Project Title

A STAT 139 Final Project

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Due December 13, 2017

Abstract

Introduction

- Obesity is an exerbating problem in the US.
- Explore the association of 21 different factors with bmi, 13 of which are behavior-related factors such as the typical number of hours sleep per night

Methods

- Data description
- data source is NHANES 2013-2014
- Variables of interest
- Only consider adults of age 20 or above
- Data preprocessing & assumptions
- Merge data by participant sequence number
- Exclude don't know/refused/missing values — discuss implications in limitations
- Perform EDA
- Fit regression models
- Check assumptions

Results

Exploratory Data Analysis

Limitations

Conclusions

Appendix

Appendix I: Data preprocessing

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
```

```
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
##         gender            age           race            edu       marriage
##              0              0              0              0              0
##        famsize      famincome    alcohol12yr     alcoholfrq        grocery
##              0              0              0              0              0
##         eatout       delivery           milk  meals_nothome meals_fastfood
##              0              0              0              0              0
##      depressed  sleep_trouble       activity         tv_hrs       sleep_hr
##              0              0              0              0              0
##          smoke            bmi      bmi_class
##              0              0              0
```

```
##         gender            age           race            edu       marriage
##       "factor"      "integer"       "factor"       "factor"       "factor"
##        famsize      famincome    alcohol12yr     alcoholfrq        grocery
##      "integer"       "factor"       "factor"      "integer"      "integer"
##         eatout       delivery           milk  meals_nothome meals_fastfood
##      "integer"      "integer"       "factor"      "integer"      "integer"
##      depressed  sleep_trouble       activity         tv_hrs       sleep_hr
##       "factor"       "factor"       "factor"       "factor"      "integer"
##          smoke            bmi      bmi_class
##       "factor"      "numeric"    "character"
```

Appendix II: Exploratory Data Analysis

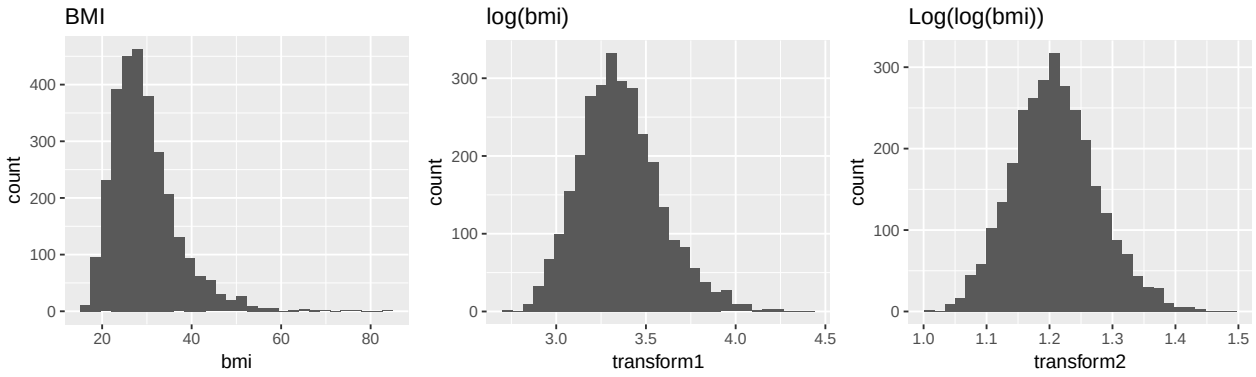
Response Variable (bmi)

```
## Loading required package: gridExtra
```

```
##
## Attaching package: 'gridExtra'
```

```
## The following object is masked from 'package:dplyr':
##
##     combine
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



Predictor Variables

Numeric Variables

Distribtuion of numeric variables

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
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```

