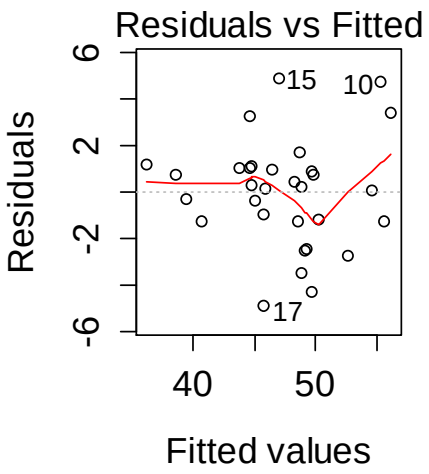
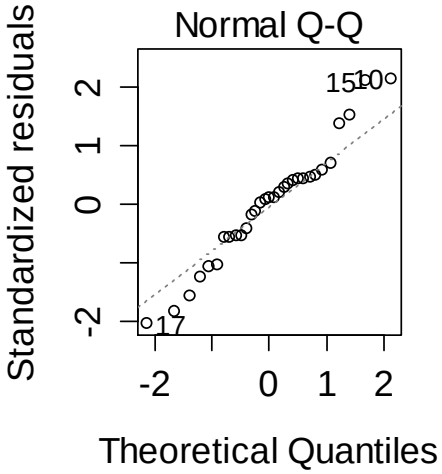
Fitness

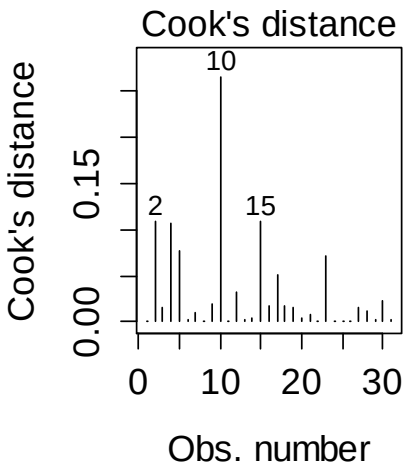
```
library(MuMIn)
str(Fitness)
cor(Fitness)

Model1 <- lm(Oxygen ~ Age + Weight + RunTime + RestPulse + RunPulse, data
= Fitness)
options(na.action = "na.fail")
AllSubsets <- dredge(Model1, rank = "AIC")
head(AllSubsets)

Model2 <- lm(Oxygen ~ Age + RunTime + RunPulse, data = Fitness)
summary(Model2)
par(mfrow=c(2,2))
plot(Model2, which = c(1:2,4:5))
```

