# Final Project

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## 1.

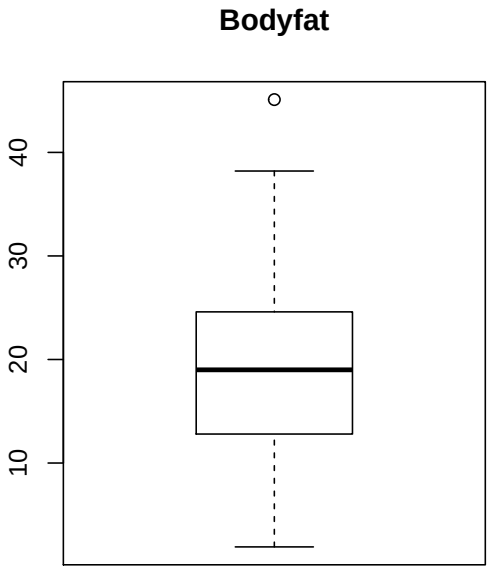
Below, we gather and process our data

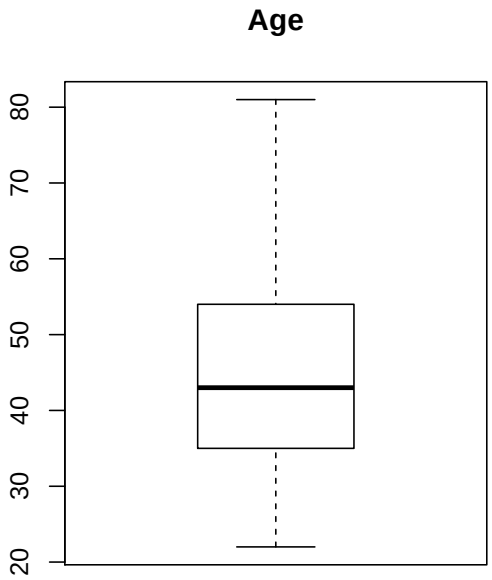
```
bodyfat.dat = read.table("http://inside.mines.edu/~wnavidi/math424/project/bodyfat.dat",
                         header = TRUE)
bodyfatDF = as.data.frame(bodyfat.dat)

min(bodyfatDF$Bodyfat)
bodyfatDF <- bodyfatDF[-c(which.min(bodyfatDF$Bodyfat)),]
min(bodyfatDF$Bodyfat)
max(bodyfatDF$Bodyfat)

min(bodyfatDF$Age)
max(bodyfatDF$Age)

min(bodyfatDF$Weight)
max(bodyfatDF$Weight)

min(bodyfatDF$Height)
bodyfatDF <- bodyfatDF[-c(which.min(bodyfatDF$Height)),]
min(bodyfatDF$Height)
max(bodyfatDF$Height)

min(bodyfatDF$BMI)
max(bodyfatDF$BMI)

min(bodyfatDF$Abdomen)
max(bodyfatDF$Abdomen)

min(bodyfatDF$Ankle)
max(bodyfatDF$Ankle)

min(bodyfatDF$Biceps)
max(bodyfatDF$Biceps)

min(bodyfatDF$Chest)
max(bodyfatDF$Chest)

min(bodyfatDF$Forearm)
max(bodyfatDF$Forearm)

min(bodyfatDF$Hip)
max(bodyfatDF$Hip)

min(bodyfatDF$Knee)
max(bodyfatDF$Knee)
```

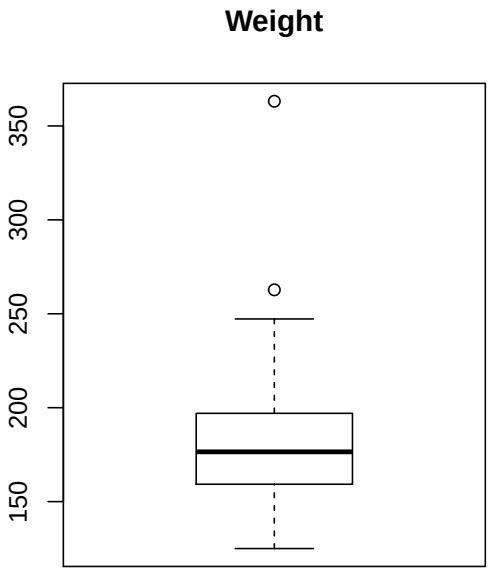
```r
min(bodyfatDF$Neck)
max(bodyfatDF$Neck)

min(bodyfatDF$Thigh)
max(bodyfatDF$Thigh)

min(bodyfatDF$Wrist)
max(bodyfatDF$Wrist)

Bodyfat = bodyfatDF$Bodyfat
Age = bodyfatDF$Age
Weight = bodyfatDF$Weight
Height = bodyfatDF$Height
BMI = bodyfatDF$BMI
Abdomen = bodyfatDF$Abdomen
Ankle = bodyfatDF$Ankle
Biceps = bodyfatDF$Biceps
Chest = bodyfatDF$Chest
Forearm = bodyfatDF$Forearm
Hip = bodyfatDF$Hip
Knee = bodyfatDF$Knee
Neck = bodyfatDF$Neck
Thigh = bodyfatDF$Thigh
Wrist = bodyfatDF$Wrist
```

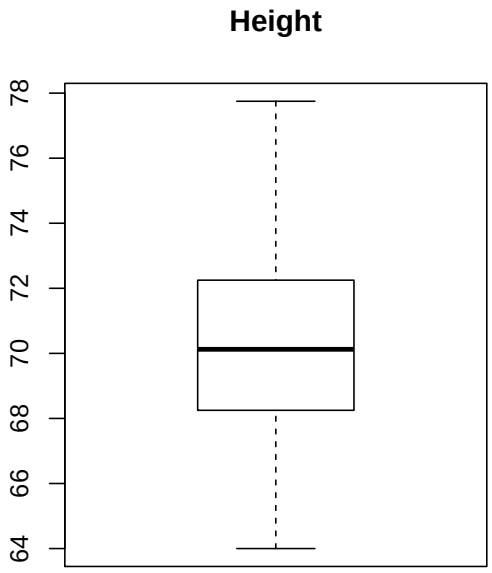
## 2.

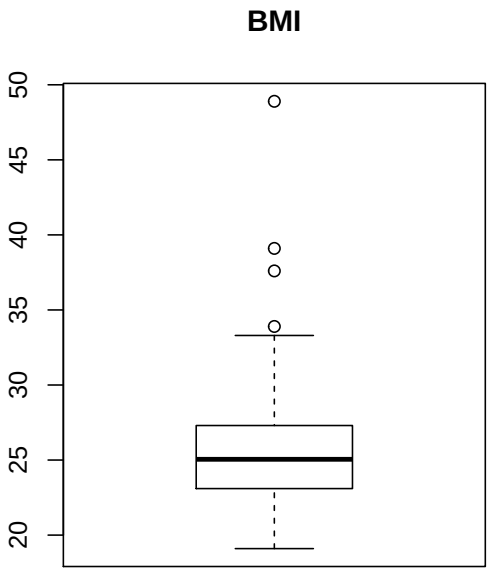
Boxplots for the data to help verify data cleaning process

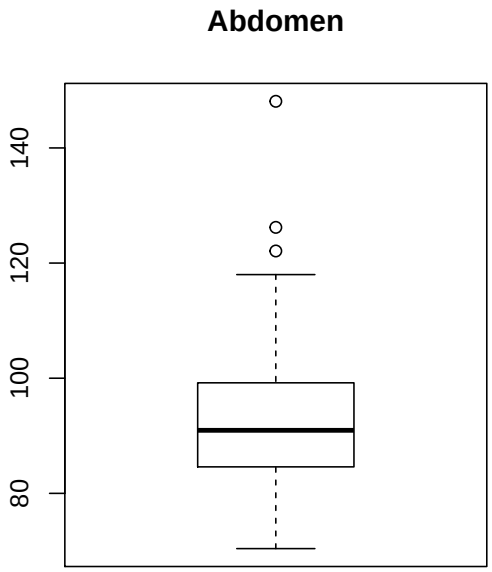


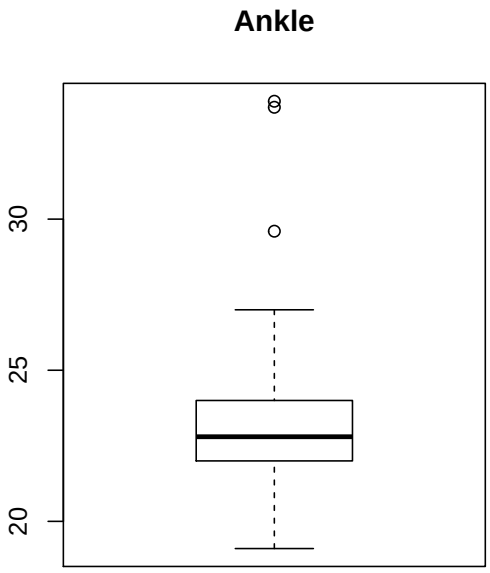



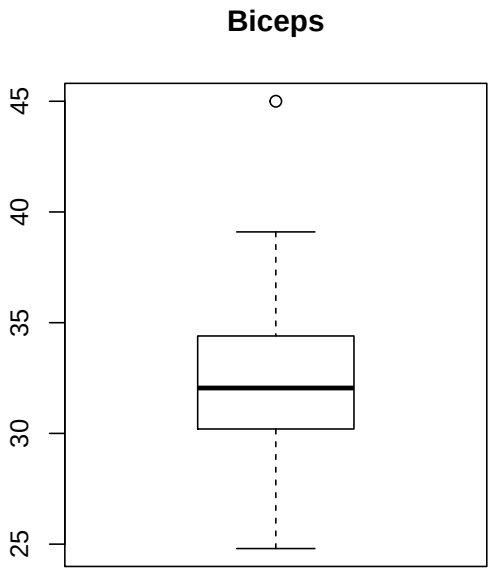

Weight
150
200
250
300
350

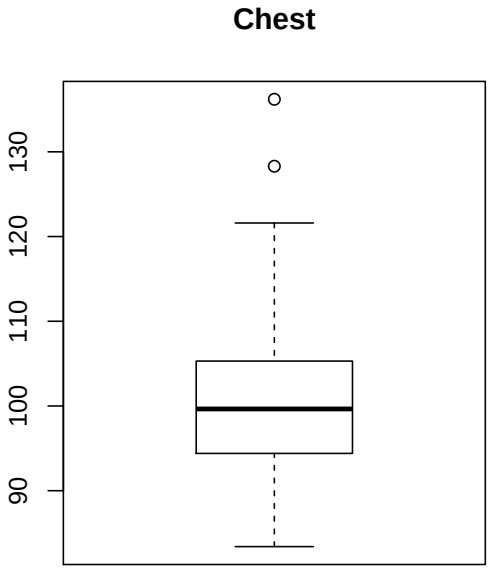

Height
64
66
68
70
72
74
76
78

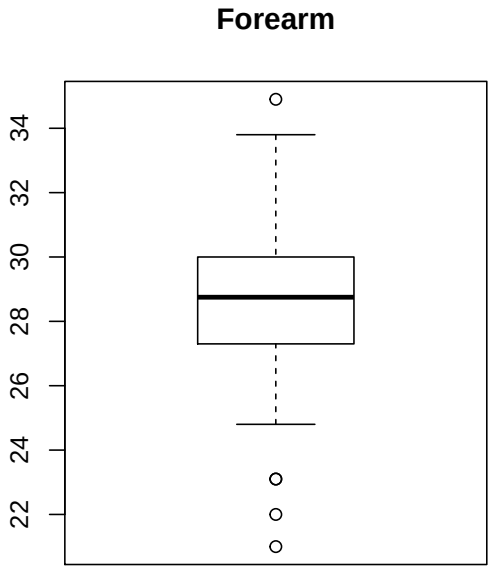

BMI
20
25
30
35
40
45
50

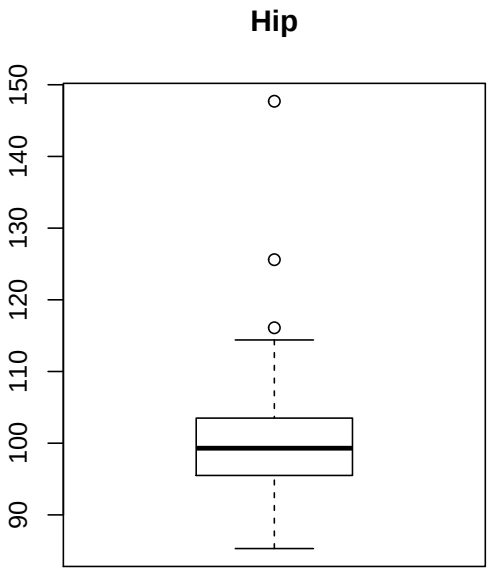

Abdomen
80
100
120
140

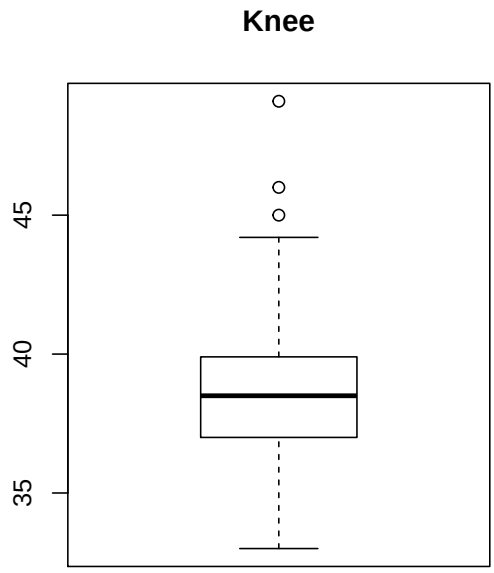

Ankle
20
25
30

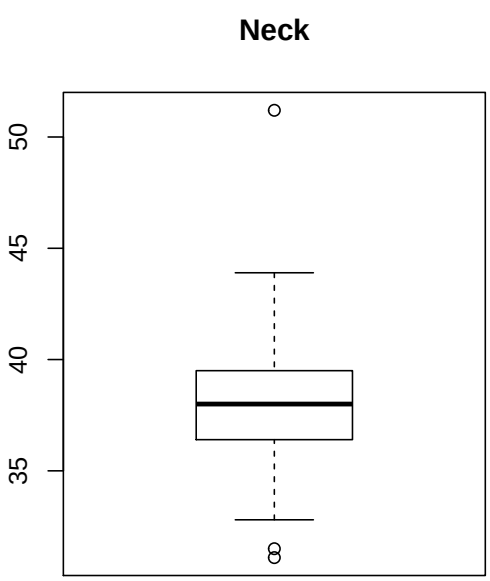

Biceps
25
30
35
40
45

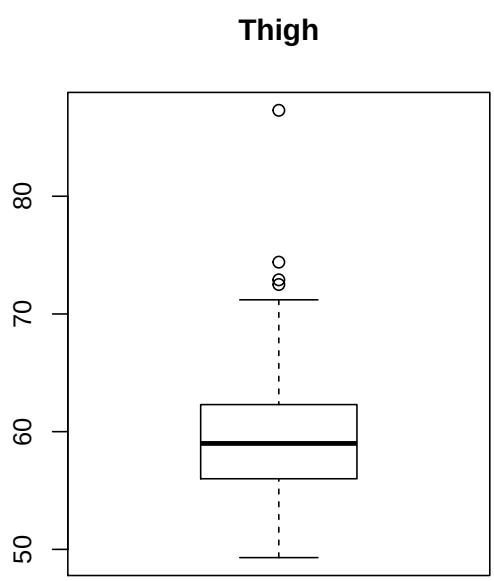

Chest
90
100
110
120
130

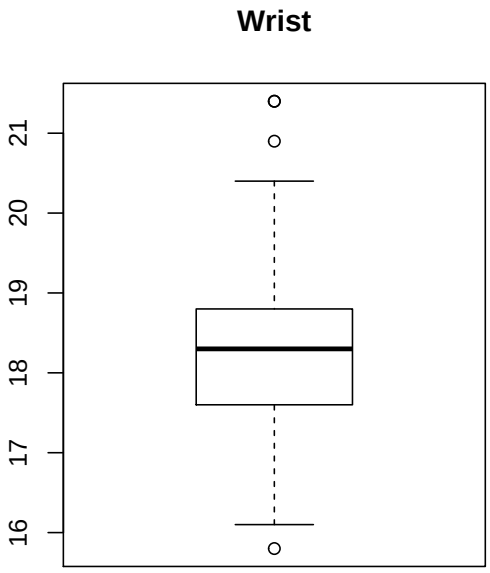

Forearm
22
24
26
28
30
32
34


Hip
150
140
130
120
110
100
90


Knee
45
40
35


Neck
50
45
40
35


Thigh
80
70
60
50




### 3.

Below we fit a simple linear model

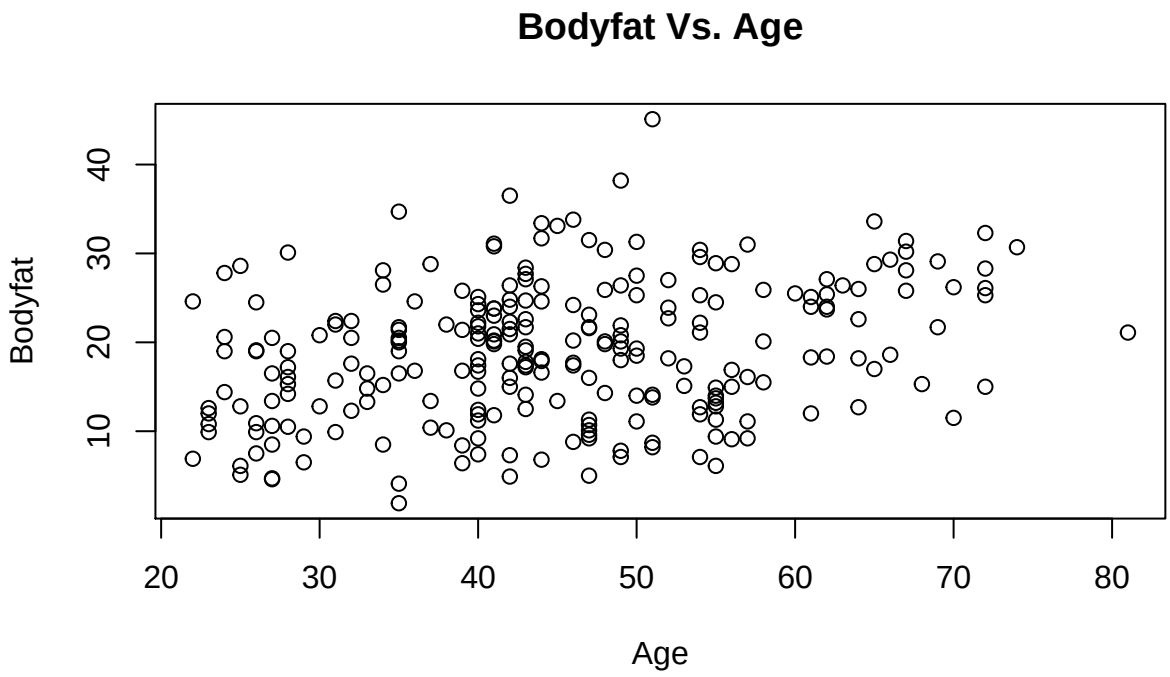
```
all.lm = lm(Bodyfat ~ Age + Weight + Height + BMI + Neck + Chest + Abdomen + Hip +
              Thigh + Knee + Ankle + Biceps + Forearm + Wrist)
all.sum = summary(all.lm)
all.sum
```

