Three-way Factorial Analysis of Variance Tutorial

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Research Context:

A Psycho-pharmacology firm has hired you to be their data analyst and provided you with a data set that consists of two demographic variables, a treatment variable, and current patient cholesterol ratings. The data set (`dat3`) contains five variables:

- `id` — Participant identification number
- `gender` — Demographic variable with two levels (`male` and `female`)
- `risk` — Demographic variable with two levels (`low` — Low risk for heart attack and `high` — High risk for heart attack)
- `drug` — Treatment variable with three levels (`A` — Placebo Treatment; `B` — Niacin Treatment; and `C` — Plant Sterol Treatment)
- `cholesterol` — Amount of cholesterol detected

The goal for this first research question was: Does participants gender, risk, and treatment interactively impact cholesterol?

```
library(psych)
library(tidyverse)
library(jmv)
library(ggpubr)
library(apaTables)
library(ez)
library(rstatix)

dat <- read.csv("anova3.csv")
dat2 <- read.csv("anova3.csv")

dat$gender<-factor(dat$gender, labels = c("Female","Male"))
dat$risk<-factor(dat$risk, labels = c("High", "Low"))
dat$drug <- factor(dat$drug, labels = c("Placebo", "Niacin", "Plant Sterol"))
```

Factorial ANOVA | Descriptive Stats

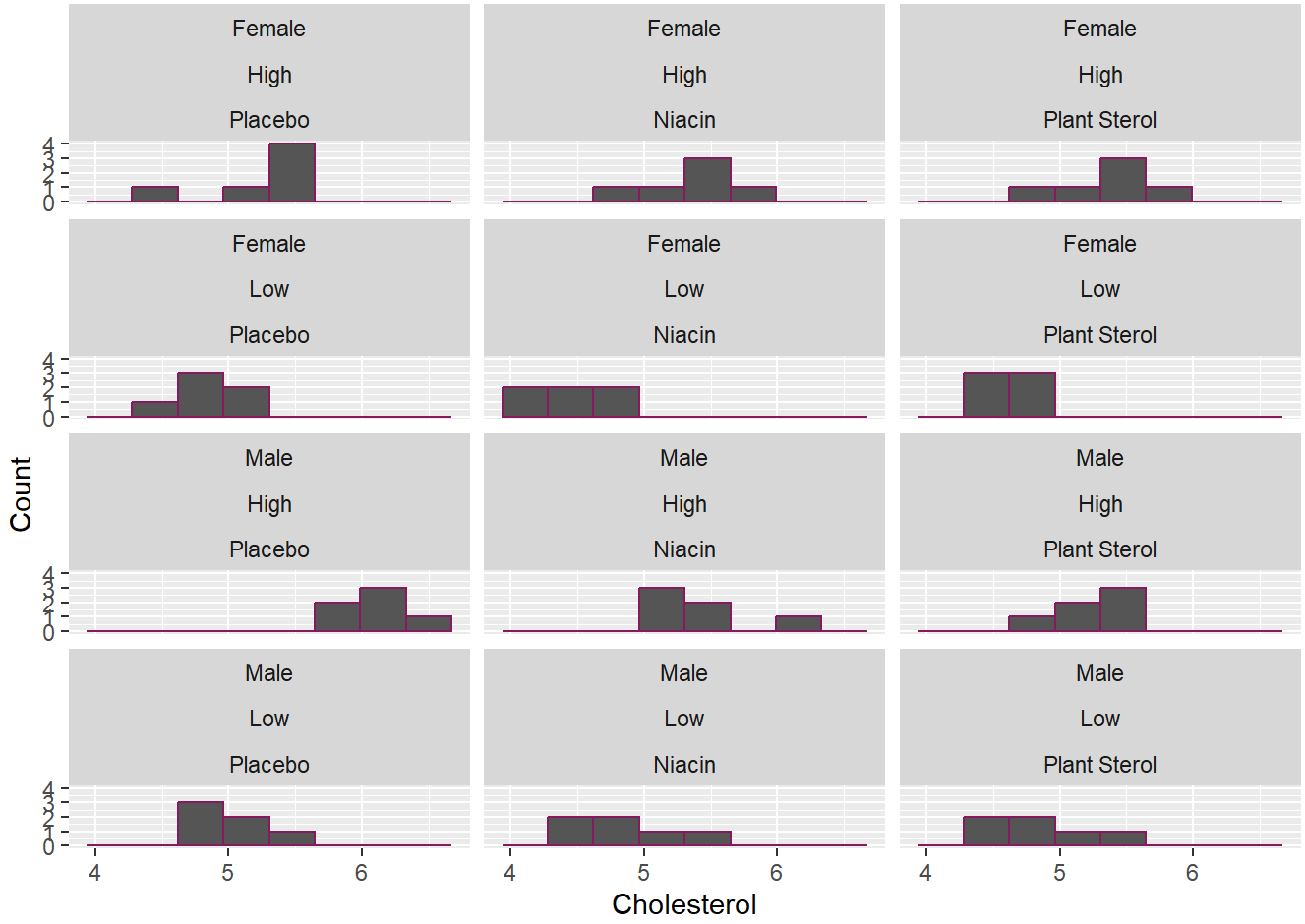
```
# Descriptive Stats

describeBy(dat$cholesterol,
           list(dat$gender,dat$risk,dat$drug),
           mat=TRUE)
```

```
##      item group1 group2       group3 vars n     mean        sd   median
## X11     1 Female   High      Placebo    1 6 5.209229 0.3511670 5.353925
## X12     2   Male   High      Placebo    1 6 6.125626 0.3379305 6.168801
## X13     3 Female    Low      Placebo    1 6 4.898199 0.2437514 4.929134
## X14     4   Male    Low      Placebo    1 6 5.023405 0.2546239 5.016537
## X15     5 Female   High       Niacin    1 6 5.361826 0.3051217 5.403721
## X16     6   Male   High       Niacin    1 6 5.438859 0.3303215 5.360847
## X17     7 Female    Low       Niacin    1 6 4.515471 0.2696156 4.540044
## X18     8   Male    Low       Niacin    1 6 4.830994 0.3147438 4.845671
## X19     9 Female   High Plant Sterol    1 6 5.352568 0.2632114 5.339850
## X110   10   Male   High Plant Sterol    1 6 5.263106 0.2672405 5.308647
## X111   11 Female    Low Plant Sterol    1 6 4.609109 0.1796392 4.596409
## X112   12   Male    Low Plant Sterol    1 6 4.917991 0.3229214 4.944042
##       trimmed        mad      min      max     range          skew   kurtosis
## X11  5.209229 0.09868694 4.515356 5.459700 0.9443436 -1.181352e+00 -0.3963686
## X12  6.125626 0.39498731 5.699909 6.605243 0.9053340  1.435622e-02 -1.7202370
## X13  4.898199 0.31812744 4.532117 5.156806 0.6246893 -2.909013e-01 -1.7266926
## X14  5.023405 0.30380958 4.678653 5.361076 0.6824222  6.531383e-05 -1.7813474
## X15  5.361826 0.22974633 4.831365 5.719552 0.8881870 -5.672197e-01 -1.1290252
## X16  5.438859 0.28762802 5.120679 6.022563 0.9018835  6.965896e-01 -1.1656270
## X17  4.515471 0.29070793 4.209694 4.937155 0.7274610  2.235818e-01 -1.5316353
## X18  4.830994 0.35010196 4.486516 5.328923 0.8424065  2.698135e-01 -1.5139468
## X19  5.352568 0.15557345 4.953143 5.755958 0.8028149  2.344317e-02 -1.1876646
## X110 5.263106 0.31924990 4.915613 5.618186 0.7025732 -8.705622e-02 -1.8123940
## X111 4.609109 0.16284718 4.323092 4.828190 0.5050975 -2.718648e-01 -1.4617354
## X112 4.917991 0.46608630 4.511342 5.312780 0.8014378 -8.710684e-02 -1.9017464
##              se
## X11  0.14336332
## X12  0.13795954
## X13  0.09951110
## X14  0.10394979
## X15  0.12456543
## X16  0.13485318
## X17  0.11007010
## X18  0.12849364
## X19  0.10745560
## X110 0.10910048
## X111 0.07333738
## X112 0.13183211
```

