

# Model4

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## Model 4

```
rm(list = ls())
gc()

##           used (Mb) gc trigger (Mb) max used (Mb)
## Ncells 471414 25.2    1016467 54.3    660860 35.3
## Vcells 890583  6.8     8388608 64.0   1800812 13.8

set.seed(123)
library(car)

## Loading required package: carData
library(ggplot2)
library(olsrr)

##
## Attaching package: 'olsrr'

## The following object is masked from 'package:datasets':
## 
##      rivers

##### (1) Data cleaning #####
## select variables
library(NHANES)
df0 <- NHANES
df <- NHANES[NHANES$Age >= 18 & NHANES$Age < 60,]
# colSums(is.na(df)) / nrow(df)
df <- df[, which(colSums(is.na(df)) / nrow(df) < 0.3)]
# exclude duplication
df <- df[!duplicated(df),]
names(df)

## [1] "ID"                  "SurveyYr"             "Gender"              "Age"
## [5] "AgeDecade"            "Race1"                "Education"            "MaritalStatus"
## [9] "HHIncome"              "HHIncomeMid"          "Poverty"              "HomeRooms"
## [13] "HomeOwn"               "Work"                 "Weight"               "Height"
## [17] "BMI"                  "BMI_WHO"              "Pulse"                "BPSysAve"
## [21] "BPDiaAve"              "BPSys1"                "BPDia1"                "BPSys2"
## [25] "BPDia2"                "BPSys3"                "BPDia3"                "DirectChol"
## [29] "TotChol"               "UrineVol1"             "UrineFlow1"            "Diabetes"
## [33] "HealthGen"              "DaysPhysHlthBad"        "DaysMentHlthBad"       "LittleInterest"
```

```

## [37] "Depressed"           "SleepHrsNight"      "SleepTrouble"       "PhysActive"
## [41] "Alcohol12PlusYr"     "AlcoholYear"        "Smoke100"          "Smoke100n"
## [45] "Marijuana"           "RegularMarij"      "HardDrugs"         "SexEver"
## [49] "SexAge"               "SexNumPartnLife"   "SexNumPartYear"    "SameSex"
## [53] "SexOrientation"

# df$BPSysAve
library(dplyr)

##
## Attaching package: 'dplyr'
## The following object is masked from 'package:car':
##
##     recode
## The following objects are masked from 'package:stats':
##
##     filter, lag
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
df2 <- df %>% select(
  SleepHrsNight,
  BMI,
  DirectChol,
  Age,
  Gender,
  Race1,
  TotChol,
  BPDiaAve,
  BPSysAve,
  AlcoholYear,
  Poverty,
  SexNumPartnLife,
  SexNumPartYear,
  DaysMentHlthBad,
  UrineFlow1,
  PhysActive,
  DaysPhysHlthBad,
  Smoke100,
  Depressed,
  HealthGen,
  SexAge
)
df3 <- na.omit(df2)
#df3$SleepHrsNight <- df3$SleepHrsNight * 60
#df3 <- df3[, -which(names(df3) %in% "SleepHrsNight")]
# cor(df3$BPSysAve, df3$BPDiaAve)
psych::describe(df3)

##                   vars     n   mean     sd median trimmed   mad   min     max
## SleepHrsNight      1 2152   6.78   1.31    7.00    6.85  1.48  2.00  12.00
## BMI                 2 2152  28.77   6.75   27.60   28.09  5.78 15.02  69.00

```

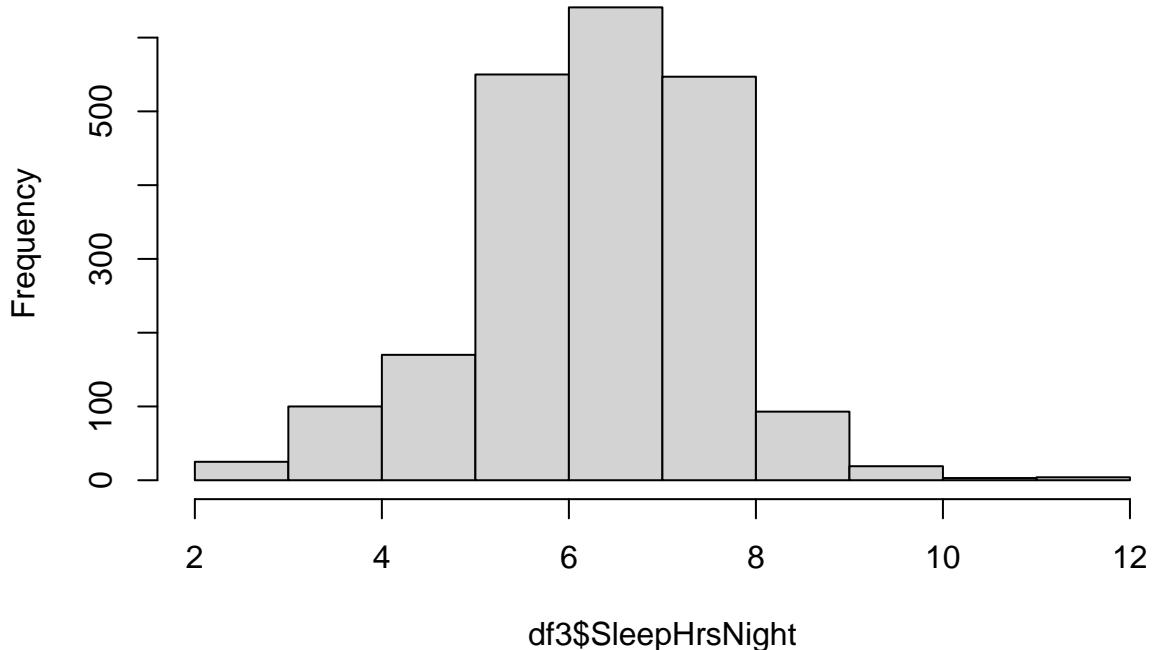
```

## DirectChol      3 2152   1.35  0.41   1.29    1.31  0.39  0.39   3.83
## Age            4 2152  39.18 11.33  39.00   39.15 14.83 20.00  59.00
## Gender*        5 2152   1.53  0.50   2.00    1.54  0.00  1.00   2.00
## Race1*         6 2152   3.43  1.15   4.00    3.57  0.00  1.00   5.00
## TotChol        7 2152   5.07  1.05   4.99    5.01  1.04  1.53  13.65
## BPDiaAve       8 2152  71.19 11.84  71.00   71.28 10.38 0.00  116.00
## BPSysAve       9 2152 117.43 14.28 116.00  116.50 13.34 78.00  209.00
## AlcoholYear    10 2152 70.59 94.22  24.00   50.94 35.58 0.00  364.00
## Poverty        11 2152   2.84  1.69   2.78    2.89  2.49  0.00   5.00
## SexNumPartnLife 12 2152 16.73 66.13  7.00    8.91  5.93  0.00 2000.00
## SexNumPartYear  13 2152   1.38  2.59   1.00    1.04  0.00  0.00  69.00
## DaysMentHlthBad 14 2152   4.47  8.02   0.00    2.40  0.00  0.00  30.00
## UrineFlow1      15 2152   1.07  0.97   0.81    0.91  0.60  0.00 10.14
## PhysActive*     16 2152   1.58  0.49   2.00    1.60  0.00  1.00   2.00
## DaysPhysHlthBad 17 2152   3.16  7.19   0.00    1.12  0.00  0.00  30.00
## Smoke100*       18 2152   1.46  0.50   1.00    1.45  0.00  1.00   2.00
## Depressed*      19 2152   1.30  0.58   1.00    1.16  0.00  1.00   3.00
## HealthGen*      20 2152   2.64  0.94   3.00    2.65  1.48  1.00   5.00
## SexAge          21 2152 17.10 3.39  17.00   16.80  2.97  9.00  44.00
##
##             range skew kurtosis se
## SleepHrsNight 10.00 -0.30    0.69 0.03
## BMI           53.98  1.28    2.96 0.15
## DirectChol    3.44  1.09    2.27 0.01
## Age            39.00  0.02   -1.15 0.24
## Gender*        1.00 -0.12   -1.99 0.01
## Race1*         4.00 -1.13    0.08 0.02
## TotChol        12.12  0.92    3.47 0.02
## BPDiaAve      116.00 -0.39   3.13 0.26
## BPSysAve       131.00  1.00    2.94 0.31
## AlcoholYear    364.00  1.66    1.98 2.03
## Poverty        5.00 -0.01   -1.47 0.04
## SexNumPartnLife 2000.00 18.82  456.62 1.43
## SexNumPartYear 69.00 14.07  293.16 0.06
## DaysMentHlthBad 30.00  2.16    3.76 0.17
## UrineFlow1      10.14  2.89   14.06 0.02
## PhysActive*     1.00 -0.32   -1.90 0.01
## DaysPhysHlthBad 30.00  2.80    7.06 0.15
## Smoke100*       1.00  0.15   -1.98 0.01
## Depressed*      2.00  1.83    2.21 0.01
## HealthGen*      4.00  0.11   -0.33 0.02
## SexAge          35.00  1.51    5.56 0.07

# psych::pairs.panels(df3)
hist(df3$SleepHrsNight)