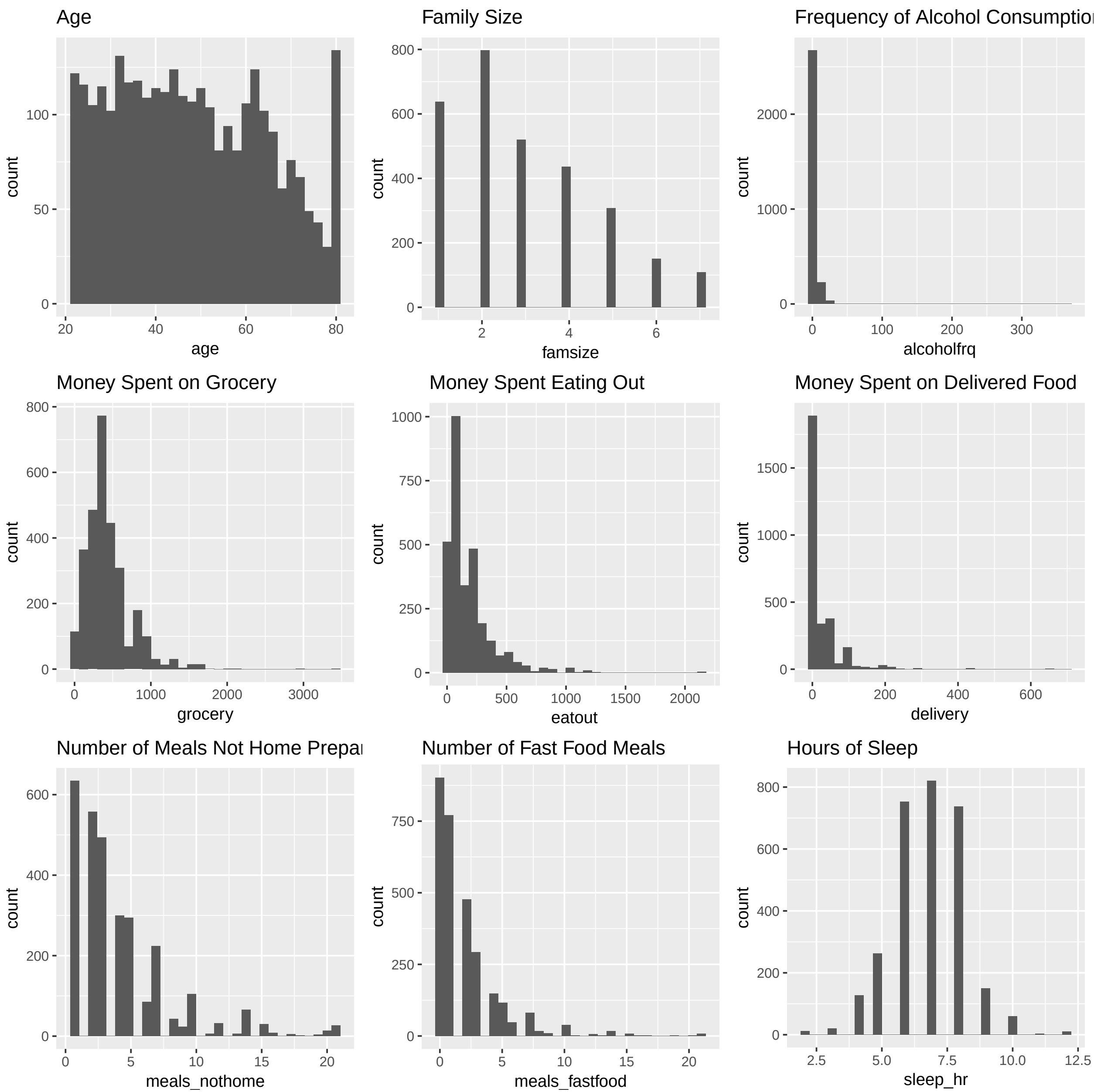


```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
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```
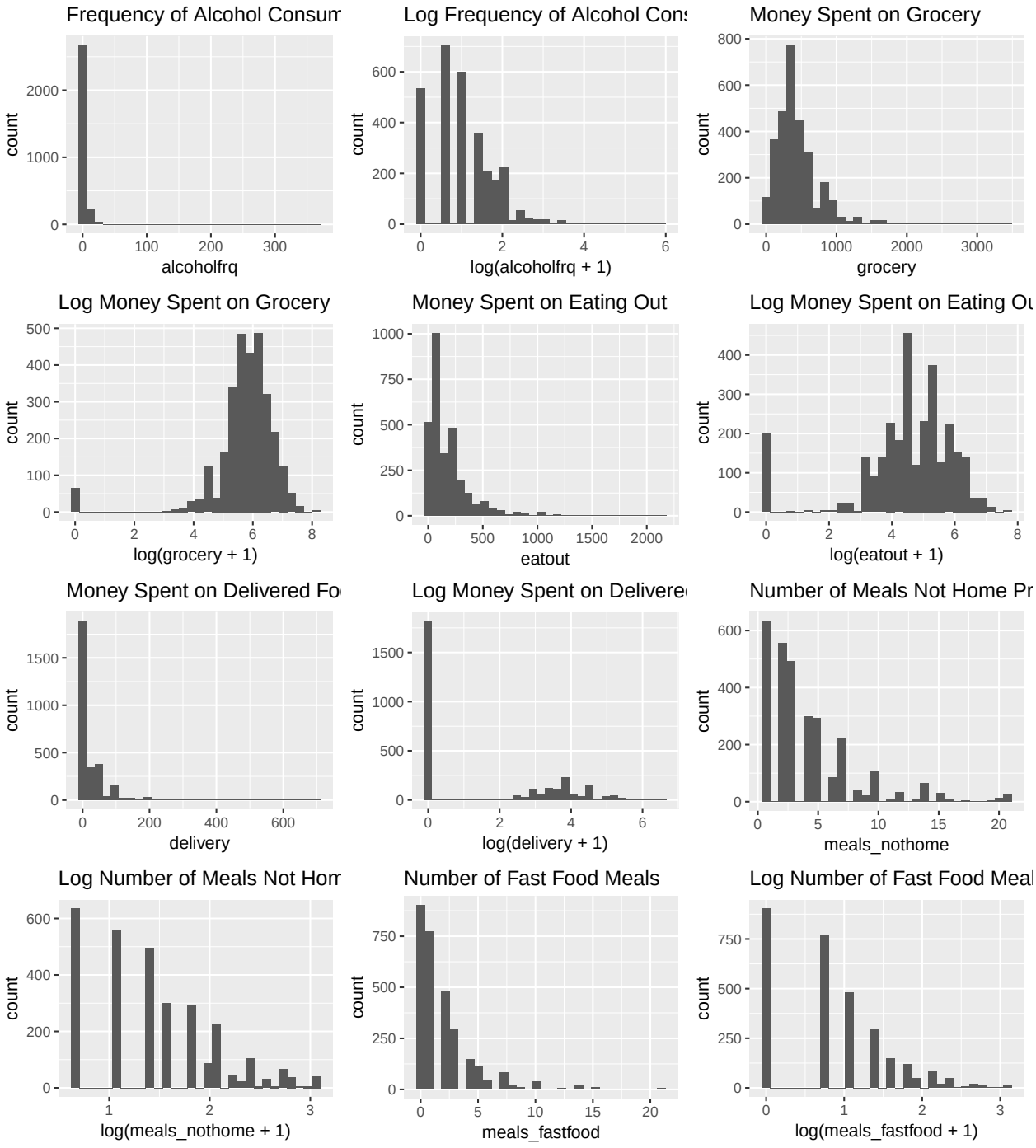
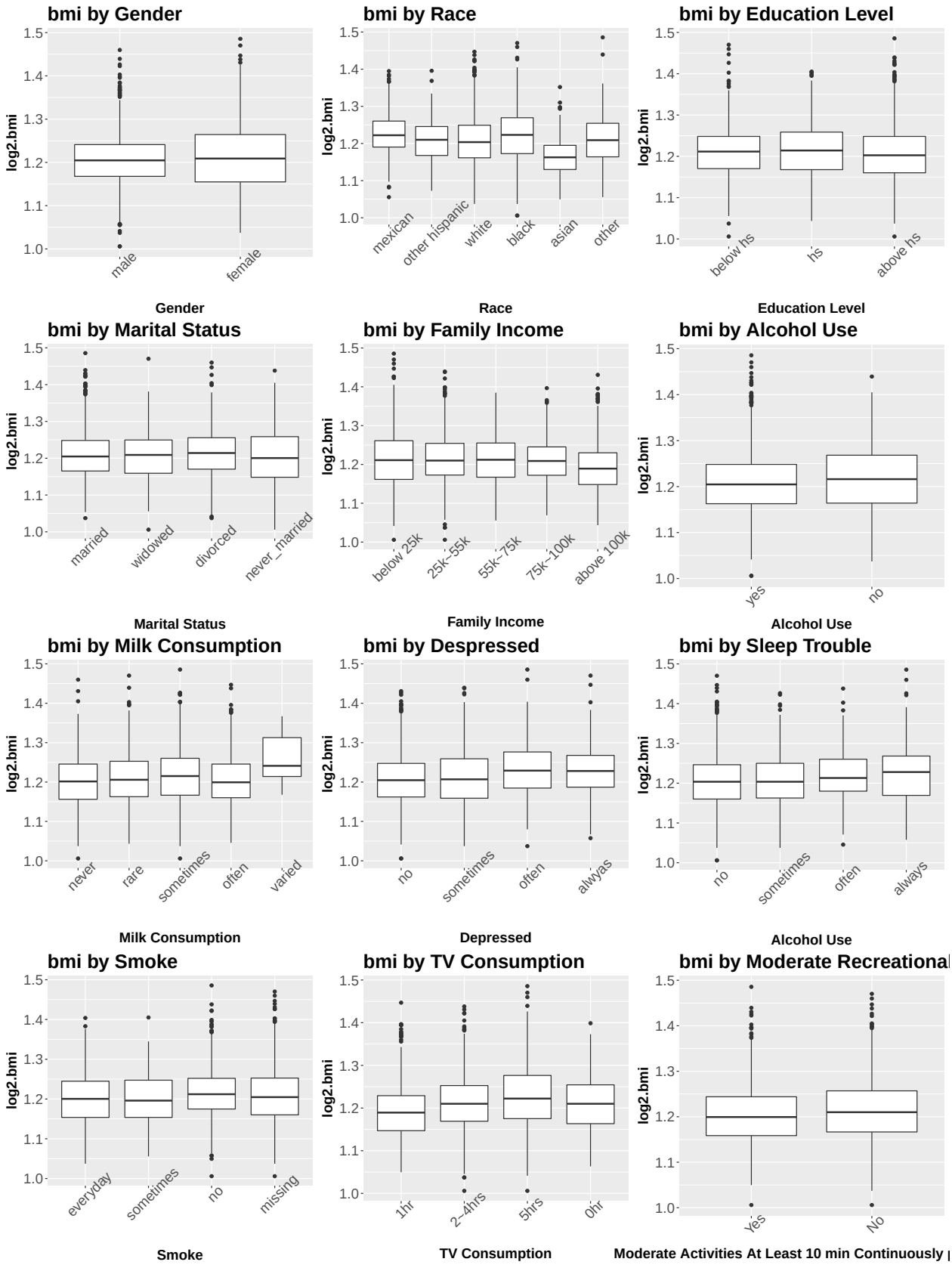
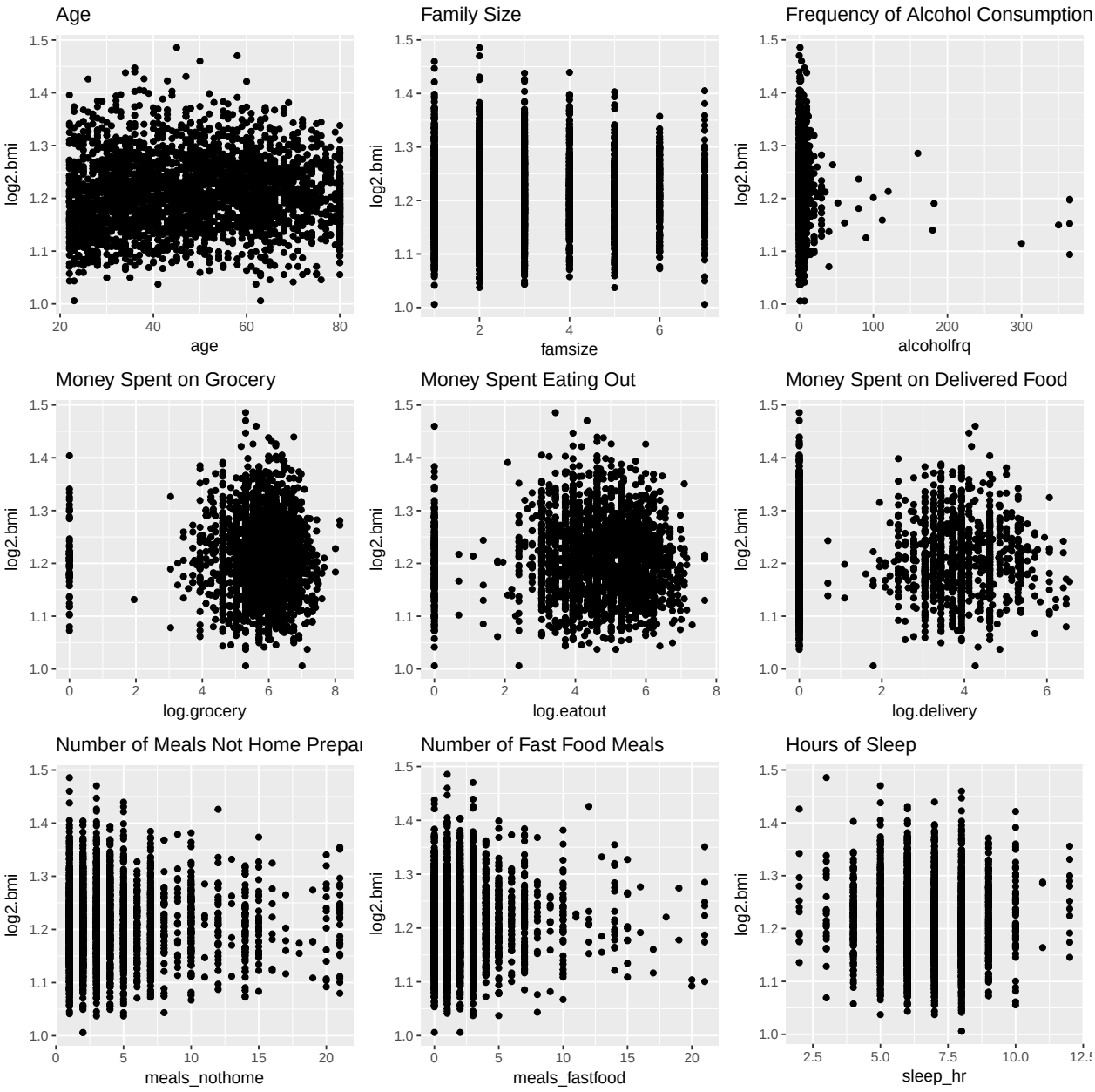



Categorical Variables



Response vs. numeric distribution



Models

