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Úvod do matematické biologie a biomedicíny

přednáška 02.12.2019

Eva Budinská (budinska@recetox.muni.cz)

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Co všechno (ne)lze vyčíst z grafů

Síla grafického znázornění dat (nejen) v biologii a medicíně

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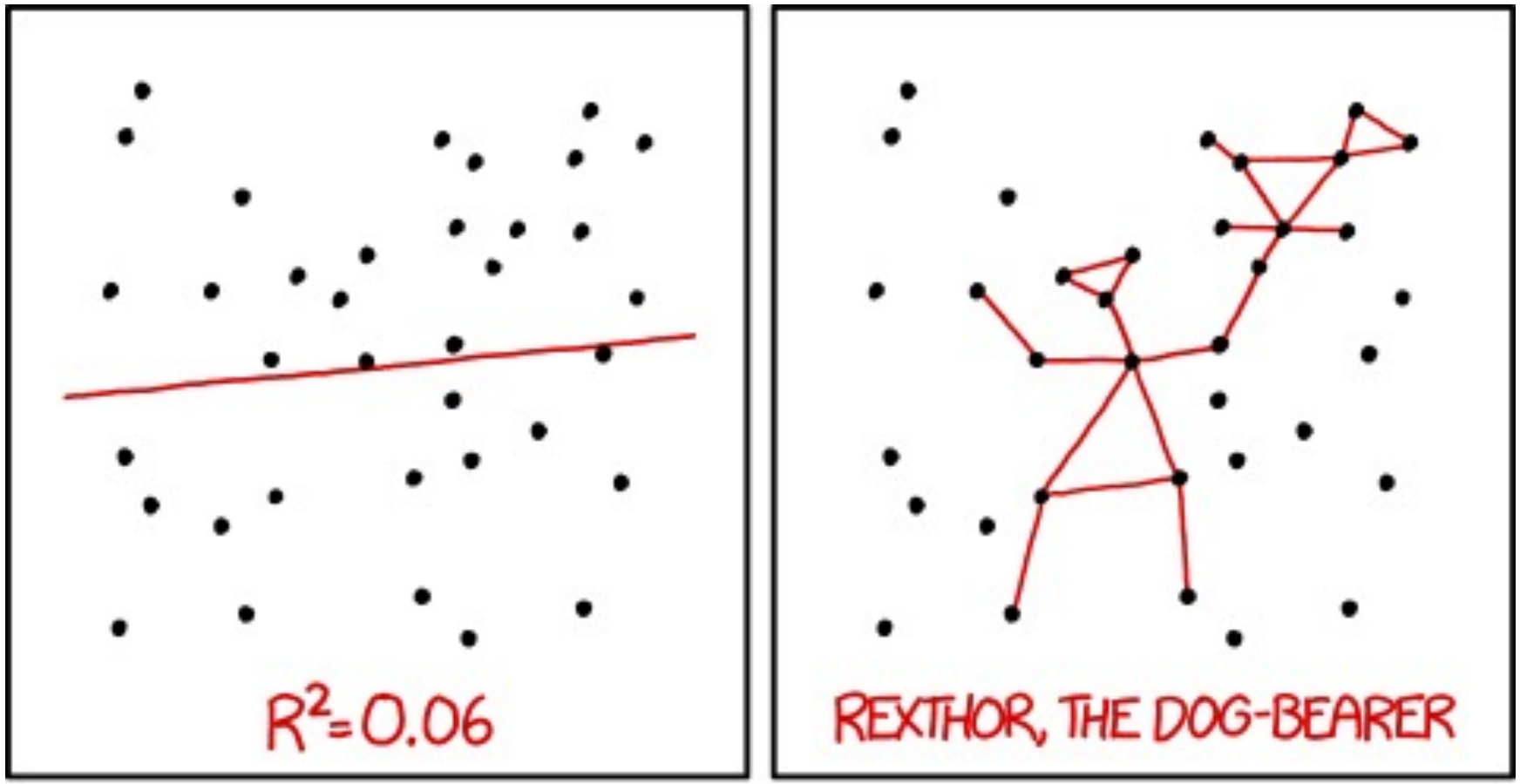
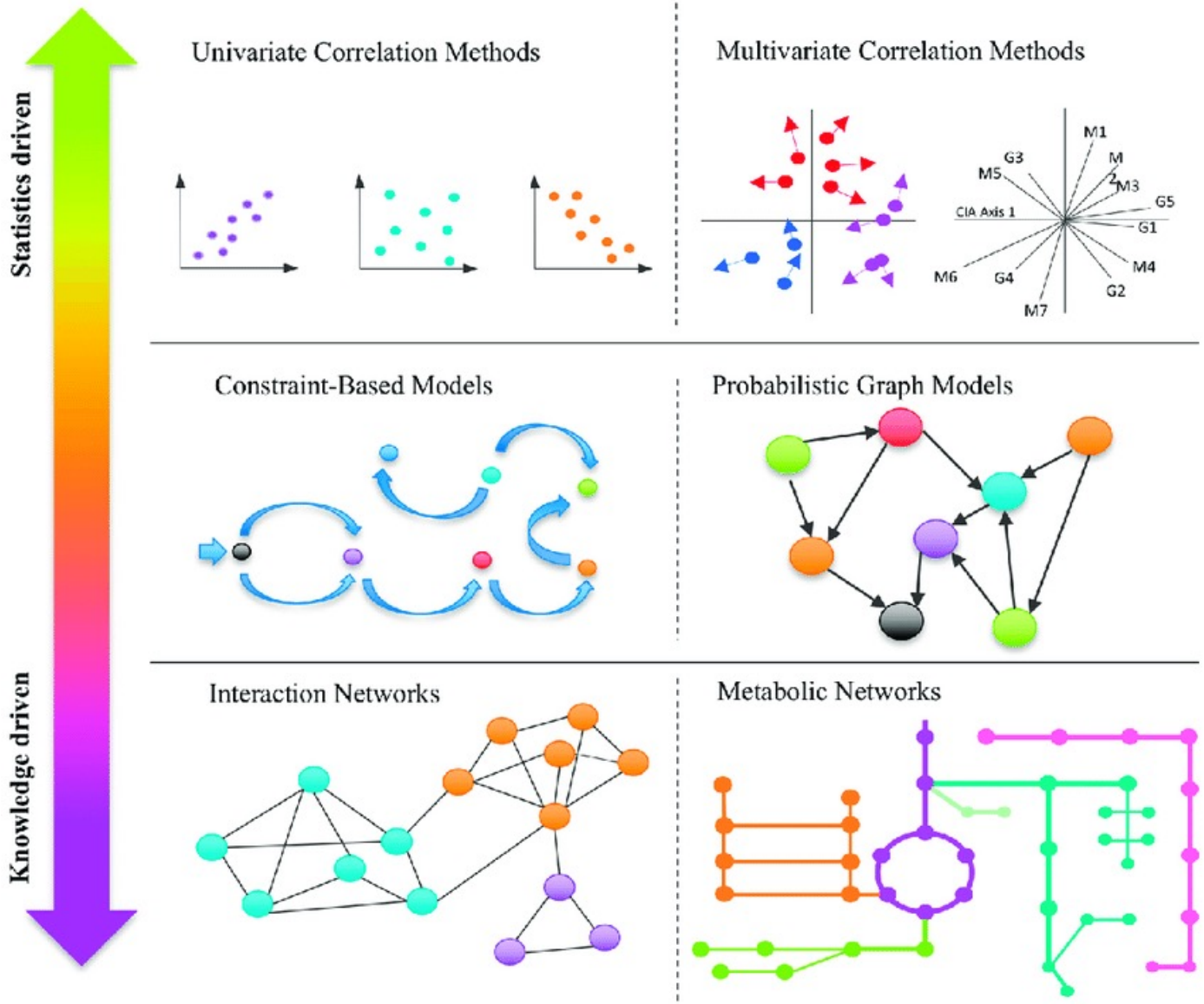


I DON'T TRUST LINEAR REGRESSIONS WHEN IT'S HARDER TO GUESS THE DIRECTION OF THE CORRELATION FROM THE SCATTER PLOT THAN TO FIND NEW CONSTELLATIONS ON IT.

- Zdroj.

Grafické znázornění dat

Nejdůležitější nástroj analýzy a komunikace výsledků!



Základné vlastnosti dobrého grafu

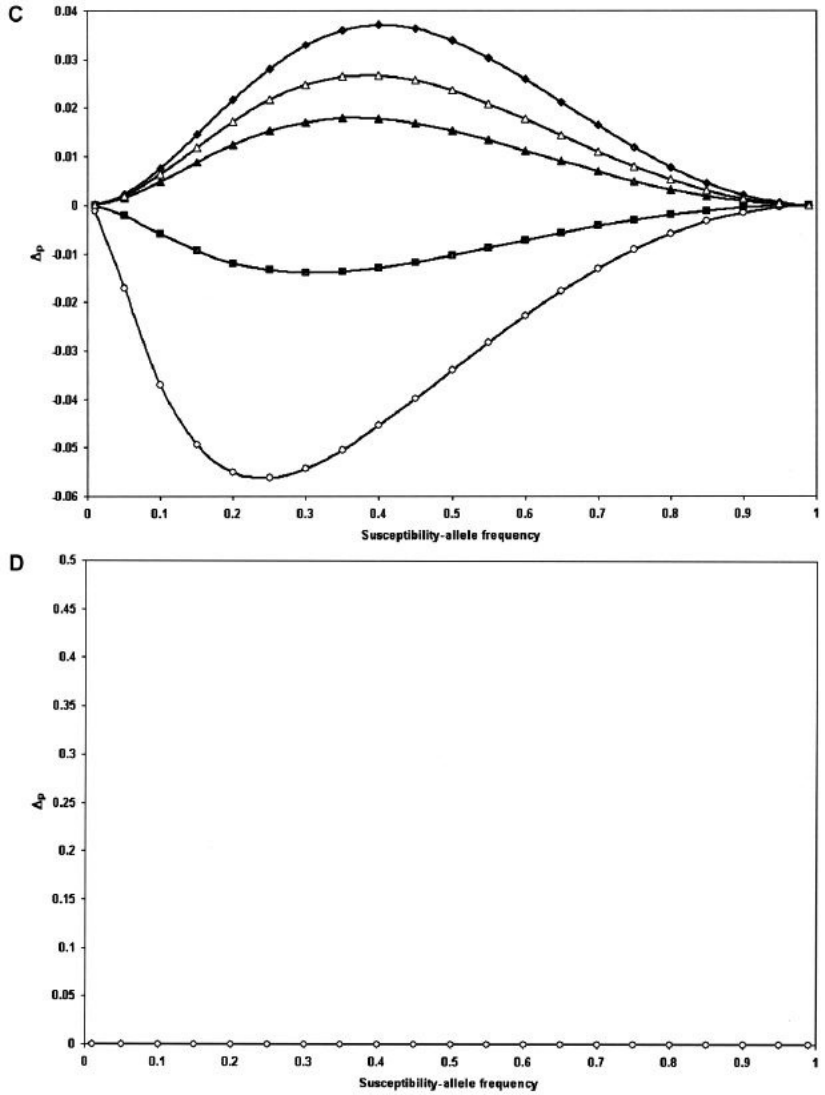
- Obsah!
- Jednoduchost
- Ne(zkreslení)

Obsah

- Graf a jeho legenda musí obsahovat všechny důležité informace

Obsah

- Žádný rozdíl nemusí mít vždy význam zobrazovat



Wittke Thompson, JK,Pluzhnikova,CoxNJ (2005) Rational inferences about departures from Hardy-Weinberg equilibrium. American Journal of Human Genetics 76:967T986,Figure1

Obsah

- Žádný rozdíl nemusí mít vždy význam zobrazovat

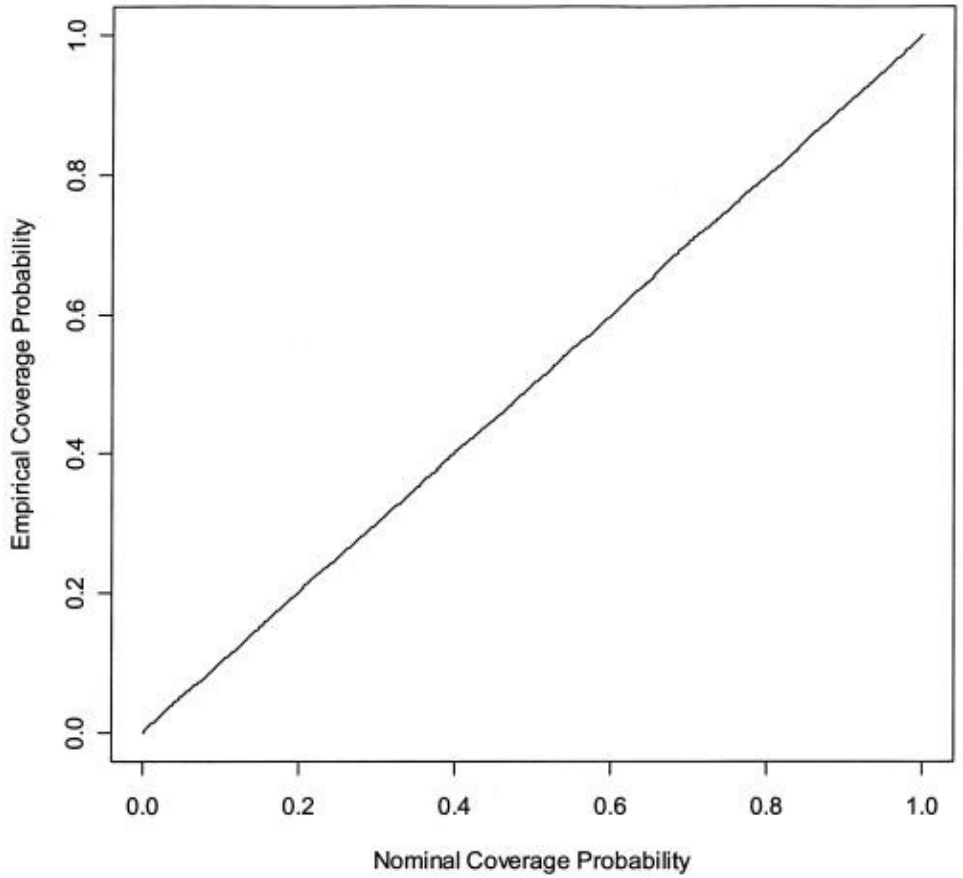


Figure 1. Empirical coverage of CIs for the relative-risk parameter β of haplotype 01100. Results are based on 10,000 simulated data sets with the same haplotype frequencies as the FUSION data. Haplotype 01100 has a multiplicative effect on disease risk, with β=0.35.

EpsteinMP,Satten GA (2003) Inference on haplotype e9ects in case-control studies using unphased genotype data. American Journal of Human Genetics 73:1316T1329, Figure 1

Jednoduchost

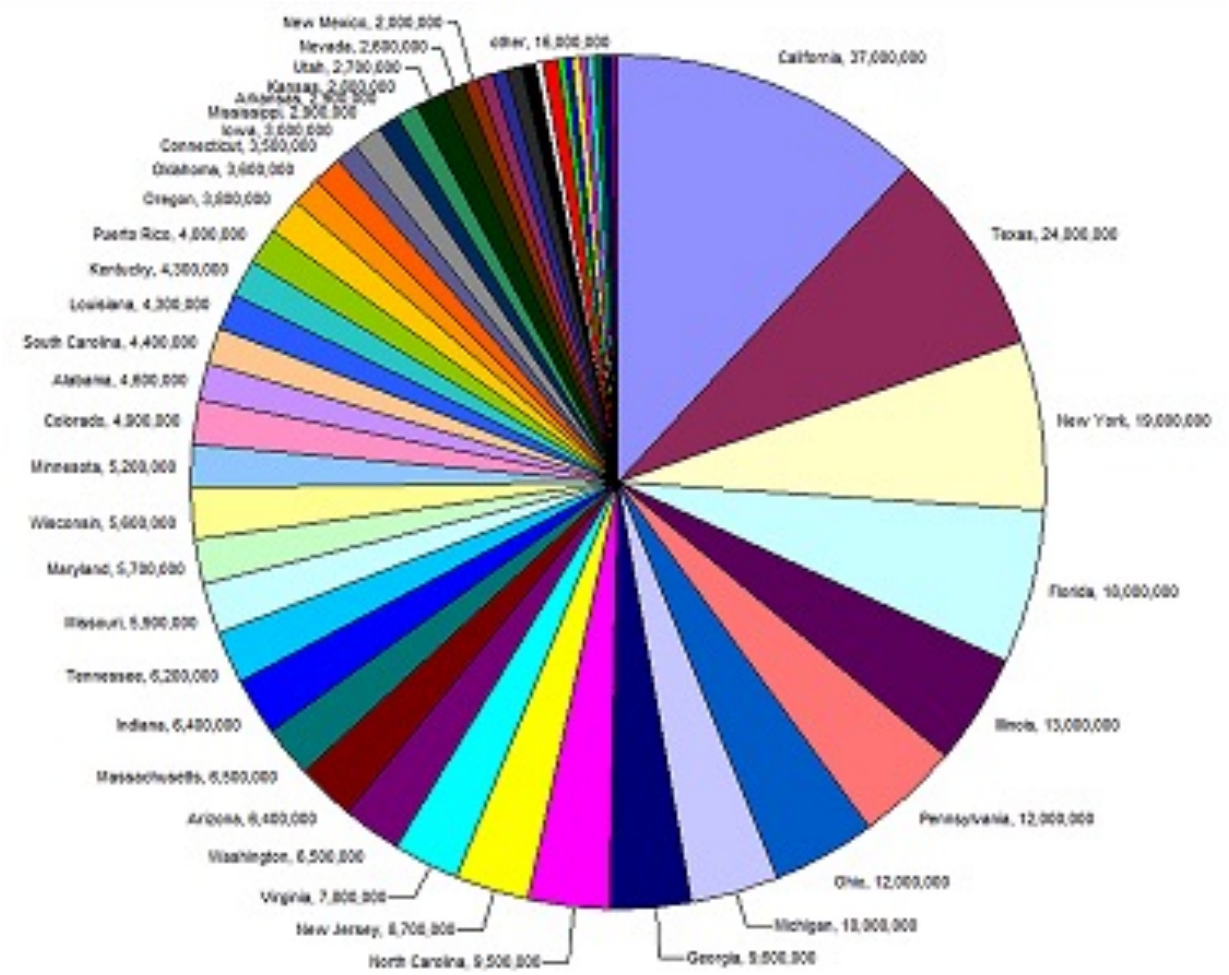
- Dobrý graf není složitější, než informace v něm obsažená
- Graf by měl **mít vysoký poměr** data / inkoust:

$$\frac{\text{Množství inkoustu použitého k zobrazení dat}}{\text{Celkové množství inkoustu použitého k zobrazení grafu}}$$

Jak zkomplikovat graf?

- Výběrem nevhodného zobrazení!
- Ozdobami, které nesouvisí s obsahem
- Nevhodnými a příliš četnými barvami
- Zbytečnými 3D efekty

Nevhodné zobrazení – mnoho kategorií



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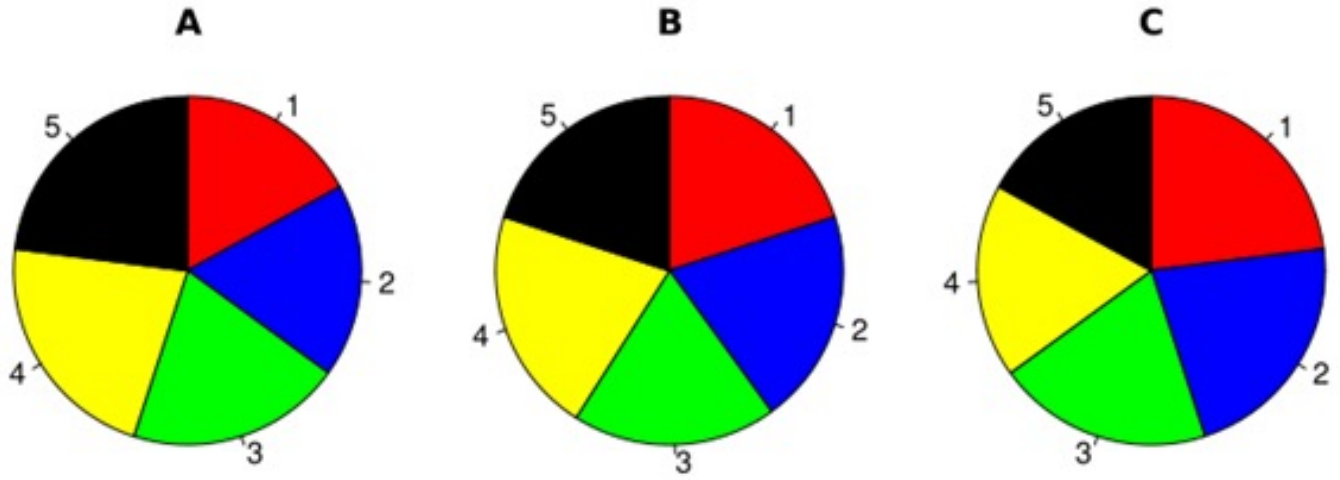
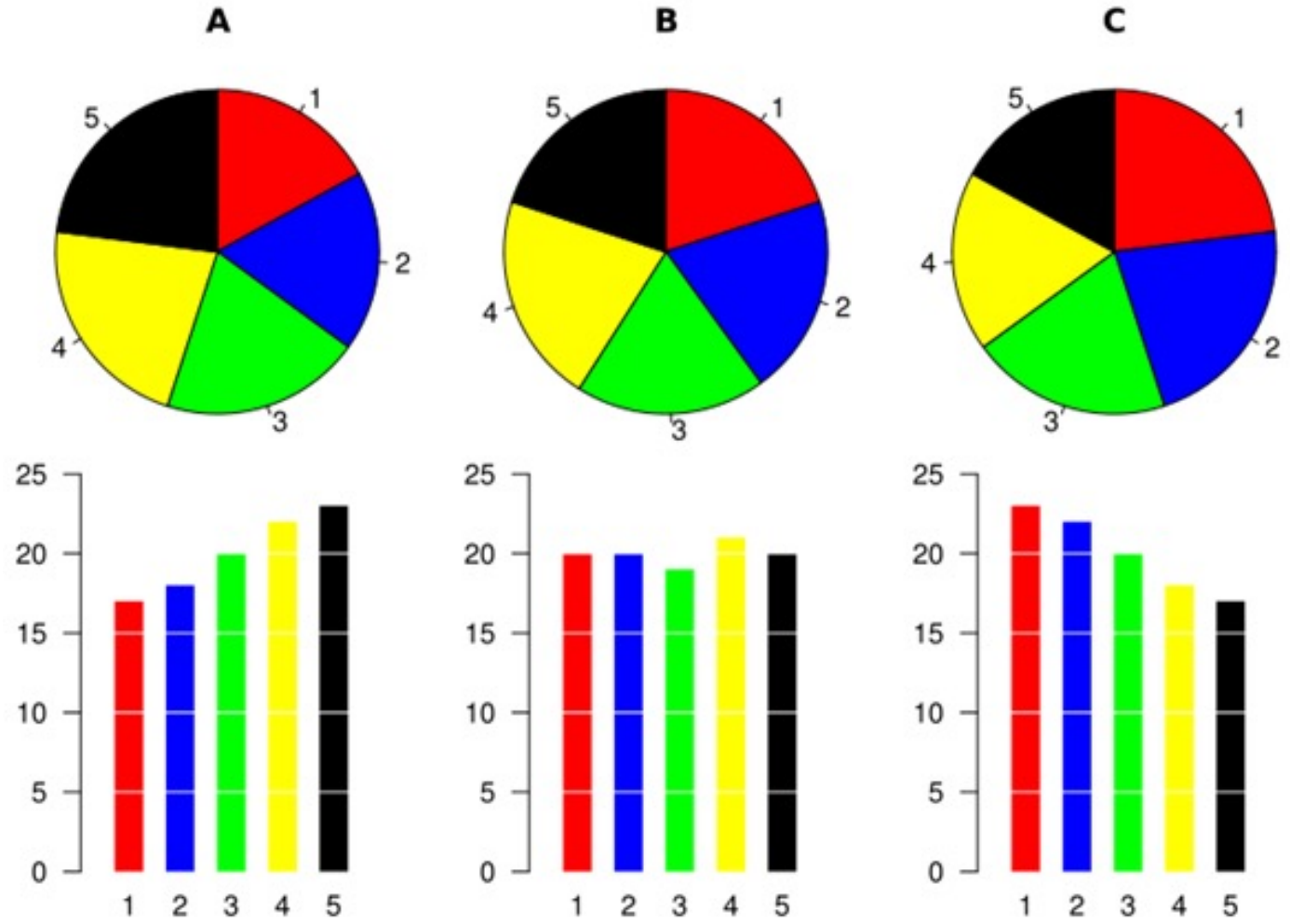
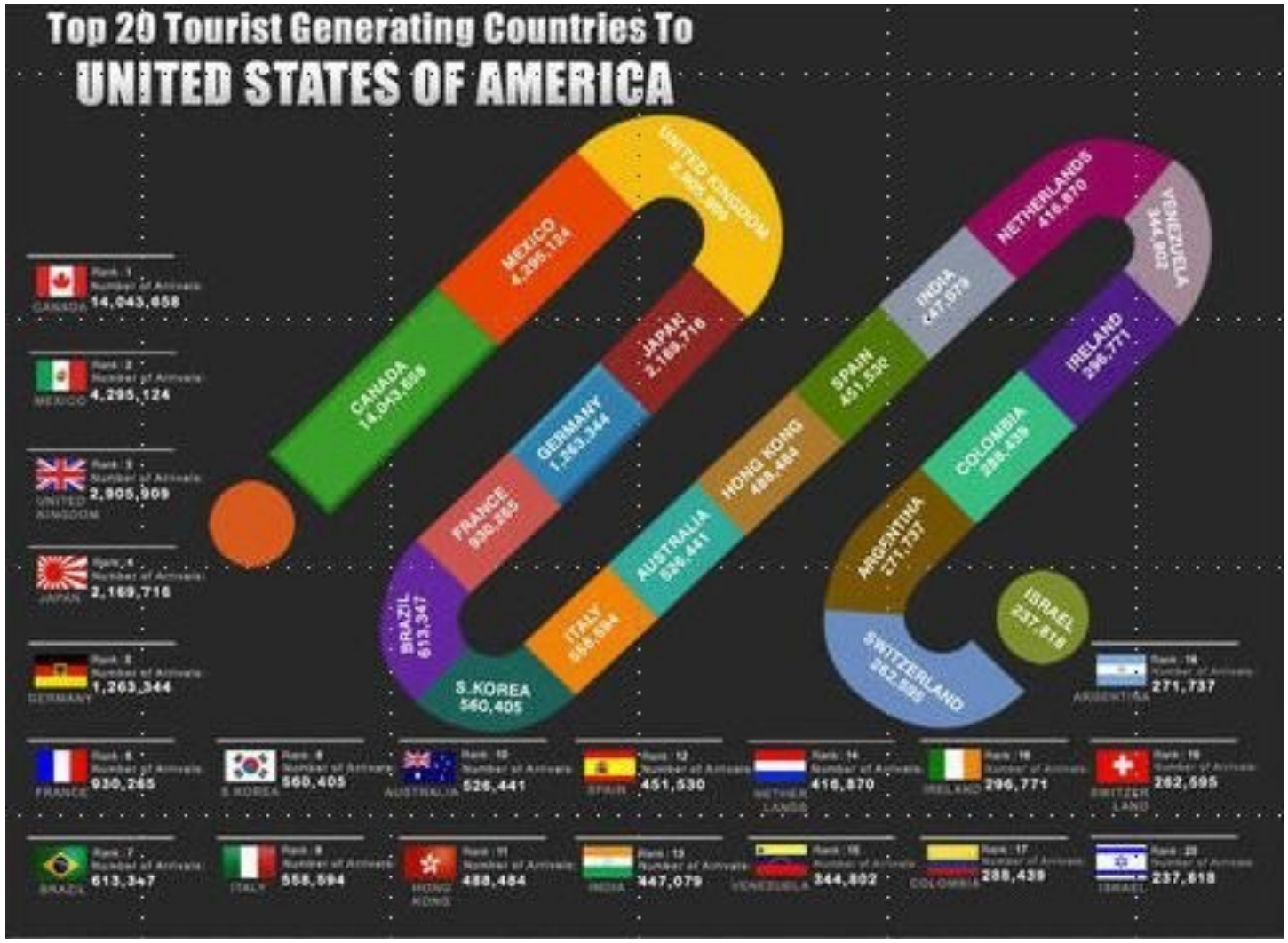
Nevhodné zobrazení – málo kategorií



