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Hyphotesis testing III

Objectives

Statistical test for frequencies:

- evaluation of the relationship between two qualitative variables
- For independent samples
  - The Chi-square test
  - The Ficher exact test
- For dependent samples
  - The Mc Nemar test

Non-parametric test

- Examples of scientific and medical articles – with explanations
- Examples of exercises for the exam

Errors in hypothesis testing

Type I error = **α** (alfa) – incorrect results if H0 is true

= to reject H0, although it is true = false positive ($\alpha \leq 0.05$)

Type II error = β (beta)– incorrect results if H1 is true

= to rejecting the H1, although it is true = false negative ($\beta \leq 0.15$)

Level of confidence, power of a test

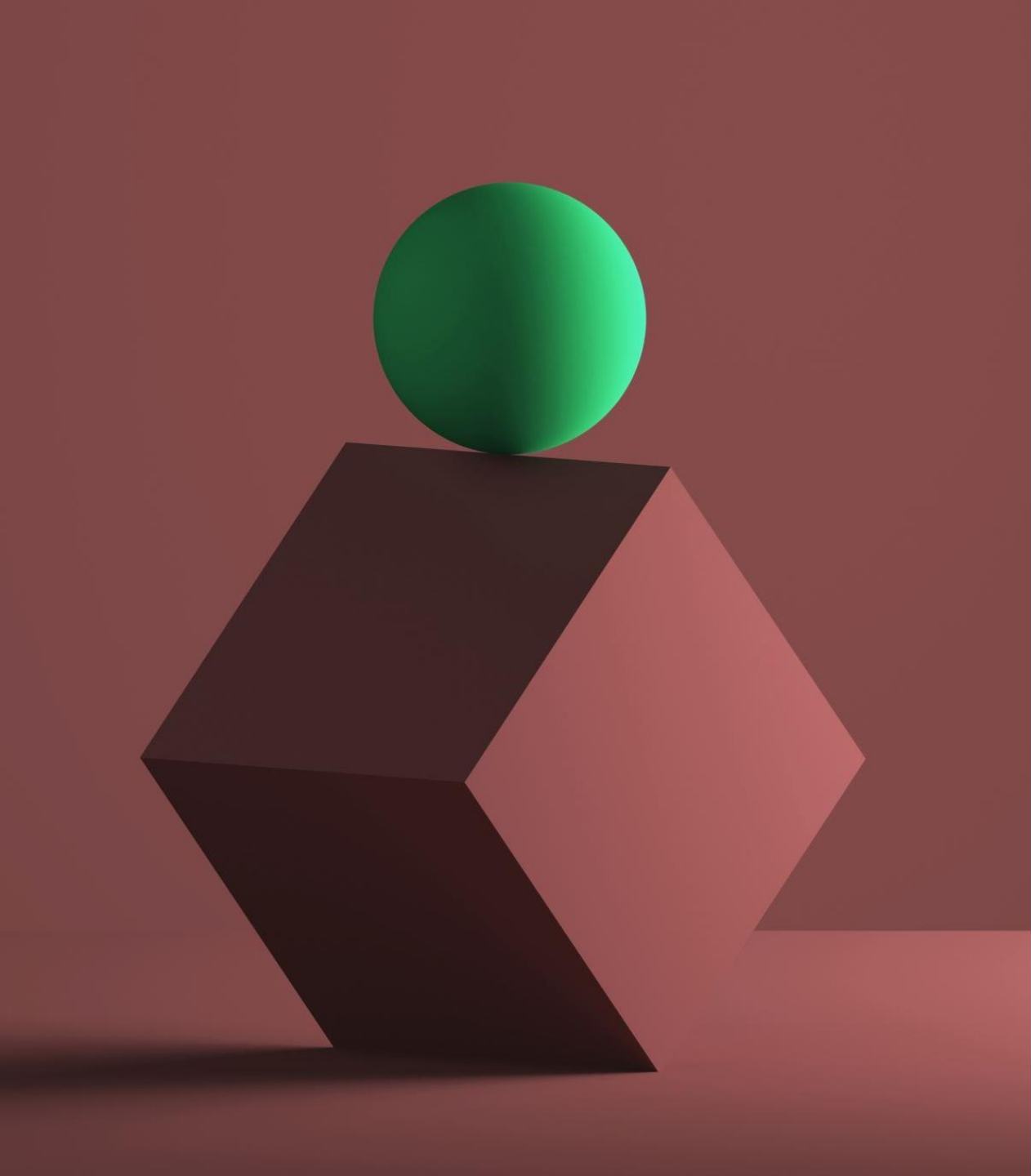
1 – α Confidence level

if α=0.05 level of error → 95% level of confidence

1 - β Test power

if α=0.15 beta error → 85% power of the test

- the power to detect a given difference of a given size, if that difference exists – the sensibility of the test
- influenced by
  - the number of individuals in a sample
  - the variation of the data
- involved in the calculation of "sample size" necessary in a study



Statistical inference – qualitative variables

Compare two frequencies

- Populations P_1, P_2,...
- Objective: the study of differences in the parameters of a qualitative variable X in two/more populations (categories of the grouping variable Y)

Frecvencies ϕ_1, ϕ_2, ...

How?

- Populations P_1, P_2,...
- Objective: the study of differences in the parameters of a qualitative variable X in two/more populations (categories of the grouping variable Y)

Frecvencies ϕ_1, ϕ_2, ...

How?

1. Extract representative samples from the populations

2. Calculate the indicators
   - Frecvencies f1, f2

3. **With statistical test**
   - verify the hypothesis: we do not have two different populations, but one population
   - obtain the probability p – the probability of finding differences equal to or smaller (extreme) than the one found on the samples under study if we repeat the study on other samples with random selection (it is due to chance)

The hypothesis that we do not have two different populations, but the same population in terms of the frequency distribution of the variable under study

Null hypothesis H0 - assumes the denial of the objective we want to investigate

- There is **no** statistically significant difference between groups in terms of frequency
- There is **no** statistically significant association between 2 variables: Risk factor – disease

Alternative hypothesis H1 (denial of H0): refers to the objective we want to investigate

- There is a statistically significant difference between groups in terms of frequency
- There is a statistically significant association between 2 variables: Risk factor – disease

Statistical test --> we choose between the two possibilities H0 or H1

Question: In some cases, graft rejection occurs immediately after kidney transplantation. Why? Are there some factors that can be associated with graft rejection?

Hypothesis:
Obese people are more likely to experience graft rejection immediately after kidney transplantation

apply a test for frequencies

i.e. Chi-square test

Identify the variables of interest and populations

Variables

- supposed risk factor – Obesity
  - Qualitative dichotomous variable
- Disease – Graft rejection
  - Qualitative dichotomous variable

Population

- People who have had kidney transplants
- Subpopulations
  - Obese people who have had kidney transplants
  - Non-obese people who have had kidney transplants

We transform the medical question into testable statistical hypotheses

The frequency of graft rejection after kidney transplantation (up to one month) differs in

obese individuals

versus

non-obese individuals

Variables

- Risk factor – Obesity
  - Qualitative dichotomous variable
- Disease – Graft rejection
  - Qualitative dichotomous variable

Population

- People who have had kidney transplants
- Subpopulations
  - Obese people who have had kidney transplants
  - Non-obese people who have had kidney transplants

Alegem testul statistic adecvat ipotezei sau metoda intervalului de încredere

- Test statistic pentru frecvențe
  - Eșantioane independente
  - Tabel de contingență df=1

Alegem această metodă

- Estimarea intervalelor de încredere de 95% pentru frecvențe

df = (2 linii-1) x (2 coloane-1) = 1

Calculate the sample size

The frequency of graft rejection after kidney transplantation (up to one month) differs in

obese individuals

versus

non-obese individuals

We consider a **2% difference** between frequencies to be **of medical importance**

- Statistical significance α=5%
- Test power β=80%

- Calculate the required sample size
- people in each sample
  - 1500 obese
  - 1500 non-obese

Conducting the study

- We randomly select from among those who are going to have kidney transplants
  - 1500 obese people
  - 1500 non-obese people
- We track the occurrence of graft rejection over a period of 1 month after the transplant

Data collection

Frecvencies in the samples

Observed contingency table

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	50	1450	1500
Obese^{-}	62	1438	1500
Total	112	2888	3000

Data collection

Observed contingency table

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	50	1450	1500
Obese^{-}	62	1438	1500
Total	112	2888	3000

Frecvencies in the samples

	(%) graft rejection $^{+}$
Obese^{+} (%)	=50/1500*100= 3.33
Obese^{-} (%)	=62/1500*100= 4.13

Sample difference: We found a difference between the frequencies of graft rejection between the obese group and non-obese group 3.33% - 4.13% = -0.8%

we want to found if this difference remain or will be higher if we repeat the study

Formulating hypotheses

Null hypothesis H0

- There is **no** statistically significant difference between obese and non-obese patients in the frequency of graft rejection after (up to one month) kidney transplantation
- There is **no** statistically significant association between obesity and graft rejection after (up to one month) kidney transplantation

Alternative hypothesis H1

- There is a statistically significant difference between obese and non-obese individuals in the frequency of graft rejection after (up to one month) kidney transplantation
-
- There is a statistically significant association between obesity and graft rejection after (up to one month) kidney transplantation

Formulating hypotheses

Null hypothesis H0

- There is **no** statistically significant difference between obese and non-obese patients in the frequency of graft rejection after (up to one month) kidney transplantation

both are good

- There is **no** statistically significant association between obesity and graft rejection after (up to one month) kidney transplantation

Alternative hypothesis H1

- There is a statistically significant difference between obese and non-obese individuals in the frequency of graft rejection after (up to one month) kidney transplantation

both are good

- There is a statistically significant association between obesity and graft rejection after (up to one month) kidney transplantation

Observed frequency table

	+	-	Total
+	a	b	a+b
-	c	d	c+d
Total	a+c	b+d	n

- We assume by absurdity that the null hypothesis is true
- We calculate the theoretical table in which obesity is not a risk factor

Theoretical frequency table

	+	-	Total
+	$\frac{(a+c)*(a+b)}{n}$	$\frac{(b+d)*(a+b)}{n}$	a+b
-	$\frac{(a+c)*(c+d)}{n}$	$\frac{(b+d)*(c+d)}{n}$	c+d
Total	a+c	b+d	n

Calculation of the theoretical table (null)

- We assume by absurdity that the null hypothesis is true
- We calculate the theoretical table in which obesity is not a risk factor

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	50	1450	1500
Obese^{-}	62	1438	1500
Total	112	2888	3000

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	=(112·1500)/3000=56	=(2888·1500)/3000=1444	1500
Obese^{-}	=(112·1500)/3000=56	=(2888·1500)/3000=1444	1500
Total	112	2888	3000

Calculation of the theoretical table (null)

- Obesity is not a risk factor in this table
- There is no difference between the frequencies graft rejection between obese and non-obese 3.73% - 3.73% = 0

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	56	1444	1500
Obese^{-}	56	1444	1500
Total	112	2888	3000

	graft rejection $^{+}$ (%)
Obese^{+} (%)	=56/1500=3.73
Obese^{-} (%)	=56/1500=3.73