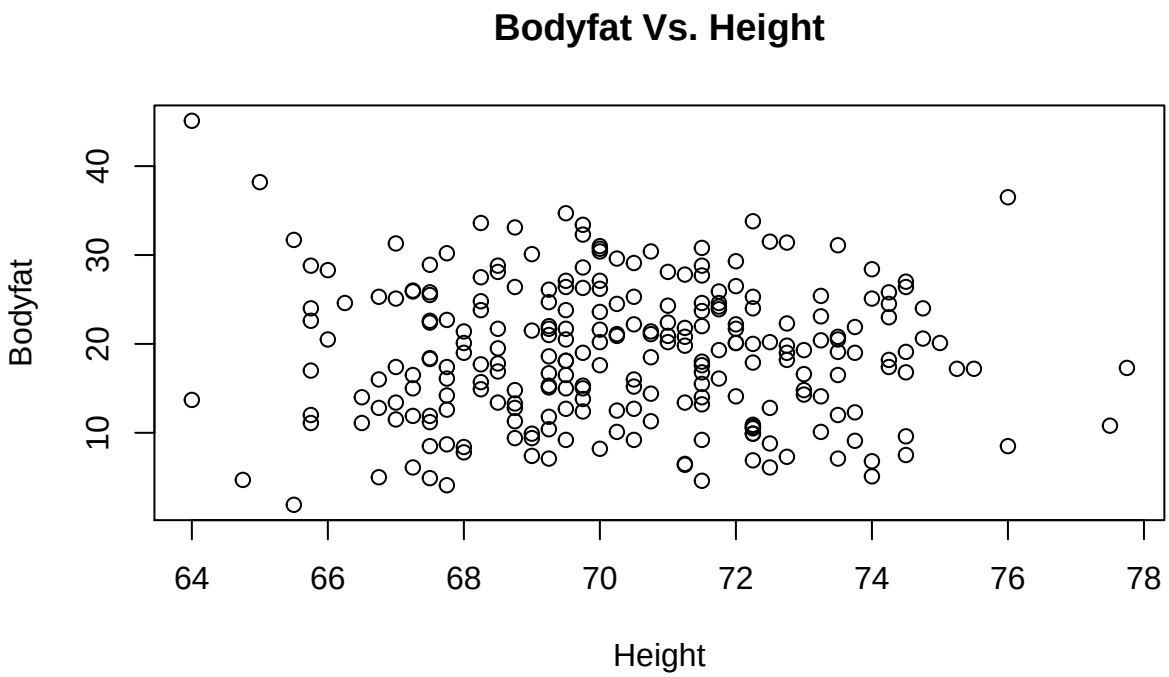
```
##
## Call:
## lm(formula = Bodyfat ~ Age + Weight + Height + BMI + Neck + Chest +
##     Abdomen + Hip + Thigh + Knee + Ankle + Biceps + Forearm +
##     Wrist)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.1062  -2.6605  -0.2011   2.8920   9.2619
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -44.91075   36.67739  -1.224  0.22200
## Age           0.05740    0.03004   1.911  0.05725 .
## Weight       -0.16239    0.10076  -1.612  0.10838
## Height        0.43668    0.50801   0.860  0.39089
## BMI           0.75340    0.73339   1.027  0.30534
## Neck         -0.42594    0.21857  -1.949  0.05251 .
## Chest        -0.05969    0.09907  -0.603  0.54740
## Abdomen       0.87126    0.08569  10.168  < 2e-16 ***
## Hip          -0.22543    0.13796  -1.634  0.10359
```

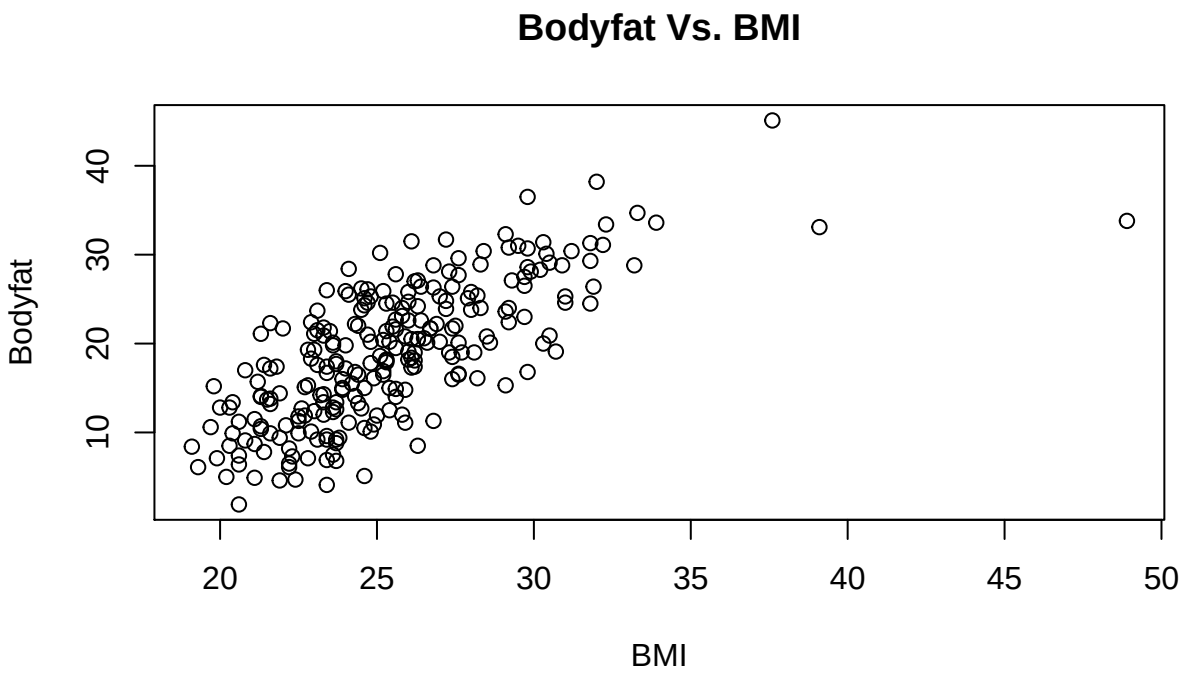
```
## Thigh         0.21780    0.13660   1.594  0.11220
## Knee         -0.01257    0.22965  -0.055  0.95639
## Ankle         0.12398    0.20837   0.595  0.55243
## Biceps        0.16357    0.16000   1.022  0.30769
## Forearm       0.39166    0.18627   2.103  0.03656 *
## Wrist        -1.49585    0.49586  -3.017  0.00284 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.988 on 235 degrees of freedom
## Multiple R-squared:  0.7432, Adjusted R-squared:  0.7279
## F-statistic: 48.58 on 14 and 235 DF,  p-value: < 2.2e-16
```

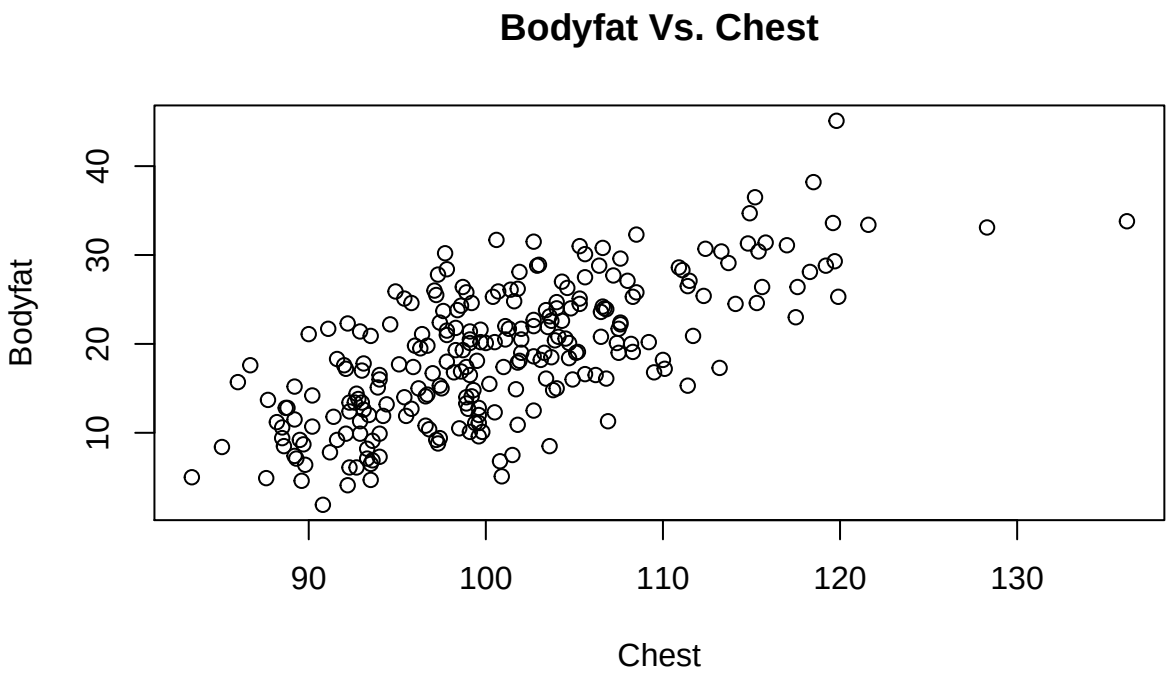
**4.**

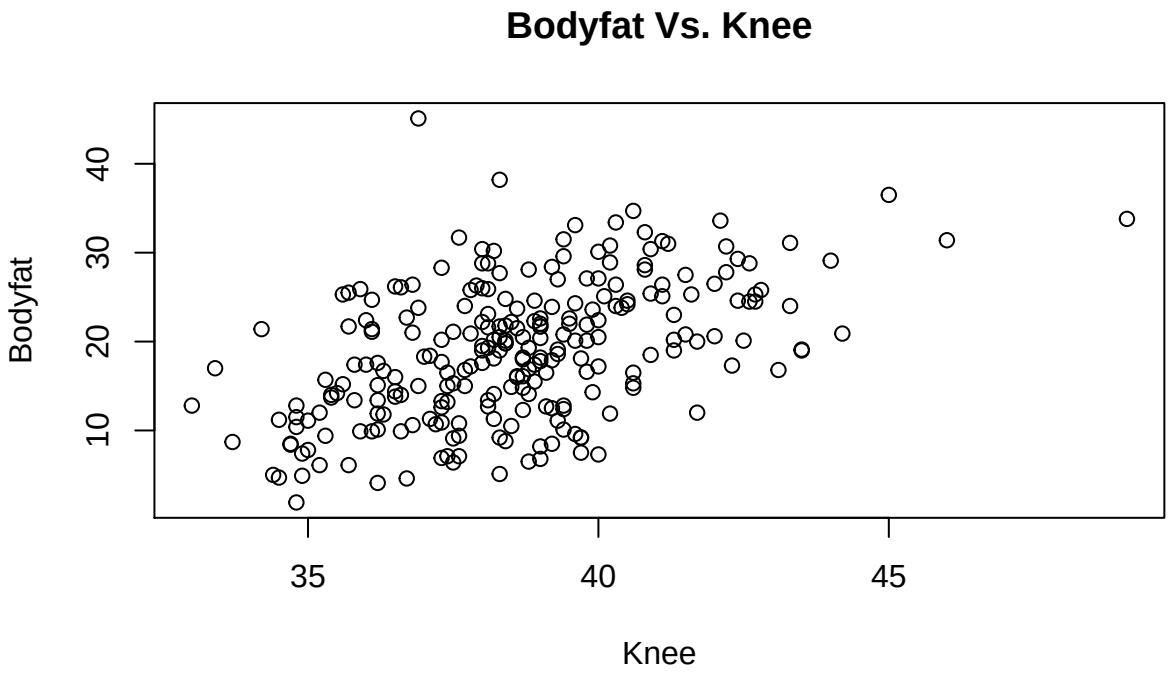
Scater plots for high p-val variables

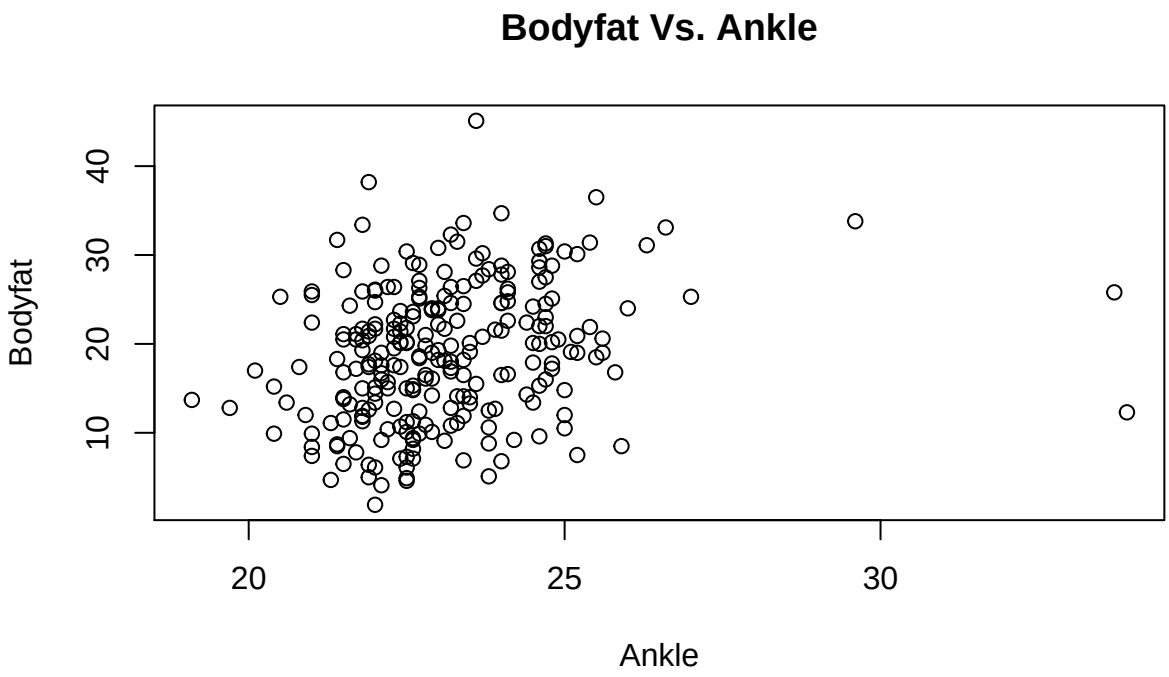


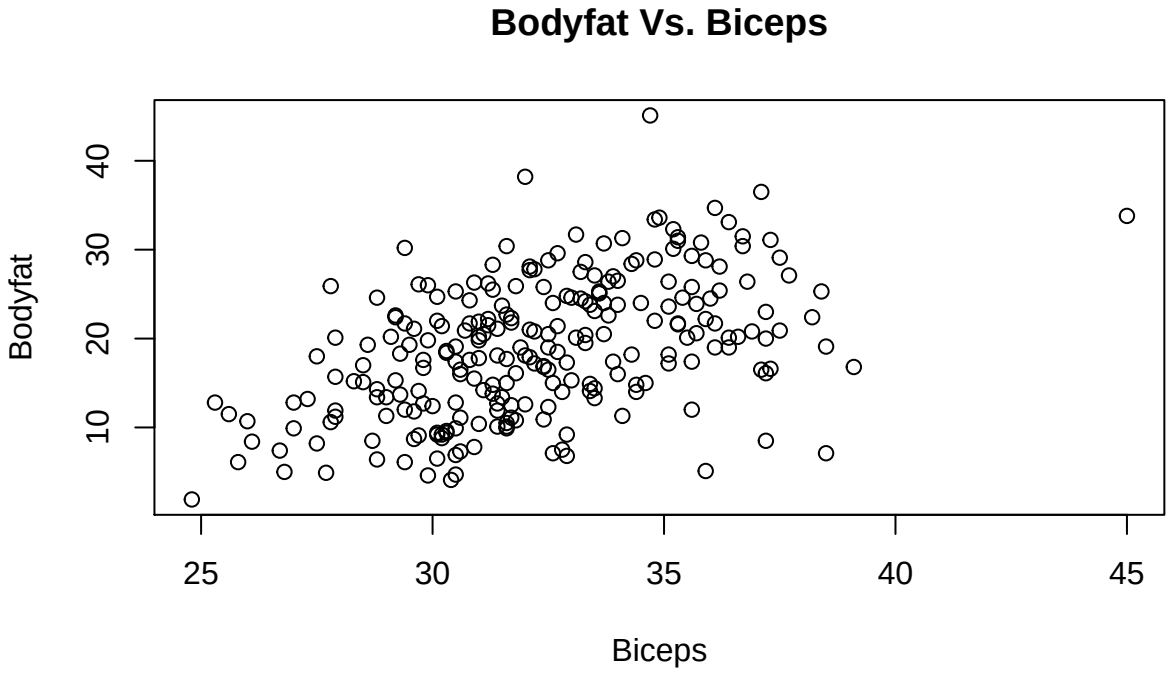

Bodyfat Vs. Height
Bodyfat
10
20
30
40
64
66
68
70
72
74
76
78
Height


Bodyfat Vs. BMI
Bodyfat
10
20
30
40
20
25
30
35
40
45
50
BMI


Bodyfat Vs. Chest
Bodyfat
10
20
30
40
90
100
110
120
130
Chest


Bodyfat Vs. Knee
Bodyfat
10
20
30
40
35
40
45
Knee




**5.**

Fit a linear model without height

```
new1.lm = lm(Bodyfat ~ Age + Weight + BMI + Neck + Chest + Abdomen + Hip + Thigh
             + Knee + Ankle + Biceps + Forearm + Wrist)
new1.sum = summary(new1.lm)
new1.sum
```

```
##
## Call:
## lm(formula = Bodyfat ~ Age + Weight + BMI + Neck + Chest + Abdomen +
##     Hip + Thigh + Knee + Ankle + Biceps + Forearm + Wrist)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.277  -2.605  -0.163   2.902   9.238
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -15.833985  14.169855  -1.117  0.26494
## Age           0.055256   0.029918   1.847  0.06601 .
## Weight       -0.084941   0.045082  -1.884  0.06077 .
## BMI           0.157594   0.239499   0.658  0.51117
## Neck         -0.436939   0.218070  -2.004  0.04625 *
## Chest        -0.050986   0.098497  -0.518  0.60519
## Abdomen       0.879453   0.085108  10.333  < 2e-16 ***
## Hip          -0.214112   0.137254  -1.560  0.12011
## Thigh         0.205946   0.135832   1.516  0.13081
## Knee         -0.004585   0.229331  -0.020  0.98407
## Ankle         0.141490   0.207258   0.683  0.49548
## Biceps        0.161964   0.159902   1.013  0.31215
## Forearm       0.410752   0.184836   2.222  0.02722 *
## Wrist        -1.486709   0.495474  -3.001  0.00298 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.986 on 236 degrees of freedom
## Multiple R-squared:  0.7424, Adjusted R-squared:  0.7282
## F-statistic: 52.32 on 13 and 236 DF,  p-value: < 2.2e-16
```

