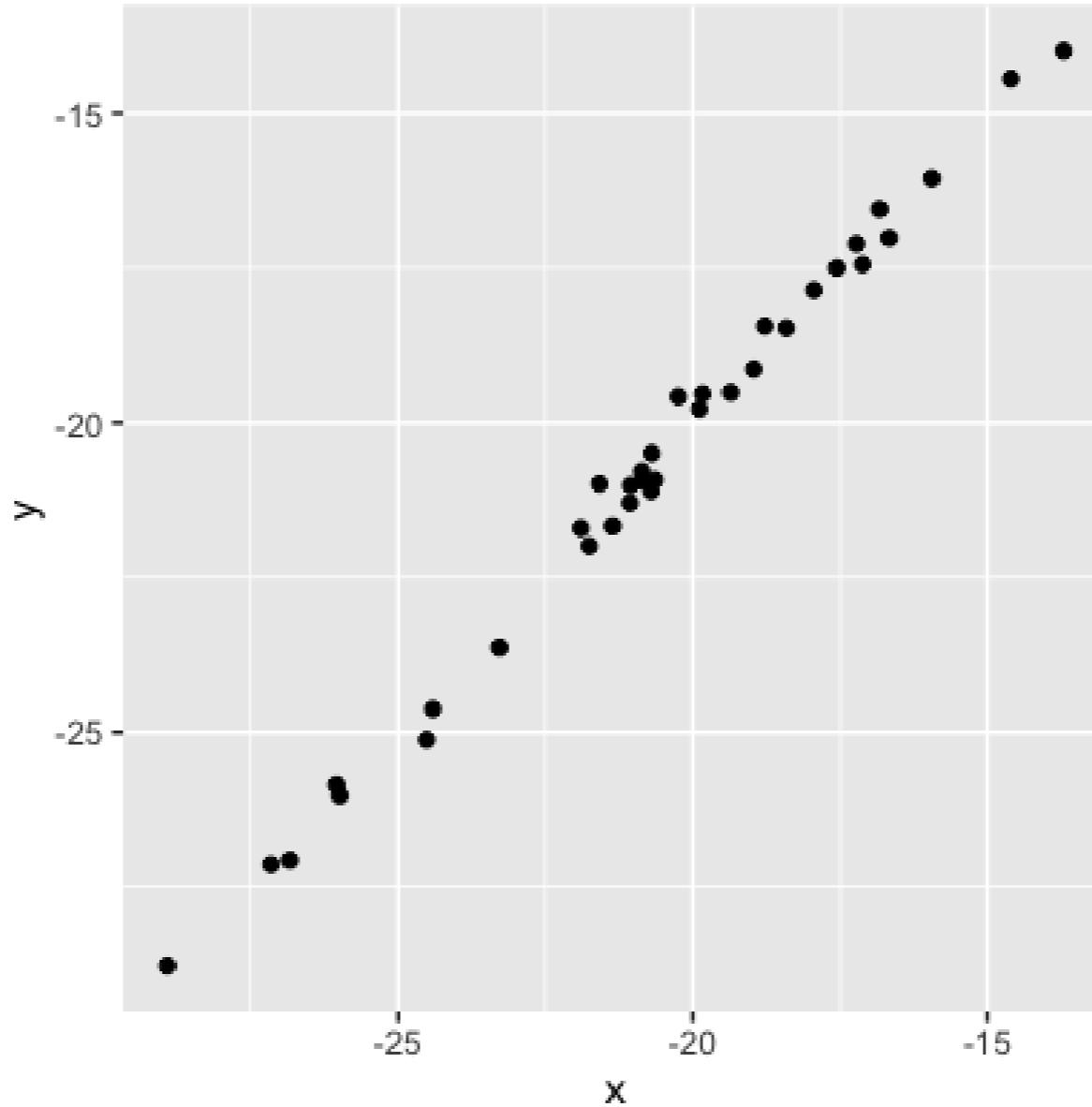
- Linear = proportionate changes between dependent and independent variables

Costs for monthly gym membership vs. a bottle of water



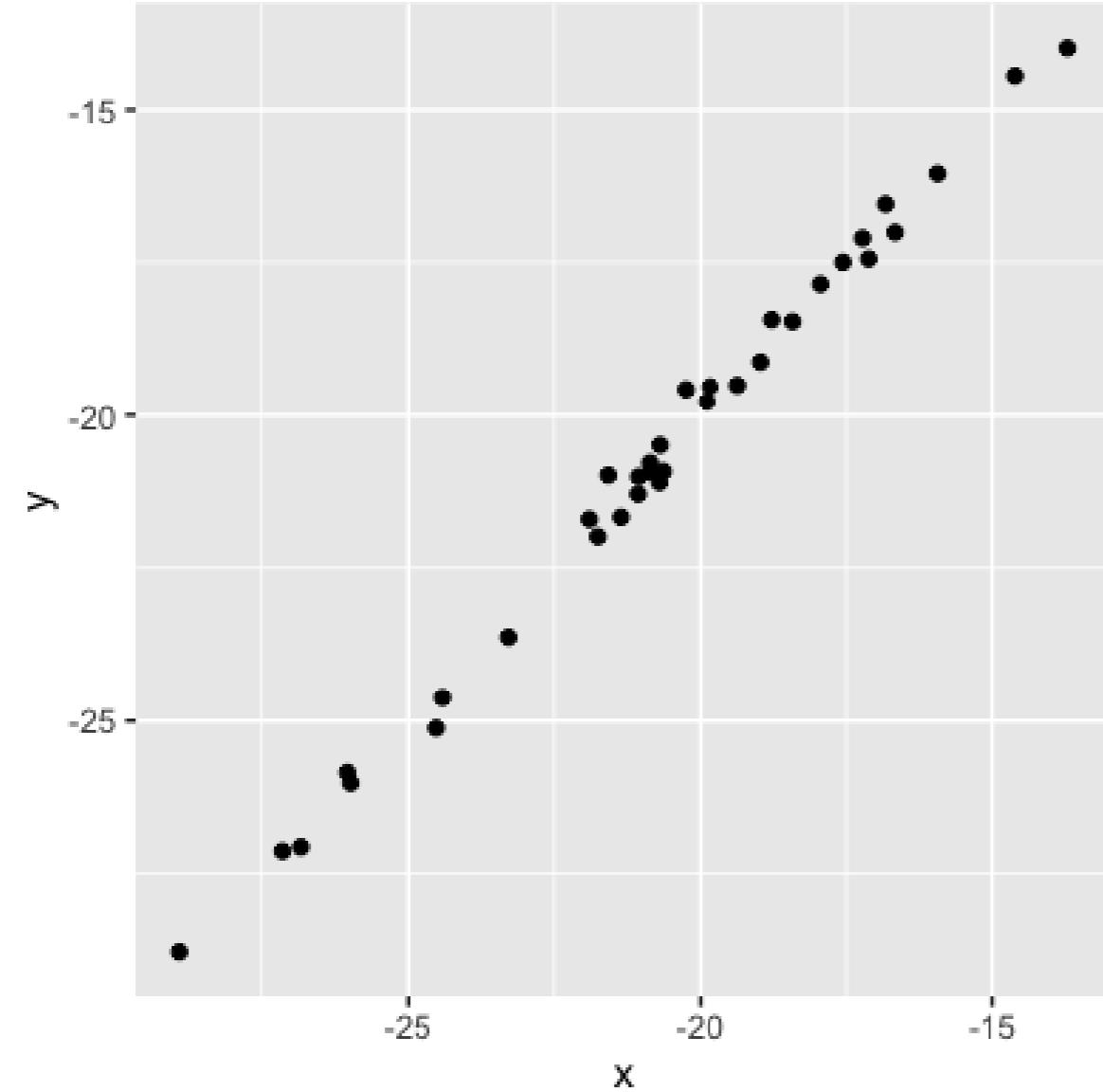
Values = strength of the relationship

0.99 (very strong relationship)

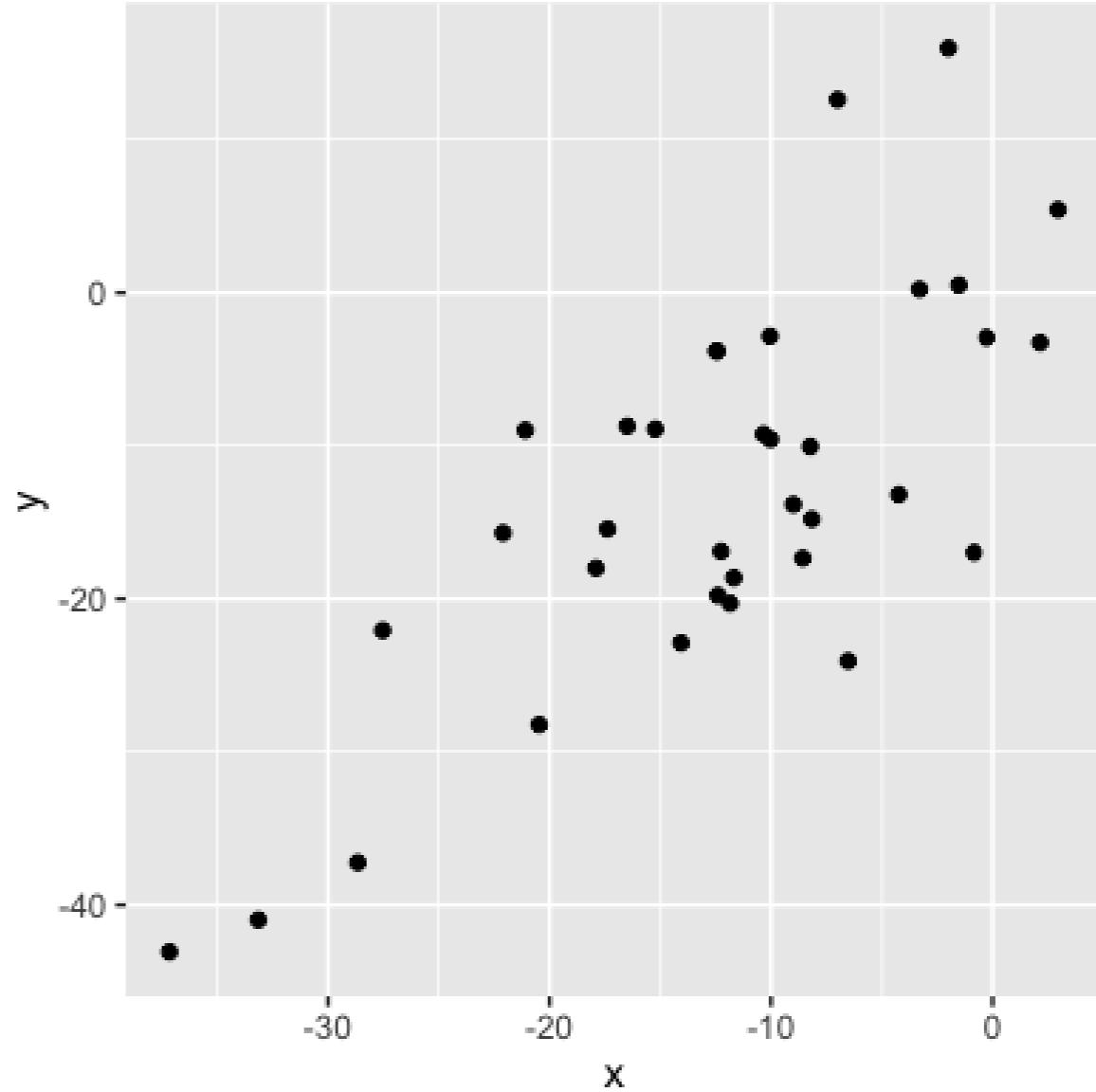


Values = strength of the relationship

0.99 (very strong relationship)