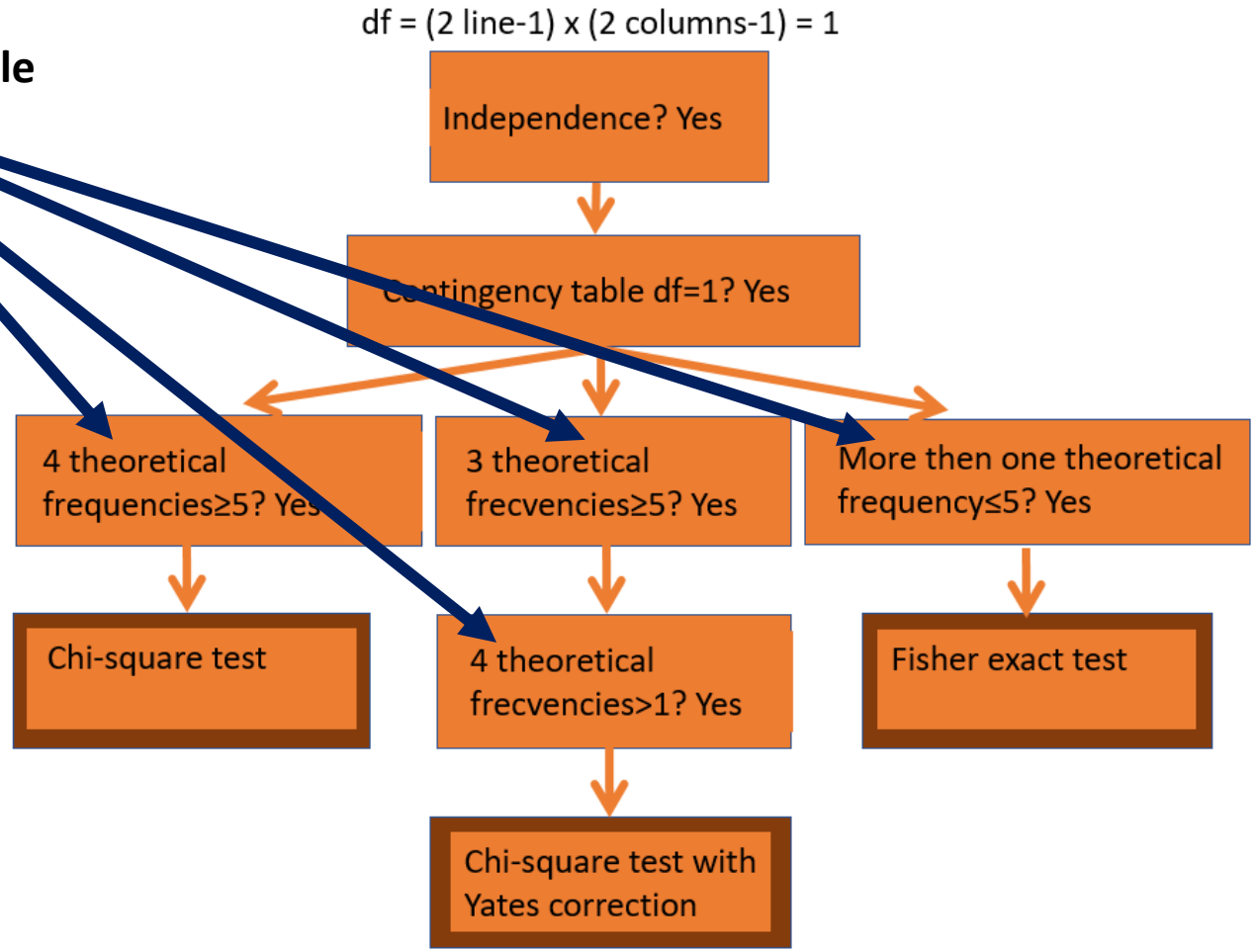
Observed frequency table

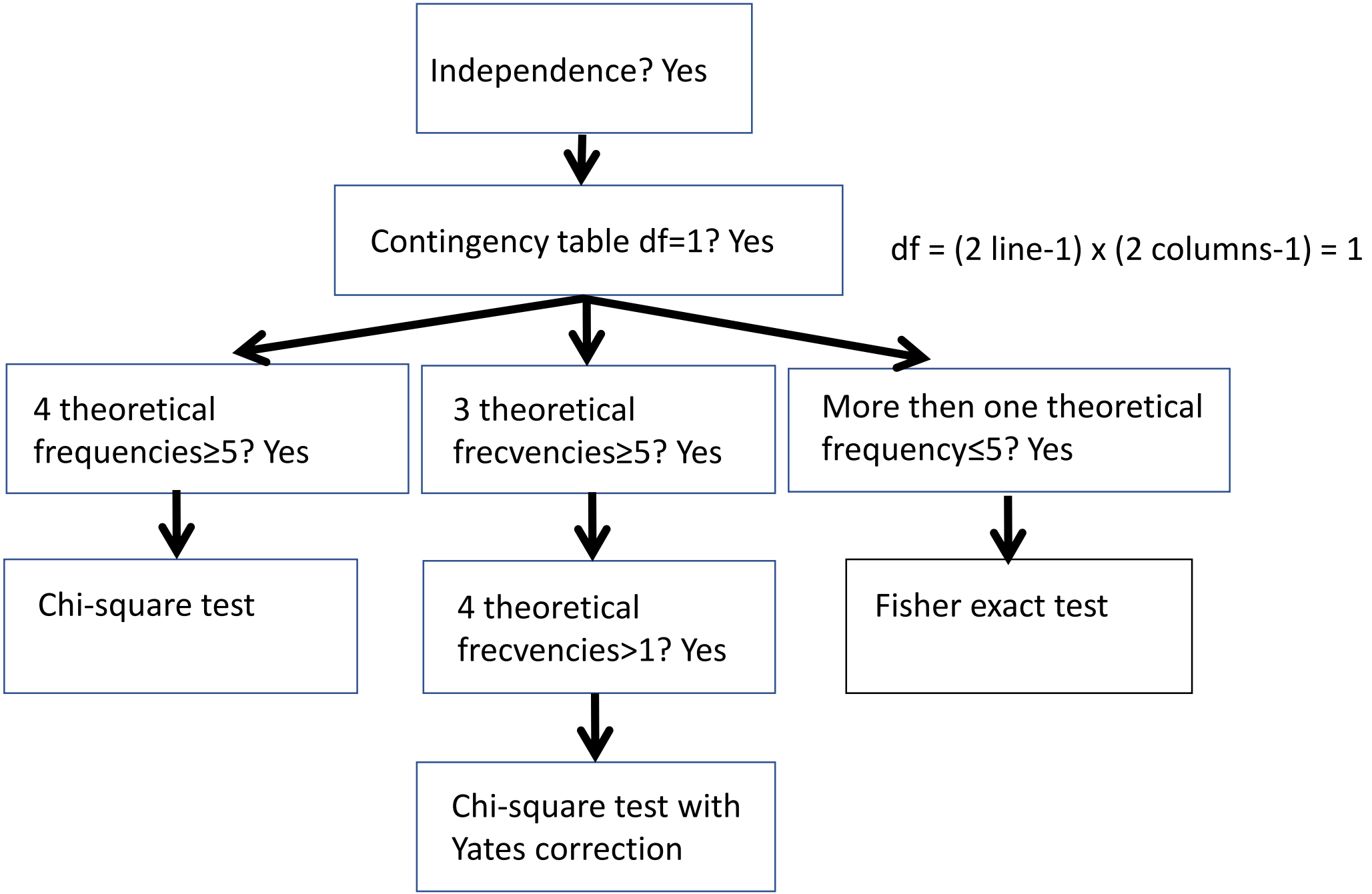
	+	-	Total
+	a	b	a+b
-	c	d	c+d
Total	a+c	b+d	n

Choosing the test

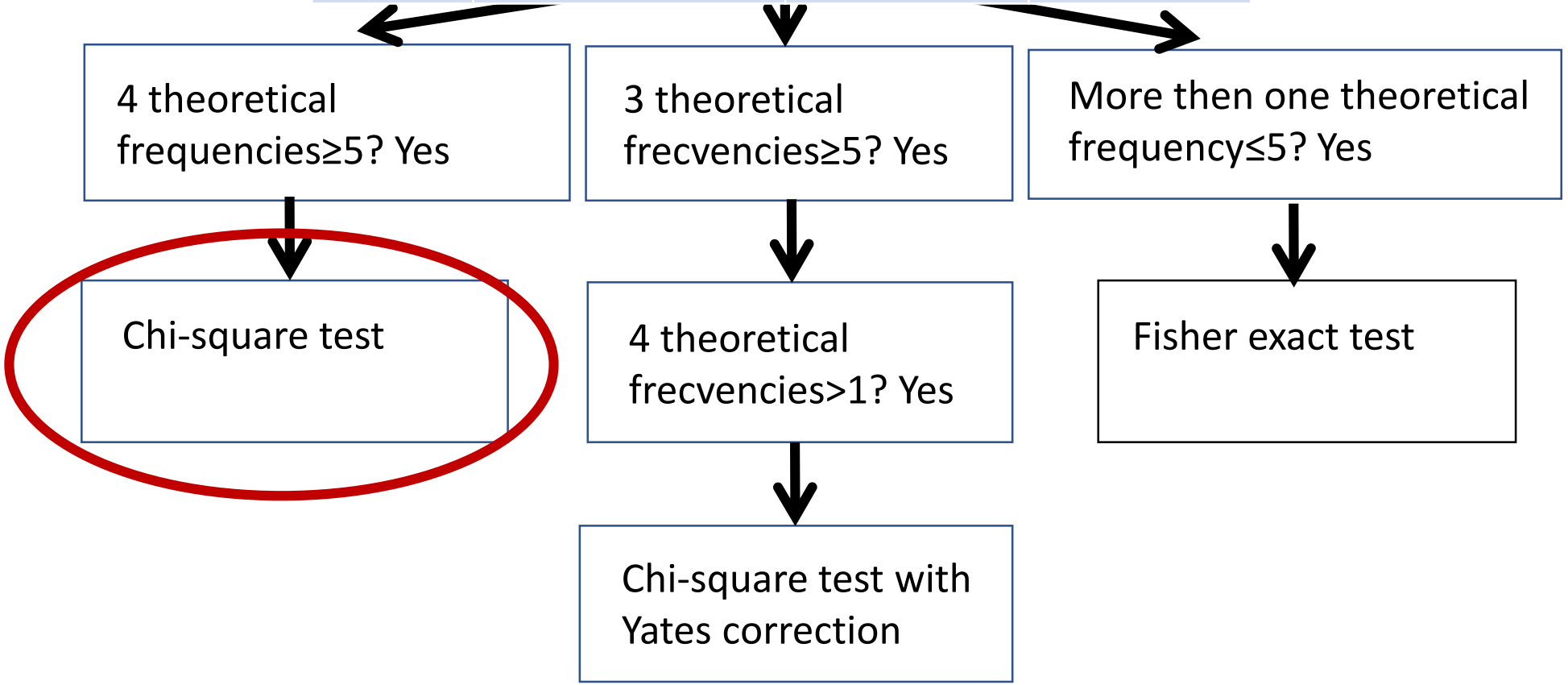
Theoretical frequency table

	+	-	Total
+	$\frac{(a+c)*(a+b)}{n}$	$\frac{(b+d)*(a+b)}{n}$	a+b
-	$\frac{(a+c)*(c+d)}{n}$	$\frac{(b+d)*(c+d)}{n}$	c+d
Total	a+c	b+d	n




Independence? Yes
Contingency table df=1? Yes
df = (2 line-1) x (2 columns-1) = 1
4 theoretical frequencies≥5? Yes
3 theoretical frecvencies≥5? Yes
More then one theoretical frequency≤5? Yes
Chi-square test
4 theoretical frecvencies>1? Yes
Fisher exact test
Chi-square test with Yates correction

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	56	1444	1500
Obese^{-}	56	1444	1500
Total	112	2888	3000



- Observed contingency table

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	50	1450	1500
Obese^{-}	62	1438	1500
Total	112	2888	3000

?

=

- Theoretic (Null) contingency table

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	56	1444	1500
Obese^{-}	56	1444	1500
Total	112	2888	3000

We calculate the difference between the tables

- If we find a small difference (below the critical threshold), then obesity is not a risk factor
- If we find a large difference (above the critical threshold), then obesity is a risk factor

Null hyphotesis: No risk factor = no difference between the observed table and the null table

- Observed contingency table

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	50	1450	1500
Obese^{-}	62	1438	1500
Total	112	2888	3000

$\neq ?$

- Theoretic (Null) contingency table

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	56	1444	1500
Obese^{-}	56	1444	1500
Total	112	2888	3000

We calculate the difference between the tables = the Chi-square test parameter

Statistical test parameter

- expresses the difference between the compared indicators
  - e.g. frequencies, observed and theoretical contingency table
- at least one is a statistic (frequency) on the sample
- Sample/samples - randomly drawn from the population
  - a random variable follows a certain probability law
  - Ex. Chi-square law etc.

Choosing the critical region

What do we decide?