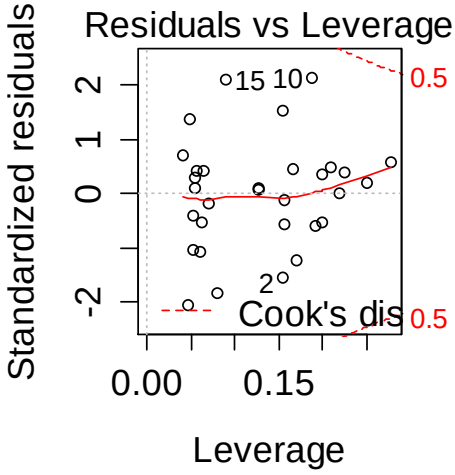
```
> str(Fitness)
'data.frame':       31 obs. of  7 variables:
 $ Age      : int  44 40 44 42 38 47 40 43 44 38 ...
 $ Weight   : num  89.5 75.1 85.8 68.2 89 ...
 $ Oxygen   : num  44.6 45.3 54.3 59.6 49.9 ...
 $ RunTime  : num  11.37 10.07 8.65 8.17 9.22 ...
 $ RestPulse: int  62 62 45 40 55 58 70 64 63 48 ...
 $ RunPulse : int  178 185 156 166 178 176 176 162 174 170 ...
 $ MaxPulse : int  182 185 168 172 180 176 180 170 176 186 ...
> cor(Fitness)
                Age      Weight     Oxygen    RunTime   RestPulse   RunPulse   MaxPulse
Age        1.0000000 -0.23353903 -0.3045924  0.1887453 -0.16409995 -0.3378703 -0.4329159
Weight    -0.2335390  1.00000000 -0.1627528  0.1435076  0.04397417  0.1815163  0.2493812
Oxygen    -0.3045924 -0.16275285  1.0000000 -0.8621949 -0.39935611 -0.3979742 -0.2367402
RunTime    0.1887453  0.14350758 -0.8621949  1.0000000  0.45038260  0.3136478  0.2261030
RestPulse -0.1640999  0.04397417 -0.3993561  0.4503826  1.00000000  0.3524606  0.3051240
RunPulse  -0.3378703  0.18151633 -0.3979742  0.3136478  0.35246060  1.0000000  0.9297538
MaxPulse  -0.4329159  0.24938123 -0.2367402  0.2261030  0.30512400  0.9297538  1.0000000
>
> Model1 <- lm(Oxygen ~ Age + Weight + RunTime + RestPulse + RunPulse, dat
a = Fitness)
> options(na.action = "na.fail")
> AllSubsets <- dredge(Model1, rank = "AIC")
Fixed term is "(Intercept)"
> head(AllSubsets)
Global model call: lm(formula = Oxygen ~ Age + Weight + RunTime + RestPuls
e + RunPulse,
    data = Fitness)
---
Model selection table
   (Intrc)     Age    RstPl    RnPls  RunTm    Weght df  logLik   AIC delta weight
14  111.70 -0.2564          -0.13090 -2.825           5 -69.506 149.0  0.00  0.425
30  115.70 -0.2764          -0.12930 -2.772 -0.04932  6 -69.056 150.1  1.10  0.245
16  112.20 -0.2621 -0.01981 -0.12870 -2.777           6 -69.458 150.9  1.91  0.164
```

```
32  116.50 -0.2853 -0.02711 -0.12630 -2.704 -0.05184  7 -68.966 151.9  2.92  0.099
10   88.46 -0.1504                   -3.204           4 -72.940 153.9  4.87  0.037
13   93.09                 -0.07351 -3.140           4 -73.124 154.2  5.24  0.031
Models ranked by AIC(x)
>
> Model2 <- lm(Oxygen ~ Age + RunTime + RunPulse, data = Fitness)
> summary(Model2)

Call:
lm(formula = Oxygen ~ Age + RunTime + RunPulse, data = Fitness)

Residuals:
    Min      1Q  Median      3Q     Max
-4.8752 -1.2493  0.2606  1.0324  4.8994

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 111.71806   10.23509  10.915 2.10e-11 ***
Age          -0.25640    0.09623  -2.664   0.0129 *
RunTime      -2.82538    0.35828  -7.886 1.77e-08 ***
RunPulse     -0.13091    0.05059  -2.588   0.0154 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.441 on 27 degrees of freedom
Multiple R-squared:  0.8111,    Adjusted R-squared:  0.7901
F-statistic: 38.64 on 3 and 27 DF,  p-value: 6.557e-10
```


Residuals vs Fitted
Residuals
Fitted values
15
10
17
-6
-2
2
6
40
50


Normal Q-Q
Standardized residuals
Theoretical Quantiles
15
10
17
-2
0
1
2

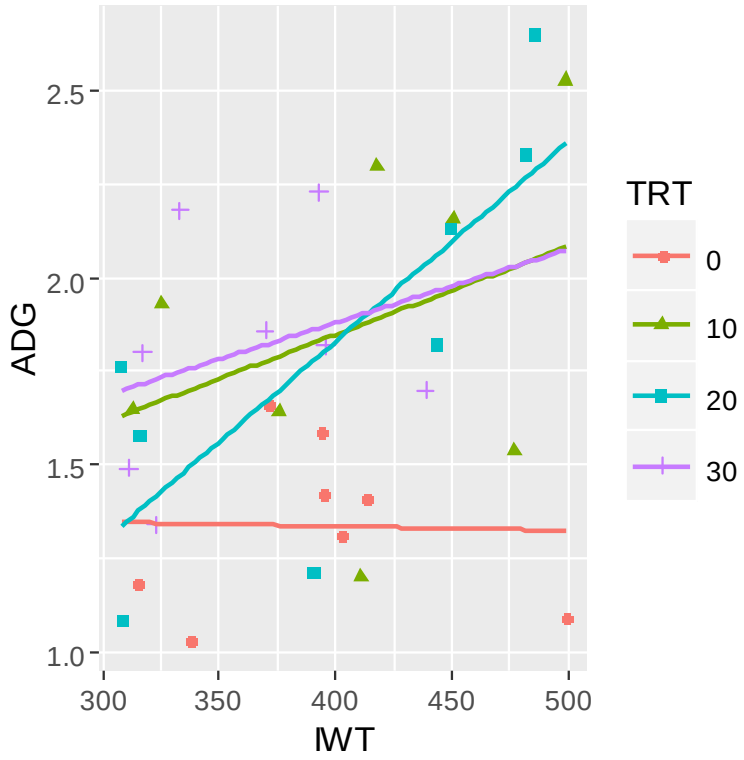

Cook's distance
Cook's distance
Obs. number
10
2
15
0.00
0.15
0
10
20
30


Residuals vs Leverage
Standardized residuals
Leverage
15
10
2
0.5
Cook's dis
0.5
-2
0
1
2
0.00
0.15