```

## Histogram of df3\$SleepHrsNight



```
# colSums(is.na(df2)) / nrow(df2)
fit0 <-
  lm(SleepHrsNight ~ .,
    data = df3)
#data type
df3$Gender <- ifelse(df3$Gender == "male", 0, 1)
df3$Smoke100 <- ifelse(df3$Smoke100 == "No", 0, 1)
df3$PhysActive <- ifelse(df3$PhysActive == "No", 0, 1)
df3 <- df3 %>%
  mutate(
    Race1 = case_when(
      Race1 == 'Black' ~ 1,
      Race1 == 'Hispanic' ~ 2,
      Race1 == 'Mexican' ~ 3,
      Race1 == 'White' ~ 4,
      Race1 == 'Other' ~ 5,
      TRUE ~ NA_integer_ # Default value if none of the conditions are met
    )
  )

## model_2 add known risk factors ##
m_full = lm(
  BMI ~ SleepHrsNight + Age + Gender + Race1 + Poverty + TotChol + BPDiaAve + BPSysAve + AlcoholYear +
  DaysPhysHlthBad + HealthGen + PhysActive + SleepHrsNight * Age + SleepHrsNight *
  Gender,
  df3
```

```

)
summary(m_full)

##
## Call:
## lm(formula = BMI ~ SleepHrsNight + Age + Gender + Race1 + Poverty +
##     TotChol + BPDiaAve + BPSysAve + AlcoholYear + Smoke100 +
##     UrineFlow1 + DaysMentHlthBad + DaysPhysHlthBad + HealthGen +
##     PhysActive + SleepHrsNight * Age + SleepHrsNight * Gender,
##     data = df3)
##
## Residuals:
##    Min      1Q  Median      3Q     Max 
## -17.019  -4.059  -0.648   3.165  36.301 
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 21.349305  2.996916  7.124 1.43e-12 ***
## SleepHrsNight -0.542616  0.378594 -1.433  0.15194  
## Age          -0.105136  0.062783 -1.675  0.09416 .  
## Gender        3.768696  1.435161  2.626  0.00870 ** 
## Race1         -0.503222  0.121964 -4.126 3.83e-05 ***
## Poverty       0.072729  0.090968  0.800  0.42409  
## TotChol        0.014773  0.135905  0.109  0.91345  
## BPDiaAve      0.058709  0.013701  4.285 1.91e-05 ***
## BPSysAve       0.054450  0.011792  4.617 4.12e-06 *** 
## AlcoholYear    -0.008396  0.001513 -5.549 3.23e-08 *** 
## Smoke100       -0.802999  0.286852 -2.799  0.00517 ** 
## UrineFlow1     -0.102218  0.142435 -0.718  0.47305  
## DaysMentHlthBad -0.030250  0.017962 -1.684  0.09230 .  
## DaysPhysHlthBad  0.015142  0.020943  0.723  0.46975  
## HealthGenVgood  1.928283  0.470249  4.101 4.28e-05 *** 
## HealthGenGood   3.559316  0.468010  7.605 4.24e-14 *** 
## HealthGenFair    5.299570  0.575060  9.216 < 2e-16 *** 
## HealthGenPoor    7.640142  1.077494  7.091 1.81e-12 *** 
## PhysActive      -0.837418  0.294615 -2.842  0.00452 ** 
## SleepHrsNight:Age  0.017092  0.009024  1.894  0.05837 .  
## SleepHrsNight:Gender -0.477032  0.206903 -2.306  0.02123 * 
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.242 on 2131 degrees of freedom
## Multiple R-squared:  0.1538, Adjusted R-squared:  0.1459 
## F-statistic: 19.37 on 20 and 2131 DF,  p-value: < 2.2e-16
car::Anova(m_full, type = "III")

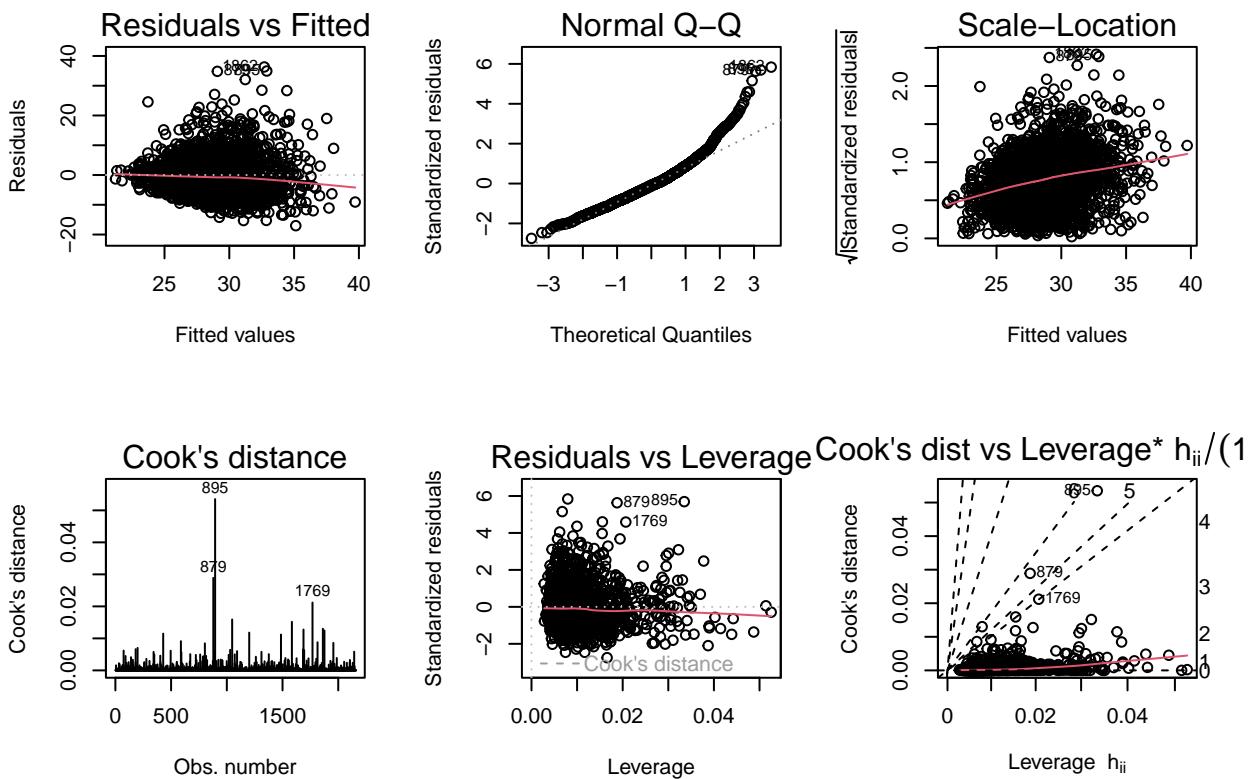
##
## Anova Table (Type III tests)
## 
## Response: BMI
##              Sum Sq Df F value    Pr(>F)    
## (Intercept) 1977   1 50.7479 1.431e-12 ***
## SleepHrsNight 80    1  2.0542  0.151936  
## Age          109   1  2.8043  0.094161 .  

```

```

## Gender           269   1  6.8957  0.008702 **
## Race1            663   1 17.0238 3.833e-05 ***
## Poverty           25   1  0.6392  0.424089
## TotChol            0   1  0.0118  0.913452
## BPDiaAve          715   1 18.3611 1.909e-05 ***
## BPSysAve           831   1 21.3201 4.118e-06 ***
## AlcoholYear        1200   1 30.7921 3.229e-08 ***
## Smoke100            305   1  7.8363  0.005167 **
## UrineFlow1           20   1  0.5150  0.473054
## DaysMentHlthBad      110   1  2.8364  0.092299 .
## DaysPhysHlthBad       20   1  0.5228  0.469750
## HealthGen          4548   4 29.1844 < 2.2e-16 ***
## PhysActive           315   1  8.0793  0.004520 **
## SleepHrsNight:Age      140   1  3.5871  0.058366 .
## SleepHrsNight:Gender     207   1  5.3157  0.021230 *
## Residuals          83018 2131
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##### model 2 diagnosis #####
par(mfrow = c(2, 3)) #read more from ?plot.lm
plot(m_full, which = 1)
plot(m_full, which = 2)
plot(m_full, which = 3)
plot(m_full, which = 4)
plot(m_full, which = 5)
plot(m_full, which = 6)