```
#df_adult
check_assumptions <- function(model){
  hist(resid(model),col="grey",breaks=15)
  plot(resid(model)~fitted(model),cex=1.5)
  abline(h=0,lwd=2)
}
```

```
library(Matrix)
library(glmnet)
```

```
## Loading required package: foreach
```

```
## Loaded glmnet 2.0-13
```

```
library(plotmo)
```

```
## Loading required package: plotrix
```

```
## Warning: package 'plotrix' was built under R version 3.4.3
```

```
## Loading required package: TeachingDemos
```

```
library(caret)
```

```
## Loading required package: lattice
```

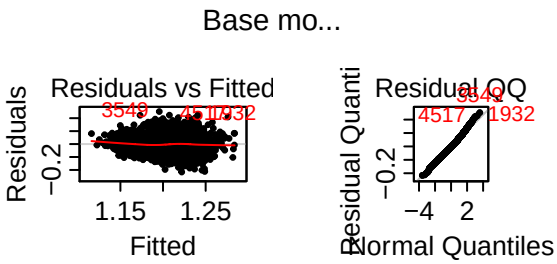
```
## Warning in as.POSIXlt.POSIXct(Sys.time()): unknown timezone 'zone/tz/2017c.
## 1.0/zoneinfo/America/New_York'
```

```
library(lattice)

set.seed(1234)
# define training control
train_control <- trainControl(method="cv", number=5)


#baseline model
model1 = lm(log2.bmi~gender+age+race+edu+marriage+famsize+famincome+alcohol12yr+alcoholfrq+log.groc

base_form = formula(model1)

summary(model1)
```

```
##
## Call:
## lm(formula = log2.bmi ~ gender + age + race + edu + marriage +
##     famsize + famincome + alcohol12yr + alcoholfrq + log.grocery +
##     log.eatout + log.delivery + milk + meals_nothome + meals_fastfood +
##     depressed + sleep_trouble + activity + tv_hrs + sleep_hr +
##     smoke, data = df_adult)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.216033 -0.042926 -0.001571  0.037661  0.251263
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)             1.174e+00  1.244e-02  94.348  < 2e-16 ***
## genderfemale            6.522e-03  2.542e-03   2.566 0.010334 *
```

```
## age                      1.238e-05  9.107e-05   0.136 0.891867
## raceother hispanic      -1.977e-02  5.433e-03  -3.639 0.000279 ***
## racewhite               -1.745e-02  4.121e-03  -4.235 2.36e-05 ***
## raceblack               -6.450e-03  4.615e-03  -1.398 0.162343
## raceasian               -5.589e-02  5.625e-03  -9.936  < 2e-16 ***
## raceother               -1.310e-02  7.660e-03  -1.710 0.087362 .
## eduhs                    6.452e-03  4.083e-03   1.580 0.114175
## eduabove hs              8.396e-03  3.834e-03   2.190 0.028624 *
## marriagewidowed         -7.843e-03  5.771e-03  -1.359 0.174211
## marriagedivorced         1.411e-03  3.712e-03   0.380 0.703971
## marriagenever_married   -6.582e-03  3.657e-03  -1.800 0.072007 .
## famsize                  1.048e-03  8.544e-04   1.227 0.220056
## famincome25k~55k         3.582e-03  3.293e-03   1.088 0.276744
## famincome55k~75k        -1.775e-03  4.446e-03  -0.399 0.689739
## famincome75k~100k       -2.414e-03  4.813e-03  -0.502 0.615958
## famincomeabove 100k     -1.285e-02  4.264e-03  -3.015 0.002594 **
## alcohol12yrno            4.590e-03  3.573e-03   1.285 0.199038
## alcoholfrq              -1.576e-04  6.709e-05  -2.349 0.018895 *
## log.grocery              4.339e-04  1.163e-03   0.373 0.709206
## log.eatout               2.039e-03  8.723e-04   2.338 0.019463 *
## log.delivery            -5.234e-04  6.241e-04  -0.839 0.401684
## milkrare                 8.184e-03  3.974e-03   2.060 0.039526 *
## milksometimes            9.926e-03  3.578e-03   2.774 0.005573 **
## milkoften                3.152e-03  3.527e-03   0.894 0.371559
## milkvaried               5.545e-02  2.158e-02   2.570 0.010224 *
## meals_nothome           -4.889e-05  4.116e-04  -0.119 0.905466
## meals_fastfood           7.922e-04  5.683e-04   1.394 0.163401
## depressedsometimes      -3.224e-04  3.304e-03  -0.098 0.922286
## depressedoften           2.130e-02  6.621e-03   3.217 0.001310 **
## depressedalwyas          8.558e-03  6.972e-03   1.227 0.219775
## sleep_troublesometimes -2.588e-04  2.984e-03  -0.087 0.930885
## sleep_troubleoften       6.435e-03  5.100e-03   1.262 0.207134
## sleep_troublealways      1.046e-02  4.610e-03   2.268 0.023388 *
## activityNo               5.992e-03  2.445e-03   2.451 0.014309 *
## tv_hrs2~4hrs             1.630e-02  2.857e-03   5.704 1.29e-08 ***
## tv_hrs5hrs               2.746e-02  4.107e-03   6.685 2.76e-11 ***
## tv_hrs0hr                1.430e-02  8.722e-03   1.639 0.101294
## sleep_hr                -1.509e-03  8.878e-04  -1.699 0.089383 .
## smokesometimes           6.294e-03  6.565e-03   0.959 0.337729
## smokeno                  2.323e-02  3.941e-03   5.894 4.20e-09 ***
## smokemissing             1.631e-02  3.667e-03   4.447 9.01e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06387 on 2916 degrees of freedom
## Multiple R-squared:  0.1153, Adjusted R-squared:  0.1025
## F-statistic: 9.047 on 42 and 2916 DF,  p-value: < 2.2e-16
```

```
plotres(model1, which=3:4, caption = "Base model assumption check")
```




```
#baseline model cv
model1_cv = train(base_form, data=df_adult, method="lm", preProcess="scale", trControl=train_contro

print("Base model cv results:")
```

```
## [1] "Base model cv results:"
```

```
print(paste("RMSE:", model1_cv$results$RMSE, "Rsquared:", model1_cv$results$Rsquared))
```

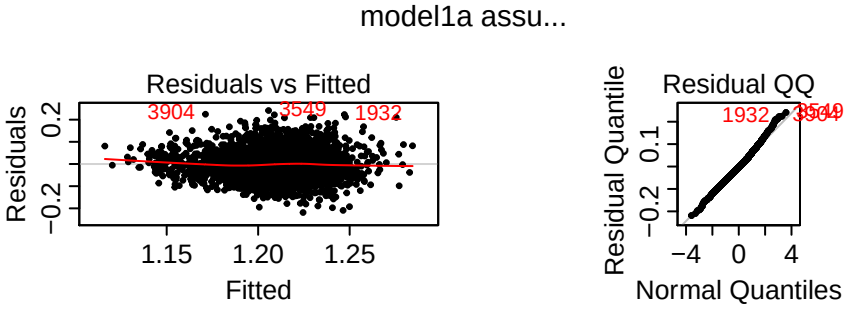
```
## [1] "RMSE: 0.0645052005209794 Rsquared: 0.088067250588867"
```

