Homework №1

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Exercise 5.14

(a) ANOVA is a natural generalization of the two-sample t test and hence, is suitable for comparing groups (their means). Therefore, this is not a reason not to use ANOVA.

(b) Car age can be considered a quantitative variable and hence, it is not a reason not to use ANOVA. However, if we consider car age to be categorical, then using something along the lines of Logistic Regression would be better (but even then, it would not hurt trying ANOVA first). But yes, it can be a valid reason not to use ANOVA if we know for sure that car age is a categorical variable.

(c) There is no equal sample size assumption when using ANOVA. However, equal sample size would be better as it would result in a well-behaved F-score. In conclusion, this is not a valid reason for not using ANOVA.

(d) Since we took a random sample of 200 people, we can generalize. However, it is true that we might have gotten unlucky with these 200 people and having a bigger sample would be more helpful. But, as already mentioned, randomization allows for generalization.

Exercise 5.16

(a) Explanatory - diet (salmon, chicken, or beef). Response - average amount of time each dog sleeps per 24 hours for the next week.

(b) This is a randomized experiment. The reason is that experimenter randomly assigned diets to 45 Border Collies and thus, has interfered with a way data is collected (in addition, randomized). This is different from an observational study where in lieu of random assignment or interference in data collection, experimenters merely observe the results of behaviors/events/etc.

(c) If we assume that 45 Border Collies IS the population, then we have just taken 100% sample from the population. The rest of the assumptions for ANOVA are met (including random sampling).

Exercise 5.18

(a) Experimental units are 45 Border Collies.

(b) Treatments are 3 types of diets (salmon, chicken, and beef).

(c) The experiment would be balanced if each type of diet (3 in total) would be assigned to the same number of Border Collies.

Exercise 5.20

- Diets - 2 degrees of freedom (because there are 3 diets in total and as soon as we know any 2, the third one is not free to vary).
- Residual - 42 degrees of freedom (because the residual degrees of freedom is n - p where n is the sample size and p is the number of predictors - we have 45 - 3 = 42).

- Total - 44 (since Diets + Residual is 2 + 42 = 44).

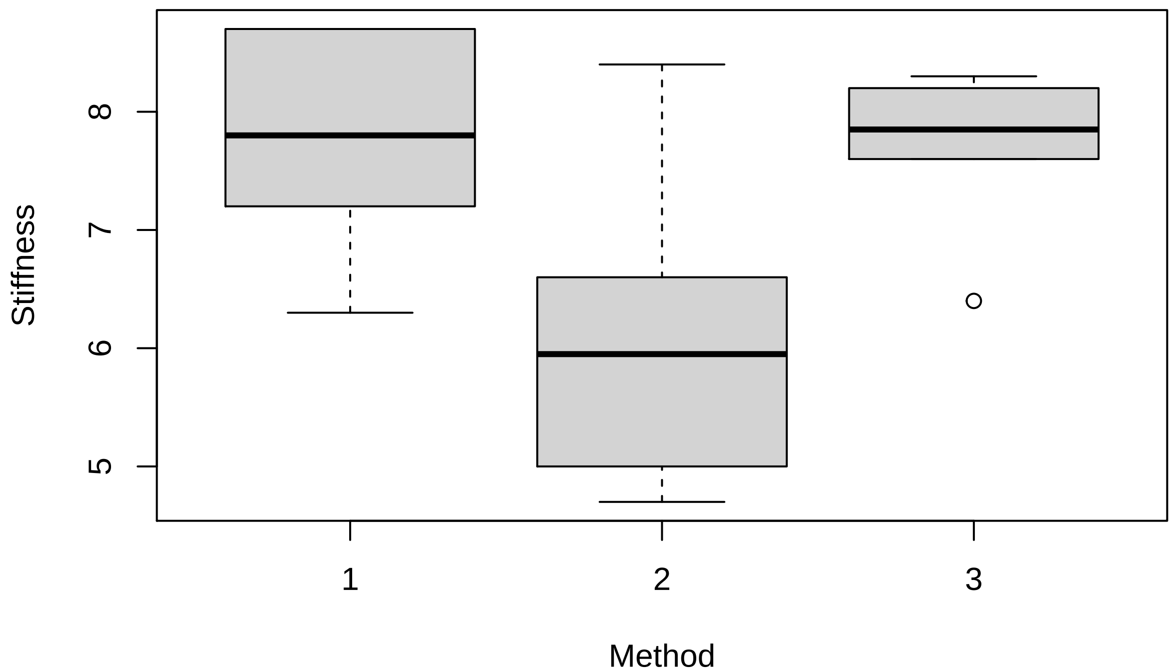
Exercise 5.38

```
library (Stat2Data)
library (emmeans)

data ("Meniscus")
head (Meniscus)
```

```
##   Method FailureLoad Displacement Stiffness
## 1      1        97.3         16.9       8.3
## 2      1       106.4         20.2       7.2
## 3      1       118.2         20.1       6.3
## 4      1        99.7         15.7       7.3
## 5      1       106.5         13.9       8.7
## 6      1        84.2         14.9       8.7
```

```
# Boxplots
boxplot (Stiffness ~ Method, data=Meniscus)
boxplot (Stiffness ~ Method, data=Meniscus)
```




```
# ANOVA
men1 = lm (Stiffness ~ as.factor (Method), data=Meniscus)
summary (men1)
```

```
##
## Call:
## lm(formula = Stiffness ~ as.factor(Method), data = Meniscus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -1.4500 -0.5250  0.0000  0.5375  2.3000
##
```

```
## Coefficients:
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)           7.7500     0.4205  18.430 1.03e-11 ***
## as.factor(Method)2  -1.6500     0.5947  -2.775   0.0142 *
## as.factor(Method)3  -0.0500     0.5947  -0.084   0.9341
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.03 on 15 degrees of freedom
## Multiple R-squared:  0.3991, Adjusted R-squared:  0.319
## F-statistic: 4.981 on 2 and 15 DF,  p-value: 0.02193
```