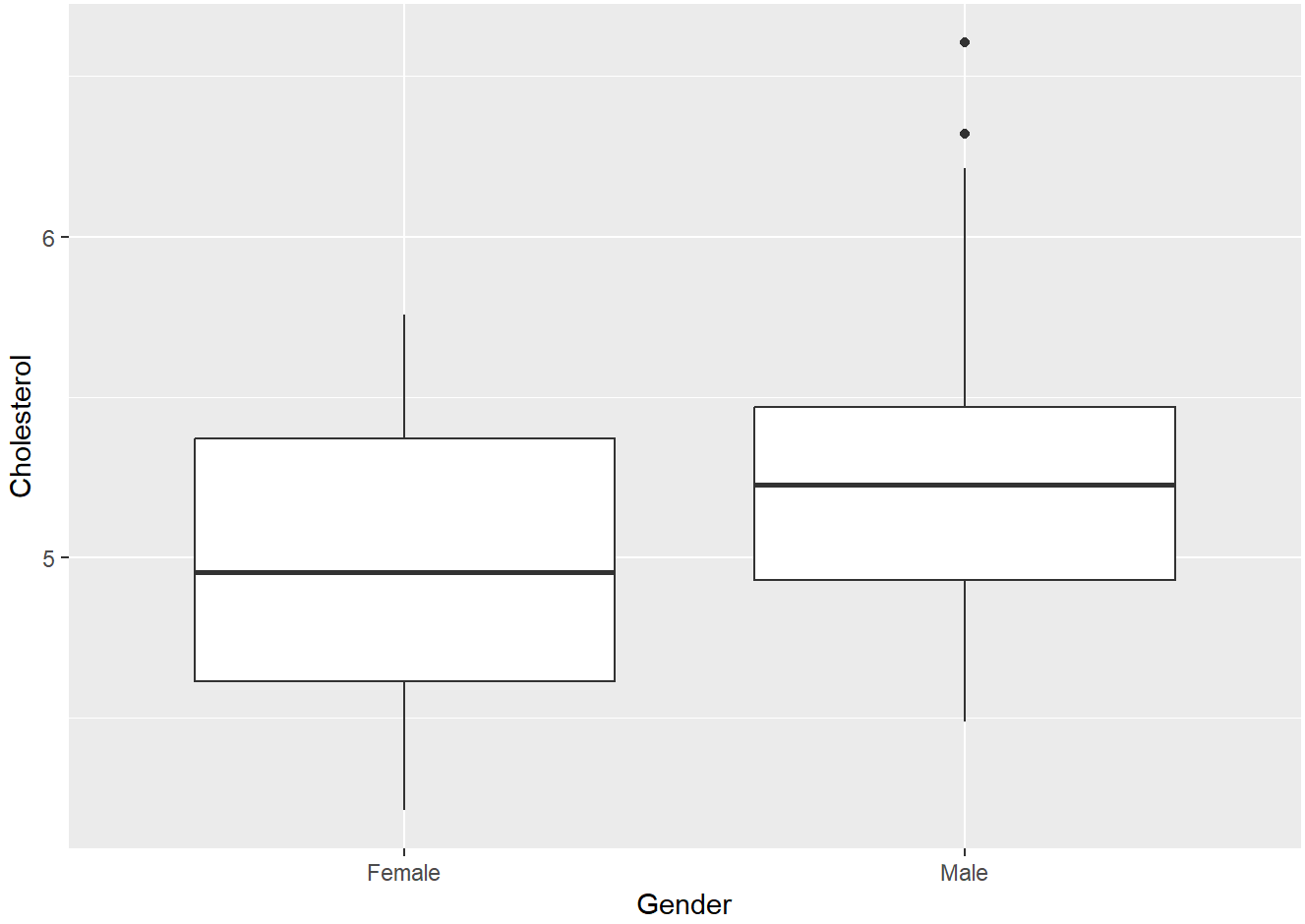
Factorial ANOVA | Histogram

```
ggplot(data = dat,
       mapping = aes(x = cholesterol)) +
  geom_histogram(bins = 8, color = "maroon4") +
  labs(y = "Count", x = "Cholesterol")+
  facet_wrap(~dat$gender+dat$risk+dat$drug, ncol =3)
```