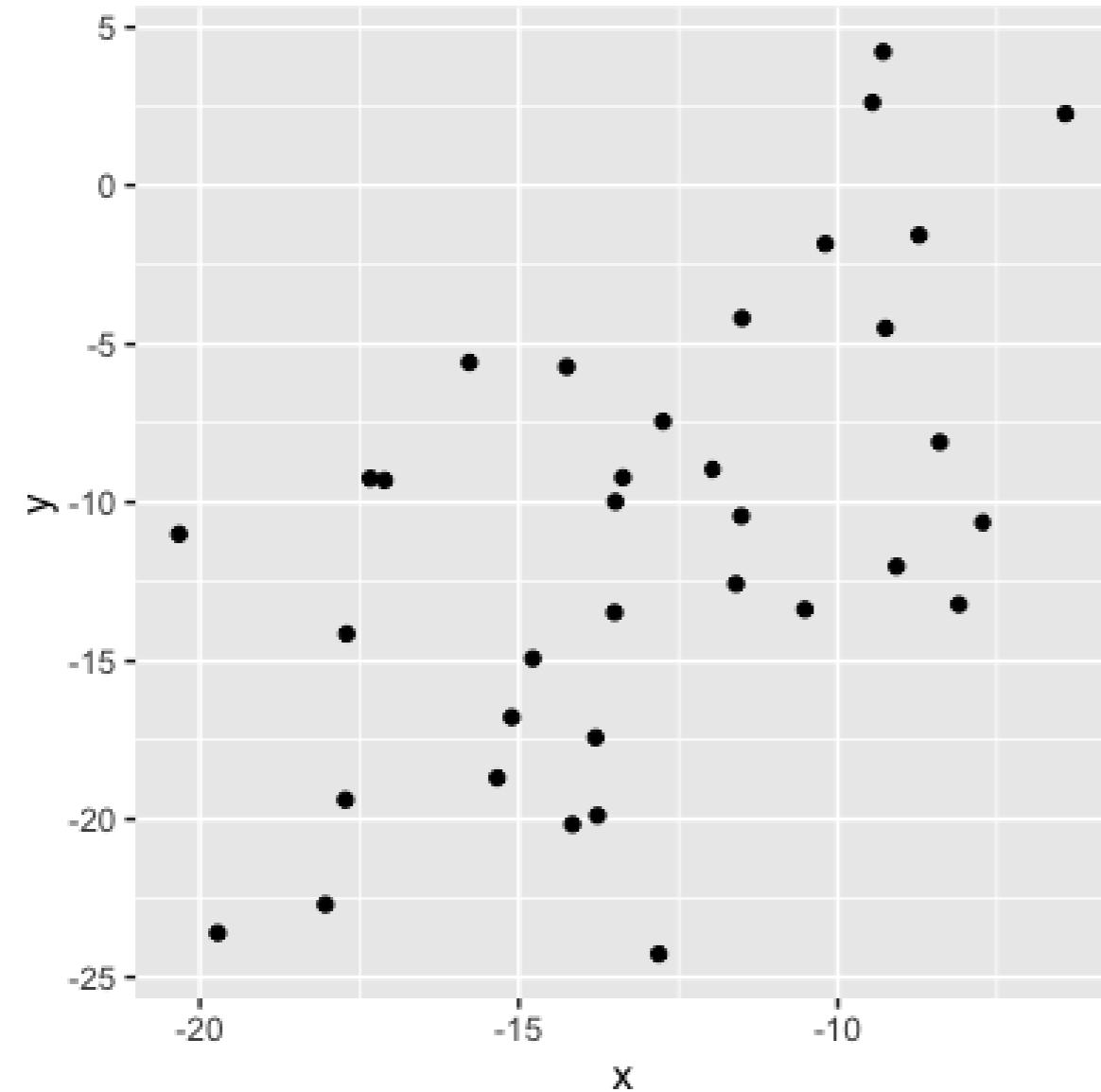


0.75 (strong relationship)



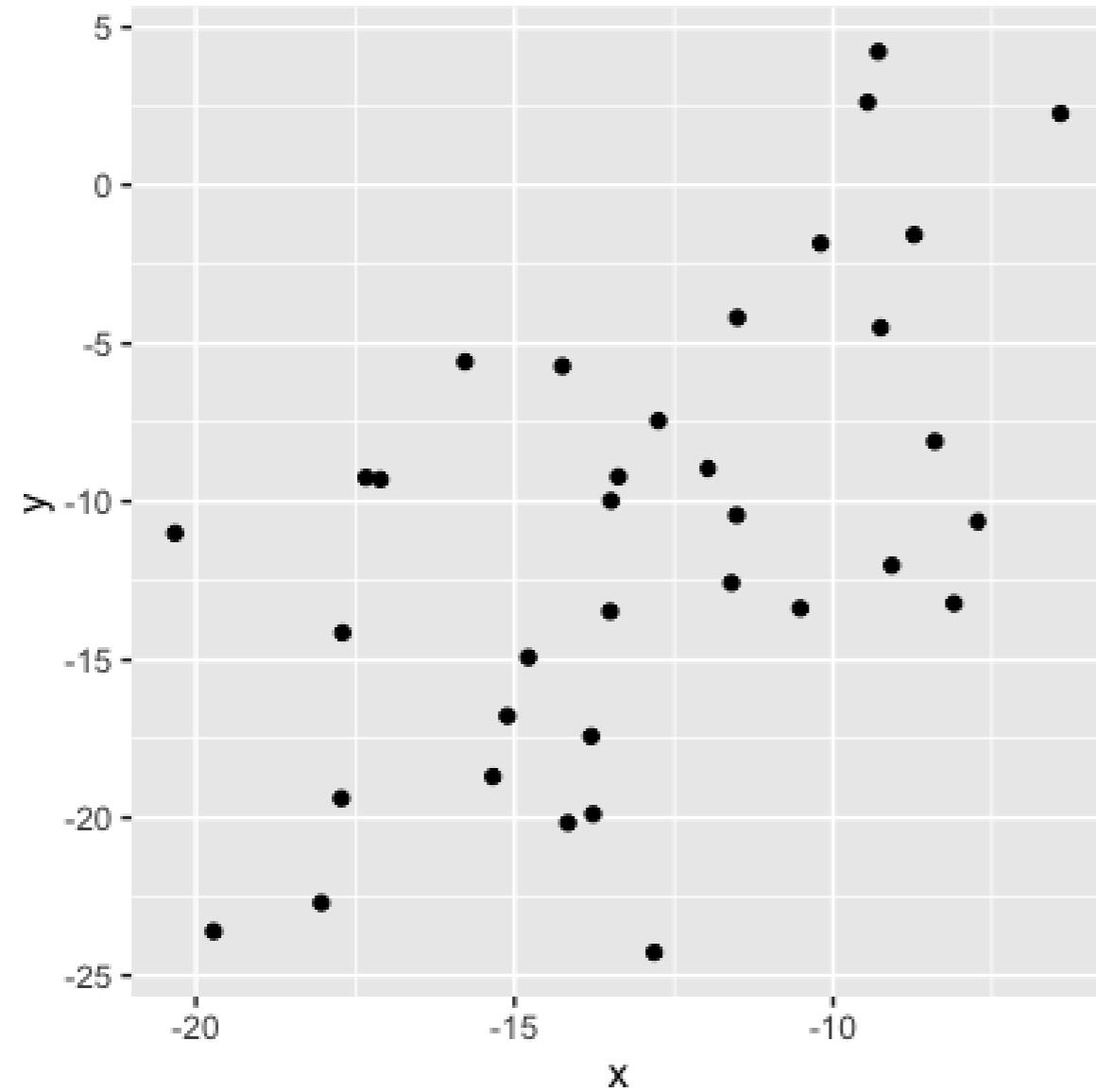
Values = strength of the relationship

0.56 (moderate relationship)

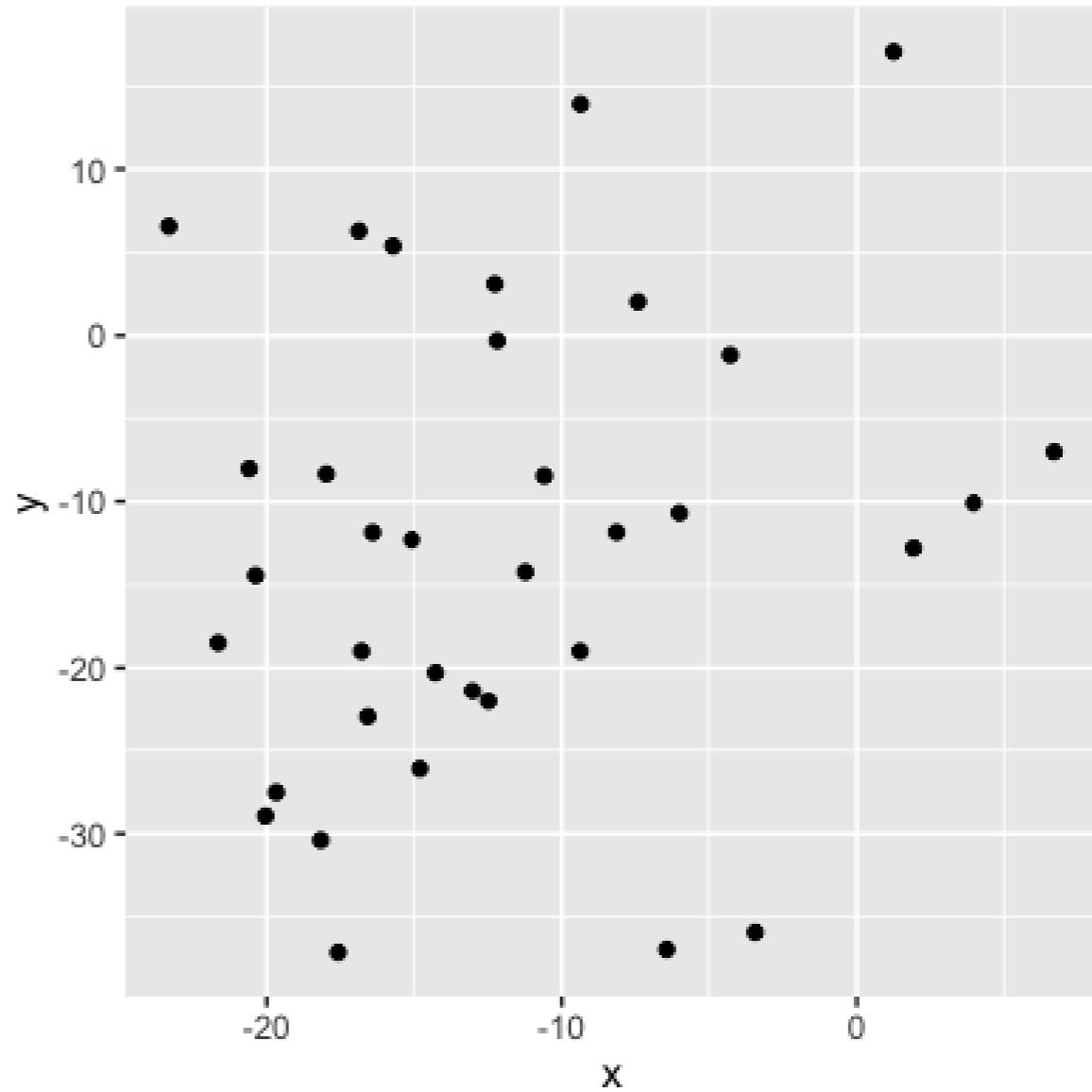


Values = strength of the relationship

0.56 (moderate relationship)