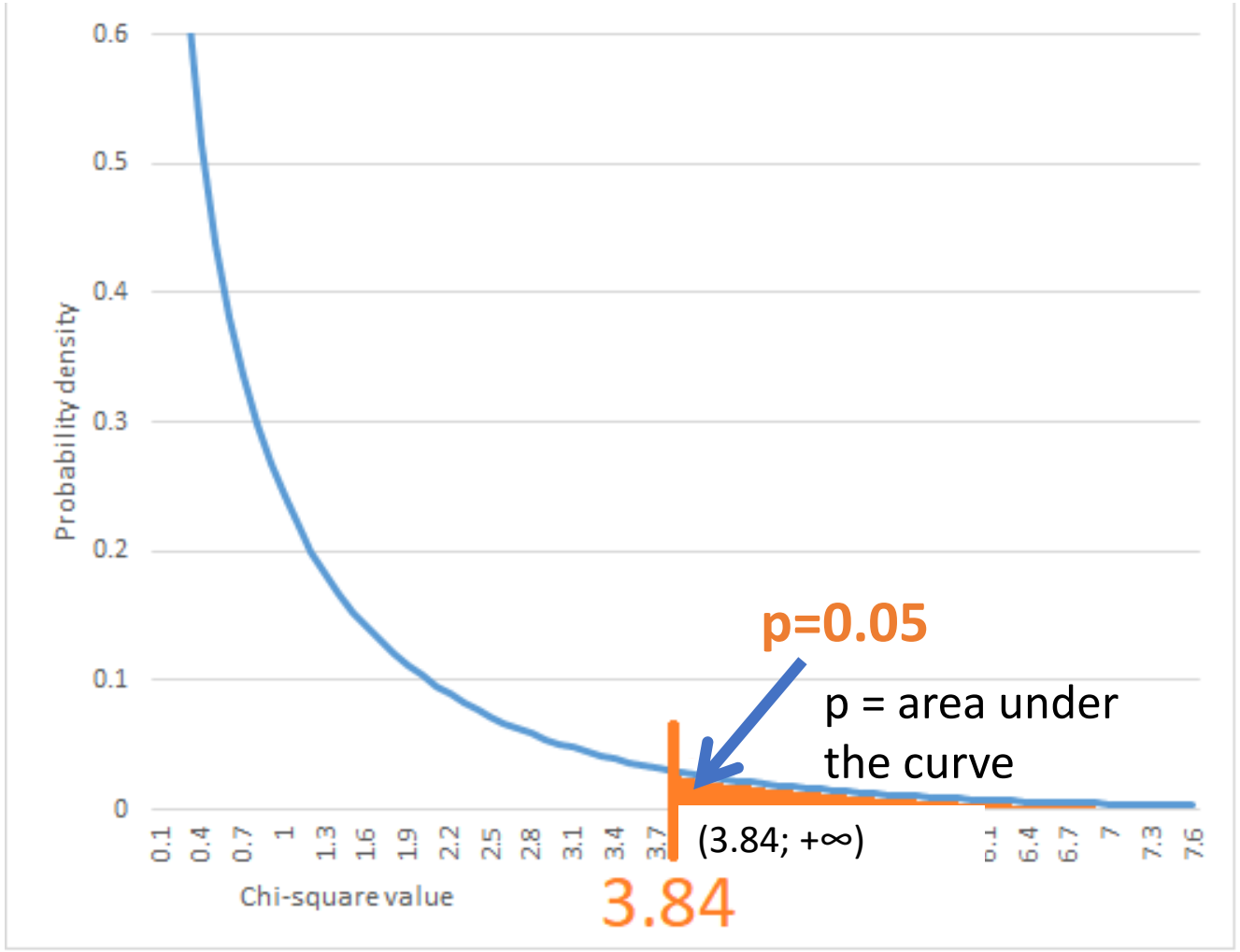
- null or alternative hypothesis,
- we decide depending on the value of the calculated parameter of the test

Choosing the size of the critical region

- depending on the size of the error risk we accept
- Significance level α = the size of the risk we are willing to assume when rejecting the null hypothesis H0 if it is true
- Usually a significance level of 1% or 5% is chosen

Choosing the significance level and establishing the critical region

- Statistical significance **α=5%**
- Rejection region (3.84; +∞)
- Acceptance area (0; 3.84]



test parameter follow the Chi-square distribution

- Observed contingency table

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	50	1450	1500
Obese^{-}	62	1438	1500
Total	112	2888	3000

?

=

- Theoretic contingency table

	graft rejection $^{+}$	graft rejection $^{-}$	Total
Obese^{+}	56	1444	1500
Obese^{-}	56	1444	1500
Total	112	2888	3000

parameter of the test

$$\chi^2 = \sum_{i=1}^{4} \frac{(f_i^o - f_i^t)^2}{f_i^t}$$

f_i^o = observed frequency, f_i^t = theoretical frequency

- Observed contingency table

	graft rejection $^+$	graft rejection $^-$	Total
Obese$^+$	50	1450	
Obese$^-$	62	1438	
Total			

- Theoretic contingency table

	graft rejection $^+$	graft rejection $^-$	Total
Obese$^+$	56	1444	
Obese$^-$	56	1444	
Total			

$$\chi^2 = \sum_{i=1}^{4} \frac{(f_i^o - f_i^t)^2}{f_i^t} = \frac{(f_1^0 - f_1^t)^2}{f_1^t} + \frac{(f_2^0 - f_2^t)^2}{f_2^t} + \frac{(f_3^0 - f_3^t)^2}{f_3^t} + \frac{(f_4^0 - f_4^t)^2}{f_4^t}$$

difference

$$= \frac{(50 - 56)^2}{56} + \frac{(1450 - 1444)^2}{1444} + \frac{(62 - 56)^2}{56} + \frac{(1438 - 1444)^2}{1444} =$$

=0.64+0.002+0.64+0.02 = 1.33

p=0.248 (from an computer application)

Test decision

A. Test decision according to the rejection region:

If $\chi 2$ belongs to $(3.84; +\infty)$

we have enough evidence to reject H0, so we accept H1

If $\chi 2$ DOES NOT belong to $(3.84; +\infty)$

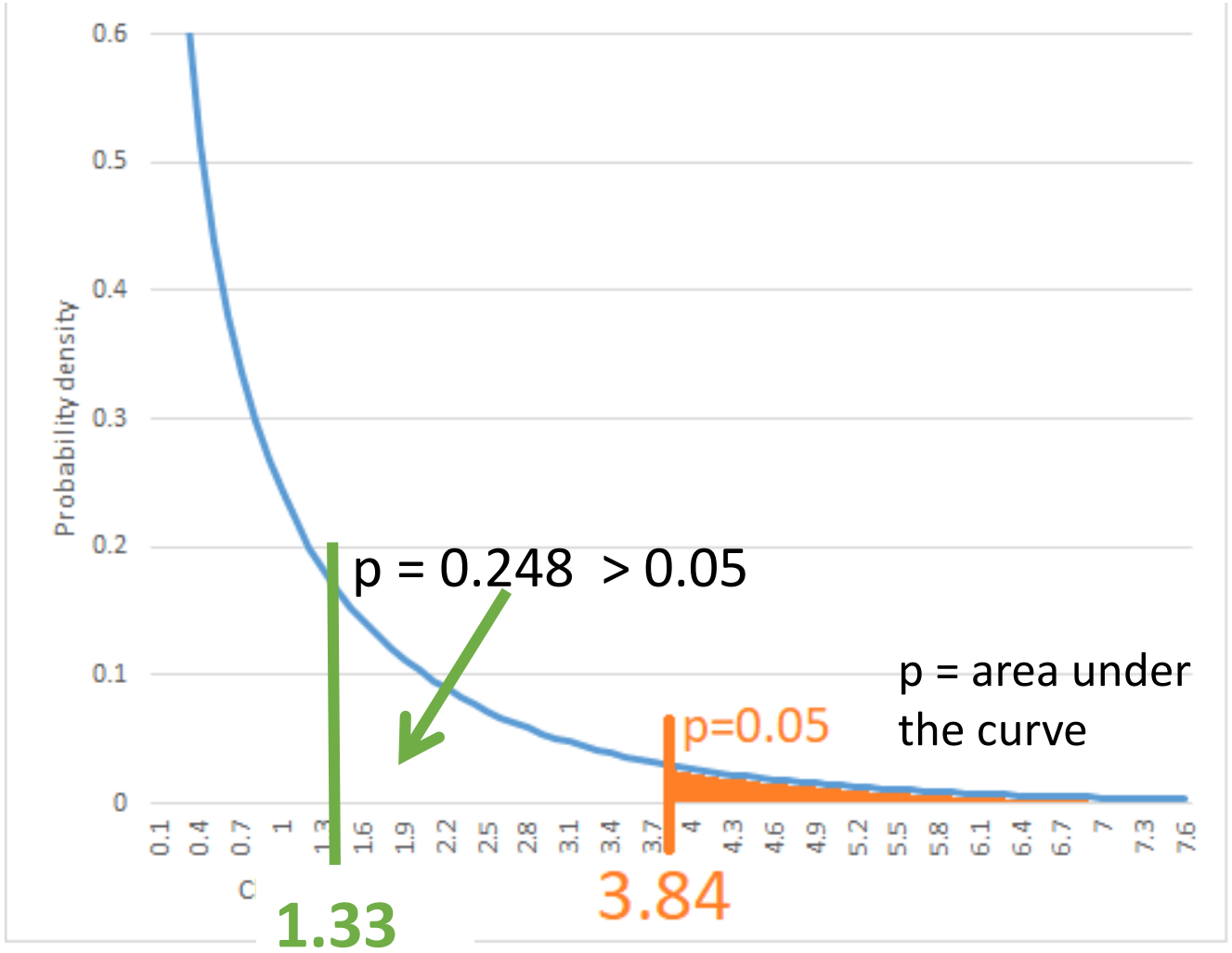
we do NOT have enough evidence to reject H0, so we are in favor of H0

In our case: $\chi 2 = 1.33$ does not belong to $(3.84, +\infty)$,

we do NOT have enough evidence to reject H0, so we are in favor of H0

Conclusion: There is no statistically significant association between obesity and graft rejection in the first month after kidney transplantation

$\chi 2 = 1.33$ does not belong to $(3.84, +\infty)$



B. Test decision based on p probability – the probability of finding a difference equal to or smaller than the one found if we repeat the study:

If $p < 0.05$

we have enough evidence to reject H0, so we accept H1

If $p \geq 0.05$

we do NOT have enough evidence to reject H0, so we are in favor of H0

In our case: $p = 0.248 > 0.05$

we do NOT have enough evidence to reject H0, so we are in favor of H0

Conclusion: There is no statistically significant association between obesity and graft rejection after (up to one month) kidney transplantation, i.e. the probability of finding a difference equal to or smaller than the found one 1.33% if we repeat the study is high

Statistical decision

We were not able to show that we have two different sub-populations (obese and non-obese) in terms of graft rejection frequency, but the same population

At the population level there is no association between obesity and graft rejection in the first month after kidney transplantation

Medical conclusion

- Since we calculated the sample size and considered 2% to be a clinically significant difference
  - we can state that the 2% target was not reached,
  - differences in graft rejection rates < 2%,
  - so the differences are clinically unimportant

- Obesity does not influence graft rejection in the first month after transplantation

Disadvantages of studies carried out without calculating the required sample size in advance

If p was significant

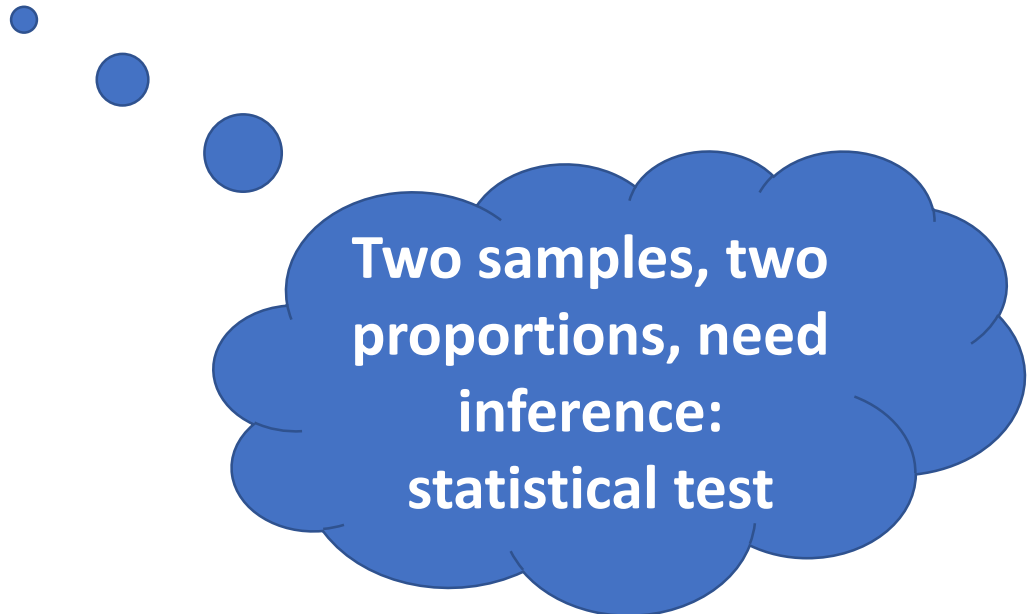
- We were able to demonstrate a statistically significant difference

At an insignificant p (≥0.05)

- possibly the study is not powerful enough (sample too small)
- !!! WE CANNOT DRAW THE CONCLUSION THAT THERE IS NO DIFFERENCE BETWEEN FREQUENCIES IN THE POPULATION
- If we were to draw this conclusion, it would be a TYPE I ERROR
- we drew the conclusion that there is no significant difference, although it exists

Scenario

- From 3000 patients with dental implants 125 experienced early implant loss. From 125 with early implant loss 50 are smokers. From 3000 patients 1600 are non-smokers.
- Question: People who smoke are more likely to have dental implant failure?