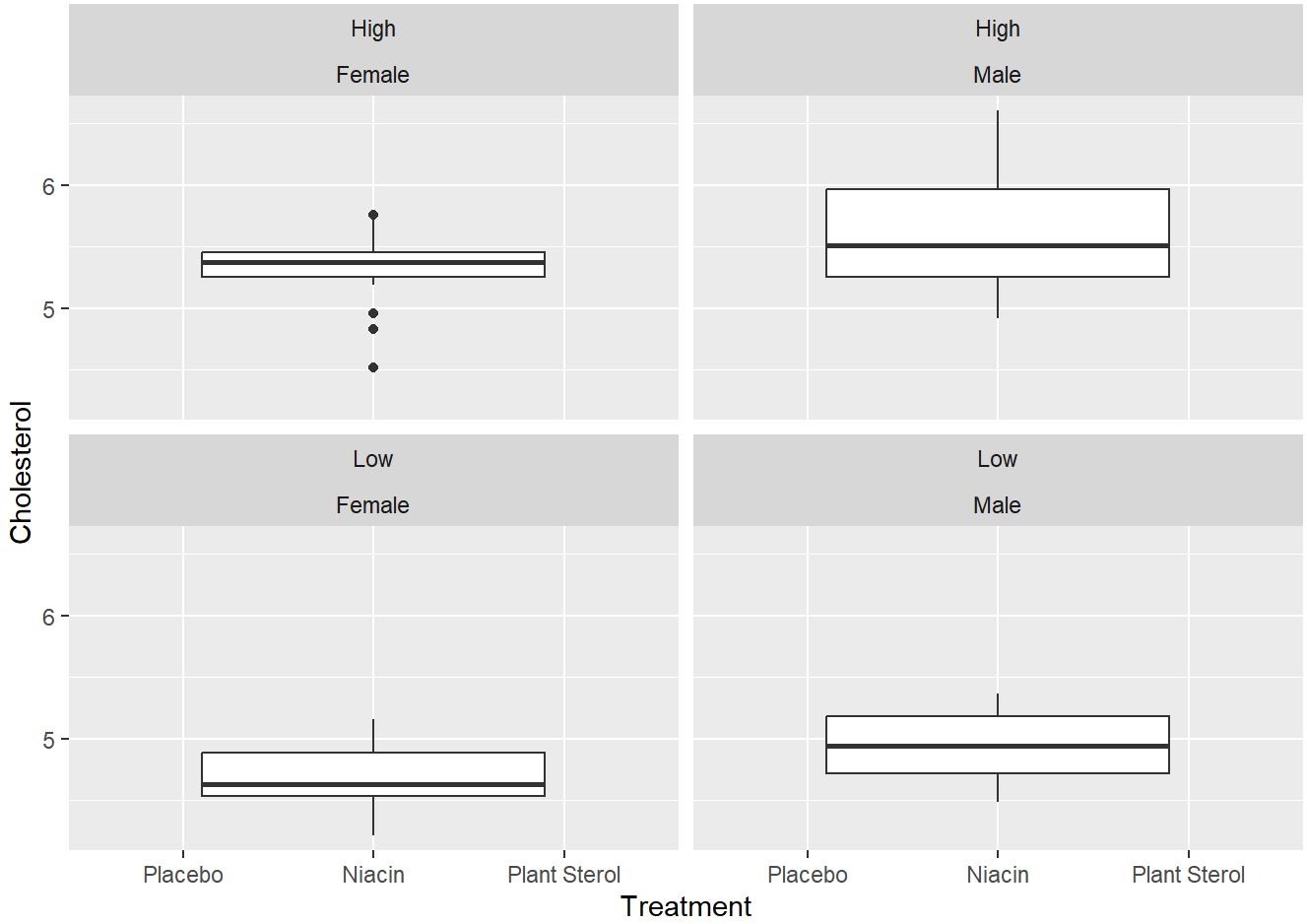
Factorial ANOVA | Boxplot

```
ggplot(data = dat,
       mapping = aes(y = cholesterol, x = gender)) +
  geom_boxplot() +
    labs(y = "Cholesterol",
         x = "Gender")
```



