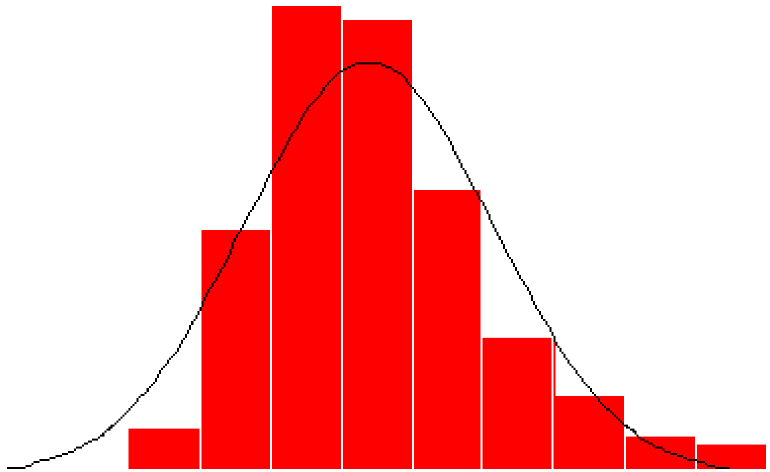
Biostatistics

Author: **Krisztina Boda** PhD

University of Szeged
Department of Medical Physics and Informatics

www.model.u-szeged.hu
www.szote.u-szeged.hu/dmi

Hypothesis tests I.
One-sample t-test, paired t-test



Motivating example

- Two lecturers argue about the mean age of the first year medical students.
  - Lecturer#1 claims that the mean age of the first year medical students is 20.
  - Lecturer#2 does not agree.
  - Who is right?
- Statistically speaking: the population is the set of ALL first year medical students (anywhere, any time).
- Lecturer#1 claims that the population mean $\mu=20$.
- Lecturer#2 claims that the population mean $\mu \neq 20$

How to find the answer

- To be sure, we have two know the age of the TOTAL population (impossible)
- To be confident, we draw a sample from the population (i.e., get the age of some first year medical students). n=137
- Calculate mean age of the sample $\bar{x} = 20.87$
- If the sample is representative, we believe that the sample mean approximates the population mean $\bar{x} \sim \mu$
- To be 95% confident, calculate the 95% confidence interval for the population mean (20.35-21.39)
- With 95% probability, the true population mean (i.e. the mean age of the first year medical students) lies somewhere between 20.35 and 21.39.

Review: interval estimate, confidence interval (CI)

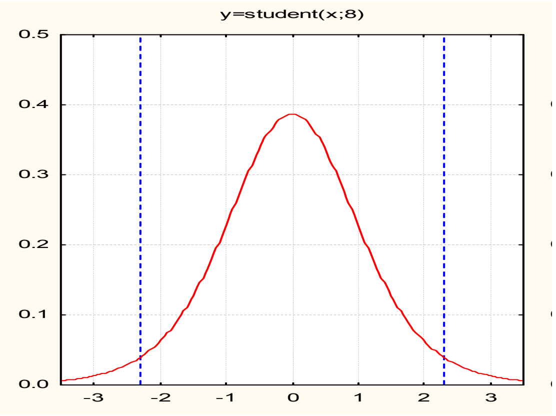
- **Confidence interval: an interval which contains the value of the (unknown) population parameter with high probability.**
- The probability assigned is the confidence level (generally: 0.90, 0.95, 0.99)
- Most often used confidence level: 0.95 (95%)

- Level of „mistake” or „error”: α=1-0.95=0.05 (5%)

Formula of the confidence interval for the normal population's mean μ when σ is unknown

$$\left(\bar{x} - t_{\alpha/2}\frac{SD}{\sqrt{n}},\quad \bar{x} + t_{\alpha/2}\frac{SD}{\sqrt{n}}\right)$$

- n=$t_{\alpha/2}$ is the two-tailed α critical value of the Student's t statistic with *n*-1 degrees of freedom



	Two-sided alfa			
df	**0.1**	**0.05**	**0.02**	**0.01**
1	6.314	12.706	31.821	63.657
2	2.920	4.303	6.965	9.925
3	2.353	3.182	4.541	5.841
4	2.132	2.776	3.747	4.604
5	2.015	2.571	3.365	4.032
6	1.943	2.447	3.143	3.707
7	1.895	2.365	2.998	3.499
8	1.860	2.306	2.896	3.355
9	1.833	2.262	2.821	3.250
10	1.812	2.228	2.764	3.169
11	1.796	2.201	2.718	3.106
12	1.782	2.179	2.681	3.055
13	1.771	2.160	2.650	3.012
14	1.761	2.145	2.624	2.977
15	1.753	2.131	2.602	2.947
16	1.746	2.120	2.583	2.921
17	1.740	2.110	2.567	2.898
18	1.734	2.101	2.552	2.878
19	1.729	2.093	2.539	2.861
20	1.725	2.086	2.528	2.845
21	1.721	2.080	2.518	2.831
22	1.717	2.074	2.508	2.819
23	1.714	2.069	2.500	2.807
24	1.711	2.064	2.492	2.797
25	1.708	2.060	2.485	2.787
26	1.706	2.056	2.479	2.779
27	1.703	2.052	2.473	2.771
28	1.701	2.048	2.467	2.763
29	1.699	2.045	2.462	2.756
30	1.697	2.042	2.457	2.750
∞	1.645	1.960	2.326	2.576

