Comparing means

Data Analysis Using R (2017)

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1 Two independent samples

1.1 Independent t-test

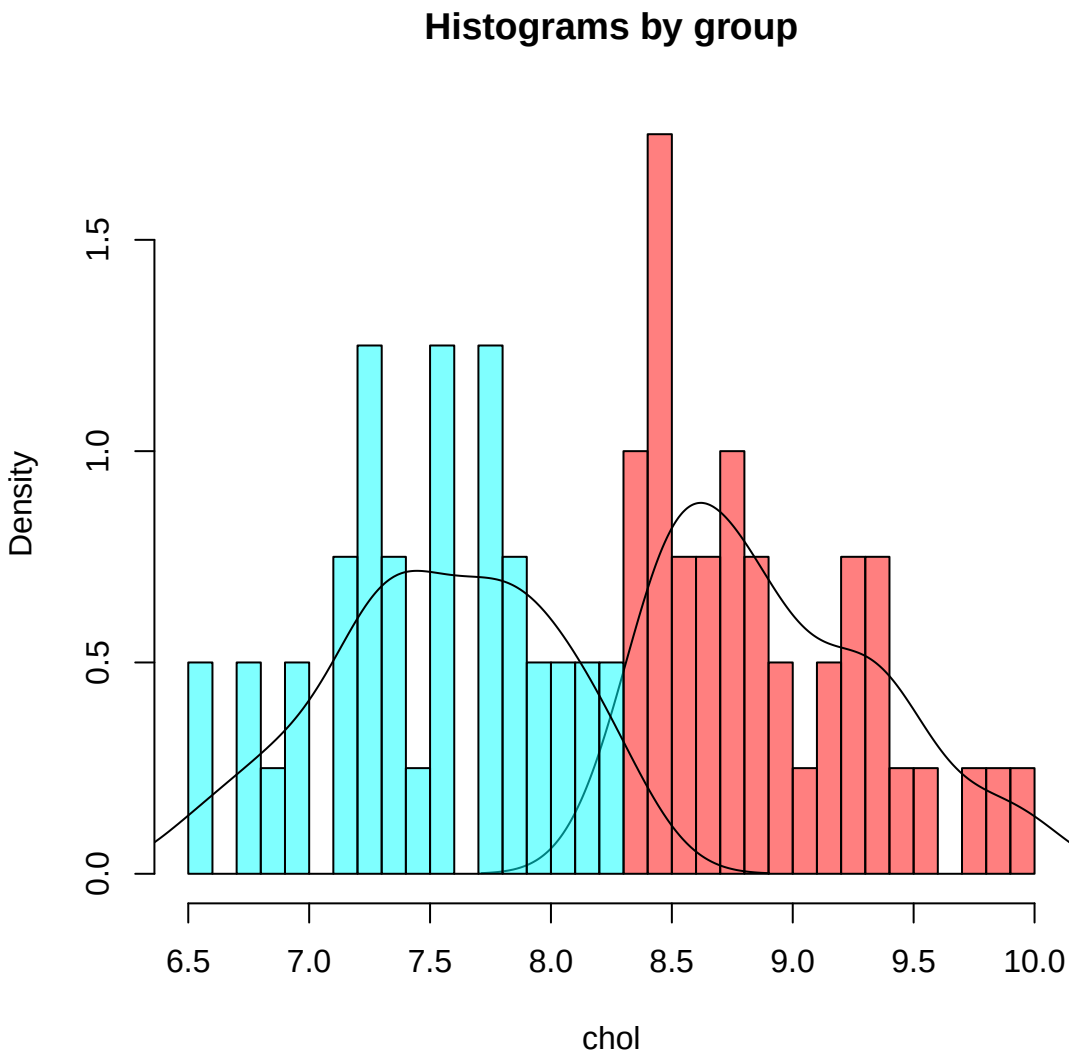
```
library(foreign)
library(psych)
cholest = read.spss("cholest.sav", to.data.frame = T)
str(cholest)
```

```
## 'data.frame':    80 obs. of  5 variables:
##  $ chol    : num  6.5 6.6 6.8 6.8 6.9 7 7 7.2 7.2 7.2 ...
##  $ age     : num  38 35 39 36 31 38 33 36 40 34 ...
##  $ exercise: num  6 5 6 5 4 4 5 5 4 6 ...
##  $ sex     : Factor w/ 2 levels "female","male": 2 2 2 2 2 2 2 2 2 2 ...
##  $ categ   : Factor w/ 3 levels "Grp A","Grp B",..: 1 1 1 1 1 1 1 1 1 1 ...
##  - attr(*, "variable.labels")= Named chr  "cholesterol in mmol/L" "age in year" "duration of exercis
##   ..- attr(*, "names")= chr  "chol" "age" "exercise" "sex" ...
##  - attr(*, "codepage")= int 65001
```