Nevhodné zobrazení – málo kategorií



Ozdoby, které nesouvisí s obsahem



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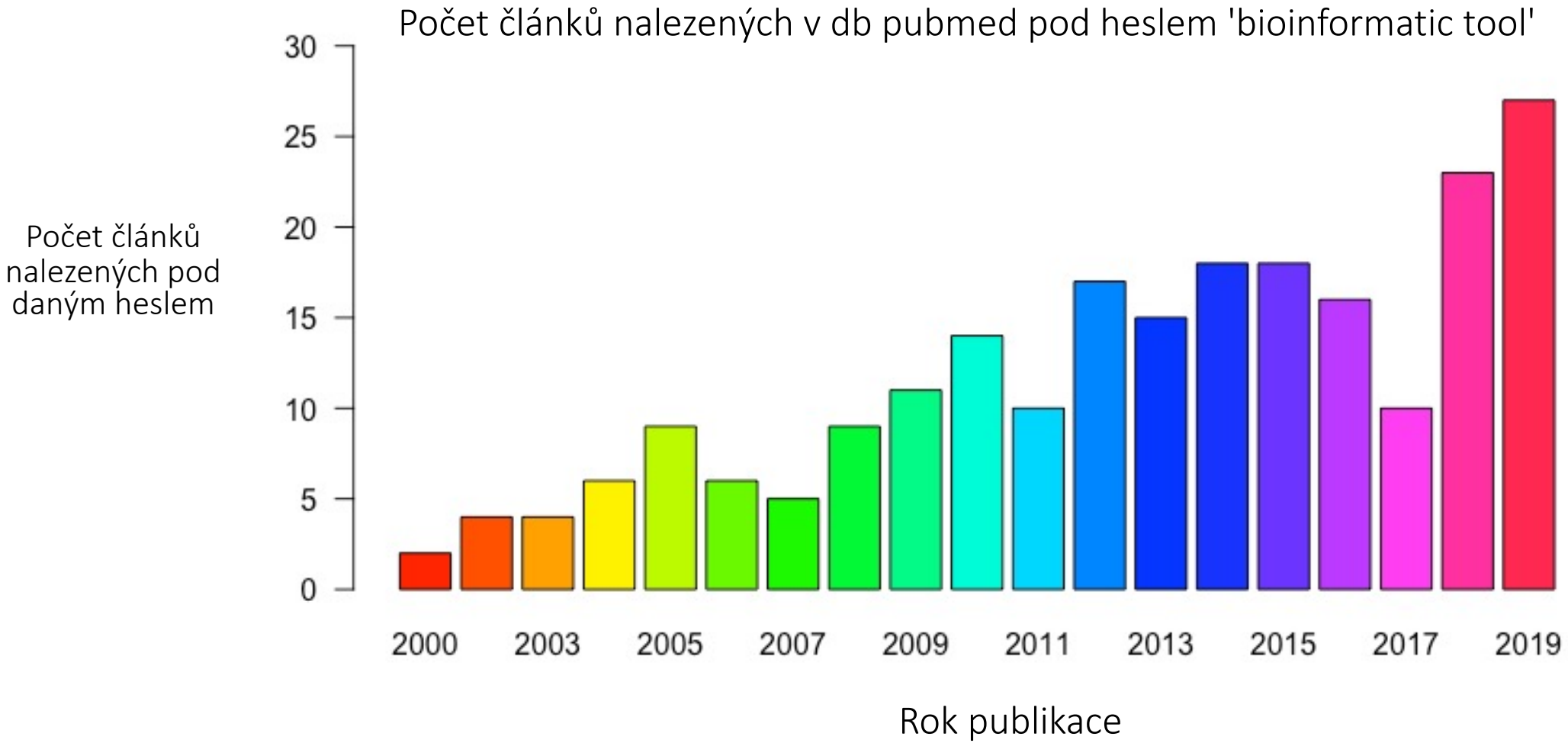
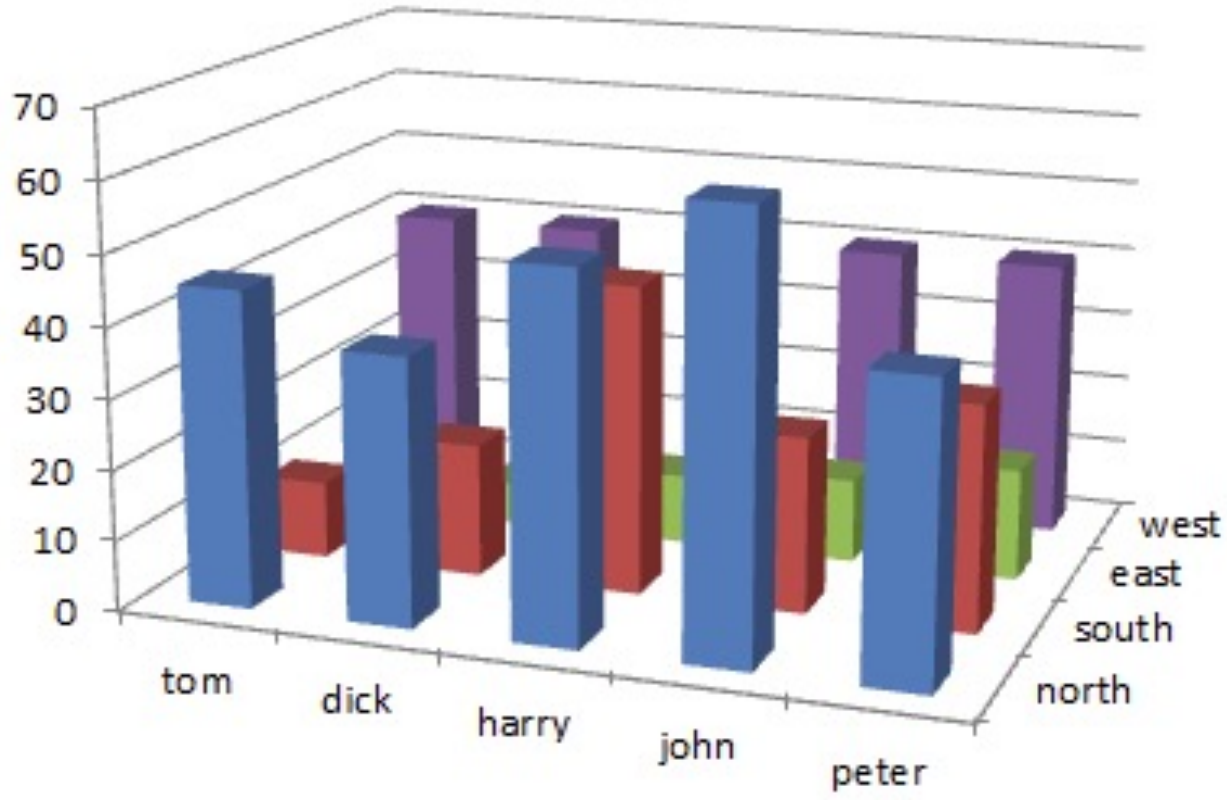
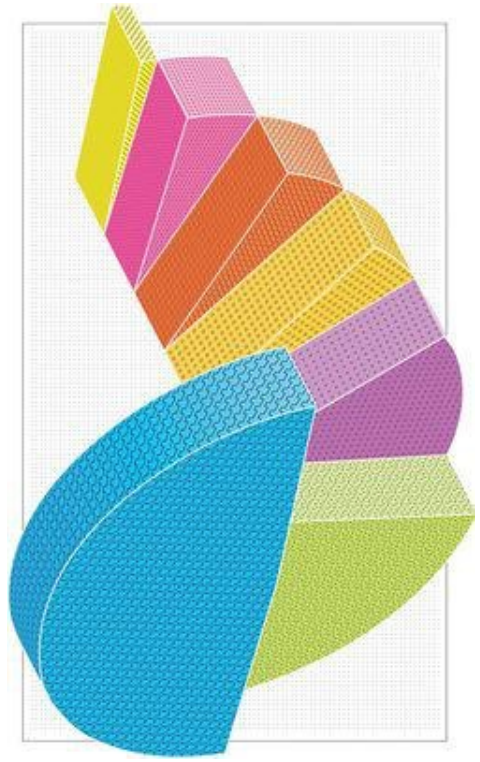
Nevhodné a příliš četné barvy



Zbytečné 3D efekty

Vědecké studie ukazují, že 3D efekty snižují srozumitelnost grafu.





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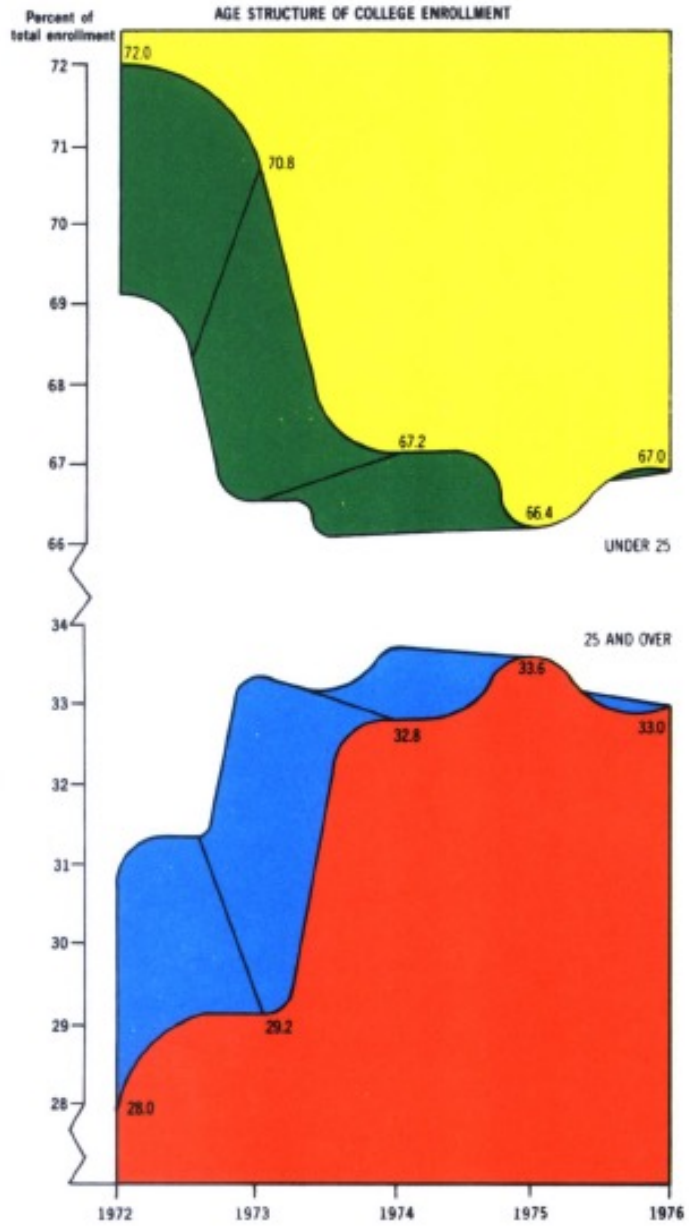
… a kombinací výše uvedeného

- Graf znázorňuje 5 čísel!
- Podíly vysokoškolských studentů nad a pod 25 let, v letech 1972 až 1976.



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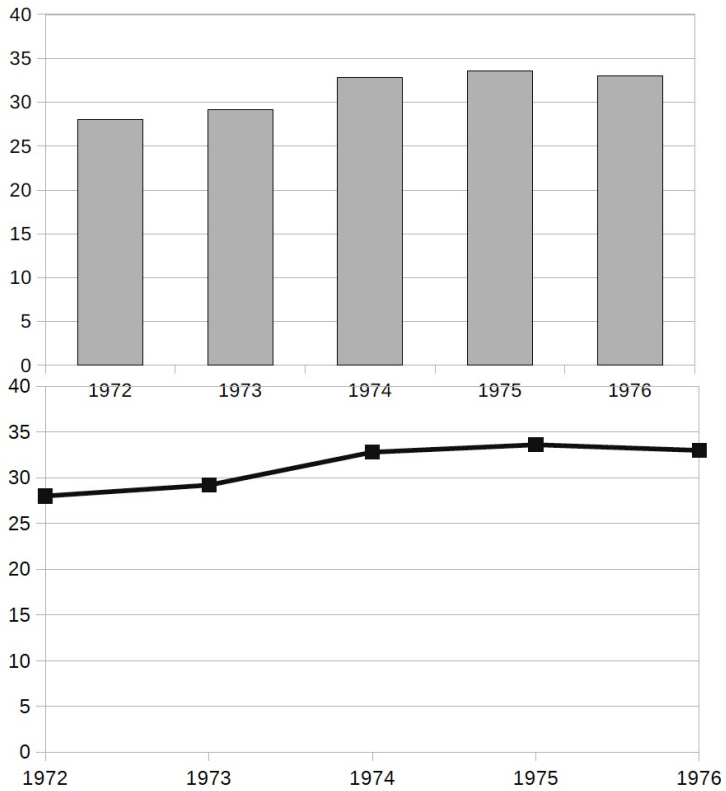

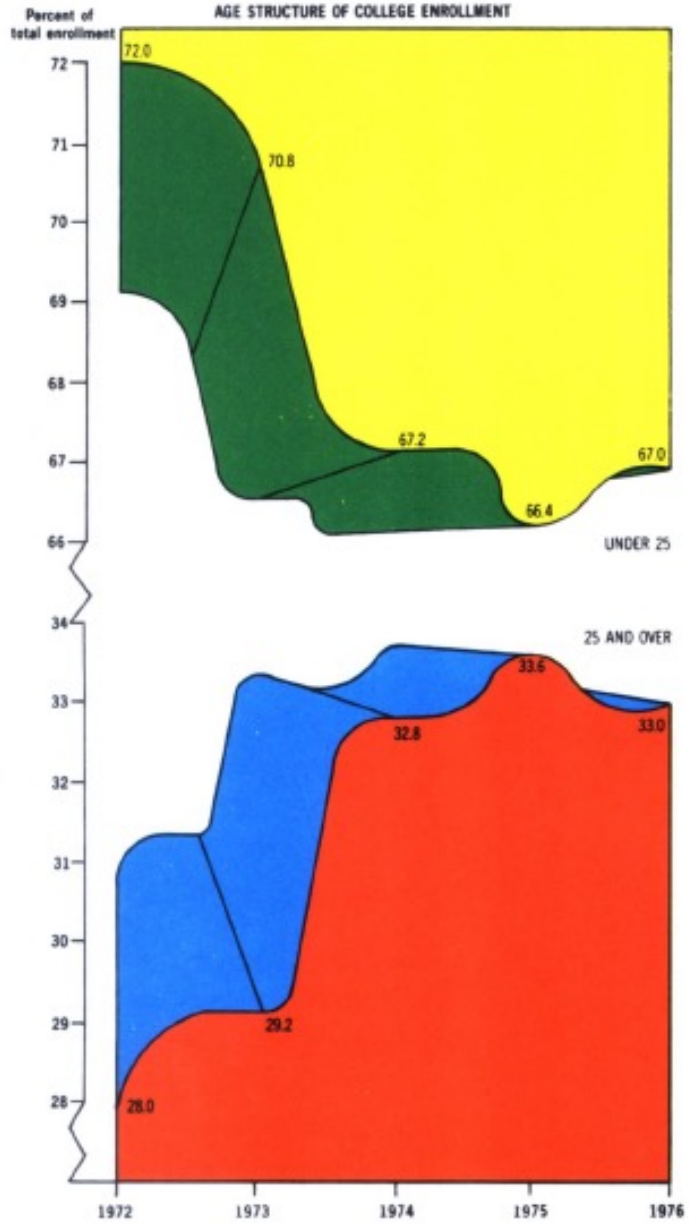

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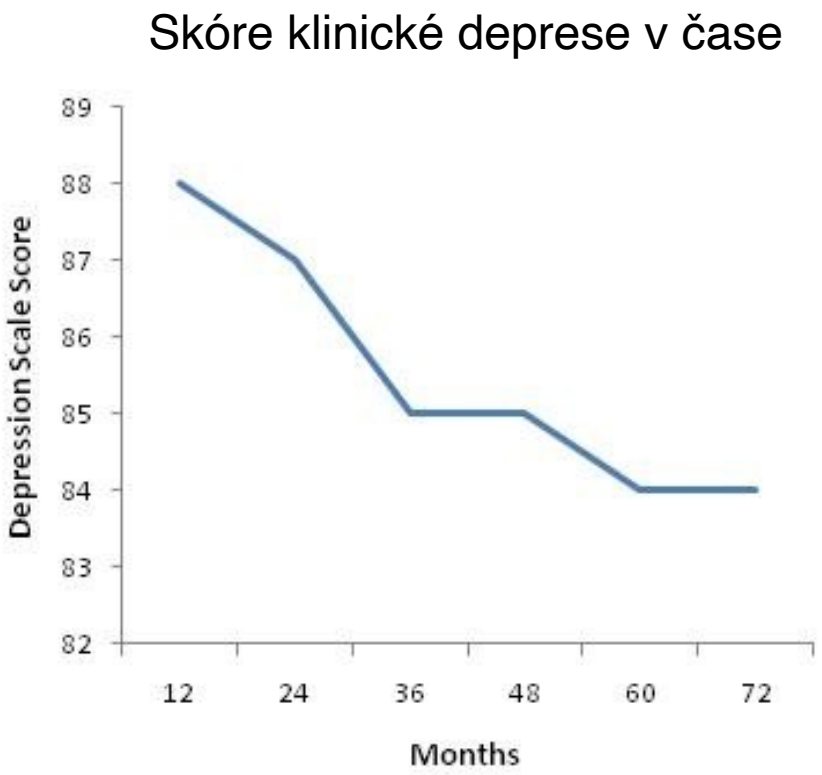
Zkreslení

- Graf by neměl zobrazovat zkreslenou skutečnost (ať už účelově nebo náhodou)

Zkreslení škálou I.

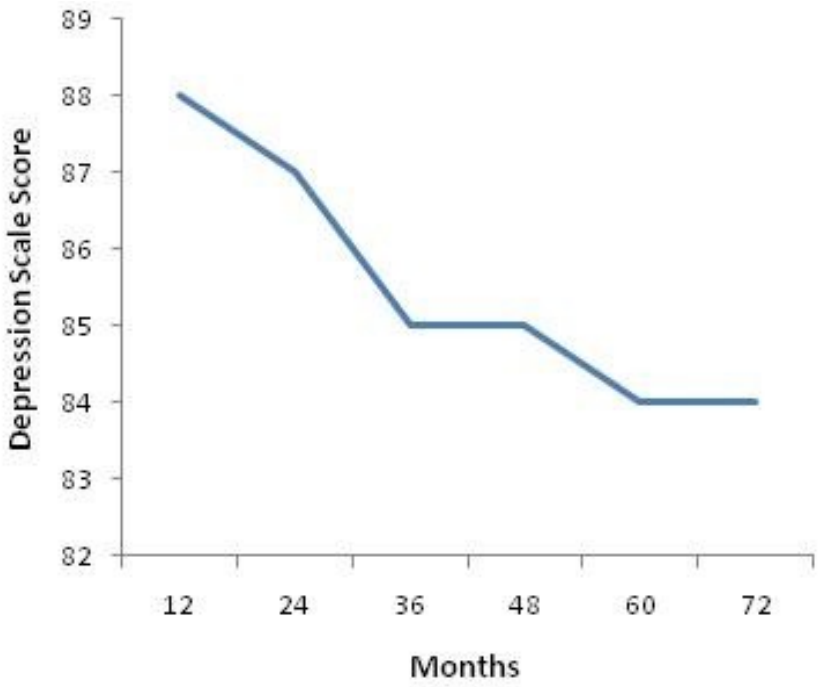
- Každý automaticky předpokládá, že osa Y začíná nulou!



Zkreslení škálou I.

- Každý automaticky předpokládá, že osa Y začíná nulou!

Skóre klinické deprese v čase



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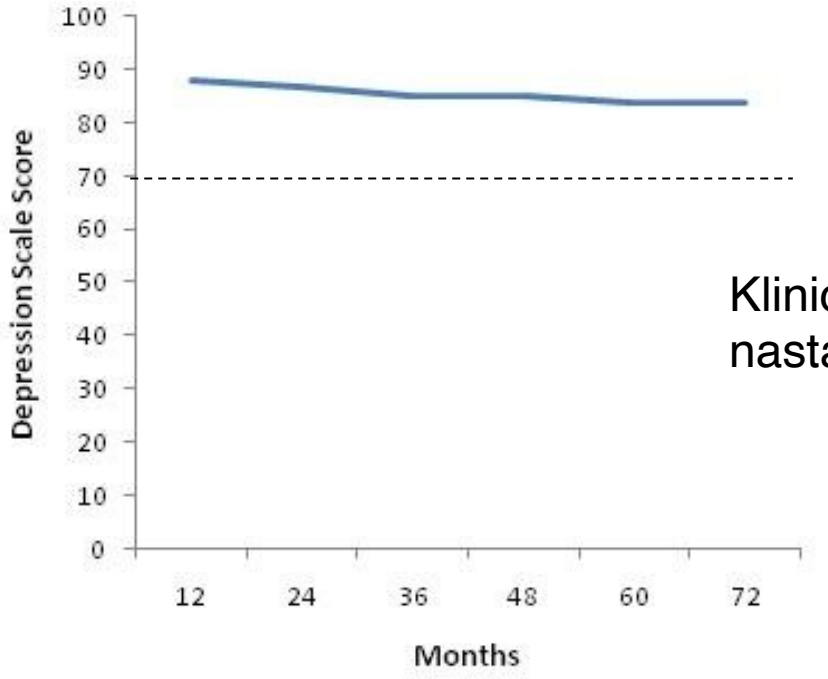
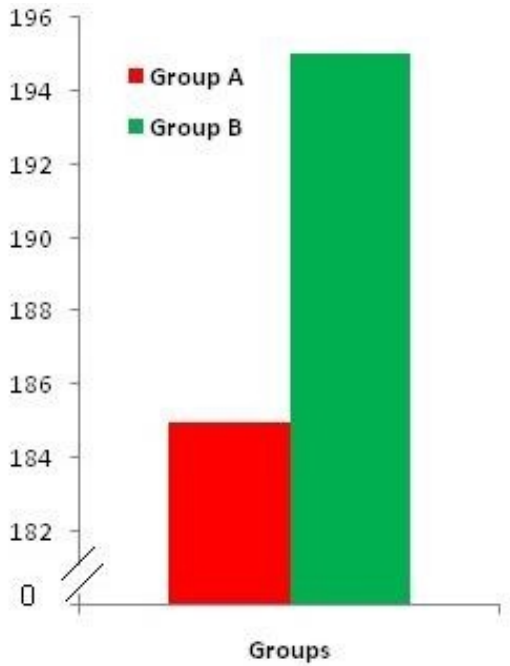


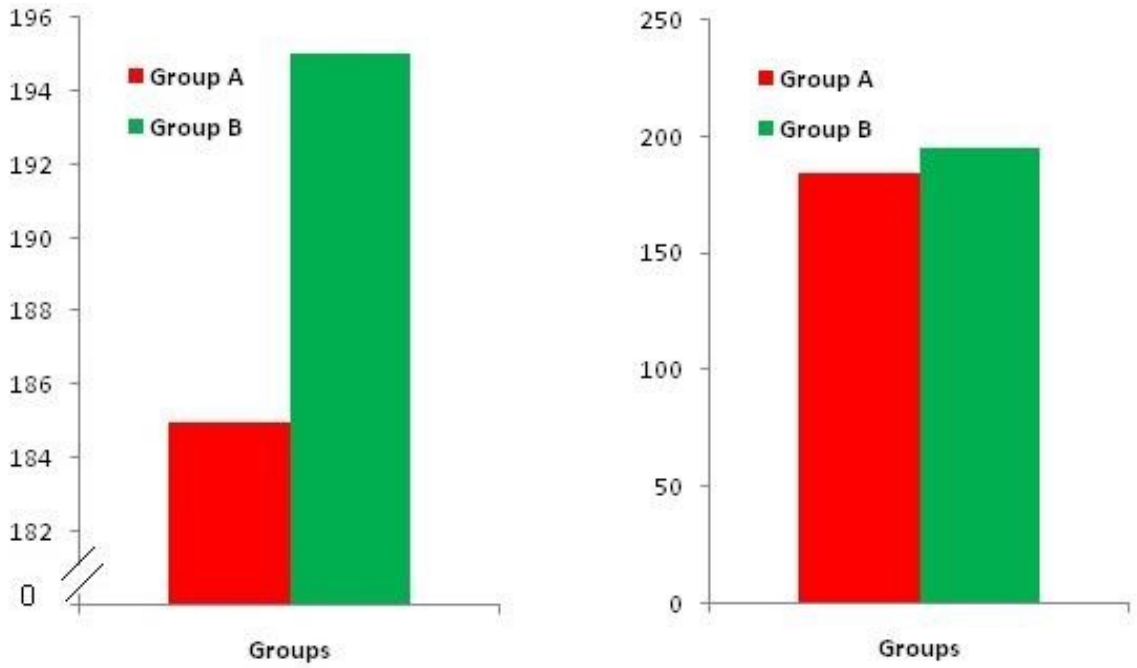
Klinická deprese nastává při skóre >70

Zkreslení škálou II.



Zkreslení škálou II.