Factorial ANOVA | Boxplot

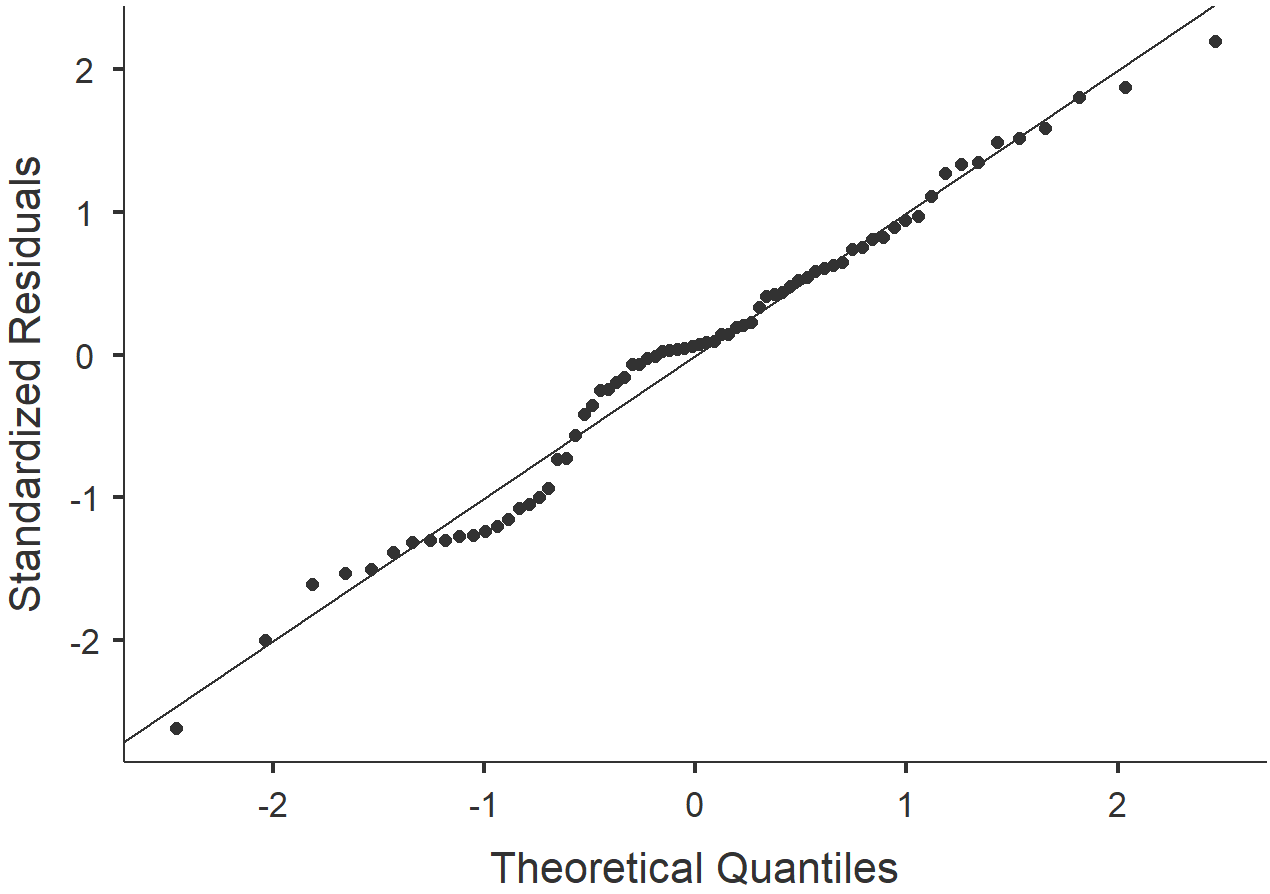
```
ggplot(data = dat,
       mapping = aes(y = cholesterol, x = drug, group = risk)) +
  geom_boxplot() +
    labs(y = "Cholesterol",
         x = "Treatment")+
  facet_wrap(c("risk", "gender"))
```