- Observed contingency table

	With dental implant failure	Without dental implant failure	Total
Smokers	50	1350	1400
Non-smokers	75	1525	1600
Total	125	2875	3000

- Dental implant failure:
- 50/1400 = 3.57% for smokers
- 75/1600 = 4.68% for non smokers

- Observed contingency table

	With dental implant failure	Without dental implant failure	Total
Smokers	50	1350	1400
Non-smokers	75	1525	1600
Total	125	2875	3000

- Dental implant failure:
- 50/1400 = 3.57% for smokers
- 75/1600 = 4.68% for non smokers

Chi-square test for independence

Chi-square test for independent samples

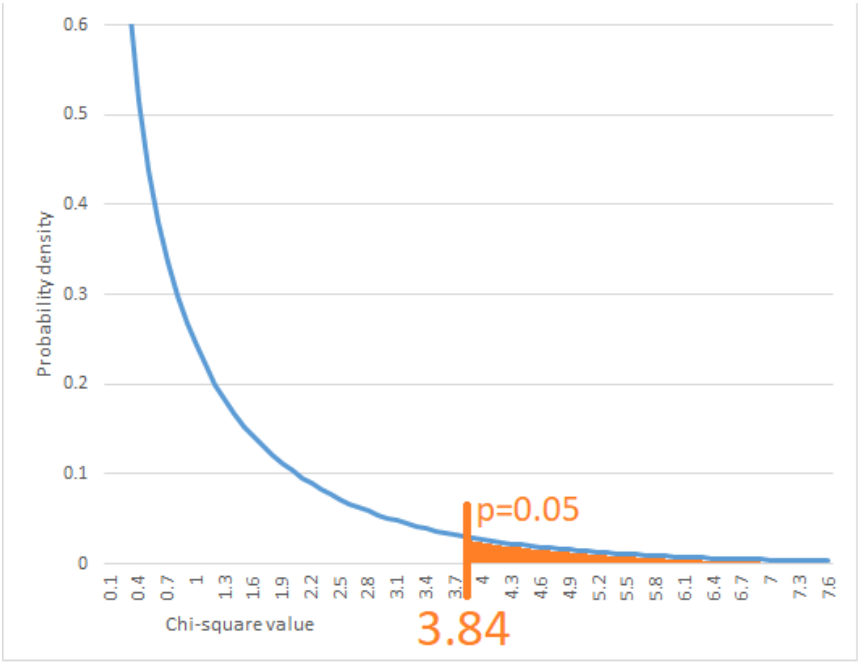
- Step 1:
  - H0 - null hypothesis: smoking and dental implants are independent
    - or (smoking is not a risk factor for dental implant failure) or (there is no significant difference between the frequency of dental implant falure of smoking vs. non-smoking individuals)
  - H1 - alternative hypothesis: smoking and dental implants are dependent
    - or (smoking is a risk factor for dental implant failure) or (there is significant difference between the frequency of dental implant falure of smoking vs. non-smoking individuals)

we have multiple possibility to formulate H0, any of these possibility are correct, only one is needed to know

- Step 2: we choose chi-square test because:
  - independent samples,
  - 2 or more than 2 proportions,
  - theoretical frequencies higher than 5

- Step 3: we choose the level of error α = 0.05,

- Step 4:
  - Rejection area $[\chi_\alpha, \infty) = [3.84, \infty)$
  - Acceptance area: $(0, \chi_\alpha) = (0, 3.84)$



	With dental implant failure	Without dental implant failure	Total
Smokers	50	1350	1400
Non-smokers	75	1525	1600
Total	125	2875	3000

Step 5: compute the theoretical contingency table with theoretical frequencies:

	With dental implant failure	Without dental implant failure	Total
Smokers	$=\frac{125 \cdot 1400}{3000}=58$	$=\frac{2875 \cdot 1400}{3000}=1342$	1400
Non-smokers	$=\frac{125 \cdot 1600}{3000}=67$	$=\frac{2875 \cdot 1600}{3000}=1533$	1600
Total	125	2875	3000

Step 5: compute the parameter of the test

Observed contingency table

	With dental implant failure	Without dental implant failure
Smokers	50	1350
Non-smokers	75	1525

Theoretical contingency table

	With dental implant failure	Without dental implant failure
Smokers	58	1342
Non-smokers	67	1533

$$\chi^2 = \sum_{i=1}^{4} \frac{(f_i^o - f_i^t)^2}{f_i^t}$$

f_i^o = observed frequencies, f_i^t = theoretical frequecies

Step 5: compute the parameter of the test

Observed contingency table

	With dental implant failure	Without dental implant failure
Smokers	50	1350
Non-smokers	75	1525

Theoretical contingency table

	With dental implant failure	Without dental implant failure
Smokers	58	1342
Non-smokers	67	1533

$$\chi^2 = \sum_{i=1}^{4} \frac{(f_i^o - f_i^t)^2}{f_i^t} =$$

$$= \frac{(50-58)^2}{58} + \frac{(1350-1342)^2}{1342} + \frac{(75-67)^2}{67} + \frac{(1525-1533)^2}{1533} =$$

$$= 1.19 + 0.05 + 1.04 + 0.05 = 2.33$$

p=0.13 (From the internet: tables for chi-square test or computed in Excel or with other application)

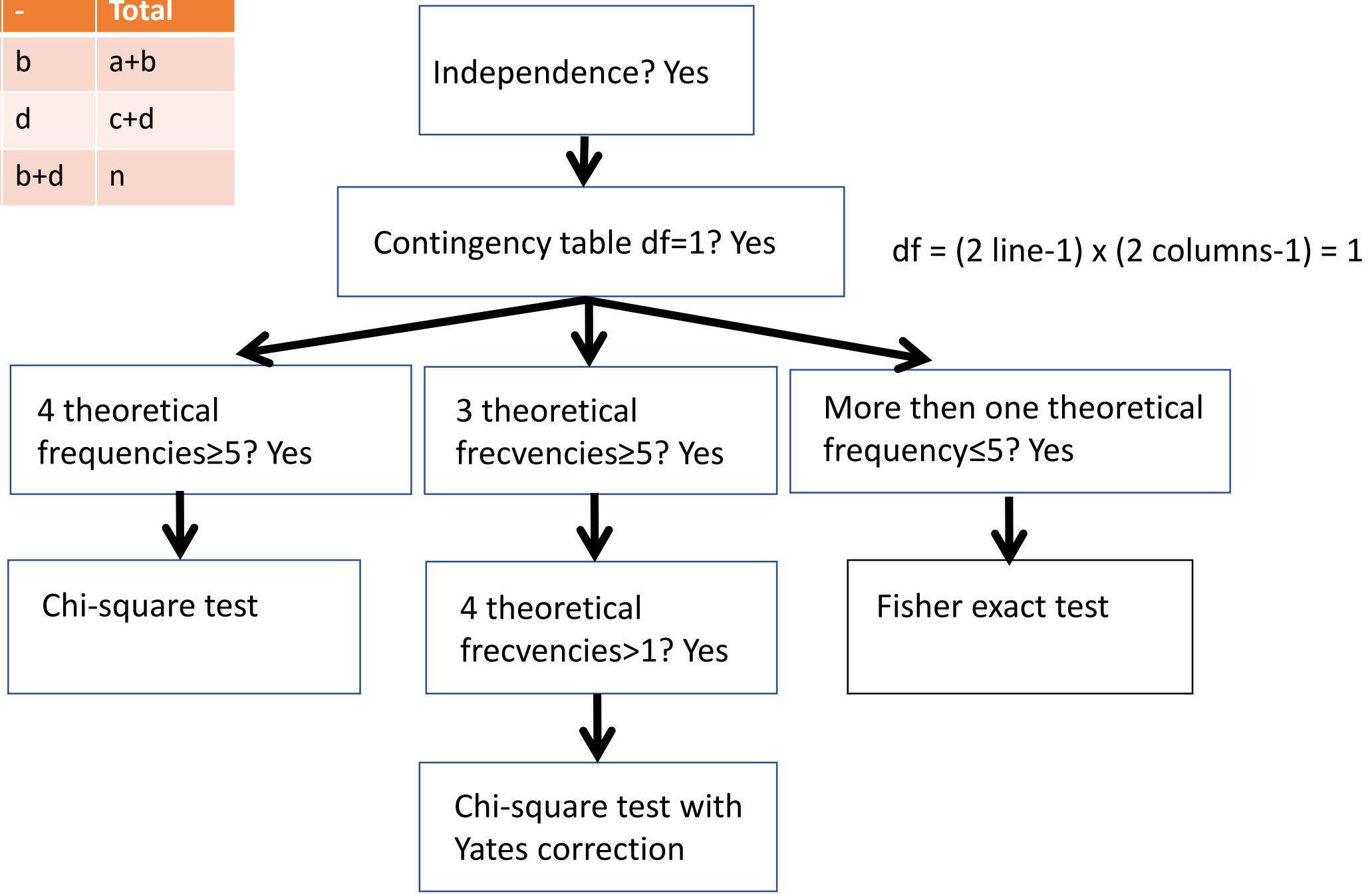
- Step 6: Conclusion

$\chi^2 = 2.33 \notin [3.84, \infty)$ fail to reject null hypothesis: smoking and dental implant are independent

Or

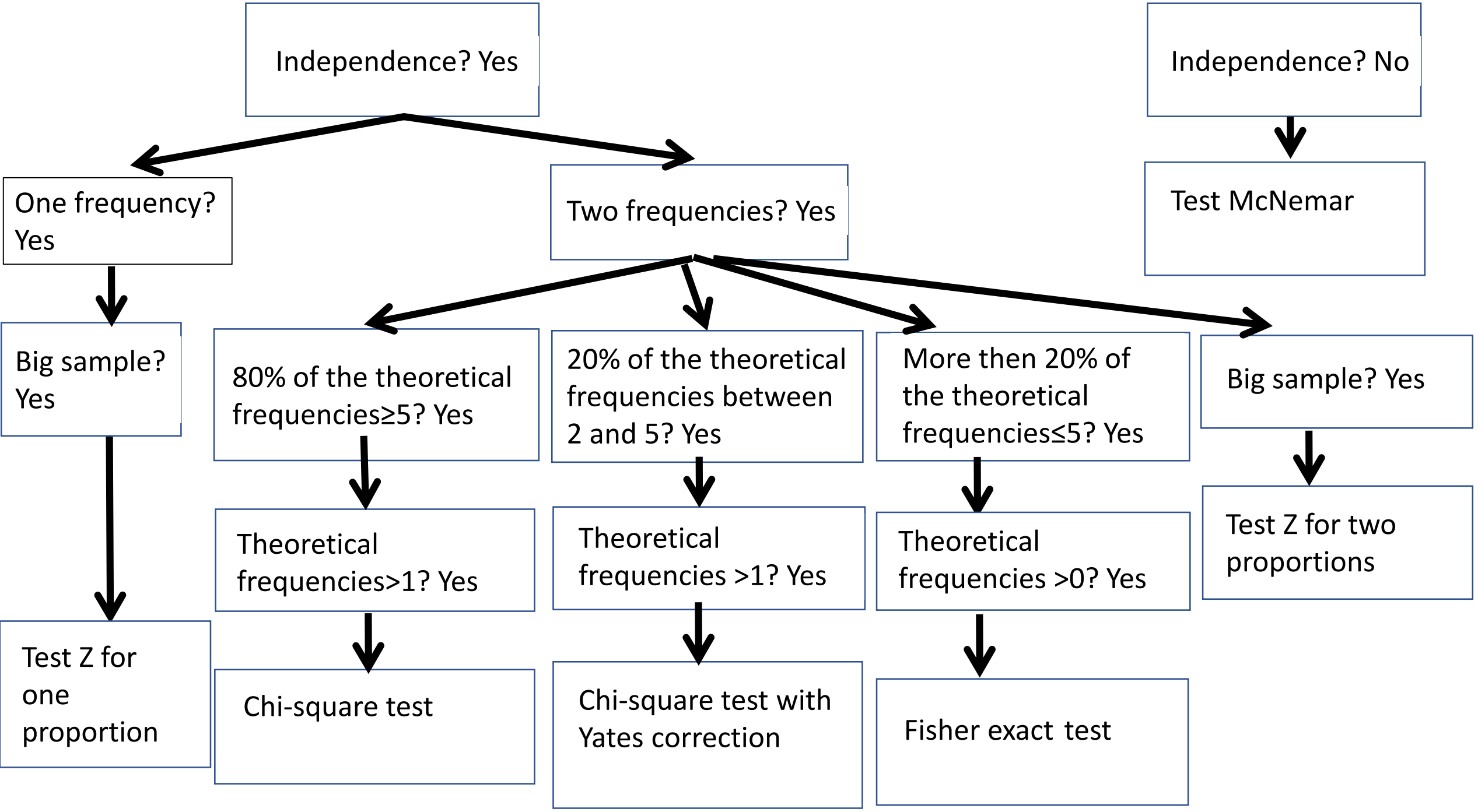
p=0.13>0.05 fail to reject null hypothesis: smoking and dental implant are independent