Average Daily Gain

```
library(ggplot2)
library(car)
library(lsmeans)
ADG$TRT <- as.factor(ADG$TRT)
str(ADG)

p <- qplot(IWT, ADG, shape = TRT, color = TRT, data = ADG)
p + geom_smooth(method = "lm", se = FALSE, fullrange = T)

aggregate(cbind(ADG, IWT) ~ TRT, data = ADG, FUN = mean)

#ADG Model 1A: ANCOVA WITH Interaction
Model1A <- lm(ADG ~ IWT*TRT, data = ADG)
summary(Model1A)
Anova(Model1A, type=3)

#ADG Model 1B: ANCOVA WITH Interaction Alternate Parameterization
Model1B <- lm(ADG ~ TRT + IWT:TRT -1, data = ADG)
summary(Model1B)
Anova(Model1B, type=3)
C1 <- c(0, 1, -1, 0, 0, 0, 0, 0)
lht(Model1B, C1, rhs = c(0))
C2 <- c(0, 0, 0, 0, 0, 1, -1, 0)
lht(Model1B, C2, rhs = c(0))

#ADG Model 2: ANCOVA NO Interaction
Model2 <- lm(ADG ~ TRT + IWT, data = ADG)
summary(Model2)
Anova(Model2, type=3)
lsmeans(Model2, pairwise ~ TRT)        # lsmeans() is equivalent to emmeans()

#ADG Model 3: One-way ANOVA
Model3 <- lm(ADG ~ TRT, data = ADG)
summary(Model3)
Anova(Model3, type=3)
```

```
> ADG$TRT <- as.factor(ADG$TRT)
> str(ADG)
'data.frame':      32 obs. of  4 variables:
 $ ID : int  1 2 3 4 5 6 7 8 9 10 ...
 $ TRT: Factor w/ 4 levels "0","10","20",..: 1 2 3 4 1 2 3 4 1 2 ...
 $ ADG: num  1.03 1.54 1.82 1.86 1.31 2.16 2.13 2.23 1.59 2.53 ...
 $ IWT: int  338 477 444 370 403 451 450 393 394 499 ...
>
> p <- qplot(IWT, ADG, shape = TRT, color = TRT, data = ADG)
> p + geom_smooth(method = "lm", se = FALSE, fullrange = T)
>
```




```
> aggregate(cbind(ADG, IWT) ~ TRT, data = ADG, FUN = mean)
  TRT      ADG     IWT
1   0 1.33625 391.125
2  10 1.86875 408.750
3  20 1.82000 398.250
4  30 1.80250 360.250
>
```

```
> #ADG Model 1A: ANCOVA WITH Interaction
> Model1A <- lm(ADG ~ IWT*TRT, data = ADG)
> summary(Model1A)

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.3818040  0.9470581   1.459   0.1575
IWT         -0.0001165  0.0024005  -0.049   0.9617
TRT10       -0.4773768  1.2473551  -0.383   0.7053
TRT20       -1.6952375  1.1714485  -1.447   0.1608
TRT30       -0.2856554  1.4040669  -0.203   0.8405
IWT:TRT10    0.0024757  0.0031007   0.798   0.4325
IWT:TRT20    0.0054735  0.0029433   1.860   0.0752 .
IWT:TRT30    0.0020772  0.0037314   0.557   0.5829
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3507 on 24 degrees of freedom
Multiple R-squared:  0.4987,    Adjusted R-squared:  0.3525
F-statistic: 3.411 on 7 and 24 DF,  p-value: 0.0113

> Anova(Model1A, type=3)
Anova Table (Type III tests)

Response: ADG
             Sum Sq Df F value Pr(>F)
(Intercept) 0.26187  1  2.1288 0.1575
IWT         0.00029  1  0.0024 0.9617
TRT         0.34487  3  0.9345 0.4393
IWT:TRT     0.47229  3  1.2798 0.3038
Residuals   2.95228 24
>
> #ADG Model 1B: ANCOVA WITH Interaction Alternate Parameteriztion
> Model1B <- lm(ADG ~ TRT + IWT:TRT -1, data = ADG)
> summary(Model1B)

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
TRT0       1.3818040  0.9470581   1.459  0.15752
TRT10      0.9044272  0.8117732   1.114  0.27625
TRT20     -0.3134335  0.6894725  -0.455  0.65348
TRT30      1.0961485  1.0365736   1.057  0.30082
TRT0:IWT  -0.0001165  0.0024005  -0.049  0.96170
TRT10:IWT  0.0023592  0.0019627   1.202  0.24108
TRT20:IWT  0.0053570  0.0017030   3.146  0.00438 **
TRT30:IWT  0.0019607  0.0028567   0.686  0.49907
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3507 on 24 degrees of freedom
```

```
Multiple R-squared:  0.9702,    Adjusted R-squared:  0.9603