Factorial ANOVA | ANOVA() Omnibus Assumption Checks

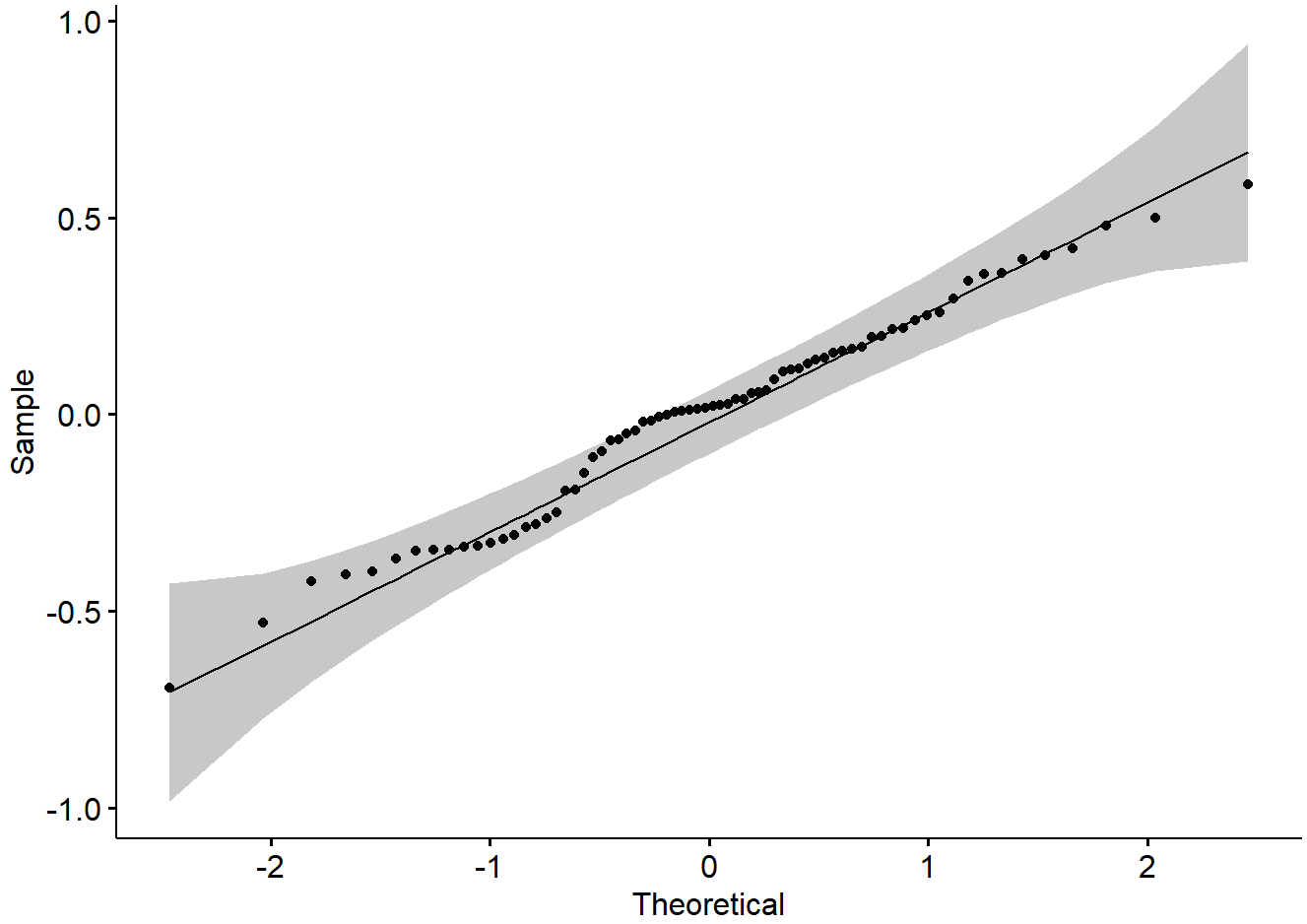
```
# Omnibus Assumption Checking
ANOVA(data = dat,
      dep = 'cholesterol',
      factors = c('gender','risk', 'drug'),
      homo = TRUE,
      norm = TRUE,
      qq = TRUE)
```

```
##
##  ANOVA
##
##  ANOVA - cholesterol
##  ──────────────────────────────────────────────────────────────────────────────────────
##                        Sum of Squares    df    Mean Square    F            p
##  ──────────────────────────────────────────────────────────────────────────────────────
##    gender                  1.36716034     1     1.36716034    16.1957462     0.0001625
##    risk                    7.82514647     1     7.82514647    92.6987735    < .0000001
##    drug                    1.23544044     2     0.61772022     7.3176786     0.0014328
##    gender:risk             0.01191333     1     0.01191333     0.1411285     0.7084867
##    gender:drug             0.56361259     2     0.28180629     3.3383526     0.0422001
##    risk:drug               0.12039494     2     0.06019747     0.7131153     0.4942214
##    gender:risk:drug        1.25039477     2     0.62519739     7.4062551     0.0013345
##    Residuals               5.06488673    60     0.08441478
##  ──────────────────────────────────────────────────────────────────────────────────────
##
##
##  ASSUMPTION CHECKS
##
##  Homogeneity of Variances Test (Levene's)
##  ──────────────────────────────────────────
##    F            df1    df2    p
##  ──────────────────────────────────────────
##    0.2370226     11     60    0.9937379
##  ──────────────────────────────────────────
##
##
##  Normality Test (Shapiro-Wilk)
##  ──────────────────────────────
##    Statistic    p
##  ──────────────────────────────
##    0.9821219    0.3980784
##  ──────────────────────────────
```



Factorial ANOVA | Group Level Assumption Checks

```
# Normality Assessment
model  <- lm(cholesterol ~ gender*risk*drug, data = dat)
# Create a QQ plot of residuals
ggqqplot(residuals(model))
```