	+	-	Total
+	a	b	a+b
-	c	d	c+d
Total	a+c	b+d	n



df=(no.of column-1)*(no. of row-1)>1

	C1	C2	C3	...	Total
L1	a	b	c	...	a+b+c+...
L2	d	e	f	...	d+e+f+...
L3	g	h	i	...	g+h+i+...
...	...	...	...	...	...
Total	a+d+g+...	b+e+h+...	c+f+i+...	...	n


Independence? Yes
Independence? No
One frequency? Yes
Two frequencies? Yes
Test McNemar
Big sample? Yes
80% of the theoretical frequencies≥5? Yes
20% of the theoretical frequencies between 2 and 5? Yes
More then 20% of the theoretical frequencies≤5? Yes
Big sample? Yes
Theoretical frequencies>1? Yes
Theoretical frequencies >1? Yes
Theoretical frequencies >0? Yes
Test Z for two proportions
Test Z for one proportion
Chi-square test
Chi-square test with Yates correction
Fisher exact test

Assumptions
- tests for frequencies (proportions)

- two qualitative variables (or quantitative with finite discrete values)
- independent observations in each sample

Chi-square test with Yates correction

- Yates correction involves reducing by 0.5 units the difference between the observed and the theoretic frequencies within the Chi-square parameter before squaring

$$\chi^2 = \sum_{i=1}^{l \cdot c} \frac{(f_i^o - f_i^t - 0.5)^2}{f_i^t}$$

- used when >20% of the theoretical frequencies between 2 and 5
- all theoretical frequencies>1

Fisher exact test

- to test the association between two qualitative variables
- to compare independent groups (2 or >2) concerning another qualitative variable (frequencies)

Assumptions:

- two qualitative variables
- independent observations in each sample
- independent samples

It is used when we cannot use the Chi-square test.

- If at least 20% of the theoretical frequencies are less than 5

Null and alternative hypothesis – the same as for the Chi-square test

- A test that requires a lot of calculations  with computer
- p value as a result

- Null and alternative hypothesis – the same as for the Chi-square test
  - See before!!!
- A test that requires a lot of calculations  with computer

The statistical decision

based on the p-value:

- $p \leq \alpha$ (=0.05) => we reject H0 and we accept H1
  - There is a difference / There is an assosiation – statistically significant
- $p > \alpha$ (=0.05) => we cannot reject H0
  - We can’t say that there is a difference/ We can’t say that there is an association – statistically significant

Mc Nemar test - for frequencies in dependent samples

- Objective: compare two frequencies studied on two dependent/paired samples

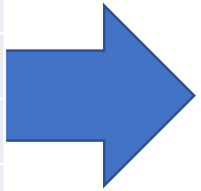
Assumptions:

- independent observations in each sample
- two dichotomous qualitative variables
- dependent/paired samples

Mc Nemar test ex.

- 200 patients suspects for facial nerve paralysis were evaluated by two neurologist to be diagnosticated in two categotries with and without facial nerve paralysis. We want to see if there is an association between the evaluation made by medical doctors

Id patient	Observer 1	Observer 2
1	No	No
2	No	No
3	Yes	Yes
4	No	No
5	Yes	No
6	Yes	Yes
7	No	No
8	Yes	Yes
9	Yes	No
10	No	Yes



	With facial nerve paralysis Observer 1	**Without facial nerve paralysis Observer 1**	**Total**
With facial nerve paralysis Observer 2	157	2	159
Without facial nerve paralysis Observer 2	7	34	41
Total	164	36	200

	+	-	Total
+	a	b	a+b
-	c	d	c+d
Total	a+c	b+d	n=a+b+c+d

Hypotheses:

- **Null hyphotesis H0**: there is **no** association between observer 1 and observer 2 when they make the diagnostic of facial nerve paralysis
- **Alternative hyphotesis H1**: there is an association between observer 1 and observer 2 when they make the diagnostic of facial nerve paralysis

- The McNemar test statistic (with continuity correction) is:
- $\chi^2_{1ddl} = \frac{(|b-c|-0.5)^2}{b+c}$
- follow the Chi-square distribution with 1 degree of freedom if: b + c > 25

3. The significance level α = 0.05

4. The critical values and the critical region:

We find in the table of the distribution of the Chi-square the critical value X, with 1 degree of freedom

$X_{1;\,0.05}$ = 3.84 => Rejection region = [3.84, + ∞)

5. Calculate the value of the test statistic:

$$\chi^2_{1ddl} = \frac{(|b-c|-0.5)^2}{b+c} = \frac{(|2-7|-0.5)^2}{2+7} = \frac{4.5^2}{9} = \frac{20.25}{9} = 2.25$$

	With facial nerve paralysis Observer 1	Without facial nerve paralysis Observer 1	Total
With facial nerve paralysis Observer 2	157	2	159
Without facial nerve paralysis Observer 2	7	34	41
Total	164	36	200

Statistical decision

6. The statistical decision according to the region of rejection:

- If χ^2 belongs to rejection area we can reject H0 and accept H1
- If χ^2 does not belong to rejection area we cannot reject H0

- $\chi^2 = 20.32$ belongs to the region of rejection $[3.84 , + \infty)$,=> we reject H0 with a risk of first type error ≤ 0.05

- The conclusion: we accept H1:
  - there is an association between observer 1 and observer 2 when they make the diagnostic of facial nerve paralysis

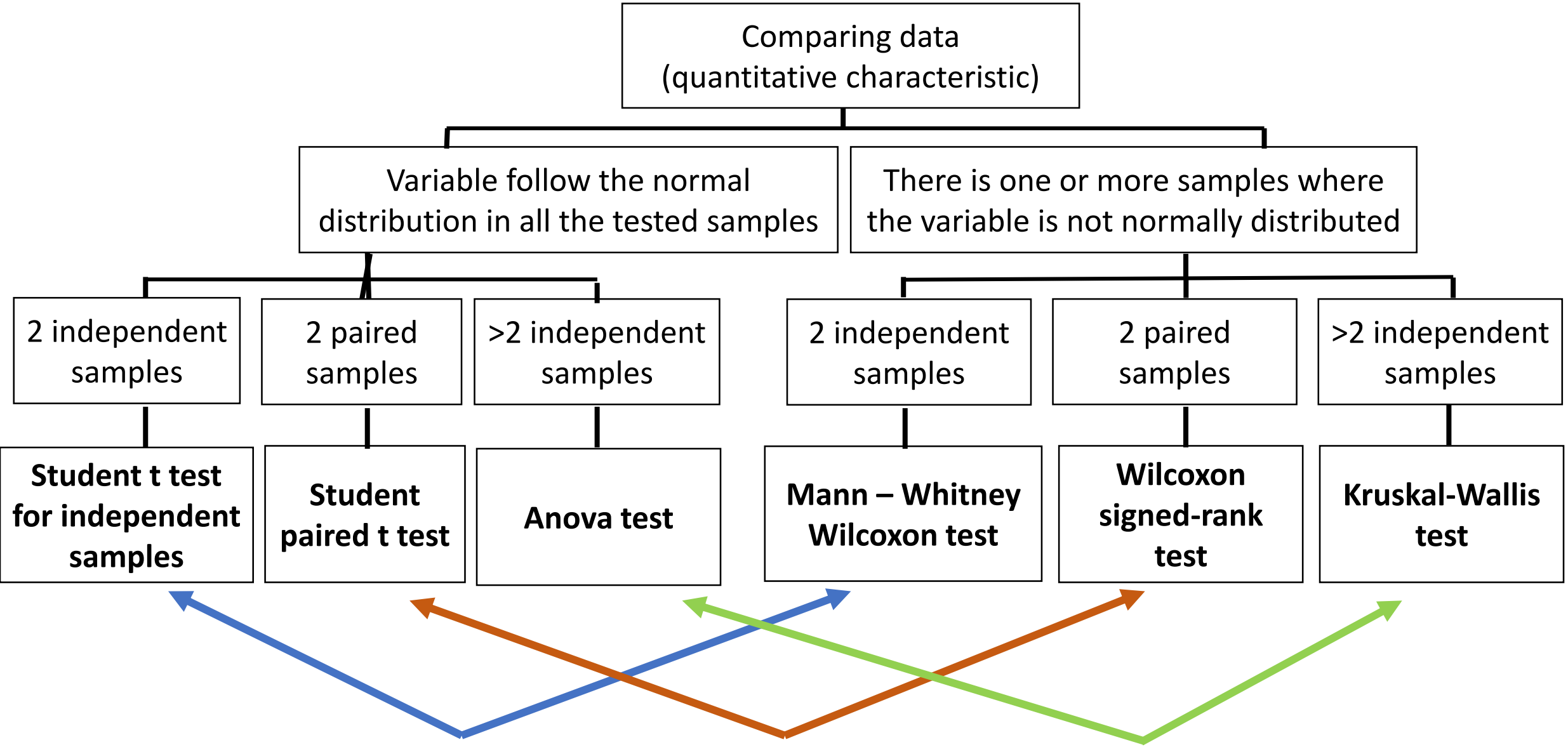
6. The statistical decision according to the p-value:

- If $p \leq \alpha$ (=0.05) => we reject H0 and we accept H1
  - There is a difference/ There is a relationship – statistically significant
- If $p > \alpha$ (=0.05) => we cannot reject H0
  - We cannot say that there is a difference/ We cannot say that there is a relationship – statistically significant
- In the example: $p < 0.001 < 0.05$ we can reject H0
  - with a risk of first type error ≤ 0.05.=> we reject H0.

Conclusion: We accept H1:

- there is an association between observer 1 and observer 2 when they make the diagnostic of facial nerve paralysis

Nonparametric test


Comparing data (quantitative characteristic)
Variable follow the normal distribution in all the tested samples
There is one or more samples where the variable is not normally distributed
2 independent samples
2 paired samples
>2 independent samples
2 independent samples
2 paired samples
>2 independent samples
Student t test for independent samples
Student paired t test
Anova test
Mann – Whitney Wilcoxon test
Wilcoxon signed-rank test
Kruskal-Wallis test

Nonparametric tests

- used as an alternative to parametric tests
  - when the data do not meet the requirements
    - e.g. do not follow the normal distribution
    - e.g. variances are not equal when applying the Anova test
- It is not necessary to use these tests
  - The data can be transformed so that they comply with the conditions
    - do not comply with the normal distribution → we apply logarithm

    → medical data will be presented using the geometric mean

    → disadvantage: Logarithmic data become difficult to interpret
  - e.g. SBP = 140 mmHg becomes logSBP = 4.94
  - the data do not have equal variances → samples with an equal number of patients can be introduced into the study → the condition that the variances are equal is no longer necessary when using the Anova test

Nonparametric tests

ADVANTAGES

- assumptions are more general
- used in comparing ordinal qualitative data
- can be used in case of data with extreme values
- easy to interpret the same as the result of a parametric test

DESADVANTAGES

- are not reliable
  - the same can be said when we compare a study on a small sample study with a study on a large sample

The principle of non-parametric tests

- transforming data into their ranks

The objective of the tests

- to compare the distributions of a quantitative variable that does not meet the requirements of other parametric tests
- to compare the distributions of a qualitative ordinal variable that cannot be tested with other parametric tests
- samples can be:
  - independent
  - dependent
  - one
  - two
  - multiple

Ranks

- rank = the ordinal number of a value after sorting (ordering) the values of a variable
- we will replace the values of the variable with their rank in the order

Why?