### 6.

New linear model dropping Ankle, Chest, Knee, Biceps

```
new2.lm = lm(Bodyfat ~ Age + Weight + BMI + Neck + Abdomen + Hip + Thigh
             + Forearm + Wrist)
new2.sum = summary(new2.lm)
new2.sum
```

```
##
## Call:
## lm(formula = Bodyfat ~ Age + Weight + BMI + Neck + Abdomen +
##     Hip + Thigh + Forearm + Wrist)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.1188  -2.7265  -0.1013   2.7409   9.3604
##
```

```
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -15.96792   11.40076  -1.401  0.16262
## Age           0.05527    0.02874   1.923  0.05569 .
## Weight       -0.07950    0.03712  -2.142  0.03324 *
## BMI           0.15700    0.20777   0.756  0.45060
## Neck         -0.44224    0.21276  -2.079  0.03872 *
## Abdomen       0.84596    0.07900  10.709  < 2e-16 ***
## Hip          -0.21651    0.13179  -1.643  0.10173
## Thigh         0.25286    0.12188   2.075  0.03908 *
## Forearm       0.45102    0.17408   2.591  0.01016 *
## Wrist        -1.37966    0.47463  -2.907  0.00399 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.967 on 240 degrees of freedom
## Multiple R-squared:  0.7405, Adjusted R-squared:  0.7308
## F-statistic: 76.11 on 9 and 240 DF,  p-value: < 2.2e-16
```

## 7.

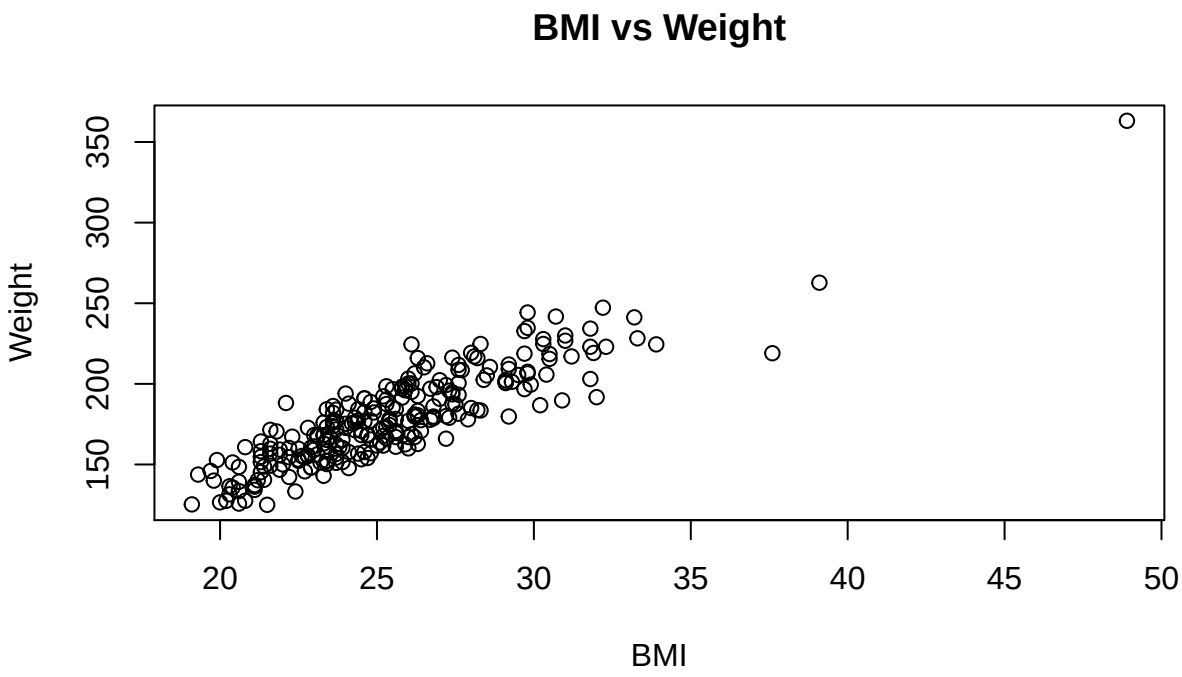
Calculate $F$-statistic for dropping Ankle, Chest, Knee, Biceps

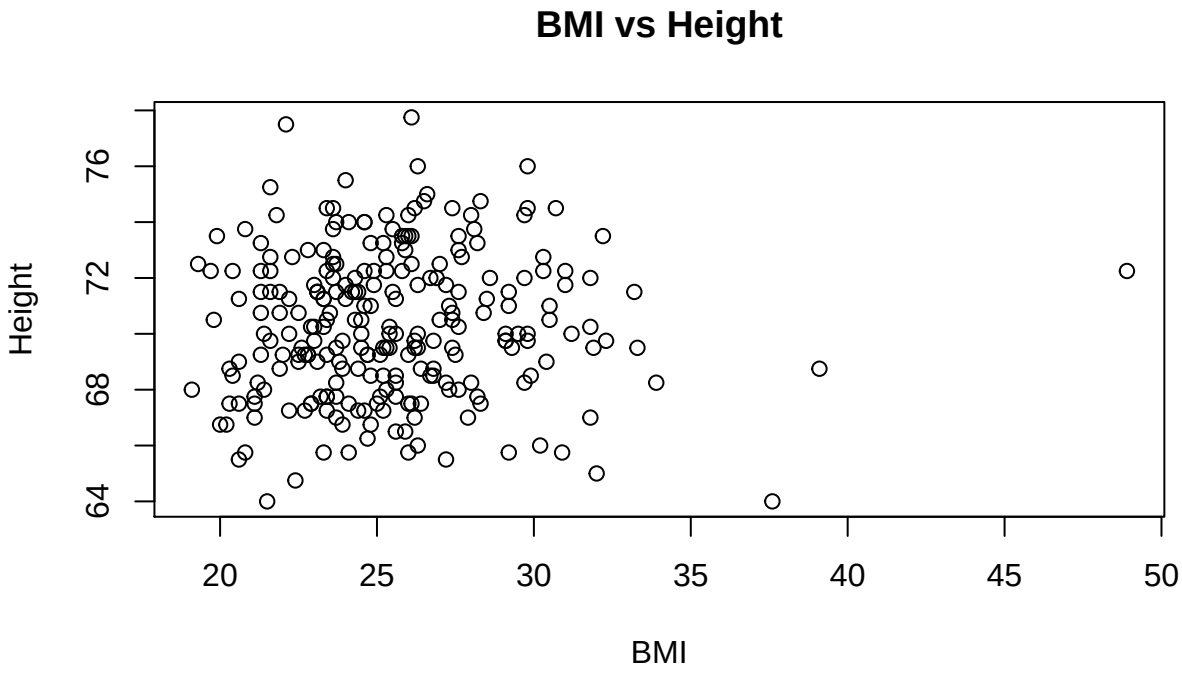
```
anova(new2.lm, new1.lm)
```

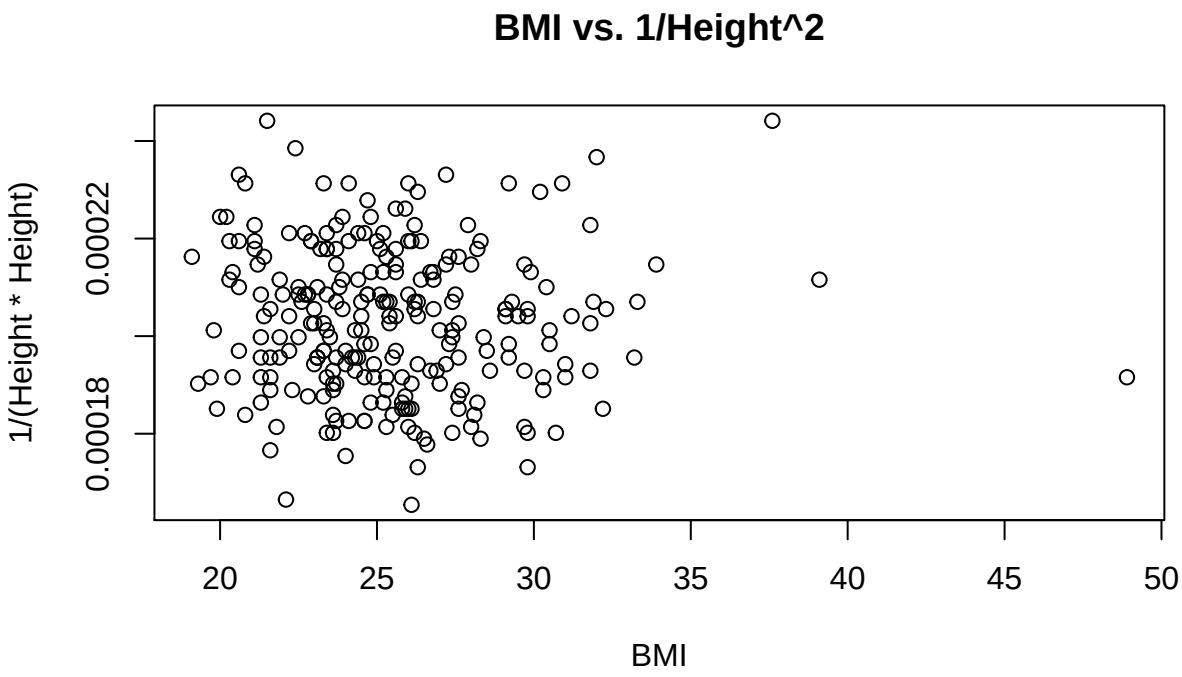
```
## Analysis of Variance Table
##
## Model 1: Bodyfat ~ Age + Weight + BMI + Neck + Abdomen + Hip + Thigh +
##     Forearm + Wrist
## Model 2: Bodyfat ~ Age + Weight + BMI + Neck + Chest + Abdomen + Hip +
##     Thigh + Knee + Ankle + Biceps + Forearm + Wrist
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1    240 3777.2
## 2    236 3750.0  4    27.168 0.4274 0.7888
```

## 8.

Investigating the colinearity of BMI


BMI vs Weight
Weight
150
200
250
300
350
20
25
30
35
40
45
50
BMI


BMI vs Height
Height
64
68
72
76
20
25
30
35
40
45
50
BMI




**9.**

New model dropping BMI

```
new3.lm = lm(Bodyfat ~ Age + Weight + Neck + Abdomen + Hip + Thigh + Forearm +
               Wrist)
new3.sum = summary(new3.lm)
new3.sum
```

```
##
## Call:
## lm(formula = Bodyfat ~ Age + Weight + Neck + Abdomen + Hip +
##     Thigh + Forearm + Wrist)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.0756  -2.7707  -0.1871   2.7057   9.5237
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -18.46826   10.90031  -1.694  0.09150 .
## Age           0.05577    0.02871   1.943  0.05323 .
## Weight       -0.08081    0.03705  -2.181  0.03014 *
## Neck         -0.41183    0.20874  -1.973  0.04965 *
## Abdomen       0.87775    0.06680  13.140  < 2e-16 ***
## Hip          -0.20063    0.12999  -1.543  0.12404
## Thigh         0.26719    0.12028   2.221  0.02726 *
## Forearm       0.46567    0.17285   2.694  0.00755 **
## Wrist        -1.39341    0.47386  -2.941  0.00359 **
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.964 on 241 degrees of freedom
## Multiple R-squared:  0.7399, Adjusted R-squared:  0.7313
## F-statistic:  85.7 on 8 and 241 DF,  p-value: < 2.2e-16
```

## 10.

Running best subsets on full linear model

```
library("leaps")
```

```
## Warning: package 'leaps' was built under R version 3.5.3
```

```
bestall = regsubsets(Bodyfat ~ Age + Weight + Height + BMI + Neck + Chest +
                       Abdomen + Hip + Thigh + Knee + Ankle + Biceps + Forearm +
                       Wrist, data = bodyfatDF[,2:15], nbest = 1, nvmax=15)
bestall.sum = summary(bestall)
bestall.sum$which
```

```
##    (Intercept)   Age Weight Height   BMI  Neck Chest Abdomen   Hip Thigh
## 1         TRUE FALSE  FALSE  FALSE FALSE FALSE FALSE    TRUE FALSE FALSE
## 2         TRUE FALSE   TRUE  FALSE FALSE FALSE FALSE    TRUE FALSE FALSE
## 3         TRUE FALSE   TRUE  FALSE FALSE FALSE FALSE    TRUE FALSE FALSE
## 4         TRUE FALSE   TRUE  FALSE FALSE FALSE FALSE    TRUE FALSE FALSE
## 5         TRUE FALSE   TRUE  FALSE FALSE  TRUE FALSE    TRUE FALSE FALSE
## 6         TRUE FALSE   TRUE  FALSE FALSE  TRUE FALSE    TRUE FALSE FALSE
## 7         TRUE  TRUE   TRUE  FALSE FALSE  TRUE FALSE    TRUE FALSE  TRUE
## 8         TRUE  TRUE   TRUE  FALSE FALSE  TRUE FALSE    TRUE  TRUE  TRUE
## 9         TRUE  TRUE   TRUE  FALSE FALSE  TRUE FALSE    TRUE  TRUE  TRUE
## 10        TRUE  TRUE   TRUE  FALSE FALSE  TRUE FALSE    TRUE  TRUE  TRUE
## 11        TRUE  TRUE   TRUE   TRUE  TRUE  TRUE FALSE    TRUE  TRUE  TRUE
## 12        TRUE  TRUE   TRUE   TRUE  TRUE  TRUE  TRUE    TRUE  TRUE  TRUE
## 13        TRUE  TRUE   TRUE   TRUE  TRUE  TRUE  TRUE    TRUE  TRUE  TRUE
## 14        TRUE  TRUE   TRUE   TRUE  TRUE  TRUE  TRUE    TRUE  TRUE  TRUE
##     Knee Ankle Biceps Forearm Wrist
## 1  FALSE FALSE  FALSE   FALSE FALSE
## 2  FALSE FALSE  FALSE   FALSE FALSE
## 3  FALSE FALSE  FALSE   FALSE  TRUE
## 4  FALSE FALSE  FALSE    TRUE  TRUE
## 5  FALSE FALSE  FALSE    TRUE  TRUE
## 6  FALSE FALSE   TRUE    TRUE  TRUE
## 7  FALSE FALSE  FALSE    TRUE  TRUE
## 8  FALSE FALSE  FALSE    TRUE  TRUE
## 9  FALSE FALSE   TRUE    TRUE  TRUE
## 10 FALSE  TRUE   TRUE    TRUE  TRUE
## 11 FALSE FALSE   TRUE    TRUE  TRUE
## 12 FALSE FALSE   TRUE    TRUE  TRUE
## 13 FALSE  TRUE   TRUE    TRUE  TRUE
## 14  TRUE  TRUE   TRUE    TRUE  TRUE
```

```
cbind(bestall.sum$rsq, bestall.sum$adjr2, bestall.sum$cp)
```

```
##            [,1]      [,2]      [,3]
##  [1,] 0.6544848 0.6530916 70.186605
##  [2,] 0.7133475 0.7110264 18.320404
```

```
##  [3,] 0.7218054 0.7184128 12.580385
##  [4,] 0.7291333 0.7247110  7.874507
##  [5,] 0.7316391 0.7261399  7.581443
##  [6,] 0.7342576 0.7276961  7.185159
##  [7,] 0.7373402 0.7297426  6.364294
##  [8,] 0.7399110 0.7312774  6.011651
##  [9,] 0.7411428 0.7314357  6.884436
## [10,] 0.7418156 0.7310129  8.268787
## [11,] 0.7423393 0.7304307  9.789467
## [12,] 0.7428117 0.7297895 11.357206
## [13,] 0.7431988 0.7290529 13.002996
## [14,] 0.7432020 0.7279034 15.000000
```