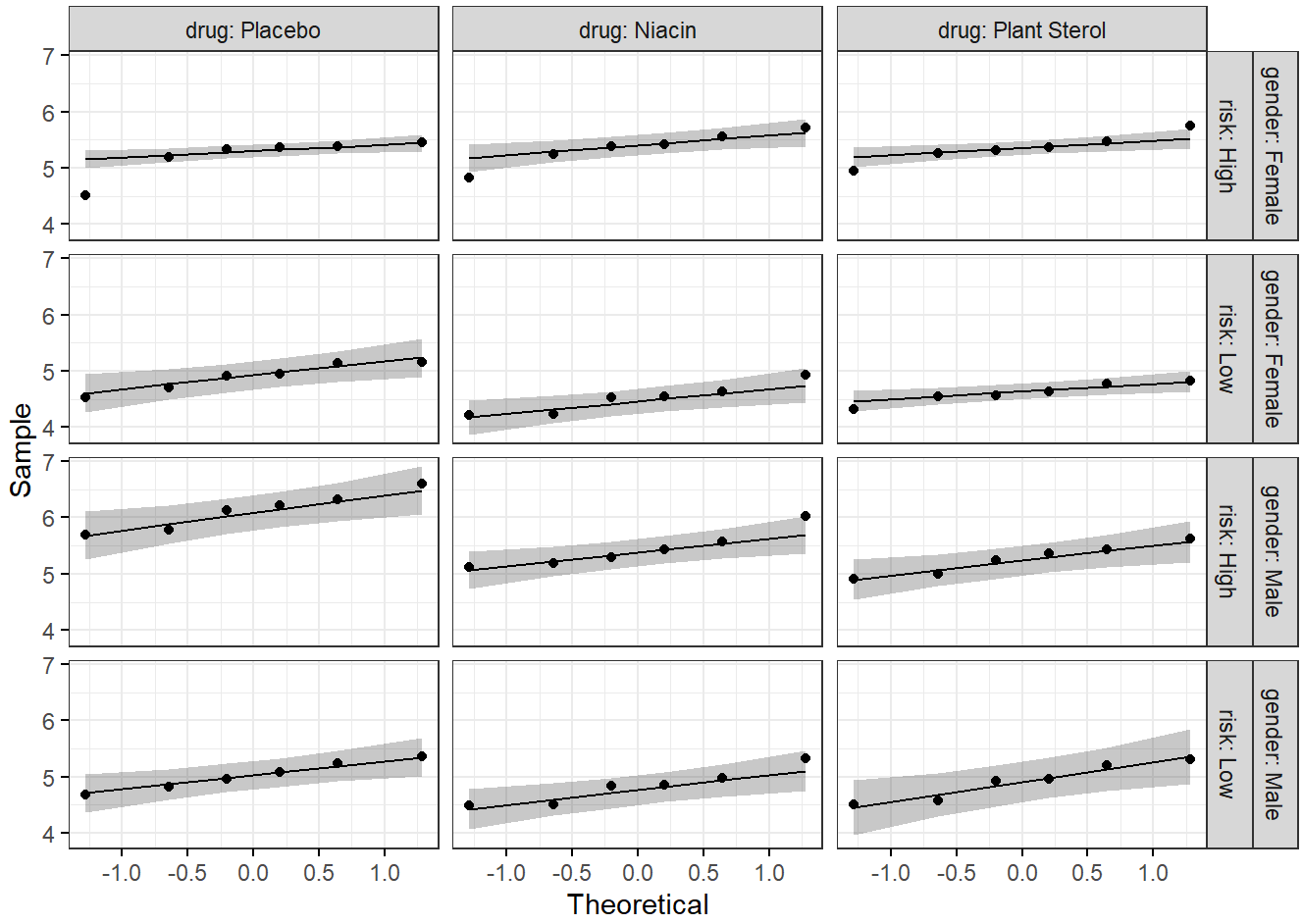

```
# Compute Shapiro-Wilk test of normality
shapiro_test(residuals(model))
```

```
## # A tibble: 1 × 3
##   variable         statistic p.value
##   <chr>                <dbl>   <dbl>
## 1 residuals(model)     0.982   0.398
```

```
# Normality by groups
dat %>%
  group_by(gender, risk, drug) %>%
  shapiro_test(cholesterol)
```

```
## # A tibble: 12 × 6
##    gender risk  drug         variable    statistic       p
##    <fct>  <fct> <fct>        <chr>           <dbl>   <dbl>
##  1 Female High  Placebo      cholesterol     0.714 0.00869
##  2 Female High  Niacin       cholesterol     0.939 0.654
##  3 Female High  Plant Sterol cholesterol     0.971 0.901
##  4 Female Low   Placebo      cholesterol     0.933 0.600
##  5 Female Low   Niacin       cholesterol     0.927 0.555
##  6 Female Low   Plant Sterol cholesterol     0.958 0.801
##  7 Male   High  Placebo      cholesterol     0.958 0.808
##  8 Male   High  Niacin       cholesterol     0.902 0.384
##  9 Male   High  Plant Sterol cholesterol     0.955 0.784
## 10 Male   Low   Placebo      cholesterol     0.982 0.962
## 11 Male   Low   Niacin       cholesterol     0.920 0.507
## 12 Male   Low   Plant Sterol cholesterol     0.924 0.535
```

```
ggqqplot(dat,
         "cholesterol",
         ggtheme = theme_bw()) +
  facet_grid(gender + risk ~ drug,
             labeller = "label_both")
```



```
dat %>%
  levene_test(cholesterol ~ gender*risk*drug,
              center = mean)
```

```
## # A tibble: 1 × 4
##     df1   df2 statistic     p
##   <int> <int>     <dbl> <dbl>
## 1    11    60     0.237 0.994
```