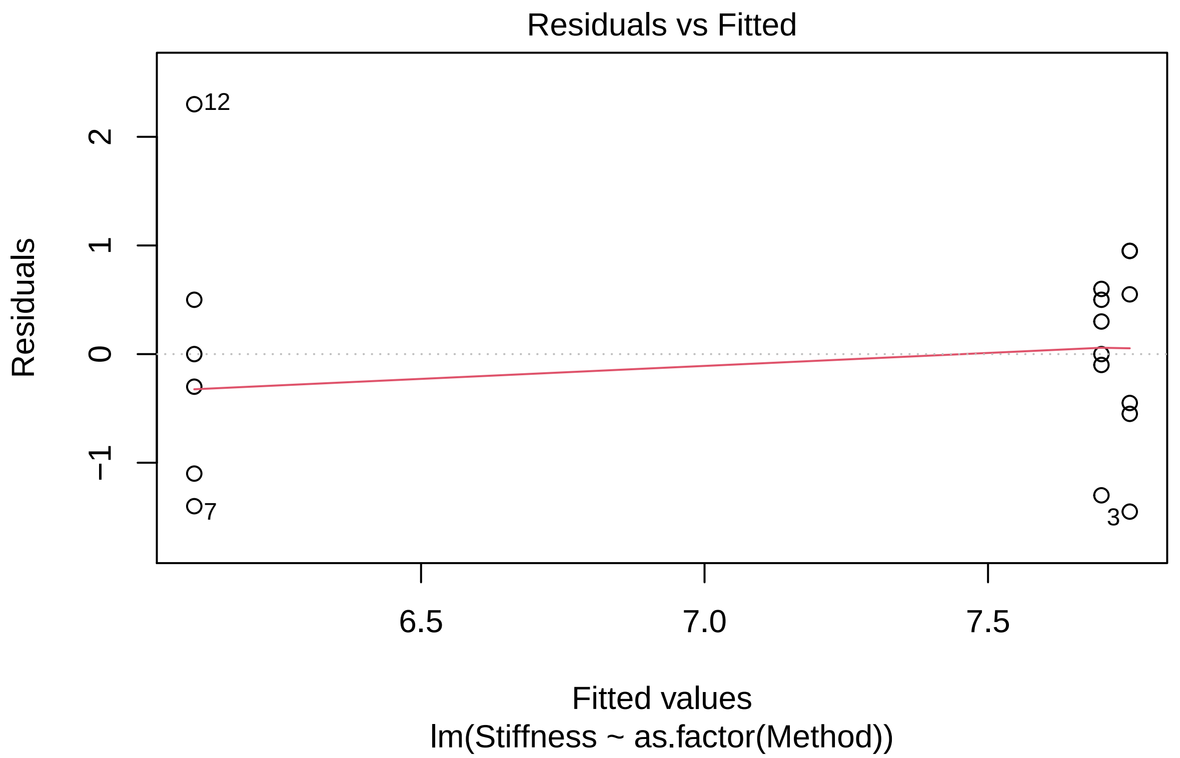
```
anova (men1)
```

```
## Analysis of Variance Table
##
## Response: Stiffness
##                   Df Sum Sq Mean Sq F value  Pr(>F)
## as.factor(Method)  2 10.570   5.285  4.9811 0.02193 *
## Residuals         15 15.915   1.061
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

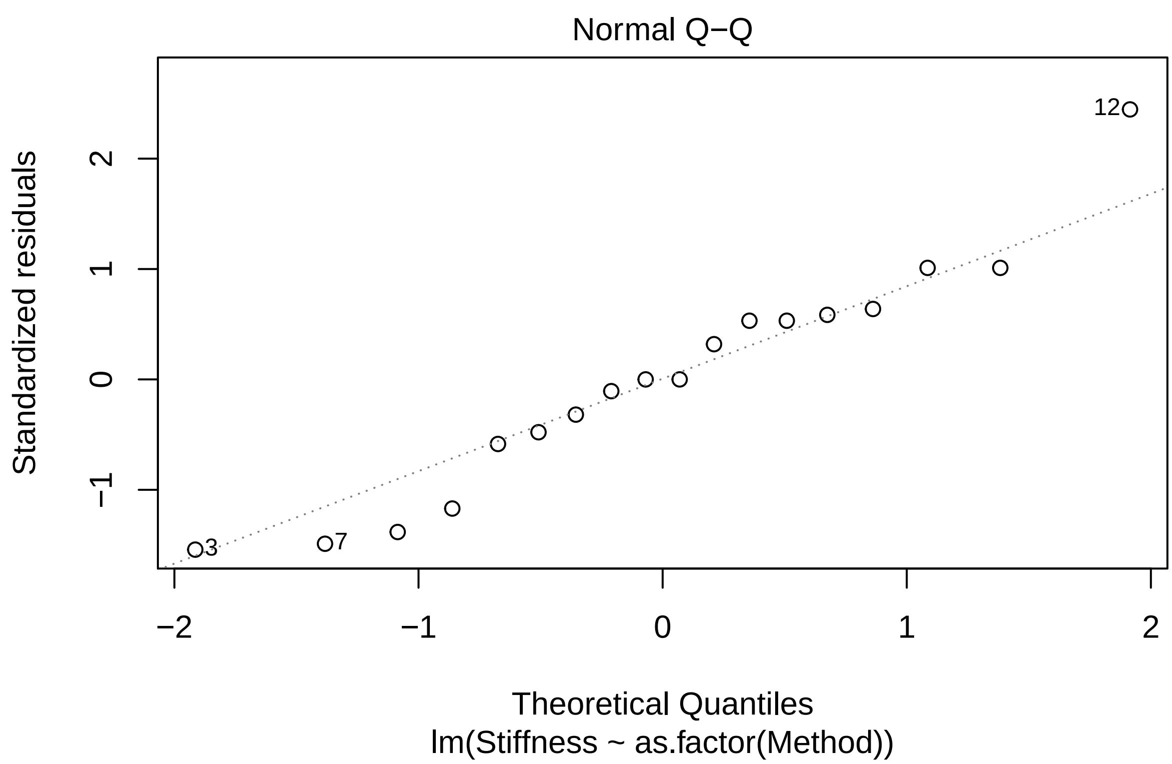
```
summary (emmeans (men1, pairwise ~ Method, adjust="none"), infer=c(T,T))
```