## 11.

Calculate $F$ statistic for the new model having dropped all insignificant variables

```
anova(new3.lm, all.lm)
```

```
## Analysis of Variance Table
##
## Model 1: Bodyfat ~ Age + Weight + Neck + Abdomen + Hip + Thigh + Forearm +
##     Wrist
## Model 2: Bodyfat ~ Age + Weight + Height + BMI + Neck + Chest + Abdomen +
##     Hip + Thigh + Knee + Ankle + Biceps + Forearm + Wrist
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1    241 3786.2
## 2    235 3738.3  6    47.908 0.5019 0.8066
```

## 12.

Calculating the linear models for all interactions of Body Measurements

```
NeckAbdomen = Neck*Abdomen
NeckHip = Neck*Hip
NeckThigh = Neck*Thigh
NeckForearm = Neck*Forearm
NeckWrist = Neck*Wrist
AbdomenHip = Abdomen*Hip
AbdomenThigh = Abdomen*Thigh
AbdomenForearm = Abdomen*Forearm
AbdomenWrist = Abdomen*Wrist
HipThigh = Hip*Thigh
HipForearm = Hip*Forearm
HipWrist = Hip*Wrist
ThighForearm = Thigh*Forearm
ThighWrist = Thigh*Wrist
ForearmWrist = Forearm*Wrist
Neck2 = Neck^2
Abdomen2 = Abdomen^2
Hip2 = Hip^2
Thigh2 = Thigh^2
Forearm2 = Forearm^2
Wrist2 = Wrist^2
logNeck = log(Neck)
logAbdomen = log(Abdomen)
```

```r
logHip = log(Hip)
logThigh = log(Thigh)
logForearm = log(Forearm)
logWrist = log(Wrist)

interactions.lm = lm(Bodyfat ~ Age + Weight + Neck + Abdomen + Hip + Thigh +
                       Forearm + Wrist + NeckAbdomen + NeckHip + NeckThigh +
                       NeckForearm + NeckWrist + AbdomenHip + AbdomenThigh +
                       AbdomenForearm + AbdomenWrist + HipThigh + HipForearm +
                       HipWrist + ThighForearm + ThighWrist + ForearmWrist +
                       Neck2 + Abdomen2 + Hip2 + Thigh2 + Forearm2 + Wrist2 +
                       logNeck + logAbdomen + logHip + logThigh + logForearm +
                       logWrist)

interactions.sum = summary(interactions.lm)
interactions.sum
```

```
##
## Call:
## lm(formula = Bodyfat ~ Age + Weight + Neck + Abdomen + Hip +
##     Thigh + Forearm + Wrist + NeckAbdomen + NeckHip + NeckThigh +
##     NeckForearm + NeckWrist + AbdomenHip + AbdomenThigh + AbdomenForearm +
##     AbdomenWrist + HipThigh + HipForearm + HipWrist + ThighForearm +
##     ThighWrist + ForearmWrist + Neck2 + Abdomen2 + Hip2 + Thigh2 +
##     Forearm2 + Wrist2 + logNeck + logAbdomen + logHip + logThigh +
##     logForearm + logWrist)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.4632 -2.1526 -0.1828  2.1902  8.3718
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -4.690e+03  5.353e+03  -0.876  0.38188
## Age             5.598e-02  2.980e-02   1.879  0.06164 .
## Weight         -7.498e-02  4.047e-02  -1.853  0.06530 .
## Neck           -6.842e+01  9.505e+01  -0.720  0.47243
## Abdomen         3.671e+00  1.026e+01   0.358  0.72070
## Hip             1.278e+01  3.294e+01   0.388  0.69838
## Thigh          -6.217e+01  3.290e+01  -1.890  0.06016 .
## Forearm         5.733e+01  5.642e+01   1.016  0.31071
## Wrist          -2.730e+01  3.995e+02  -0.068  0.94557
## NeckAbdomen     5.458e-02  4.812e-02   1.134  0.25795
## NeckHip         5.876e-05  1.033e-01   0.001  0.99955
## NeckThigh      -1.942e-01  1.026e-01  -1.894  0.05959 .
## NeckForearm     3.208e-01  1.762e-01   1.821  0.07007 .
## NeckWrist      -1.128e+00  4.170e-01  -2.705  0.00737 **
## AbdomenHip      3.215e-02  2.971e-02   1.082  0.28039
## AbdomenThigh    1.911e-02  2.738e-02   0.698  0.48600
## AbdomenForearm -1.118e-01  5.360e-02  -2.086  0.03818 *
## AbdomenWrist    2.101e-01  1.066e-01   1.971  0.05004 .
## HipThigh       -3.723e-02  6.089e-02  -0.611  0.54156
## HipForearm      1.605e-01  1.063e-01   1.510  0.13257
## HipWrist       -3.159e-01  2.010e-01  -1.571  0.11760
```

```
## ThighForearm    2.595e-02  1.088e-01   0.238  0.81174
## ThighWrist      3.395e-01  2.244e-01   1.513  0.13169
## ForearmWrist   -9.816e-01  3.813e-01  -2.575  0.01071 *
## Neck2           6.807e-01  6.697e-01   1.016  0.31064
## Abdomen2       -3.375e-02  2.725e-02  -1.238  0.21693
## Hip2           -4.349e-02  8.126e-02  -0.535  0.59305
## Thigh2          2.651e-01  1.358e-01   1.952  0.05219 .
## Forearm2       -5.159e-01  5.226e-01  -0.987  0.32464
## Wrist2          2.064e+00  5.366e+00   0.385  0.70083
## logNeck         1.302e+03  1.809e+03   0.720  0.47251
## logAbdomen     -3.360e+02  4.631e+02  -0.726  0.46889
## logHip         -3.780e+02  1.694e+03  -0.223  0.82363
## logThigh        1.974e+03  9.777e+02   2.019  0.04477 *
## logForearm     -8.270e+02  8.144e+02  -1.015  0.31107
## logWrist        2.373e+02  3.695e+03   0.064  0.94885
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.813 on 214 degrees of freedom
## Multiple R-squared:  0.7862, Adjusted R-squared:  0.7513
## F-statistic: 22.49 on 35 and 214 DF,  p-value: < 2.2e-16
```

### 13.

Best Subsets on the interactions

```
interactDF = as.data.frame(cbind(Age, Weight, Neck, Abdomen, Hip, Thigh, Forearm,
                                 Wrist, NeckAbdomen, NeckHip, NeckThigh, NeckForearm,
                                 NeckWrist, AbdomenHip, AbdomenThigh, AbdomenForearm,
                                 AbdomenWrist, HipThigh, HipForearm, HipWrist,
                                 ThighForearm, ThighWrist, ForearmWrist, Neck2,
                                 Abdomen2, Hip2, Thigh2, Forearm2, Wrist2, logNeck,
                                 logAbdomen, logHip, logThigh, logForearm, logWrist))


interactbest = regsubsets(Bodyfat ~ Age + Weight + Neck + Abdomen + Hip + Thigh +
                            Forearm + Wrist + NeckAbdomen + NeckHip + NeckThigh +
                            NeckForearm + NeckWrist + AbdomenHip + AbdomenThigh +
                            AbdomenForearm + AbdomenWrist + HipThigh + HipForearm +
                            HipWrist + ThighForearm + ThighWrist + ForearmWrist +
                            Neck2 + Abdomen2 + Hip2 + Thigh2 + Forearm2 + Wrist2 +
                            logNeck + logAbdomen + logHip + logThigh + logForearm +
                            logWrist, data = interactDF, nbest = 1, nvmax=35)
interactbest.sum = summary(interactbest)
interactbest.sum$which
```

```
##    (Intercept)   Age Weight  Neck Abdomen   Hip Thigh Forearm Wrist
## 1         TRUE FALSE  FALSE FALSE   FALSE FALSE FALSE   FALSE FALSE
## 2         TRUE FALSE  FALSE FALSE   FALSE FALSE FALSE   FALSE FALSE
## 3         TRUE FALSE  FALSE FALSE   FALSE FALSE FALSE   FALSE FALSE
## 4         TRUE FALSE   TRUE FALSE   FALSE FALSE FALSE   FALSE FALSE
## 5         TRUE  TRUE  FALSE FALSE   FALSE FALSE FALSE   FALSE FALSE
## 6         TRUE  TRUE   TRUE FALSE   FALSE FALSE FALSE   FALSE FALSE
## 7         TRUE  TRUE   TRUE FALSE   FALSE FALSE FALSE   FALSE FALSE
## 8         TRUE  TRUE   TRUE FALSE   FALSE FALSE  TRUE   FALSE FALSE
```

```
## 9         TRUE  TRUE   TRUE FALSE   FALSE FALSE  TRUE   FALSE FALSE
## 10        TRUE  TRUE   TRUE FALSE   FALSE FALSE  TRUE   FALSE FALSE
## 11        TRUE  TRUE   TRUE FALSE   FALSE FALSE FALSE    TRUE FALSE
## 12        TRUE  TRUE   TRUE  TRUE   FALSE FALSE FALSE    TRUE FALSE
## 13        TRUE  TRUE   TRUE FALSE   FALSE FALSE FALSE    TRUE  TRUE
## 14        TRUE  TRUE   TRUE FALSE   FALSE FALSE FALSE   FALSE FALSE
## 15        TRUE  TRUE   TRUE FALSE    TRUE FALSE  TRUE   FALSE FALSE
## 16        TRUE  TRUE   TRUE FALSE    TRUE FALSE  TRUE   FALSE FALSE
## 17        TRUE  TRUE   TRUE FALSE    TRUE FALSE  TRUE   FALSE FALSE
## 18        TRUE  TRUE   TRUE FALSE    TRUE FALSE  TRUE   FALSE FALSE
## 19        TRUE  TRUE   TRUE FALSE    TRUE FALSE  TRUE   FALSE FALSE
## 20        TRUE  TRUE  FALSE FALSE   FALSE  TRUE  TRUE   FALSE FALSE
## 21        TRUE  TRUE   TRUE FALSE   FALSE  TRUE  TRUE   FALSE FALSE
## 22        TRUE  TRUE   TRUE FALSE   FALSE  TRUE  TRUE   FALSE FALSE
## 23        TRUE  TRUE   TRUE FALSE    TRUE  TRUE  TRUE   FALSE FALSE
## 24        TRUE  TRUE   TRUE FALSE    TRUE FALSE  TRUE   FALSE FALSE
## 25        TRUE  TRUE   TRUE FALSE   FALSE  TRUE  TRUE    TRUE FALSE
## 26        TRUE  TRUE   TRUE FALSE   FALSE FALSE  TRUE    TRUE FALSE
## 27        TRUE  TRUE   TRUE FALSE   FALSE  TRUE  TRUE    TRUE FALSE
## 28        TRUE  TRUE   TRUE FALSE    TRUE  TRUE  TRUE    TRUE FALSE
## 29        TRUE  TRUE   TRUE  TRUE   FALSE  TRUE  TRUE    TRUE FALSE
## 30        TRUE  TRUE   TRUE  TRUE    TRUE  TRUE  TRUE    TRUE FALSE
## 31        TRUE  TRUE   TRUE  TRUE    TRUE  TRUE  TRUE    TRUE FALSE
## 32        TRUE  TRUE   TRUE  TRUE    TRUE  TRUE  TRUE    TRUE FALSE
## 33        TRUE  TRUE   TRUE  TRUE    TRUE  TRUE  TRUE    TRUE  TRUE
## 34        TRUE  TRUE   TRUE  TRUE    TRUE  TRUE  TRUE    TRUE  TRUE
## 35        TRUE  TRUE   TRUE  TRUE    TRUE  TRUE  TRUE    TRUE  TRUE
##    NeckAbdomen NeckHip NeckThigh NeckForearm NeckWrist AbdomenHip
## 1        FALSE   FALSE     FALSE       FALSE     FALSE      FALSE
## 2        FALSE   FALSE     FALSE       FALSE     FALSE      FALSE
## 3        FALSE   FALSE     FALSE       FALSE     FALSE      FALSE
## 4        FALSE   FALSE     FALSE       FALSE     FALSE      FALSE
## 5         TRUE   FALSE      TRUE       FALSE     FALSE      FALSE
## 6        FALSE   FALSE     FALSE       FALSE     FALSE      FALSE
## 7        FALSE    TRUE     FALSE       FALSE     FALSE      FALSE
## 8         TRUE   FALSE      TRUE       FALSE     FALSE      FALSE
## 9        FALSE   FALSE      TRUE       FALSE      TRUE      FALSE
## 10       FALSE   FALSE      TRUE        TRUE      TRUE      FALSE
## 11       FALSE   FALSE      TRUE       FALSE     FALSE      FALSE
## 12       FALSE   FALSE      TRUE       FALSE     FALSE       TRUE
## 13        TRUE   FALSE      TRUE       FALSE      TRUE      FALSE
## 14        TRUE   FALSE      TRUE       FALSE      TRUE      FALSE
## 15       FALSE   FALSE      TRUE        TRUE      TRUE      FALSE
## 16       FALSE   FALSE      TRUE        TRUE      TRUE      FALSE
## 17       FALSE   FALSE      TRUE        TRUE      TRUE      FALSE
## 18       FALSE   FALSE      TRUE        TRUE      TRUE      FALSE
## 19       FALSE   FALSE      TRUE        TRUE      TRUE      FALSE
## 20       FALSE   FALSE      TRUE        TRUE      TRUE       TRUE
## 21       FALSE   FALSE      TRUE        TRUE      TRUE       TRUE
## 22        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 23        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 24        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 25        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 26        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
```

```
## 27        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 28        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 29        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 30        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 31        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 32        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 33        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 34        TRUE   FALSE      TRUE        TRUE      TRUE       TRUE
## 35        TRUE    TRUE      TRUE        TRUE      TRUE       TRUE
##    AbdomenThigh AbdomenForearm AbdomenWrist HipThigh HipForearm HipWrist
## 1         FALSE          FALSE        FALSE    FALSE      FALSE    FALSE
## 2         FALSE          FALSE        FALSE    FALSE      FALSE     TRUE
## 3         FALSE          FALSE         TRUE    FALSE      FALSE     TRUE
## 4         FALSE          FALSE         TRUE    FALSE      FALSE    FALSE
## 5         FALSE          FALSE        FALSE    FALSE      FALSE     TRUE
## 6         FALSE          FALSE         TRUE    FALSE      FALSE    FALSE
## 7         FALSE          FALSE         TRUE    FALSE      FALSE    FALSE
## 8         FALSE          FALSE        FALSE    FALSE      FALSE    FALSE
## 9         FALSE          FALSE         TRUE    FALSE      FALSE    FALSE
## 10        FALSE          FALSE         TRUE    FALSE      FALSE    FALSE
## 11        FALSE          FALSE         TRUE    FALSE      FALSE    FALSE
## 12        FALSE          FALSE         TRUE    FALSE      FALSE    FALSE
## 13        FALSE          FALSE        FALSE    FALSE      FALSE    FALSE
## 14         TRUE          FALSE        FALSE    FALSE      FALSE    FALSE
## 15        FALSE          FALSE         TRUE    FALSE      FALSE     TRUE
## 16        FALSE          FALSE         TRUE    FALSE      FALSE     TRUE
## 17        FALSE          FALSE         TRUE    FALSE      FALSE     TRUE
## 18        FALSE           TRUE         TRUE    FALSE       TRUE     TRUE
## 19         TRUE           TRUE         TRUE    FALSE       TRUE     TRUE
## 20        FALSE           TRUE         TRUE    FALSE       TRUE     TRUE
## 21        FALSE           TRUE         TRUE    FALSE       TRUE     TRUE
## 22        FALSE           TRUE         TRUE    FALSE       TRUE     TRUE
## 23        FALSE           TRUE         TRUE    FALSE       TRUE     TRUE
## 24         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 25        FALSE           TRUE         TRUE    FALSE       TRUE     TRUE
## 26         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 27         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 28         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 29         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 30         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 31         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 32         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 33         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 34         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
## 35         TRUE           TRUE         TRUE     TRUE       TRUE     TRUE
##    ThighForearm ThighWrist ForearmWrist Neck2 Abdomen2  Hip2 Thigh2
## 1         FALSE      FALSE        FALSE FALSE    FALSE FALSE  FALSE
## 2         FALSE      FALSE        FALSE FALSE    FALSE FALSE  FALSE
## 3         FALSE      FALSE        FALSE FALSE    FALSE FALSE  FALSE
## 4         FALSE       TRUE        FALSE FALSE    FALSE FALSE  FALSE
## 5         FALSE      FALSE        FALSE FALSE    FALSE FALSE  FALSE
## 6         FALSE       TRUE        FALSE FALSE    FALSE FALSE  FALSE
## 7         FALSE       TRUE        FALSE FALSE    FALSE FALSE  FALSE
## 8         FALSE      FALSE         TRUE FALSE     TRUE FALSE  FALSE
```

```
## 9         FALSE      FALSE        FALSE  TRUE    FALSE FALSE  FALSE
## 10        FALSE      FALSE         TRUE  TRUE    FALSE FALSE  FALSE
## 11         TRUE      FALSE         TRUE  TRUE    FALSE FALSE  FALSE
## 12         TRUE      FALSE         TRUE  TRUE    FALSE FALSE  FALSE
## 13         TRUE      FALSE         TRUE  TRUE     TRUE FALSE  FALSE
## 14         TRUE      FALSE         TRUE  TRUE     TRUE FALSE  FALSE
## 15        FALSE      FALSE         TRUE  TRUE    FALSE FALSE   TRUE
## 16        FALSE      FALSE         TRUE  TRUE    FALSE FALSE   TRUE
## 17         TRUE      FALSE         TRUE  TRUE    FALSE FALSE   TRUE
## 18        FALSE       TRUE         TRUE  TRUE    FALSE FALSE   TRUE
## 19        FALSE       TRUE         TRUE  TRUE    FALSE FALSE   TRUE
## 20        FALSE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 21        FALSE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 22        FALSE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 23        FALSE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 24        FALSE       TRUE         TRUE  TRUE     TRUE FALSE   TRUE
## 25        FALSE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 26        FALSE       TRUE         TRUE  TRUE     TRUE FALSE   TRUE
## 27        FALSE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 28        FALSE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 29        FALSE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 30        FALSE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 31         TRUE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 32         TRUE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 33         TRUE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 34         TRUE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
## 35         TRUE       TRUE         TRUE  TRUE     TRUE  TRUE   TRUE
##    Forearm2 Wrist2 logNeck logAbdomen logHip logThigh logForearm logWrist
## 1     FALSE  FALSE   FALSE       TRUE  FALSE    FALSE      FALSE    FALSE
## 2     FALSE  FALSE   FALSE       TRUE  FALSE    FALSE      FALSE    FALSE
## 3     FALSE  FALSE   FALSE      FALSE   TRUE    FALSE      FALSE    FALSE
## 4     FALSE  FALSE   FALSE      FALSE  FALSE     TRUE      FALSE    FALSE
## 5     FALSE  FALSE   FALSE      FALSE  FALSE     TRUE      FALSE    FALSE
## 6      TRUE  FALSE   FALSE      FALSE  FALSE     TRUE      FALSE    FALSE
## 7      TRUE  FALSE   FALSE      FALSE  FALSE     TRUE      FALSE    FALSE
## 8      TRUE  FALSE   FALSE      FALSE  FALSE    FALSE      FALSE    FALSE
## 9      TRUE   TRUE   FALSE      FALSE  FALSE    FALSE      FALSE    FALSE
## 10    FALSE   TRUE   FALSE      FALSE  FALSE    FALSE      FALSE    FALSE
## 11    FALSE   TRUE    TRUE      FALSE  FALSE     TRUE      FALSE    FALSE
## 12    FALSE   TRUE   FALSE      FALSE  FALSE     TRUE      FALSE    FALSE
## 13    FALSE  FALSE   FALSE      FALSE  FALSE     TRUE      FALSE     TRUE
## 14     TRUE   TRUE   FALSE       TRUE  FALSE     TRUE      FALSE    FALSE
## 15    FALSE   TRUE   FALSE      FALSE   TRUE     TRUE      FALSE    FALSE
## 16     TRUE   TRUE   FALSE      FALSE   TRUE     TRUE      FALSE    FALSE
## 17     TRUE   TRUE   FALSE      FALSE   TRUE     TRUE      FALSE    FALSE
## 18    FALSE   TRUE   FALSE      FALSE   TRUE     TRUE      FALSE    FALSE
## 19    FALSE   TRUE   FALSE      FALSE   TRUE     TRUE      FALSE    FALSE
## 20    FALSE   TRUE   FALSE       TRUE  FALSE     TRUE      FALSE    FALSE
## 21    FALSE   TRUE   FALSE       TRUE  FALSE     TRUE      FALSE    FALSE
## 22    FALSE   TRUE   FALSE       TRUE  FALSE     TRUE      FALSE    FALSE
## 23    FALSE   TRUE   FALSE       TRUE  FALSE     TRUE      FALSE    FALSE
## 24    FALSE   TRUE   FALSE       TRUE   TRUE     TRUE      FALSE    FALSE
## 25     TRUE   TRUE   FALSE       TRUE  FALSE     TRUE       TRUE    FALSE
## 26     TRUE   TRUE   FALSE       TRUE   TRUE     TRUE       TRUE    FALSE
```

```
## 27     TRUE   TRUE   FALSE       TRUE  FALSE     TRUE       TRUE    FALSE
## 28     TRUE   TRUE   FALSE       TRUE  FALSE     TRUE       TRUE    FALSE
## 29     TRUE   TRUE    TRUE       TRUE  FALSE     TRUE       TRUE    FALSE
## 30     TRUE   TRUE    TRUE       TRUE  FALSE     TRUE       TRUE    FALSE
## 31     TRUE   TRUE    TRUE       TRUE  FALSE     TRUE       TRUE    FALSE
## 32     TRUE   TRUE    TRUE       TRUE   TRUE     TRUE       TRUE    FALSE
## 33     TRUE   TRUE    TRUE       TRUE   TRUE     TRUE       TRUE    FALSE
## 34     TRUE   TRUE    TRUE       TRUE   TRUE     TRUE       TRUE     TRUE
## 35     TRUE   TRUE    TRUE       TRUE   TRUE     TRUE       TRUE     TRUE
```

```
cbind(bestall.sum$rsq, bestall.sum$adjr2, bestall.sum$cp)
```

```
##            [,1]      [,2]      [,3]
##  [1,] 0.6544848 0.6530916 70.186605
##  [2,] 0.7133475 0.7110264 18.320404
##  [3,] 0.7218054 0.7184128 12.580385
##  [4,] 0.7291333 0.7247110  7.874507
##  [5,] 0.7316391 0.7261399  7.581443
##  [6,] 0.7342576 0.7276961  7.185159
##  [7,] 0.7373402 0.7297426  6.364294
##  [8,] 0.7399110 0.7312774  6.011651
##  [9,] 0.7411428 0.7314357  6.884436
## [10,] 0.7418156 0.7310129  8.268787
## [11,] 0.7423393 0.7304307  9.789467
## [12,] 0.7428117 0.7297895 11.357206
## [13,] 0.7431988 0.7290529 13.002996
## [14,] 0.7432020 0.7279034 15.000000
```

```
maxradj = which.max(bestall.sum$adjr2)
mincp = which.min(bestall.sum$cp)
maxradj
```

```
## [1] 9
```

```
mincp
```

```
## [1] 8
```