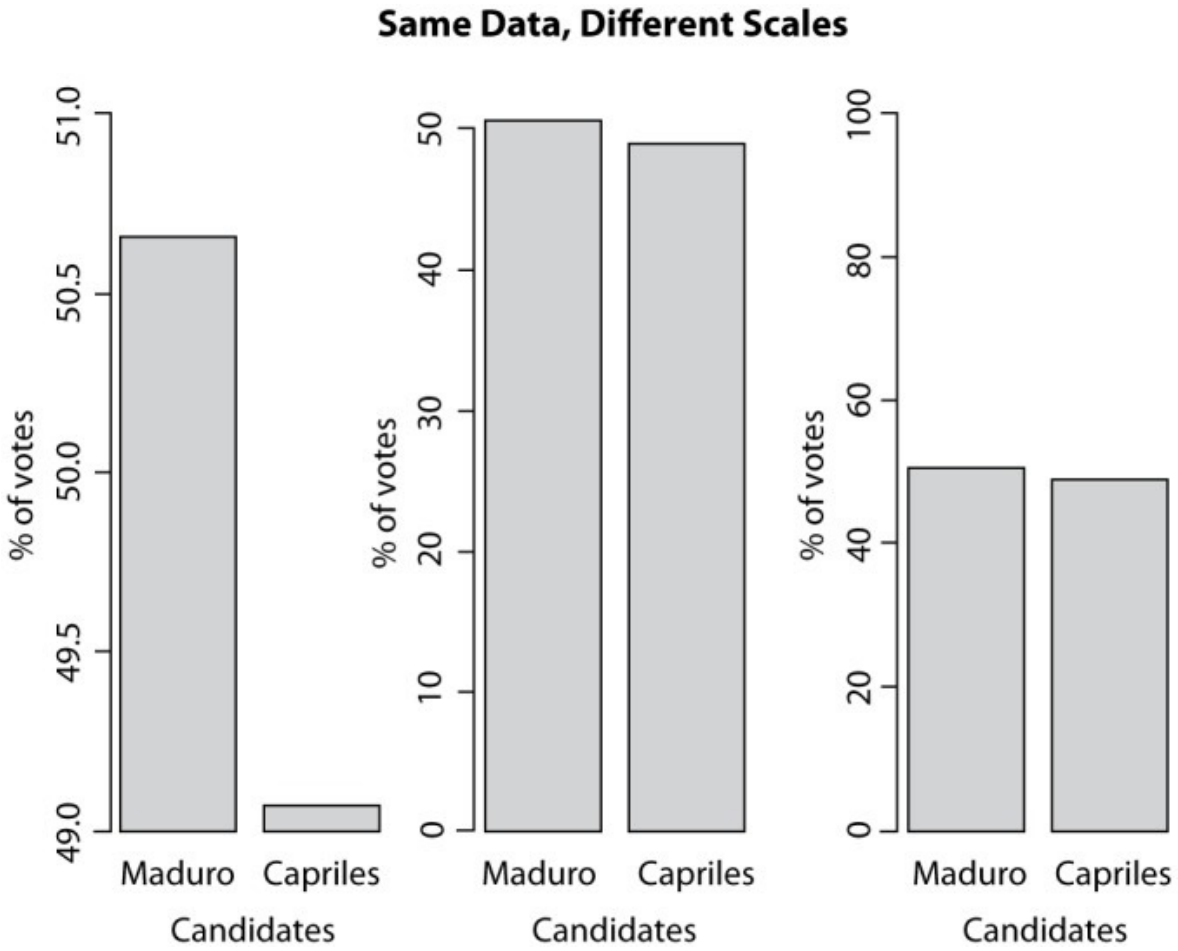
- Zkrácení osy y vyvolává dojem velkého rozdílu



http://www.exercisebiology.com/index.php/site/articles/how_graphs_can_fool_you/

Zkreslení škálou II

- Prezidentské volby ve Venezuele



Takto rozdíl prezentován v novinách

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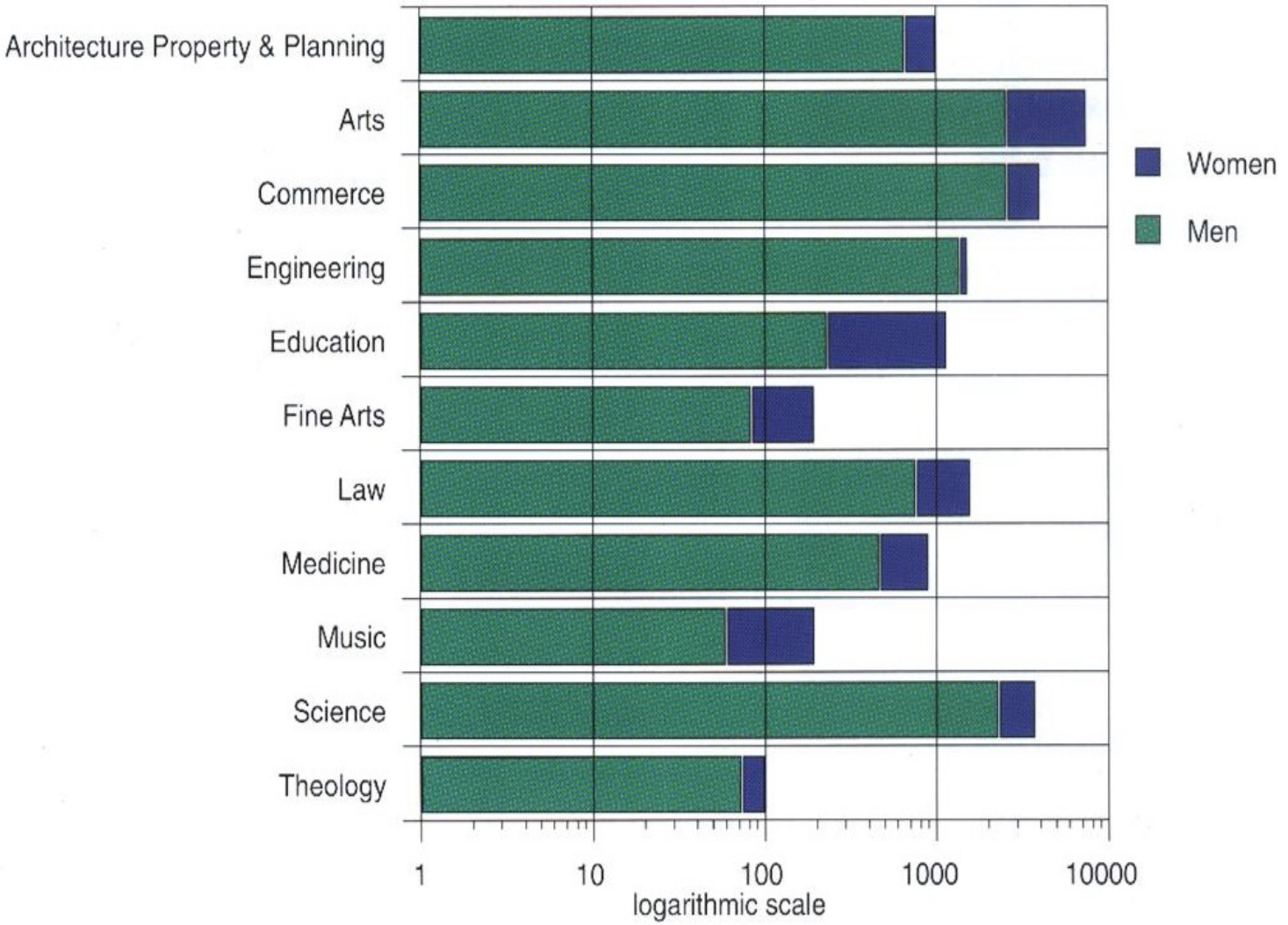
Počty studentů na různých fakultách a podíl mužů a žen

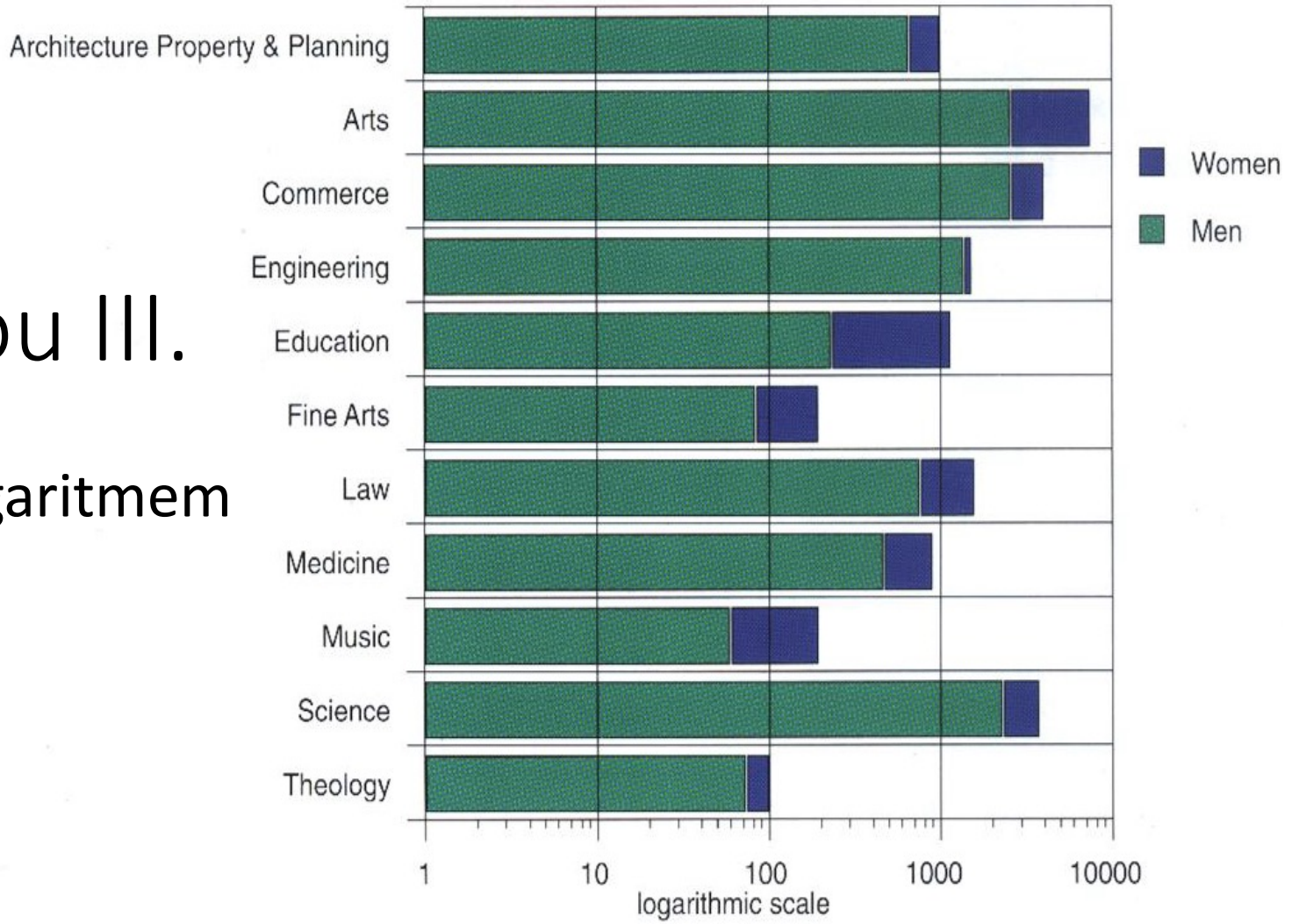


http://www.stat.auckland.ac.nz/~ihaka/120/Lectures/lecture03.pdf

Počty studentů na různých fakultách a podíl mužů a žen

Zkreslení škálou III.

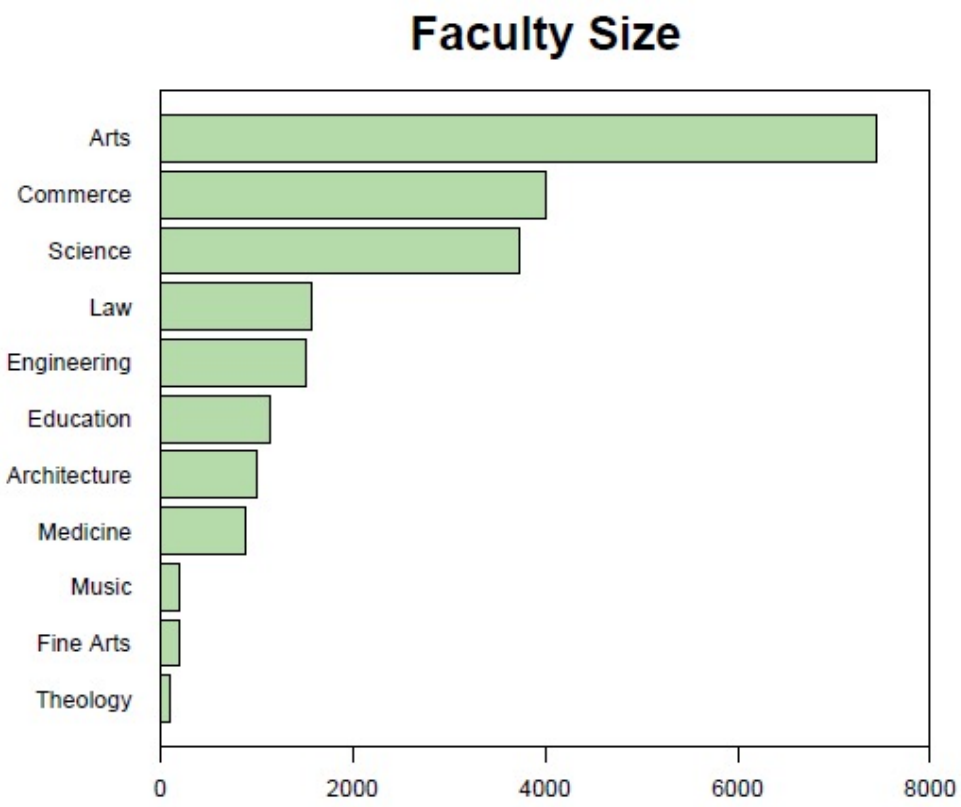
- Transformace osy logaritmem

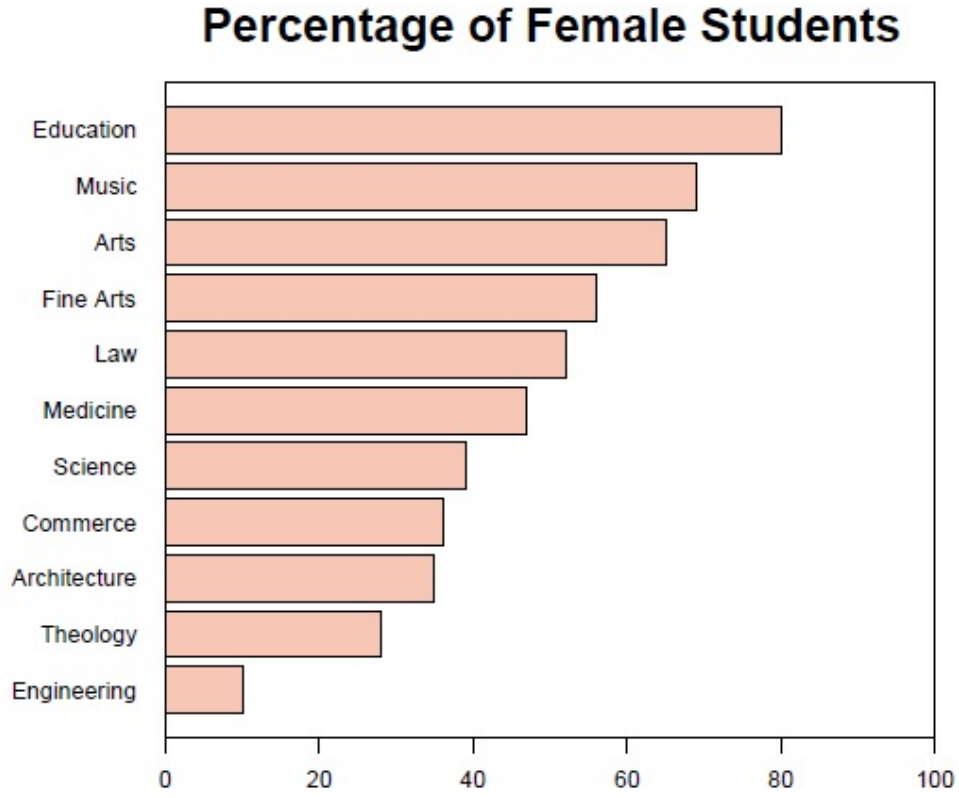


http://www.stat.auckland.ac.nz/~ihaka/120/Lectures/lecture03.pdf

Zkreslení škálou III.

- … to samé bez transformace

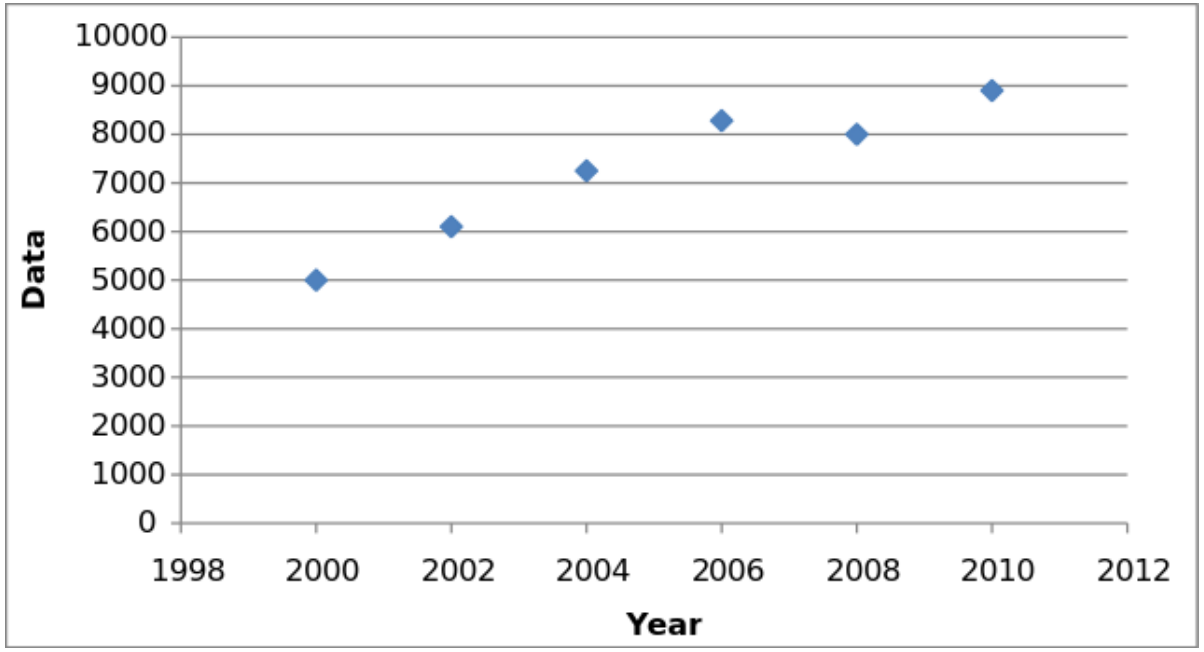




http://www.stat.auckland.ac.nz/~ihaka/120/Lectures/lecture03.pdf

Zkreslení škálou IV.

Chybějící body na ose x – zkreslení linearity



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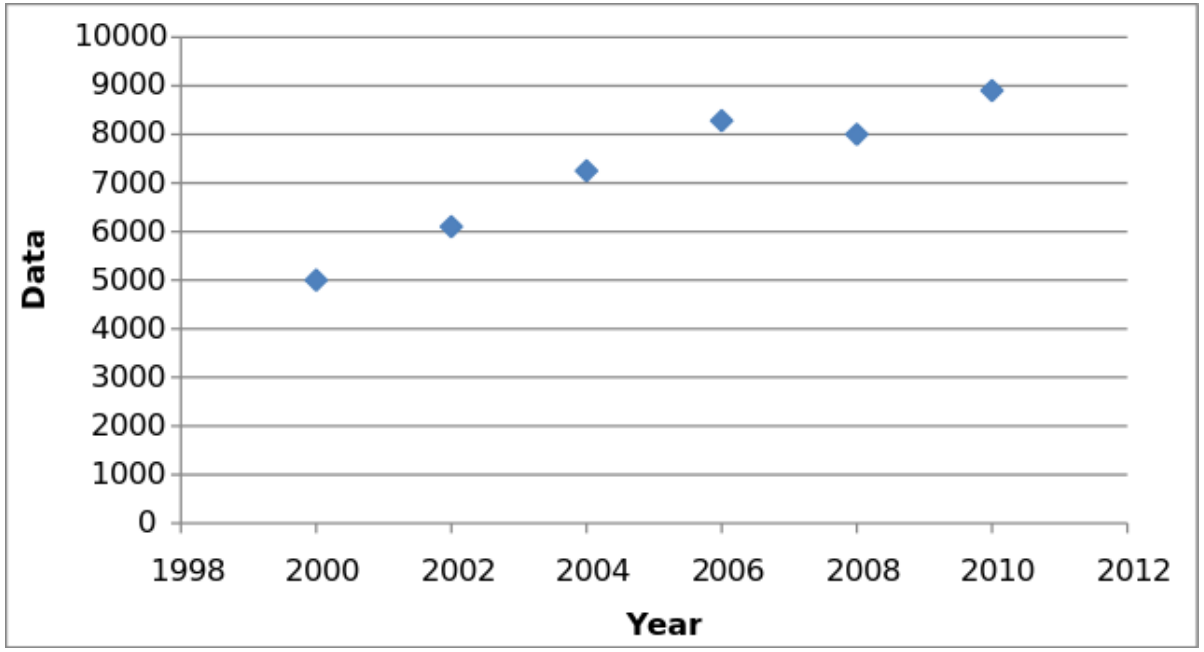
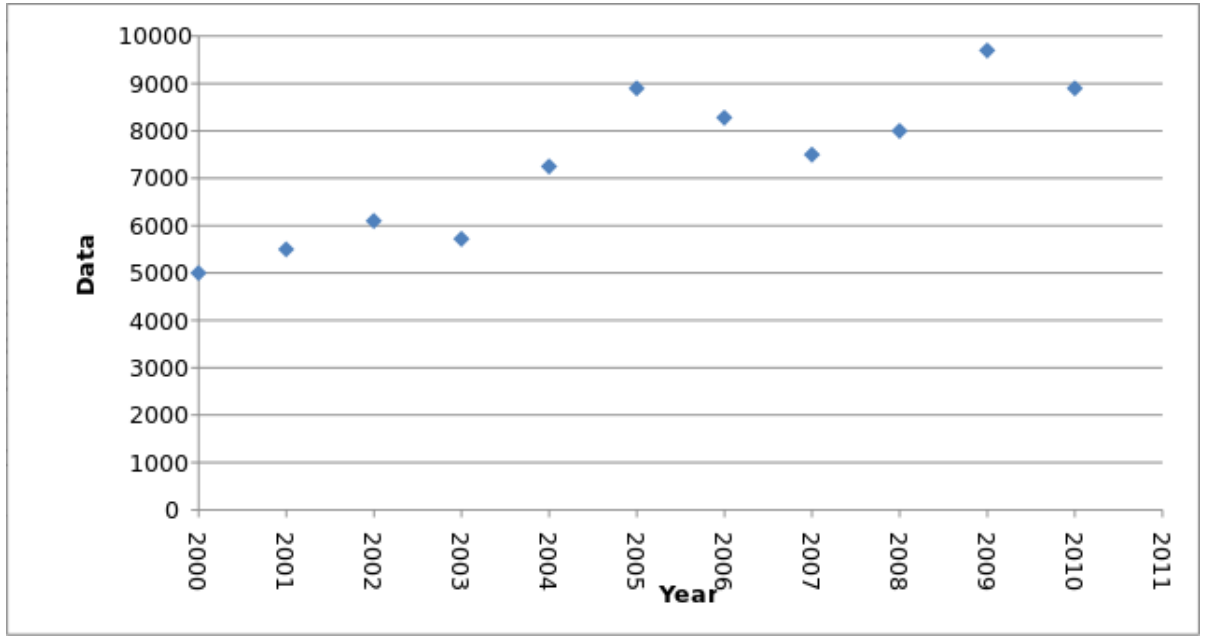
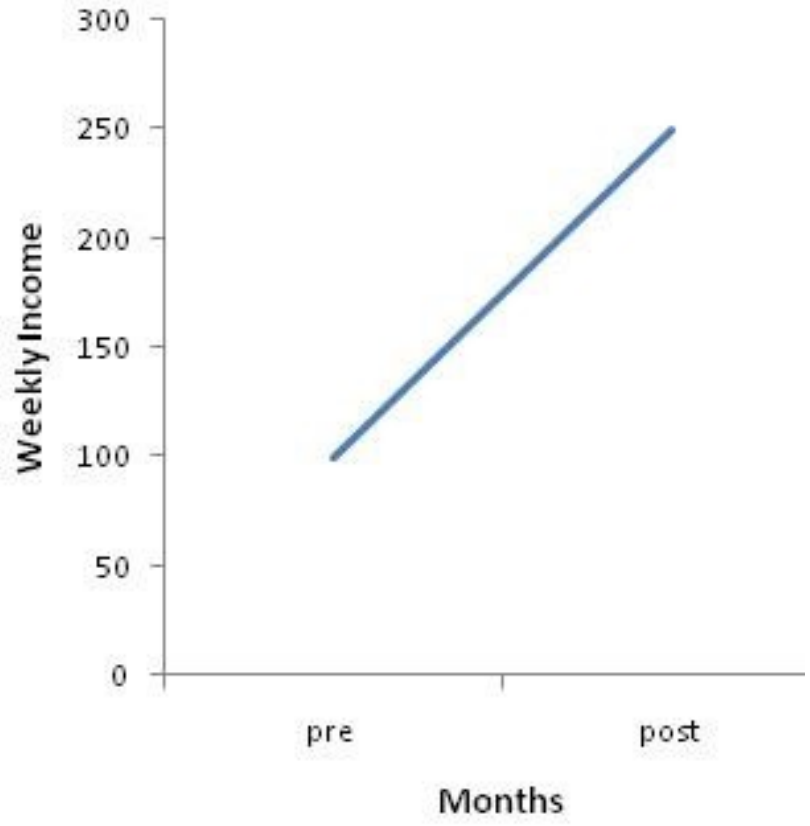




Zkreslení škálou V

Chybějící body na ose x – zkreslení linearity

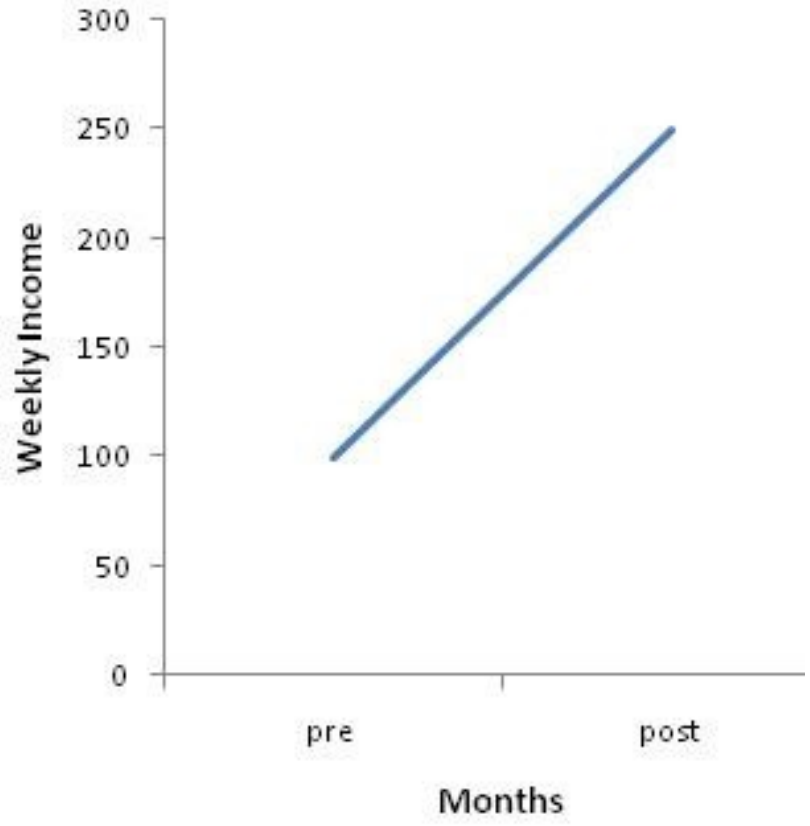


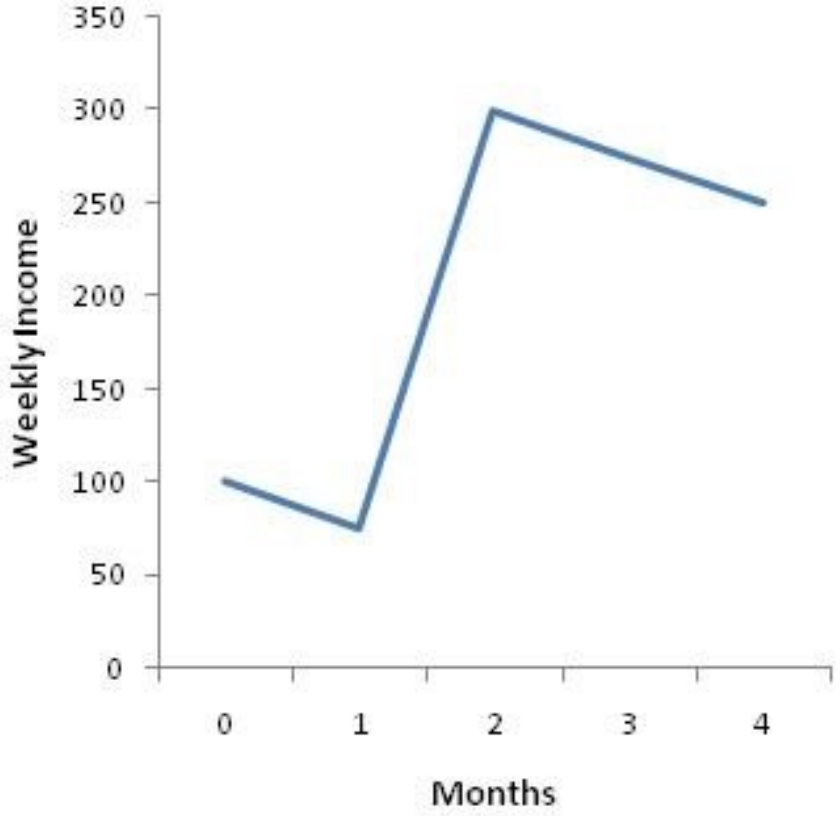
Změny týdenního příjmu

http://www.exercisebiology.com/index.php/site/articles/how_graphs_can_fool_you/

Zkreslení škálou V

Chybějící body na ose x – zkreslení linearity





Změny týdenního příjmu

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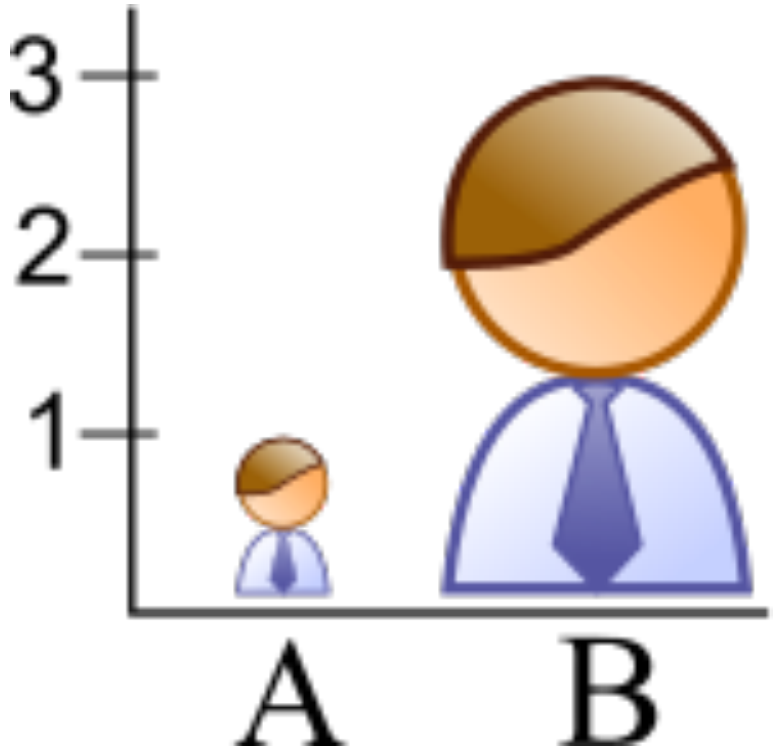
Zkreslení škálou VI