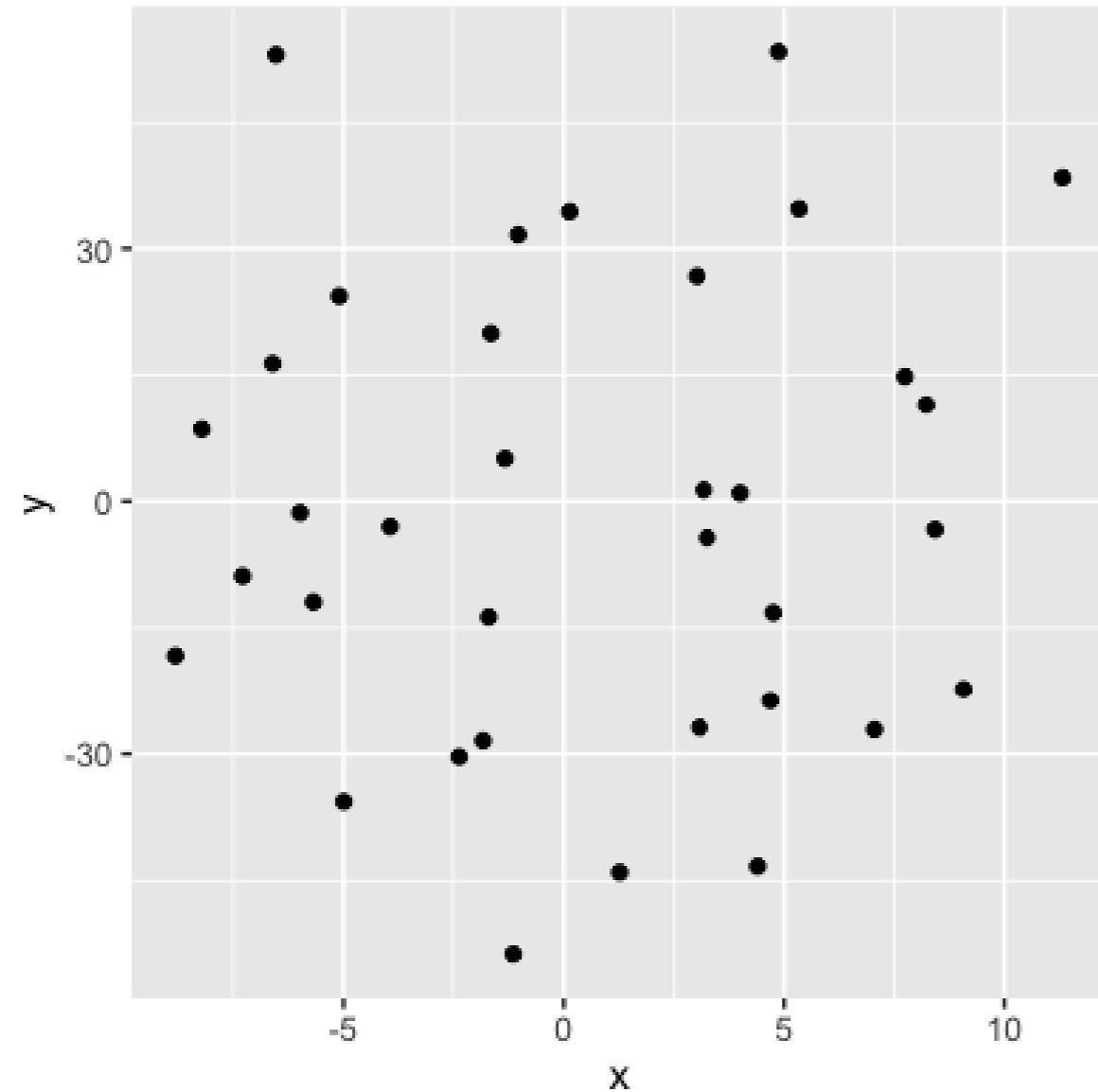


0.21 (weak relationship)



Values = strength of the relationship

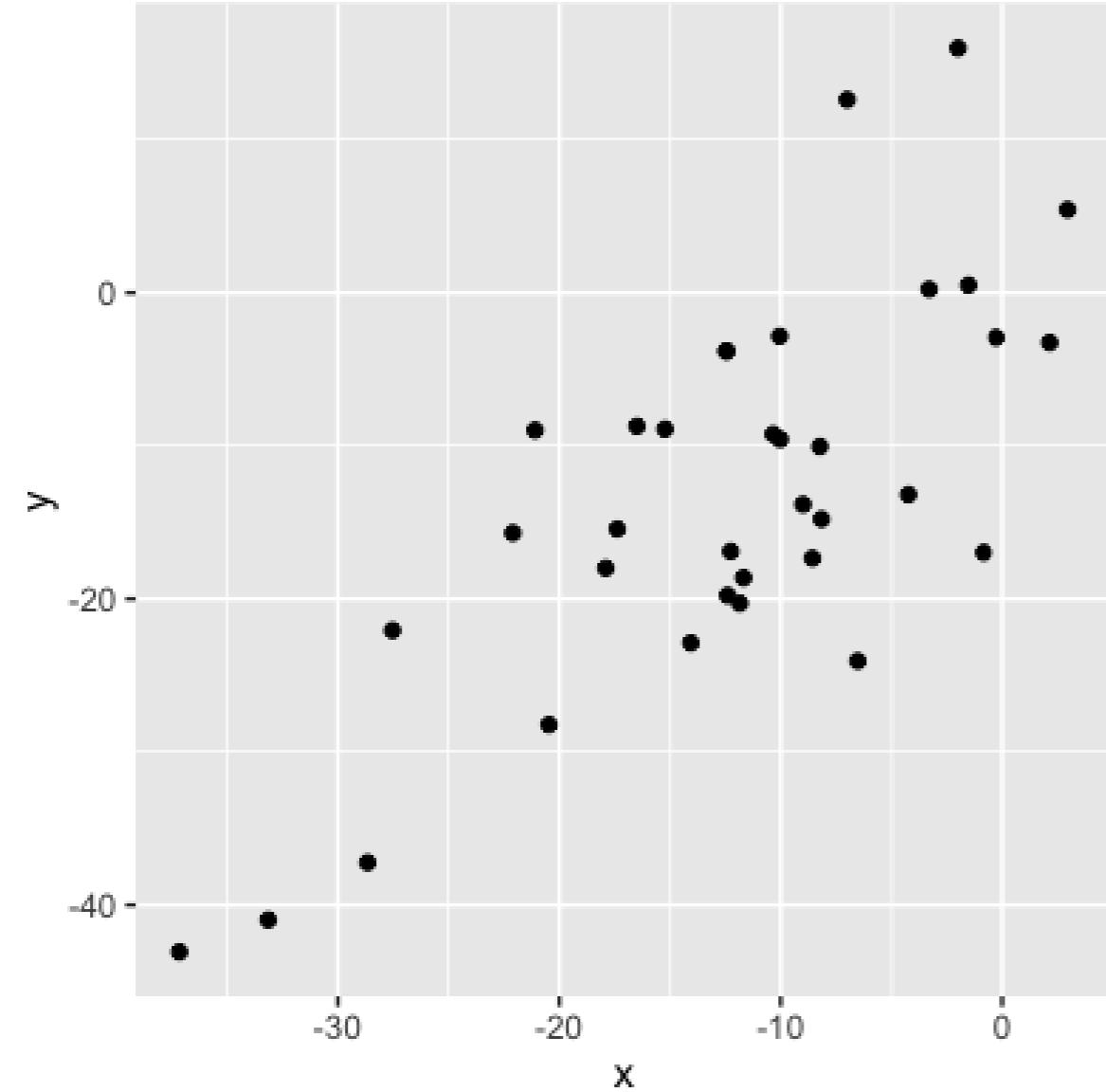
0.04 (no relationship)



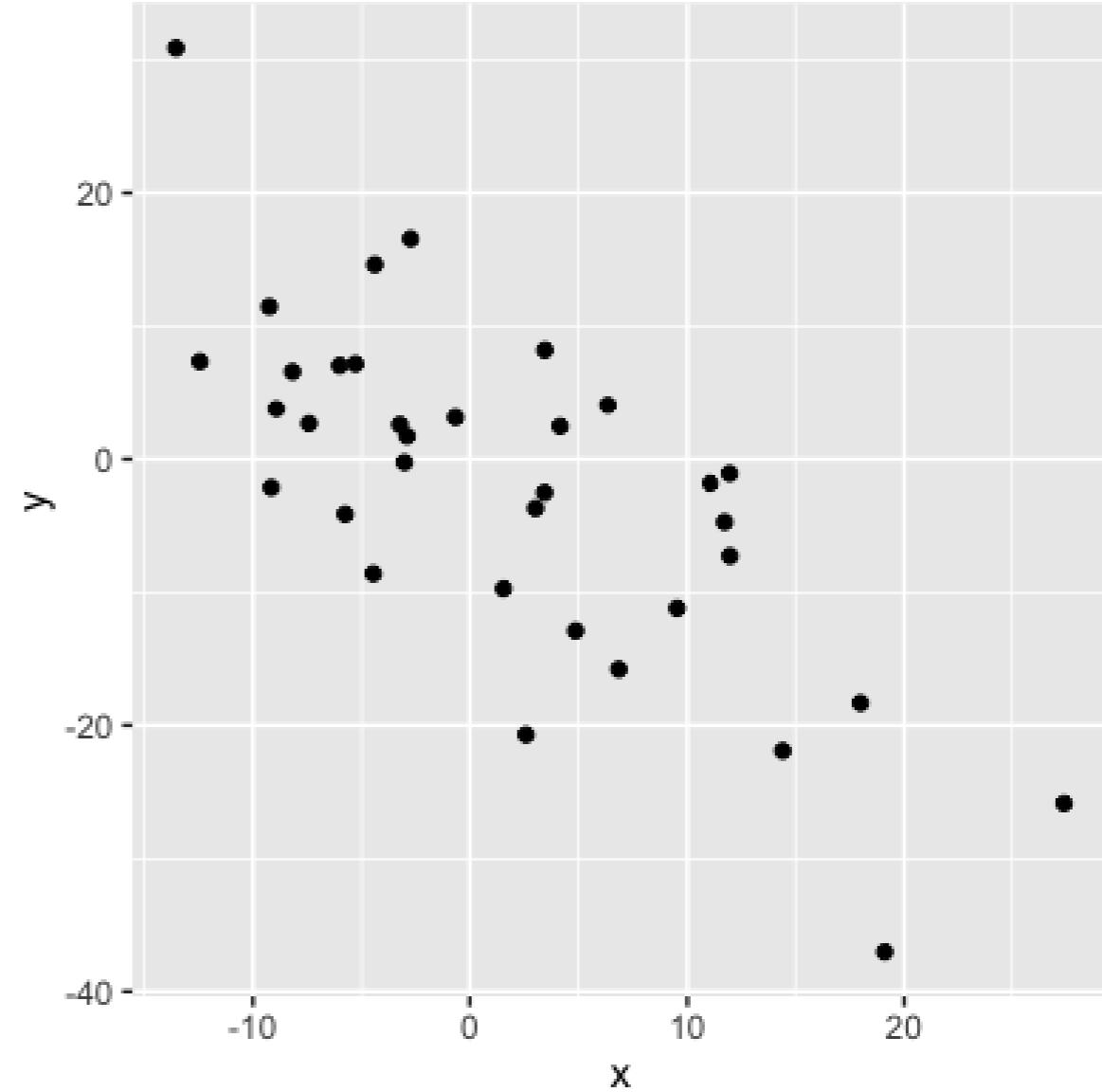
- Knowing the value of x doesn't tell us anything about y