```
## $emmeans
##  Method emmean    SE df lower.CL upper.CL t.ratio p.value
##       1   7.75 0.421 15     6.85     8.65 18.430  <.0001
##       2   6.10 0.421 15     5.20     7.00 14.506  <.0001
##       3   7.70 0.421 15     6.80     8.60 18.311  <.0001
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df lower.CL upper.CL t.ratio p.value
##  1 - 2        1.65 0.595 15    0.382    2.918   2.775  0.0142
##  1 - 3        0.05 0.595 15   -1.218    1.318   0.084  0.9341
##  2 - 3       -1.60 0.595 15   -2.868   -0.332 -2.690  0.0168
##
## Confidence level used: 0.95
```

```
# Residuals vs Fitted and Normal QQ
plot(men1, which=1)
```




```
plot(men1, which=2)
```



(a) $H_0 : \mu_1 = \mu_2 = \mu_3$ and H_A : at least one μ_i is different (where $i \in \{1, 2, 3\}$).

(b) Notice that the methods are independent from each other and thus, the independence condition is met. The Residuals vs Fitted plot shows that the equality of variance condition is met (the red line approximately follows the dotted line) The QQ plot shows that the condition of normality is also met (dots approximately follow the line). Therefore, conditions for ANOVA are met for this data.

(c) Notice that F value is 4.98. Hence, the average variance between groups is approximately 5 times larger than the average variance within groups. Now, given that the p-value is approximately 0.022 smaller than $\alpha = 0.5$ cutoff, we have enough evidence to reject the null hypothesis and accept the alternative which states that mean values of stiffness are different, and varies depending on the type of meniscus repair.