Nesprávné zobrazení jednorozměrného násobného rozdílu pomocí plochy



Zkreslení škálou VI

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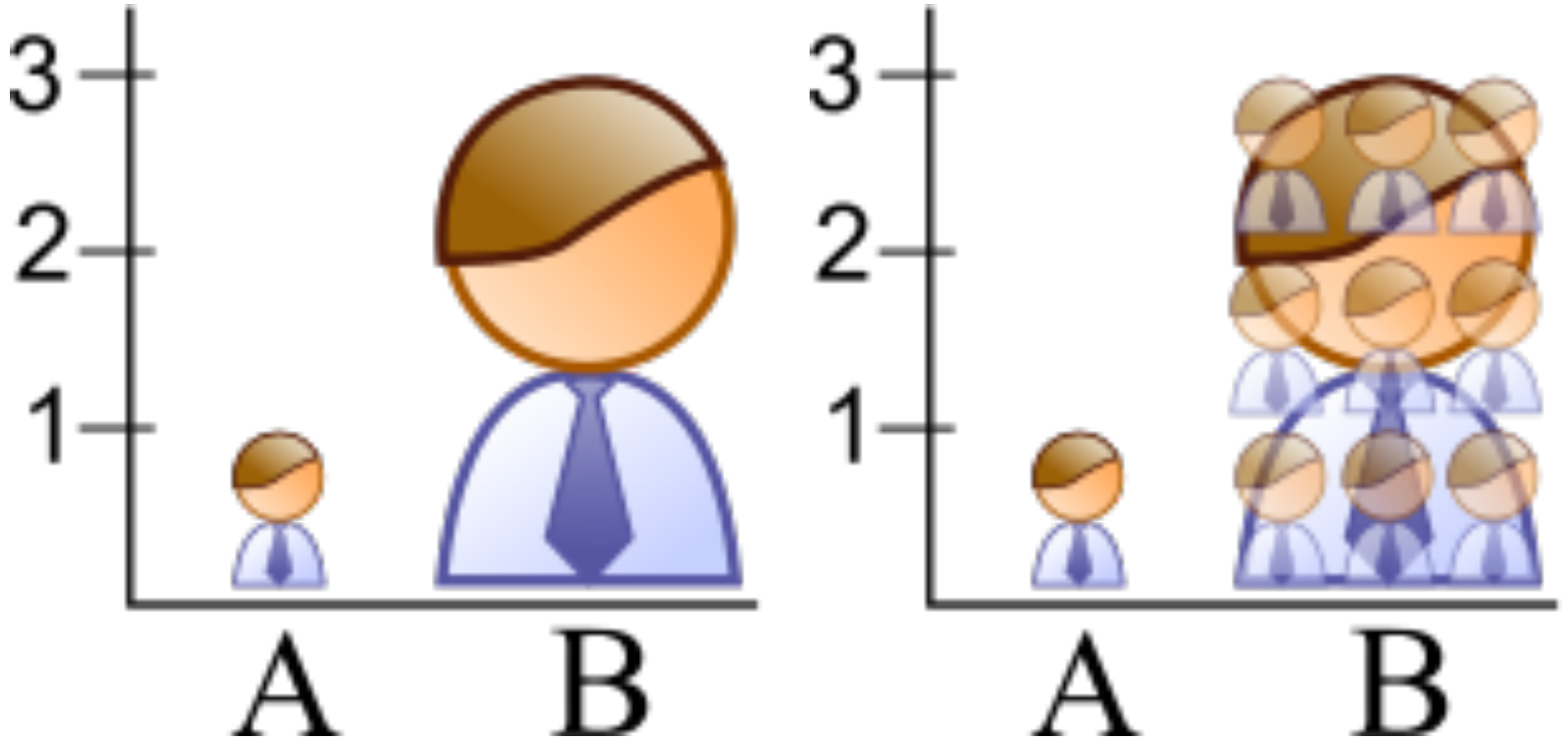
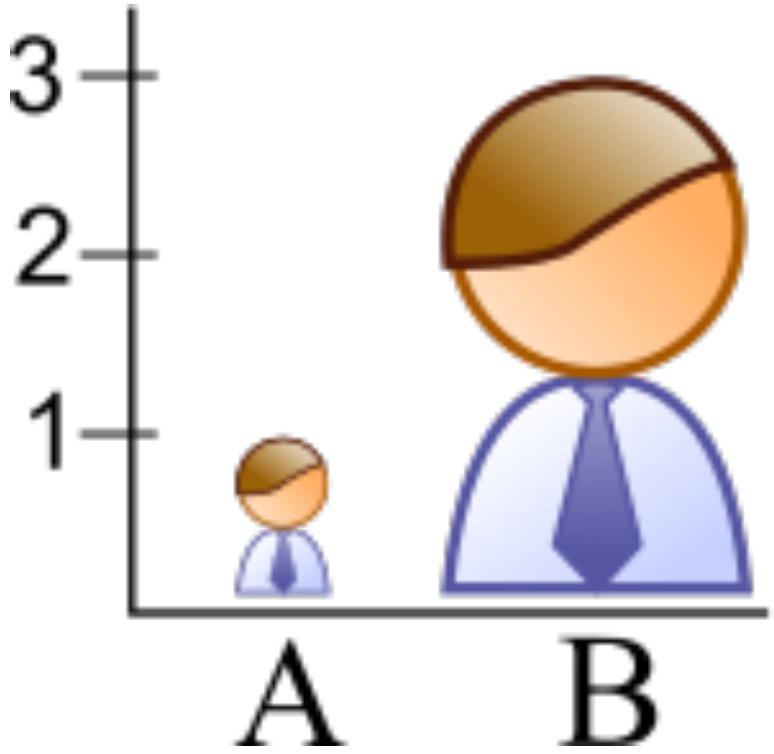
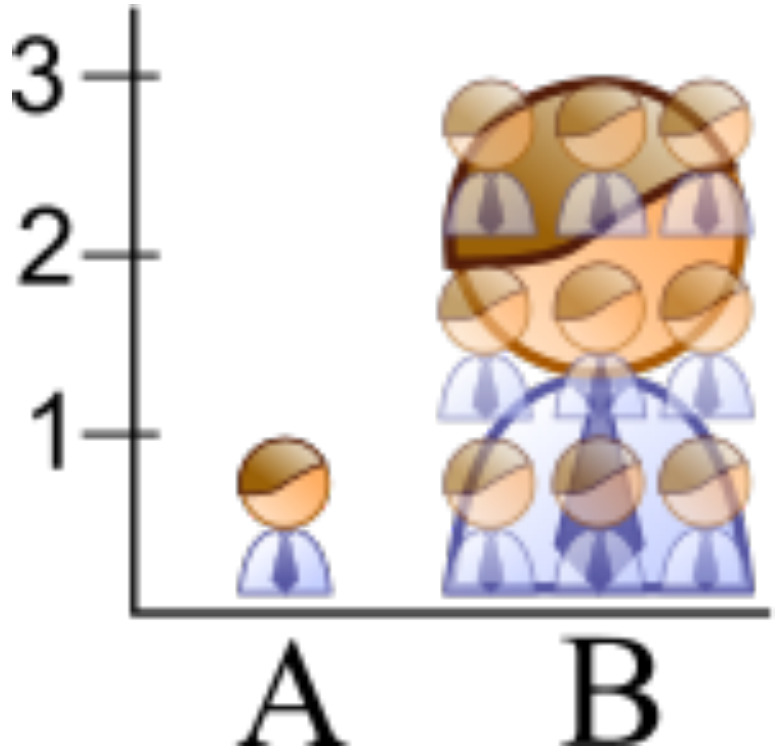


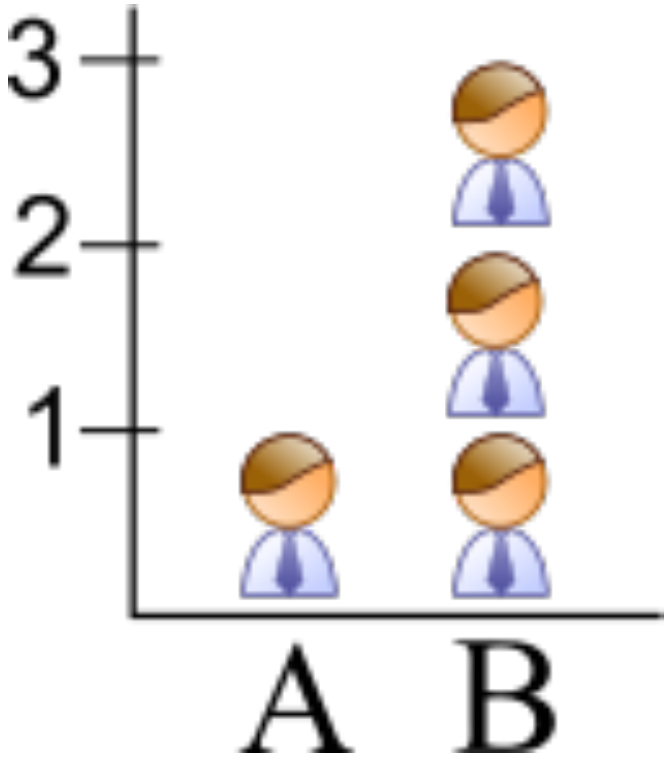
Trojnásobný rozdíl působí jako devítinásobný

Zkreslení škálou VI

Nesprávné zobrazení jednorozměrného násobného rozdílu pomocí plochy







Trojnásobný rozdíl působí jako devítinásobný

Správné zobrazení

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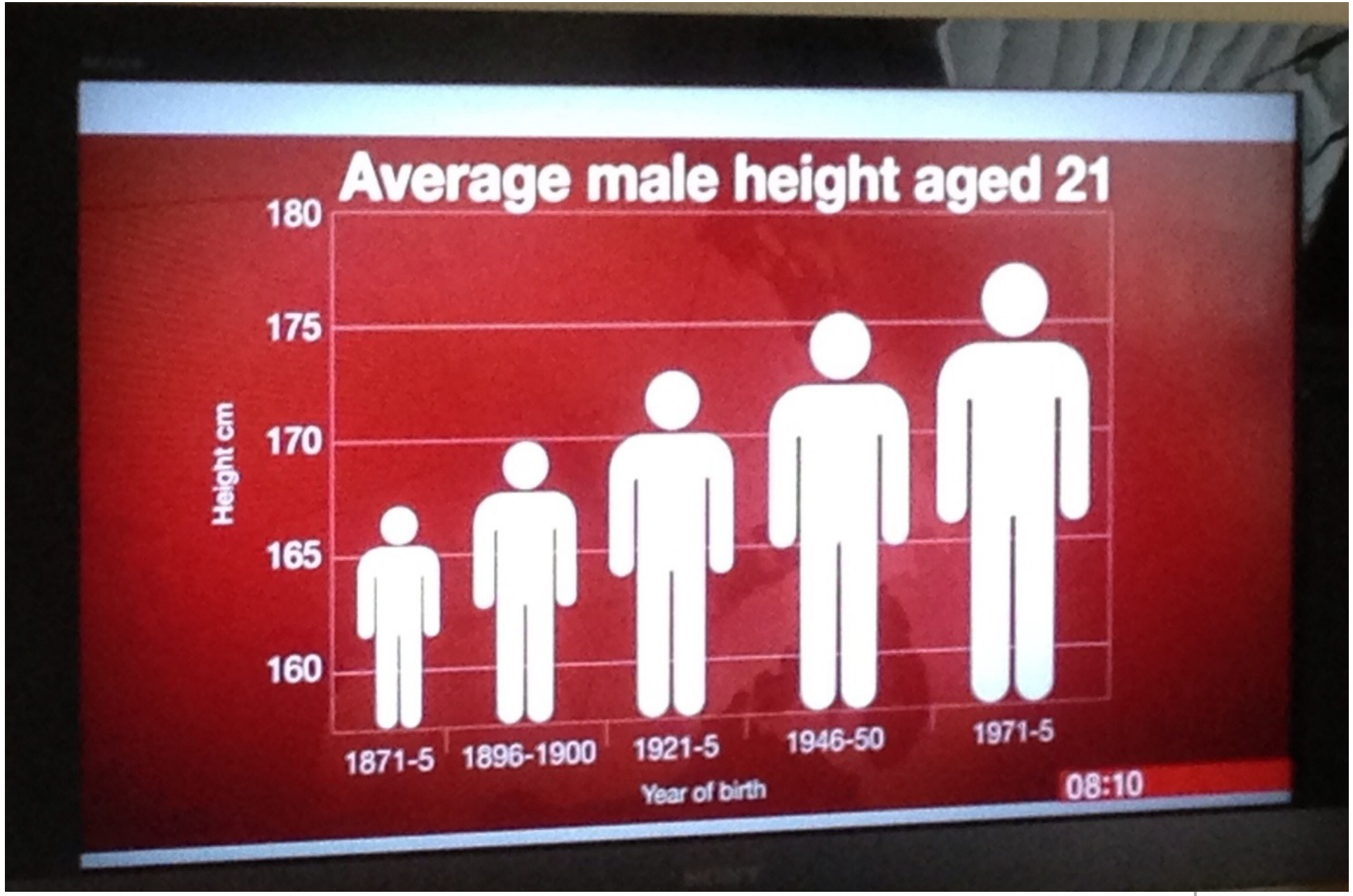
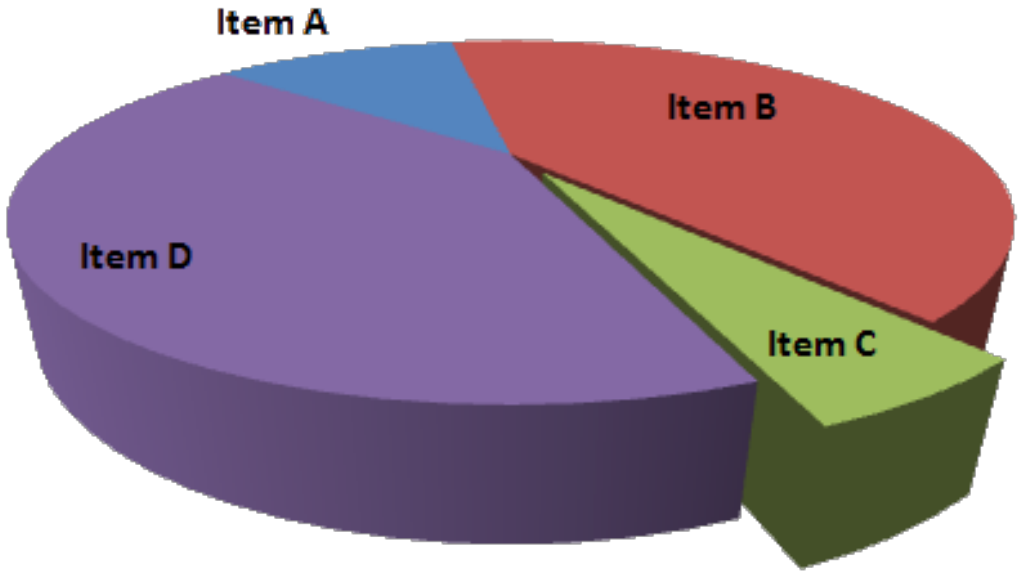
Zkreslení škálou VI.

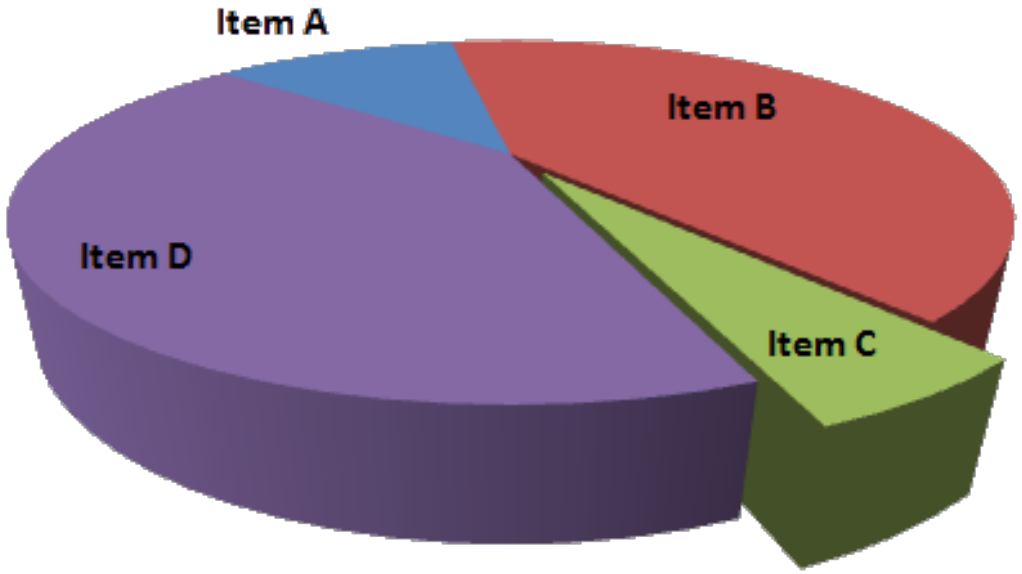

Average male height aged 21
180
175
170
165
160
Height cm
1871-5
1896-1900
1921-5
1946-50
1971-5
Year of birth
08:10

Zkreslení úhlem pohledu a 3D efekty



Item C > Item A ?

Zkreslení úhlem pohledu a 3D efekty



Item C > Item A ?

Item C < Item A !

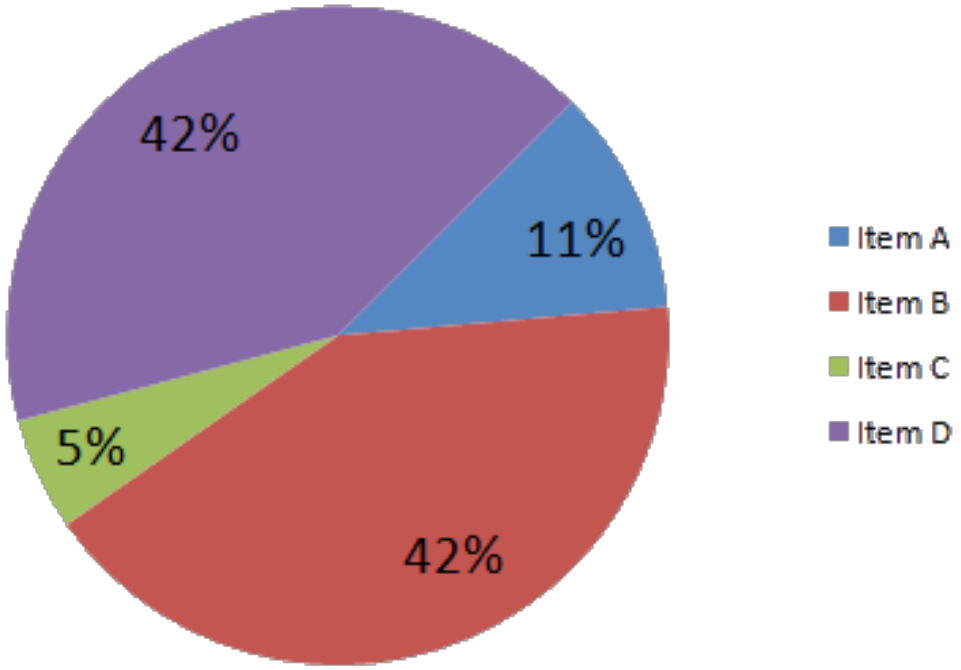


Figure 1. Source: Erickson Times

https://www.forbes.com/sites/naomirobbins/2012/02/16/misleading-graphs-figures-not-drawn-to-scale/#7ea98afa15ef

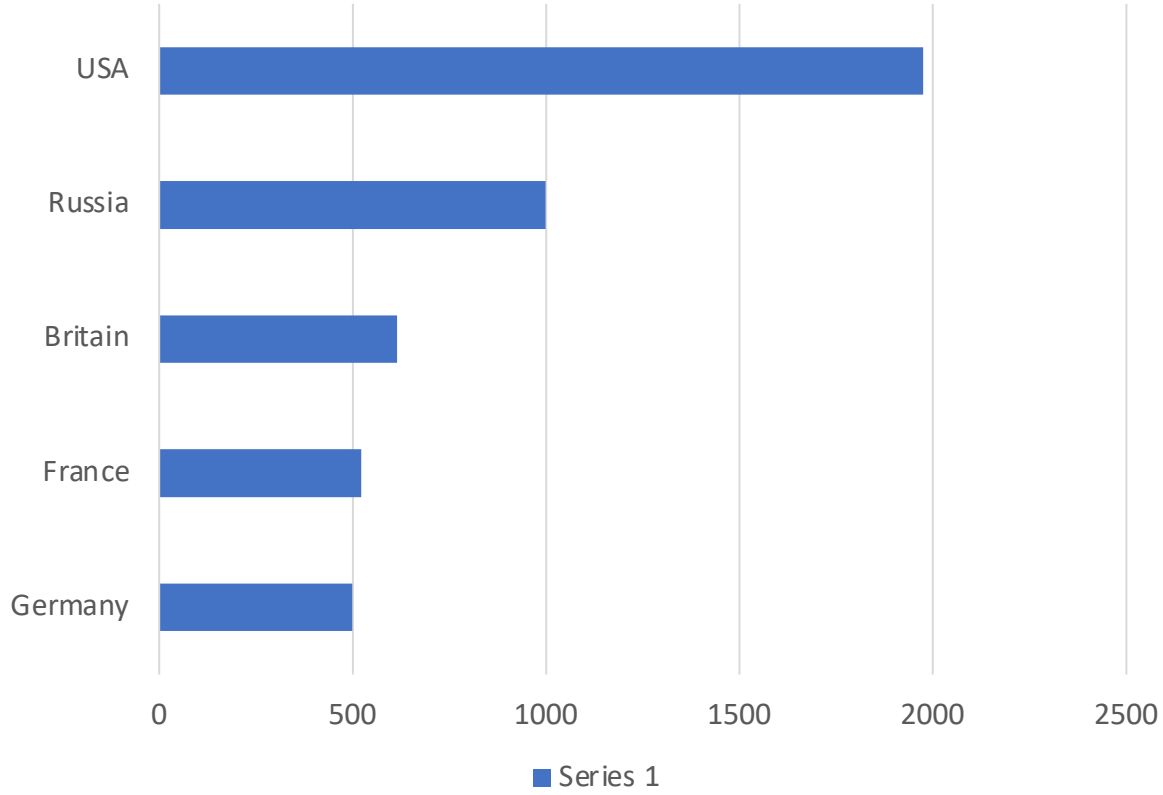


Figure 1. Source: Erickson Times

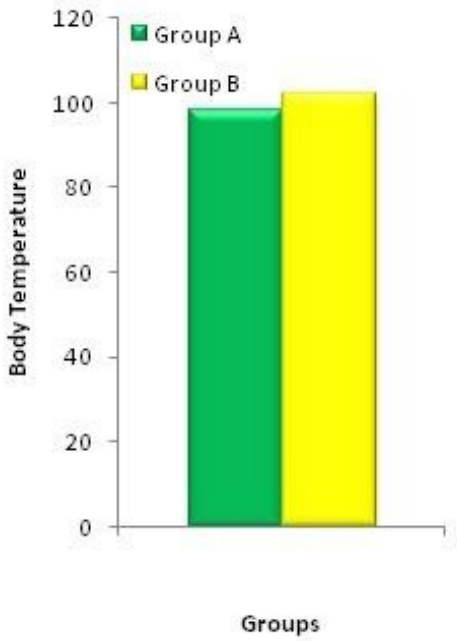
https://www.forbes.com/sites/naomirobbins/2012/02/16/misleading-graphs-figures-not-drawn-to-scale/#7ea98afa15ef

Faktor klamu

$$Faktor\ klamu = \frac{Velikost\ efektu\ v\ grafu}{Velikost\ efektu\ v\ datech}$$

Faktor klamu >1 => změna v grafu je přehnaná
Faktor klamu mezi 0 a 1 => změna v grafu není dostatečně viditelná
Faktor klamu = 1 => perfektní reprezentace skutečného rozdílu

Nesprávný graf – zkreslení významu

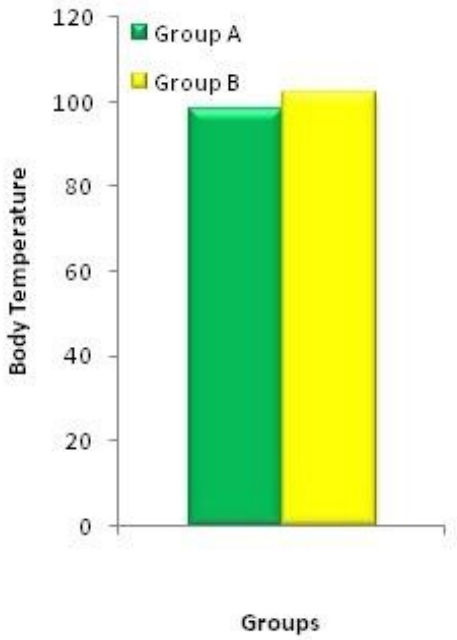


Průměrná tělesná teplota ve dvou skupinách

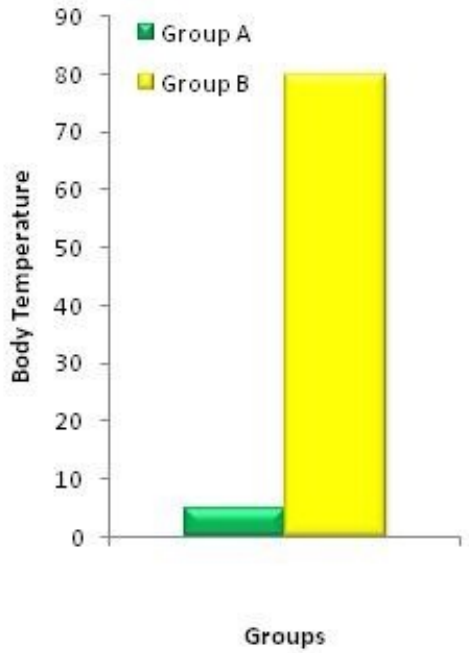
http://www.exercisebiology.com/index.php/site/articles/how_graphs_can_fool_you/