Calculation of the confidence interval for the population's mean *μ* for the example

- Let the sample be the data of the questionnaire filled in by students at the first lecture.
- We calculated the sample characteristics
  - n=137
  - Sample mean=20.87
  - Sample SD=3.071

Calculation of the confidence interval for the population's mean μ for the example

$$\left(\bar{x} - t_{\alpha/2}\frac{SD}{\sqrt{n}},\quad \bar{x} + t_{\alpha/2}\frac{SD}{\sqrt{n}}\right)$$

- n=137
- df=136 (degrees of freedom
- sample mean $\bar{x} = 20.87$
- SD=3.071
- $t_{\alpha/2}$ = 1.977 (from the table)

$$t_{\alpha/2}\cdot\frac{SD}{\sqrt{n}} = 1.977\cdot\frac{3.071}{\sqrt{137}} = 1.977\cdot 0.262 = 0.518$$

- Lower limit: 20.87-0.518=20.352
- Upper limit: 20.87+0.518=21.388
- 95%CI: (20.35-21.39)

	Two-sided alfa			
df	**0.1**	**0.05**	**0.02**	**0.01**
1	6.314	12.706	31.821	63.657
2	2.920	4.303	6.965	9.925
3	2.353	3.182	4.541	5.841
4	2.132	2.776	3.747	4.604
5	2.015	2.571	3.365	4.032
6	1.943	2.447	3.143	3.707
7	1.895	2.365	2.998	3.499
8	1.860	2.306	2.896	3.355
9	1.833	2.262	2.821	3.250
10	1.812	2.228	2.764	3.169
11	1.796	2.201	2.718	3.106
12	1.782	2.179	2.681	3.055
13	1.771	2.160	2.650	3.012
14	1.761	2.145	2.624	2.977
15	1.753	2.131	2.602	2.947
16	1.746	2.120	2.583	2.921
17	1.740	2.110	2.567	2.898
18	1.734	2.101	2.552	2.878
19	1.729	2.093	2.539	2.861
20	1.725	2.086	2.528	2.845
21	1.721	2.080	2.518	2.831
22	1.717	2.074	2.508	2.819
23	1.714	2.069	2.500	2.807
24	1.711	2.064	2.492	2.797
25	1.708	2.060	2.485	2.787
26	1.706	2.056	2.479	2.779
27	1.703	2.052	2.473	2.771
28	1.701	2.048	2.467	2.763
29	1.699	2.045	2.462	2.756
30	1.697	2.042	2.457	2.750
….	….	….	….	….
136	1.656	1.977	2.354	2.612
∞	1.645	1.960	2.326	2.576

SPSS result

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age Age in years	137	99.3%	1	.7%	138	100.0%

Descriptives

			Statistic	Std. Error
Age Age in years	Mean		20.87	.262
	95% Confidence Interval for Mean	Lower Bound	20.35	
		Upper Bound	21.39	
	5% Trimmed Mean		20.59	
	Median		20.00	
	Variance		9.434	
	Std. Deviation		3.071	
	Minimum		16	
	Maximum		33	
	Range		17	
	Interquartile Range		3	
	Skewness		1.533	.207
	Kurtosis		2.566	.411

Hypothesis testing

- Hypothesis: a statement about the population
- Based on our data (sample) we conclude to the whole phenomenon (population)
- We examine whether our result (difference in samples) is greater then the difference caused only by chance.

Hypothesis

- Hypothesis: a statement about the population
- Examples
  - H1: $p=0.5$ (a coin is fair - half the flips would result in Heads and half, in Tails)
  - H2: $p \neq 0.5$ (a coin is not fair)
  - H3: $\mu=20$ (the population mean is 19)
  - H4: $\mu \neq 20$ (the population mean is not 12)
- Statisticians usually test the hypothesis which tells them what to expect by giving a specific value to work with. They refer to this hypothesis as the **null hypothesis** and symbolize it as H_0. The null hypothesis is often the one that assumes fairness, honesty or equality.
- The opposite hypothesis is called **alternative hypothesis** and is symbolized by H_a. This hypothesis, however, is often the one that is of interest.

Steps of hypothesis-testing

- **Step 1**. *State the motivated (alternative) hypothesis* H_a.
- **Step 2**. *State the null hypothesis* H_0.
- **Step 3**. S*elect the , the probability of Type I error, or the* α *significance level*. α =0.05 or α =0.01.
- **Step 4**. Choose the *size n of the random sample*
- **Step 5.** *Select a random sample* from the appropriate population and obtain your data.
- **Step 6**. *Calculate the decision rule –it depends on problem, assumptions, type of data, etc..*.
- **Step 7**. *Decision*.
- a) Reject the null hypothesis and claim that the alternative hypothesis was correct the difference is significant at α100% level.
- b) Fail to reject the null hypothesis correct the difference is not significant at α 100% level .