F-statistic: 97.72 on 8 and 24 DF,  p-value: < 2.2e-16

> Anova(Model1B, type=3)
Anova Table (Type III tests)

Response: ADG
            Sum Sq Df F value  Pr(>F)
TRT       0.57754  4  1.1738 0.34725
TRT:IWT   1.45314  4  2.9533 0.04068 *
Residuals 2.95228 24
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> C1 <- c(0, 1, -1, 0, 0, 0, 0, 0)
> lht(Model1B, C1, rhs = c(0))
Linear hypothesis test

Hypothesis:
TRT10 - TRT20 = 0

Model 1: restricted model
Model 2: ADG ~ TRT + IWT:TRT - 1

  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1     25 3.1131
2     24 2.9523  1   0.16084 1.3075 0.2641
> C2 <- c(0, 0, 0, 0, 0, 1, -1, 0)
> lht(Model1B, C2, rhs = c(0))
Linear hypothesis test

Hypothesis:
TRT10:IWT - TRT20:IWT = 0

Model 1: restricted model
Model 2: ADG ~ TRT + IWT:TRT - 1

  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1     25 3.1160
2     24 2.9523  1   0.16372 1.3309   0.26
>
```

```
> #ADG Model 2: ANCOVA NO Interaction
> Model2 <- lm(ADG ~ TRT + IWT, data = ADG)
> summary(Model2)

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.172359   0.437064   0.394  0.69642
TRT10       0.480052   0.179066   2.681  0.01237 *
TRT20       0.462548   0.178233   2.595  0.01510 *
TRT30       0.558126   0.181109   3.082  0.00470 **
IWT         0.002976   0.001070   2.781  0.00976 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3561 on 27 degrees of freedom
Multiple R-squared:  0.4185,    Adjusted R-squared:  0.3324
F-statistic: 4.858 on 4 and 27 DF,  p-value: 0.004405

> Anova(Model2, type=3)
Anova Table (Type III tests)

Response: ADG
            Sum Sq Df F value  Pr(>F)
(Intercept) 0.0197  1  0.1555 0.69642
TRT         1.5376  3  4.0408 0.01702 *
IWT         0.9809  1  7.7333 0.00976 **
Residuals   3.4246 27
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsmeans(Model2, pairwise ~ TRT)     # lsmeans() is equivalent to emmeans()
$lsmeans
 TRT   lsmean        SE df lower.CL upper.CL
 0   1.331693 0.1259253 27 1.073316 1.590071
 10  1.811746 0.1275723 27 1.549989 2.073502
 20  1.794241 0.1262548 27 1.535188 2.053295
 30  1.889820 0.1297708 27 1.623552 2.156087

Confidence level used: 0.95

$contrasts
 contrast    estimate        SE df t.ratio p.value
 0 - 10   -0.48005237 0.1790661 27  -2.681  0.0564
 0 - 20   -0.46254777 0.1782333 27  -2.595  0.0677
 0 - 30   -0.55812635 0.1811091 27  -3.082  0.0229
 10 - 20   0.01750460 0.1784243 27   0.098  0.9997
 10 - 30  -0.07807398 0.1854790 27  -0.421  0.9744
 20 - 30  -0.09557858 0.1826539 27  -0.523  0.9527

P value adjustment: tukey method for comparing a family of 4 estimates
```

```
>
> #ADG Model 3: One-way ANOVA
> Model3 <- lm(ADG ~ TRT, data = ADG)
> summary(Model3)

Call:
lm(formula = ADG ~ TRT, data = ADG)

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   1.3362     0.1402   9.528 2.77e-10 ***
TRT10         0.5325     0.1983   2.685   0.0121 *
TRT20         0.4837     0.1983   2.439   0.0213 *
TRT30         0.4663     0.1983   2.351   0.0260 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3967 on 28 degrees of freedom
Multiple R-squared:  0.252,     Adjusted R-squared:  0.1718
F-statistic: 3.144 on 3 and 28 DF,  p-value: 0.04077

> Anova(Model3, type=3)
Anova Table (Type III tests)

Response: ADG
             Sum Sq Df F value    Pr(>F)
(Intercept) 14.2845  1 90.7895 2.766e-10 ***
TRT          1.4841  3  3.1441   0.04077 *
Residuals    4.4054 28
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```