Nesprávný graf – zkreslení významu

Nesprávné zobrazení výsledků dává pocit, že jde o nevýznamný rozdíl



Průměrná tělesná teplota ve dvou skupinách



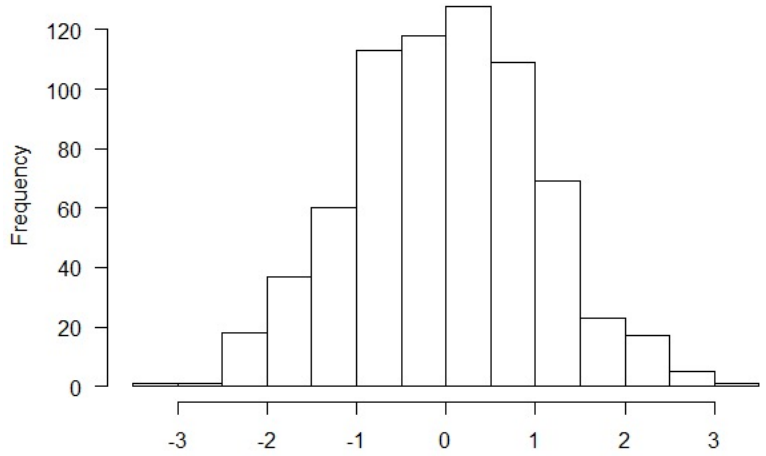
Podíl pacientů se zvýšenou teplotou (>37C)

http://www.exercisebiology.com/index.php/site/articles/how_graphs_can_fool_you/

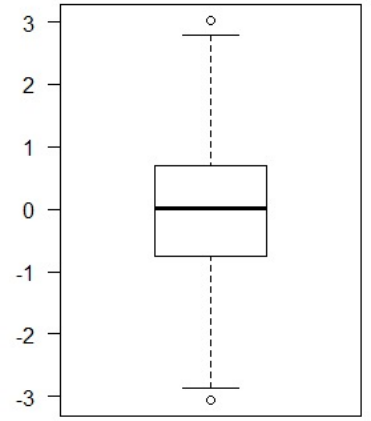
Výběr správného grafu

Grafy zobrazující **rozložení spojitých** proměnných

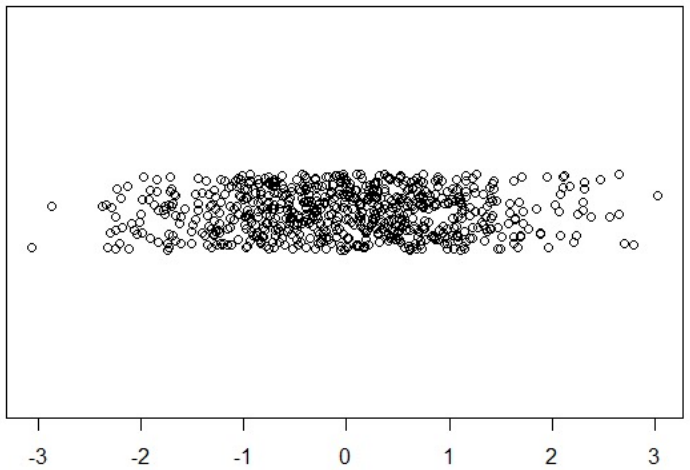
- Histogram



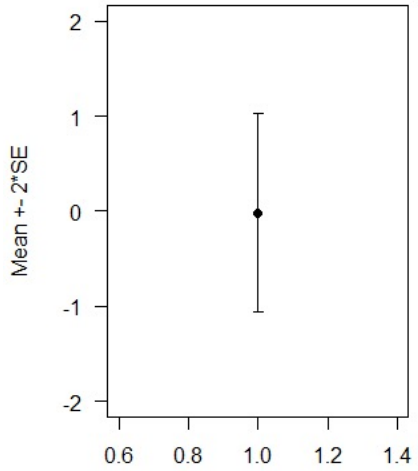
- Krabicový graf



- Jednorozměrný bodový graf



- Průměr a chyba



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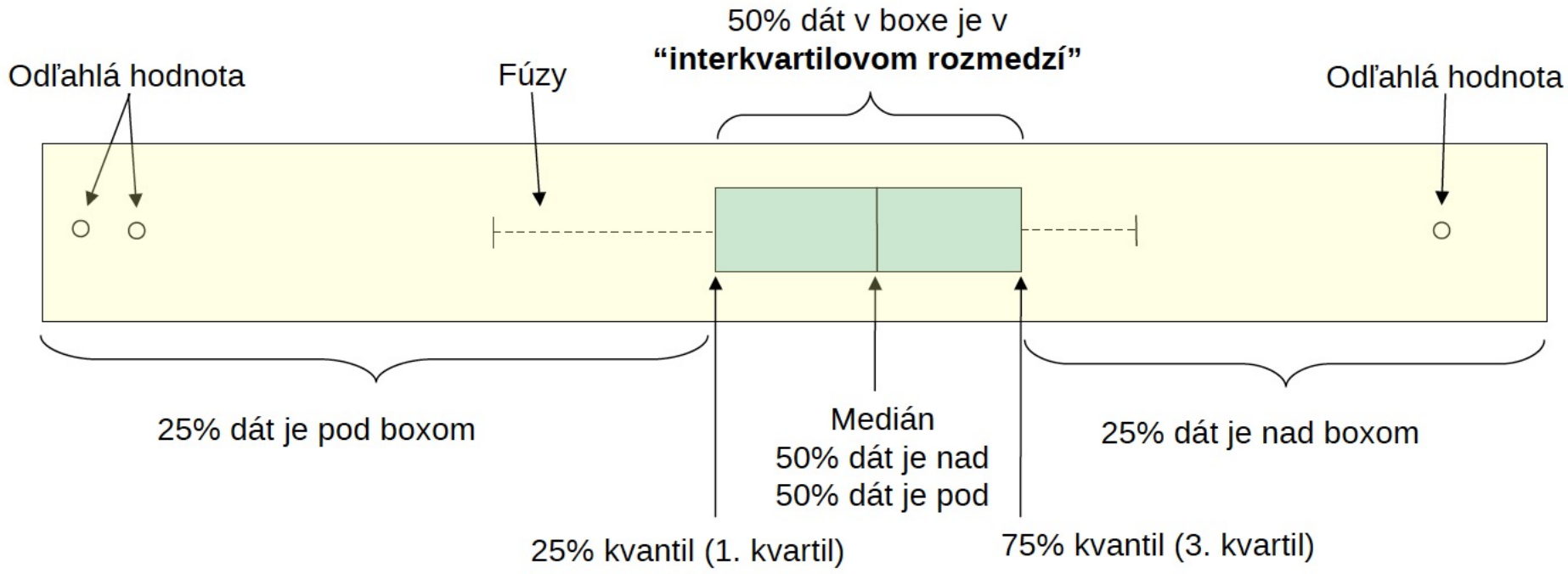
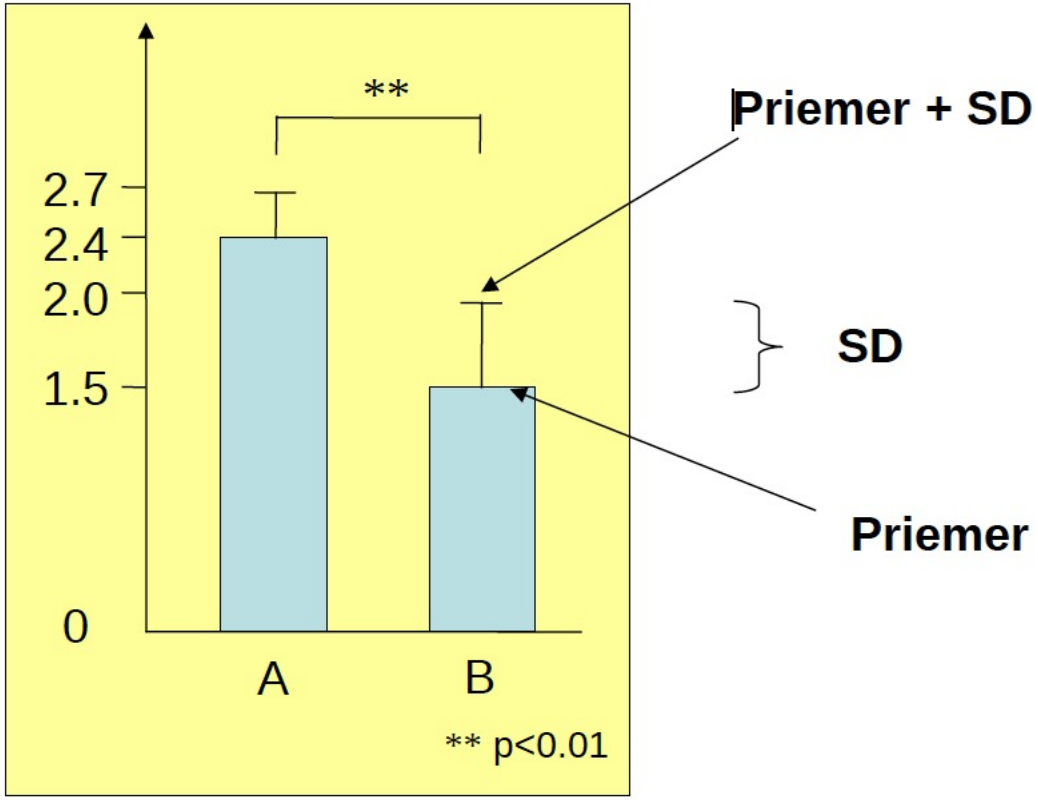
Krabicový graf (box and whisker plot)



- **Odľahlé hodnoty** (neobvyklé hodnoty) – tie dátové body, ktorých vzdialenosť od boxu je väčšia ako 1.5 krát interkvartilové rozmedzie.
- **Fúzy** (whiskers) sa rozpínajú k poslednému neodľahlému bodu
- Boxplot je grafická reprezentácia **5-číselného zhrnutia**:

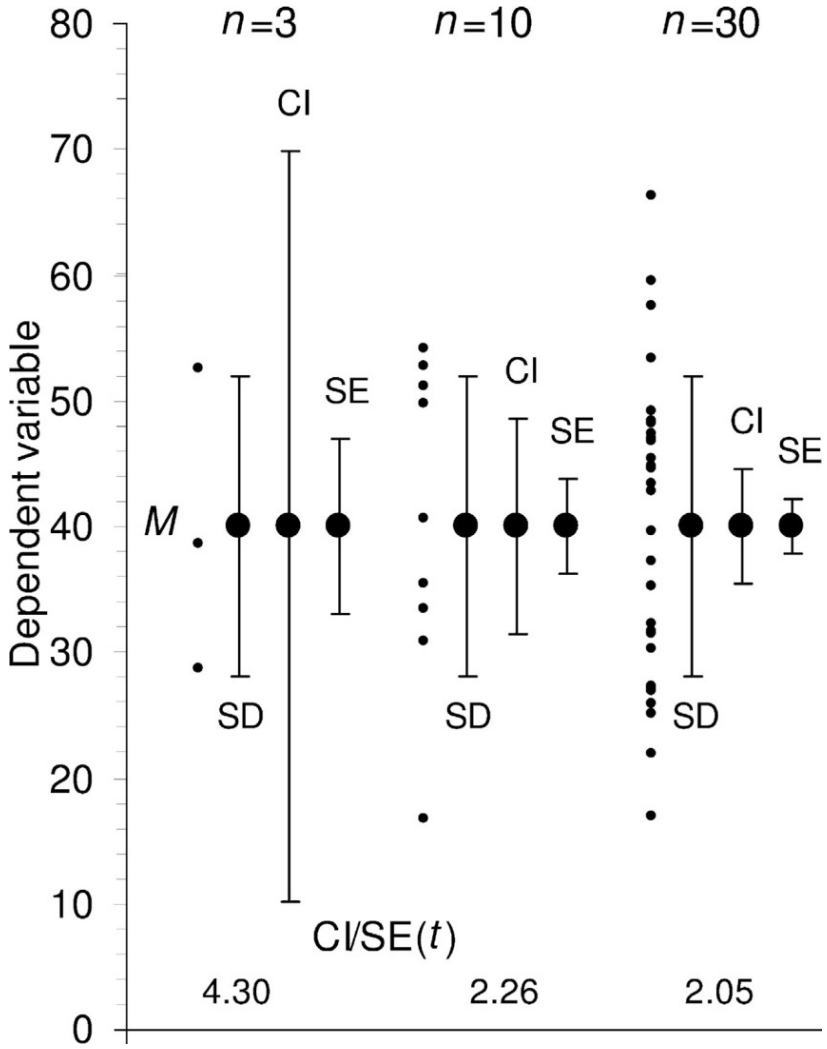
Minimum, Prvý kvartil (25%), Medián, Tretí kvartil (75%), Maximum

Speciální případ – sloupcový graf s chybou



Průměr měření skupiny A (25 vzorků) a B (18 vzorků) s indikací směrodatné odchylky každé skupiny; byl aplikován oboustranný dvouvýběrový T-test.

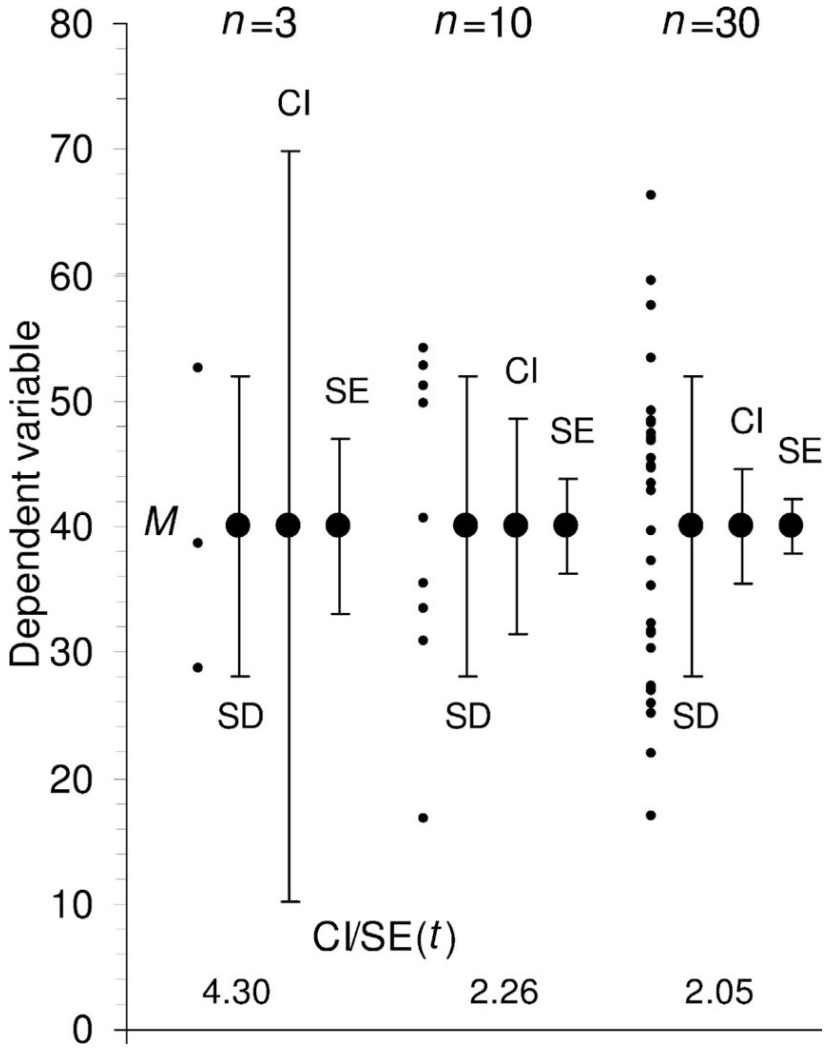
Sloupcový graf s chybou – ale kterou?



Popisná chyba:
SD - směrodatná odchylka

Inferenční (odvozovací) chyba:
SE - standardní chyba
CI - interval spolehlivosti

Sloupcový graf s chybou – ale kterou?



$$SD = \sqrt{\frac{\sum (X - \bar{X})^2}{n - 1}}$$

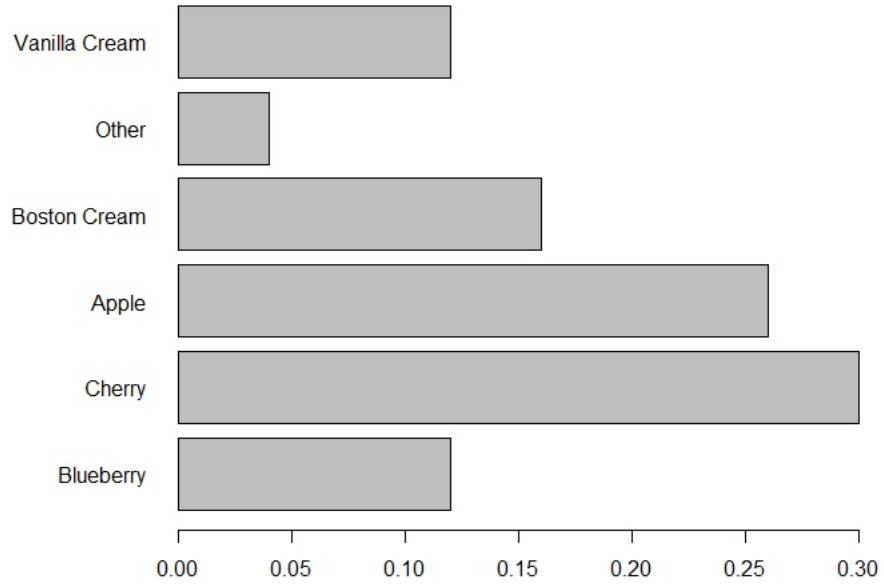
$$SE_{\bar{x}} = \frac{SD}{\sqrt{n}}$$

$$\bar{x} \pm 1.96 \times SE_{\bar{x}}$$

Grafy zobrazující **frekvenci kategoriálních** proměnných

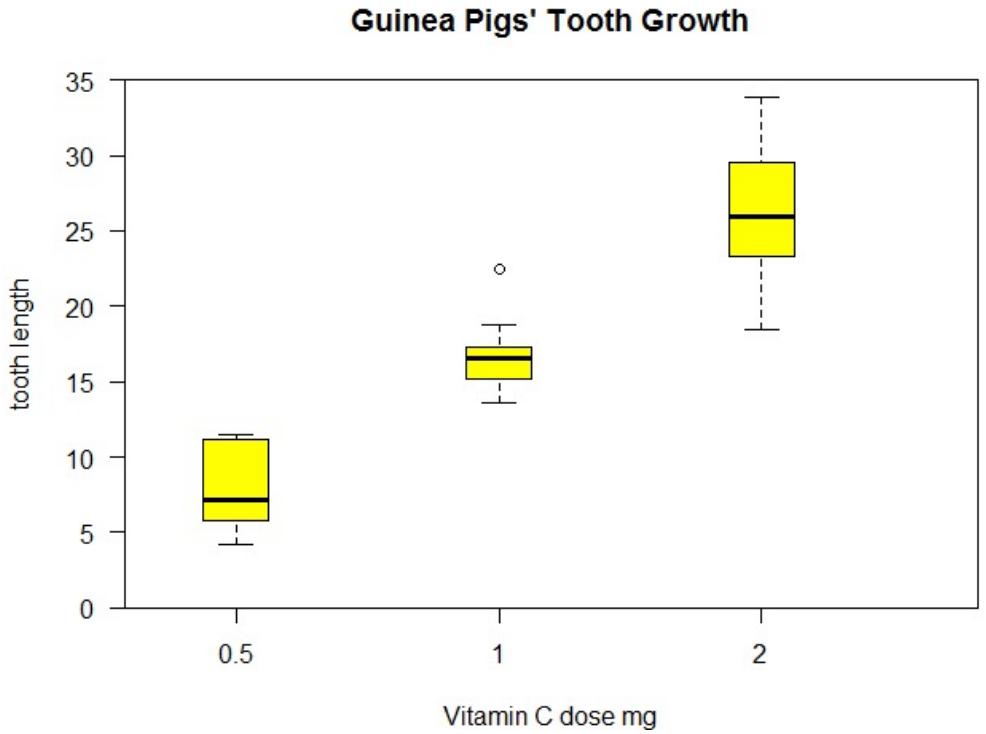
- Koláčový graf

- Sloupcový graf

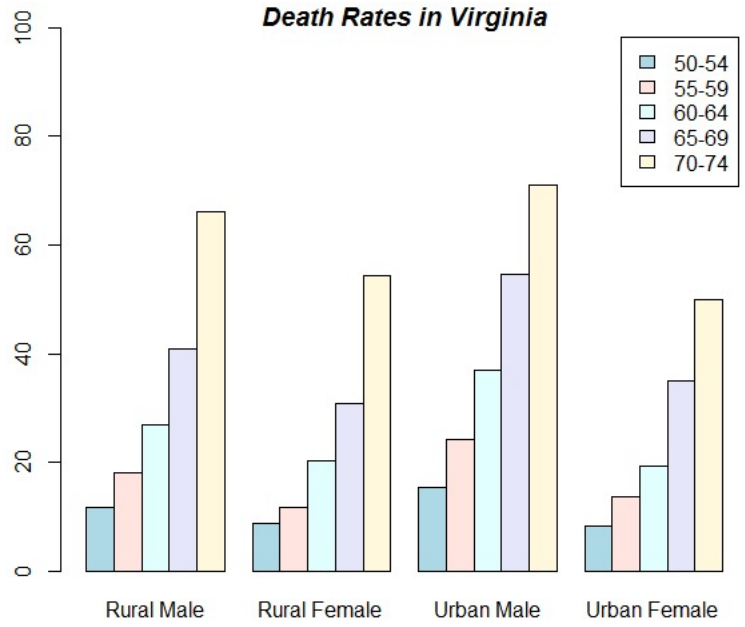


Grafy zobrazující asociaci **kategoriální** a **spojité** proměnné

- Krabicové grafy v kategoriích



- Kategorizovaný sloupcový graf



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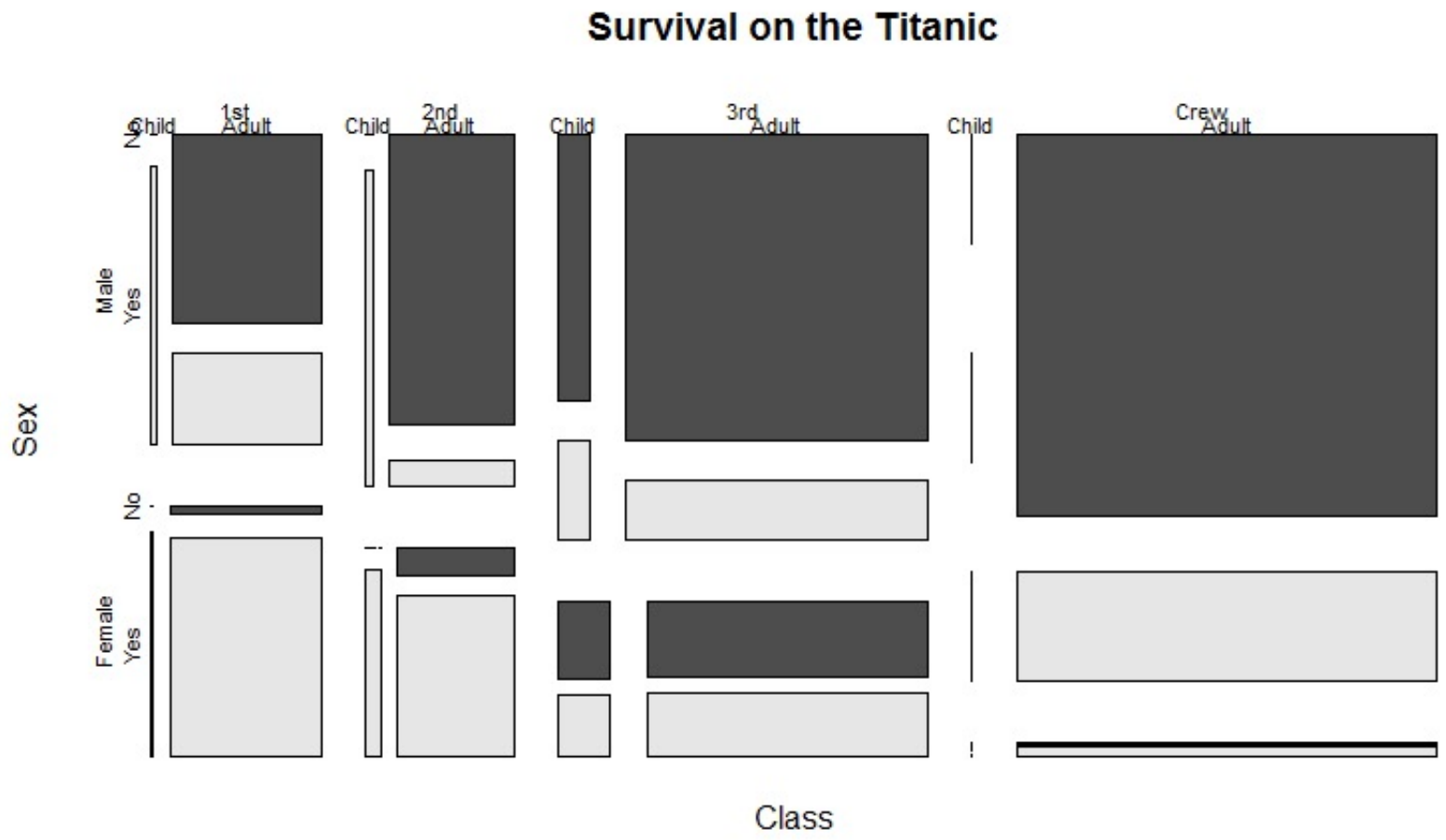
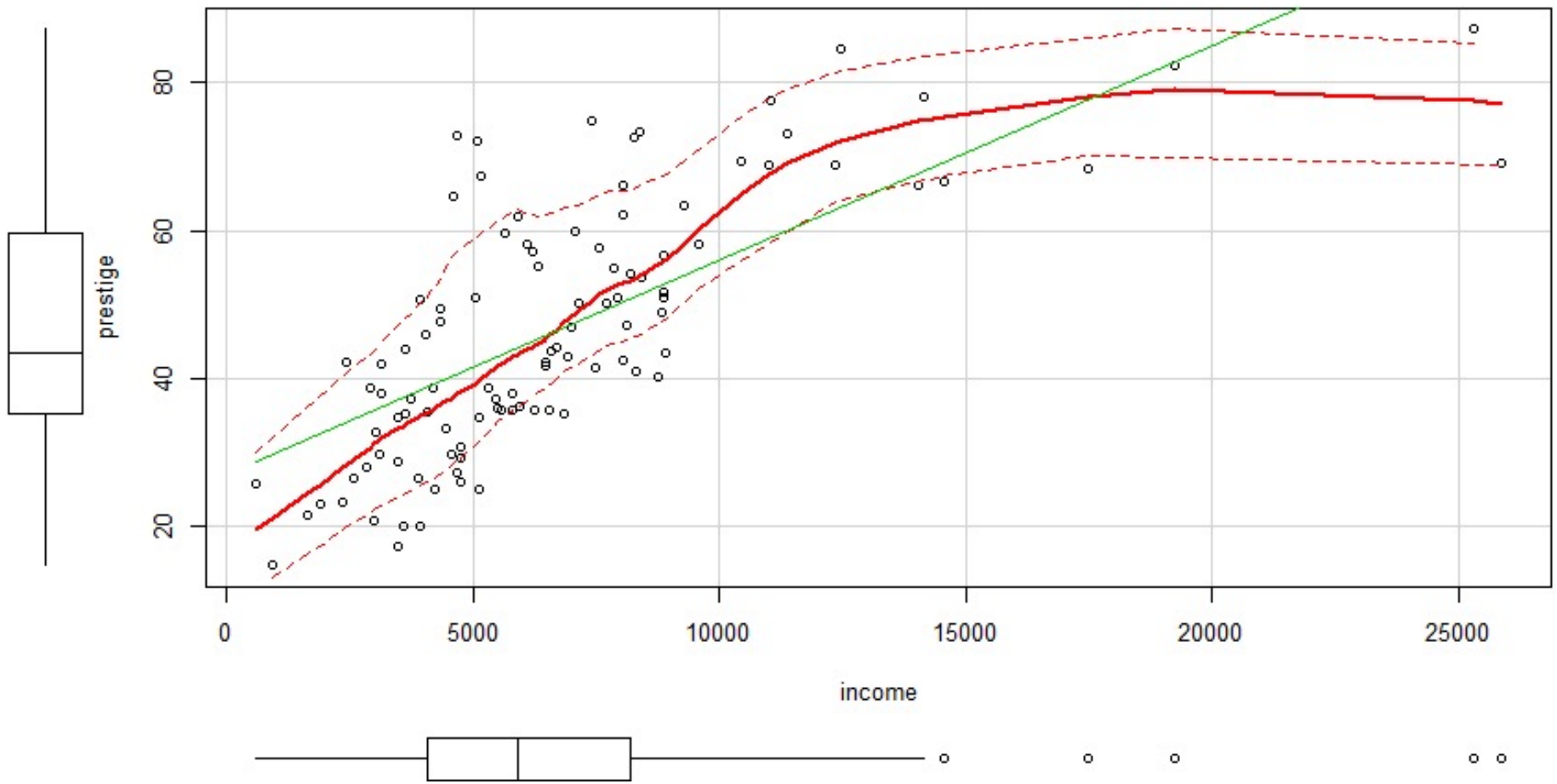
Grafy zobrazující asociaci **dvou kategoriálních** proměnných