Testing the mean μ of a sample drawn from a normal population for the data of the example

- **Step 1-2**. *State null and the alternative hypotheses*
  - H_0: $\mu=20$, H_a: $\mu\neq 20$
- **Step 3**. *Select the , the probability of Type I error, or the* α *significance level*.
  - α =0.05
- **Step 4-5**. Choose the *size n of the random sample and select a random sample* from the appropriate population and obtain your data.
- **Step 6**. *Calculate the decision rule – now: confidence interval*
  - Calculate the 95% confidence interval for the population mean:
    (20.35-21.39).
  - With 95% probability, the true population mean (i.e. the mean age of the first year medical students) lies somewhere between 20.35 and 21.39.
  - ***Decision rule***: check whether the hypothesised mean (20) is in the interval or not
- **Step 7**. *Decision*.
  - 20 is not in the interval so we reject the null hypothesis and claim that the alternative hypothesis was correct the difference is significant at 5% level.

.

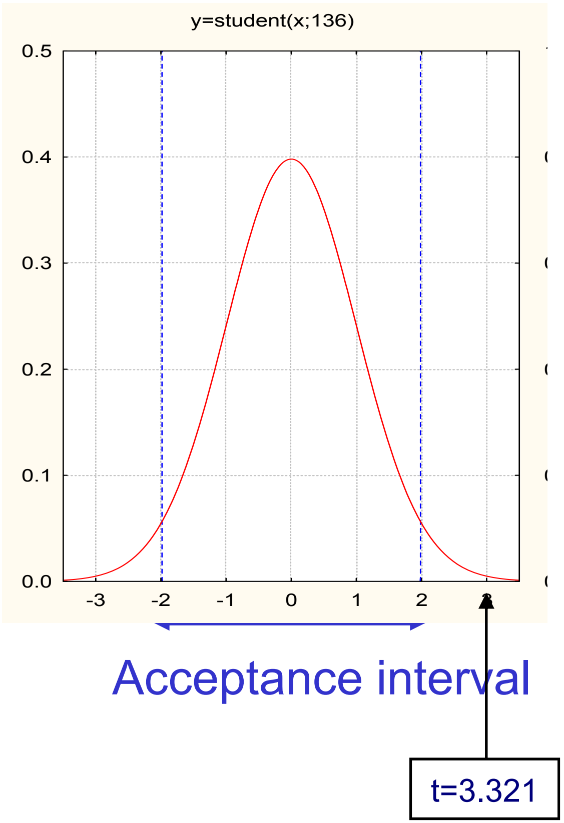
Testing the mean μ of a sample drawn from a normal population: one-sample t-test (general) <u>Decision rule based on confidence interval</u>

- **Step 1-2**. *State null and the alternative hypotheses*
  - H_0: $\mu = c$, H_a: $\mu \neq c$, c is a given constant
- **Step 3**. You *select the , the probability of Type I error, or the α significance level*.
  - $\alpha = 0.05$
- **Step 4-5**. You choose the *size n of the random sample and select a random sample* from the appropriate population and obtain your data.
- **Step 6**. *Calculate the decision rule*.
  - Calculate the 95% confidence interval for the population mean. ***Decision rule***: check whether the hypothesised mean (*c*) is in the interval or not
- **Step 7**. *Decision*.
  - a) if ***c*** is not in the interval, we reject the null hypothesis and claim that the alternative hypothesis was correct the difference is significant at 5% level.
  - b) if ***c*** is in the interval, we fail to reject the null hypothesis (we accept it) and claim that your null hypothesis was correct, the difference is not significant at 5% level.