Sign = direction

0.75: as x increases, y increases

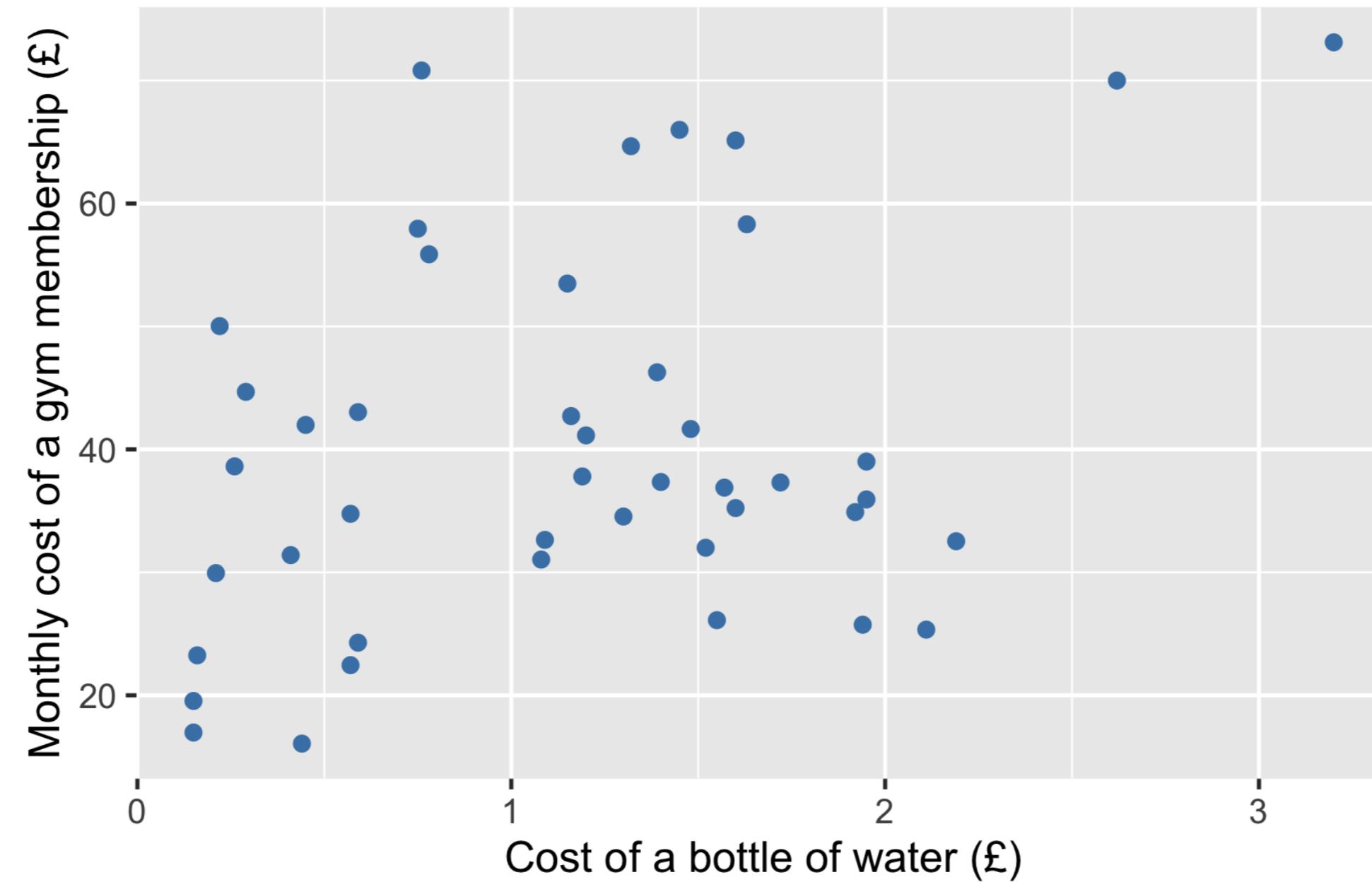


-0.75: as x increases, y decreases



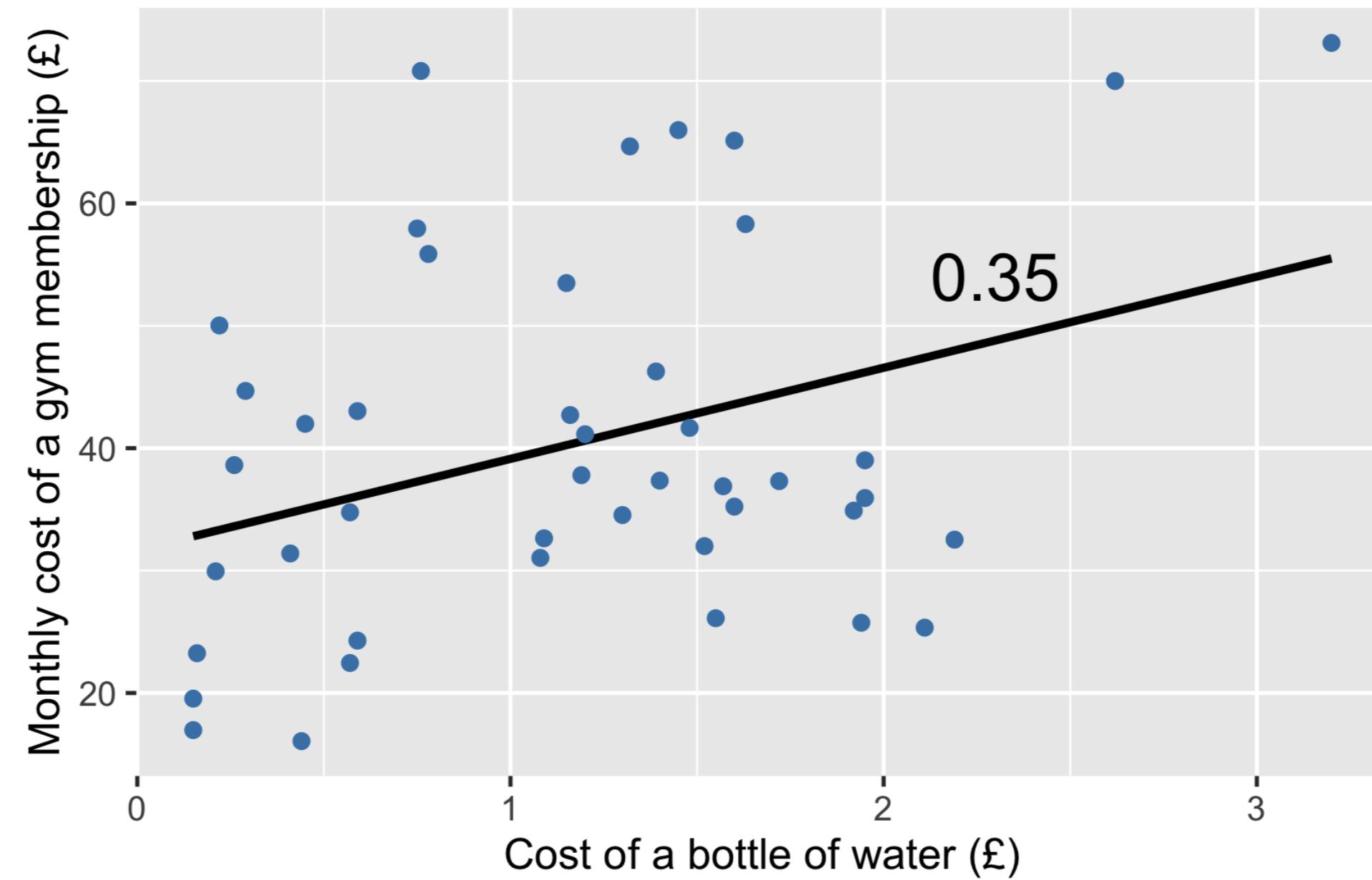
Gym costs vs. water costs

Costs for monthly gym membership vs. a bottle of water



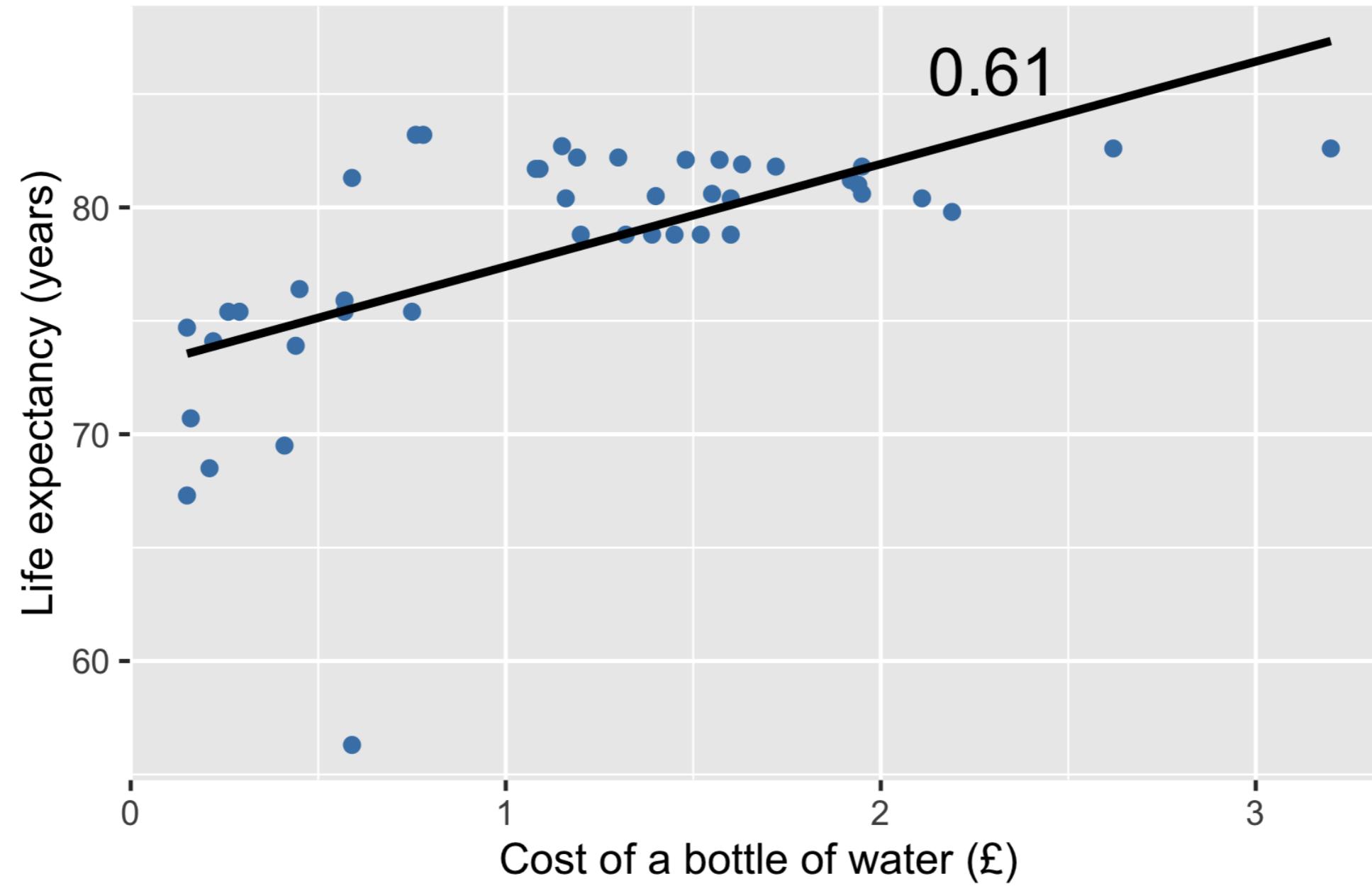
Adding a trendline

Costs for monthly gym membership vs. a bottle of water



Life expectancy vs. cost of a bottle of water

Life expectancy (years) vs. cost of a bottle of water (£)



Correlation does not equal causation

- Will increasing the cost of water result in an increase in life expectancy?



- Correlation does not equal **causation**

¹ Image credit: <https://unsplash.com/@micheile>; https://unsplash.com/@jon_chng

Confounding variables

- What else might be affecting life expectancy?
 - A bottle of water costs more in countries with strong economies
 - These countries generally offer access to high-quality healthcare
- The strength of the *economy* could be a **confounding variable**
 - A confounding variable is not measured, but may affect the relationship between our variables



Let's practice!

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Interpreting hypothesis test results

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Life expectancy in Chicago vs. Bangkok

- Null hypothesis:
 - There is no difference in life expectancy between Chicago residents and Bangkok residents
- Alternative hypothesis:
 - Chicago residents have a longer life expectancy than Bangkok residents