- Mozaikový graf



Grafy zobrazující asociaci **dvou spojitých** proměnných

- Dvouroměrný x-y graf



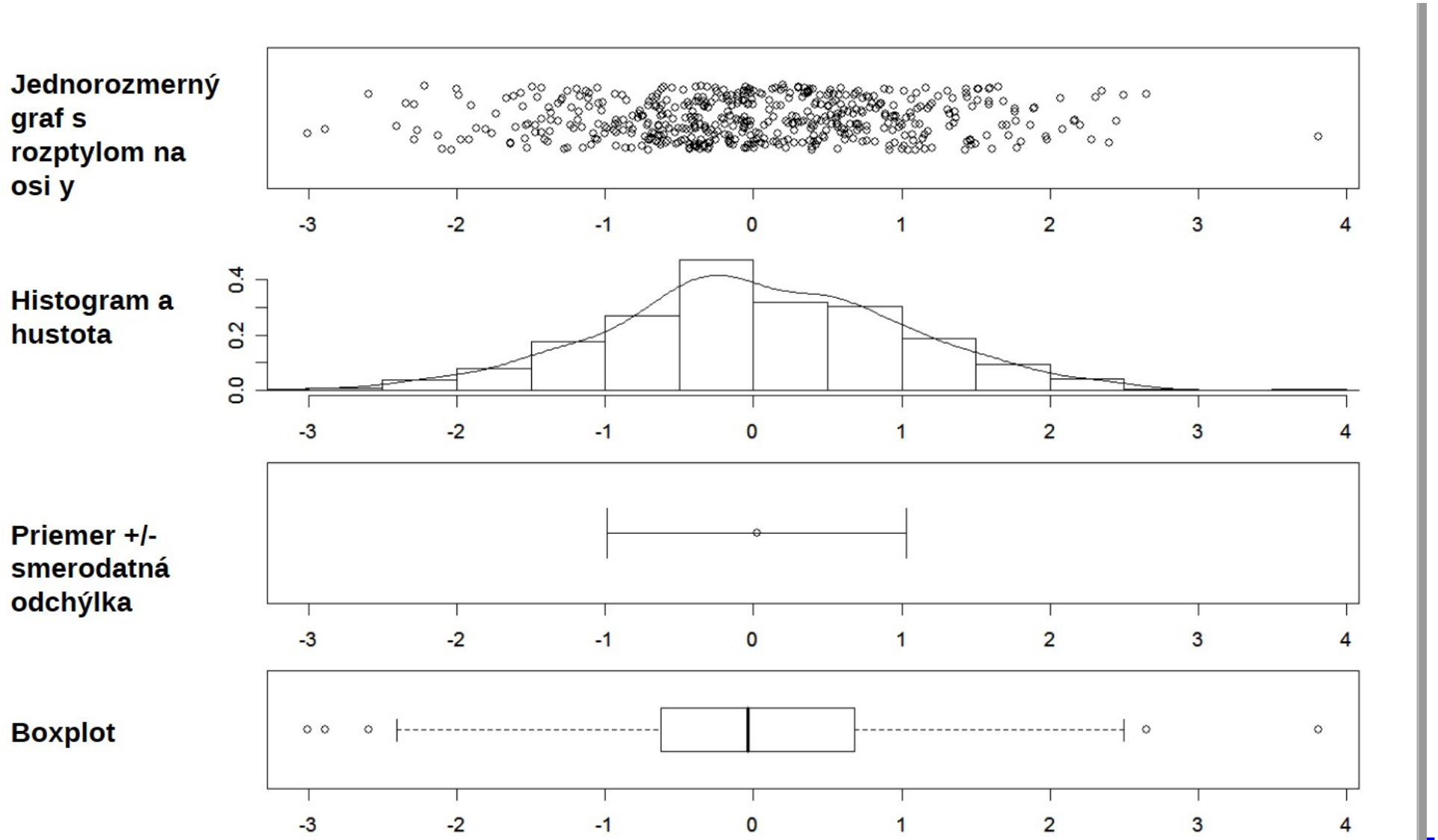
Cvičení

- Různé datové soubory vs. 4 metody zobrazení:

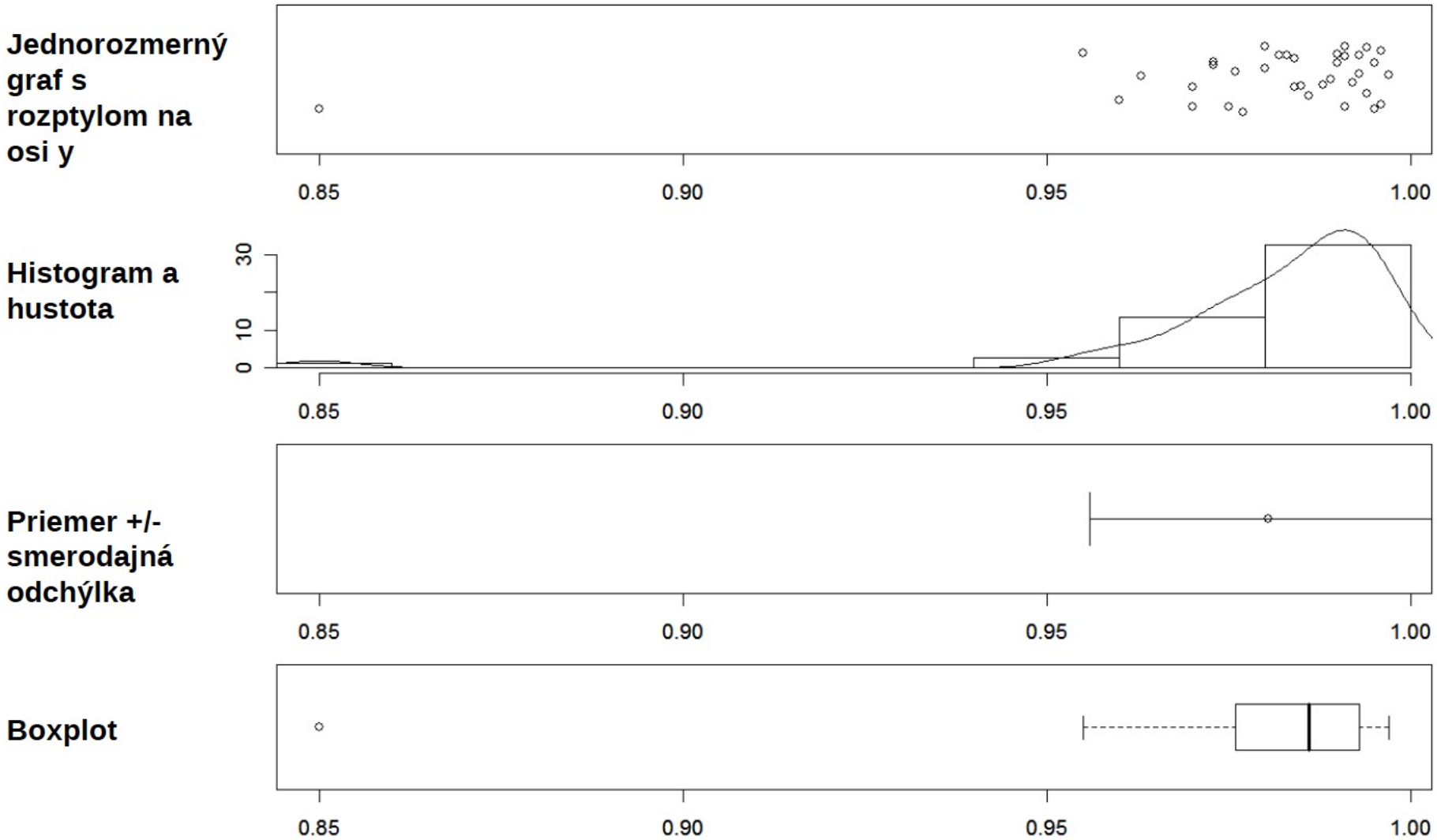
- Jednorozměrné individuální body (s rozptylem na ose y)
- Histogram s hustotou
- Průměr +/- směrodatná odchylka
- Boxplot

Vyberte **nejvíce** a **nejméně informativní** graf co se týká **rozložení hodnot**, u každého datového souboru.

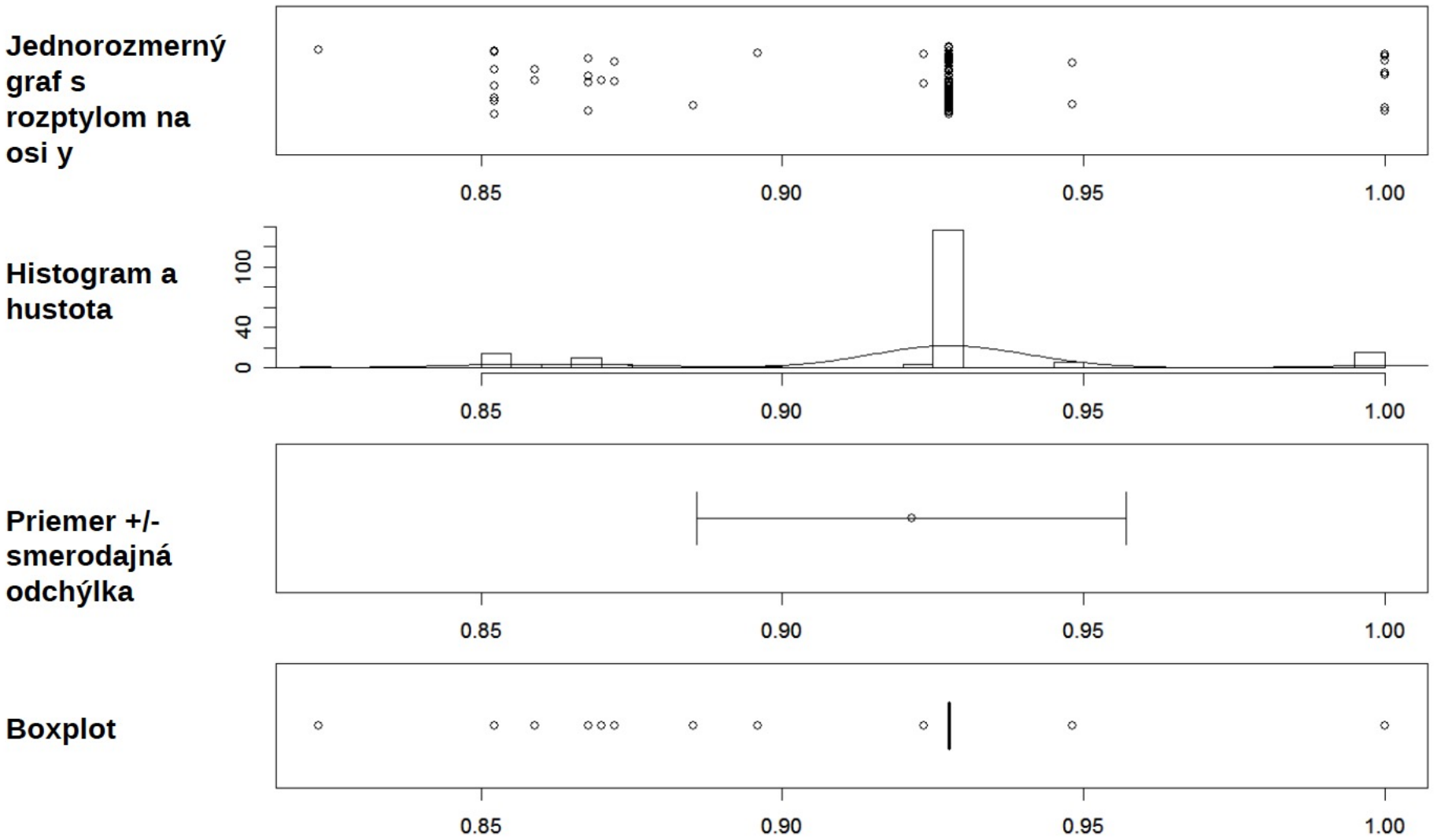
Příklad 1. Náhodné rozložení, N=400



Príklad 2. N=37



Príklad 3. N=100



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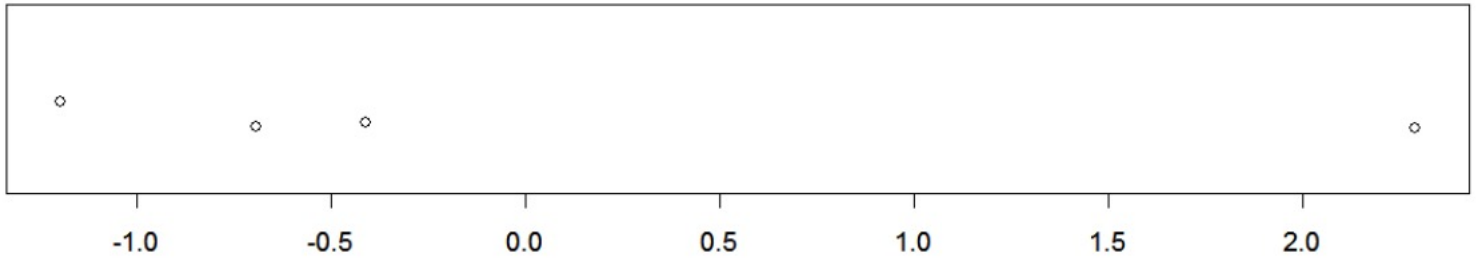
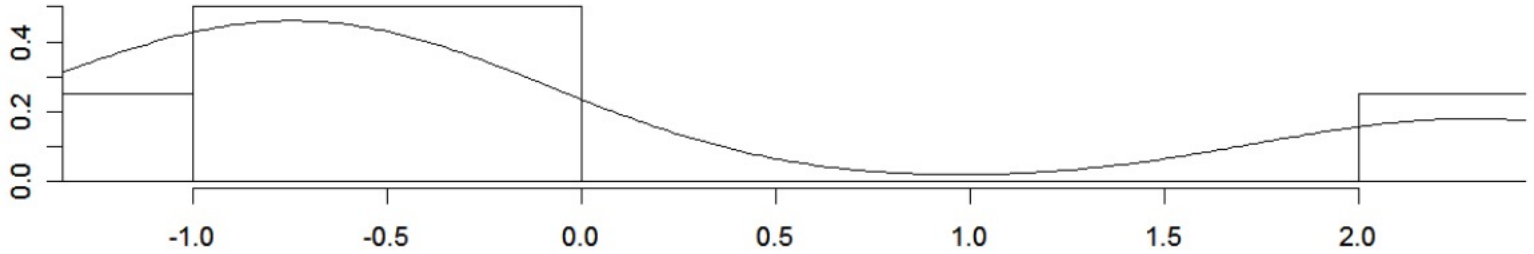
Príklad 4. N=4

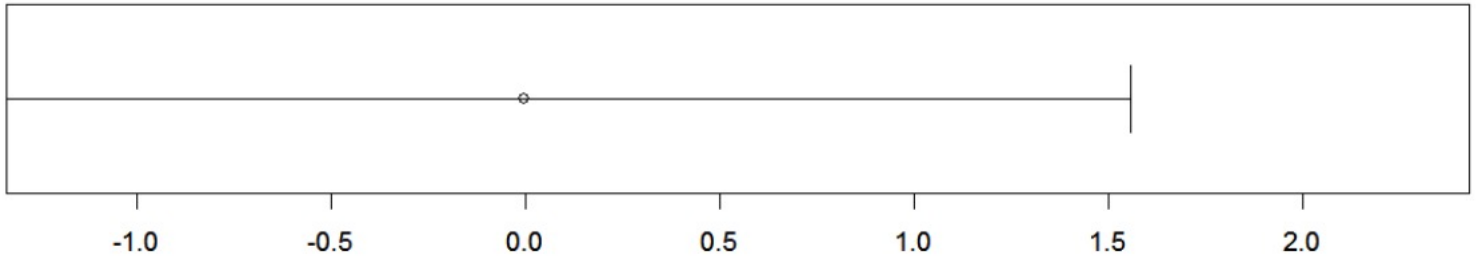
Jednorozmerný graf s rozptylom na osi y



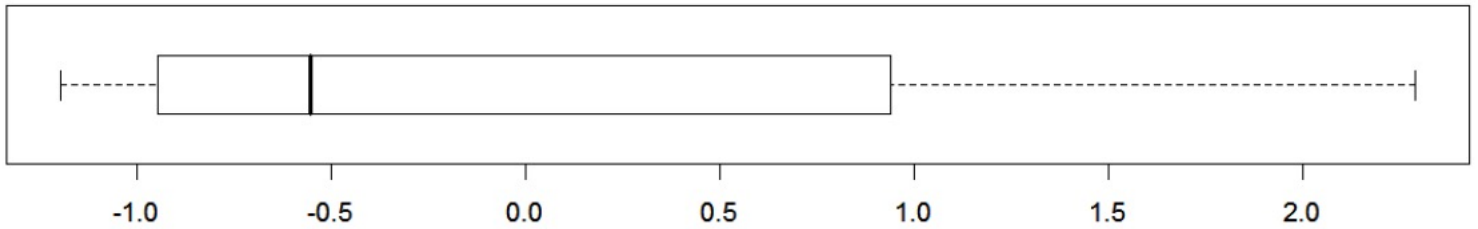
Histogram a hustota



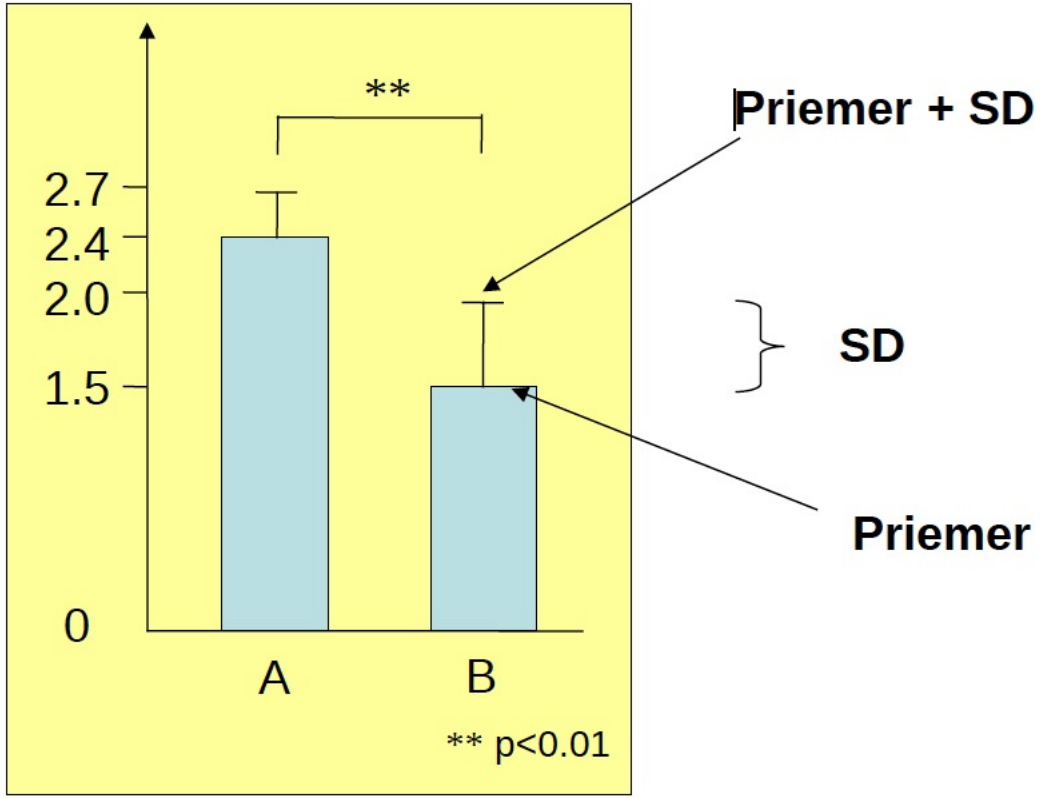
Priemer +/- smerodajná odchýlka



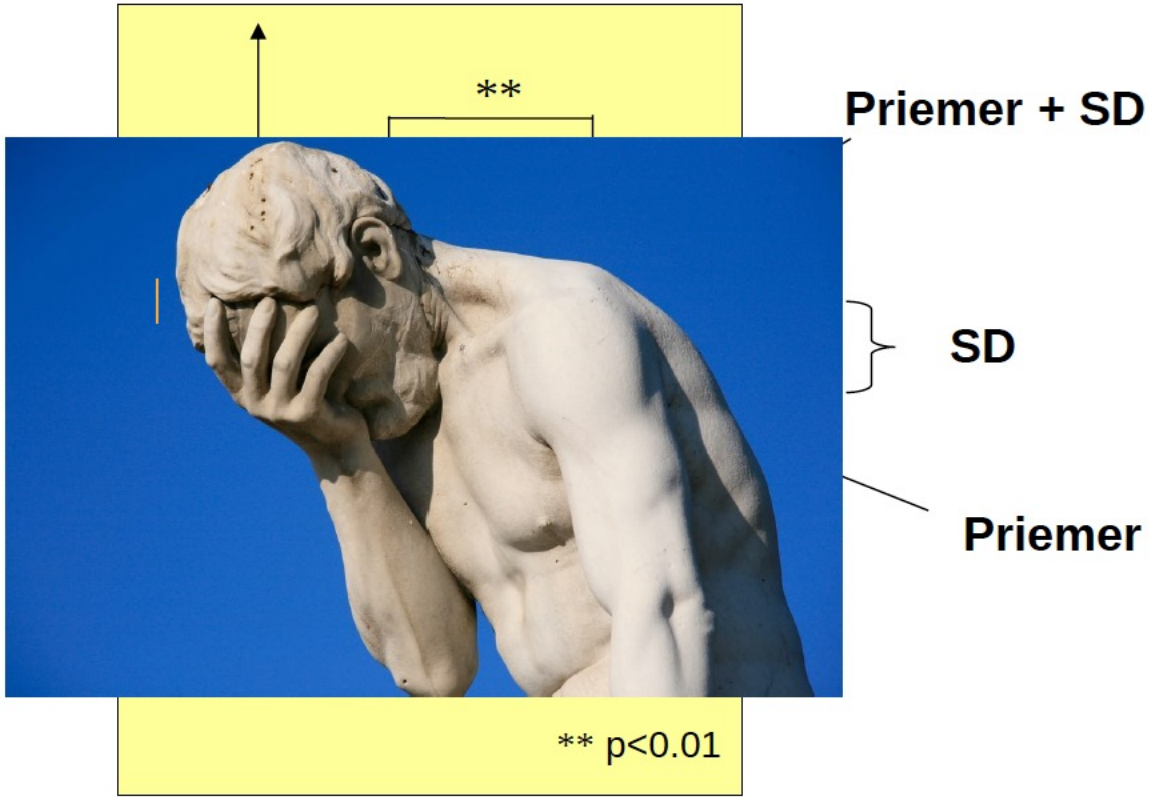
Boxplot



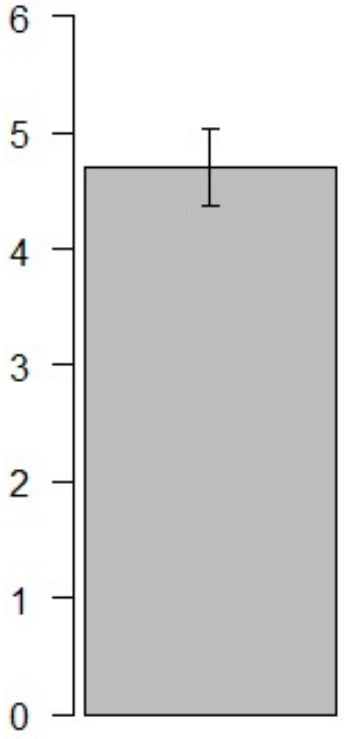
Proč se vyhýbat sloupcovým grafům s chybou



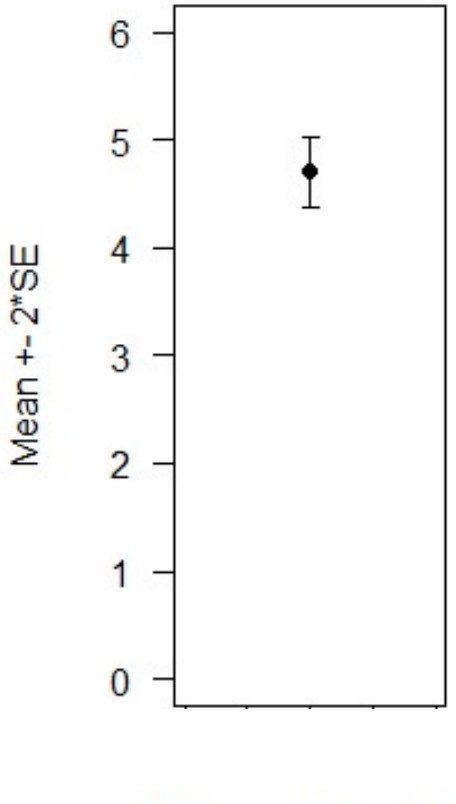
Proč se vyhýbat sloupcovým grafům s chybou



Proč se vyhýbat sloupcovým grafům s chybou



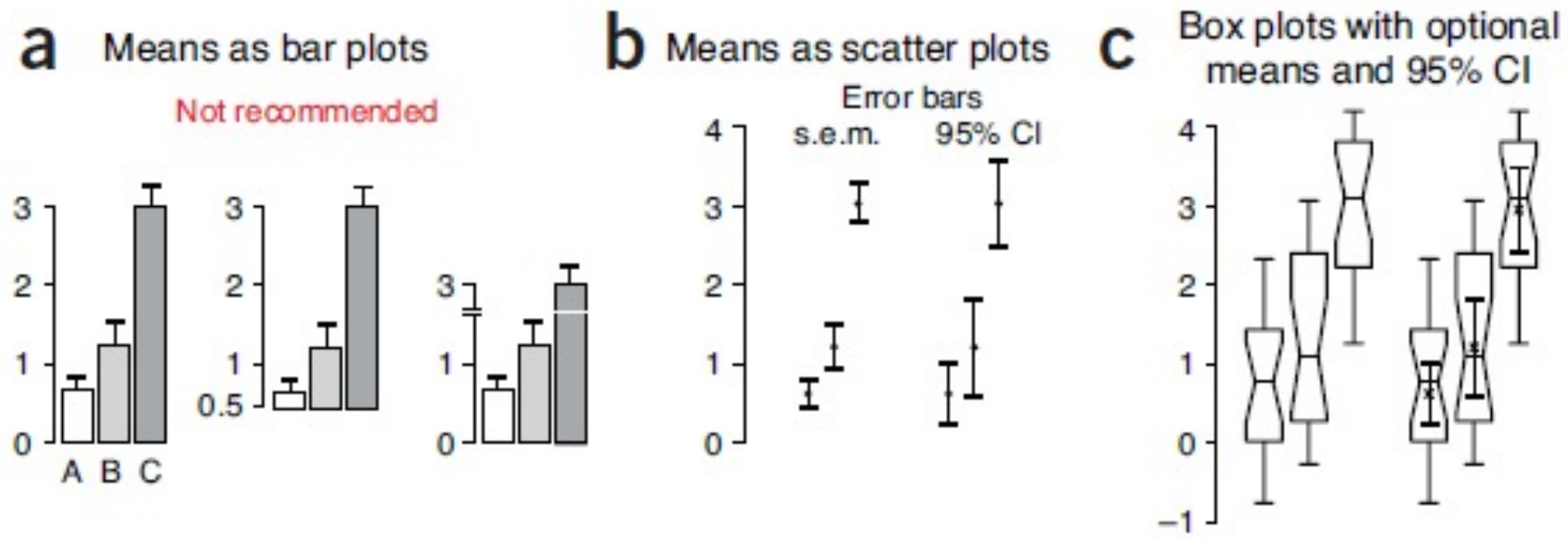
Mají příliš nízký poměr data/atrament



Alternativa bez sloupce

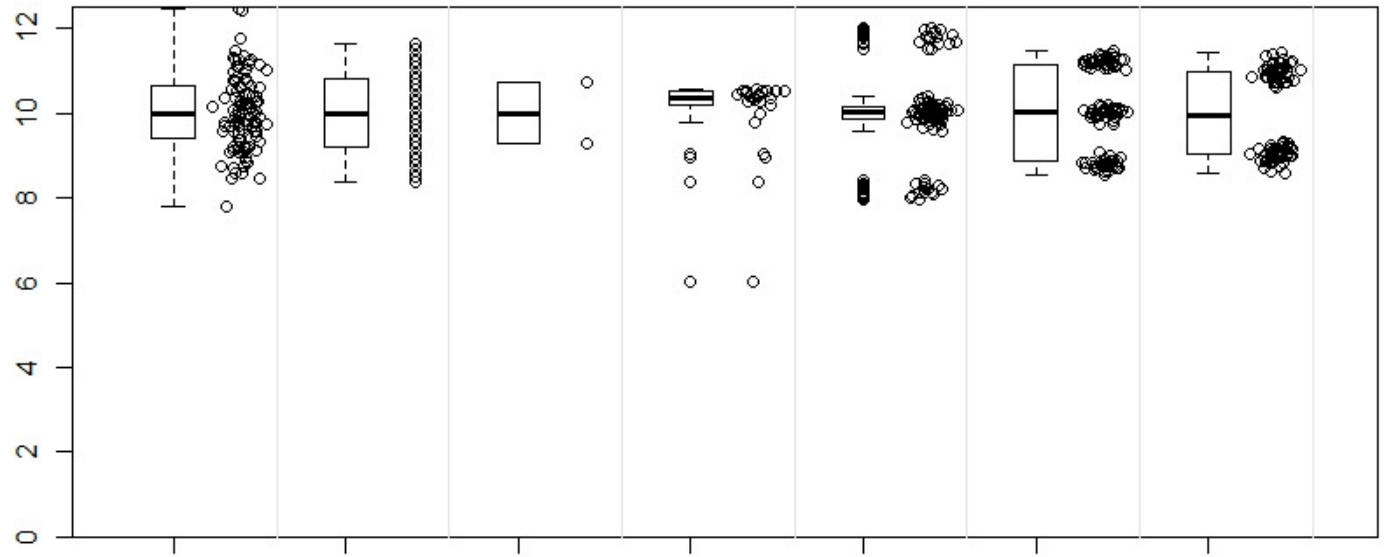
Proč se vyhýbat sloupcovým grafům s chybou