Testing the mean μ of a sample drawn from a normal population: one-sample t-test

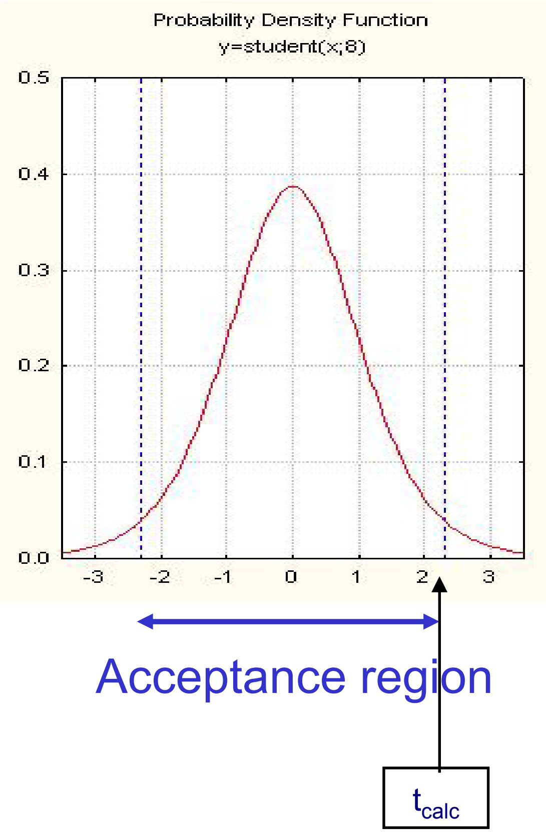
Decision rule based on *t*-value

- **Step 1-2**. H_0: μ=20 , H_a: μ≠20
- **Step 3**. α =0.05
- **Step 4-5**. You choose the *size n of the random sample and select a random sample* from the appropriate population and obtain your data.
- **Step 6**. *Calculate the decision rule*.
  - Calculate the test-statistic: $t = \frac{\bar{x} - c}{SE} = \frac{20.87 - 20}{0.262} = 3.321$
  - If H_0 is true, this test-statistic has a t-distribution with n-1 degrees of freedom.
  - The acceptance (non-rejection) region is the set of values for which we accept the null hypothesis (- 1.977, 1.977*)*
  - The critical region (rejection region) is the set of values for which the null hypothesis is rejected.
  - ***Decision rule***: check whether the calculated *t*-value (*t*) is in the acceptance interval or not
- **Step 7**. ***Decision:***
  - as *t=3.321* is not in the acceptance region, 3.321>1.977, |*t*|>t_{table}, the difference is significant at 5% level



Testing the mean μ of a sample drawn from a normal population: one-sample t-test (general) Decision rule based on *t*-value

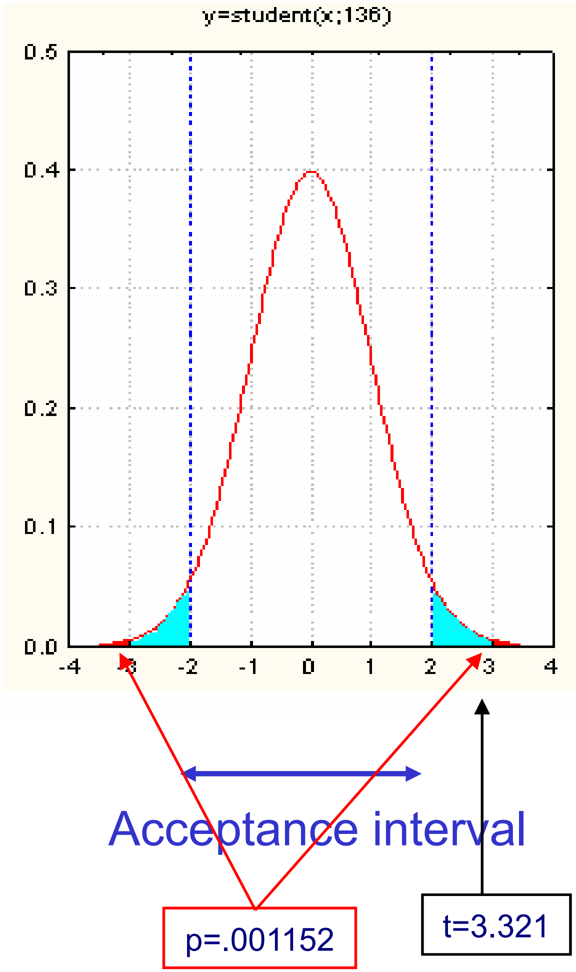
- **Step 1-2**. H_0: μ=c , H_a: μ≠c c is a given constant
- **Step 3**. α =0.05
- **Step 4-5**. You choose the *size n of the random sample and select a random sample* from the appropriate population and obtain your data.
- **Step 6**. *Calculate the decision rule*.
  - Calculate the test-statistic: $t = \frac{\bar{x} - c}{SE}$
  - If H_0 is true, this test-statistic has a t-distribution with n-1 degrees of freedom.
  - The acceptance (non-rejection) region is the set of values for which we accept the null hypothesis (- t_{table}, t_{table})
  - The critical region (rejection region) is the set of values for which the null hypothesis is rejected.
  - ***Decision rule***: check whether the calculated *t*-value (*t*) is in the acceptance interval or not
- **Step 7**. ***Decision:***
  - if t is not in the acceptance region (t> t_{table} or t< - t_{table}, i.e, $|t|>t_{table}$), the difference is significant at α level
  - if t is in the acceptance region (- t_{table}<t< t_{table}, *i.e.* $|t|<t_{table}$), the difference is not significant at α level



Testing the mean μ of a sample drawn from a normal population: one-sample t-test

<u>Decision rule based on *p*-value</u>

- **Step 1-2**. H_0: $\mu=19$, H_a: $\mu\neq19$
- **Step 3**. $\alpha = 0.05$
- **Step 4-5**. Choose the *size n of the random sample and select a random sample* from the appropriate population and obtain your data.
- **Step 6**. *Calculate the decision rule*.
  - Calculate the test-statistic: $t = \frac{\bar{x} - c}{SE} = \frac{20.87 - 20}{0.262} = 3.321$
  - If H_0 is true, this test-statistic has a t-distribution with n-1 degrees of freedom.
  - The acceptance (non-rejection) region is the set of values for which we accept the null hypothesis (-1.977, 1.977*)*
  - p-value=the two tailed tail area under the curve cut by our calculated t-value