```
#model1a: baseline model step
set.seed(1234)
model1a = step(model1, trace = 0, direction = "backward")

summary(model1a)
```

```
##
## Call:
## lm(formula = log2.bmi ~ gender + race + marriage + famincome +
##     alcoholfrq + log.eatout + milk + meals_fastfood + depressed +
##     sleep_trouble + activity + tv_hrs + sleep_hr + smoke, data = df_adult)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.218643 -0.042895 -0.001923  0.038362  0.241206
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)              1.1843326  0.0093716 126.375  < 2e-16 ***
## genderfemale             0.0076379  0.0024725   3.089 0.002026 **
## raceother hispanic      -0.0191613  0.0053818  -3.560 0.000376 ***
## racewhite               -0.0165158  0.0039074  -4.227 2.44e-05 ***
## raceblack               -0.0056150  0.0044921  -1.250 0.211404
## raceasian               -0.0538556  0.0054758  -9.835  < 2e-16 ***
## raceother               -0.0114075  0.0075490  -1.511 0.130862
## marriagewidowed         -0.0088122  0.0055040  -1.601 0.109475
## marriagedivorced         0.0006233  0.0036014   0.173 0.862610
## marriagenever_married   -0.0071471  0.0034005  -2.102 0.035661 *
## famincome25k~55k         0.0044158  0.0032507   1.358 0.174438
```

```
## famincome55k~75k       -0.0005382  0.0043425  -0.124 0.901373
## famincome75k~100k      -0.0007125  0.0046866  -0.152 0.879172
## famincomeabove 100k    -0.0109757  0.0040286  -2.724 0.006480 **
## alcoholfrq             -0.0001616  0.0000670  -2.412 0.015912 *
## log.eatout              0.0021437  0.0008550   2.507 0.012221 *
## milkrare                0.0083961  0.0039669   2.117 0.034383 *
## milksometimes           0.0102260  0.0035706   2.864 0.004214 **
## milkoften               0.0034727  0.0035217   0.986 0.324176
## milkvaried              0.0551352  0.0215682   2.556 0.010629 *
## meals_fastfood          0.0007148  0.0004502   1.588 0.112457
## depressedsometimes     -0.0002451  0.0032985  -0.074 0.940782
## depressedoften          0.0210983  0.0066160   3.189 0.001443 **
## depressedalwyas         0.0078500  0.0069587   1.128 0.259378
## sleep_troublesometimes -0.0003573  0.0029785  -0.120 0.904527
## sleep_troubleoften      0.0066860  0.0050872   1.314 0.188851
## sleep_troublealways     0.0100479  0.0046037   2.183 0.029146 *
## activityNo              0.0057577  0.0024291   2.370 0.017836 *
## tv_hrs2~4hrs            0.0159792  0.0028168   5.673 1.54e-08 ***
## tv_hrs5hrs              0.0267812  0.0040156   6.669 3.06e-11 ***
## tv_hrs0hr               0.0143202  0.0087118   1.644 0.100330
## sleep_hr               -0.0016220  0.0008811  -1.841 0.065743 .
## smokesometimes          0.0065914  0.0065442   1.007 0.313915
## smokeno                 0.0236999  0.0038542   6.149 8.85e-10 ***
## smokemissing            0.0174996  0.0035986   4.863 1.22e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06387 on 2924 degrees of freedom
## Multiple R-squared:  0.1128, Adjusted R-squared:  0.1025
## F-statistic: 10.94 on 34 and 2924 DF,  p-value: < 2.2e-16
```

```
plotres(model1a, which=3:4, caption = "model1a assumption check")
```




```
base_1a_form = formula(model1a)
#baseline model cv
model1a_cv = train(base_1a_form, data=df_adult, method="lm", preProcess="scale", trControl=train_co

print("model1a cv results:")
```

```
## [1] "model1a cv results:"
```

```r
print(paste("RMSE:", model1a_cv$results$RMSE, "Rsquared:", model1a_cv$results$Rsquared))
```

```
## [1] "RMSE: 0.0644145278641605 Rsquared: 0.0903970403193655"
```

```r
#compare model1 with model1a
set.seed(1234)
anova(model1a, model1)
```

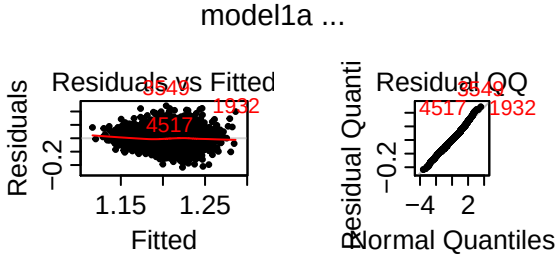
```
## Analysis of Variance Table
##
## Model 1: log2.bmi ~ gender + race + marriage + famincome + alcoholfrq +
##     log.eatout + milk + meals_fastfood + depressed + sleep_trouble +
##     activity + tv_hrs + sleep_hr + smoke
## Model 2: log2.bmi ~ gender + age + race + edu + marriage + famsize + famincome +
##     alcohol12yr + alcoholfrq + log.grocery + log.eatout + log.delivery +
##     milk + meals_nothome + meals_fastfood + depressed + sleep_trouble +
##     activity + tv_hrs + sleep_hr + smoke
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1   2924 11.928
## 2   2916 11.896  8   0.03278 1.0044 0.4303
```

```r
#model1b: add sleep^2 to model1a
set.seed(1234)

base_sleep_form = update.formula(base_1a_form, . ~. + I(sleep_hr^2))

model1b = lm(base_sleep_form, data = df_adult)
summary(model1b)
```

```
##
## Call:
## lm(formula = base_sleep_form, data = df_adult)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.217409 -0.042988 -0.001923  0.038642  0.243013
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)              1.235e+00  1.891e-02  65.315  < 2e-16 ***
## genderfemale             7.449e-03  2.470e-03   3.016 0.002580 **
## raceother hispanic      -1.952e-02  5.375e-03  -3.632 0.000286 ***
## racewhite               -1.674e-02  3.902e-03  -4.289 1.85e-05 ***
## raceblack               -6.228e-03  4.490e-03  -1.387 0.165540
## raceasian               -5.392e-02  5.468e-03  -9.862  < 2e-16 ***
## raceother               -1.194e-02  7.540e-03  -1.584 0.113340
## marriagewidowed         -8.714e-03  5.496e-03  -1.585 0.112965
## marriagedivorced         5.573e-04  3.596e-03   0.155 0.876858
## marriagenever_married   -7.255e-03  3.396e-03  -2.136 0.032727 *
```

```
## famincome25k~55k         4.861e-03  3.249e-03   1.496 0.134752
## famincome55k~75k         2.292e-04  4.343e-03   0.053 0.957925
## famincome75k~100k       -7.039e-05  4.684e-03  -0.015 0.988012
## famincomeabove 100k     -1.005e-02  4.034e-03  -2.493 0.012735 *
## alcoholfrq              -1.589e-04  6.691e-05  -2.375 0.017622 *
## log.eatout               2.173e-03  8.538e-04   2.545 0.010964 *
## milkrare                 8.423e-03  3.961e-03   2.127 0.033545 *
## milksometimes            1.012e-02  3.566e-03   2.839 0.004557 **
## milkoften                3.346e-03  3.517e-03   0.951 0.341453
## milkvaried               5.522e-02  2.154e-02   2.564 0.010402 *
## meals_fastfood           6.490e-04  4.501e-04   1.442 0.149418
## depressedsometimes      -2.810e-04  3.294e-03  -0.085 0.932007
## depressedoften           1.991e-02  6.618e-03   3.008 0.002651 **
## depressedalwyas          6.766e-03  6.957e-03   0.972 0.330911
## sleep_troublesometimes -2.703e-04  2.974e-03  -0.091 0.927591
## sleep_troubleoften       6.380e-03  5.081e-03   1.256 0.209333
## sleep_troublealways      8.915e-03  4.611e-03   1.933 0.053309 .
## activityNo               5.632e-03  2.426e-03   2.322 0.020319 *
## tv_hrs2~4hrs             1.603e-02  2.813e-03   5.699 1.32e-08 ***
## tv_hrs5hrs               2.624e-02  4.013e-03   6.539 7.28e-11 ***
## tv_hrs0hr                1.394e-02  8.700e-03   1.602 0.109261
## sleep_hr                -1.732e-02  5.146e-03  -3.365 0.000775 ***
## smokesometimes           6.946e-03  6.536e-03   1.063 0.287939
## smokeno                  2.396e-02  3.850e-03   6.225 5.52e-10 ***
## smokemissing             1.802e-02  3.597e-03   5.009 5.78e-07 ***
## I(sleep_hr^2)            1.158e-03  3.741e-04   3.096 0.001983 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06378 on 2923 degrees of freedom
## Multiple R-squared:  0.1157, Adjusted R-squared:  0.1052
## F-statistic: 10.93 on 35 and 2923 DF,  p-value: < 2.2e-16
```