Často trpí neduhem **– zkreslení škálou**

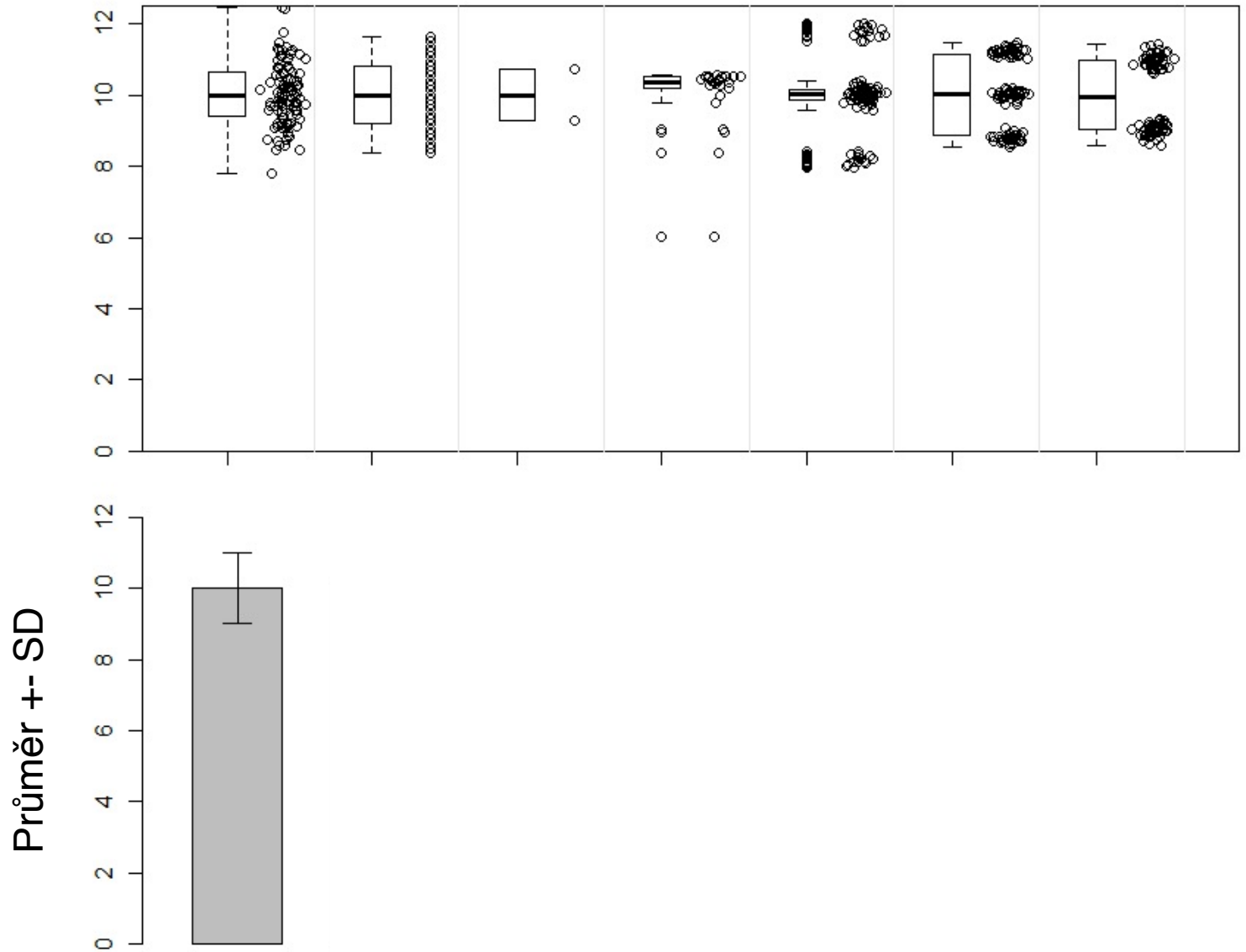


Krzywinski M, Altman N. (2014) Visualizing samples with box plots. Nat Methods. 2014 Feb;11(2):119-20.

Proč se vyhýbat sloupcovým grafům s chybou

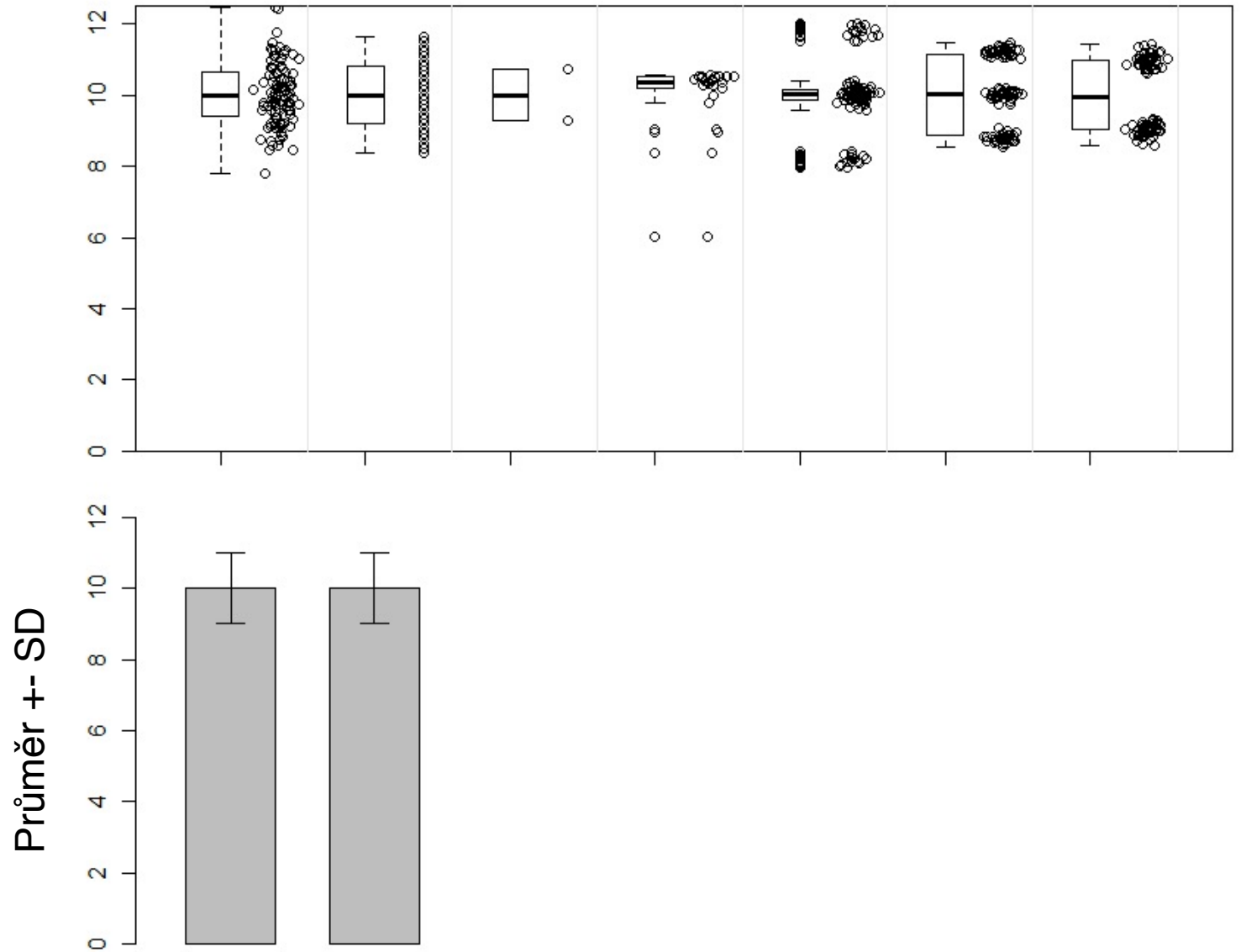


Proč se vyhýbat sloupcovým grafům s chybou



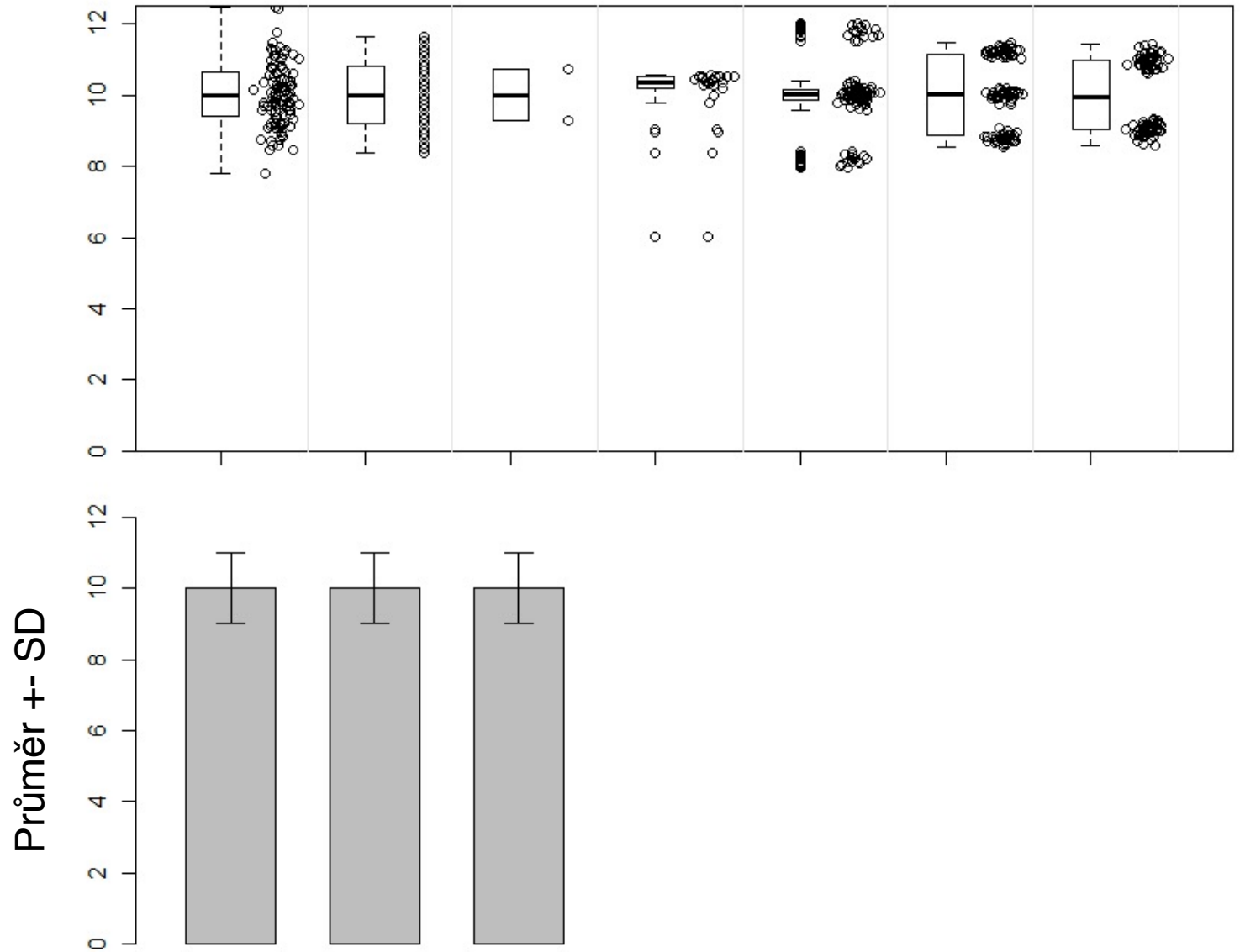
RECETOX

Proč se vyhýbat sloupcovým grafům s chybou



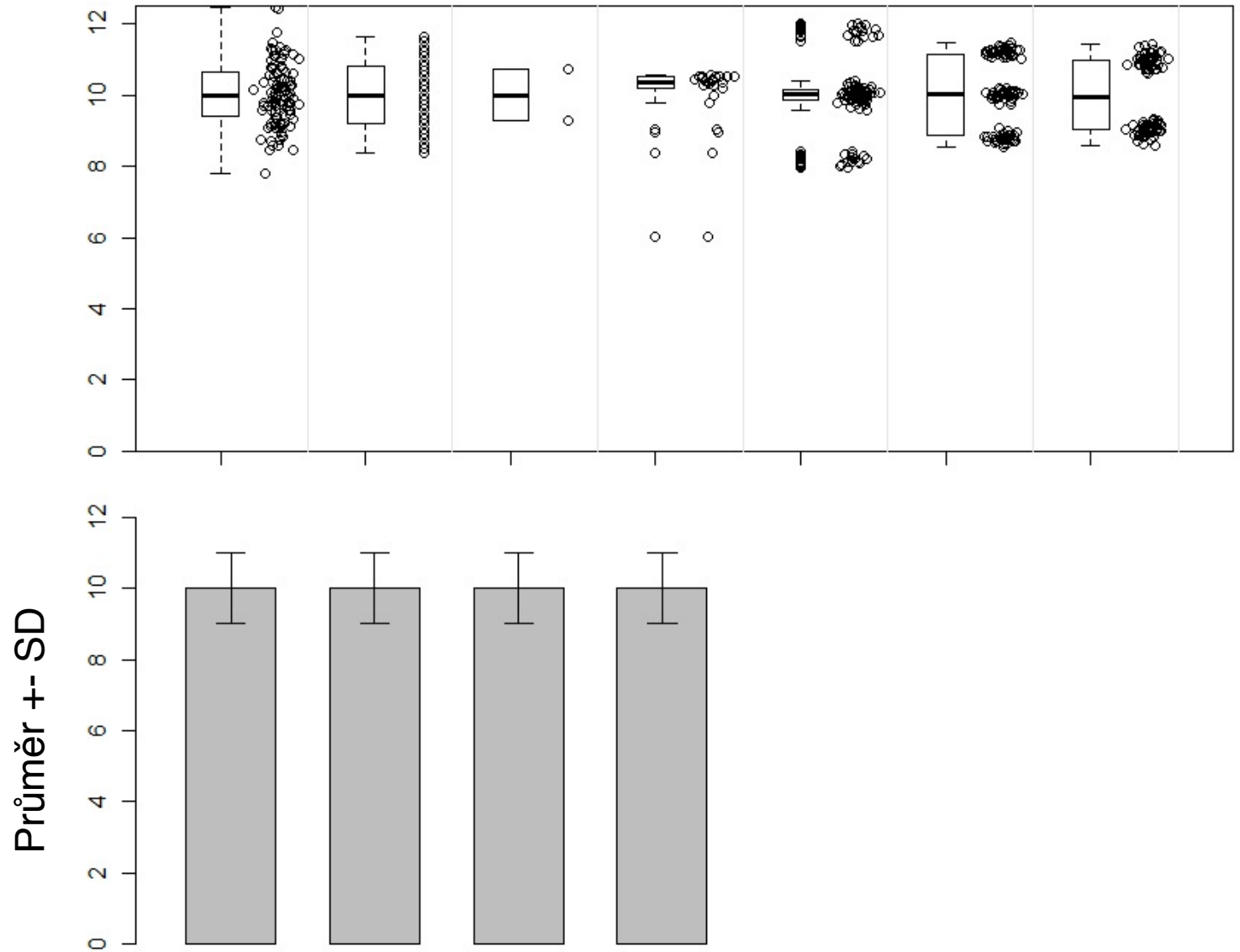
RECETOX

Proč se vyhýbat sloupcovým grafům s chybou



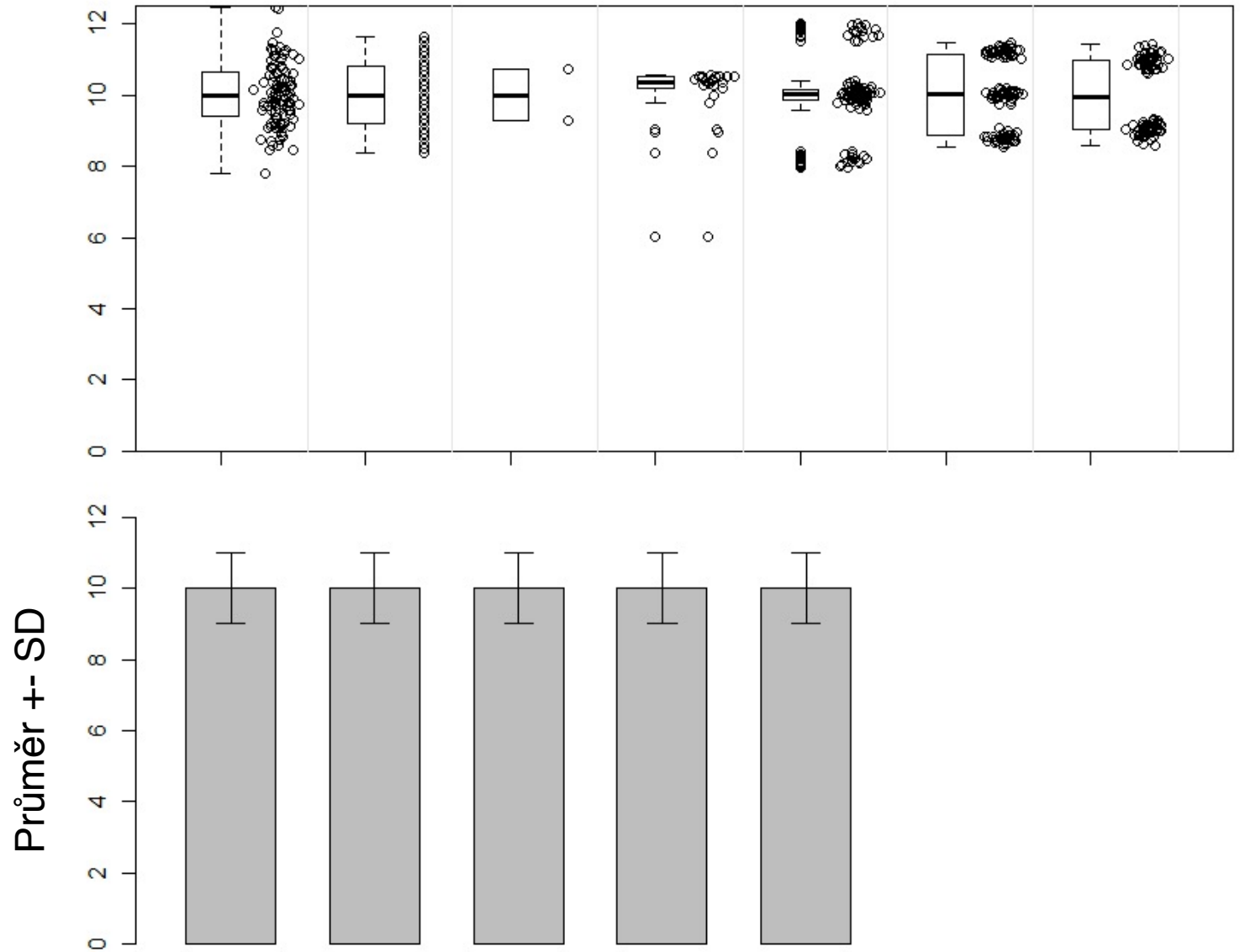
RECETOX

Proč se vyhýbat sloupcovým grafům s chybou



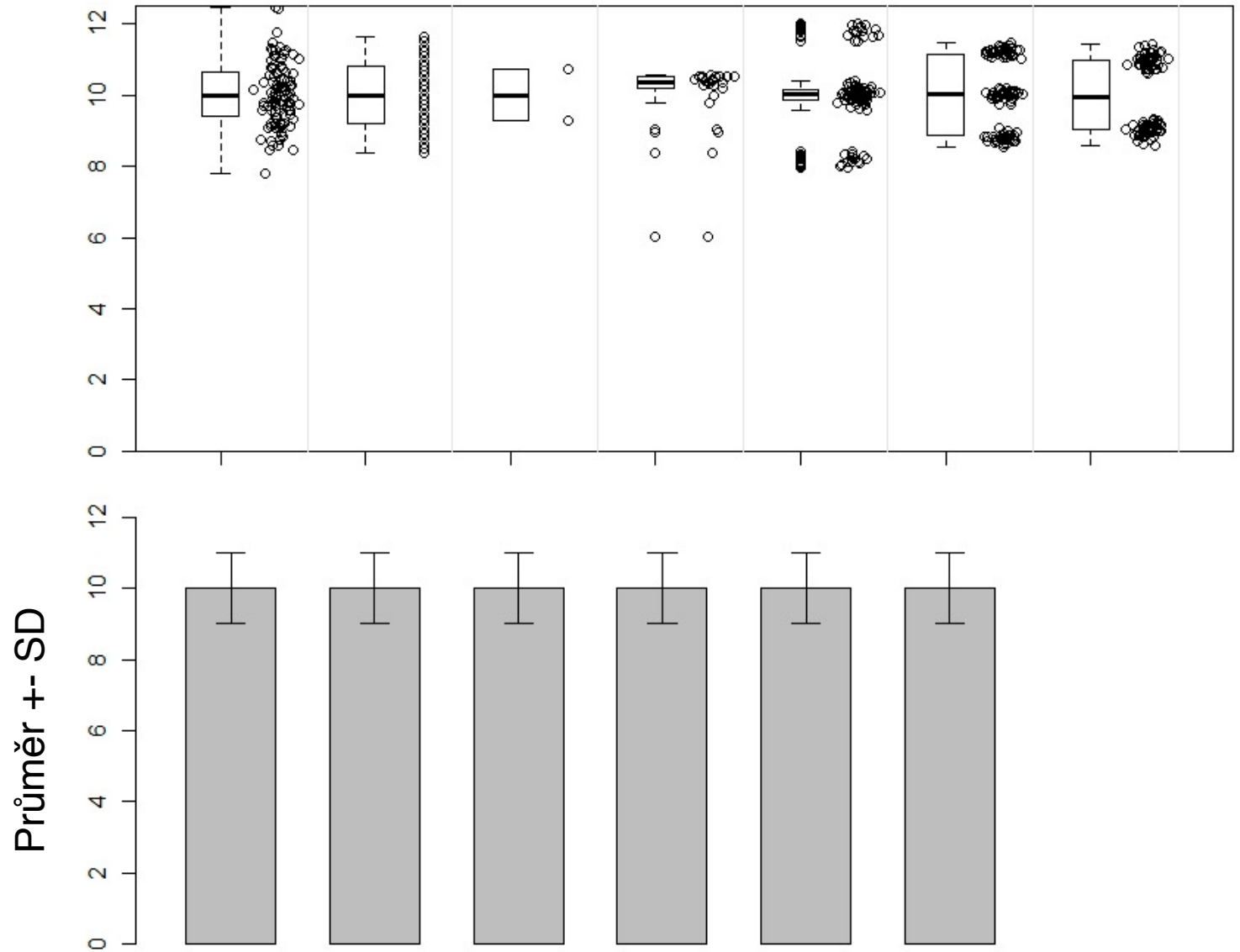
RECETOX

Proč se vyhýbat sloupcovým grafům s chybou



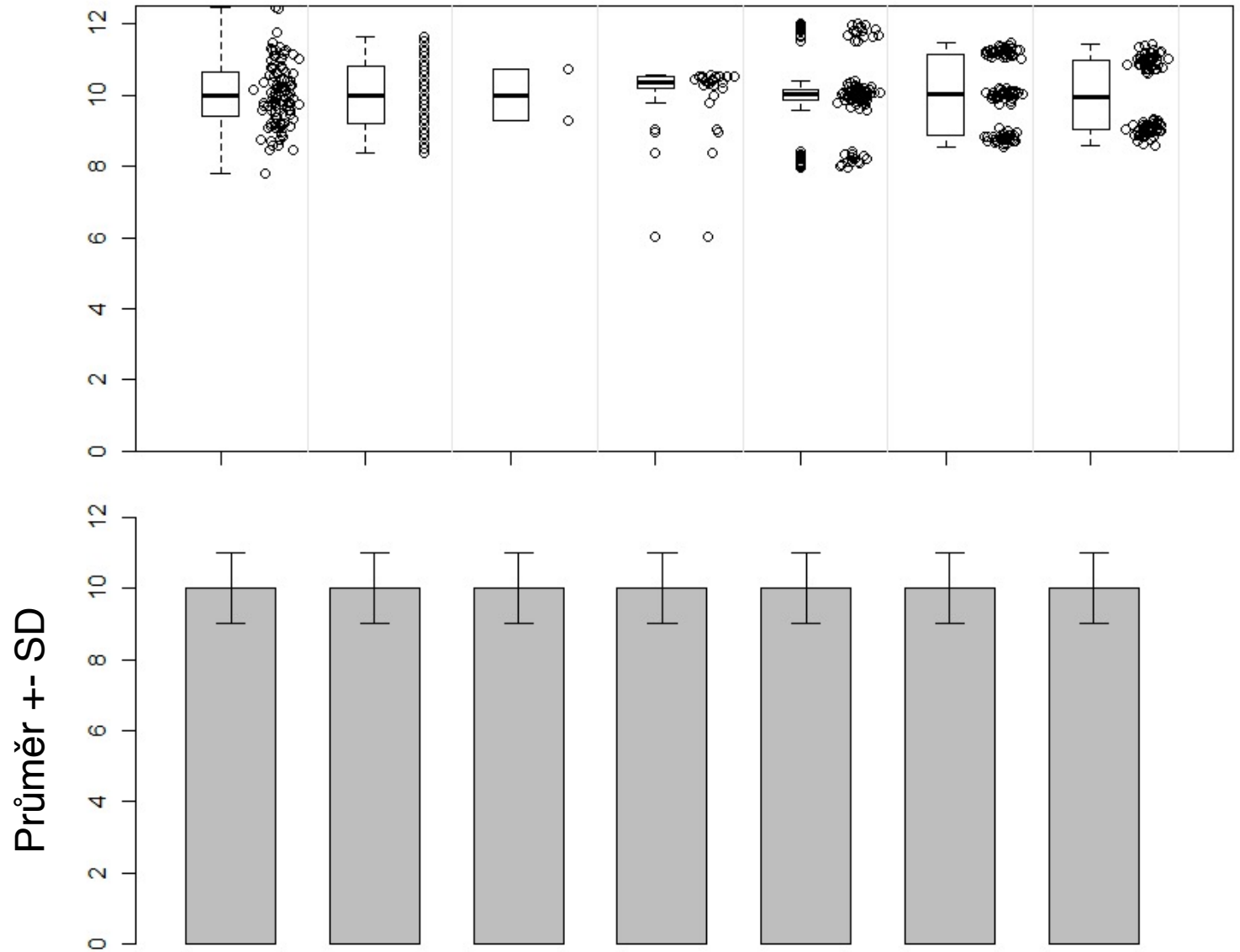
RECETOX

Proč se vyhýbat sloupcovým grafům s chybou



RECETOX

Proč se vyhýbat sloupcovým grafům s chybou



RECETOX

Kdy nejsou vhodné ani krabicové grafy

Když je jen málo bodů na zobrazení, krabicové grafy postrádají význam, jsou degenerované