```



```

par(mfrow = c(1, 1)) # reset

m_full.yhat = m_full$fitted.values
m_full.res = m_full$residuals
m_full.h = hatvalues(m_full)
m_full.r = rstandard(m_full)
m_full.rr = rstudent(m_full)
#which subject is most outlying with respect to the x space
Hmisc::describe(m_full.h)

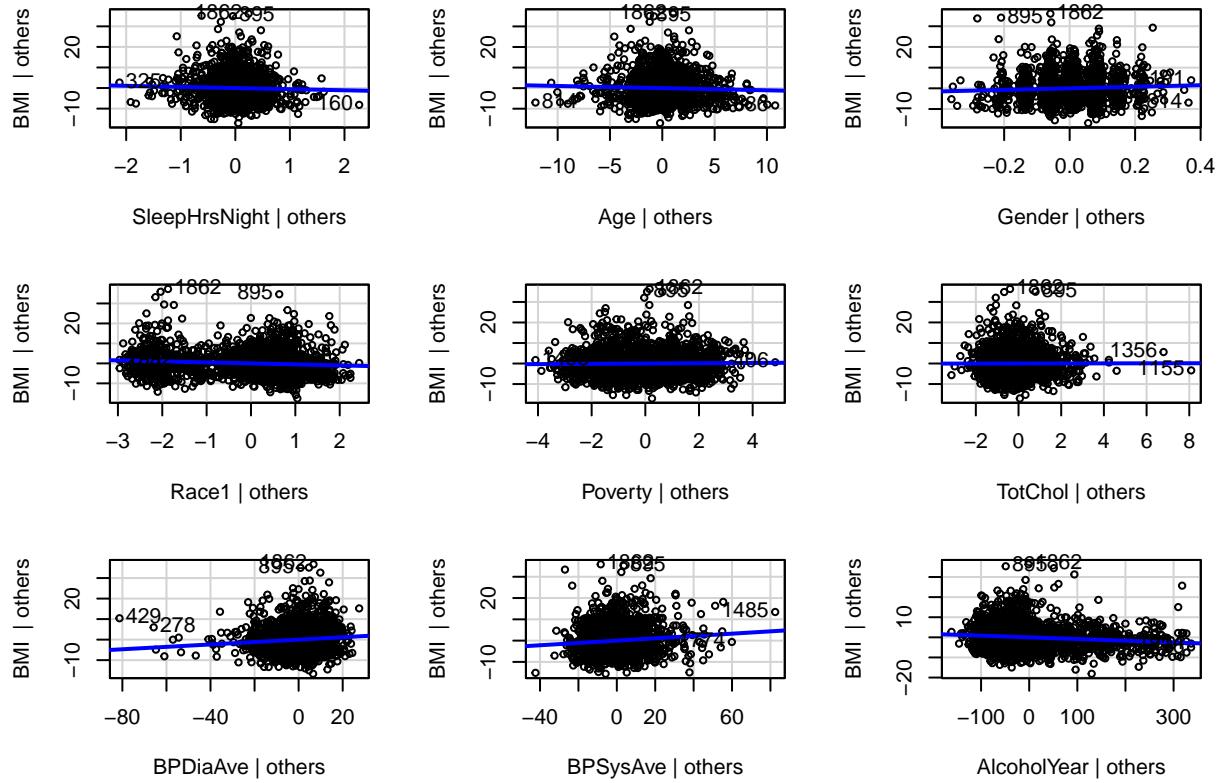
## m_full.h
##      n  missing distinct      Info      Mean      Gmd      .05      .10
##    2152        0     2152          1 0.009758 0.005425 0.004453 0.005041
##    .25       .50     .75       .90       .95
## 0.006148 0.008122 0.011389 0.016108 0.020491
##
## lowest : 0.002781565 0.002839218 0.003194507 0.003255413 0.003296775
## highest: 0.043894006 0.044237670 0.048729461 0.051407460 0.052560897

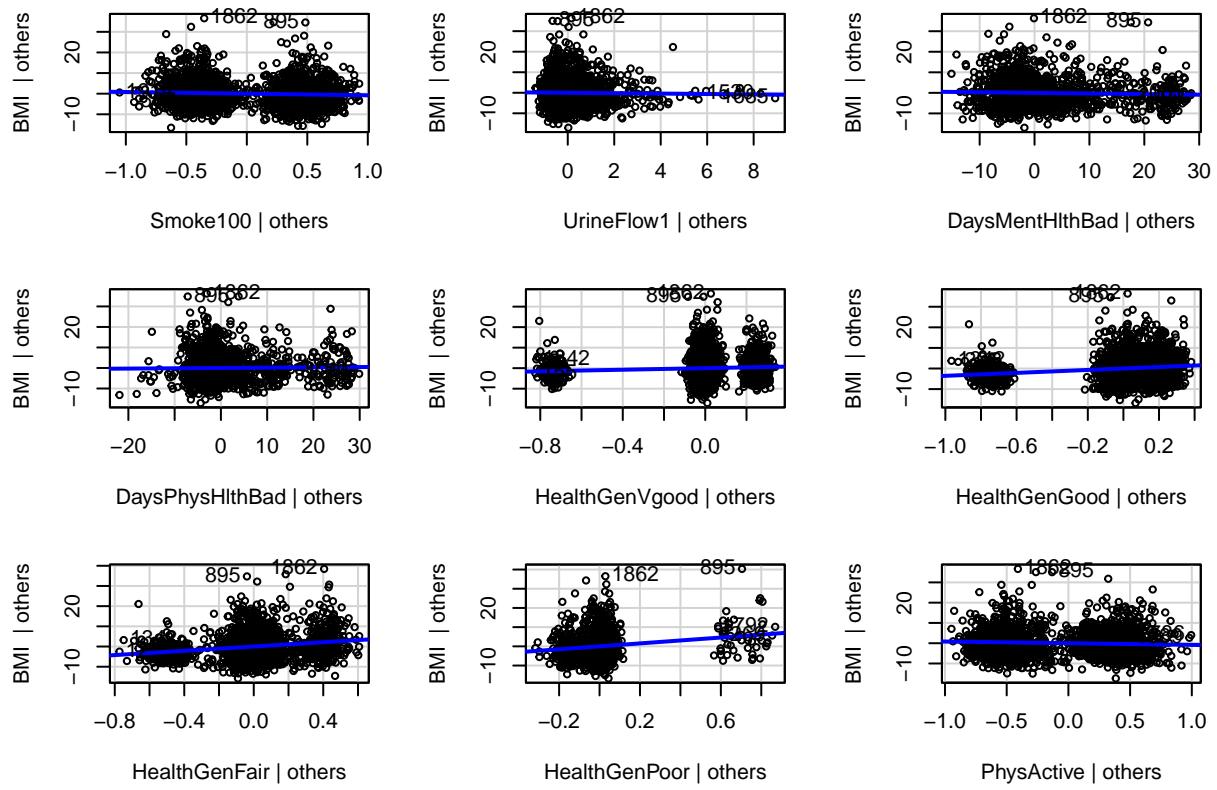
m_full.h[which.max(m_full.h)]

##      1685
## 0.0525609
#####
##### Assumption:LINE #####
#(1)Linear: 2 approaches

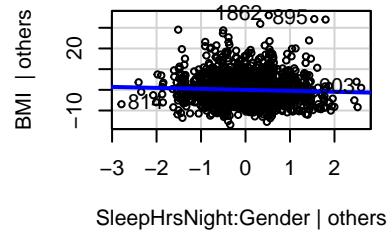
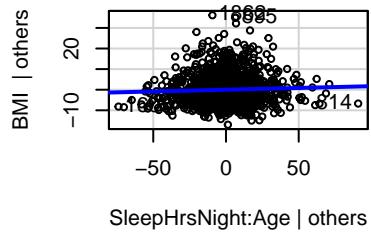
```

```
# partial regression plots  
car::avPlots(m_full)
```



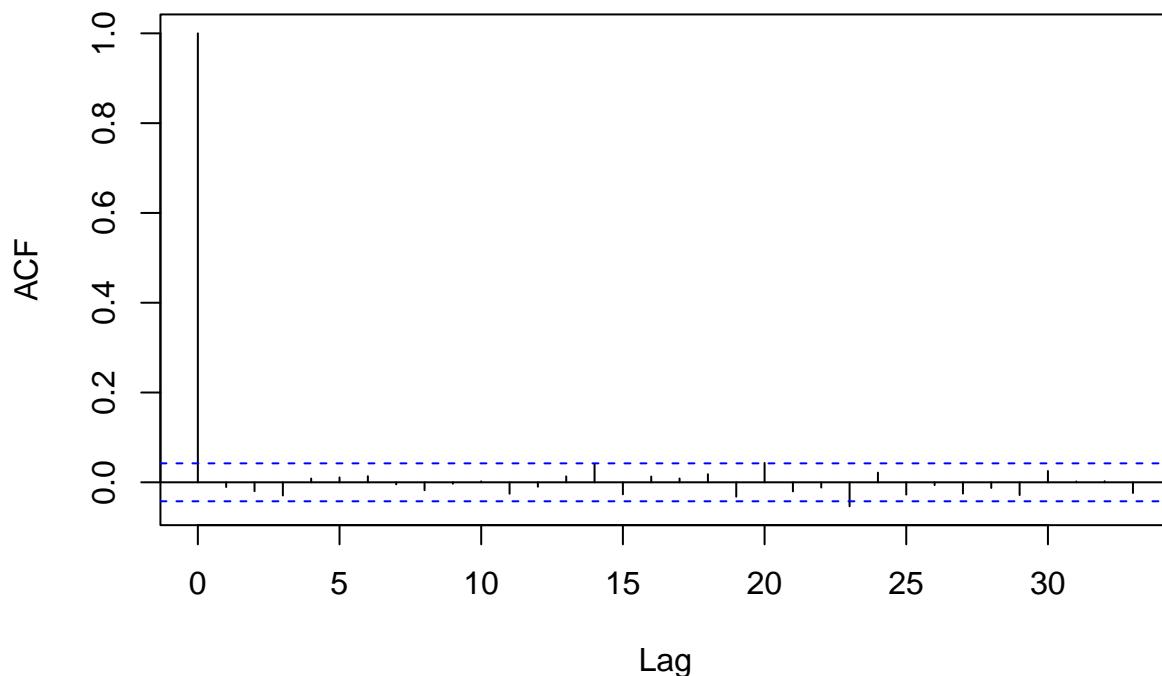


## Added-Variable Plots



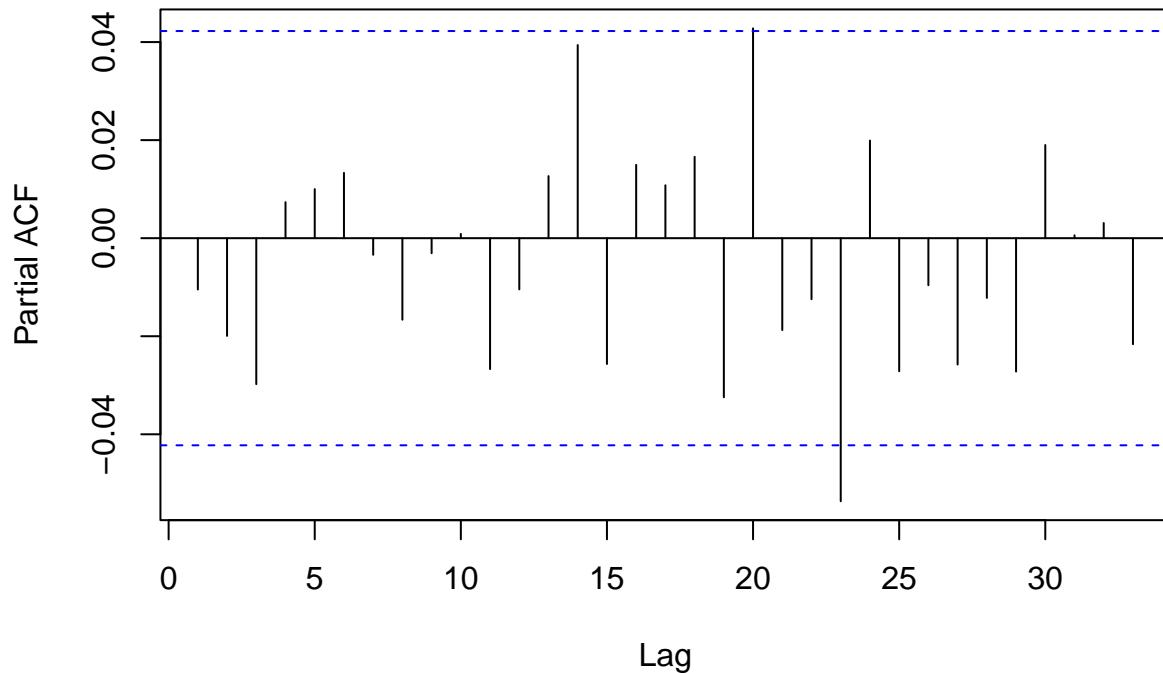
```
#(2) Independence:  
  
residuals <- resid(m_full)  
acf(residuals, main = "Autocorrelation Function of Residuals")
```