```
plotres(model1b, which=3:4, caption = "model1a plus sleephour^2 assumption check")
```




```
model1b_form = formula(model1b)

#model1b cv
model1b_cv = train(base_sleep_form, data=df_adult, method="lm", preProcess="scale", trControl=train
```

```r
print("model1a plus sleephour^2 cv results:")
```

```
## [1] "model1a plus sleephour^2 cv results:"
```

```r
print(paste("RMSE:", model1b_cv$results$RMSE, "Rsquared:", model1b_cv$results$Rsquared))
```

```
## [1] "RMSE: 0.064348660409757 Rsquared: 0.0924950285909764"
```

```r
#compare model1b to model1a
set.seed(1234)
anova(model1a, model1b)
```

```
## Analysis of Variance Table
##
## Model 1: log2.bmi ~ gender + race + marriage + famincome + alcoholfrq +
##     log.eatout + milk + meals_fastfood + depressed + sleep_trouble +
##     activity + tv_hrs + sleep_hr + smoke
## Model 2: log2.bmi ~ gender + race + marriage + famincome + alcoholfrq +
##     log.eatout + milk + meals_fastfood + depressed + sleep_trouble +
##     activity + tv_hrs + sleep_hr + smoke + I(sleep_hr^2)
##   Res.Df    RSS Df Sum of Sq      F   Pr(>F)
## 1   2924 11.928
## 2   2923 11.889  1  0.038976 9.5821 0.001983 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#model1c: add famsize interactions
set.seed(1234)
model1c = lm(update.formula(model1b_form, .~.+famsize*(famincome+log.grocery+log.eatout+log.deliver

summary(model1c)
```

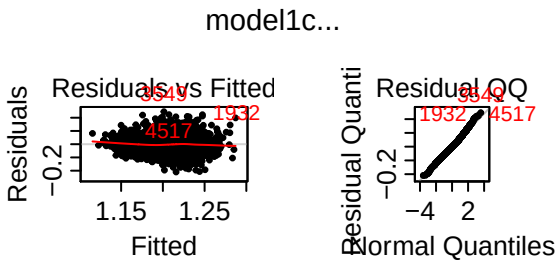
```
##
## Call:
## lm(formula = update.formula(model1b_form, . ~ . + famsize * (famincome +
##     log.grocery + log.eatout + log.delivery)), data = df_adult)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.209958 -0.043047 -0.002103  0.038688  0.245642
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  1.227e+00  2.340e-02  52.458  < 2e-16 ***
## genderfemale                 7.109e-03  2.481e-03   2.865 0.004204 **
## raceother hispanic          -1.949e-02  5.427e-03  -3.591 0.000334 ***
## racewhite                   -1.645e-02  4.024e-03  -4.088 4.48e-05 ***
## raceblack                   -5.758e-03  4.559e-03  -1.263 0.206664
## raceasian                   -5.371e-02  5.539e-03  -9.698  < 2e-16 ***
## raceother                   -1.238e-02  7.592e-03  -1.631 0.102998
```

```
## marriagewidowed             -8.949e-03  5.657e-03  -1.582 0.113756
## marriagedivorced             1.510e-03  3.733e-03   0.405 0.685774
## marriagenever_married       -6.199e-03  3.483e-03  -1.780 0.075192 .
## famincome25k~55k             1.312e-03  6.033e-03   0.217 0.827835
## famincome55k~75k            -9.220e-03  8.754e-03  -1.053 0.292305
## famincome75k~100k           -3.015e-03  9.913e-03  -0.304 0.761064
## famincomeabove 100k         -1.701e-02  8.343e-03  -2.039 0.041506 *
## alcoholfrq                  -1.549e-04  6.701e-05  -2.312 0.020860 *
## log.eatout                   2.945e-04  1.649e-03   0.179 0.858299
## milkrare                     8.484e-03  3.970e-03   2.137 0.032684 *
## milksometimes                1.032e-02  3.571e-03   2.890 0.003883 **
## milkoften                    3.478e-03  3.520e-03   0.988 0.323243
## milkvaried                   5.508e-02  2.156e-02   2.555 0.010666 *
## meals_fastfood               7.499e-04  4.564e-04   1.643 0.100436
## depressedsometimes          -7.110e-05  3.304e-03  -0.022 0.982831
## depressedoften               2.020e-02  6.627e-03   3.048 0.002325 **
## depressedalwyas              6.918e-03  6.966e-03   0.993 0.320738
## sleep_troublesometimes      -2.440e-04  2.979e-03  -0.082 0.934715
## sleep_troubleoften           6.163e-03  5.091e-03   1.211 0.226127
## sleep_troublealways          8.463e-03  4.619e-03   1.832 0.067003 .
## activityNo                   5.238e-03  2.438e-03   2.148 0.031777 *
## tv_hrs2~4hrs                 1.636e-02  2.825e-03   5.792 7.71e-09 ***
## tv_hrs5hrs                   2.676e-02  4.041e-03   6.621 4.24e-11 ***
## tv_hrs0hr                    1.400e-02  8.712e-03   1.607 0.108083
## sleep_hr                    -1.731e-02  5.152e-03  -3.360 0.000789 ***
## smokesometimes               7.369e-03  6.542e-03   1.126 0.260136
## smokeno                      2.437e-02  3.873e-03   6.290 3.64e-10 ***
## smokemissing                 1.833e-02  3.621e-03   5.063 4.38e-07 ***
## I(sleep_hr^2)                1.161e-03  3.744e-04   3.101 0.001950 **
## famsize                      1.386e-03  4.399e-03   0.315 0.752728
## log.grocery                  3.224e-03  2.328e-03   1.385 0.166186
## log.delivery                -1.602e-03  1.289e-03  -1.242 0.214193
## famincome25k~55k:famsize     1.296e-03  1.855e-03   0.699 0.484903
## famincome55k~75k:famsize     3.438e-03  2.669e-03   1.288 0.197809
## famincome75k~100k:famsize    9.321e-04  2.828e-03   0.330 0.741759
## famincomeabove 100k:famsize  2.175e-03  2.353e-03   0.924 0.355398
## famsize:log.grocery         -8.860e-04  6.712e-04  -1.320 0.186948
## log.eatout:famsize           6.197e-04  4.639e-04   1.336 0.181685
## famsize:log.delivery         3.407e-04  3.619e-04   0.941 0.346558
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06378 on 2913 degrees of freedom
## Multiple R-squared:  0.1186, Adjusted R-squared:  0.105
## F-statistic: 8.709 on 45 and 2913 DF,  p-value: < 2.2e-16
```

```
extractAIC(model1c)
```

```
## [1]     46.00 -16242.17
```

```
plotres(model1c, which=3:4, caption = "model1c assumption check")
```




```
#model1a cv
model1c_cv = train(formula(model1c), data=df_adult, method="lm", preProcess="scale", trControl=trai

print("Model1c cv results:")
```

```
## [1] "Model1c cv results:"
```

```
print(paste("RMSE:", model1c_cv$results$RMSE, "Rsquared:", model1c_cv$results$Rsquared))
```

```
## [1] "RMSE: 0.064451866512309 Rsquared: 0.0901468116644371"
```

```
#compare model1c to model1b
set.seed(1234)
anova(model1b, model1c)
```

```
## Analysis of Variance Table
##
## Model 1: log2.bmi ~ gender + race + marriage + famincome + alcoholfrq +
##     log.eatout + milk + meals_fastfood + depressed + sleep_trouble +
##     activity + tv_hrs + sleep_hr + smoke + I(sleep_hr^2)
## Model 2: log2.bmi ~ gender + race + marriage + famincome + alcoholfrq +
##     log.eatout + milk + meals_fastfood + depressed + sleep_trouble +
##     activity + tv_hrs + sleep_hr + smoke + I(sleep_hr^2) + famsize +
##     log.grocery + log.delivery + famincome:famsize + famsize:log.grocery +
##     log.eatout:famsize + famsize:log.delivery
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1   2923 11.889
## 2   2913 11.851 10  0.038099 0.9365 0.4981
```