Factorial ANOVA | Conducting the ANOVA

```
# Between-Subject Factorial ANOVA (jmv)
ANOVA(data = dat,
      dep = 'cholesterol',
      factors = list('gender','risk','drug'),
      effectSize = 'partEta',
      postHoc = ~drug + drug:gender + gender:risk:drug,
      postHocCorr = 'bonf',
      postHocES = 'd',
      postHocEsCi = TRUE,
      emMeans = ~gender + risk + drug + drug:risk + drug:gender + drug:gender:risk,
      emmPlots = TRUE,
      emmPlotData = TRUE,
      emmTables = TRUE)
```

```
## NOTE: Results may be misleading due to involvement in interactions
## NOTE: Results may be misleading due to involvement in interactions
```

```
##
##  ANOVA
##
##  ANOVA - cholesterol
##  ──────────────────────────────────────────────────────────────────────────────────────────────
──────
##                       Sum of Squares    df    Mean Square    F            p             η²p
##  ──────────────────────────────────────────────────────────────────────────────────────────────
──────
##    gender                  1.36716034     1     1.36716034    16.1957462     0.0001625    0.2
125545
##    risk                    7.82514647     1     7.82514647    92.6987735    < .0000001    0.6
070695
##    drug                    1.23544044     2     0.61772022     7.3176786     0.0014328    0.1
960915
##    gender:risk             0.01191333     1     0.01191333     0.1411285     0.7084867    0.0
023466
##    gender:drug             0.56361259     2     0.28180629     3.3383526     0.0422001    0.1
001355
##    risk:drug               0.12039494     2     0.06019747     0.7131153     0.4942214    0.0
232186
##    gender:risk:drug        1.25039477     2     0.62519739     7.4062551     0.0013345    0.1
979951
##    Residuals               5.06488673    60     0.08441478
##  ──────────────────────────────────────────────────────────────────────────────────────────────
──────
##
##
##  POST HOC TESTS
##
##  Post Hoc Comparisons - drug
##  ──────────────────────────────────────────────────────────────────────────────────────────────
──────────────────────────────────────────────────────────
##    drug            drug            Mean Difference    SE            df          t
p-bonferroni    Cohen's d      Lower         Upper
##  ──────────────────────────────────────────────────────────────────────────────────────────────
──────────────────────────────────────────────────────────
##    Placebo    -    Niacin             0.277327333    0.08387231    60.00000    3.30654208
0.0047955    0.954516481     0.3513484    1.5576845
##               -    Plant Sterol       0.278421280    0.08387231    60.00000    3.31958509
0.0046104    0.958281672     0.3549146    1.5616488
##    Niacin     -    Plant Sterol       0.001093947    0.08387231    60.00000    0.01304300
1.0000000    0.003765190    -0.5736715    0.5812018
##  ──────────────────────────────────────────────────────────────────────────────────────────────
──────────────────────────────────────────────────────────
##    Note. Comparisons are based on estimated marginal means
##
##
##  Post Hoc Comparisons - drug:gender
##  ──────────────────────────────────────────────────────────────────────────────────────────────
──────────────────────────────────────────────────────────────────────────────
##    drug            gender         drug            gender    Mean Difference    SE           d
```

```
f          t             p-bonferroni    Cohen's d     Lower         Upper
##  ------------------------------------------------------------------------------------------------------------------------
##    Placebo         Female    -    Placebo         Male          -0.52080163    0.1186134    6
0.00000    -4.3907501       0.0006989    -1.7925162    -2.6722895    -0.9127430
##                              -    Niacin          Female         0.11506532    0.1186134    6
0.00000     0.9700874       1.0000000     0.3960365    -0.4237775     1.2158505
##                              -    Niacin          Male          -0.08121229    0.1186134    6
0.00000    -0.6846808       1.0000000    -0.2795198    -1.0977315     0.5386919
##                              -    Plant Sterol    Female         0.07287538    0.1186134    6
0.00000     0.6143943       1.0000000     0.2508254    -0.5670761     1.0687270
##                              -    Plant Sterol    Male          -0.03683445    0.1186134    6
0.00000    -0.3105422       1.0000000    -0.1267783    -0.9437245     0.6901679
##                    Male      -    Niacin          Female         0.63586696    0.1186134    6
0.00000     5.3608374       0.0000209    -2.1885527    -3.0977125    -1.2793929
##                              -    Niacin          Male           0.43958934    0.1186134    6
0.00000     3.7060693       0.0069153     1.5129965     0.6509099     2.3750830
##                              -    Plant Sterol    Female         0.59367701    0.1186134    6
0.00000     5.0051444       0.0000778    -2.0433416    -2.9411621    -1.1455212
##                              -    Plant Sterol    Male           0.48396718    0.1186134    6
0.00000     4.0802079       0.0020221     1.6657379     0.7943125     2.5371633
##    Niacin          Female    -    Niacin          Male          -0.19627761    0.1186134    6
0.00000    -1.6547681       1.0000000    -0.6755563    -1.5014390     0.1503265
##                              -    Plant Sterol    Female        -0.04218995    0.1186134    6
0.00000    -0.3556930       1.0000000    -0.1452111    -0.9622596     0.6718375
##                              -    Plant Sterol    Male          -0.15189977    0.1186134    6
0.00000    -1.2806295       1.0000000    -0.5228148    -1.3449943     0.2993647
##                    Male      -    Plant Sterol    Female         0.15408767    0.1186134    6
0.00000     1.2990751       1.0000000    -0.5303452    -1.3526855     0.2919951
##                              -    Plant Sterol    Male           0.04437784    0.1186134    6
0.00000     0.3741386       1.0000000     0.1527415    -0.6643529     0.9698358
##    Plant Sterol    Female    -    Plant Sterol    Male          -0.10970983    0.1186134    6
0.00000    -0.9249365       1.0000000    -0.3776037    -1.1971277     0.4419202
##  ------------------------------------------------------------------------------------------------------------------------

##    Note. Comparisons are based on estimated marginal means
##
##
##  Post Hoc Comparisons - gender:risk:drug
##  ------------------------------------------------------------------------------------------------------------------------

------

##    gender    risk    drug                gender    risk    drug            Mean Difference
SE           df          t              p-bonferroni    Cohen's d      Lower          Upper
##  ------------------------------------------------------------------------------------------------------------------------

------

##    Female    High    Placebo         -    Female    High    Niacin             -0.152597297
0.1677446    60.00000    -0.90970006       1.0000000    -0.52521558    -1.68406339     0.6336322
33
##                                      -    Female    High    Plant Sterol       -0.143339277
0.1677446    60.00000    -0.85450891       1.0000000    -0.49335095    -1.65173173     0.6650298
```

```
39
##                                 -    Female    Low     Placebo             0.311029527
0.1677446    60.00000     1.85418475       1.0000000     1.07051406    -0.10078515     2.2418132
77
##                                 -    Female    Low     Niacin              0.693757470
0.1677446    60.00000     4.13579550       0.0073757     2.38780265     1.15336332     3.6222419
71
##                                 -    Female    Low     Plant Sterol        0.600119557
0.1677446    60.00000     3.57757843       0.0457658     2.06551587     0.85061477     3.2804169
70
##                                 -    Male      High    Placebo            -0.916397433
0.1677446    60.00000    -5.46305091       0.0000626    -3.15409391    -4.44461300    -1.8635748
28
##                                 -    Male      High    Niacin             -0.229630167
0.1677446    60.00000    -1.36892711       1.0000000    -0.79035044    -1.95420543     0.3735045
60
##                                 -    Male      High    Plant Sterol       -0.053877474
0.1677446    60.00000    -0.32118748       1.0000000    -0.18543768    -1.34080647     0.9699311
10
##                                 -    Male      Low     Placebo             0.185823694
0.1677446    60.00000     1.10777733       1.0000000     0.63957554    -0.52118703     1.8003381
13
##                                 -    Male      Low     Niacin              0.378235115
0.1677446    60.00000     2.25482701       1.0000000     1.30182498     0.12274106     2.4809089
05
##                                 -    Male      Low     Plant Sterol        0.291238102
0.1677446    60.00000     1.73619930       1.0000000     1.00239513    -0.16689253     2.1716827
92
##                     Niacin      -    Female    High    Plant Sterol        0.009258020
0.1677446    60.00000     0.05519116       1.0000000     0.03186463    -1.12302252     1.1867517
72
##                                 -    Female    Low     Placebo             0.463626824
0.1677446    60.00000     2.76388481       0.4999228    -1.59572964    -2.78679394    -0.4046653
35
##                                 -    Female    Low     Niacin              0.846354767
0.1677446    60.00000     5.04549556       0.0002954     2.91301822     1.64153462     4.1845018
21
##                                 -    Female    Low     Plant Sterol        0.752716854
0.1677446    60.00000     4.48727850       0.0021949     2.59073145     1.34272234     3.8387405
60
##                                 -    Male      High    Placebo            -0.763800136
0.1677446    60.00000    -4.55335085       0.0017395     2.62887834     1.37821220     3.8795444
72
##                                 -    Male      High    Niacin             -0.077032870
0.1677446    60.00000    -0.45922705       1.0000000    -0.26513486    -1.42102169     0.8907519
73
##                                 -    Male      High    Plant Sterol        0.098719823
0.1677446    60.00000     0.58851258       1.0000000     0.33977790    -0.81676000     1.4963157
94
##                                 -    Male      Low     Placebo             0.338420991
0.1677446    60.00000     2.01747739       1.0000000    -1.16479112    -2.33908603     0.0095037
96
```