## Autocorrelation Function of Residuals

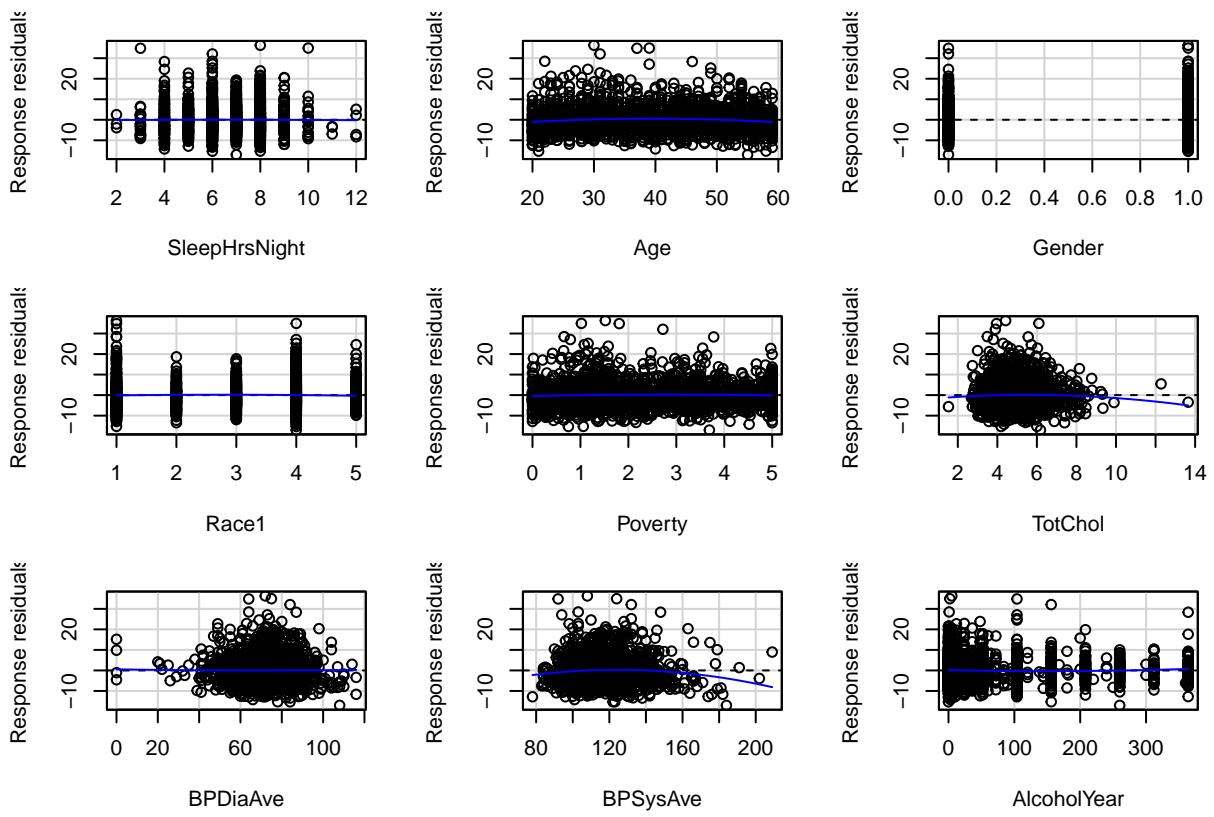


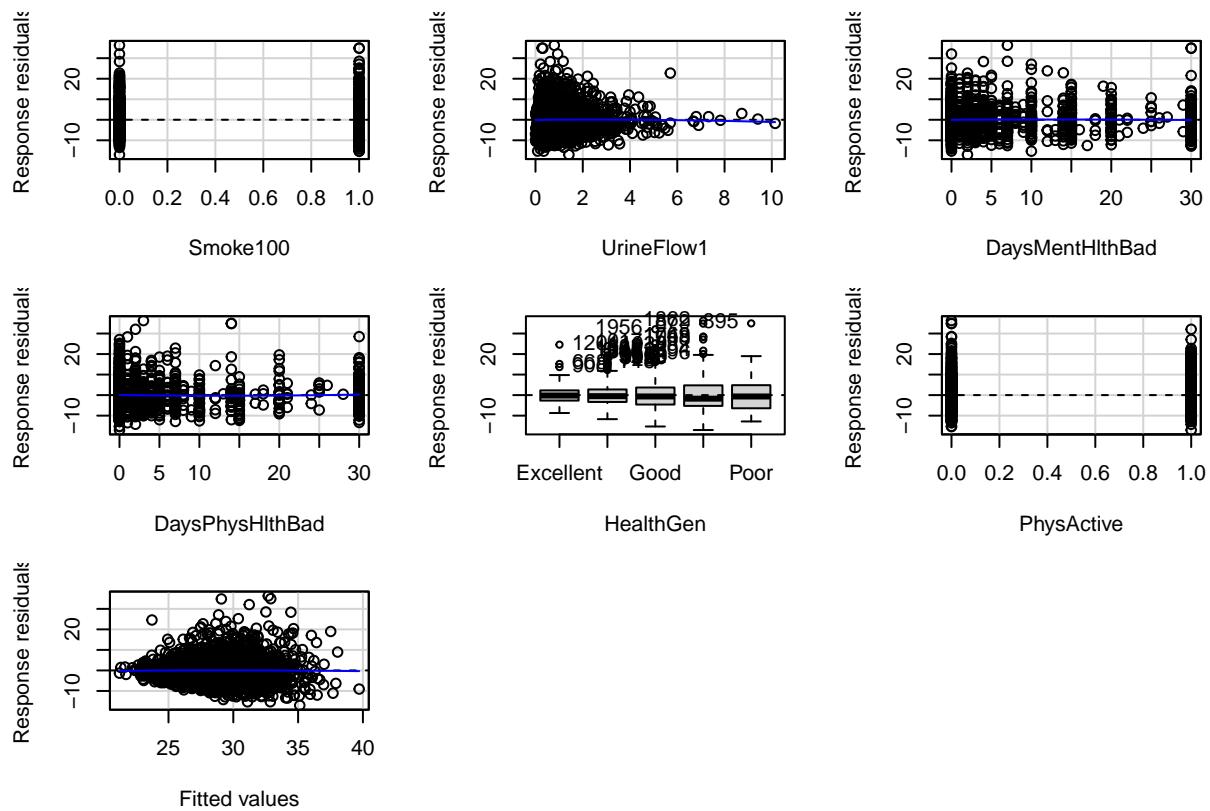
```
pacf(residuals, main = "Partial Autocorrelation Function of Residuals")
```

## Partial Autocorrelation Function of Residuals



```
#(3)E: constant var: residuals-fitted values; transform for variance-stable... (total: 4 solutions)
car:::residualPlots(m_full, type = "response")
```