```
##
## Call:
## lm(formula = log2.bmi ~ race + tv_hrs + smoke + depressed + milk +
##     famincome + gender + log.eatout + activity + alcoholfrq +
##     marriage + meals_fastfood + sleep_trouble + tv_hrs:depressed +
##     famincome:gender + race:gender + smoke:gender + race:activity +
##     smoke:marriage + race:meals_fastfood + gender:meals_fastfood +
##     depressed:milk + tv_hrs:log.eatout, data = df_adult)
##
## Residuals:
```

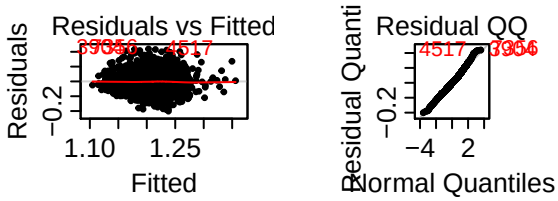
```
##       Min        1Q    Median        3Q       Max
## -0.200795 -0.040473 -0.002891  0.037567  0.219548
##
## Coefficients: (2 not defined because of singularities)
##                                      Estimate Std. Error t value
## (Intercept)                          1.148e+00  1.215e-02  94.550
## raceother hispanic                  -6.377e-03  1.051e-02  -0.607
## racewhite                           -1.149e-02  7.842e-03  -1.465
## raceblack                            1.110e-02  8.875e-03   1.251
## raceasian                           -2.578e-02  1.012e-02  -2.548
## raceother                            2.100e-02  1.562e-02   1.344
## tv_hrs2~4hrs                         2.176e-02  9.357e-03   2.326
## tv_hrs5hrs                           7.280e-03  1.153e-02   0.631
## tv_hrs0hr                            1.184e-02  2.673e-02   0.443
## smokesometimes                      -5.033e-03  1.018e-02  -0.494
## smokeno                              3.052e-02  5.810e-03   5.254
## smokemissing                         3.314e-02  5.636e-03   5.880
## depressedsometimes                  -1.944e-02  9.465e-03  -2.054
## depressedoften                      -1.178e-02  1.770e-02  -0.666
## depressedalwyas                      7.267e-03  2.083e-02   0.349
## milkrare                             5.320e-03  4.487e-03   1.186
## milksometimes                        8.312e-03  4.003e-03   2.076
## milkoften                            1.192e-04  3.950e-03   0.030
## milkvaried                           5.257e-02  2.242e-02   2.344
## famincome25k~55k                     1.041e-02  4.465e-03   2.332
## famincome55k~75k                     6.884e-03  5.673e-03   1.213
## famincome75k~100k                    7.329e-03  6.120e-03   1.198
## famincomeabove 100k                  2.493e-03  5.163e-03   0.483
## genderfemale                         3.552e-02  9.897e-03   3.589
## log.eatout                           3.181e-03  1.595e-03   1.994
## activityNo                           1.815e-02  6.950e-03   2.611
## alcoholfrq                          -1.759e-04  6.576e-05  -2.674
## marriagewidowed                     -2.478e-02  1.886e-02  -1.314
## marriagedivorced                     9.006e-03  7.573e-03   1.189
## marriagenever_married               -1.730e-03  7.144e-03  -0.242
## meals_fastfood                       8.205e-04  1.207e-03   0.680
## sleep_troublesometimes               8.224e-05  2.936e-03   0.028
## sleep_troubleoften                   8.354e-03  4.983e-03   1.677
## sleep_troublealways                  9.883e-03  4.490e-03   2.201
## tv_hrs2~4hrs:depressedsometimes      8.323e-03  7.516e-03   1.107
## tv_hrs5hrs:depressedsometimes        1.577e-02  9.635e-03   1.636
## tv_hrs0hr:depressedsometimes         3.996e-02  2.244e-02   1.781
## tv_hrs2~4hrs:depressedoften          1.555e-02  1.575e-02   0.987
## tv_hrs5hrs:depressedoften            7.323e-02  2.011e-02   3.640
## tv_hrs0hr:depressedoften             2.634e-03  2.919e-02   0.090
## tv_hrs2~4hrs:depressedalwyas        -1.618e-02  1.735e-02  -0.933
## tv_hrs5hrs:depressedalwyas          -1.862e-02  1.884e-02  -0.988
## tv_hrs0hr:depressedalwyas           -6.512e-02  6.578e-02  -0.990
```

```
## famincome25k~55k:genderfemale        -1.037e-02  6.296e-03  -1.648
## famincome55k~75k:genderfemale        -1.300e-02  8.367e-03  -1.554
## famincome75k~100k:genderfemale       -1.710e-02  8.864e-03  -1.929
## famincomeabove 100k:genderfemale     -2.853e-02  7.044e-03  -4.050
## raceother hispanic:genderfemale      -1.402e-02  1.084e-02  -1.293
## racewhite:genderfemale               -8.346e-03  7.754e-03  -1.076
## raceblack:genderfemale                8.942e-03  8.740e-03   1.023
## raceasian:genderfemale               -2.434e-02  1.083e-02  -2.248
## raceother:genderfemale               -2.078e-02  1.569e-02  -1.324
## smokesometimes:genderfemale          -2.045e-03  1.334e-02  -0.153
## smokeno:genderfemale                 -4.893e-03  7.585e-03  -0.645
## smokemissing:genderfemale            -2.318e-02  7.008e-03  -3.308
## raceother hispanic:activityNo        -1.373e-02  1.077e-02  -1.275
## racewhite:activityNo                 -7.821e-03  7.703e-03  -1.015
## raceblack:activityNo                 -2.208e-02  8.838e-03  -2.498
## raceasian:activityNo                 -3.017e-02  1.062e-02  -2.842
## raceother:activityNo                 -1.405e-02  1.512e-02  -0.929
## smokesometimes:marriagewidowed        2.820e-02  3.554e-02   0.793
## smokeno:marriagewidowed              -3.129e-03  2.063e-02  -0.152
## smokemissing:marriagewidowed          3.382e-02  2.023e-02   1.672
## smokesometimes:marriagedivorced       2.225e-02  1.785e-02   1.247
## smokeno:marriagedivorced             -1.047e-02  9.743e-03  -1.075
## smokemissing:marriagedivorced        -1.556e-02  9.094e-03  -1.711
## smokesometimes:marriagenever_married  2.818e-02  1.527e-02   1.845
## smokeno:marriagenever_married         4.362e-03  1.032e-02   0.423
## smokemissing:marriagenever_married   -1.494e-02  8.293e-03  -1.802
## raceother hispanic:meals_fastfood     9.099e-04  1.922e-03   0.473
## racewhite:meals_fastfood              8.098e-04  1.332e-03   0.608
## raceblack:meals_fastfood             -3.007e-03  1.432e-03  -2.101
## raceasian:meals_fastfood             -1.690e-03  2.511e-03  -0.673
## raceother:meals_fastfood             -4.747e-03  2.427e-03  -1.956
## genderfemale:meals_fastfood           2.647e-03  9.281e-04   2.852
## depressedsometimes:milkrare           1.830e-02  1.047e-02   1.749
## depressedoften:milkrare              -6.829e-03  2.010e-02  -0.340
## depressedalwyas:milkrare              3.656e-02  2.106e-02   1.736
## depressedsometimes:milksometimes      7.195e-03  9.558e-03   0.753
## depressedoften:milksometimes          3.048e-02  1.904e-02   1.601
## depressedalwyas:milksometimes        -1.515e-02  1.937e-02  -0.782
## depressedsometimes:milkoften          1.525e-02  9.384e-03   1.625
## depressedoften:milkoften              2.109e-02  1.767e-02   1.193
## depressedalwyas:milkoften             3.418e-02  1.905e-02   1.794
## depressedsometimes:milkvaried         1.003e-01  6.727e-02   1.491
## depressedoften:milkvaried                    NA         NA      NA
## depressedalwyas:milkvaried                   NA         NA      NA
## tv_hrs2~4hrs:log.eatout              -1.934e-03  1.863e-03  -1.038
## tv_hrs5hrs:log.eatout                 3.814e-03  2.370e-03   1.609
## tv_hrs0hr:log.eatout                 -3.707e-04  5.890e-03  -0.063
##                                     Pr(>|t|)
```