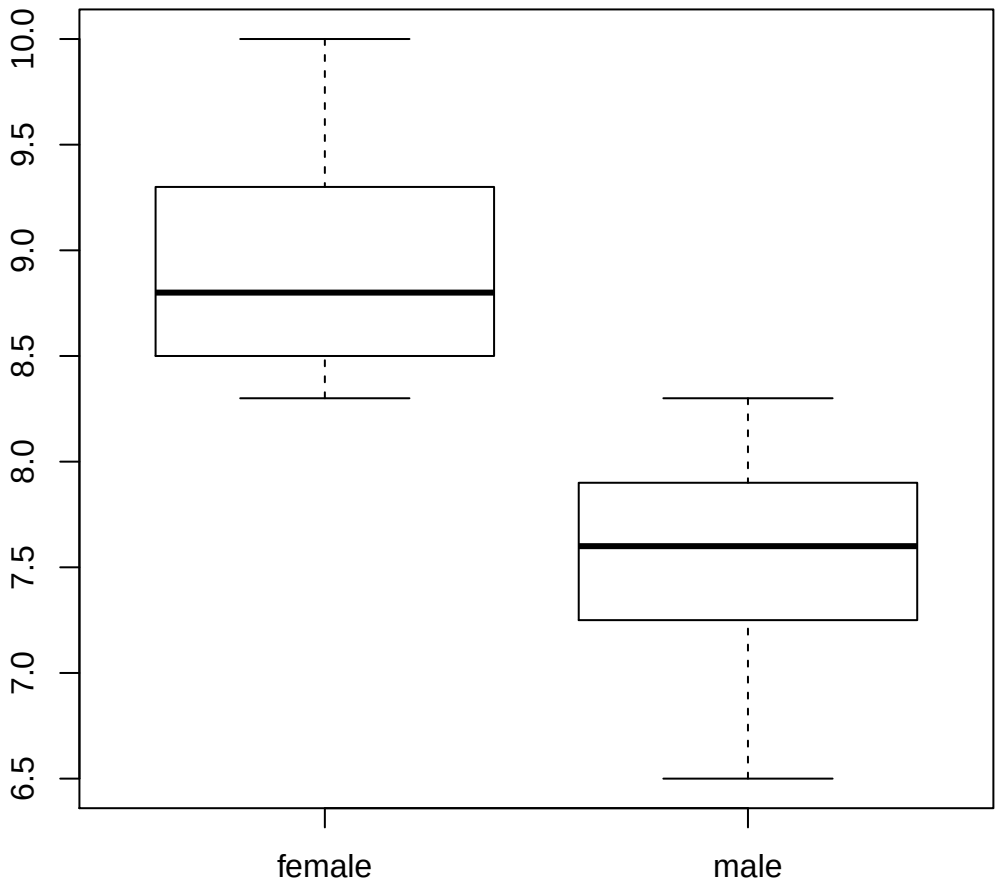
```r
head(cholest)
```

```
##   chol age exercise  sex categ
## 1  6.5  38        6 male Grp A
## 2  6.6  35        5 male Grp A
## 3  6.8  39        6 male Grp A
## 4  6.8  36        5 male Grp A
## 5  6.9  31        4 male Grp A
## 6  7.0  38        4 male Grp A
```

```r
histBy(cholest, "chol", group = "sex")
```




```r
boxplot(chol ~ sex, data = cholest)
```




```
t.test(chol ~ sex, data = cholest)
```

```
##
##  Welch Two Sample t-test
##
## data:  chol by sex
## t = 13.504, df = 77.933, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  1.189337 1.600663
## sample estimates:
## mean in group female   mean in group male
##               8.9275               7.5325
```

```
# ?t.test # other options
```

1.2 Mann-Whitney U test / Wilcoxon rank-sum test

```
wilcox.test(chol ~ sex, data = cholest)  # not accurate for ties
```

```
## Warning in wilcox.test.default(x = c(8.3, 8.3, 8.4, 8.4, 8.5, 8.5, 8.5, : cannot compute
## exact p-value with ties
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  chol by sex
## W = 1598, p-value = 1.568e-14
## alternative hypothesis: true location shift is not equal to 0
```

```
# ?wilcox.test
library(coin)
```

```
## Loading required package: survival
```

```
wilcox_test(chol ~ sex, data = cholest)
```

```
##
##  Asymptotic Wilcoxon-Mann-Whitney Test
##
## data:  chol by sex (female, male)
## Z = 7.6867, p-value = 1.51e-14
## alternative hypothesis: true mu is not equal to 0
```

```
wilcox_test(chol ~ sex, data = cholest, distribution = "exact")
```

```
##
##  Exact Wilcoxon-Mann-Whitney Test
##
## data:  chol by sex (female, male)
## Z = 7.6867, p-value < 2.2e-16
## alternative hypothesis: true mu is not equal to 0
```

```
# ?wilcox_test
```