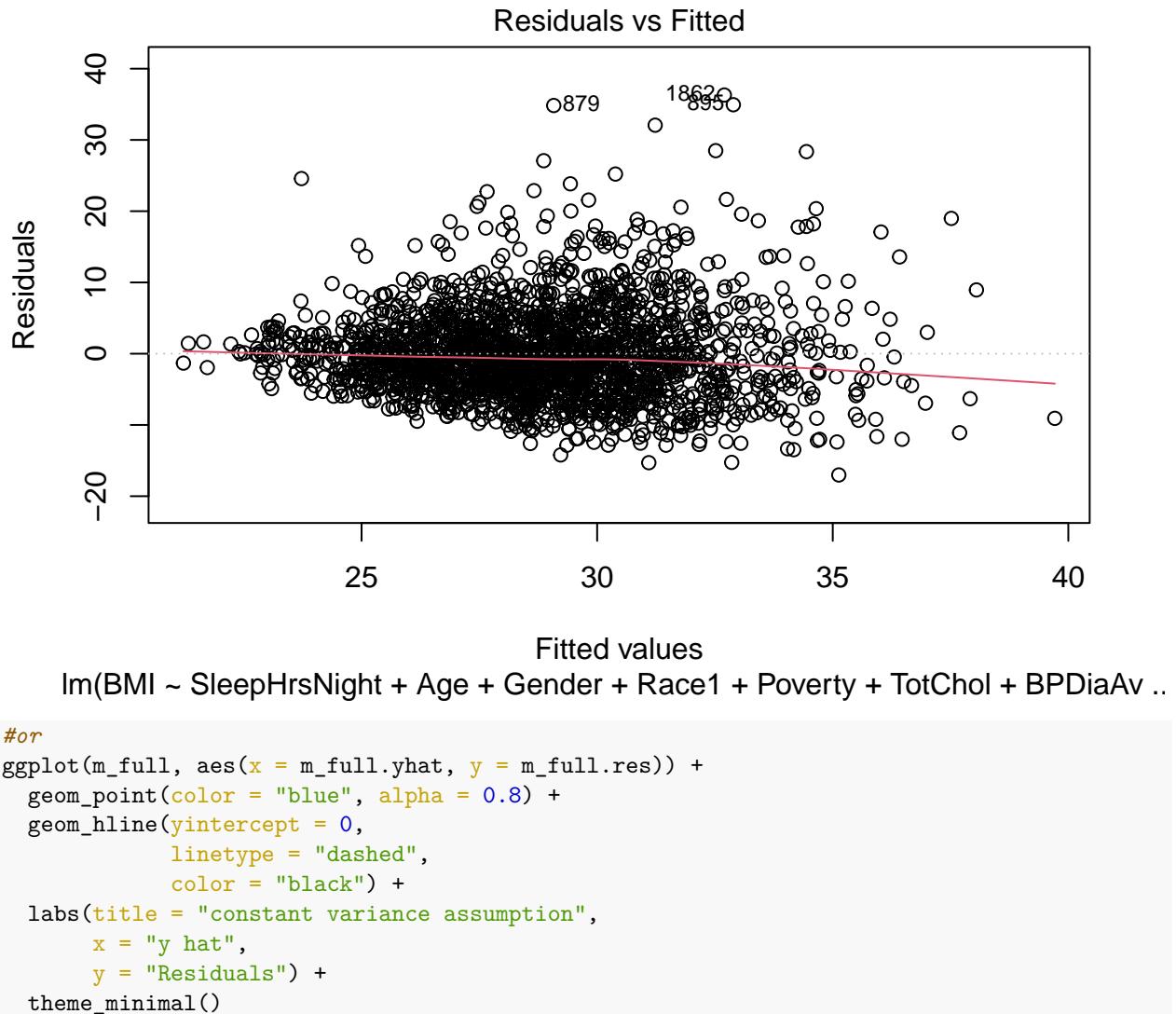




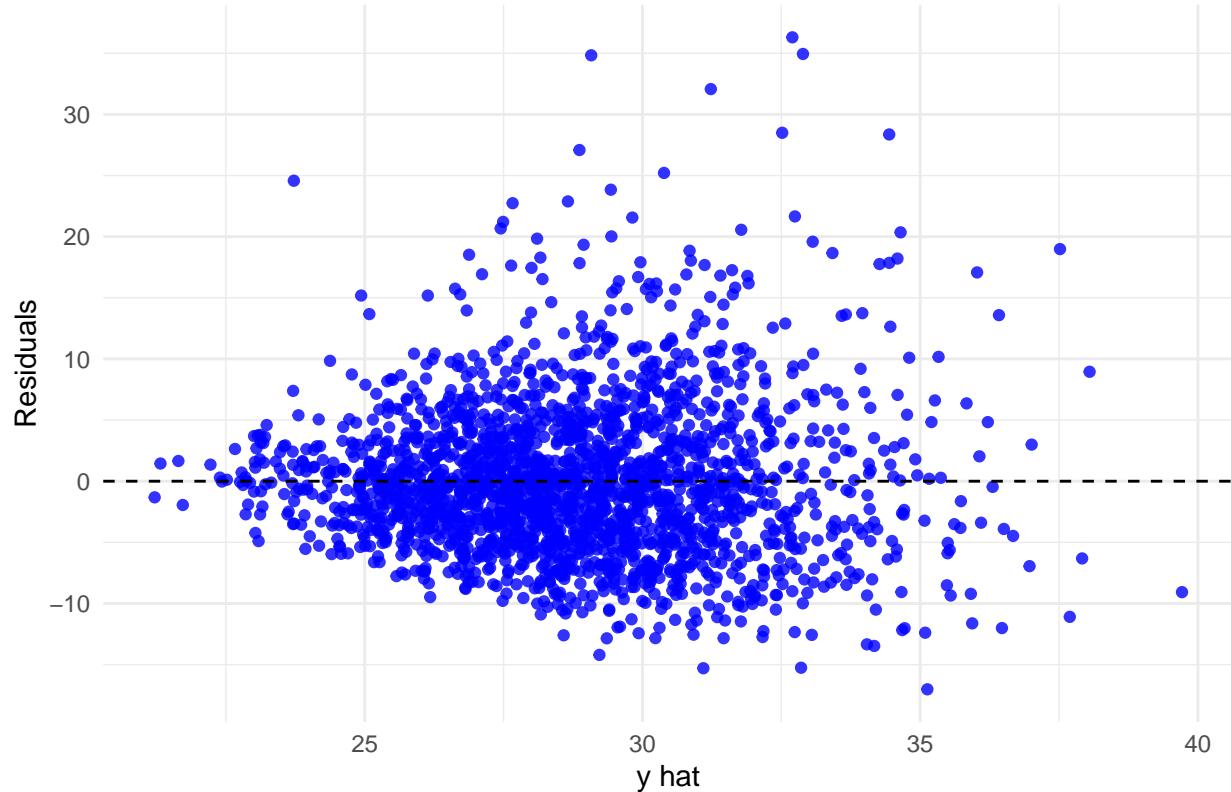
```

##                                     Test stat Pr(>|Test stat|)
## SleepHrsNight          -0.1682      0.8664592
## Age                     -3.6818      0.0002374 ***
## Gender                  0.3790      0.7047535
## Race1                   -0.9121      0.3618251
## Poverty                 -1.4371      0.1508401
## TotChol                 -1.3948      0.1632108
## BPDiaAve                0.2900      0.7718192
## BPSysAve                -3.6373      0.0002820 ***
## AlcoholYear              1.7583      0.0788482 .
## Smoke100                 0.6279      0.5301459
## UrineFlow1               -0.3979      0.6907472
## DaysMentHlthBad         -0.4167      0.6769121
## DaysPhysHlthBad          0.9004      0.3680075
## HealthGen
## PhysActive              -0.0387      0.9691385
## Tukey test                -0.3128      0.7544028
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
plot(m_full, which = 1)

```



## constant variance assumption



```
#conclusion: the constant variance assumption is basically not violated. The spread of the residuals appears roughly constant across the range of y-hat.

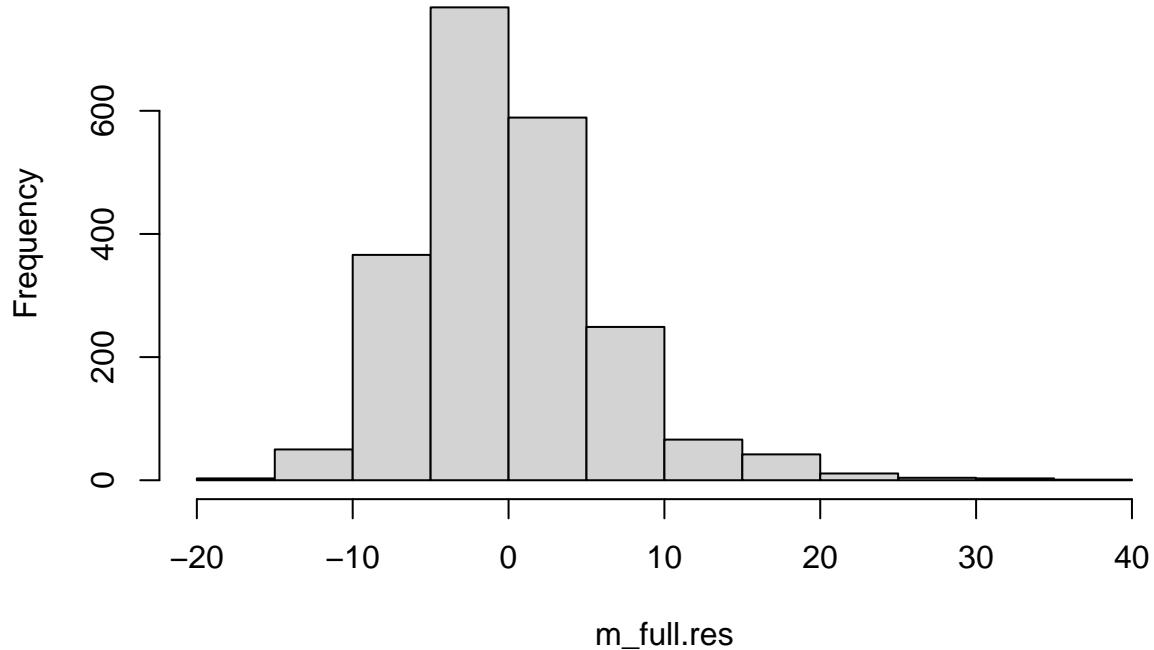
#(4)Normality: residuals freq - residuals (4 plots: his, box, Q-Q, shapiro); transform
#exam quartiles of the residuals
Hmisc::describe(m_full.res)

## m_full.res
##      n    missing   distinct      Info      Mean       Gmd      .05
##     2152        0     2152        1 -1.446e-16    6.685 -8.5512
##     .10        .25     .50        .75        .90       .95
##    -7.1412    -4.0587   -0.6485     3.1655     7.5311    10.6716
##
## lowest : -17.01907 -15.29660 -15.25576 -14.20568 -13.47199
## highest:  28.49374  32.06884  34.83171  34.94008  36.30097
Hmisc::describe(m_full.res)$counts[c(".25", ".50", ".75")] #not symmetric

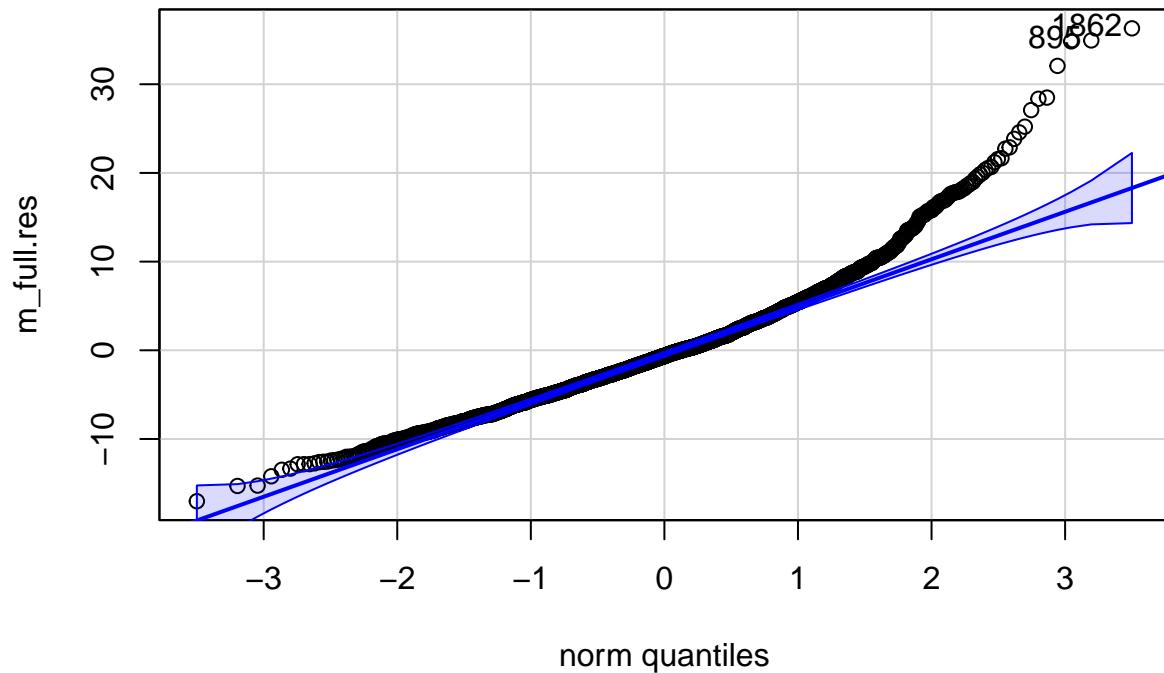
##      .25      .50      .75
## "-4.0587" "-0.6485" " 3.1655"

#histogram
par(mfrow = c(1, 1))
hist(m_full.res, breaks = 15)
```