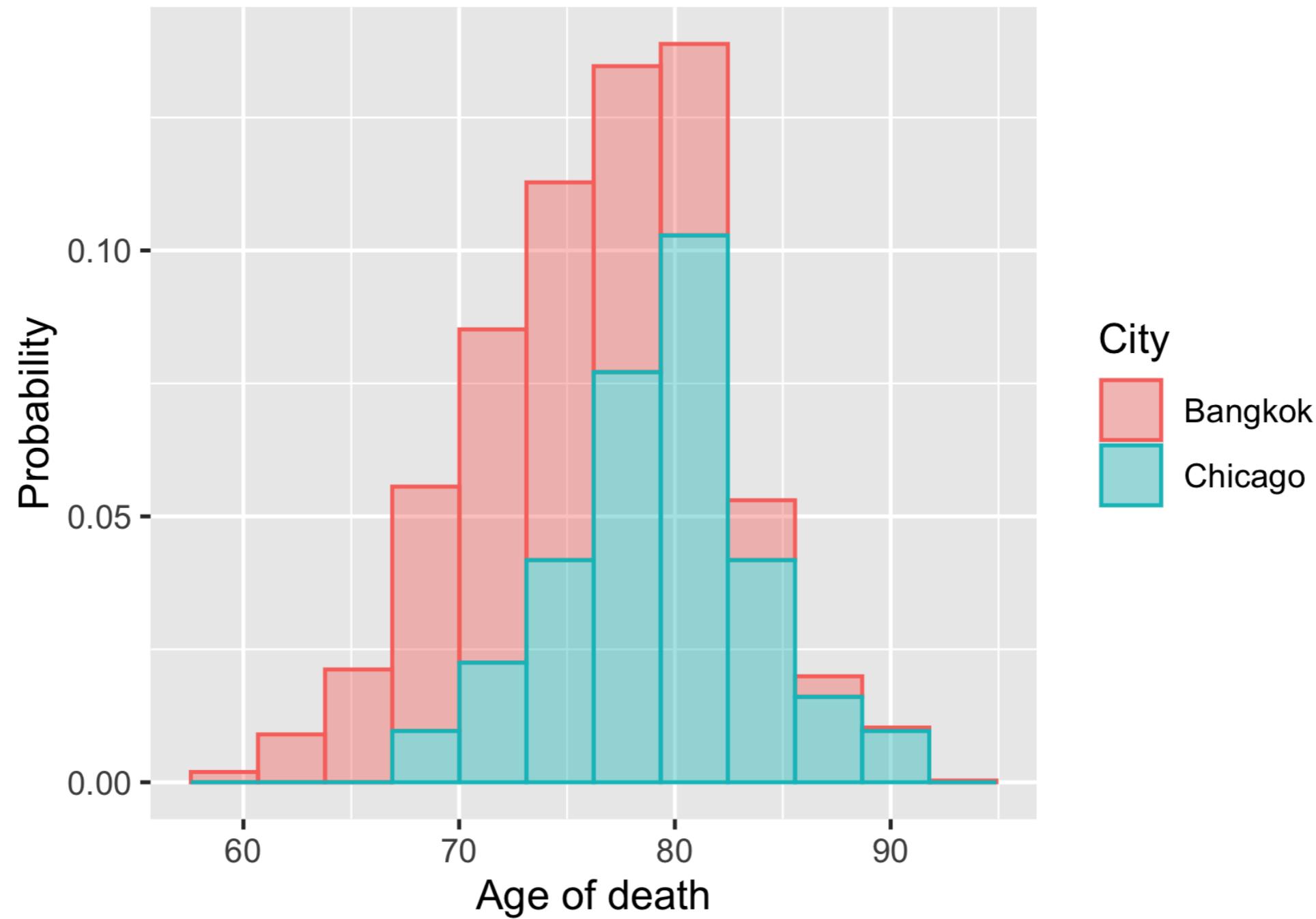
Chicago



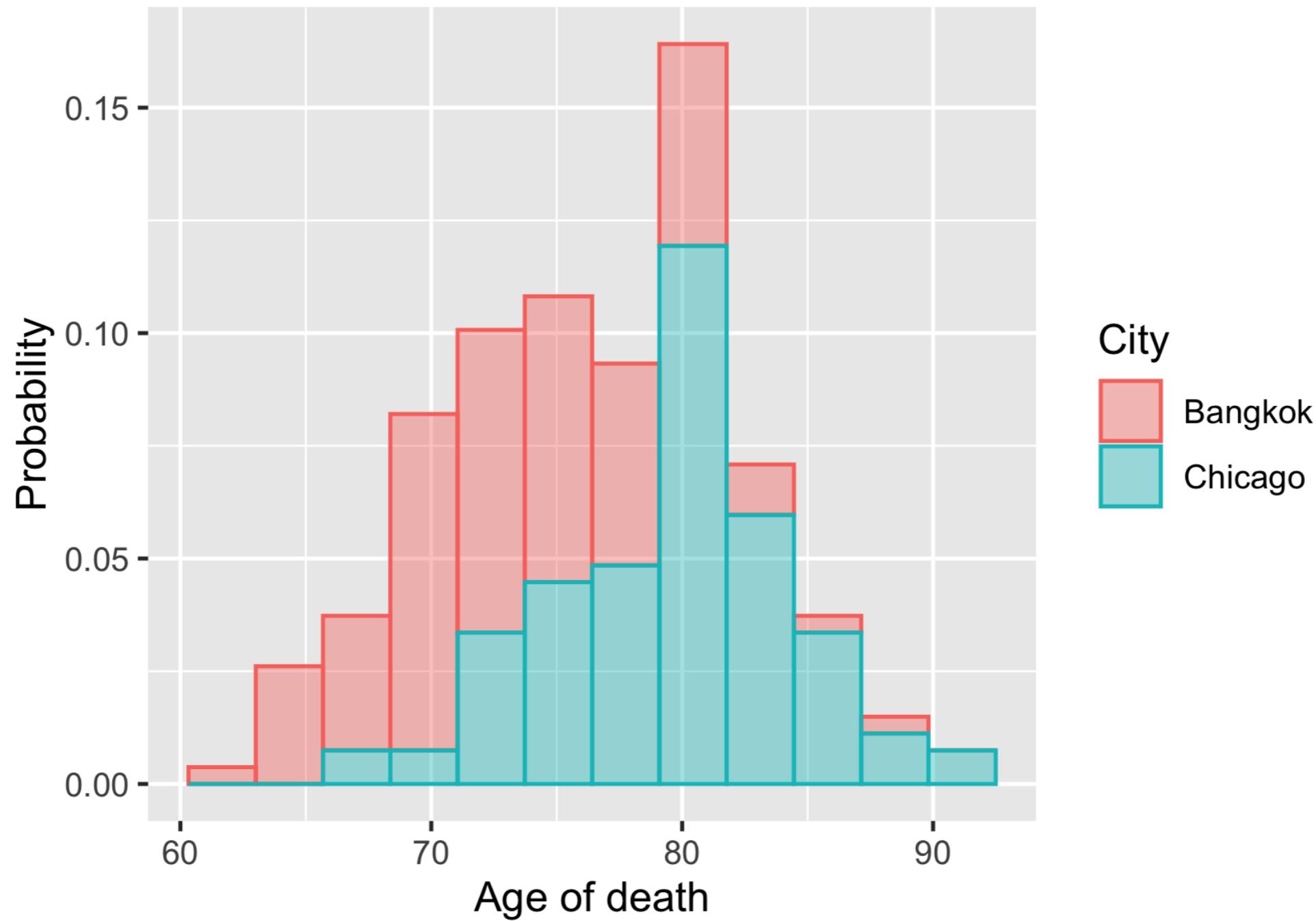
Bangkok



Sampling distribution

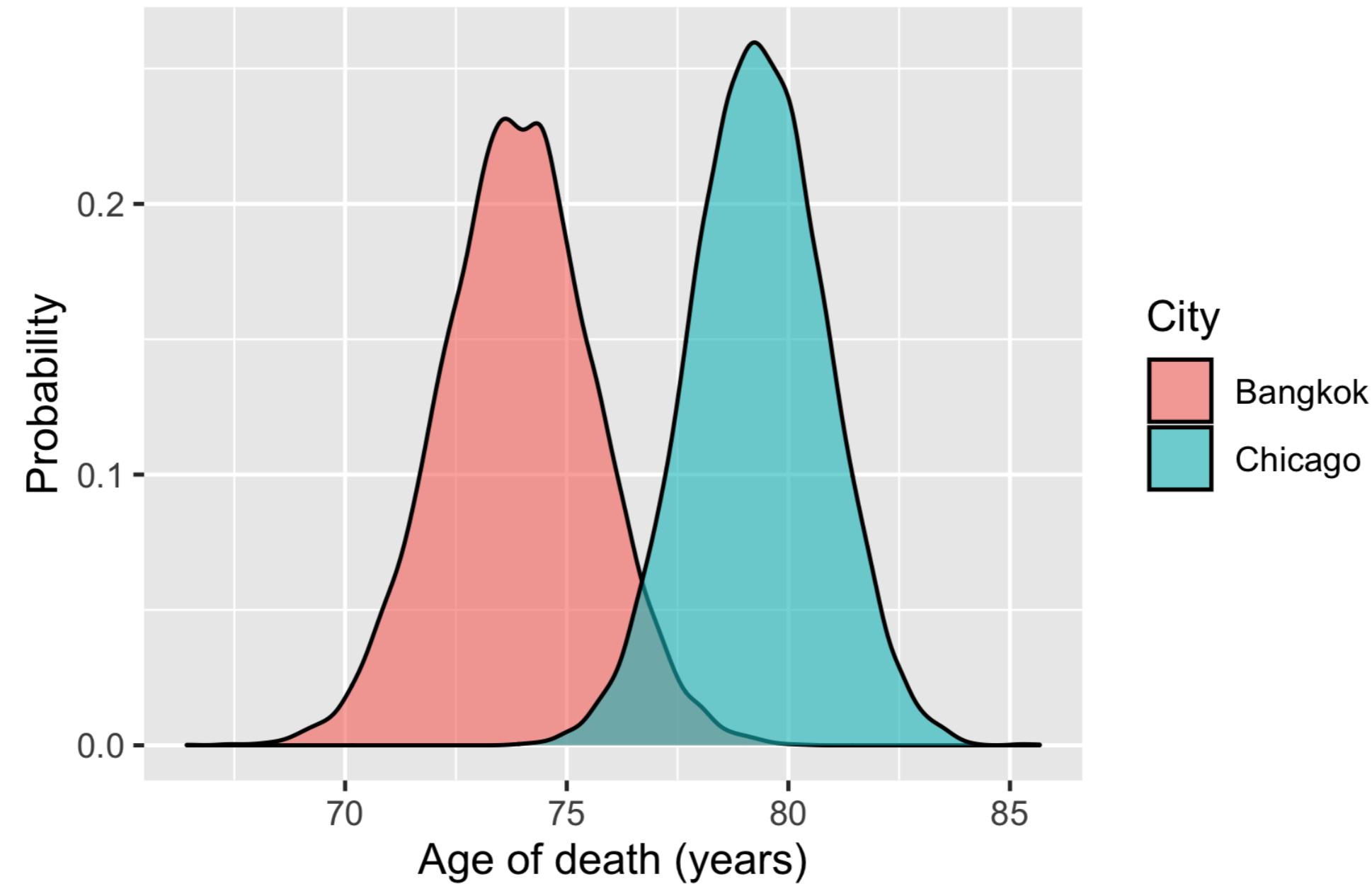


Different samples



Sampling distribution of mean life expectancy