## 14.

Fit linear model for the best subsets

```
subsets.lm = lm(Bodyfat ~ Age + Weight + Thigh + Neck + Abdomen + Forearm +
                  Wrist + NeckAbdomen + NeckThigh + ForearmWrist + Abdomen2 +
                  Forearm2)
subsets.sum = summary(subsets.lm)
subsets.sum
```

```
##
## Call:
## lm(formula = Bodyfat ~ Age + Weight + Thigh + Neck + Abdomen +
##     Forearm + Wrist + NeckAbdomen + NeckThigh + ForearmWrist +
##     Abdomen2 + Forearm2)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -9.941 -2.477 -0.218  2.562  9.314
```

```
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -1.394e+02  5.642e+01  -2.472 0.014155 *
## Age           5.739e-02  2.801e-02   2.049 0.041563 *
## Weight       -9.440e-02  3.231e-02  -2.922 0.003819 **
## Thigh         4.906e+00  1.317e+00   3.724 0.000245 ***
## Neck         -1.993e-01  1.360e+00  -0.147 0.883580
## Abdomen      -7.867e-01  6.513e-01  -1.208 0.228292
## Forearm       8.256e-01  2.644e+00   0.312 0.755145
## Wrist         2.732e+00  3.069e+00   0.890 0.374257
## NeckAbdomen   7.670e-02  2.329e-02   3.293 0.001144 **
## NeckThigh    -1.226e-01  3.388e-02  -3.617 0.000364 ***
## ForearmWrist -1.495e-01  1.064e-01  -1.405 0.161376
## Abdomen2     -6.997e-03  3.041e-03  -2.301 0.022272 *
## Forearm2      4.079e-02  3.891e-02   1.048 0.295580
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.839 on 237 degrees of freedom
## Multiple R-squared:   0.76,  Adjusted R-squared:  0.7479
## F-statistic: 62.55 on 12 and 237 DF,  p-value: < 2.2e-16
```