- the distribution become
  - symmetric
  - with no extreme values

C reactive protein	
60.40	38.38
56.13	136.77
59.88	46.09
22.06	17.87
26.00	15.44
22.40	17.59
89.31	2.45
121.25	2.24
91.77	2.43
186.57	2.28
124.75	2.10
181.73	2.27

sort

C reactive protein	
2.10	38.38
2.24	46.09
2.27	56.13
2.28	59.88
2.43	60.40
2.45	89.31
15.44	91.77
17.59	121.25
17.87	124.75
22.06	136.77
22.40	181.73
26.00	186.57

rank

Rank CRP	
1	13
2	14
3	15
4	16
5	17
6	18
7	19
8	20
9	21
10	22
11	23
12	24

extreme values of the variable, the assigned ranks do not contain extreme values

CRP	
60.40	38.38
56.13	136.77
59.88	46.09
22.06	17.87
26.00	15.44
22.40	17.59
89.31	2.45
121.25	2.24
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186.57	2.28
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sort

CRP	
2.10	38.38
2.24	46.09
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2.28	59.88
2.43	60.40
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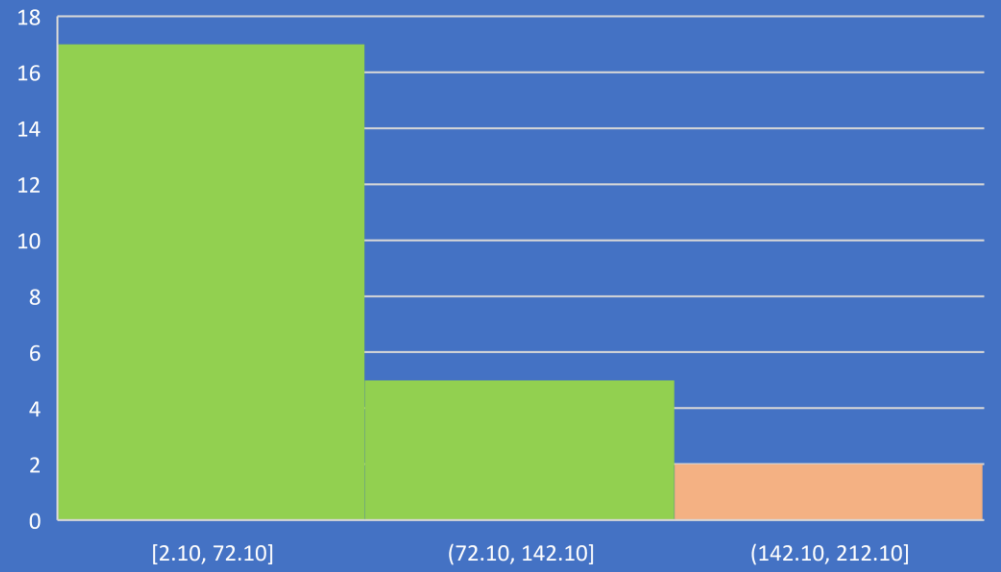
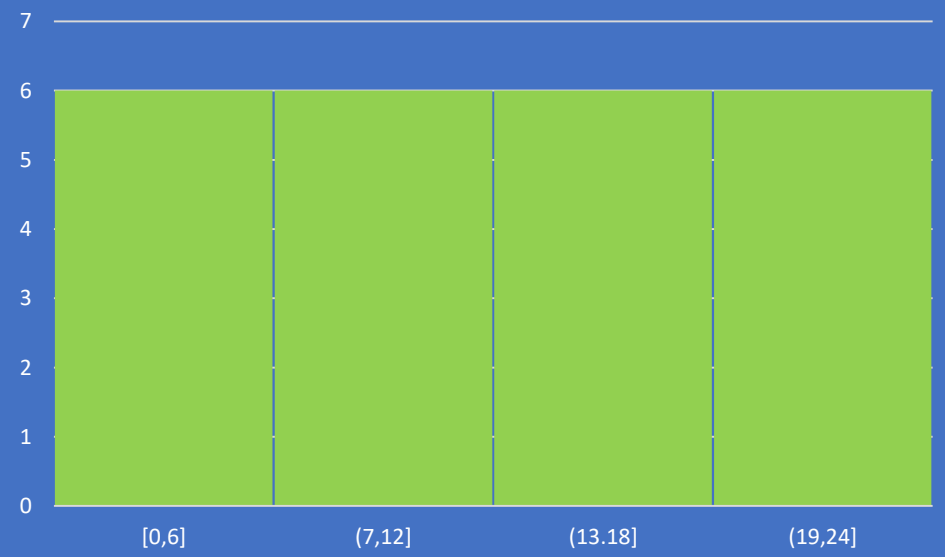
15.44	91.77
17.59	121.25
17.87	124.75
22.06	136.77
22.40	181.73
26.00	186.57

rank

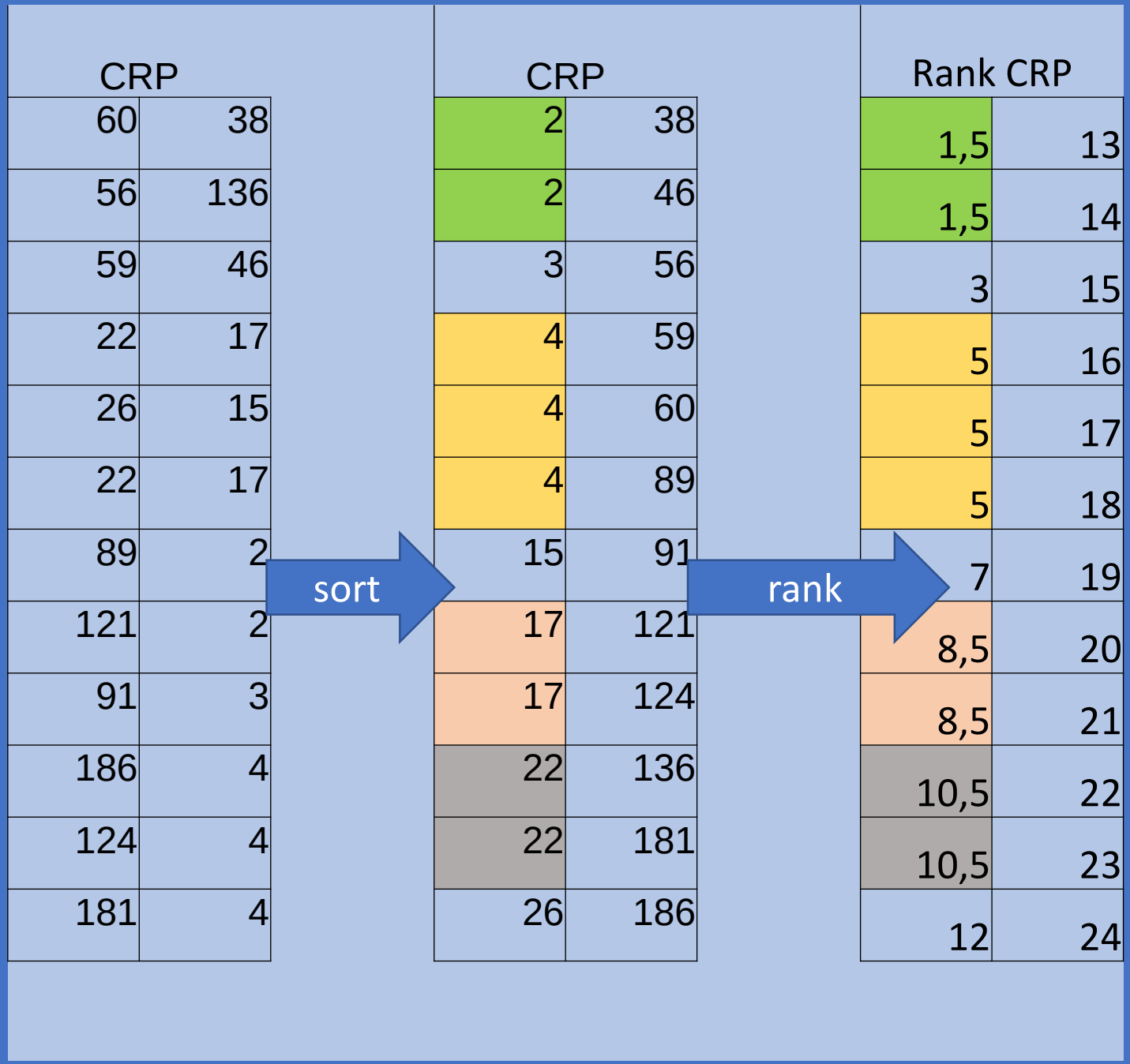
Rank	CRP
1	13
2	14
3	15
4	16
5	17
6	18
7	19
8	20
9	21
10	22
11	23
12	24





Equal numbers?

- for equal numbers
  - assign the same rank
  - average of their ranks
- for the next number we assign a rank by adding to the previous one the number of equal values



Two groups?

- Gr.1 with diabetes
- Gr.2 without diabetes
- ranks are assigned for the combined values of the two groups

Gr.1	Gr.2
6	8
5	13
9	6
2	7
6	5
2	7
8	2
12	2
9	5
8	7
4	3
8	4

sort

Gr.1	Gr.2
2	2
2	2
4	3
5	4
6	5
6	5
8	6
8	7
8	7
9	7
9	8
12	13

rank

Gr.1	Gr.2
2,5	2,5
2,5	2,5
6,5	5
9	6,5
12	9
12	9
18,5	12
18,5	15
18,5	15
21,5	15
21,5	18,5
23	24

How we compare groups?

- by calculating the average/sum of ranks
- for each group

Gr.1	Gr.2
6	8
5	13
9	6
2	7
6	5
2	7
8	2
12	2
9	5
8	7
4	3
8	4
6.58	5.75

sort

Gr.1	Gr.2
2	2
2	2
4	3
5	4
6	5
6	5
8	6
8	7
8	7
9	7
9	8
12	13

rank

Gr.1	Gr.2
2,5	2,5
2,5	2,5
6,5	5
9	6,5
12	9
12	9
18,5	12
18,5	15
18,5	15
21,5	15
21,5	18,5
23	24
14	13

Mann-Whitney U test

Nonparametric equivalent of Student's t-test for independent samples

- Application conditions
  - observations are independent within the sample
  - **counter example.** in the evaluation of rheumatoid arthritis a patient appears in the studied group twice
    - with data coming from the left hand
    - with data coming from the right hand
    - these data are dependent within the sample
  - two independent samples
  - **counter example.** dependent groups: in the evaluation of rheumatoid arthritis the same patients are compared
    - group1: before treatment
    - group2: after treatment
    - these groups are NOT independent, but are paired/dependent
  - variable of interest
    - quantitative
    - **qualitative ordered (ordinal)**
- Commonly used when the data do not have a normal distribution and the samples are small (n<30)

Mann-Whitney U test

Nonparametric equivalent of Student's t-test for **independent samples**
Assumptions

- observations are independent within the sample
- we are comparing two independent samples
- variable of interest
  - quantitative
  - **qualitative ordered (ordinal)**

Commonly used when data do not have a normal distribution

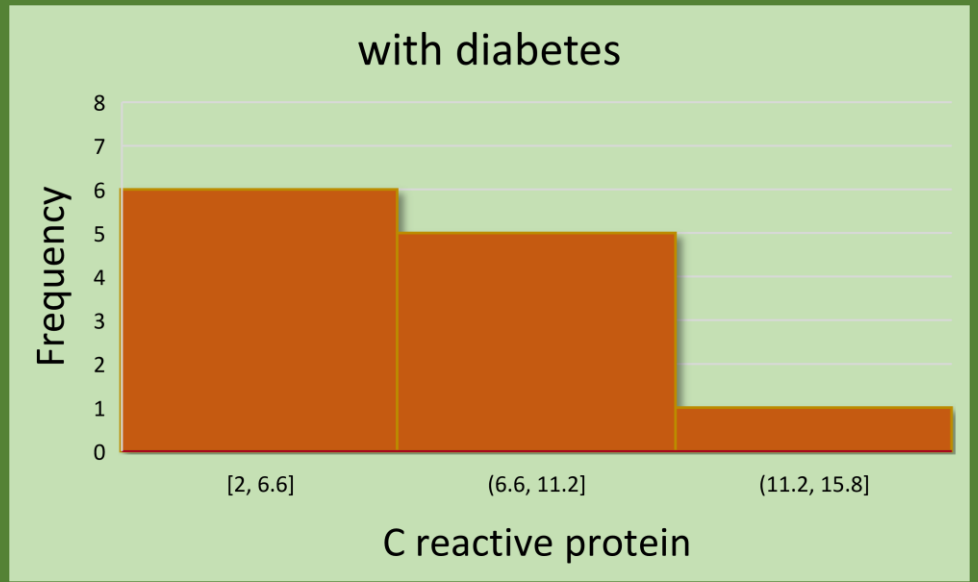
Mann-Whitney U testul

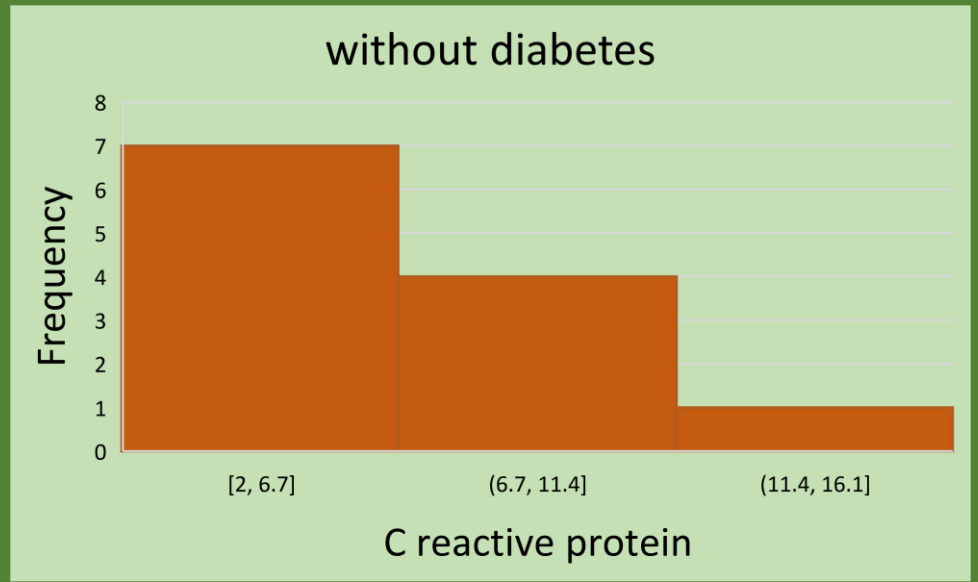
- **Null hypothesis H0**: There is no significant difference between the distributions of scores or ranks of the variable of interest in the two populations
- **Alternative hypothesis H1**: There is a significant difference between the distributions of scores or ranks of the variable of interest in the two populations
- H1 could be formulated:
  - there is a difference between the **mean** of the ranks associated with the values of the variable of interest in the two populations
  - there is a significant difference between the **medians** of the ranks associated with the values of the variable of interest in the two populations