2 Two dependent samples

2.1 Paired t-test

```
sbp = read.spss("sbp.sav", to.data.frame = T)
t.test(sbp$S1, sbp$S2, paired = T)
```

```
##
##  Paired t-test
##
## data:  sbp$S1 and sbp$S2
## t = -0.81954, df = 10, p-value = 0.4316
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -5.071058  2.343785
## sample estimates:
```

```
## mean of the differences
##               -1.363636
```

2.2 Wilcoxon signed-rank test

```
wilcox.test(sbp$S1, sbp$S2, paired = T)
```

```
## Warning in wilcox.test.default(sbp$S1, sbp$S2, paired = T): cannot compute exact p-value
## with ties
```

```
## Warning in wilcox.test.default(sbp$S1, sbp$S2, paired = T): cannot compute exact p-value
## with zeroes
```

```
##
##  Wilcoxon signed rank test with continuity correction
##
## data:  sbp$S1 and sbp$S2
## V = 3, p-value = 0.5708
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcoxsign_test(sbp$S1 ~ sbp$S2)
```

```
##
##  Asymptotic Wilcoxon-Pratt Signed-Rank Test
##
## data:  y by x (pos, neg)
##   stratified by block
## Z = -0.94346, p-value = 0.3454
## alternative hypothesis: true mu is not equal to 0
```

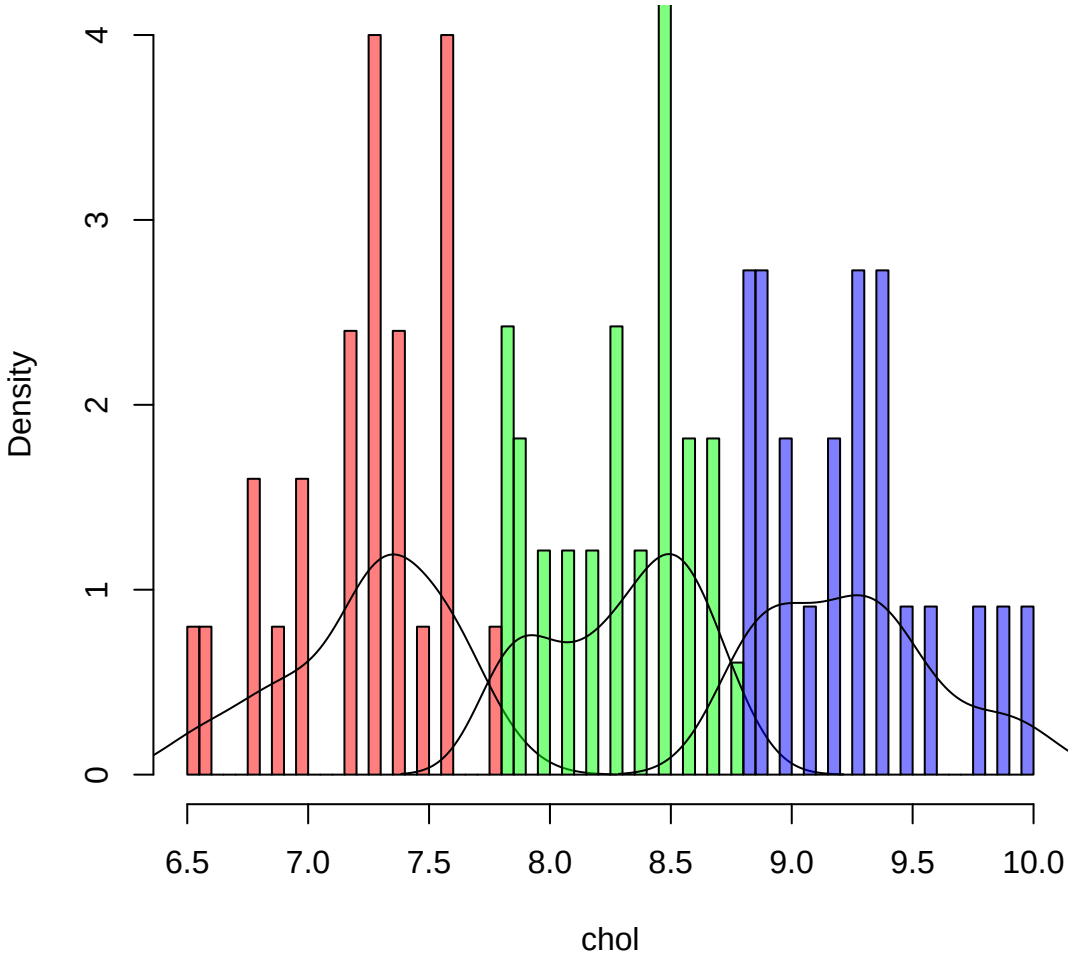
```
wilcoxsign_test(sbp$S1 ~ sbp$S2, distribution = "exact")
```

```
##
##  Exact Wilcoxon-Pratt Signed-Rank Test
##
## data:  y by x (pos, neg)
##   stratified by block
## Z = -0.94346, p-value = 0.625
## alternative hypothesis: true mu is not equal to 0
```