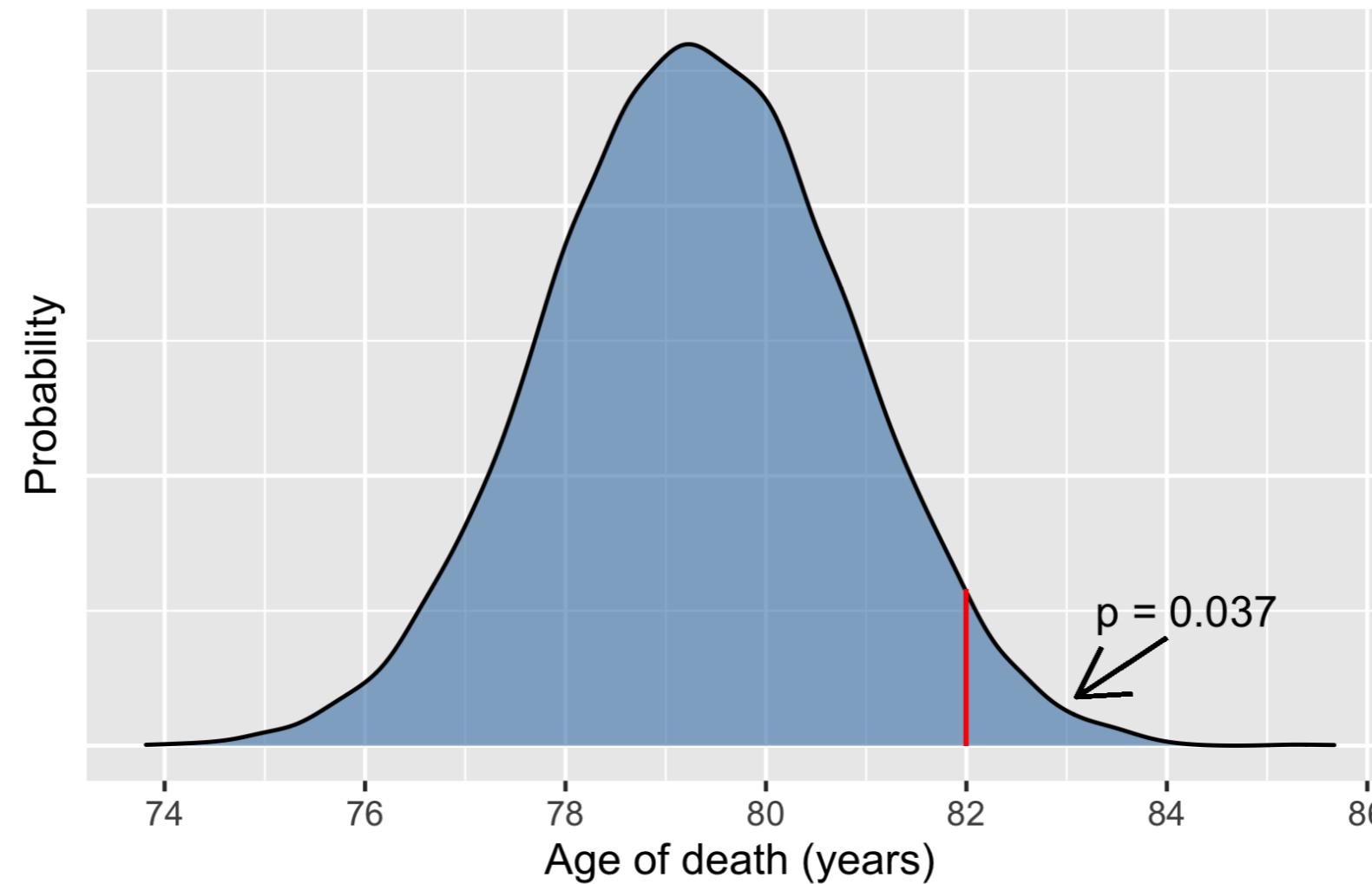
Sampling distribution of mean life expectancy



p-value

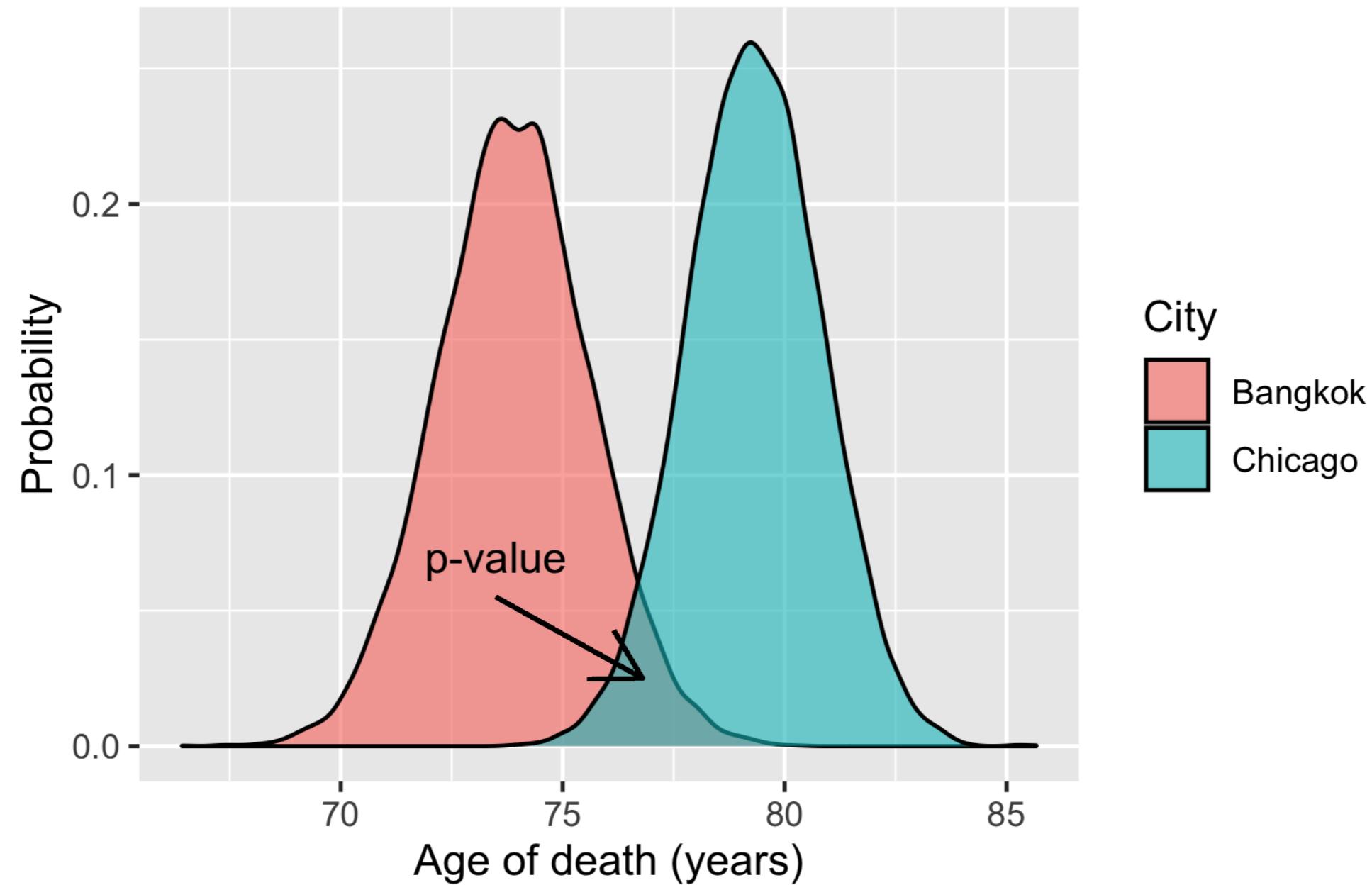
- p
 - Probability of achieving this result, assuming the null hypothesis is true