```
## (Intercept)                          < 2e-16 ***
## raceother hispanic                   0.543892
## racewhite                            0.142916
## raceblack                            0.210948
## raceasian                            0.010872 *
## raceother                            0.178922
## tv_hrs2~4hrs                         0.020088 *
## tv_hrs5hrs                           0.527863
## tv_hrs0hr                            0.657737
## smokesometimes                       0.621020
## smokeno                              1.60e-07 ***
## smokemissing                         4.58e-09 ***
## depressedsometimes                   0.040052 *
## depressedoften                       0.505640
## depressedalwyas                      0.727259
## milkrare                             0.235859
## milksometimes                        0.037947 *
## milkoften                            0.975925
## milkvaried                           0.019130 *
## famincome25k~55k                     0.019794 *
## famincome55k~75k                     0.225075
## famincome75k~100k                    0.231208
## famincomeabove 100k                  0.629275
## genderfemale                         0.000338 ***
## log.eatout                           0.046259 *
## activityNo                           0.009063 **
## alcoholfrq                           0.007533 **
## marriagewidowed                      0.189031
## marriagedivorced                     0.234445
## marriagenever_married                0.808701
## meals_fastfood                       0.496494
## sleep_troublesometimes               0.977659
## sleep_troubleoften                   0.093744 .
## sleep_troublealways                  0.027823 *
## tv_hrs2~4hrs:depressedsometimes      0.268203
## tv_hrs5hrs:depressedsometimes        0.101873
## tv_hrs0hr:depressedsometimes         0.075022 .
## tv_hrs2~4hrs:depressedoften          0.323580
## tv_hrs5hrs:depressedoften            0.000277 ***
## tv_hrs0hr:depressedoften             0.928104
## tv_hrs2~4hrs:depressedalwyas         0.351029
## tv_hrs5hrs:depressedalwyas           0.323085
## tv_hrs0hr:depressedalwyas            0.322296
## famincome25k~55k:genderfemale        0.099523 .
## famincome55k~75k:genderfemale        0.120323
## famincome75k~100k:genderfemale       0.053776 .
## famincomeabove 100k:genderfemale     5.25e-05 ***
## raceother hispanic:genderfemale      0.195981
```

```
## racewhite:genderfemale               0.281832
## raceblack:genderfemale               0.306336
## raceasian:genderfemale               0.024639 *
## raceother:genderfemale               0.185608
## smokesometimes:genderfemale          0.878136
## smokeno:genderfemale                 0.518889
## smokemissing:genderfemale            0.000952 ***
## raceother hispanic:activityNo        0.202484
## racewhite:activityNo                 0.310063
## raceblack:activityNo                 0.012535 *
## raceasian:activityNo                 0.004516 **
## raceother:activityNo                 0.352884
## smokesometimes:marriagewidowed       0.427572
## smokeno:marriagewidowed              0.879435
## smokemissing:marriagewidowed         0.094677 .
## smokesometimes:marriagedivorced      0.212546
## smokeno:marriagedivorced             0.282530
## smokemissing:marriagedivorced        0.087206 .
## smokesometimes:marriagenever_married 0.065179 .
## smokeno:marriagenever_married        0.672569
## smokemissing:marriagenever_married   0.071681 .
## raceother hispanic:meals_fastfood    0.635912
## racewhite:meals_fastfood             0.543311
## raceblack:meals_fastfood             0.035759 *
## raceasian:meals_fastfood             0.500897
## raceother:meals_fastfood             0.050541 .
## genderfemale:meals_fastfood          0.004371 **
## depressedsometimes:milkrare          0.080461 .
## depressedoften:milkrare              0.734057
## depressedalwyas:milkrare             0.082692 .
## depressedsometimes:milksometimes     0.451671
## depressedoften:milksometimes         0.109455
## depressedalwyas:milksometimes        0.434429
## depressedsometimes:milkoften         0.104281
## depressedoften:milkoften             0.232896
## depressedalwyas:milkoften            0.072965 .
## depressedsometimes:milkvaried        0.136021
## depressedoften:milkvaried                 NA
## depressedalwyas:milkvaried                NA
## tv_hrs2~4hrs:log.eatout              0.299346
## tv_hrs5hrs:log.eatout                0.107636
## tv_hrs0hr:log.eatout                 0.949828
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06233 on 2871 degrees of freedom
## Multiple R-squared:  0.1705, Adjusted R-squared:  0.1453
## F-statistic: 6.782 on 87 and 2871 DF,  p-value: < 2.2e-16
```

model1d...



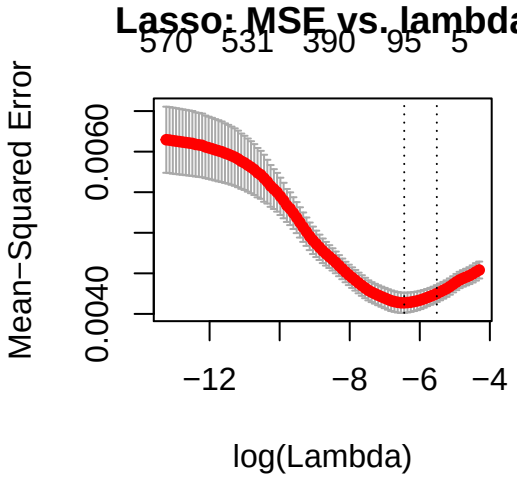

```
## [1] "model1d cv results:"
```

```
## [1] "RMSE: 0.0635994339787107 Rsquared: 0.116642266562635"
```

```
#compare model1d to model1b
set.seed(1234)
anova(model1b, model1d)
```

```
## Analysis of Variance Table
##
## Model 1: log2.bmi ~ gender + race + marriage + famincome + alcoholfrq +
##     log.eatout + milk + meals_fastfood + depressed + sleep_trouble +
##     activity + tv_hrs + sleep_hr + smoke + I(sleep_hr^2)
## Model 2: log2.bmi ~ race + tv_hrs + smoke + depressed + milk + famincome +
##     gender + log.eatout + activity + alcoholfrq + marriage +
##     meals_fastfood + sleep_trouble + tv_hrs:depressed + famincome:gender +
##     race:gender + smoke:gender + race:activity + smoke:marriage +
##     race:meals_fastfood + gender:meals_fastfood + depressed:milk +
##     tv_hrs:log.eatout
##   Res.Df    RSS Df Sum of Sq      F    Pr(>F)
## 1   2923 11.889
## 2   2871 11.153 52   0.73587 3.6427 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

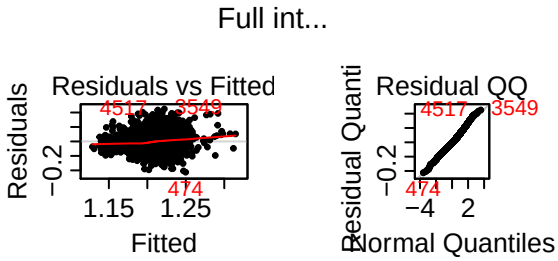
```
#lasso cv
set.seed(1234)
x.lasso = model.matrix(update(full_intr_form, .~.+0), data=df_adult)
cv_lasso = cv.glmnet(x.lasso, df_adult$log2.bmi, nfolds = 5)

lasso.lambda.min = cv_lasso$lambda.min
lasso.mse.min = min(cv_lasso$cvm)

coef.lasso = coef(cv_lasso, s = "lambda.min")
nonzero_coef_lasso = cbind(rownames(coef.lasso)[which(coef.lasso != 0)], coef.lasso[which(coef.lass

#lasso
model_lasso = glmnet(x.lasso, df_adult$log2.bmi, lambda = lasso.lambda.min)

#plot
plot(cv_lasso, main="Lasso: MSE vs. lambda")
```




```
summary(model_lasso)
```

```
##           Length Class     Mode
## a0           1   -none-    numeric
## beta       594   dgCMatrix S4
## df           1   -none-    numeric
## dim          2   -none-    numeric
## lambda       1   -none-    numeric
## dev.ratio    1   -none-    numeric
## nulldev      1   -none-    numeric
## npasses      1   -none-    numeric
## jerr         1   -none-    numeric
## offset       1   -none-    logical
## call         4   -none-    call
## nobs         1   -none-    numeric
```

```
plotres(model_lasso, which=3:4, caption = "Full interaction Lasso model assumption check")
```