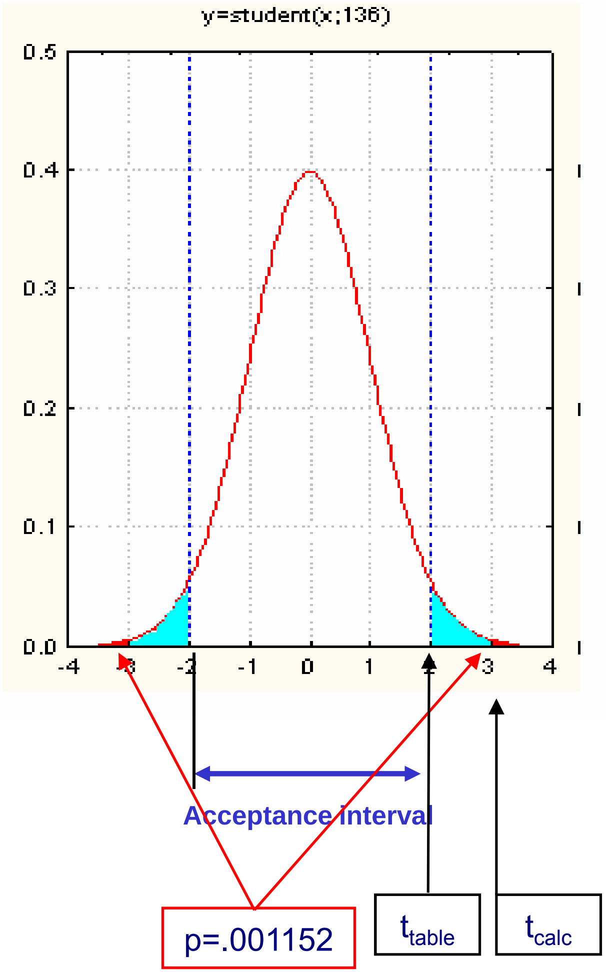


- **Step 7**. ***Decision:***
  - as p=0.001152<0.05,
    the difference is significant at 5% level

Testing the mean μ of a sample drawn from a normal population: one-sample t-test

Decision rule based on *p*-value (general)

- **Step 1-2**. H_0: $\mu=19$, H_a: $\mu\neq19$
- **Step 3**. α =0.05
- **Step 4-5**. Choose the *size n of the random sample and select a random sample* from the appropriate population and obtain your data.
- **Step 6**. *Calculate the decision rule*.
  - Calculate the test-statistic (t_{calc})
  - If H_0 is true, this test-statistic has a t-distribution with n-1 degrees of freedom.
  - p-value=the two tailed tail area under the curve cut by our calculated t-value
- **Step 7**. ***Decision:***
  - If $p<\alpha$, we decide that the difference is significant at α 100% level
  - If $p>\alpha$, we decide that the difference is not significant at α 100% level



Summary of the equivalent decision rules for one-sample t-test
Assumption: normality (the sample is drawn from a normal distribution)

1. H0: μ=c, (c given constant).
2. Ha: $\mu \neq$c.
3. Select α
4. Find the sample size *n*
5. Select a random sample $x_1, x_2, \ldots, x_n$., calculate the sample mean and SD
6. The decision rule:

	Confidence interval	Critical points (t-value)	p-value
Decision rules	$(\bar{x} - t_{\alpha/2}\frac{s}{\sqrt{n}}, \quad \bar{x} + t_{\alpha/2}\frac{s}{\sqrt{n}})$	$t = \frac{\bar{x} - c}{\frac{SD}{\sqrt{n}}} = \frac{\bar{x} - c}{SE}$	p-values are calculated by computer programs

$\mathbf{t}_{\alpha/2}$= critical two-tailed t-value from t-table

7. Decision:

Decision			
	Confidence interval	Critical points (t-value)	p-value
a) H_a : reject H0, the difference is **significant** at $\alpha \cdot$100%-level.	the confidence interval does not contain ***c***	$\lvert t \rvert > t_{\alpha/2}$	$p < \alpha$
a) H_0 : do not reject H0, the difference is **not significant** at $\alpha \cdot$100%-level.	the confidence interval contains the value ***c***	$\lvert t \rvert < t_{\alpha/2}$	$p > \alpha$

SPSS result

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Age Age in years	137	20.87	3.071	.262

One-Sample Test

	Test Value = 20					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Age Age in years	3.324	136	.001	.872	.35	1.39

To decide based on t-value
and degrees of freedom,
we need a t-table

p-value,
If $p<\alpha$, the difference is significant,
If $p<\alpha$, the difference is not significant

One-sample t-test, example 2.