Sampling distribution of Chicago mean life expectancy



p-value

Sampling distribution of mean life expectancy



Significance level (α)

- To reduce the risk of drawing a false conclusion:
 - Set a probability threshold for rejecting the null hypothesis
- Known as α or *significance level*
- Decided before data collection to minimize bias:
 - Otherwise they could choose a different α to serve their interests
- A typical threshold is 0.05
 - 5% chance of wrongly concluding that Chicago residents live longer than Bangkok residents
- If $p \leq \alpha$, reject the null hypothesis
- These results are said to be *statistically significant*

Type I/II error

	Null hypothesis is TRUE	Null hypothesis is FALSE
Reject null hypothesis	Type I Error	
Accept null hypothesis		

Type I/II error

	Null hypothesis is TRUE	Null hypothesis is FALSE
Reject null hypothesis	Type I Error	
Accept null hypothesis		Type II Error

Type I/II error

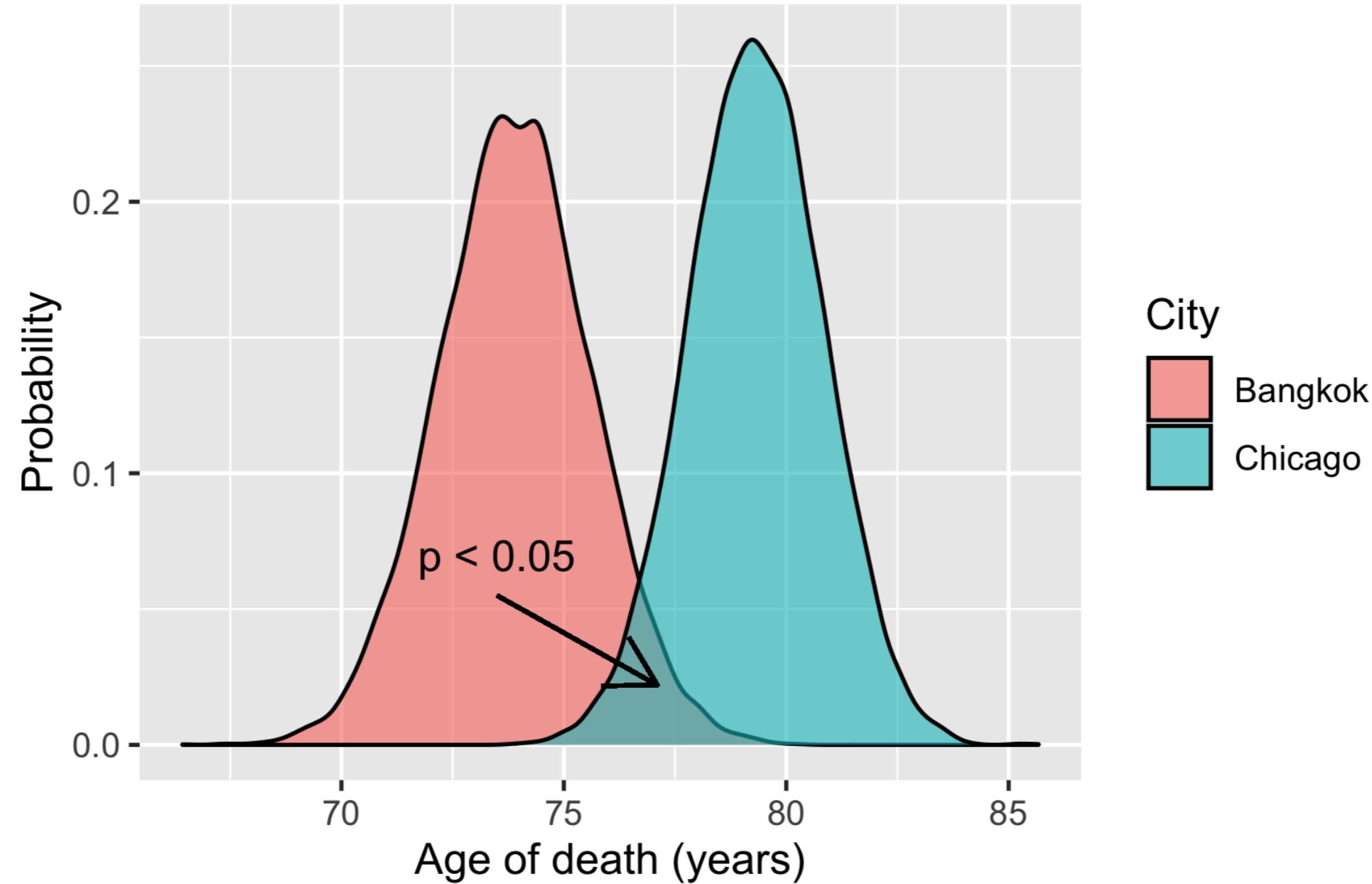
	Null hypothesis is TRUE	Null hypothesis is FALSE
Reject null hypothesis	Type I Error	
Accept null hypothesis	Correct conclusion	Type II Error

Type I/II error

	Null hypothesis is TRUE	Null hypothesis is FALSE
Reject null hypothesis	Type I Error	Correct conclusion
Accept null hypothesis	Correct conclusion	Type II Error

Drawing a conclusion

Sampling distribution of mean life expectancy



Let's practice!

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Congratulations!

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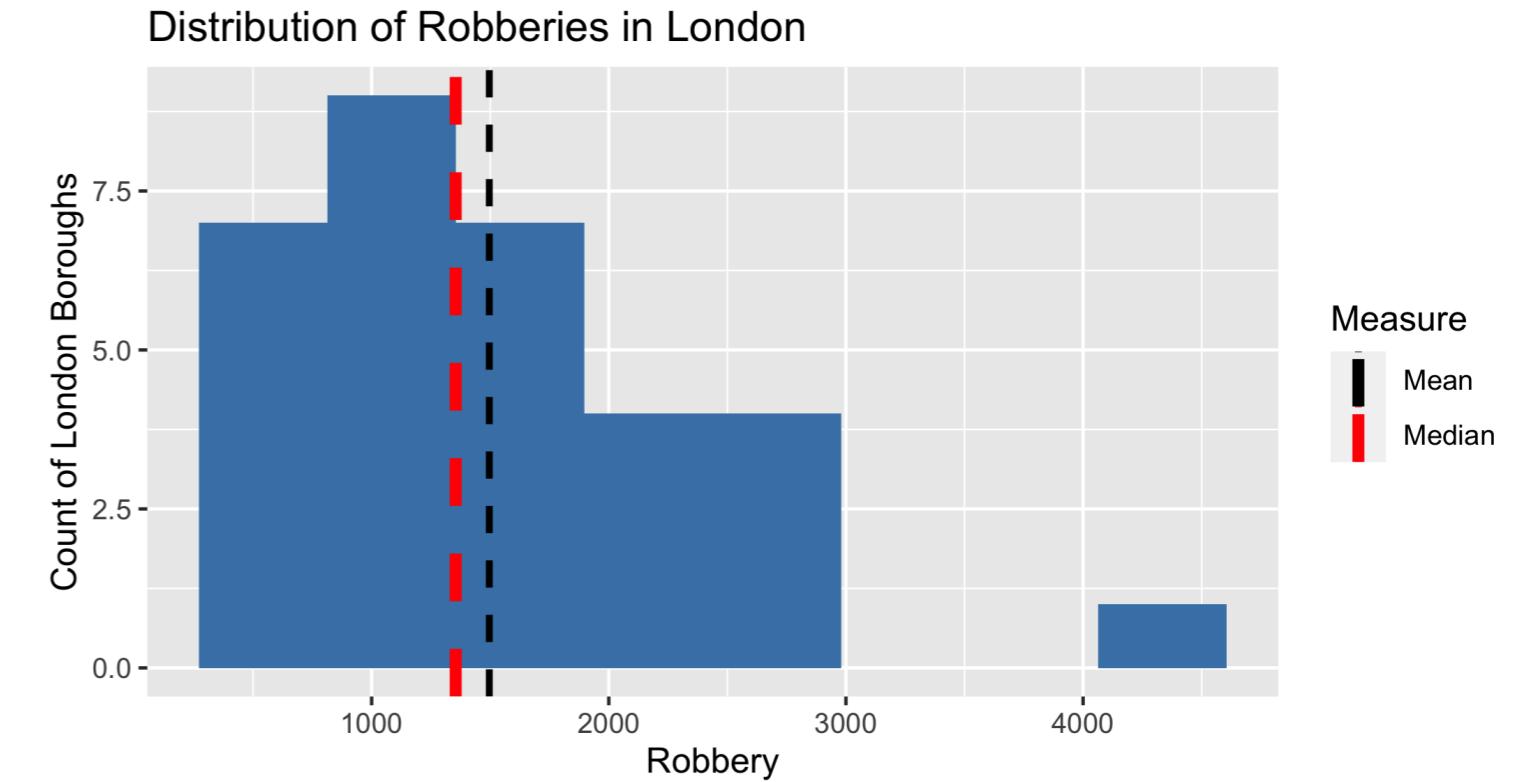