Example

Objective

- C-reactive protein differs statistically significantly between patients with and without diabetes
- 12 patients were included in the study in each group
- Gr.1 with diabetes
- Gr.2 without diabetes
- Data are not normally distributed





Formulating hypotheses

- **Null hypothesis H0**: There is no significant difference between the rank distributions of CRP in those with and without diabetes
- **Alternative hypothesis H1**: There is a significant difference between the rank distributions of CRP in those with and without diabetes

Gr.1	Gr.2
6	8
5	13
9	6
2	7
6	5
2	7
8	2
12	2
9	5
8	7
4	3
8	4
6.58	5.75

sort

Gr.1	Gr.2
2	2
2	2
4	3
5	4
6	5
6	5
8	6
8	7
8	7
9	7
9	8
12	13

rank

Gr.1	Gr.2
2,5	2,5
2,5	2,5
6,5	5
9	6,5
12	9
12	9
18,5	12
18,5	15
18,5	15
21,5	15
21,5	18,5
23	24
14	13

Establishing the confidence level
We find the region of acceptance of the H_0

Determine the critical value U_α

- Small samples (n1, n2 ≤ 15) ⇒ search the Mann-Whitney table for the critical value Uα
  - Acceptance region of H0 = [Uα, +∞)
- Large samples (n1, n2 > 15) ⇒ the test statistic U follows a normal distribution N(μ, σ^2),

  where the mean $\mu = \frac{n_1 n_2}{2}$ and the variance $\sigma^2 = \frac{n_1 n_2 (n_1+n_2+1)}{12}$
- if we center and reduce we arrive at a standardized distribution N(0, 1) using $Z=\frac{U-\mu}{\sigma}$⇨
  - Acceptance region of H0 = [– Z_α, Z_α], where Z_α = critical value in the table of the standardized normal law N (0,1)

- We take the confidence level α=0.05

Establishing the confidence level
Finding the region of acceptance of H_0

Determine the critical value Uα

- Small samples (n_1, $n_2 \leq 15$) ⇒ search the Mann-Whitney table for the critical value U_α
  - Acceptance region of $H_0 = [U_\alpha, +\infty)$
- Large samples (n_1, $n_2 > 15$) ⇒
  - Acceptance region of $H_0 = [-Z_\alpha, Z_\alpha]$, where Z_α = critical value in the table of the standardized normal law N (0,1)

- We take the confidence level α=0.05
- In our case $n_1 = 12$, $n_2 = 12$ the samples are small we look for the critical value $U_{0.05}$=37 in the Mann-Whitney table

Alpha = .05 (two-tailed)

n1\n2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2							0	0	0	0	1	1	1	1	1	2	2	2	2
3				0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
4			0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14
5		0	1	2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
6		1	2	3	5	6	8	10	11	13	14	16	17	19	21	22	24	25	27
7		1	3	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
8	0	2	4	6	8	10	13	15	17	19	22	24	26	29	31	34	36	38	41
9	0	2	4	7	10	12	15	17	20	23	26	28	31	34	37	39	42	45	48
10	0	3	5	8	11	14	17	20	23	26	29	33	36	39	42	45	48	52	55
11	0	3	6	9	13	16	19	23	26	30	33	37	40	44	47	51	55	58	62
12	1	4	7	11	14	18	22	26	29	33	37	41	45	49	53	57	61	65	69
13	1	4	8	12	16	20	24	28	33	37	41	45	50	54	59	63	67	72	76
14	1	5	9	13	17	22	26	31	36	40	45	50	55	59	64	69	74	78	83
15	1	5	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80	85	90
16	1	6	11	15	21	26	31	37	42	47	53	59	64	70	75	81	86	92	98
17	2	6	11	17	22	28	34	39	45	51	57	63	69	75	81	87	93	99	105
18	2	7	12	18	24	30	36	42	48	55	61	67	74	80	86	93	99	106	112
19	2	7	13	19	25	32	38	45	52	58	65	72	78	85	92	99	106	113	119
20	2	8	14	20	27	34	41	48	55	62	69	76	83	90	98	105	112	119	127

Establishing the confidence level
Find

Determine

- Small sa
  the Ma
  critical v
  - Acc
- Large sa
  - Acc
    wh
    the

critical value

Alpha = .05 (two-tailed)

n1\n2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2							0	0	0	0	1	1	1	1	1	2	2	2	2
3				0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
4			0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14
5		0	1	2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
6		1	2	3	5	6	8	10	11	13	14	16	17	19	21	22	24	25	27
7		1	3	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
8	0	2	4	6	8	10	13	15	17	19	22	24	26	29	31	34	36	38	41
9	0	2	4	7	10	12	15	17	20	23	26	28	31	34	37	39	42	45	48
10	0	3	5	8	11	14	17	20	23	26	29	33	36	39	42	45	48	52	55
11	0	3	6	9	13	16	19	23	26	30	33	37	40	44	47	51	55	58	62
12	1	4	7	11	14	18	22	26	29	33	37	41	45	49	53	57	61	65	69
13	1	4	8	12	16	20	24	28	33	37	41	45	50	54	59	63	67	72	76
14	1	5	9	13	17	22	26	31	36	40	45	50	55	59	64	69	74	78	83
15	1	5	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80	85	90
16	1	6	11	15	21	26	31	37	42	47	53	59	64	70	75	81	86	92	98
17	2	6	11	17	22	28	34	39	45	51	57	63	69	75	81	87	93	99	105
18	2	7	12	18	24	30	36	42	48	55	61	67	74	80	86	93	99	106	112
19	2	7	13	19	25	32	38	45	52	58	65	72	78	85	92	99	106	113	119
20	2	8	14	20	27	34	41	48	55	62	69	76	83	90	98	105	112	119	127

Establishing the confidence level
Finding the region of acceptance of H_0

Determine the critical value Uα

- Small samples (n_1, $n_2 \leq 15$) ⇒ search the Mann-Whitney table for the critical value U_α
  - Acceptance region of $H_0 = [U_\alpha, +\infty)$
- Large samples (n_1, $n_2 > 15$) ⇒
  - Acceptance region of $H_0 = [-Z_\alpha, Z_\alpha]$, where Z_α = critical value in the table of the standardized normal law N (0,1)

- We take the confidence level $\alpha=0.05$
- In our case $n_1 = 12$, $n_2 = 12$ the samples are small we look for the critical value $U_{0.05}=37$ in the Mann-Whitney table
- The acceptance region of $H_0 = [37, +\infty)$

Alpha = .05 (two-tailed)

n1\n2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2							0	0	0	0	1	1	1	1	1	2	2	2	2
3				0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
4			0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14
5		0	1	2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
6		1	2	3	5	6	8	10	11	13	14	16	17	19	21	22	24	25	27
7		1	3	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
8	0	2	4	6	8	10	13	15	17	19	22	24	26	29	31	34	36	38	41
9	0	2	4	7	10	12	15	17	20	23	26	28	31	34	37	39	42	45	48
10	0	3	5	8	11	14	17	20	23	26	29	33	36	39	42	45	48	52	55
11	0	3	6	9	13	16	19	23	26	30	33	37	40	44	47	51	55	58	62
12	1	4	7	11	14	18	22	26	29	33	37	41	45	49	53	57	61	65	69
13	1	4	8	12	16	20	24	28	33	37	41	45	50	54	59	63	67	72	76
14	1	5	9	13	17	22	26	31	36	40	45	50	55	59	64	69	74	78	83
15	1	5	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80	85	90
16	1	6	11	15	21	26	31	37	42	47	53	59	64	70	75	81	86	92	98
17	2	6	11	17	22	28	34	39	45	51	57	63	69	75	81	87	93	99	105
18	2	7	12	18	24	30	36	42	48	55	61	67	74	80	86	93	99	106	112
19	2	7	13	19	25	32	38	45	52	58	65	72	78	85	92	99	106	113	119
20	2	8	14	20	27	34	41	48	55	62	69	76	83	90	98	105	112	119	127

Calculating the U-test parameter

Calculating U as a function of n_1, n_2 and n_i, where i = 1 or 2

Sum of ranks = SR

$$U_1 = n_1 n_2 + n_1 \frac{n_1+1}{2} - SR_1$$

$$U_2 = n_1 n_2 + n_2 \frac{n_2+1}{2} - SR_2$$

Test parameter U = min (U_1, U_2)

$n_1 = 12, n_2 = 12$

Calcularea parametrului testului U

Calculating U as a function of n_1, n_2 and n_i, where i = 1 or 2

Sum of ranks = SR

$$U_1 = n_1 n_2 + n_1 \frac{n_1+1}{2} - SR_1$$

$$U_2 = n_1 n_2 + n_2 \frac{n_2+1}{2} - SR_2$$

Test parameter U = min (U_1, U_2)

$n_1 = 12, n_2 = 12$

$SR_1 = 56$, $SR_2 = 104$

$U_1 = 12 \cdot 12 + 12 \frac{12+1}{2} - 56 = 166$

$U_2 = 12 \cdot 12 + 12 \frac{12+1}{2} - 104 = 118$

U = min (166, 118) = 118

U = 118

Statistical decision

Small samples (n_1, $n_2 \leq 15$)

$U \geq U_\alpha$ → we cannot reject H0

$U < U_\alpha$ → we reject H0, we accept H_1

Large samples (n_1, $n_2 > 15$)

$|Z| \leq Z_\alpha$ → we cannot reject H0

$|Z| > Z_\alpha$ → we reject H0, we accept H1

Decision based on probability p

$p \geq \alpha$ → we cannot reject H0

$p < \alpha$ → we reject H0, we accept H1

U = 118

Statistical decision

Small samples (n_1, $n_2 \leq 15$)

$U \geq U_\alpha$ → we cannot reject H0

$U < U_\alpha$ → we reject H0, we accept H_1

Large samples (n_1, $n_2 > 15$)

$|Z| \leq Z_\alpha$ → we cannot reject H0

$|Z| > Z_\alpha$ → we reject H0, we accept H1

Decision based on probability p

$p \geq \alpha$ → we cannot reject H0

$p < \alpha$ → we reject H0, we accept H1

Decision based on U

U = 118

U = 118 ≥ 37 → we cannot reject H_0: There is no statistically significant difference between CRP values in those with and without diabetes

Decision based on probability p

p = 0.378

p = 0.378 ≥ 0.05 → we cannot reject H_0: There is no statistically significant difference between CRP values in those with and without diabetes

Statistical decision

Decision based on probability p

p = 0.378

p = 0.378 ≥ 0.05 → we cannot reject H_0: There is no statistically significant difference between the rank distributions of CRP values in those with and without diabetes

Significant differences between ranks

= one of the samples is characterized by higher values of the tested characteristic, compared to the values of the other group.

it can be concluded that there are differences in the tested characteristic between the two samples.

there are no significant differences between ranks

= the values between the two samples are mixed approximately evenly

it can be concluded that there are no differences in the tested characteristic between the two samples.