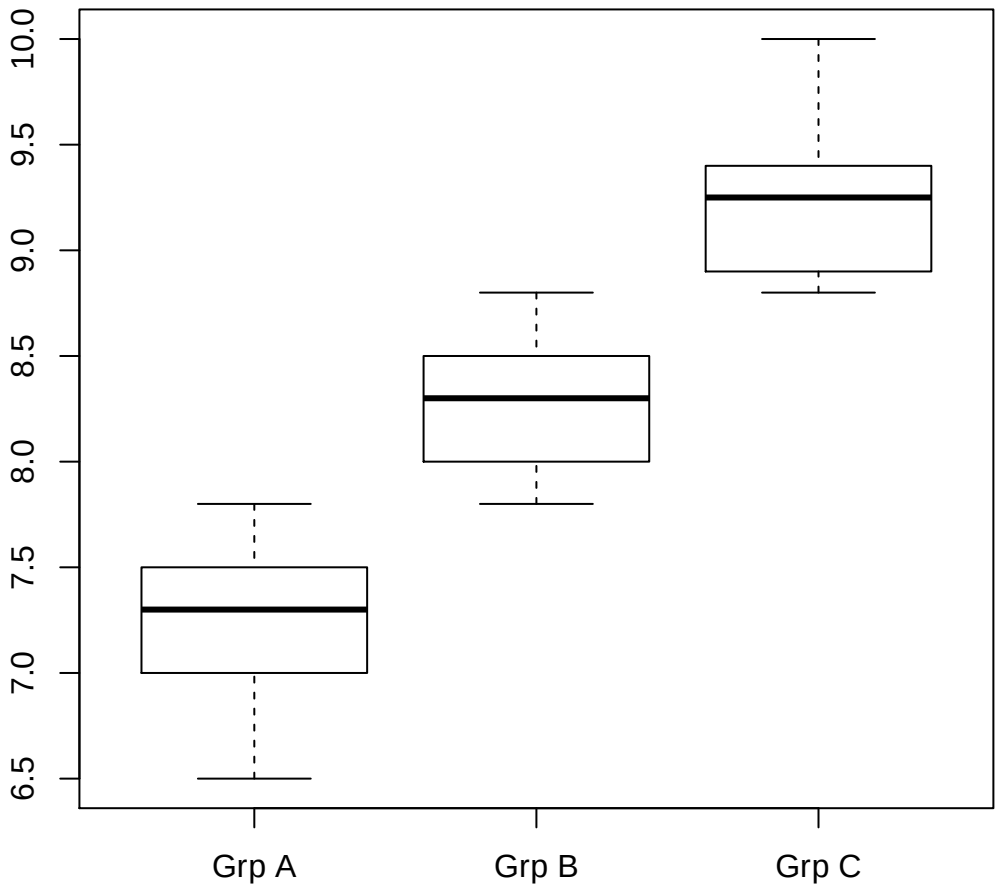
3 Independent samples

3.1 One-way ANOVA

```
histBy(cholest, "chol", group = "categ")
```




```
boxplot(chol ~ categ, data = cholest)
```




```
aov_chol = aov(chol ~ categ, data = cholest)
summary(aov_chol)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## categ        2  47.13   23.57   215.1 <2e-16 ***
## Residuals   77   8.44    0.11
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

3.2 Kruskal-Wallis test

```
kruskal.test(chol ~ categ, data = cholest)
```

```
##
##  Kruskal-Wallis rank sum test
##
```

```
## data:  chol by categ
## Kruskal-Wallis chi-squared = 69.188, df = 2, p-value = 9.464e-16
```

4 Dependent samples

4.1 Repeated measures ANOVA