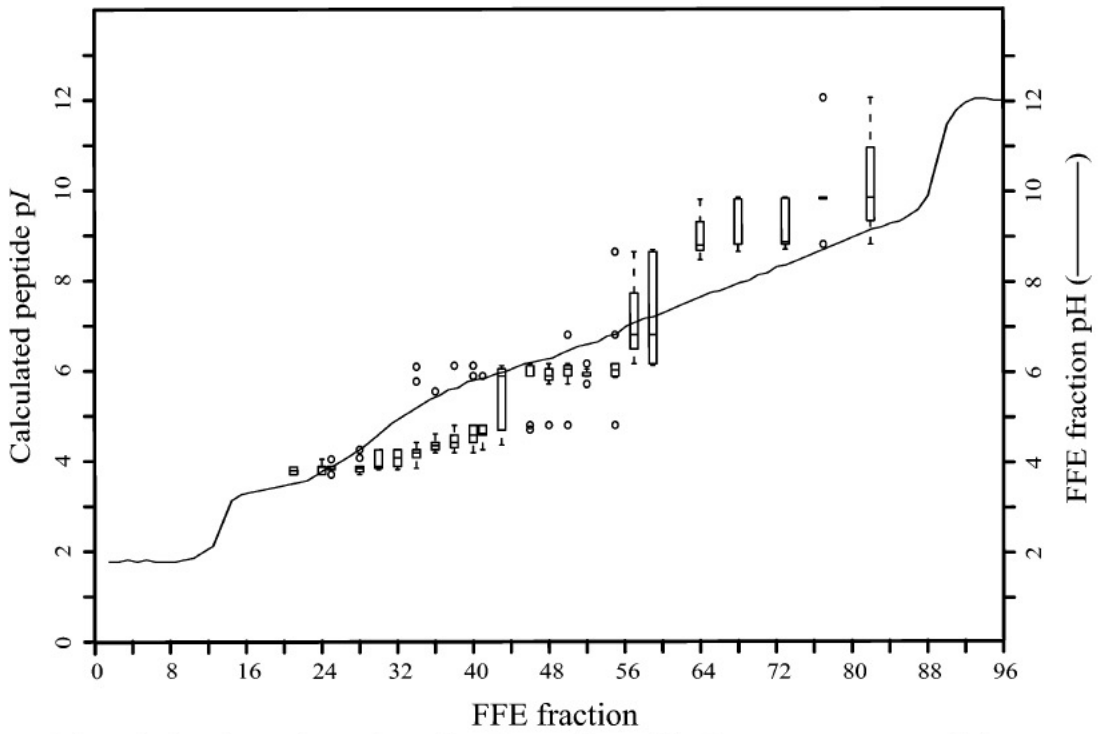
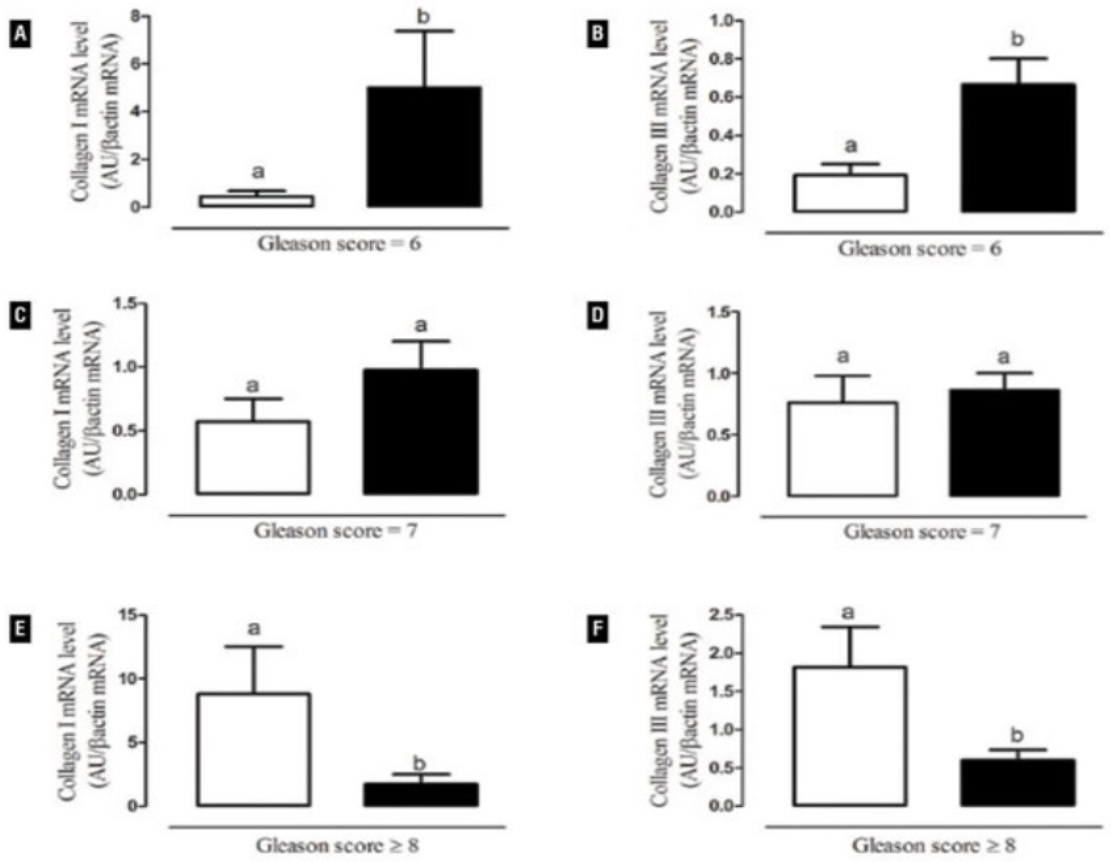


Figure 9. Comparison of theoretical and experimental p/ values for tryptic peptides from LIM 1215 cytosolic lysate separated by 2D FFE-IEF (pH 3−10)/RP-HPLC. Box plots were automatically generated using the statistical package R, version 1.5.0 (http://www.r-project.org) using the default parameters (i.e., the box represents scores between 25 and 75%, with the median at 50%, outliners are scores >1.5 times the interquartile range (75−25%) from the box and are indicated by dots (○), whiskers (+ − +) extend to the highest or lowest score not considered to be an outlier).

From Moritz et al., Anal. Chem. 2004 Aug 15; 76(16):4811-24

Nájdite aspoň 3 chyby

Figure 2 - Gene expression of collagen I and III in the benign (white bar) and tumor (black bar) areas of prostate of Gleason score=6 (A,B), Gleason score=7 (C,D) and Gleason score≥8 (E,F). β actin was used as an internal control. Data are represented as means ± SEM. Sample numbers were 13 for Gleason score=6; 10 for Gleason score=7 and 10 for Gleason score≥8. Different letters mean statistical significance evaluated by Student's-t-test.

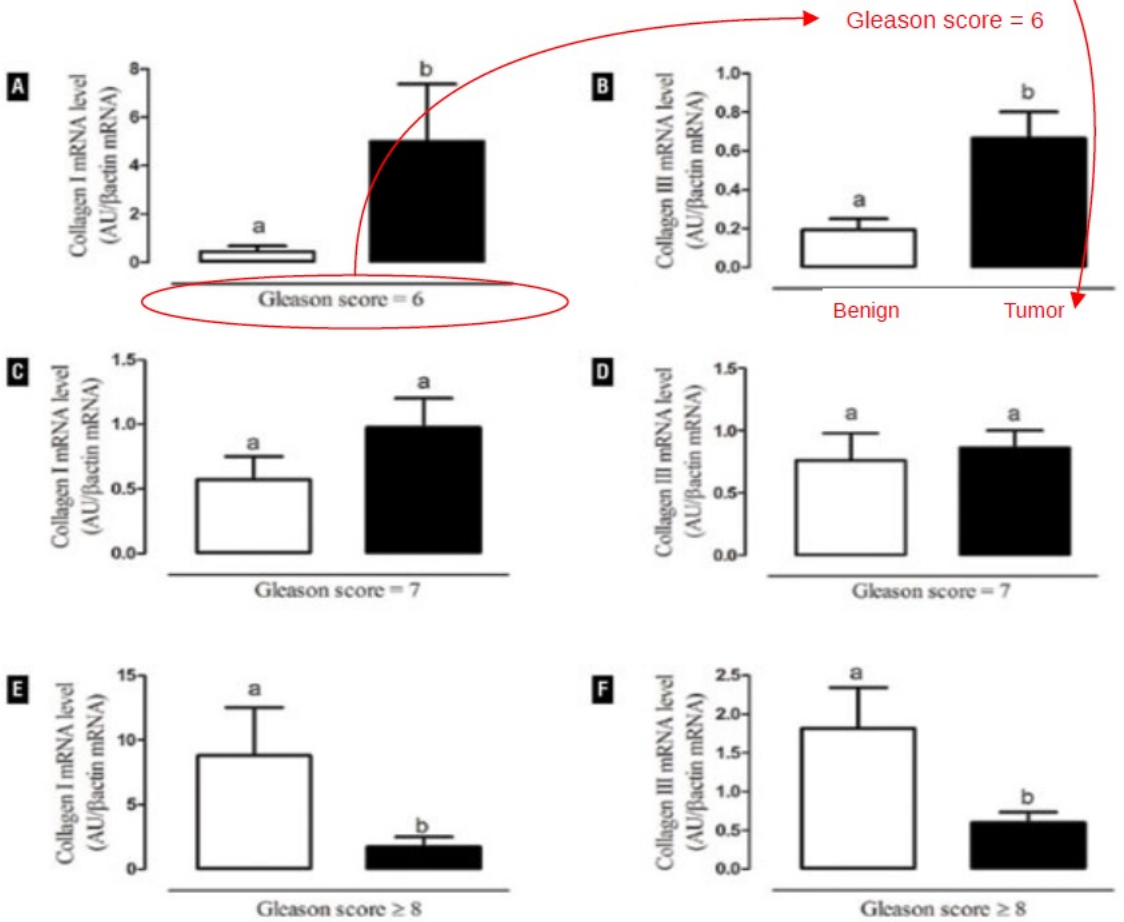


Antonio H. Duarte; Sicilia Colli; Jorge L. Alves-Pereira; Max P. Martins; Francisco J. B. Sampaio; Cristiane F. Ramos. Collagen I and III and metalloproteinase gene and protein expression in prostate cancer in relation to Gleason score. Int. braz j urol. vol.38 no.3 Rio de Janeiro May/June 2012

ETOX

Nájdite 3 chyby

Figure 2 - Gene expression of collagen I and III in the benign (white bar) and tumor (black bar) areas of prostate of Gleason score=6 (A,B), Gleason score=7 (C,D) and Gleason score≥8 (E,F). β actin was used as an internal control. Data are represented as means ± SEM. Sample numbers were 13 for Gleason score=6; 10 for Gleason score=7 and 10 for Gleason score≥8. Different letters mean statistical significance evaluated by Student's-t-test.



Gleason score = 6

1. Chýbajúci popis kategórií boxplotov na osi x

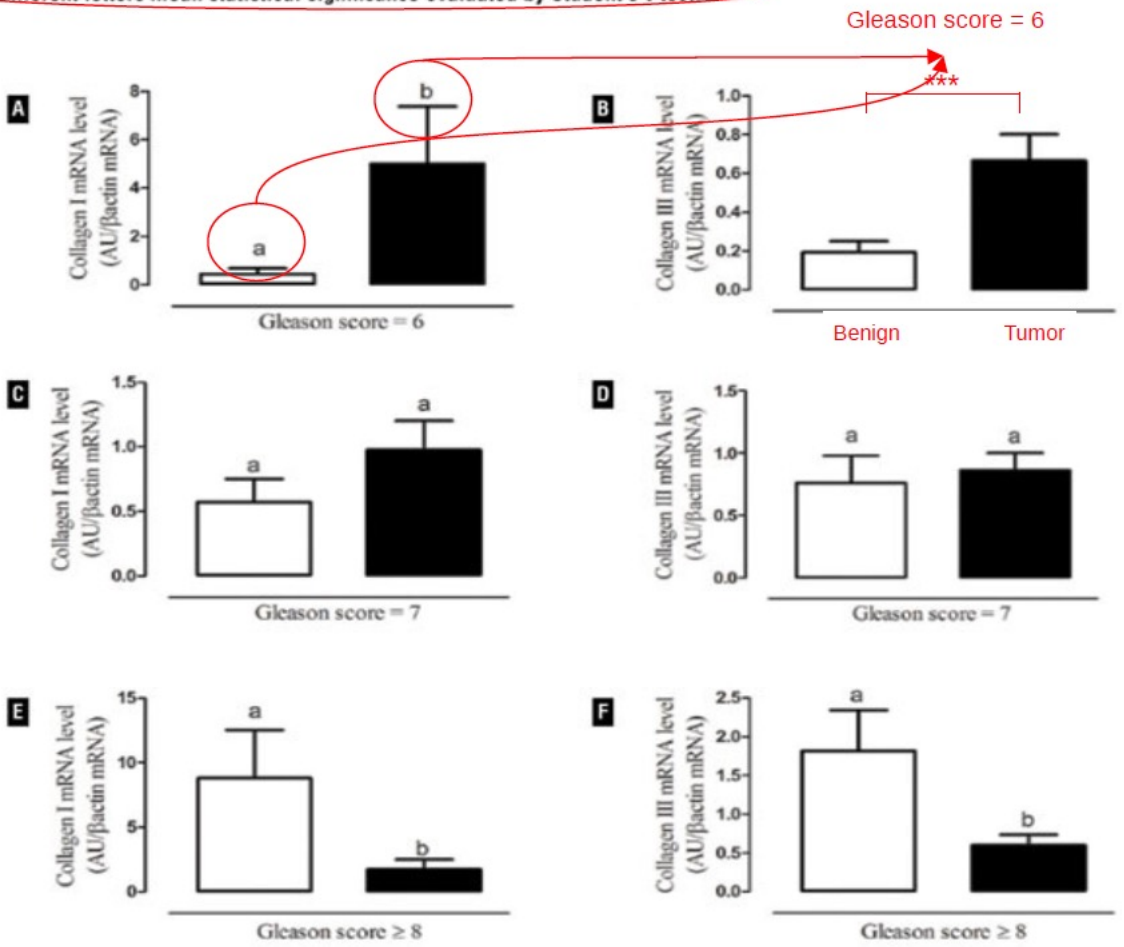
2. Popis skóre uvedený nesprávne na osi x

Antonio H. Duarte; Sicilia Colli; Jorge L. Alves-Pereira; Max P. Martins; Francisco J. B. Sampaio; Cristiane F. Ramos. Collagen I and III and metalloproteinase gene and protein expression in prostate cancer in relation to Gleason score. Int. braz j urol. vol.38 no.3 Rio de Janeiro May/June 2012

ETOX

2. Nevhodné zobrazenie štatistickej významnosti

Figure 2 - Gene expression of collagen I and III in the benign (white bar) and tumor (black bar) areas of prostate of Gleason score=6 (A,B), Gleason score=7 (C,D) and Gleason score≥8 (E,F). β actin was used as an internal control. Data are represented as means ± SEM. Sample numbers were 13 for Gleason score=6; 10 for Gleason score=7 and 10 for Gleason score≥8. Different letters mean statistical significance evaluated by Student's-t-test.



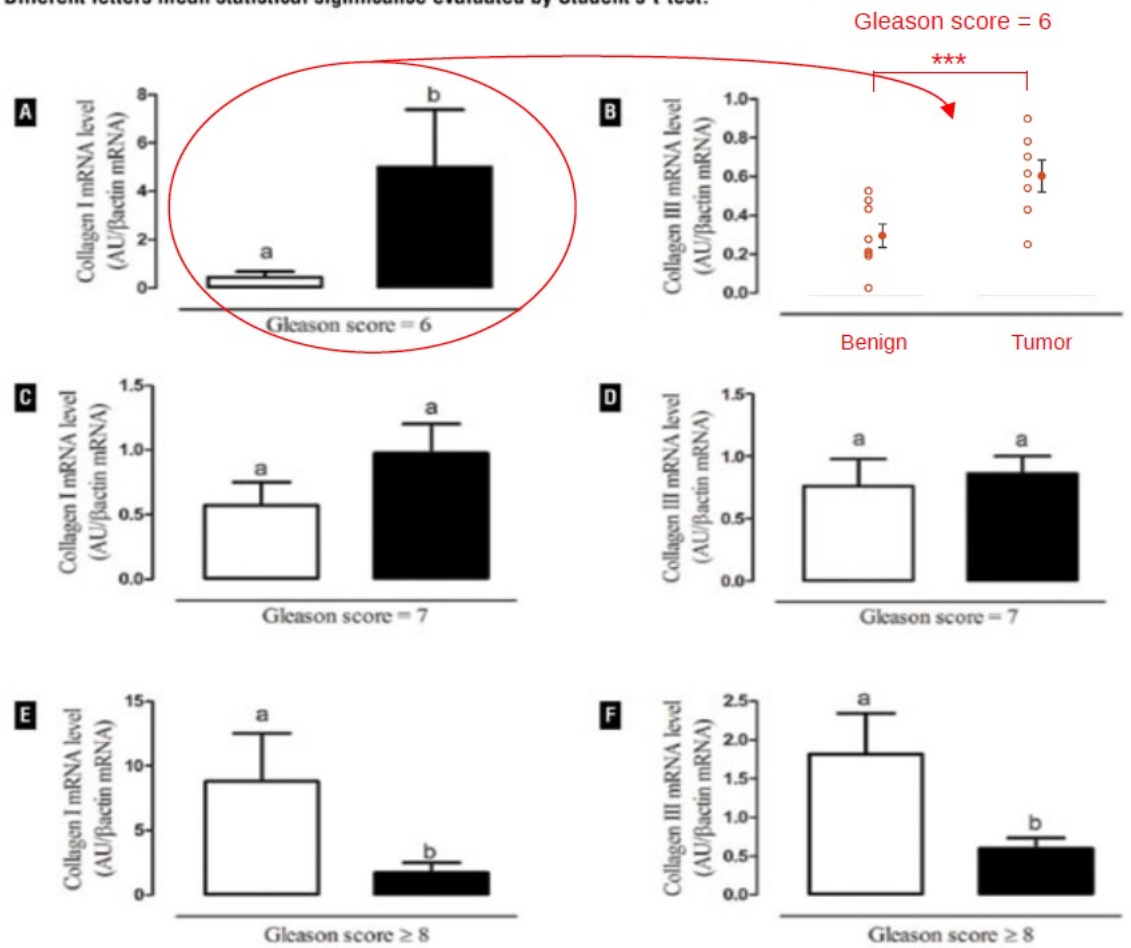
Veľmi neštandardné, navyše písmená a, b vyzerajú ako názvy kategórií/boxplotov

Antonio H. Duarte; Sicilia Colli; Jorge L. Alves-Pereira; Max P. Martins; Francisco J. B. Sampaio; Cristiane F. Ramos. Collagen I and III and metalloproteinase gene and protein expression in prostate cancer in relation to Gleason score. Int. braz j urol. vol.38 no.3 Rio de Janeiro May/June 2012

ETOX

3. Nevhodný graf !

Figure 2 - Gene expression of collagen I and III in the benign (white bar) and tumor (black bar) areas of prostate of Gleason score=6 (A,B), Gleason score=7 (C,D) and Gleason score≥8 (E,F). β actin was used as an internal control. Data are represented as means ± SEM. Sample numbers were 13 for Gleason score=6; 10 for Gleason score=7 and 10 for Gleason score≥8. Different letters mean statistical significance evaluated by Student's-t-test.



Menej atramentu, viac informácie!

N=13

N=10

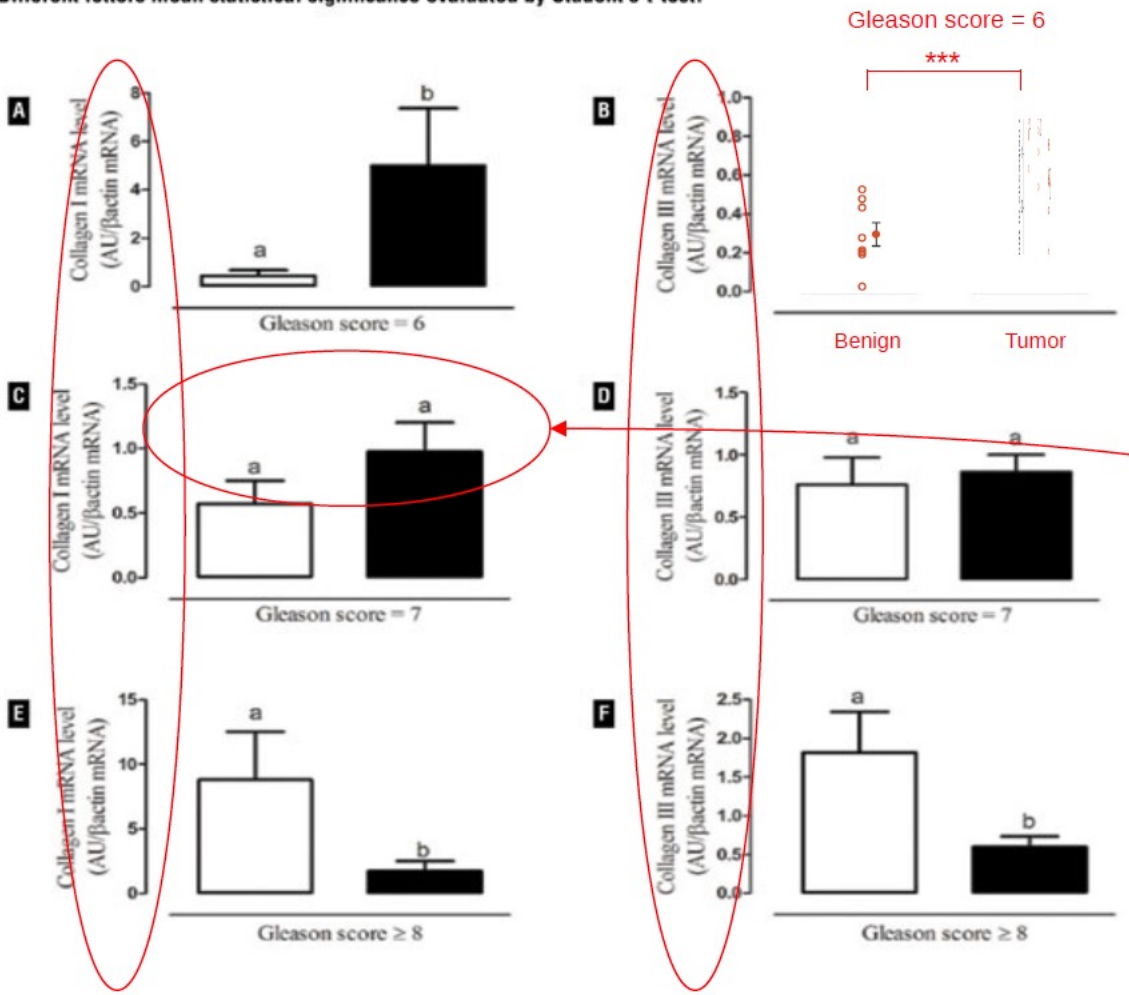
N=10

Antonio H. Duarte; Sicilia Colli; Jorge L. Alves-Pereira; Max P. Martins; Francisco J. B. Sampaio; Cristiane F. Ramos. Collagen I and III and metalloproteinase gene and protein expression in prostate cancer in relation to Gleason score. Int. braz j urol. vol.38 no.3 Rio de Janeiro May/June 2012

ETOX

4. Odlišné škály na osi y

Figure 2 - Gene expression of collagen I and III in the benign (white bar) and tumor (black bar) areas of prostate of Gleason score=6 (A,B), Gleason score=7 (C,D) and Gleason score≥8 (E,F). β actin was used as an internal control. Data are represented as means ± SEM. Sample numbers were 13 for Gleason score=6; 10 for Gleason score=7 and 10 for Gleason score≥8. Different letters mean statistical significance evaluated by Student's-t-test.



Odlišná škála pôsobí dojmom veľkého rozdielu v expresii!

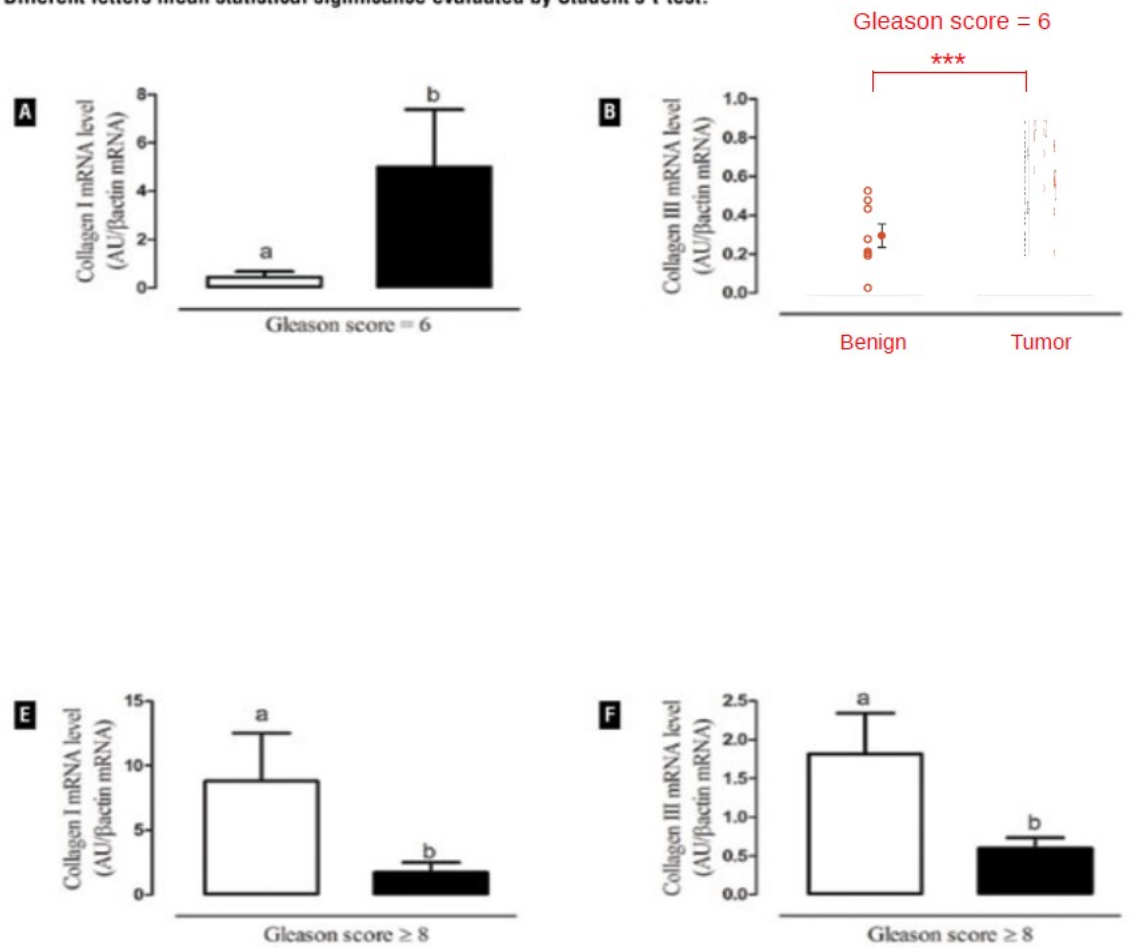
Nemožnosť priameho porovnania medzi grafmi

Antonio H. Duarte; Sicilia Colli; Jorge L. Alves-Pereira; Max P. Martins; Francisco J. B. Sampaio; Cristiane F. Ramos. Collagen I and III and metalloproteinase gene and protein expression in prostate cancer in relation to Gleason score. Int. braz j urol. vol.38 no.3 Rio de Janeiro May/June 2012

ETOX

5. Redundantné grafy C a D

Figure 2 - Gene expression of collagen I and III in the benign (white bar) and tumor (black bar) areas of prostate of Gleason score=6 (A,B), Gleason score=7 (C,D) and Gleason score≥8 (E,F). β actin was used as an internal control. Data are represented as means ± SEM. Sample numbers were 13 for Gleason score=6; 10 for Gleason score=7 and 10 for Gleason score≥8. Different letters mean statistical significance evaluated by Student's-t-test.



Nevýznamný výsledok netreba zobrazovať, prípadne dať do supplemental

Antonio H. Duarte; Sicilia Colli; Jorge L. Alves-Pereira; Max P. Martins; Francisco J. B. Sampaio; Cristiane F. Ramos. Collagen I and III and metalloproteinase gene and protein expression in prostate cancer in relation to Gleason score. Int. braz j urol. vol.38 no.3 Rio de Janeiro May/June 2012

ETOX

Další čtení

- https://eagereyes.org
- http://www.biostat.wisc.edu/~kbroman/topten_worstgraphs/mykland_disc.html
- http://www.exercisebiology.com/index.php/site/articles/how_graphs_can_fool_you/
- https://www.eea.europa.eu/data-and-maps/daviz/learn-more/chart-dos-and-donts#toc-2
- http://www.radford.edu/jkell/statsgraphs.pdf
- http://www.stat.auckland.ac.nz/~ihaka/120/Lectures/lecture03.pdf
- http://people.stat.sfu.ca/~cschwarz/Stat650/Notes/PDF/ChapterBadgraphs.pdf
- http://www.datavis.ca/gallery/index.php
- http://www.doc.govt.nz/documents/science-and-technical/docts32.pdf
- http://www.edwardtufte.com/tufte/

- Geoff Cumming, Fiona Fidler, David L. Vaux (2007). Error bars in experimental biology. JCB Hom. 177 (1): 7e