- A company produces a 16 ml bottle of some drug (solution). The bottles are filled by an automated bottle-filling process. If this process is substantially overfilling or under filling bottles, then this process must be shut down and readjusted. Overfilling results in lost profits for the company, while under filling is unfair to consumers. For a given adjustment of the bottles consider the infinite population of all the bottle fills that could potentially be produced. We let denote the mean of the infinite population of all the bottle fills.
- The company has decided that it will shut down and readjust the process if it can be *very* certain that the mean fill is above or below the desired 16 ml.
- Now suppose that the company observes the following sample of n=6 bottle fills:
- 15.68, 16.00, 15.61, 15.93, 15.86, 15.72
- It can be verified that this sample has mean=15.8 and standard deviation SD=0.156.
- Question: Is it true that the mean bottle fill in the population is 16?

1. H0: μ=c, (c given constant). H_0: μ=16.

2. Ha: μ≠c. H_a: μ ≠16

3. Select α α=0.05or α=0.01

4. Find the sample size *n* n=6

5. Select a random sample $x_1, x_2, \ldots, x_n$. 15.68, 16.00, 15.61, 15.93, 15.86, 15.72

6. The decision rule:

Confidence interval	Critical points (t-value)	p-value
$(\bar{x} - t_{\alpha/2}\frac{s}{\sqrt{n}}, \quad \bar{x} + t_{\alpha/2}\frac{s}{\sqrt{n}})$	$t = \frac{\bar{x}-c}{\frac{SD}{\sqrt{n}}} = \frac{\bar{x}-c}{SE}$ and find $t_{\alpha/2}$	p (Sig. level Sig. 2 tail Prob....)
$(15.8 - 2.57\frac{0.1532}{\sqrt{6}}, 15.8 + 2.57\frac{0.1532}{\sqrt{6}}) = (15.639, 15.96)$	$t = \frac{(15.8-16)}{0.1532}\sqrt{6} = -3.197$ $t_{\alpha/2} = 2.57$	2-tail Sig=0.024

16 is not in the interval (15.64, 15.96)	$\lvert t\rvert > t_{\alpha/2}$ $\lvert -3.197\rvert = 3.197 > 2.57$	$0.024 < 0.05$

the difference is **significant** at 5%-level

A one-sample *t* test for paired differences (paired *t*-test)

- Self-control experiment
- Related data:
  - Before treatment – after treatment
  - Left side – right side
  - Matched pairs
- Null hypothesis: there is no treatment-effect, the difference is only by chance
- HO: $\mu_{before} = \mu_{after}$ or $\mu_{difference} = 0$
- Alternative hypothesis: there is a treatment effect
- HA: $\mu_{before} \neq \mu_{after}$ or $\mu_{difference} \neq 0$

Paired t-test, example

- A study was conducted to determine weight loss, body composition, etc. in obese women before and after 12 weeks of treatment with a very-low-calorie diet .
- We wish to know if these data provide sufficient evidence to allow us to conclude that the treatment is effective in causing weight reduction in obese women.
- The mean difference is actually 4. Is it a real difference? Big or small? If the study were to be repeated, would we get the same result or less, even 0?

	Before	After	Difference
	85	86	-1
	95	90	5
	75	72	3
	110	100	10
	81	75	6
	92	88	4
	83	83	0
	94	93	1
	88	82	6
	105	99	6
Mean	90.8	86.8	4.
SD	10.79	9.25	3.333

Paired t-test, example (cont).

- Idea: if the treatment is not effective, the mean sample difference is small (close to O), if it is effective, the mean difference is big.
- HO: $\mu_{before} = \mu_{after}$ or $\mu_{difference} = 0$ (c=0)!!
- HA: $\mu_{before} \neq \mu_{after}$ or $\mu_{difference} \neq 0$
- Let α=0.
- Degrees of freedom=10-1=9,
- $t_{table}=t_{0.05,9}=2.262$
- Mean=4, SD=3.333
- SE=3.333/$\sqrt{10}$=1.054

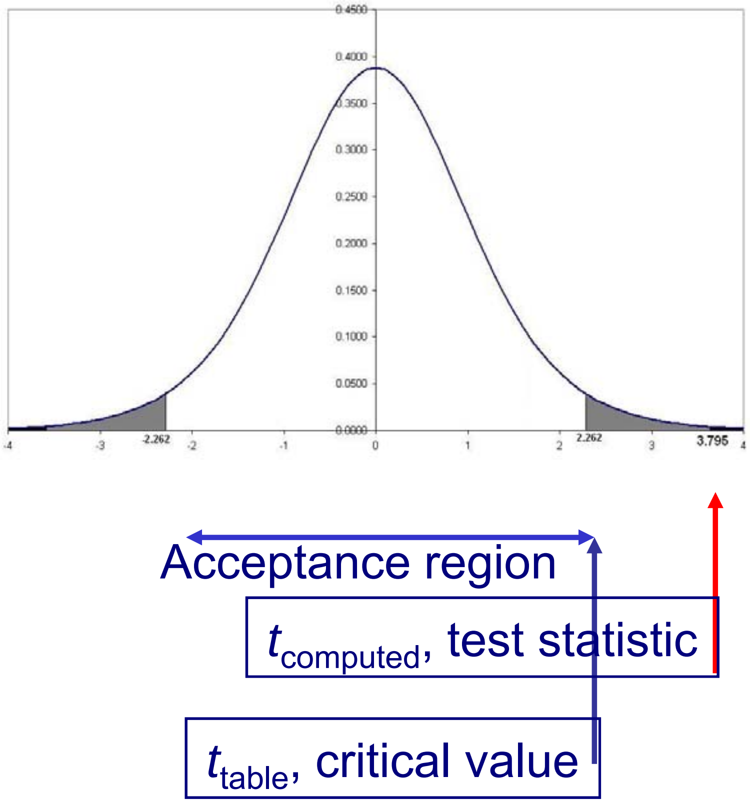
Paired t-test, example (cont.)