### Histogram of m\_full.res



```
# Q-Q plot
qq.m_full.res = car::qqPlot(m_full.res)
```

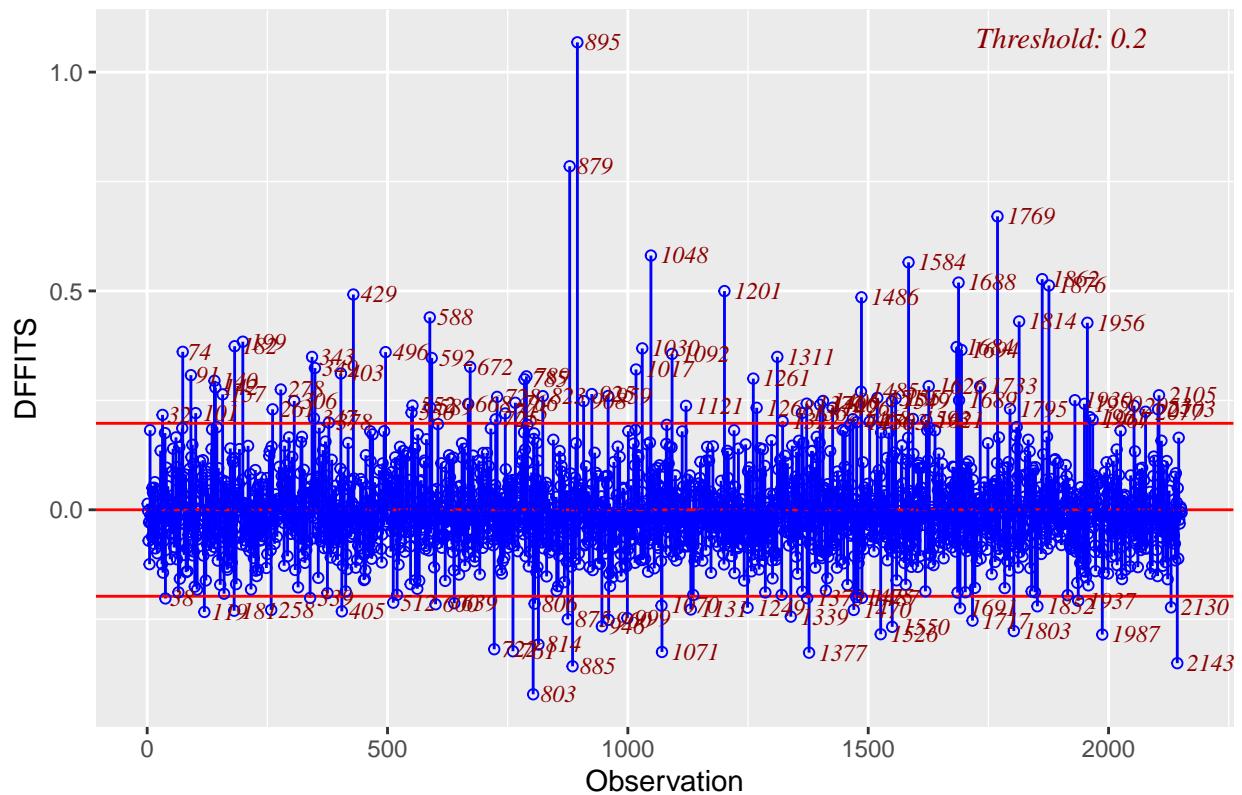


```
m_full.res[qq.m_full.res]

##      1862      895
## 36.30097 34.94008

##### influential observations #####
influence2 = data.frame(
  Residual = resid(m_full),
  Rstudent = rstudent(m_full),
  HatDiagH = hat(model.matrix(m_full)),
  CovRatio = covratio(m_full),
  DFFITS = dffits(m_full),
  COOKsDistance = cooks.distance(m_full)
)
# DFFITS
ols_plot_dffits(m_full)
```

## Influence Diagnostics for BMI



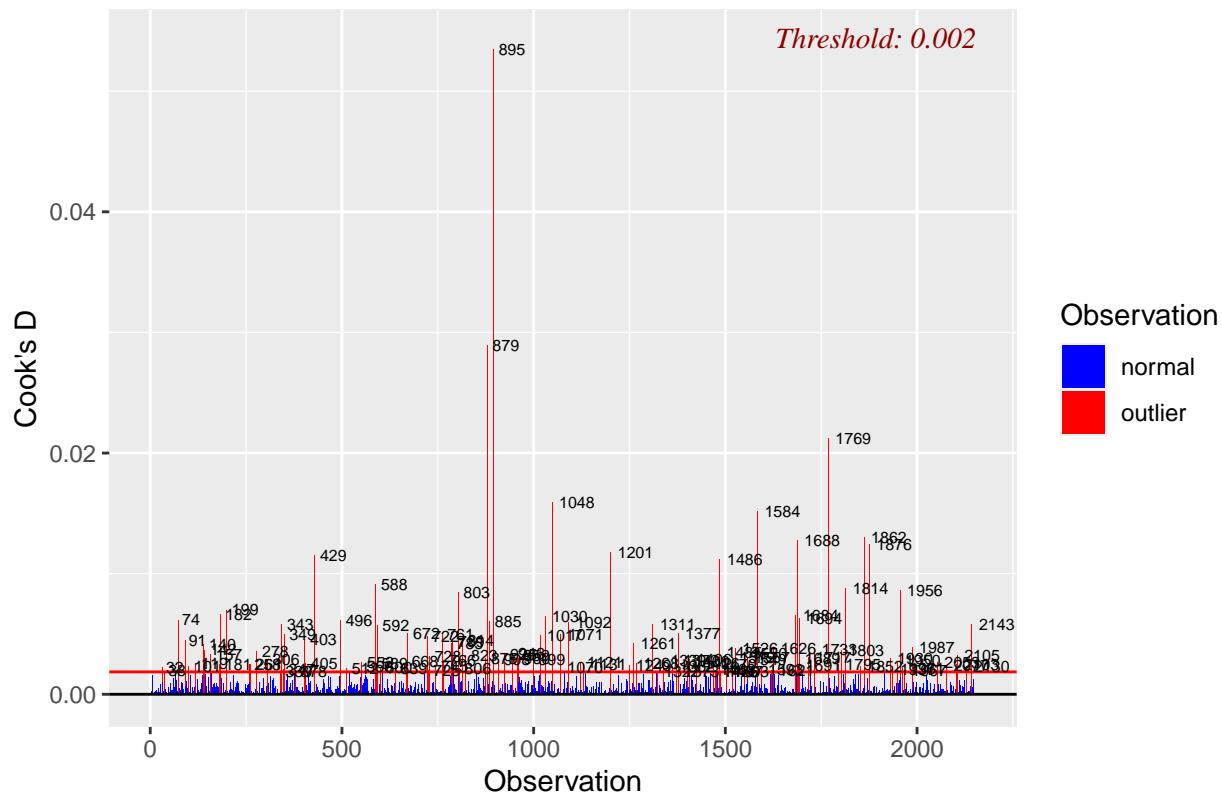
```
influence2[order(abs(influence2$DFFITS), decreasing = T), ] %>% head()
```

```
##      Residual Rstudent   HatDiagH CovRatio     DFFITS COOKsDistance
## 895  34.94008 5.736619 0.033498837 0.7572647 1.0679961  0.05351373
## 879  34.83171 5.674807 0.018766799 0.7510219 0.7848020  0.02890599
## 1769 28.35783 4.612895 0.020681924 0.8369471 0.6703585  0.02119736
## 1048 28.49374 4.622993 0.015543867 0.8318213 0.5809043  0.01591687
## 1584 18.98322 3.097879 0.032232760 0.9495341 0.5653635  0.01515960
## 1862 36.30097 5.885164 0.007952567 0.7255062 0.5269216  0.01301582
```

#From the plot above, we can see 2 observations with the largest (magnitude) of DFFITS, observation 879

```
# Cook's D
ols_plot_cooksd_bar(m_full)
```

## Cook's D Bar Plot



```
influence2[order(influence2$COOKsDistance, decreasing = T), ] %>% head()
```

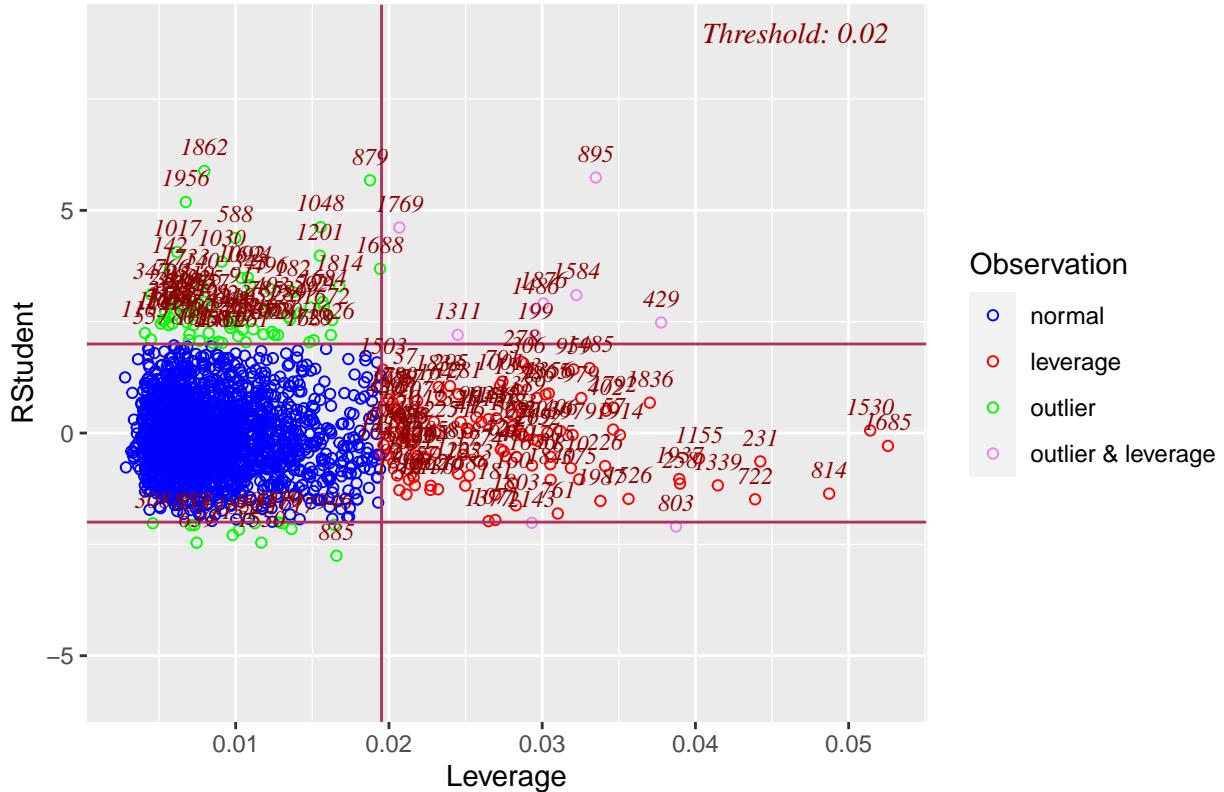
```
##      Residual Rstudent    HatDiagH CovRatio   DFFITS COOKsDistance
## 895  34.94008 5.736619 0.033498837 0.7572647 1.0679961  0.05351373
## 879  34.83171 5.674807 0.018766799 0.7510219 0.7848020  0.02890599
## 1769 28.35783 4.612895 0.020681924 0.8369471 0.6703585  0.02119736
## 1048 28.49374 4.622993 0.015543867 0.8318213 0.5809043  0.01591687
## 1584 18.98322 3.097879 0.032232760 0.9495341 0.5653635  0.01515960
## 1862 36.30097 5.885164 0.007952567 0.7255062 0.5269216  0.01301582
```

#From the plot above, we can see that the observation 879 and 1769 also have the largest Cook's Distance