Wilcoxon test

Nonparametric equivalent of Student's t-test for **dependent samples** (pairs)

Assumptions

- observations are independent within the sample
- we are comparing two dependent samples
- variable of interest
  - quantitative
  - **qualitative ordered (ordinal)**

Commonly used when data do not have a normal distribution

Wilcoxon test

- **Null hypothesis H0**: There is **no** significant difference between the distributions of scores or ranks of the variable of interest (or between the differences between paired data and zero)
- **Alternative hypothesis H1**: There is significant difference between the distributions of scores or ranks of the variable of interest (or between the differences between paired data and zero)

Example

Objective

Treatment with Glubifer (Iron +vitamins) statistically significantly improves Sideremia (Iron) values in patients with anemia

13 patients with anemia were included in the study. They were treated with Glubifer for 3 months. Sideremia was tested before (M1) and after the 3 months of treatment (M2)

Data are not normally distributed

Id patient	M1	M2	Difference d_i	Sign d_i	Rank $\lvert d_i \rvert$
1	55	75	20	+	3
2	40	55	15	+	1
3	25	65	40	+	9
4	33	12	-21	-	4
5	44	44	0		
6	45	61	16	+	2
7	30	67	37	+	8
8	27	70	43	+	10
9	35	80	45	+	11
10	32	66	34	+	5
11	50	86	36	+	7
12	49	14	-35	-	6
13	45	95	50	+	12

differences equal to 0 are ignored

Formulating hypotheses

- **Null hypothesis H0:** There is **no** significant difference between the rank distributions of Sideremia in those with anemia before and after treatment with Glubifer
- **Alternative hypothesis H1**: There is a significant difference between the rank distributions of Sideremia in those with anemia before and after treatment with Glubifer

Id patient	M1	M2	Difference d_i	Sign d_i	Rank $\lvert d_i \rvert$
1	55	75	20	+	3
2	40	55	15	+	1
3	25	65	40	+	9
4	33	12	-21	-	4
5	44	44	0		
6	45	61	16	+	2
7	30	67	37	+	8
8	27	70	43	+	10
9	35	80	45	+	11
10	32	66	34	+	5
11	50	86	36	+	7
12	49	14	-35	-	6
13	45	95	50	+	12

Establishing the confidence level
We find the region of acceptance of the null hypothesis

We determine the critical value Wα

Small samples (n ≤ 15) ⇒ we search the Wilcoxon table for the critical value W_α

- Acceptance region of H_0 = [W_α, $\frac{n(n+1)}{2} - W_\alpha$]

Large samples (n > 15) ⇒ test parameter

$$Z = \frac{T_+ - \frac{n(n+1)}{4}}{\sqrt{\frac{n(n+1)(2n+1)}{24}}}$$

Z follows a standardized normal distribution N(0, 1)

⇨ Acceptance region of H0 = [$-Z_\alpha$, Z_α],

where Z_α = critical value in the table of the standardized normal law N (0,1)

- We take the confidence level α=0.05

Establishing the confidence level
We find the region of acceptance of the null hypothesis

n	Two-Tailed Test		One-Tailed Test	
	α = .05	α = .01	α = .05	α = .01
5	--	--	0	--
6	0	--	2	--
7	2	--	3	0
8	3	0	5	1
9	5	1	8	3
10	8	3	10	5
11	10	5	13	7
12	13	7	17	9
13	17	9	21	12
14	21	12	25	15
15	25	15	30	19
16	29	19	35	23
17	34	23	41	27
18	40	27	47	32
19	46	32	53	37
20	52	37	60	43
21	58	42	67	49
22	65	48	75	55
23	73	54	83	62
24	81	61	91	69
25	89	68	100	76
26	98	75	110	84
27	107	83	119	92
28	116	91	130	101
29	126	100	140	110
30	137	109	151	120

- We take the confidence level $\alpha=0.05$
- In our case n = 13 is a small sample
- we search in the Wilcoxon distribution table
  - critical value $W_{0.05}=17$

- Acceptance area $H_0 = [17, \frac{13(13+1)}{2} - 17] = [17, 74]$

Calculating the test parameter W

Negative rank sum W-

Positive rank sum W+

Parameter of the test W = min (W-, W+)

$n = 13$

W- = 4+6 = 10

W+ = 3+1+9+2+8+10+

11+5+7+12 = 68

W = min (10, 68) = 10

p = 0.028

Sign d_i	Rank $\lvert d_i \rvert$
+	3
+	1
+	9
-	4
+	2
+	8
+	10
+	11
+	5
+	7
-	6
+	12

Statistical decision

Small sample ($n \leq 15$)

$W \in [W_\alpha, \frac{n(n+1)}{2} - W_\alpha]$ → we fail to reject H_0

$W \notin [W_\alpha, \frac{n(n+1)}{2} - W_\alpha]$ → reject H0, accept H_1

Large sample ($n > 15$)

$|Z| \leq Z_\alpha$ → we fail to reject H_0

$|Z| > Z_\alpha$ → reject H0, accept H_1

$W = 16$

- Decision based on probability p
- $p \geq \alpha$ → we cannot reject H0
- $p < \alpha$ → we reject H0, we accept H1

Statistical decision

Small sample (n ≤ 15)

W ∈ [W_α, $\frac{n(n+1)}{2} - W_\alpha$] → we fail to reject H_0

W ∉ [W_α, $\frac{n(n+1)}{2} - W_\alpha$] → reject H0, accept

Large sample (n > 15)

$|Z| \leq Z_\alpha$ → we fail to reject H_0

$|Z| > Z_\alpha$ → reject H0, accept H_1

- Decision based on probability p
- p ≥ α → we cannot reject H0
- p < α → we reject H0, we accept H1

Decision based on W

W = 10

W = 10 ∉ [17, 74] → we reject H0, we accept H1: There is a significant difference between the rank distributions of Sideremia in those with anemia before and after treatment with Glubifer

Decision based on the probability p

p = 0.028

p = 0.028 < 0.05 → we reject H0, we accept H1: There is a significant difference between the rank distributions of Sideremia in those with anemia before and after treatment with Glubifer

Decizia statistică

- Decision based on probability p
- $p \geq \alpha \rightarrow$ we cannot reject H0
- $p < \alpha \rightarrow$ we reject H0, we accept H1

Decision based on the probability p

$p = 0.028$

$p = 0.028 < 0.05 \rightarrow$ we reject H0, we accept H1: There is a significant difference between the rank distributions of Sideremia in those with anemia before and after treatment with Glubifer

Kruskal-Wallis Test

The nonparametric equivalent of the Anova test for testing multiple means on independent samples

Assumptions

- observations are independent within the sample
- we are comparing more than two independent samples
- variable of interest
  - quantitative
  - qualitative ordered (ordinal)

Commonly used when data do not have equal variances

Kruskal-Wallis Test

- **Null hypothesis H0**: There is no significant difference between the distributions of scores or ranks of the variable of interest
- **Alternative hypothesis H1**: There is a significant difference between the distributions of scores or ranks of the variable of interest

Example

- Objective
- The depression score differs statistically significantly between the various age categories: 18-35 years, 36 – 65 years and 66 – 95 years

- 3 samples of 12,10, respectively 13 patients were included in the study
- Gr.1 n_1 = 12 aged between 18 - 35 years
- Gr.2 n_2 = 10 aged between 36 - 65 years
- Gr.3 n_3 = 13 aged between 66 - 95 years

- The data belong to an ordinal qualitative variable

Statistical test steps

- **Null hypothesis H0:** There is no significant difference between the distributions of depression scores in the three age groups
- **Alternative hypothesis H1:** There is a significant difference between the distributions of depression scores in the three age groups
- we take the confidence level $\alpha=0.05$

- Calculating the probability p

Decision based on the probability p

$p \geq \alpha \rightarrow$ we cannot reject H0

$p < \alpha \rightarrow$ we reject H0, we accept H_1

Friedman Test

The nonparametric equivalent of the Anova test for repeated measures

Application conditions

- observations are independent within the sample
- we compare more than two dependent samples
- variable of interest
  - quantitative
  - qualitative ordered (ordinal)

Friedman Test

- **Null hypothesis H0**: There is no significant difference between the distributions of scores or ranks of the variable of interest between the tested moments
- **Alternative hypothesis H1**: There is a significant difference between the distributions of scores or ranks of the variable of interest between the tested moments

Example

Objective

Depression score differs statistically significantly between testings

- 15 patients with depression were included in the study

Patients were treated with fluoxetine for 6 months

Patients were tested at baseline, one month and at 6 months

Data belong to an ordinal qualitative variable

Statistical test steps

- **Null hypothesis H0:** There is no significant difference between the distributions of depression scores in the three tests
- **Alternative hypothesis H1:** There is a significant difference between the distributions of depression scores in the three tests
- we choose the confidence level $\alpha=0.05$

Calculating the probability p

Decision based on the probability p

$p \geq \alpha \rightarrow$ we cannot reject H0

$p < \alpha \rightarrow$ we reject H0, we accept H1

Resourses

- Cannot be performed in Excel
- All these non-parametric tests can be performed in Jamovi, R, SPSS

Randomized Controlled Trial > Am J Phys Med Rehabil. 2022 Feb 1;101(2):113-118.
doi: 10.1097/PHM.0000000000001740.

Influencing Medical Students' Knowledge and Attitudes Related to Disability: A Randomized Controlled Trial

Khader A Almhdawi [1]

Affiliations + expand

PMID: 33657029 DOI: 10.1097/PHM.0000000000001740

Abstract

Purposes: The aims of the study were to evaluate and to compare the efficacy of an online and a traditionally delivered undergraduate elective course in improving medical students' disability-related knowledge and attitudes.

Methods: A randomized controlled design was implemented. Participants were medical students randomly assigned into summer 8-wk disability and the society (OT100) online course, OT100 traditional course, or wellness and lifestyles (PT100) control. Demographics were collected in addition to participants' level disability knowledge and attitudes toward people with disability scale scores (1 wk before the semester and 1 wk after it). Multivariate analysis of covariance using general linear model was conducted to evaluate groups' differences in main outcome measures.

Results: In total, 198 undergraduate medical students successfully completed the study conditions: OT100 online (n = 74), OT100 traditional (n = 59), and PT100 (n = 65). OT100 groups (traditional and online) change scores were statistical similar for disability knowledge (P = 0.966) and attitudes (P = 0.705) but significantly better (P < 0.001) than the control group.

Conclusions: OT100 course delivered traditionally or online seemed effective in improving medical students' disability knowledge and attitudes toward people with disability. More studies are needed to create effective methods improving healthcare professionals' disability-related knowledge and attitudes.

- online courses
- traditional courses
- control group without courses

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Conclusions: OT100 course delivered traditionally or online seemed effective in improving medical students' disability knowledge and attitudes toward people with disability. More studies are needed to create effective methods improving healthcare professionals' disability-related knowledge and attitudes.

- p=0.966 – no difference at the population level between traditional and online courses
- p<0.001 – there was difference at the population level between the control group and the other groups

Randomized Controlled Trial > BMC Med Educ. 2018 Mar 20;18(1):41.
doi: 10.1186/s12909-018-1151-0.

Evaluation of the utility of teaching joint relocations using cadaveric specimens

John Au [1], Edward Palmer [2], Ian Johnson [3], Mellick Chehade [4]

Affiliations + expand

PMID: 29554966 PMCID: PMC5859743 DOI: 10.1186/s12909-018-1151-0

Abstract

Background: Like other procedural skills, the ability to relocate a joint is an important aspect of junior doctor education. Changes in the approach to teaching and learning from the traditional apprenticeship-style model have made the teaching of practical skills more difficult logistically. Workshops utilising cadaveric specimens offer a solution to this problem.

Methods: One hundred forty-six fourth year medical students were randomly divided into 5 groups. Each group received a different teaching intervention based on ankle, patella and hip relocation. The interventions consisted of online learning modules, instructional cards and workshops using skeleton models and cadaveric dislocation models. Following the intervention students were given a test containing multiple choice and true/false style questions. A 13-item 5-point Likert scale questionnaire was also delivered before and after the intervention. The data was analysed using one-way analysis of variance (ANOVA) and the Bonferroni post-hoc test.

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one-, two- or all three- joints, nor any significant difference between all the cadaveric dislocation groups and the group receiving instruction on the skeleton model.

Conclusion: The results of the present study suggest that workshops utilising cadaveric dislocation models are effective in teaching joint relocation. In addition, the finding that lower fidelity models may be of equal utility may provide institutions with flexibility of delivery needed to meet financial and resource constraints.

- 146 students divided in 5 groups
- instructions
  - on skeleton models
  - on cadaveric specimens

Randomized Controlled Trial > BMC Med Educ. 2018 Mar 20;18(1):41.
doi: 10.1186/s12909-018-1151-0.

Results: Compared to the instructional cards group, the other 4 groups showed a 10.8-19.2% improvement in total test score ($p < 0.01$) and an 18.4-25.3% improvement in self-reported understanding and confidence in performing joint relocations ($P < 0.01$). There was no significant difference in total test scores between groups exposed to cadaveric instruction on the relocation of one-, two- or all three- joints, nor any significant difference between all the cadaveric dislocation groups and the group receiving instruction on the skeleton model.

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Conclusion: The results of the present study suggest that workshops utilising cadaveric dislocation models are effective in teaching joint relocation. In addition, the finding that lower fidelity models may be of equal utility may provide institutions with flexibility of delivery needed to meet financial and resource constraints.

- compare to skeleton models, those who learnt on the cadaveric specimens show an improvement in total test score and also on self reported confidence.

Thank you!