- Decision based on confidence interval:
  - 95%CI: (4-2.262*1.054, 4+2.262*1.054)=(1.615, 6.384)
  - If H0 were true, 0 were inside the confidence interval
  - Now 0 is outside the confidence interval, the difference is significant at 5% level, the treatment was effective.
  - The mean loss of body weight was 4 kg, which could be even 6.36 but minimum 1.615, with 95% probability.

- Decision based on test statistic (*t*-value):

$$t = \frac{\bar{x} - c}{SE} = \frac{\bar{x} - 0}{SE} = \frac{4}{1.054} = 3.795$$

  - This t has to be compared to the critical t-value in the table.
  - $|t|=3.795>2.262(=t_{0.05,9})$, the difference is significant at 5% level
- Decision based on p-value:
  - $p=0.004$, $p<0.05$, the difference is significant at 5% level



Example from the medical literature

V. Lindén: Vitamin D and Myocardial Infarction. BMJ 1974,3,647-650

TABLE II—*Paired Comparisons between Daily Intakes of Vitamin D in Infarction Patients and Matched Controls according to Age*

Born	No.	Mean Difference (μg)	S.D.	S.E. of Mean	*t*	P
			Men			
Before 1905	37	6·68	28·82	4·74	1·41	0·2 >P>0·1
1905-9	35	0·21	24·60	4·16	0·05	P>0·8
1910-4	14	1·29	23·23	6·21	0·21	P>0·8
1915-59	21	27·40	28·30	6·18	4·44	P<0·001
After 1919	11	15·23	15·69	4·73	3·22	0·01 >P>0·005
Total	118	8·61	27·30	2·51	3·42	P<0·001
			Women			
Before 1905	11	8·58	31·86	9·61	0·89	
1905-14	15	17·91	22·18	5·73	3·13	0·005>P>0·0025
After 1914	6	9·58	17·27	7·05	1·36	
Total	32	13·14	24·87	4·40	2·99	0·005>P>0·0025

all other groups. To study the differences more closely the *t* test was applied to a paired comparison of differences in daily intakes between male and female infarction patients and the corresponding matched controls (table II). The differences in daily intakes between male and female infarction patients and their corresponding matched controls were highly significant (P <0·001 and P> 0·0025 respectively). No significant differences were found when a paired comparison was made for either sex between angina pectoris patients and matched controls or between patients suffering from degenerative joint diseases and matched controls.

Summary

A detailed investigation was carried out into the consumption of vitamin D from different sources in patients who had suffered from myocardial infarction, angina pectoris, and degenerative joint diseases. Randomly selected controls of the same ages and sex were drawn from the Central Bureau of Statistics. The consumption was significantly higher in infarction patients. A daily intake of 30 μg may be the critical level. Student's t test for trend showed increasing probability of myocardial infarction with increasing intake of vitamin D, and more infarction patients than controls had a history of kidney stone. Long-term high consumption of vitamin D may be a precipitating cause of myocardial infarction.