#leverage

```
ols_plot_resid_lev(m_full)
```

# Outlier and Leverage Diagnostics for BMI



*#high leverage*

```
influence2[order(influence2$HatDiagH, decreasing = T), ] %>% head()
```

```

##      Residual   Rstudent   HatDiagH CovRatio      DFFITS COOKsDistance
## 1685 -1.7567114 -0.28909280 0.05256090 1.065054 -0.06809152 2.208785e-04
## 1530  0.3556433  0.05848965 0.05140746 1.064600  0.01361609 8.832597e-06
## 814   -8.2792096 -1.36028339 0.04872946 1.042455 -0.30787411 4.511841e-03
## 231  -3.8895732 -0.63734177 0.04423767 1.052426 -0.13711771 8.955479e-04
## 722  -9.0732124 -1.48709041 0.04389401 1.033501 -0.31863022 4.831787e-03
## 1339 -7.1745361 -1.17417737 0.04146227 1.039370 -0.24420562 2.839323e-03

```

*#high studentized residual*

```
influence2[order(influence2$Rstudent, decreasing = T), ] %>% head()
```

##	Residual	Rstudent	HatDiagH	CovRatio	DFFITS	COOKsDistance
## 1862	36.30097	5.885164	0.007952567	0.7255062	0.5269216	0.013015818
## 895	34.94008	5.736619	0.033498837	0.7572647	1.0679961	0.053513733
## 879	34.83171	5.674807	0.018766799	0.7510219	0.7848020	0.028905986
## 1956	32.06884	5.186586	0.006742466	0.7811915	0.4273267	0.008591205
## 1048	28.49374	4.622993	0.015543867	0.8318213	0.5809043	0.015916873
## 1769	28.35783	4.612895	0.020681924	0.8369471	0.6703585	0.021197359

#From the plot above, we can see that the observation 1155 has the largest leverage (0.0368). Observati

#From the plot above, there are 7 observations (1048, 1769, 1684, 74, 72, 1689, 1311) located in the intervals [1048, 1769], [1684, 74], [72, 1689] and [1311, 1311]. The thresholds for the externally studentized residual are -2 and 2, i.e. 2 in magnitude. The threshold for the Cook's distance is 1.

```

#From (DFFITS), observations 879 and 1769 appear to be influential observations. Observation 1155 has e

rm2.df3 = df3[-c(879, 1769, 1155, 1048, 1769, 1684, 74, 72, 1689, 1311), ]
rm.m_full = lm(
  BMI ~ SleepHrsNight + Age + Gender + Race1 + TotChol + BPDiaAve + BPSysAve + AlcoholYear + Smoke100 +
  DaysPhysHlthBad + PhysActive,
  rm2.df3
)
## Before removing these observations, the estimated coefficients are:
summary(m_full)$coef

##                               Estimate Std. Error   t value Pr(>|t|)
## (Intercept)            21.349305448 2.996916146 7.1237580 1.430603e-12
## SleepHrsNight          -0.542616261 0.378593774 -1.4332414 1.519356e-01
## Age                   -0.105135734 0.062782895 -1.6745920 9.416104e-02
## Gender                 3.768696209 1.435160571 2.6259753 8.701945e-03
## Race1                  -0.503221762 0.121963771 -4.1259938 3.833266e-05
## Poverty                0.072728633 0.090967555 0.7995008 4.240892e-01
## TotChol                 0.014772748 0.135905287 0.1086988 9.134516e-01
## BPDiaAve               0.058709170 0.013701124 4.2849894 1.908793e-05
## BPSysAve                0.054449503 0.011792323 4.6173687 4.117883e-06
## AlcoholYear              -0.008395832 0.001513018 -5.5490621 3.229358e-08
## Smoke100                -0.802999282 0.286852351 -2.7993470 5.166730e-03
## UrineFlow1              -0.102217843 0.142434820 -0.7176465 4.730540e-01
## DaysMentHlthBad         -0.030249912 0.017961509 -1.6841521 9.229873e-02
## DaysPhysHlthBad          0.015141809 0.020942592 0.7230150 4.697500e-01
## HealthGenVgood           1.928282830 0.470248557 4.1005609 4.276195e-05
## HealthGenGood             3.559315708 0.468009737 7.6052172 4.238019e-14
## HealthGenFair             5.299570135 0.575060245 9.2156781 7.192101e-20
## HealthGenPoor              7.640141955 1.077494210 7.0906571 1.808115e-12
## PhysActive                 -0.837417930 0.294615309 -2.8424115 4.519990e-03
## SleepHrsNight:Age          0.017091879 0.009024443 1.8939539 5.836644e-02
## SleepHrsNight:Gender        -0.477031856 0.206903401 -2.3055776 2.122985e-02

## After removing these observations, the estimated coefficients are:
summary(rm.m_full)$coef

##                               Estimate Std. Error   t value Pr(>|t|)
## (Intercept)            20.35681885 1.591402458 12.7917478 3.758113e-36
## SleepHrsNight          -0.16992002 0.105487052 -1.6108140 1.073684e-01
## Age                   0.01603432 0.013256274 1.2095650 2.265800e-01
## Gender                 0.38567462 0.286107176 1.3480075 1.777992e-01
## Race1                  -0.49166686 0.120767754 -4.0711767 4.848398e-05
## TotChol                 0.09239091 0.138702544 0.6661082 5.054140e-01
## BPDiaAve               0.05080608 0.013773193 3.6887658 2.309889e-04
## BPSysAve                0.06676170 0.011857120 5.6305153 2.034003e-08
## AlcoholYear              -0.01071753 0.001509265 -7.1011608 1.678800e-12
## Smoke100                -0.57220143 0.282360003 -2.0264961 4.283829e-02
## DaysPhysHlthBad          0.04676614 0.019585316 2.3878164 1.703545e-02
## PhysActive                -1.18819428 0.286816208 -4.1427027 3.566379e-05

#### change percent
abs((rm.m_full$coefficients - m_full$coefficients) / (m_full$coefficients) * 100)

## Warning in rm.m_full$coefficients - m_full$coefficients: longer object length

```

```

## is not a multiple of shorter object length

##          (Intercept)      SleepHrsNight        Age
##            4.648800       68.685049    115.251070
##             Gender           Race1        Poverty
##            89.766365       2.296184    27.035122
##             TotChol         BPDiaAve     BPSysAve
##            243.917613      13.715961   119.683431
##            AlcoholYear      Smoke100      UrineFlow1
##            6715.303845      105.823933  1062.413764
##            DaysMentHlthBad  DaysPhysHlthBad HealthGenVgood
##            67395.464736      1222.191001  99.168466
##            HealthGenGood   HealthGenFair  HealthGenPoor
##            89.164360        109.277486   98.790717
##            PhysActive      SleepHrsNight:Age SleepHrsNight:Gender
##            106.066993        290.604779   97.753288

#The estimated regression coefficients doesn't change slightly after removing these observations. 5 of

##### multicollinearity #####
#Pearson correlations
var2 = c(
  "BMI",
  "SleepHrsNight",
  "Age",
  "Gender",
  "Race1",
  "TotChol",
  "BPDiaAve",
  "BPSysAve",
  "AlcoholYear",
  "Smoke100",
  "DaysPhysHlthBad",
  "PhysActive"
)
newData2 = df3[, var2]
library("corrplot")

## corrplot 0.92 loaded
par(mfrow = c(1, 2))
cormat2 = cor(as.matrix(newData2[, -c(1)]), method = "pearson")
p.mat2 = cor.mtest(as.matrix(newData2[, -c(1)]))$p
corrplot(
  cormat2,
  method = "color",
  type = "upper",
  number.cex = 1,
  diag = FALSE,
  addCoef.col = "black",
  tl.col = "black",
  tl.srt = 90,
  p.mat = p.mat2,
  sig.level = 0.05,
  insig = "blank",
)

```

```

#None of the covariates seem strongly correlated. There is no evidence of collinearity from the pair-wis

# collinearity diagnostics (VIF)
car::vif(m_full)

## there are higher-order terms (interactions) in this model
## consider setting type = 'predictor'; see ?vif

##          GVIF Df GVIF^(1/(2*Df))
## SleepHrsNight    13.583457  1     3.685574
## Age             27.952318  1     5.286995
## Gender          28.340488  1     5.323579
## Race1           1.092306  1     1.045135
## Poverty          1.307058  1     1.143266
## TotChol          1.127465  1     1.061822
## BPDiaAve         1.453678  1     1.205686
## BPSysAve          1.565996  1     1.251398
## AlcoholYear       1.122185  1     1.059332
## Smoke100          1.130221  1     1.063119
## UrineFlow1         1.045986  1     1.022734
## DaysMentHlthBad   1.146283  1     1.070646
## DaysPhysHlthBad   1.251072  1     1.118513
## HealthGen          1.447335  4     1.047300
## PhysActive          1.168763  1     1.081093
## SleepHrsNight:Age   37.541993  1     6.127152
## SleepHrsNight:Gender 29.940850  1     5.471823

#From the VIF values in the output above, once again we do not observe any potential collinearity issue

##### using log-transformed BMI #####
# log BMI
df3$logBMI = log(df3$BMI + 1)
m_full.log = lm(
  logBMI ~ SleepHrsNight + Age + Gender + Race1 + TotChol + BPDiaAve + BPSysAve + AlcoholYear + Smoke100 +
    DaysPhysHlthBad + PhysActive,
  df3
)
p21.log = ols_plot_resid_lev(m_full.log)
p22.log = ols_plot_cooksd_bar(m_full.log)
library(gridExtra)

##
## Attaching package: 'gridExtra'
## The following object is masked from 'package:dplyr':
##   combine
p23.log = ggplot(m_full.log, aes(sample = rstudent(m_full.log))) + geom_qq() + stat_qq_line() +
  labs(title = "Q-Q plot")
p24.log = ggplot() + geom_point(aes(y = rstudent(m_full.log), x = m_full.log$fitted.values)) + labs(x =
  geom_hline(yintercept = c(-2, 2))
grid.arrange(p23.log, p24.log, nrow = 2)