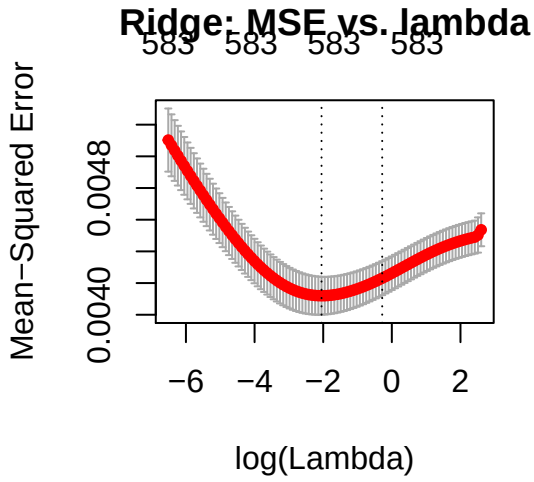



```
lasso.mse.min
```

```
## [1] 0.004137175
```

```
#ridge cv
set.seed(1234)
x.ridge = model.matrix(update(full_intr_form, .~.+0), data=df_adult)
cv_ridge = cv.glmnet(x.ridge, df_adult$log2.bmi, alpha = 0, nfolds = 5)

ridge.lambda.min = cv_ridge$lambda.min
```

```
ridge.mse.min = min(cv_ridge$cvm)

coef.ridge = coef(cv_ridge, s = "lambda.min")
nonzero_coef_ridge = cbind(rownames(coef.ridge)[which(coef.ridge != 0)], coef.ridge[which(coef.ridg

#ridge
model_ridge = glmnet(x.ridge, df_adult$log2.bmi, lambda = ridge.lambda.min, alpha = 0)

#plot
plot(cv_ridge, main="Ridge: MSE vs. lambda")
```

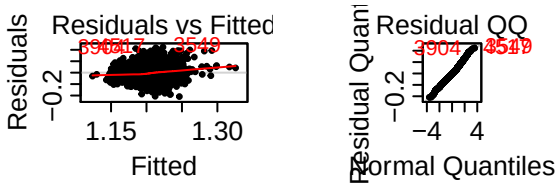



```
summary(model_ridge)
```

```
##           Length Class     Mode
## a0           1   -none-    numeric
## beta       594   dgCMatrix S4
## df           1   -none-    numeric
## dim          2   -none-    numeric
## lambda       1   -none-    numeric
## dev.ratio    1   -none-    numeric
## nulldev      1   -none-    numeric
## npasses      1   -none-    numeric
## jerr         1   -none-    numeric
## offset       1   -none-    logical
## call         5   -none-    call
## nobs         1   -none-    numeric
```

```
plotres(model_ridge, which=3:4, caption = "Full interaction Lasso model \n assumption check")
```

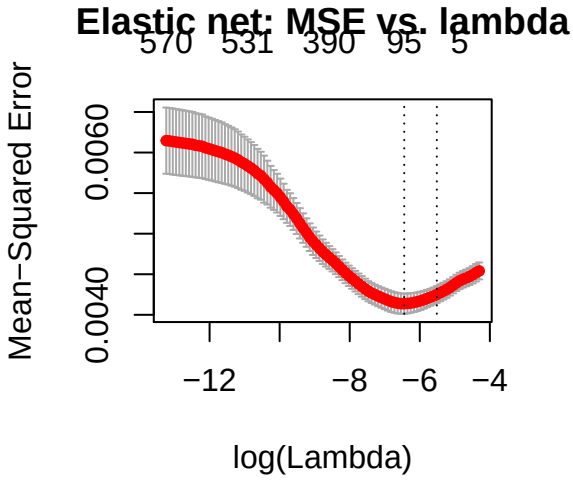
Full in...
assump...




```
ridge.mse.min
```

```
## [1] 0.004119922
```

```
#elastic net cv
set.seed(1234)
x.elastic = model.matrix(update(full_intr_form, .~.+0), data=df_adult)
cv_elastic = cv.glmnet(x.elastic, df_adult$log2.bmi, nfolds = 5)

elastic.lambda.min = cv_elastic$lambda.min
elastic.mse.min = min(cv_elastic$cvm)

coef.elastic = coef(cv_elastic, s = "lambda.min")
nonzero_coef_elastic = cbind(rownames(coef.elastic)[which(coef.elastic != 0)], coef.elastic[which(c

#elastic net
model_elastic = glmnet(x.elastic, df_adult$log2.bmi, lambda = elastic.lambda.min, alpha=0.5)

#plot
plot(cv_elastic, main="Elastic net: MSE vs. lambda")
```

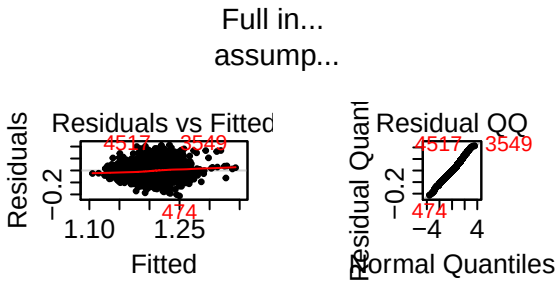



```
summary(model_elastic)
```

```
##           Length Class     Mode
## a0           1   -none-    numeric
## beta       594   dgCMatrix S4
## df           1   -none-    numeric
```

```
## dim         2    -none-    numeric
## lambda      1    -none-    numeric
## dev.ratio   1    -none-    numeric
## nulldev     1    -none-    numeric
## npasses     1    -none-    numeric
## jerr        1    -none-    numeric
## offset      1    -none-    logical
## call        5    -none-    call
## nobs        1    -none-    numeric
```

```
plotres(model_elastic, which=3:4, caption = "Full interaction Elastic model \n assumption check")
```




```
elastic.mse.min
```

```
## [1] 0.004137175
```

```
# best model (model1d) bootstraping

# Bootstrap 95% CI for regression coefficients
set.seed(1234)
library(boot)
```

```
##
## Attaching package: 'boot'
```

```
## The following object is masked from 'package:lattice':
##
##     melanoma
```

```
# function to obtain regression weights
bs <- function(formula, data, indices) {
  d <- data[indices,] # allows boot to select sample
  fit <- lm(formula, data=d)
  return(coef(fit))
}
# bootstrapping with 1000 replications
nsim = 500
results <- boot(data=df_adult, statistic=bs, R=nsim, formula=formula(model1d))
names_ = names(coef(lm(formula(model1d), data=df_adult)))

ci = data.frame(matrix(ncol = 3, nrow = length(names_)))
```

```r
print("the following coef is statistically significant from 0:")
```

```
## [1] "the following coef is statistically significant from 0:"
```

```r
for (i in c(1:85, 88:90)){
  ci[i, 1:2] = boot.ci(boot.out=results, conf = 0.95, type = "perc", index= i)$perc[,4:5]
  ci[i, 3] = (0 < ci[i, 2]) & (0 > ci[i, 1])
  if (ci[i, 3] == FALSE) {print(names_[i])}
}
```

```
## [1] "(Intercept)"
## [1] "raceasian"
## [1] "tv_hrs2~4hrs"
## [1] "smokeno"
## [1] "smokemissing"
## [1] "milksometimes"
## [1] "milkvaried"
## [1] "famincome25k~55k"
## [1] "genderfemale"
## [1] "log.eatout"
## [1] "activityNo"
## [1] "alcoholfrq"
## [1] "tv_hrs5hrs:depressedoften"
## [1] "tv_hrs0hr:depressedalwyas"
## [1] "famincomeabove 100k:genderfemale"
## [1] "raceasian:genderfemale"
## [1] "smokemissing:genderfemale"
## [1] "raceblack:activityNo"
## [1] "raceasian:activityNo"
## [1] "raceblack:meals_fastfood"
## [1] "raceother:meals_fastfood"
## [1] "genderfemale:meals_fastfood"
## [1] "depressedsometimes:milkvaried"
```

```
## [1] "Multinomial classification base model cv accuracy: 0.490360456372346"
```

```
## [1] "Multinomial classification model1d cv results: 0.470764705006836"
```

```r
write.csv(data.frame(summary(model1)$coefficients), file="table1.csv")
write.csv(data.frame(summary(model1a)$coefficients), file="table1a.csv")
write.csv(data.frame(summary(model1b)$coefficients), file="table1b.csv")
write.csv(data.frame(summary(model1c)$coefficients), file="table1c.csv")

write.csv(data.frame(nonzero_coef_lasso), file="table_lasso.csv")
write.csv(data.frame(nonzero_coef_ridge), file="table_ridge.csv")
write.csv(data.frame(nonzero_coef_elastic), file="table_elastic.csv")
```