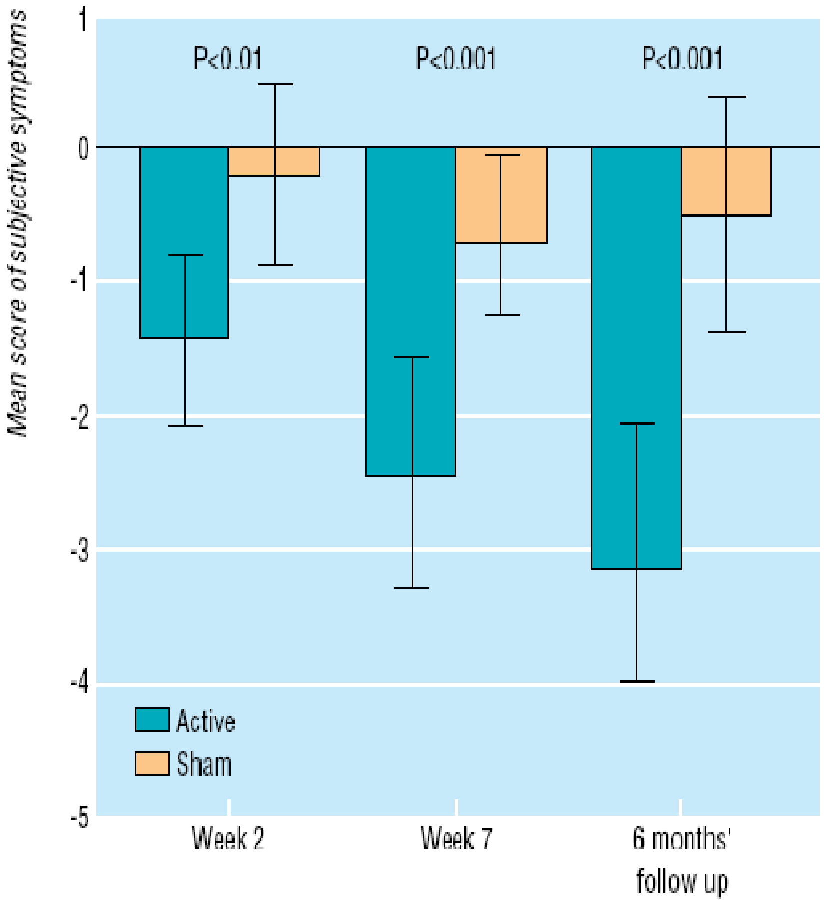


Fig 2 Mean change (and 95% confidence intervals) from baseline score for all subjective symptoms (active versus sham treatment) at week 2, end of treatment, and 6 months' follow up (paired *t* test)

Ultrasound treatment for treating the carpal tunnel syndrome: randomised "sham" controlled trial

Gerold R Ebenbichler, Karl L Resch, Peter Nicolakis, Günther F Wiesinger, Frank Uhl, Abdel-Halim Ghanem, Veronika Fialka

BMJ VOLUME 316 7 MARCH 1998

Review questions and problems

- What is a hypothesis
- Null-and alternative hypothesis
- Steps of hypothesis testing
- The null- and alternative hypothesis of the one-sample t-test
- The assumption of the one-sample t-test
- Decision rules of the one-sample t-test
- Testing significance based on a confidence interval
- Testing significance based on t-statistic
- Testing significance based on p-value
- Meaning of the p-value
- In a study, systolic blood pressure of 10 healthy women was measured. The mean was 119, the standard error 0.664. Supposing that this sample was drawn from a normal distribution, check whether the population mean is 125! (α=0.05, t_{table}=2.26).
- To test the effect of a new drug, the systolic blood pressure was measured on the same 5 patients before and after the treatment. The mean of the differences is = 6, the standard error of the differences is SE=4.65. To test the effect of the drug, what is the appropriate test? Find the value of the test statistics and decide whether the difference is significant or not. (α =0.05, t_{table}=2.57)

Presentation of results

Table 2 | Primary and secondary outcomes according to treatment in the 502 randomised children according to allocation to new treatment (oral co-amoxiclav) or standard treatment (intravenous ceftriaxone followed by oral co-amoxiclav). Figures are means (SD) unless specified otherwise

Parameter	New treatment (n=244)	Standard treatment (n=258)	Mean difference (95% CI)
Short term outcomes			
Time to defervescence (hours)	36.9 (19.7) (n=241)	34.3 (20) (n=253)	2.6 (−0.9 to 6)
White cell count (×10^9/l)*	9.8 (3.5) (n=230)	9.5 (3.1) (n=243)	0.3 (−0.3 to 0.9)
Neutrophils (×10^9/l)*	3.0 (2.2) (n=207)	2.8 (1.9) (n=217)	0.2 (−0.2 to 0.6)
Erythrocyte sedimentation rate (mm in first hour)*	50.8 (32) (n=170)	52.6 (27.9) (n=168)	−1.8 (−8.2 to 4.7)
C reactive protein (mg/l)*†	9.3 (20.9) (n=235)	8.2 (15.4) (n=251)	1.1 (−2.6 to 4.1)
Sterile urine	185/186 (99.45%)	203/204 (99.5%)	−0.05% (−1.5% to 1.4%)
Primary outcome			
Scar on renal scan at 12 months	27/197 (13.7%)	36/203 (17.7%)	−4% (−11.1% to 3.1%)

*Parameters obtained 72 hours after start of antibiotic treatment.
†Ratio between obtained value and upper limit of normal reference values for each laboratory.

BMJ | ONLINE FIRST | bmj.com

BMJ

Antibiotic treatment for pyelonephritis in children: multicentre randomised controlled non-inferiority trial

Giovanni Montini, Antonella Toffolo, Pietro Zucchetta, Roberto Dall'Amico, Daniela Gobber, Alessandro Calderan, Francesca Maschio, Luigi Pavanello, Pier Paolo Molinari, Dante Scorrano, Sergio Zanchetta, Walburga Cassar, Paolo Brisotto, Andrea Corsini, Stefano Sartori, Liviana Da Dalt, Luisa Murer and Graziella Zacchello

BMJ 2007;335;386-; originally published online 4 Jul 2007;
doi:10.1136/bmj.39244.692442.55