```

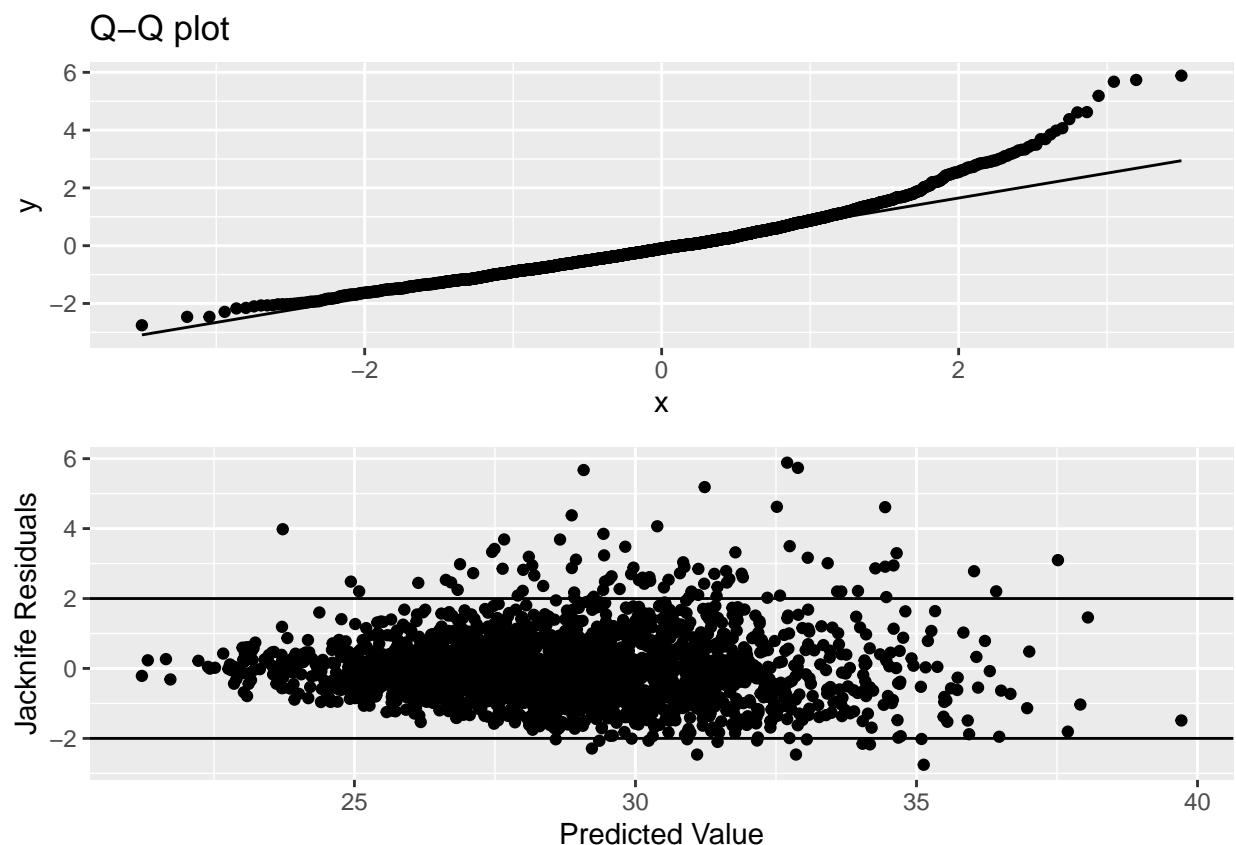
```

p23 = ggplot(m_full, aes(sample = rstudent(m_full))) + geom_qq() + stat_qq_line() +
  labs(title = "Q-Q plot")
p24 = ggplot() + geom_point(aes(y = rstudent(m_full), x = m_full$fitted.values)) + labs(x = "Predicted Value")
  geom_hline(yintercept = c(-2, 2))
grid.arrange(p23, p24, nrow = 2)

m_full.3.yhat = m_full.log$fitted.values
m_full.3.res = m_full.log$residuals
m_full.3.h = hatvalues(m_full.log)
m_full.3.r = rstandard(m_full.log)
m_full.3.rr = rstudent(m_full.log)

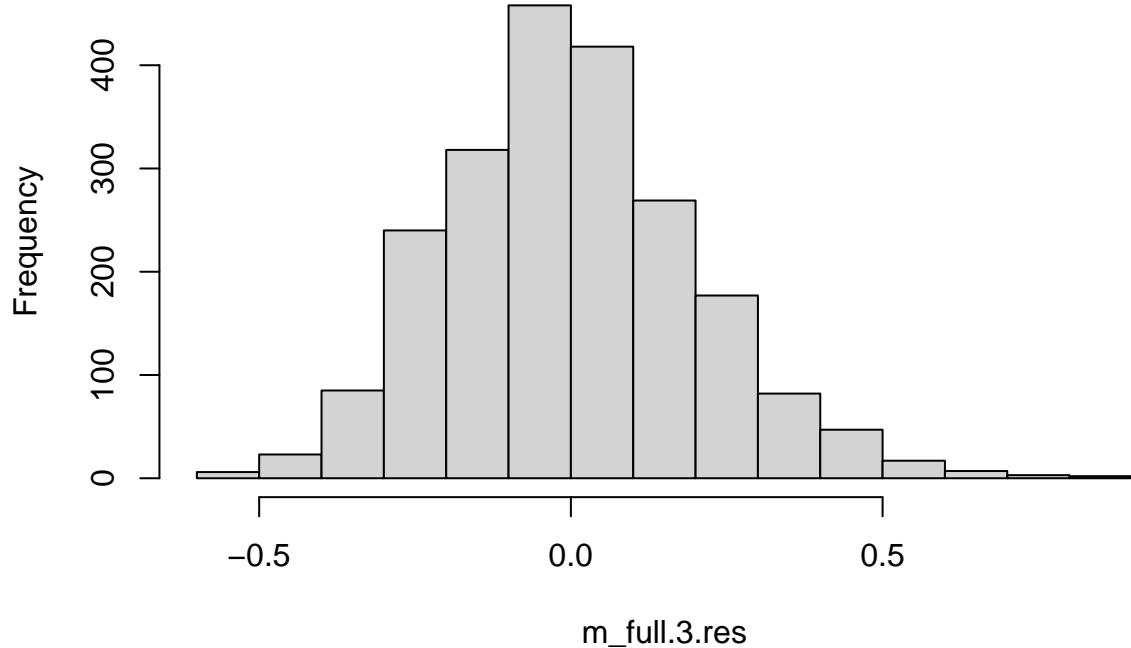
par(mfrow = c(1, 1))

```

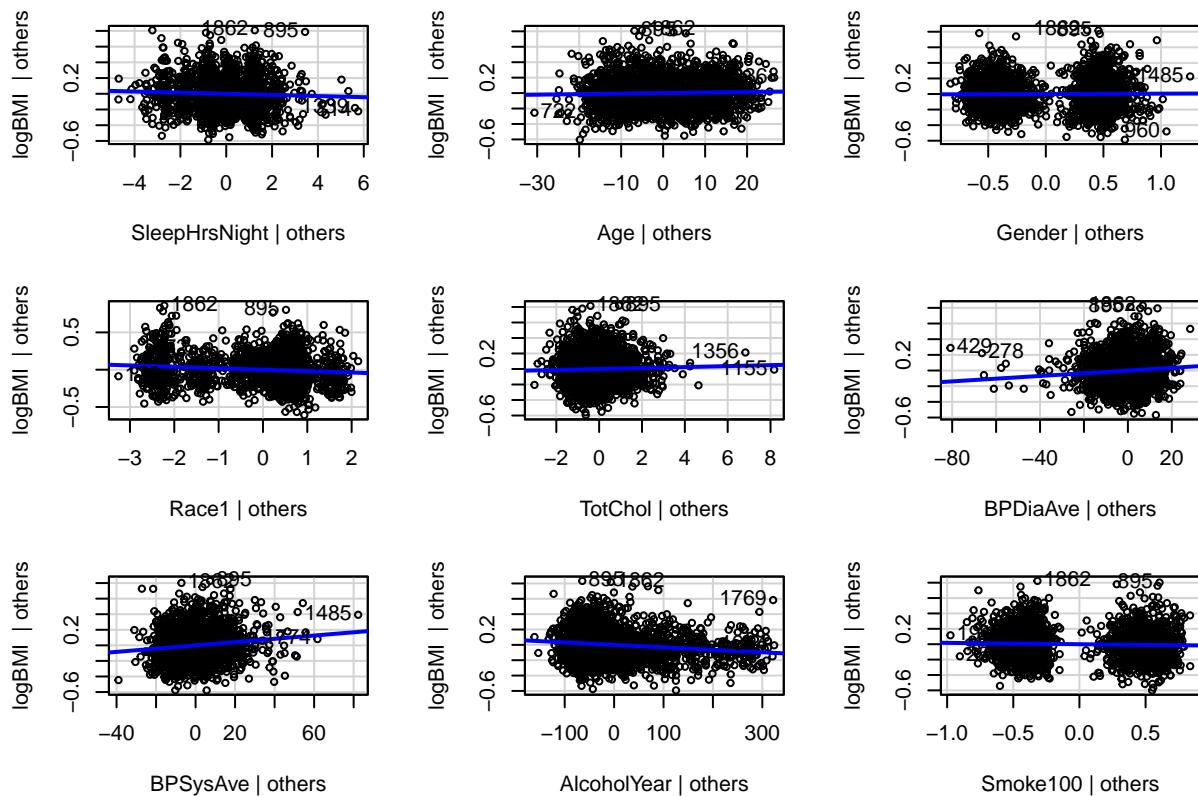


```
hist(m_full.3.res, breaks = 15)
```

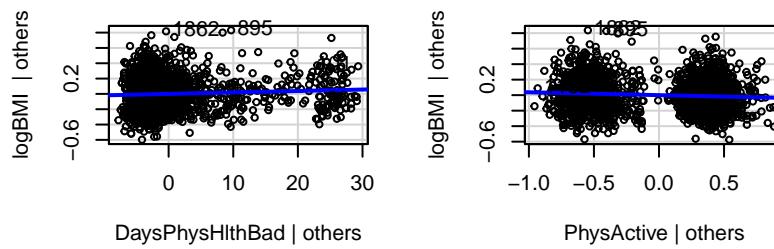
**Histogram of m\_full.3.res**



```
car::avPlots(m_full.log)
```



## Added-Variable Plots



```
#After looking at residuals from models using the log-transformed (natural log scale) BMI adjusted for other variables, I decided to run a model with just the variables that had VIF values greater than 10. These variables were SleepHrsNight, Age, Gender, Race1, and TotChol. I ran a model with these variables and found that the VIF values for all of them were less than 10. This suggests that there is no multicollinearity between these variables.

#collinearity diagnostics

car::vif(m_full.log)

##      SleepHrsNight          Age        Gender       Race1      TotChol
##            1.035419     1.223319    1.106167   1.045711   1.122357
##      BPDiaAve      BPSysAve    AlcoholYear Smoke100 DaysPhysHlthBad
##            1.447702     1.542999    1.091195   1.078534    1.057582
##      PhysActive
##            1.093222

#The VIF from both the models are the same. None of the VIF values are greater than 10. So there are no problems with multicollinearity.
```