### 15.

Stepwise Regression on all interactions

```
model0 = lm(Bodyfat ~ 1, data = interactDF)
model1 = lm(Bodyfat ~ ., data = interactDF)
step(model0, scope = list(lower=model0, upper=model1), direction="both")
```

```
## Start:  AIC=1018.1
## Bodyfat ~ 1
##
##                   Df Sum of Sq     RSS     AIC
## + logAbdomen       1    9711.7  4845.6  745.09
## + Abdomen          1    9527.6  5029.8  754.42
## + Abdomen2         1    9109.4  5447.9  774.38
## + AbdomenHip       1    7913.8  6643.6  823.99
## + AbdomenForearm   1    7706.2  6851.1  831.68
## + NeckAbdomen      1    7683.5  6873.9  832.51
## + AbdomenThigh     1    7582.7  6974.6  836.14
## + AbdomenWrist     1    7558.3  6999.0  837.02
## + logHip           1    5662.9  8894.5  896.93
## + Hip              1    5467.3  9090.0  902.37
## + Weight           1    5307.3  9250.0  906.73
## + Hip2             1    5164.5  9392.9  910.56
## + NeckHip          1    4915.2  9642.1  917.11
## + HipThigh         1    4837.7  9719.6  919.11
## + NeckThigh        1    4455.8 10101.6  928.75
## + logThigh         1    4443.6 10113.7  929.05
## + HipForearm       1    4372.9 10184.4  930.79
## + Thigh            1    4322.2 10235.2  932.03
## + HipWrist         1    4308.0 10249.4  932.38
## + Thigh2           1    4141.3 10416.0  936.41
```

```
## + ThighWrist      1    3947.7 10609.6  941.01
## + ThighForearm    1    3852.3 10705.0  943.25
## + Neck            1    3497.8 11059.5  951.40
## + logNeck         1    3487.8 11069.6  951.62
## + Neck2           1    3469.3 11088.1  952.04
## + NeckForearm     1    3113.0 11444.3  959.95
## + NeckWrist       1    2986.0 11571.4  962.71
## + ForearmWrist    1    2201.4 12356.0  979.11
## + Forearm2        1    1820.7 12736.6  986.69
## + Forearm         1    1809.1 12748.3  986.92
## + logForearm      1    1769.6 12787.7  987.69
## + Wrist2          1    1745.7 12811.7  988.16
## + Wrist           1    1724.8 12832.5  988.57
## + logWrist        1    1700.8 12856.5  989.04
## + Age             1    1232.9 13324.4  997.97
## <none>                        14557.3 1018.10
##
## Step:  AIC=745.09
## Bodyfat ~ logAbdomen
##
##                  Df Sum of Sq     RSS     AIC
## + HipWrist        1     862.9  3982.8  698.07
## + Weight          1     777.2  4068.4  703.39
## + NeckWrist       1     772.5  4073.1  703.68
## + NeckHip         1     734.7  4110.9  705.99
## + AbdomenWrist    1     649.3  4196.4  711.13
## + Wrist2          1     644.7  4201.0  711.40
## + Wrist           1     639.9  4205.7  711.68
## + logWrist        1     632.5  4213.1  712.12
## + ThighWrist      1     596.1  4249.5  714.28
## + Neck2           1     538.1  4307.6  717.67
## + Neck            1     514.1  4331.5  719.05
## + NeckThigh       1     495.8  4349.8  720.11
## + NeckAbdomen     1     490.4  4355.3  720.42
## + logNeck         1     485.5  4360.2  720.70
## + Hip2            1     444.3  4401.4  723.05
## + Hip             1     429.5  4416.1  723.89
## + logHip          1     395.0  4450.7  725.84
## + HipThigh        1     346.1  4499.5  728.57
## + ForearmWrist    1     338.1  4507.5  729.01
## + AbdomenHip      1     329.6  4516.0  729.48
## + NeckForearm     1     292.3  4553.3  731.54
## + HipForearm      1     276.7  4568.9  732.39
## + AbdomenThigh    1     232.2  4613.5  734.82
## + Thigh2          1     218.1  4627.6  735.58
## + ThighForearm    1     193.0  4652.6  736.93
## + Thigh           1     183.8  4661.8  737.42
## + logThigh        1     150.2  4695.4  739.22
## + Age             1     146.1  4699.6  739.44
## + AbdomenForearm  1      91.3  4754.3  742.34
## + Forearm2        1      83.3  4762.4  742.76
## + Forearm         1      77.5  4768.1  743.06
## + logForearm      1      70.4  4775.2  743.43
## + Abdomen2        1      42.7  4803.0  744.88
```

```
## <none>                          4845.6  745.09
## + Abdomen         1      32.0  4813.7  745.44
## - logAbdomen      1    9711.7 14557.3 1018.10
##
## Step:  AIC=698.07
## Bodyfat ~ logAbdomen + HipWrist
##
##                  Df Sum of Sq     RSS    AIC
## + logNeck         1      73.3  3909.4 695.42
## + Neck            1      72.8  3910.0 695.46
## + Neck2           1      71.0  3911.7 695.57
## + NeckWrist       1      68.3  3914.4 695.74
## + Weight          1      55.3  3927.5 696.57
## + NeckAbdomen     1      35.8  3947.0 697.81
## + NeckHip         1      33.4  3949.4 697.96
## <none>                          3982.8 698.07
## + Age             1      22.7  3960.1 698.64
## + logHip          1      19.3  3963.5 698.85
## + logThigh        1      15.4  3967.4 699.10
## + Hip             1      14.3  3968.4 699.17
## + Abdomen         1      12.7  3970.1 699.27
## + HipForearm      1      11.6  3971.2 699.34
## + AbdomenHip      1      11.1  3971.6 699.37
## + Thigh           1      11.0  3971.8 699.38
## + ThighForearm    1      10.7  3972.1 699.40
## + logWrist        1      10.7  3972.1 699.40
## + AbdomenThigh    1      10.3  3972.5 699.42
## + AbdomenForearm  1      10.1  3972.7 699.44
## + Wrist           1      10.0  3972.8 699.44
## + Abdomen2        1       9.7  3973.1 699.46
## + HipThigh        1       9.1  3973.6 699.49
## + Wrist2          1       9.0  3973.8 699.50
## + Hip2            1       8.5  3974.2 699.53
## + NeckThigh       1       8.3  3974.5 699.55
## + Thigh2          1       7.0  3975.8 699.63
## + NeckForearm     1       5.8  3977.0 699.70
## + logForearm      1       5.3  3977.5 699.74
## + Forearm         1       5.1  3977.7 699.75
## + Forearm2        1       4.9  3977.9 699.76
## + ThighWrist      1       2.0  3980.8 699.94
## + AbdomenWrist    1       0.8  3982.0 700.02
## + ForearmWrist    1       0.3  3982.4 700.05
## - HipWrist        1     862.9  4845.6 745.09
## - logAbdomen      1    6266.6 10249.4 932.38
##
## Step:  AIC=695.42
## Bodyfat ~ logAbdomen + HipWrist + logNeck
##
##                  Df Sum of Sq     RSS    AIC
## + AbdomenForearm  1      32.2  3877.2 695.35
## + Weight          1      31.2  3878.2 695.42
## <none>                          3909.4 695.42
## + ThighForearm    1      28.8  3880.6 695.57
## + Forearm         1      26.7  3882.8 695.71
```

```
## + Forearm2        1      26.5  3883.0 695.72
## + HipForearm      1      26.4  3883.0 695.73
## + logForearm      1      26.4  3883.0 695.73
## + Age             1      25.7  3883.7 695.77
## + NeckForearm     1      25.0  3884.4 695.82
## + logThigh        1      18.3  3891.1 696.25
## + ForearmWrist    1      14.7  3894.8 696.48
## + Thigh           1      12.8  3896.7 696.60
## + ThighWrist      1       8.6  3900.8 696.87
## + AbdomenThigh    1       8.5  3900.9 696.88
## + Thigh2          1       7.8  3901.6 696.92
## + NeckThigh       1       7.1  3902.4 696.97
## + logHip          1       6.6  3902.9 697.00
## + Abdomen         1       6.3  3903.1 697.02
## + HipThigh        1       5.6  3903.8 697.06
## + Abdomen2        1       4.3  3905.2 697.15
## + Hip             1       3.2  3906.2 697.22
## + NeckWrist       1       2.4  3907.1 697.27
## + AbdomenHip      1       2.2  3907.3 697.28
## + NeckAbdomen     1       1.8  3907.7 697.31
## + logWrist        1       1.4  3908.1 697.33
## + Wrist           1       1.2  3908.3 697.35
## + Wrist2          1       0.9  3908.5 697.36
## + Hip2            1       0.8  3908.6 697.37
## + NeckHip         1       0.5  3909.0 697.39
## + AbdomenWrist    1       0.2  3909.3 697.41
## + Neck2           1       0.1  3909.4 697.42
## + Neck            1       0.0  3909.4 697.42
## - logNeck         1      73.3  3982.8 698.07
## - HipWrist        1     450.7  4360.2 720.70
## - logAbdomen      1    6230.2 10139.7 931.69
##
## Step:  AIC=695.35
## Bodyfat ~ logAbdomen + HipWrist + logNeck + AbdomenForearm
##
##                  Df Sum of Sq    RSS    AIC
## + Weight          1     49.73 3827.5 694.12
## + Age             1     39.11 3838.1 694.82
## <none>                        3877.2 695.35
## - AbdomenForearm  1     32.24 3909.4 695.42
## + logThigh        1     12.33 3864.9 696.56
## + Thigh           1      8.19 3869.0 696.82
## + NeckForearm     1      6.68 3870.5 696.92
## + Abdomen         1      6.56 3870.6 696.93
## + AbdomenThigh    1      6.06 3871.1 696.96
## + Abdomen2        1      5.07 3872.1 697.03
## + logHip          1      4.90 3872.3 697.04
## + Thigh2          1      4.77 3872.4 697.04
## + NeckThigh       1      4.70 3872.5 697.05
## + ThighWrist      1      4.59 3872.6 697.06
## + ForearmWrist    1      4.50 3872.7 697.06
## + HipThigh        1      3.83 3873.4 697.11
## + NeckAbdomen     1      3.21 3874.0 697.14
## + AbdomenHip      1      2.80 3874.4 697.17
```

```
## + Hip             1      2.66 3874.5 697.18
## + ThighForearm    1      2.52 3874.7 697.19
## + NeckWrist       1      1.65 3875.6 697.25
## + logWrist        1      1.63 3875.6 697.25
## + Wrist           1      1.29 3875.9 697.27
## + Forearm2        1      1.10 3876.1 697.28
## + Hip2            1      0.97 3876.2 697.29
## + Forearm         1      0.97 3876.2 697.29
## + Wrist2          1      0.92 3876.3 697.29
## + NeckHip         1      0.91 3876.3 697.29
## + logForearm      1      0.84 3876.4 697.30
## + AbdomenWrist    1      0.37 3876.8 697.33
## + Neck            1      0.31 3876.9 697.33
## + Neck2           1      0.21 3877.0 697.34
## + HipForearm      1      0.03 3877.2 697.35
## - logNeck         1     95.51 3972.7 699.44
## - HipWrist        1    482.88 4360.1 722.70
## - logAbdomen      1   2470.38 6347.6 816.59
##
## Step:  AIC=694.12
## Bodyfat ~ logAbdomen + HipWrist + logNeck + AbdomenForearm +
##     Weight
##
##                  Df Sum of Sq    RSS    AIC
## + logThigh        1     44.88 3782.6 693.18
## + Thigh           1     38.78 3788.7 693.58
## + HipThigh        1     38.37 3789.1 693.61
## + AbdomenThigh    1     37.86 3789.6 693.64
## + logHip          1     36.45 3791.0 693.73
## + NeckThigh       1     35.15 3792.3 693.82
## + Hip             1     32.38 3795.1 694.00
## + Thigh2          1     32.11 3795.4 694.02
## + ForearmWrist    1     31.70 3795.8 694.05
## <none>                        3827.5 694.12
## + logWrist        1     27.70 3799.8 694.31
## + Wrist           1     26.98 3800.5 694.36
## + Wrist2          1     25.64 3801.8 694.44
## + NeckHip         1     25.10 3802.4 694.48
## + NeckWrist       1     24.28 3803.2 694.53
## + Hip2            1     24.17 3803.3 694.54
## + AbdomenHip      1     21.84 3805.6 694.69
## + ThighForearm    1     19.07 3808.4 694.88
## + ThighWrist      1     14.66 3812.8 695.17
## + Abdomen         1     13.06 3814.4 695.27
## - Weight          1     49.73 3877.2 695.35
## + Age             1     11.17 3816.3 695.39
## + Abdomen2        1     11.11 3816.4 695.40
## - AbdomenForearm  1     50.74 3878.2 695.42
## + NeckAbdomen     1     10.60 3816.9 695.43
## + NeckForearm     1      8.72 3818.7 695.55
## + HipForearm      1      7.81 3819.7 695.61
## + AbdomenWrist    1      5.53 3821.9 695.76
## + Neck            1      4.63 3822.8 695.82
## + Neck2           1      4.32 3823.2 695.84
```

```
## + logForearm      1      3.39 3824.1 695.90
## + Forearm         1      3.21 3824.3 695.92
## + Forearm2        1      2.87 3824.6 695.94
## - logNeck         1     70.69 3898.2 696.70
## - HipWrist        1    116.25 3943.7 699.60
## - logAbdomen      1   2514.48 6342.0 818.37
##
## Step:  AIC=693.18
## Bodyfat ~ logAbdomen + HipWrist + logNeck + AbdomenForearm +
##     Weight + logThigh
##
##                   Df Sum of Sq    RSS    AIC
## + ThighForearm     1    102.70 3679.9 688.29
## + Age              1     55.20 3727.4 691.50
## <none>                         3782.6 693.18
## + Abdomen          1     27.64 3755.0 693.34
## + NeckAbdomen      1     24.43 3758.2 693.56
## + Abdomen2         1     24.32 3758.3 693.56
## + ThighWrist       1     22.65 3759.9 693.67
## + ForearmWrist     1     20.20 3762.4 693.84
## + NeckForearm      1     17.64 3765.0 694.01
## + AbdomenHip       1     16.27 3766.3 694.10
## - logThigh         1     44.88 3827.5 694.12
## - AbdomenForearm   1     45.27 3827.9 694.15
## + Neck             1     12.84 3769.8 694.33
## + Neck2            1     12.14 3770.5 694.37
## + Forearm          1     10.96 3771.6 694.45
## + logForearm       1     10.96 3771.6 694.45
## + NeckHip          1     10.93 3771.7 694.45
## + Forearm2         1      9.77 3772.8 694.53
## + logWrist         1      9.41 3773.2 694.55
## + logHip           1      8.79 3773.8 694.59
## + Hip              1      8.41 3774.2 694.62
## + Wrist            1      8.10 3774.5 694.64
## + Thigh            1      7.80 3774.8 694.66
## + Hip2             1      7.05 3775.5 694.71
## + Wrist2           1      6.55 3776.0 694.74
## + Thigh2           1      5.62 3777.0 694.80
## + NeckWrist        1      4.05 3778.5 694.91
## + AbdomenWrist     1      2.78 3779.8 694.99
## + AbdomenThigh     1      2.60 3780.0 695.00
## + HipForearm       1      1.09 3781.5 695.10
## + HipThigh         1      0.62 3782.0 695.14
## + NeckThigh        1      0.16 3782.4 695.17
## - logNeck          1     62.75 3845.3 695.29
## - Weight           1     82.28 3864.9 696.56
## - HipWrist         1    126.71 3909.3 699.41
## - logAbdomen       1   2529.11 6311.7 819.17
##
## Step:  AIC=688.29
## Bodyfat ~ logAbdomen + HipWrist + logNeck + AbdomenForearm +
##     Weight + logThigh + ThighForearm
##
##                   Df Sum of Sq    RSS    AIC
```

```
## + Age              1    54.424 3625.5 686.57
## - logAbdomen       1     5.288 3685.2 686.65
## <none>                         3679.9 688.29
## + Forearm2         1    22.672 3657.2 688.75
## - logNeck          1    37.460 3717.4 688.83
## + NeckForearm      1    19.315 3660.6 688.98
## + Forearm          1    17.435 3662.5 689.11
## + logForearm       1    10.043 3669.9 689.61
## + Thigh            1     9.713 3670.2 689.63
## + Thigh2           1     8.137 3671.8 689.74
## + AbdomenThigh     1     6.830 3673.1 689.83
## + ThighWrist       1     5.768 3674.1 689.90
## + Abdomen2         1     4.723 3675.2 689.97
## + NeckThigh        1     4.544 3675.4 689.99
## + Abdomen          1     4.454 3675.4 689.99
## + HipForearm       1     3.956 3675.9 690.03
## + logHip           1     3.205 3676.7 690.08
## + HipThigh         1     2.701 3677.2 690.11
## + AbdomenHip       1     1.678 3678.2 690.18
## + ForearmWrist     1     1.090 3678.8 690.22
## + Neck             1     0.842 3679.1 690.24
## + AbdomenWrist     1     0.692 3679.2 690.25
## + Neck2            1     0.596 3679.3 690.25
## + Hip              1     0.504 3679.4 690.26
## + NeckAbdomen      1     0.459 3679.4 690.26
## + Hip2             1     0.110 3679.8 690.29
## + Wrist2           1     0.042 3679.9 690.29
## + NeckWrist        1     0.020 3679.9 690.29
## + Wrist            1     0.018 3679.9 690.29
## + logWrist         1     0.006 3679.9 690.29
## + NeckHip          1     0.000 3679.9 690.29
## - Weight           1   100.747 3780.6 693.05
## - ThighForearm     1   102.695 3782.6 693.18
## - AbdomenForearm   1   126.316 3806.2 694.73
## - logThigh         1   128.511 3808.4 694.88
## - HipWrist         1   149.058 3829.0 696.22
##
## Step:  AIC=686.57
## Bodyfat ~ logAbdomen + HipWrist + logNeck + AbdomenForearm +
##     Weight + logThigh + ThighForearm + Age
##
##                   Df Sum of Sq    RSS    AIC
## - logAbdomen       1     1.688 3627.2 684.69
## <none>                         3625.5 686.57
## + Forearm2         1    26.271 3599.2 686.75
## + NeckForearm      1    19.994 3605.5 687.19
## + Forearm          1    18.378 3607.1 687.30
## + ThighWrist       1    16.482 3609.0 687.43
## + HipForearm       1    14.328 3611.1 687.58
## + logHip           1    13.850 3611.6 687.61
## + logForearm       1     9.296 3616.2 687.93
## - Weight           1    49.567 3675.0 687.96
## + Thigh            1     7.747 3617.7 688.03
## + AbdomenWrist     1     6.905 3618.6 688.09
```

```
## + Hip              1     6.789 3618.7 688.10
## + Thigh2           1     6.599 3618.9 688.11
## + AbdomenThigh     1     5.465 3620.0 688.19
## - logNeck          1    53.212 3678.7 688.21
## + NeckThigh        1     4.164 3621.3 688.28
## + Abdomen2         1     4.101 3621.4 688.29
## - Age              1    54.424 3679.9 688.29
## + NeckWrist        1     3.933 3621.5 688.30
## + Abdomen          1     3.711 3621.8 688.31
## + logWrist         1     3.031 3622.4 688.36
## + Wrist            1     2.793 3622.7 688.38
## + Wrist2           1     2.460 3623.0 688.40
## + NeckHip          1     1.802 3623.7 688.45
## + Hip2             1     1.727 3623.7 688.45
## + Neck             1     0.930 3624.5 688.51
## + Neck2            1     0.630 3624.8 688.53
## + NeckAbdomen      1     0.511 3625.0 688.53
## + HipThigh         1     0.156 3625.3 688.56
## + ForearmWrist     1     0.076 3625.4 688.56
## + AbdomenHip       1     0.039 3625.4 688.57
## - ThighForearm     1   101.920 3727.4 691.50
## - AbdomenForearm   1   127.822 3753.3 693.23
## - logThigh         1   145.987 3771.5 694.44
## - HipWrist         1   189.443 3814.9 697.30
##
## Step:  AIC=684.69
## Bodyfat ~ HipWrist + logNeck + AbdomenForearm + Weight + logThigh +
##     ThighForearm + Age
##
##                  Df Sum of Sq    RSS    AIC
## <none>                        3627.2 684.69
## + Forearm2        1      26.6 3600.6 684.85
## + Forearm         1      18.3 3608.8 685.42
## + NeckForearm     1      16.5 3610.6 685.54
## + ThighWrist      1      14.9 3612.2 685.66
## + logHip          1      13.8 3613.3 685.73
## + HipForearm      1      12.4 3614.7 685.83
## + logForearm      1       9.0 3618.1 686.06
## - Weight          1      49.7 3676.8 686.09
## + Thigh           1       8.0 3619.1 686.13
## + Thigh2          1       6.9 3620.2 686.21
## - logNeck         1      51.7 3678.9 686.23
## + AbdomenThigh    1       6.0 3621.1 686.27
## + Hip             1       6.0 3621.2 686.27
## + AbdomenWrist    1       5.3 3621.8 686.32
## + Abdomen2        1       5.2 3622.0 686.33
## + NeckThigh       1       5.0 3622.2 686.34
## + NeckWrist       1       3.5 3623.6 686.44
## + logWrist        1       2.0 3625.2 686.55
## + Wrist           1       1.9 3625.3 686.56
## + Wrist2          1       1.7 3625.4 686.57
## + logAbdomen      1       1.7 3625.5 686.57
## + Abdomen         1       1.5 3625.7 686.58
## + Hip2            1       1.0 3626.1 686.61
```

```
## + NeckHip          1       0.9 3626.2 686.62
## + NeckAbdomen      1       0.8 3626.3 686.63
## - Age              1      58.0 3685.2 686.65
## + HipThigh         1       0.4 3626.8 686.66
## + Neck             1       0.3 3626.8 686.66
## + AbdomenHip       1       0.2 3627.0 686.67
## + Neck2            1       0.2 3627.0 686.67
## + ForearmWrist     1       0.0 3627.1 686.69
## - HipWrist         1     197.3 3824.5 695.93
## - ThighForearm     1    1689.2 5316.3 778.27
## - logThigh         1    1721.3 5348.4 779.77
## - AbdomenForearm   1    3240.8 6868.0 842.29
```

```
##
## Call:
## lm(formula = Bodyfat ~ HipWrist + logNeck + AbdomenForearm +
##     Weight + logThigh + ThighForearm + Age, data = interactDF)
##
## Coefficients:
##    (Intercept)        HipWrist         logNeck  AbdomenForearm
##     -281.09537        -0.01355       -13.51502         0.03003
##         Weight        logThigh    ThighForearm             Age
##       -0.06359        91.93300        -0.04226         0.05280
```

## 16.

We fit the linear model suggested by stepwise regression

```
stepwise.lm = lm(Bodyfat ~ logAbdomen + HipWrist + Neck + ThighForearm +
                   Age + Abdomen + Hip + Wrist + Thigh + Forearm)
stepwise.sum = summary(stepwise.lm)
stepwise.sum
```

```
##
## Call:
## lm(formula = Bodyfat ~ logAbdomen + HipWrist + Neck + ThighForearm +
##     Age + Abdomen + Hip + Wrist + Thigh + Forearm)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.3850 -2.6137 -0.2316  2.4801 10.0554
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -177.09958  104.26367  -1.699   0.0907 .
## logAbdomen     11.21323   40.00751   0.280   0.7795
## HipWrist       -0.04770    0.03721  -1.282   0.2011
## Neck           -0.50179    0.20074  -2.500   0.0131 *
## ThighForearm   -0.02869    0.02134  -1.345   0.1800
## Age             0.07002    0.02772   2.526   0.0122 *
## Abdomen         0.68729    0.43263   1.589   0.1135
## Hip             0.60381    0.69585   0.868   0.3864
## Wrist           2.95815    3.79348   0.780   0.4363
## Thigh           1.04333    0.63549   1.642   0.1020
## Forearm         2.00697    1.31443   1.527   0.1281
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.939 on 239 degrees of freedom
## Multiple R-squared:  0.7453, Adjusted R-squared:  0.7346
## F-statistic: 69.94 on 10 and 239 DF,  p-value: < 2.2e-16
```

## 17.

Compare the linear models

```
##
## Call:
## lm(formula = Bodyfat ~ Age + Weight + Neck + Abdomen + Hip +
##     Thigh + Forearm + Wrist)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.0756  -2.7707  -0.1871   2.7057   9.5237
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -18.46826   10.90031  -1.694  0.09150 .
## Age           0.05577    0.02871   1.943  0.05323 .
## Weight       -0.08081    0.03705  -2.181  0.03014 *
## Neck         -0.41183    0.20874  -1.973  0.04965 *
## Abdomen       0.87775    0.06680  13.140  < 2e-16 ***
## Hip          -0.20063    0.12999  -1.543  0.12404
## Thigh         0.26719    0.12028   2.221  0.02726 *
## Forearm       0.46567    0.17285   2.694  0.00755 **
## Wrist        -1.39341    0.47386  -2.941  0.00359 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.964 on 241 degrees of freedom
## Multiple R-squared:  0.7399, Adjusted R-squared:  0.7313
## F-statistic:  85.7 on 8 and 241 DF,  p-value: < 2.2e-16
```

```
##
## Call:
## lm(formula = Bodyfat ~ Age + Weight + Thigh + Neck + Abdomen +
##     Forearm + Wrist + NeckAbdomen + NeckThigh + ForearmWrist +
##     Abdomen2 + Forearm2)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -9.941 -2.477 -0.218  2.562  9.314
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -1.394e+02  5.642e+01  -2.472 0.014155 *
## Age           5.739e-02  2.801e-02   2.049 0.041563 *
## Weight       -9.440e-02  3.231e-02  -2.922 0.003819 **
## Thigh         4.906e+00  1.317e+00   3.724 0.000245 ***
## Neck         -1.993e-01  1.360e+00  -0.147 0.883580
```

```
## Abdomen      -7.867e-01  6.513e-01  -1.208 0.228292
## Forearm       8.256e-01  2.644e+00   0.312 0.755145
## Wrist         2.732e+00  3.069e+00   0.890 0.374257
## NeckAbdomen   7.670e-02  2.329e-02   3.293 0.001144 **
## NeckThigh    -1.226e-01  3.388e-02  -3.617 0.000364 ***
## ForearmWrist -1.495e-01  1.064e-01  -1.405 0.161376
## Abdomen2     -6.997e-03  3.041e-03  -2.301 0.022272 *
## Forearm2      4.079e-02  3.891e-02   1.048 0.295580
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.839 on 237 degrees of freedom
## Multiple R-squared:   0.76,  Adjusted R-squared:  0.7479
## F-statistic: 62.55 on 12 and 237 DF,  p-value: < 2.2e-16
```

```
##
## Call:
## lm(formula = Bodyfat ~ logAbdomen + HipWrist + Neck + ThighForearm +
##     Age + Abdomen + Hip + Wrist + Thigh + Forearm)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.3850 -2.6137 -0.2316  2.4801 10.0554
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -177.09958  104.26367  -1.699   0.0907 .
## logAbdomen     11.21323   40.00751   0.280   0.7795
## HipWrist       -0.04770    0.03721  -1.282   0.2011
## Neck           -0.50179    0.20074  -2.500   0.0131 *
## ThighForearm   -0.02869    0.02134  -1.345   0.1800
## Age             0.07002    0.02772   2.526   0.0122 *
## Abdomen         0.68729    0.43263   1.589   0.1135
## Hip             0.60381    0.69585   0.868   0.3864
## Wrist           2.95815    3.79348   0.780   0.4363
## Thigh           1.04333    0.63549   1.642   0.1020
## Forearm         2.00697    1.31443   1.527   0.1281
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.939 on 239 degrees of freedom
## Multiple R-squared:  0.7453, Adjusted R-squared:  0.7346
## F-statistic: 69.94 on 10 and 239 DF,  p-value: < 2.2e-16
```