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What you've covered

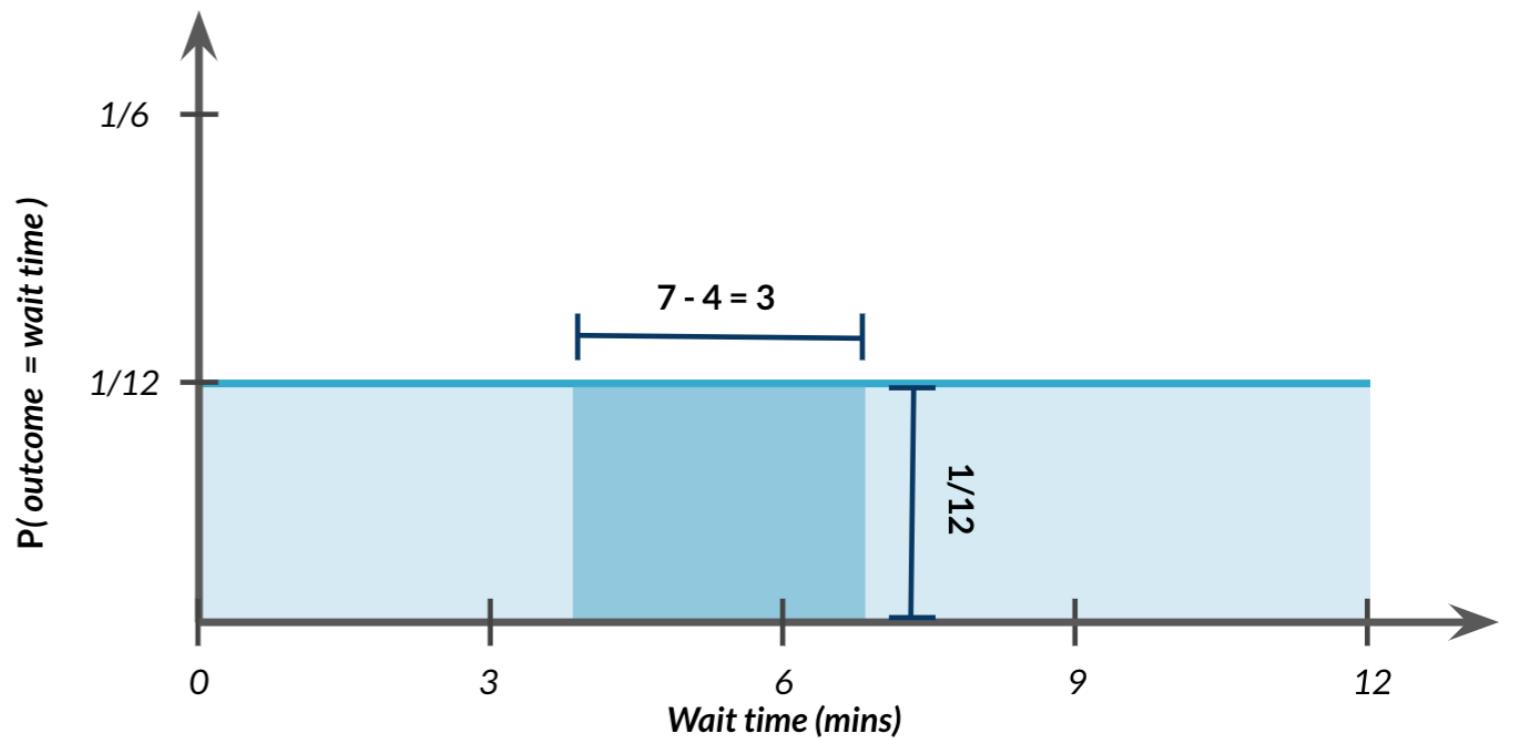
- Types of data
 - Ordinal, nominal, continuous, interval
- Descriptive and inferential statistics
- Measures of center
 - Mean, median, mode
- Measures of spread
 - Variance, standard deviation



What you've covered

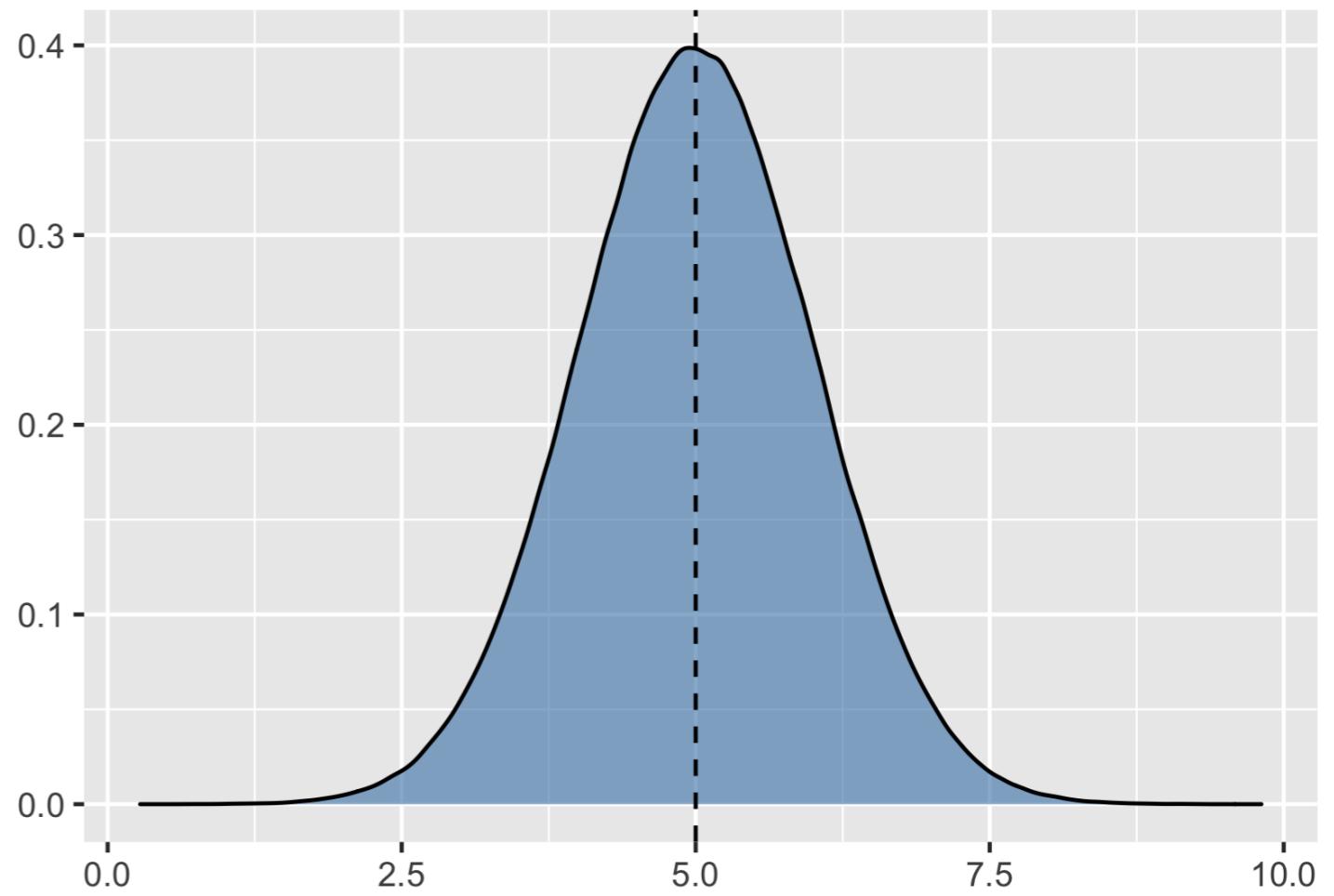
- Probability
- Conditional probability
- Discrete distributions
- Continuous distributions

$$P(4 \leq \text{wait time} \leq 7) = 3 \times 1/12 = 3/12$$



What you've covered

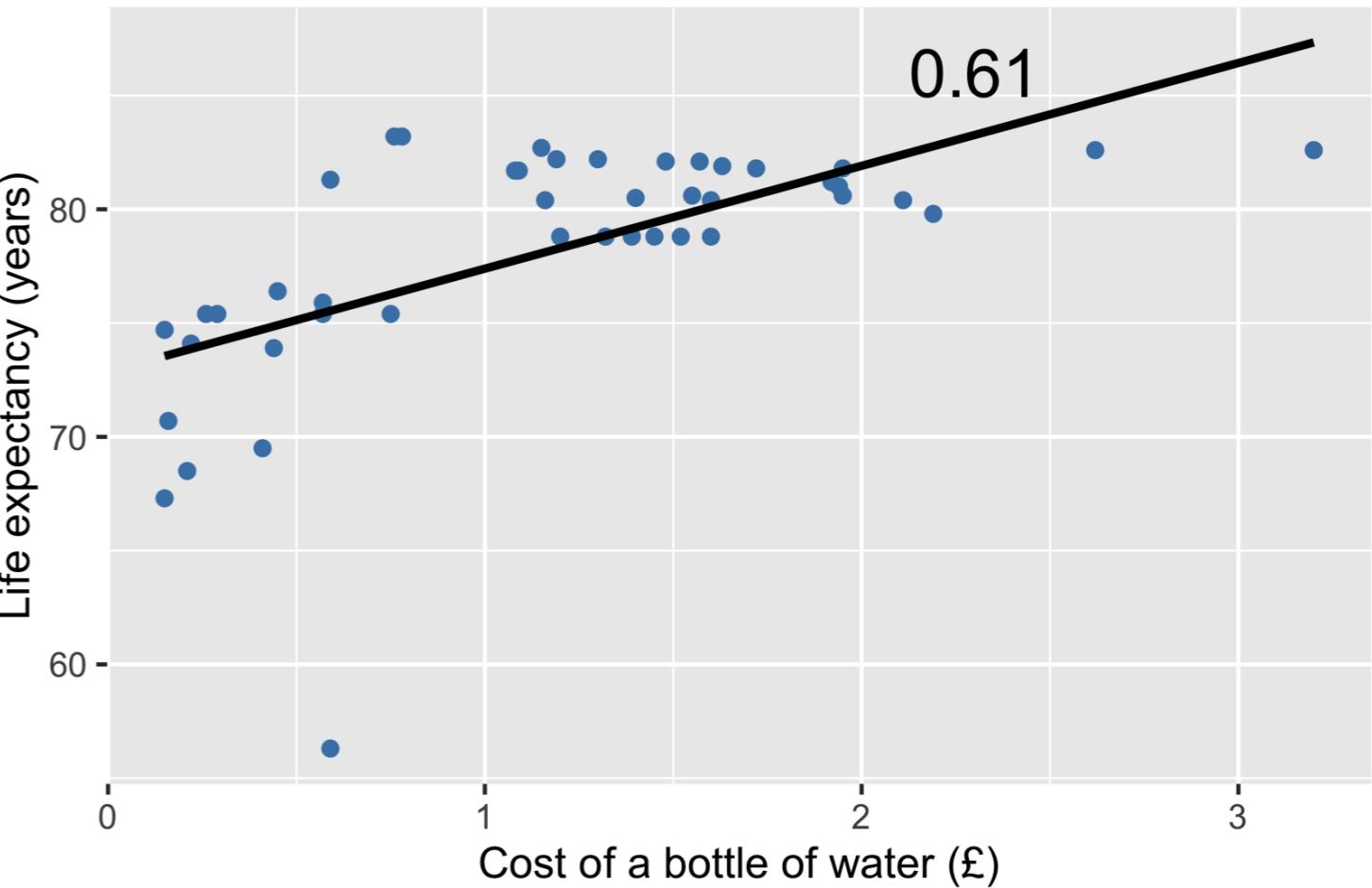
- The binomial distribution
- The normal distribution
- The Poisson distribution
- The central limit theorem



What you've covered

- Hypothesis testing
- Randomization, treatment, and control
- Correlation
- Interpreting hypothesis test results

Life expectancy (years) vs. cost of a bottle of water (£)



Where to from here?

- [Understanding Data Science](#)
- [Data Science for Business](#)
- [Understanding Machine Learning](#)

Thank you!

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