```
library(car)
```

```
##
## Attaching package: 'car'
```

```
## The following object is masked from 'package:psych':
##
##     logit
```

```
time = ordered(rep(1:3))
idesign = data.frame(time)
model_rm = lm(cbind(S1, S2, S3) ~ 1, sbp)
aov_rm = Anova(model_rm, idata = idesign, idesign = ~time)
```

```
## Note: model has only an intercept; equivalent type-III tests substituted.
```

```
summary(aov_rm, multivariate = F)  # univariate approach
```

```
## Warning in summary.Anova.mlm(aov_rm, multivariate = F): HF eps > 1 treated as 1
```

```
##
## Univariate Type III Repeated-Measures ANOVA Assuming Sphericity
##
##                 SS num Df Error SS den Df        F    Pr(>F)
## (Intercept) 487276      1   5824.2     10 836.6337 5.686e-11 ***
## time            29      2    271.2     20   1.0615    0.3647
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Mauchly Tests for Sphericity
##
##      Test statistic p-value
## time        0.91149 0.65899
##
##
## Greenhouse-Geisser and Huynh-Feldt Corrections
##  for Departure from Sphericity
##
##       GG eps Pr(>F[GG])
## time 0.91869     0.3608
##
##        HF eps Pr(>F[HF])
## time 1.115516  0.3646518
```

```
summary(aov_rm)  # multivariate approach
```

```
## Warning in summary.Anova.mlm(aov_rm): HF eps > 1 treated as 1
```

```
##
## Type III Repeated Measures MANOVA Tests:
##
## ----------------------------------------
##
## Term: (Intercept)
##
##  Response transformation matrix:
##    (Intercept)
## S1           1
## S2           1
## S3           1
##
## Sum of squares and products for the hypothesis:
##             (Intercept)
## (Intercept)     1461827
##
## Multivariate Tests: (Intercept)
##                  Df test stat approx F num Df den Df     Pr(>F)
## Pillai            1   0.98819 836.6337      1     10 5.6855e-11 ***
## Wilks             1   0.01181 836.6337      1     10 5.6855e-11 ***
## Hotelling-Lawley  1  83.66337 836.6337      1     10 5.6855e-11 ***
## Roy               1  83.66337 836.6337      1     10 5.6855e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## ----------------------------------------
##
## Term: time
##
##  Response transformation matrix:
##           time.L     time.Q
## S1 -7.071068e-01  0.4082483
## S2 -7.850462e-17 -0.8164966
## S3  7.071068e-01  0.4082483
##
## Sum of squares and products for the hypothesis:
##           time.L   time.Q
## time.L  4.545455 10.49728
## time.Q 10.497278 24.24242
##
## Multivariate Tests: time
##                  Df test stat  approx F num Df den Df  Pr(>F)
## Pillai            1  0.153110 0.8135593      2      9 0.47339
## Wilks             1  0.846890 0.8135593      2      9 0.47339
## Hotelling-Lawley  1  0.180791 0.8135593      2      9 0.47339
## Roy               1  0.180791 0.8135593      2      9 0.47339
##
## Univariate Type III Repeated-Measures ANOVA Assuming Sphericity
##
##                 SS num Df Error SS den Df        F    Pr(>F)
## (Intercept) 487276      1   5824.2     10 836.6337 5.686e-11 ***
## time            29      2    271.2     20   1.0615    0.3647
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Mauchly Tests for Sphericity
##
##      Test statistic p-value
## time        0.91149 0.65899
##
##
## Greenhouse-Geisser and Huynh-Feldt Corrections
##  for Departure from Sphericity
##
##       GG eps Pr(>F[GG])
## time 0.91869     0.3608
##
##        HF eps Pr(>F[HF])
## time 1.115516  0.3646518
```

4.2 Friedman test

```
friedman.test(as.matrix(sbp[, c("S1", "S2", "S3")]))
```

```
##
##  Friedman rank sum test
##
## data:  as.matrix(sbp[, c("S1", "S2", "S3")])
## Friedman chi-squared = 1.2381, df = 2, p-value = 0.5385
```

References

Fox, J., & Weisberg, S. (2017). *Car: Companion to applied regression*. Retrieved from https://CRAN.R-project.org/package=car

Hothorn, T., Hornik, K., van de Wiel, M. A., Winell, H., & Zeileis, A. (2017). *Coin: Conditional inference procedures in a permutation test framework*. Retrieved from https://CRAN.R-project.org/package=coin

Revelle, W. (2017). *Psych: Procedures for psychological, psychometric, and personality research*. Retrieved from https://CRAN.R-project.org/package=psych