## 18.

Test our model with training and testing data

```
newDF_x = as.data.frame(cbind(Age, Weight, Neck, Abdomen, Hip, Thigh,
                              Forearm, Wrist))
train = sample(1:250, 200)
test = (-train)
trainX = newDF_x[train,]
trainY = Bodyfat[train]
testX = newDF_x[test,]
```

```
testY = Bodyfat[test]

train.lm = lm(trainY ~ Age + Weight + Neck + Abdomen + Hip + Thigh + Forearm +
                Wrist, data=trainX)
train.sum = summary(train.lm)
train.sum
```

```
##
## Call:
## lm(formula = trainY ~ Age + Weight + Neck + Abdomen + Hip + Thigh +
##     Forearm + Wrist, data = trainX)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.0539  -2.7732  -0.0753   2.9406   9.3181
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -17.33723   11.91598  -1.455 0.147323
## Age           0.06652    0.03122   2.131 0.034395 *
## Weight       -0.05986    0.03992  -1.500 0.135346
## Neck         -0.37764    0.22122  -1.707 0.089434 .
## Abdomen       0.82284    0.07340  11.211  < 2e-16 ***
## Hip          -0.21101    0.14178  -1.488 0.138326
## Thigh         0.23482    0.13504   1.739 0.083665 .
## Forearm       0.76535    0.22319   3.429 0.000742 ***
## Wrist        -1.78730    0.52857  -3.381 0.000875 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.883 on 191 degrees of freedom
## Multiple R-squared:  0.7493, Adjusted R-squared:  0.7388
## F-statistic: 71.35 on 8 and 191 DF,  p-value: < 2.2e-16
```

```
test.lm = lm(testY ~ Age + Weight + Neck + Abdomen + Hip + Thigh + Forearm +
               Wrist, data=testX)
test.sum = summary(test.lm)
test.sum
```

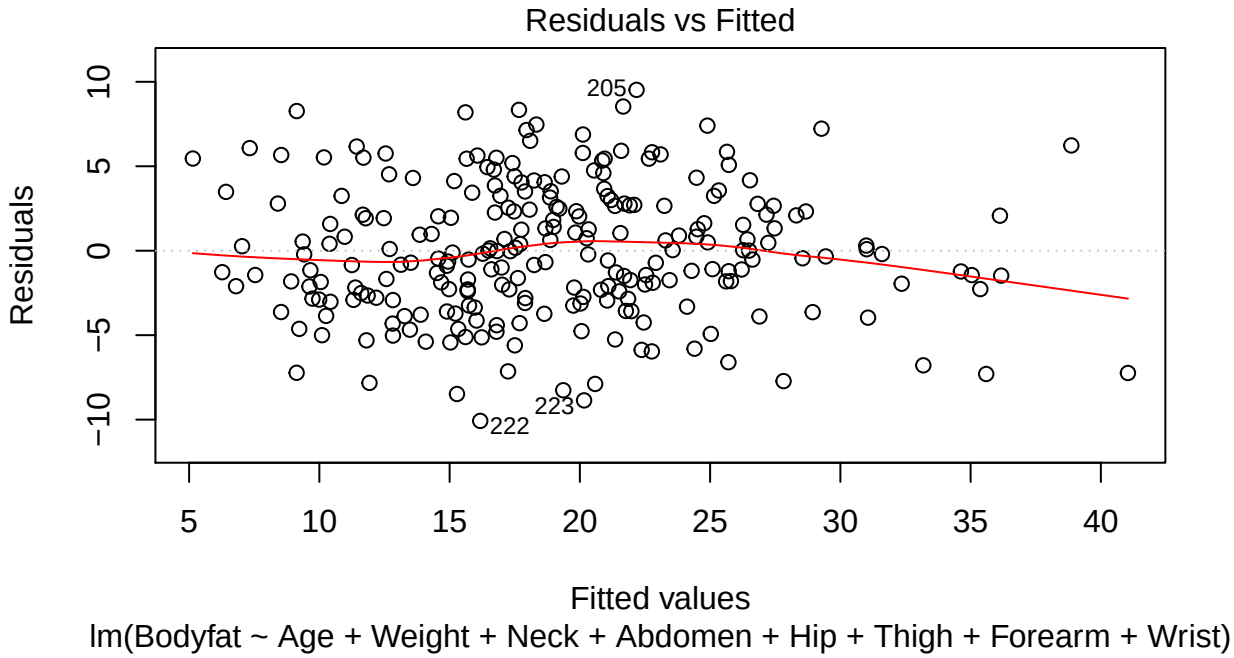
```
##
## Call:
## lm(formula = testY ~ Age + Weight + Neck + Abdomen + Hip + Thigh +
##     Forearm + Wrist, data = testX)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.6611 -2.8145  0.2463  3.1223  7.2618
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -17.719430  28.944137  -0.612   0.5438
## Age          -0.005241   0.080586  -0.065   0.9485
## Weight       -0.185773   0.106023  -1.752   0.0872 .
## Neck         -0.992922   0.666334  -1.490   0.1438
## Abdomen       1.184757   0.185388   6.391  1.2e-07 ***
```

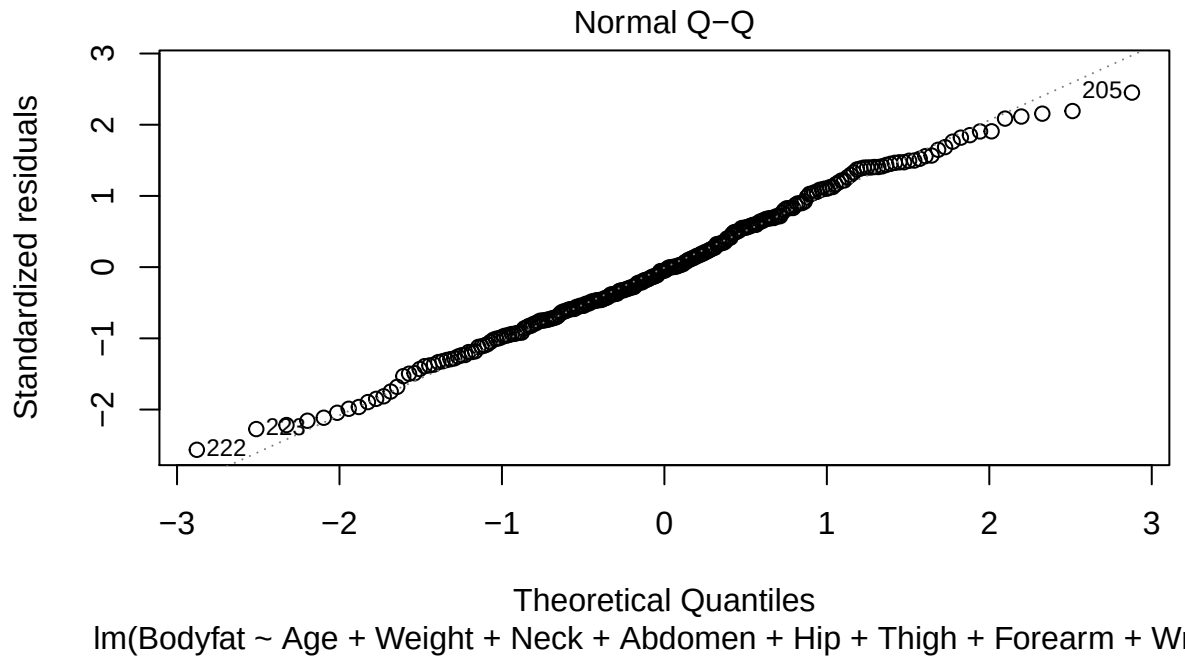
```
## Hip          -0.376564   0.362496  -1.039   0.3050
## Thigh         0.465266   0.293059   1.588   0.1201
## Forearm       0.158718   0.306573   0.518   0.6074
## Wrist         0.187465   1.481236   0.127   0.8999
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.262 on 41 degrees of freedom
## Multiple R-squared:  0.7523, Adjusted R-squared:  0.704
## F-statistic: 15.57 on 8 and 41 DF,  p-value: 3.179e-10
```

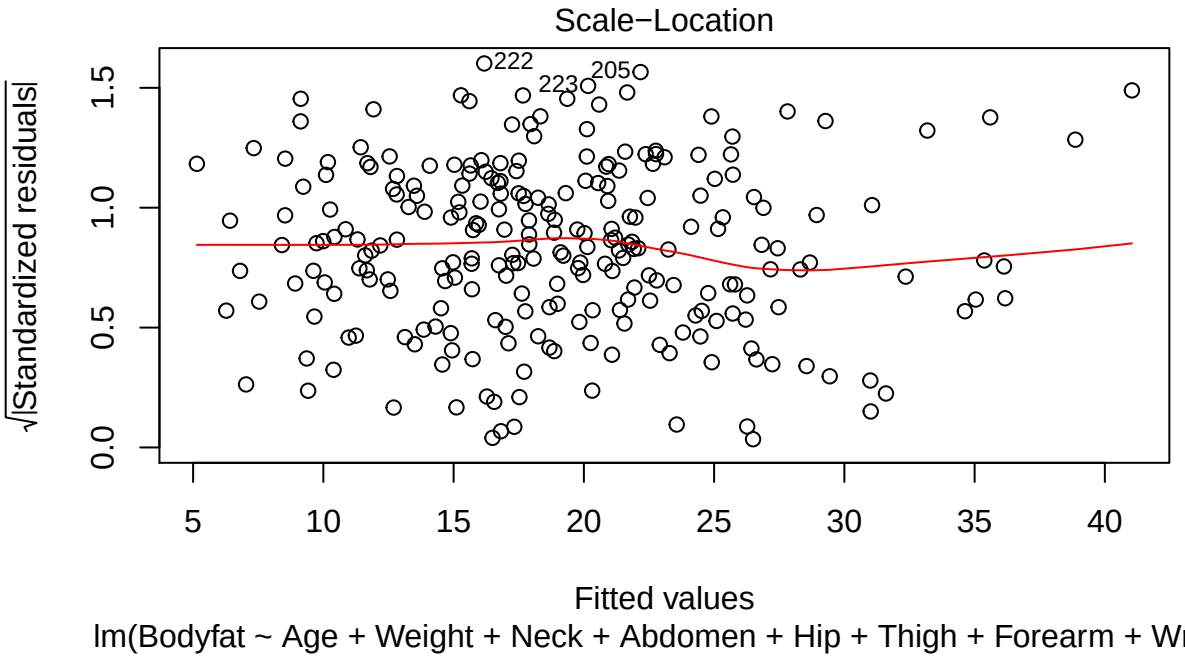
### 19.

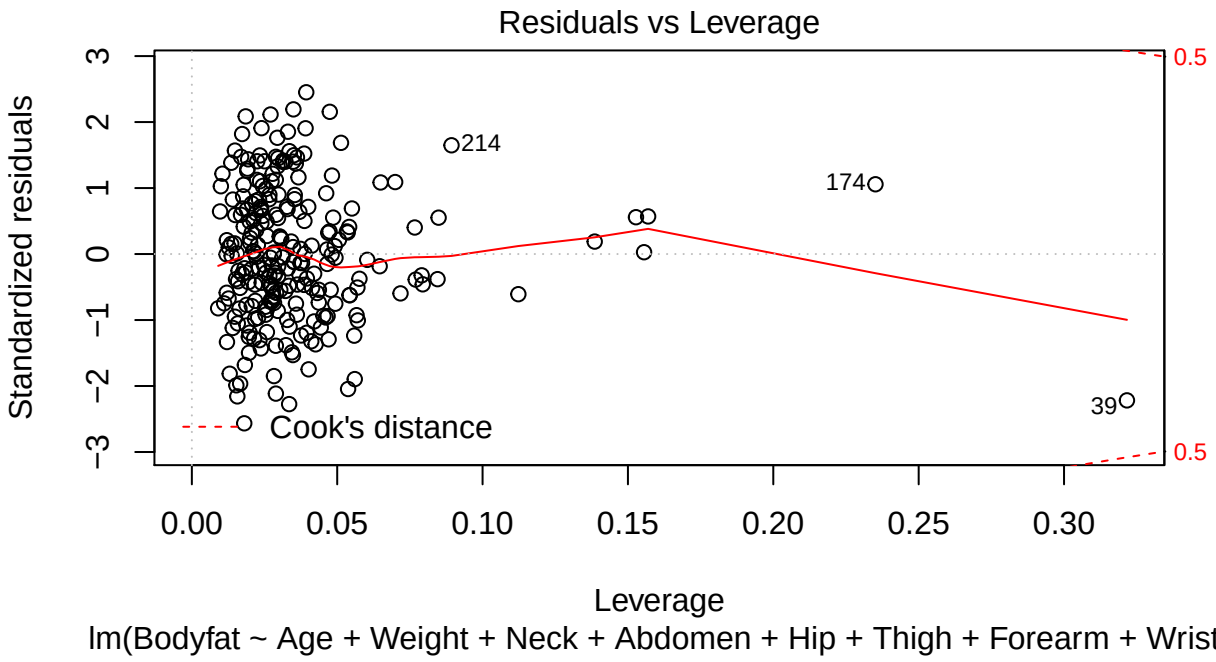
Plotting residuals for the model and residuals for the single variables

```
plot(new3.lm)
```



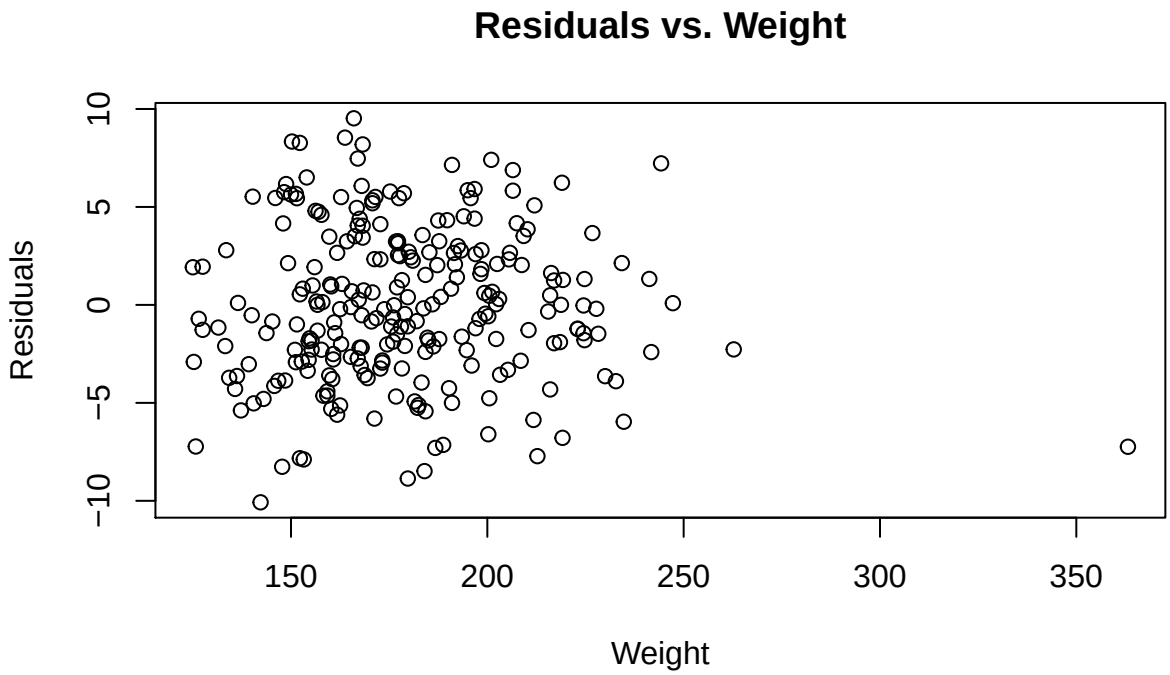

Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(Bodyfat ~ Age + Weight + Neck + Abdomen + Hip + Thigh + Forearm + Wrist)
222
223
205


Scale−Location
√|Standardized residuals|
Fitted values
lm(Bodyfat ~ Age + Weight + Neck + Abdomen + Hip + Thigh + Forearm + Wrist)
222
223
205

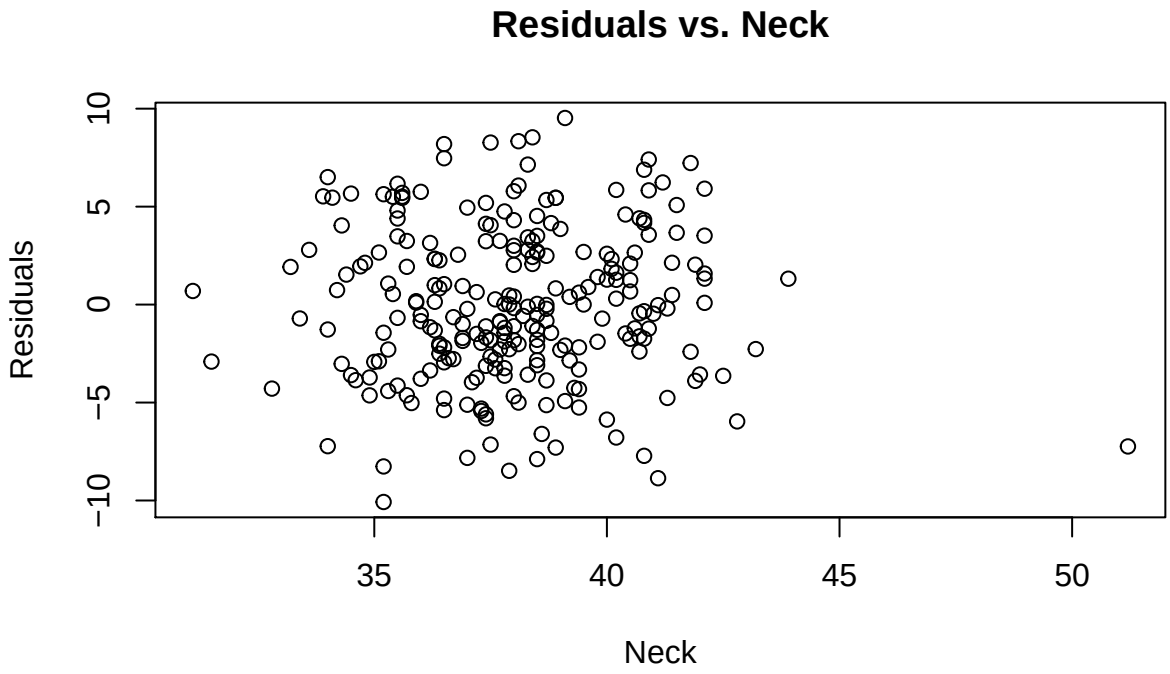



```
Residuals = new3.lm$residuals
plot(Age, Residuals, main="Residuals vs. Age")
```

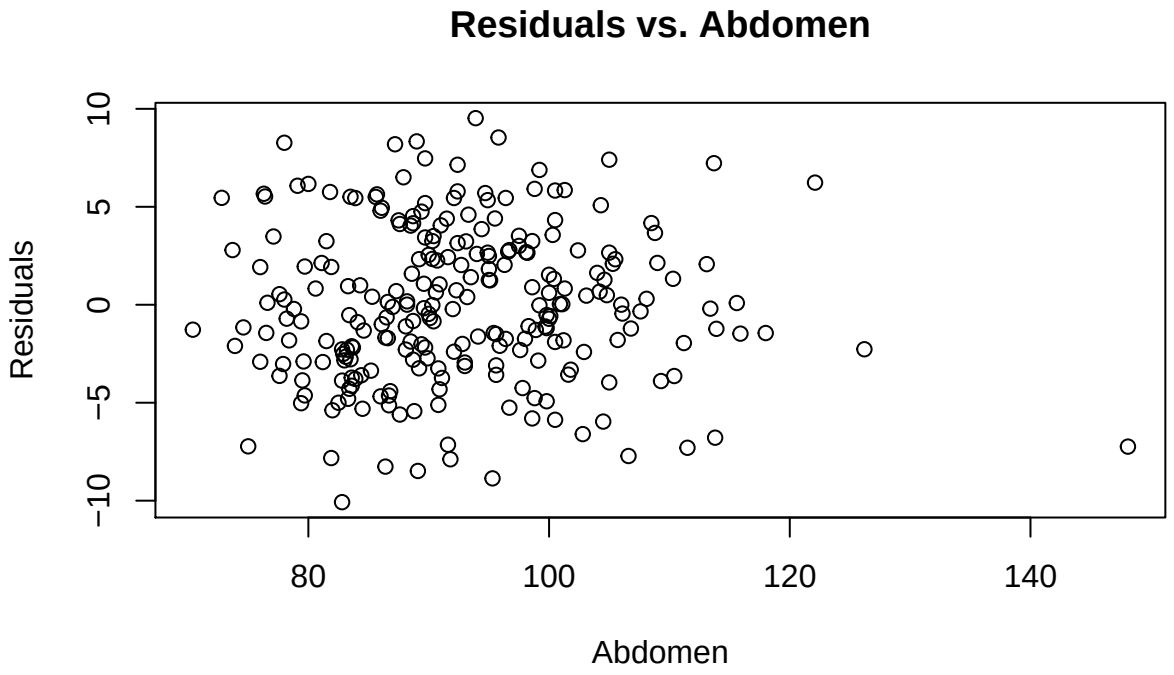
```
plot(Weight, Residuals, main="Residuals vs. Weight")
```



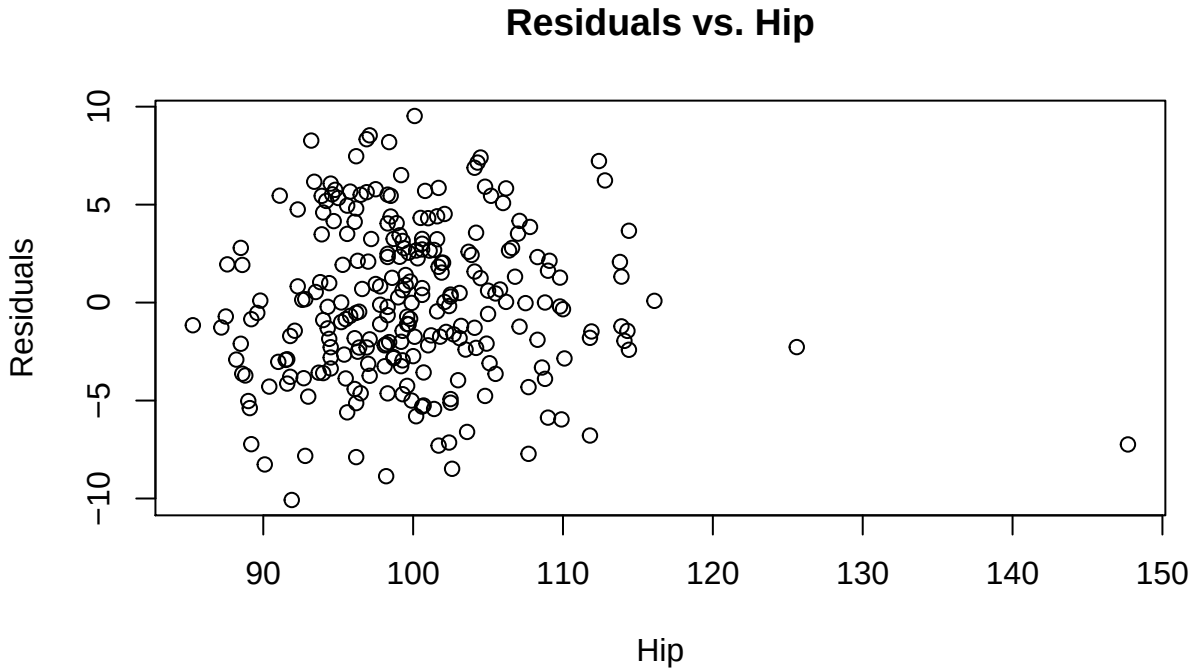

```
plot(Neck, Residuals, main="Residuals vs. Neck")
```



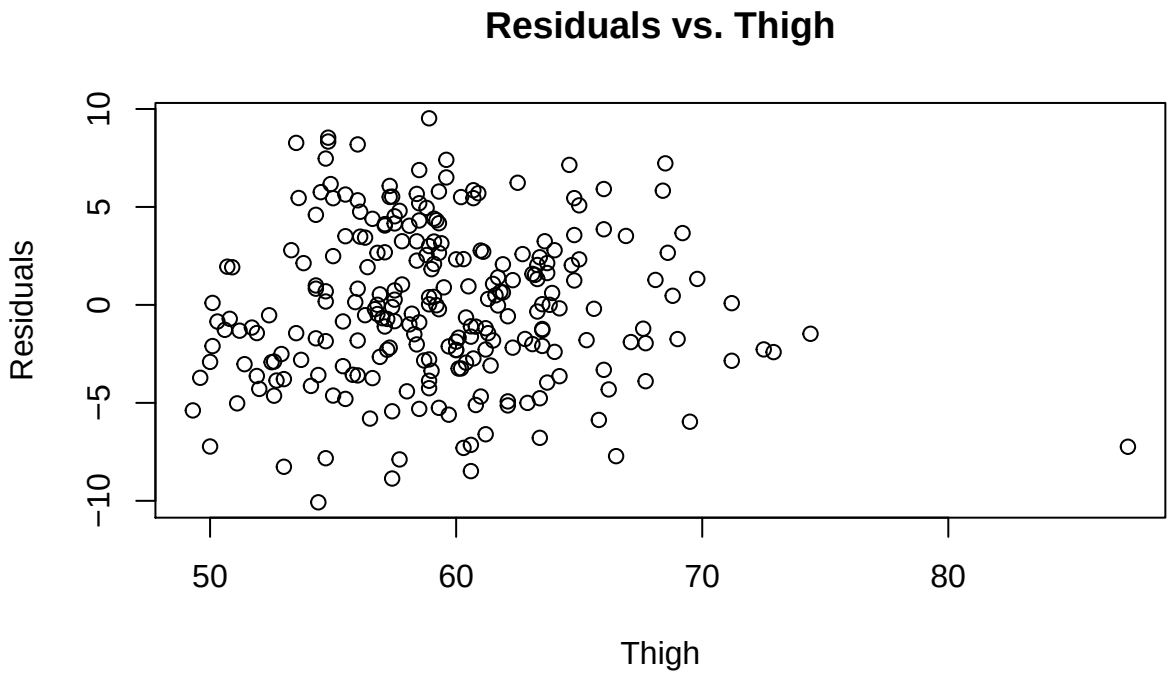
```
plot(Abdomen, Residuals, main="Residuals vs. Abdomen")
```



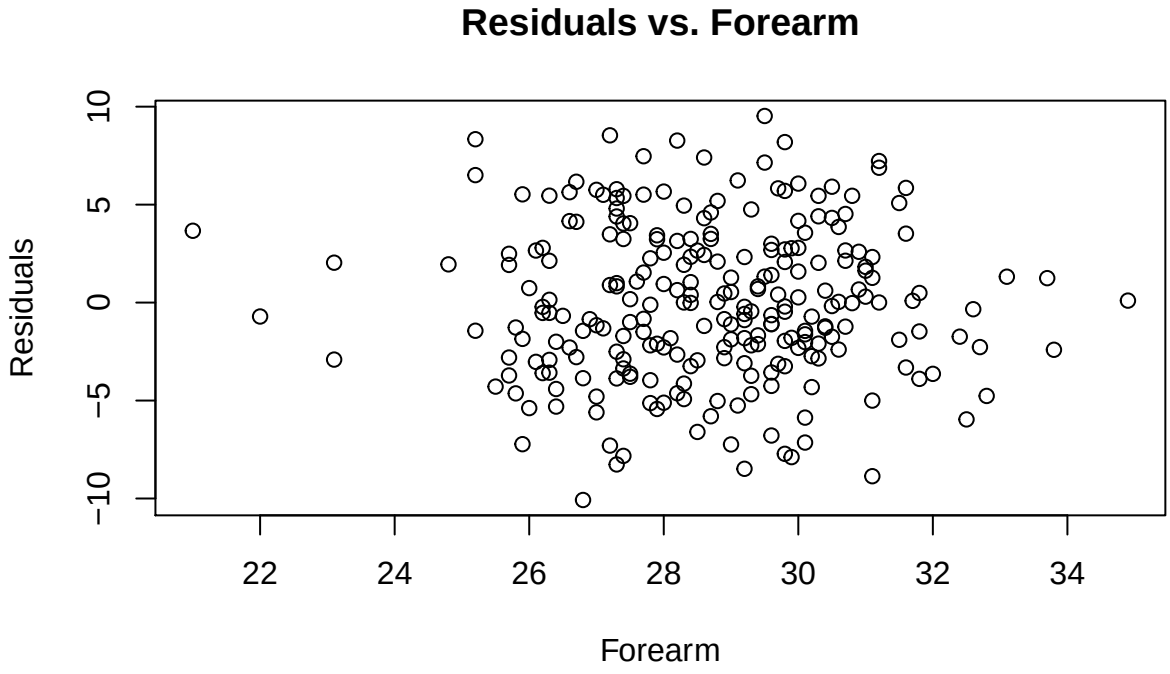

```
plot(Hip, Residuals, main="Residuals vs. Hip")
```



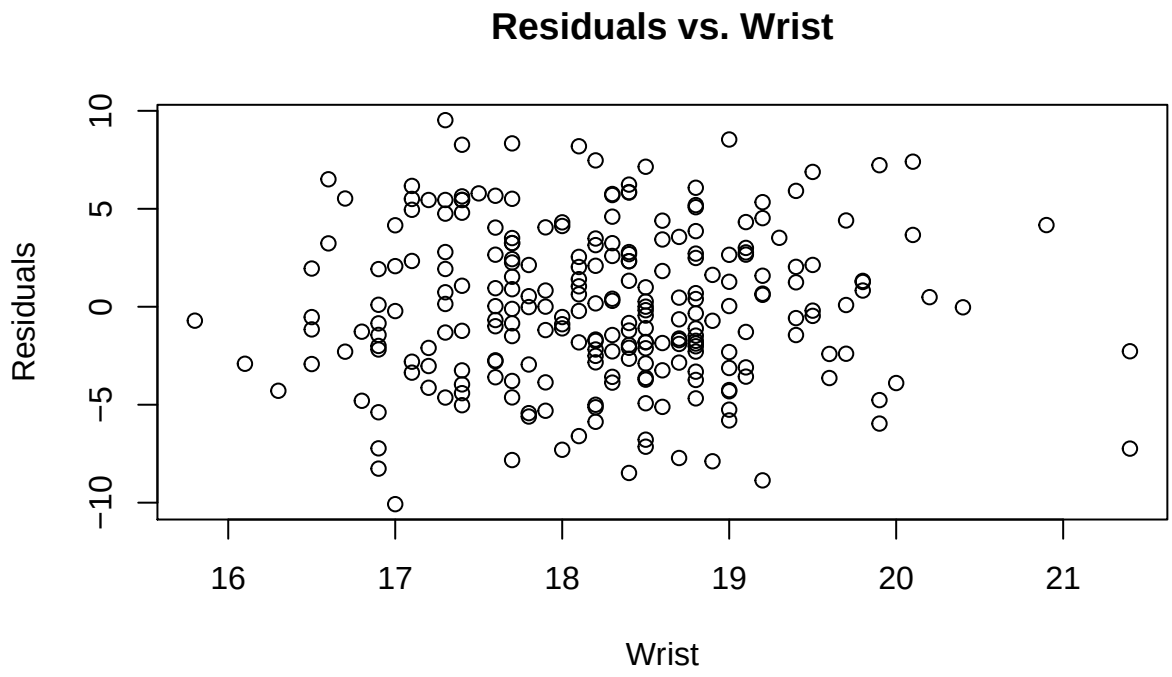
```
plot(Thigh, Residuals, main="Residuals vs. Thigh")
```




```
plot(Forearm, Residuals, main="Residuals vs. Forearm")
```



```r
plot(Wrist, Residuals, main="Residuals vs. Wrist")
```




**20.**

Removing the high leverage points from the model and refitting the model

```r
# new data model includes age, weight, neck, abdomen, hip, thigh, forearm, wrist
# without the two high leverage points
bodyfatDF_no_lev <- bodyfatDF[-c(39, 174),]
Bodyfat_no_lev = bodyfatDF_no_lev$Bodyfat
Age_no_lev = bodyfatDF_no_lev$Age
Weight_no_lev = bodyfatDF_no_lev$Weight
Neck_no_lev = bodyfatDF_no_lev$Neck
Abdomen_no_lev = bodyfatDF_no_lev$Abdomen
Hip_no_lev = bodyfatDF_no_lev$Hip
Thigh_no_lev = bodyfatDF_no_lev$Thigh
Forearm_no_lev = bodyfatDF_no_lev$Forearm
Wrist_no_lev = bodyfatDF_no_lev$Wrist

newDF_x_no_lev = as.data.frame(cbind(Age_no_lev, Weight_no_lev, Neck_no_lev,
                                     Abdomen_no_lev, Hip_no_lev, Thigh_no_lev,
                                     Forearm_no_lev, Wrist_no_lev))
train_no_lev = sample(1:248, 200)
test_no_lev = (-train_no_lev)
trainX_no_lev = newDF_x_no_lev[train_no_lev,]
trainY_no_lev = Bodyfat_no_lev[train_no_lev]
testX_no_lev = newDF_x_no_lev[test_no_lev,]
testY_no_lev = Bodyfat_no_lev[test_no_lev]
```

```
train.lm_no_lev = lm(trainY_no_lev ~ Age_no_lev + Weight_no_lev + Neck_no_lev
                     + Abdomen_no_lev + Hip_no_lev + Thigh_no_lev + Forearm_no_lev
                     + Wrist_no_lev, data=trainX_no_lev)
train.sum_no_lev = summary(train.lm_no_lev)
train.sum_no_lev
```

```
##
## Call:
## lm(formula = trainY_no_lev ~ Age_no_lev + Weight_no_lev + Neck_no_lev +
##     Abdomen_no_lev + Hip_no_lev + Thigh_no_lev + Forearm_no_lev +
##     Wrist_no_lev, data = trainX_no_lev)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.0110  -2.5886  -0.0134   2.8008   9.3569
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -23.47340   12.10656  -1.939  0.05399 .
## Age_no_lev       0.06708    0.03385   1.982  0.04895 *
## Weight_no_lev   -0.08220    0.04018  -2.046  0.04214 *
## Neck_no_lev     -0.28536    0.23926  -1.193  0.23448
## Abdomen_no_lev   0.84921    0.07623  11.141  < 2e-16 ***
## Hip_no_lev      -0.18510    0.14722  -1.257  0.21018
## Thigh_no_lev     0.34619    0.13927   2.486  0.01379 *
## Forearm_no_lev   0.37039    0.22853   1.621  0.10671
## Wrist_no_lev    -1.43707    0.54761  -2.624  0.00939 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.997 on 191 degrees of freedom
## Multiple R-squared:  0.7333, Adjusted R-squared:  0.7221
## F-statistic: 65.65 on 8 and 191 DF,  p-value: < 2.2e-16
```

```
test.lm_no_lev = lm(testY_no_lev ~ Age_no_lev + Weight_no_lev + Neck_no_lev
                    + Abdomen_no_lev + Hip_no_lev + Thigh_no_lev + Forearm_no_lev +
                      Wrist_no_lev, data=testX_no_lev)
test.sum_no_lev = summary(test.lm_no_lev)
test.sum_no_lev
```

```
##
## Call:
## lm(formula = testY_no_lev ~ Age_no_lev + Weight_no_lev + Neck_no_lev +
##     Abdomen_no_lev + Hip_no_lev + Thigh_no_lev + Forearm_no_lev +
##     Wrist_no_lev, data = testX_no_lev)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -7.687 -2.286 -0.516  1.983  7.456
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)     7.89249   30.20895   0.261   0.7953
## Age_no_lev      0.05772    0.06037   0.956   0.3449
```

```
## Weight_no_lev   0.01125    0.11673   0.096   0.9237
## Neck_no_lev    -0.65883    0.53691  -1.227   0.2272
## Abdomen_no_lev  0.82353    0.18279   4.505 5.88e-05 ***
## Hip_no_lev     -0.18929    0.35923  -0.527   0.6012
## Thigh_no_lev   -0.07548    0.25601  -0.295   0.7697
## Forearm_no_lev  0.74027    0.61782   1.198   0.2381
## Wrist_no_lev   -2.35008    1.16952  -2.009   0.0514 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.895 on 39 degrees of freedom
## Multiple R-squared:  0.7924, Adjusted R-squared:  0.7498
## F-statistic: 18.61 on 8 and 39 DF,  p-value: 4.146e-11
```