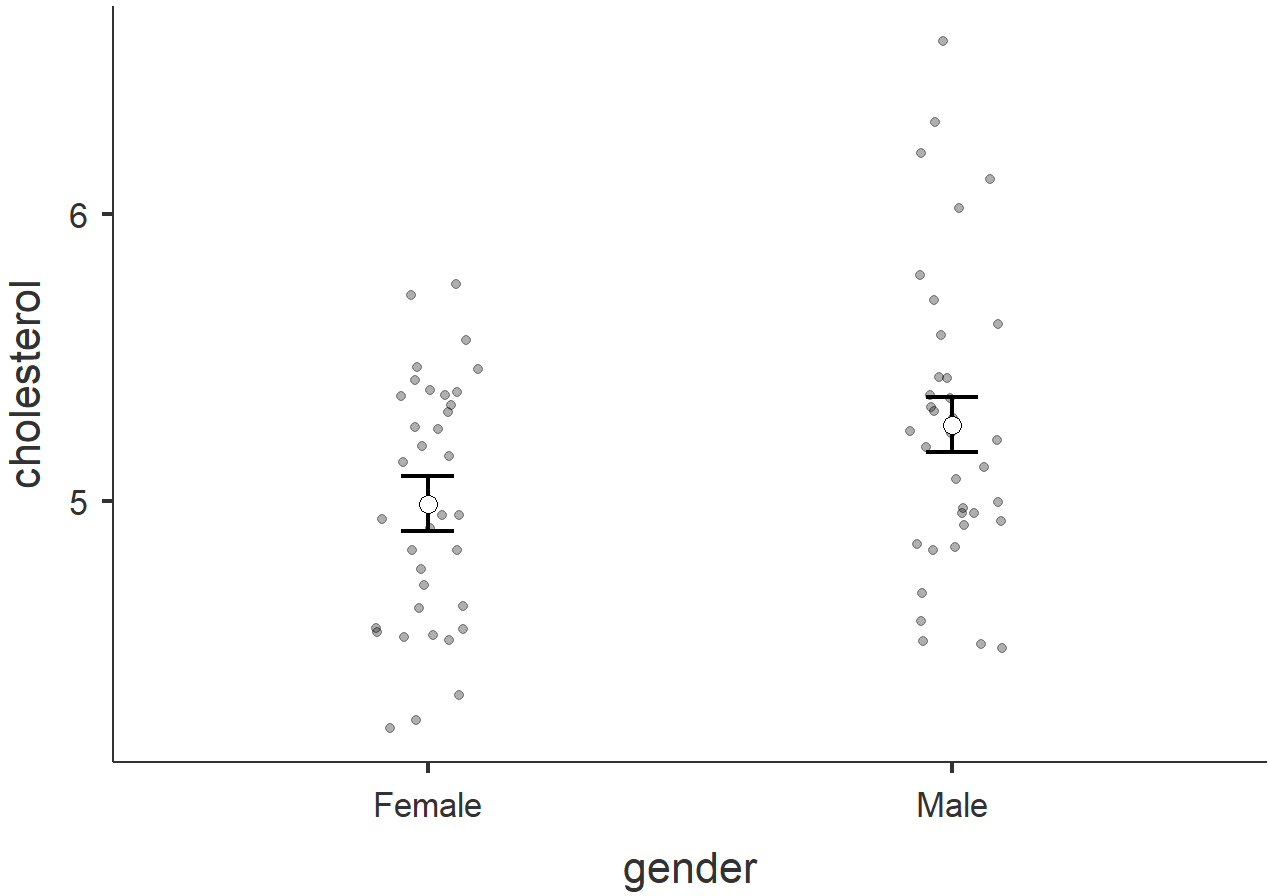
```
##                                    -    Male      Low     Niacin              0.530832412
0.1677446    60.00000     3.16452708       0.1610111     1.82704056     0.62494537     3.0291357
47
##                                    -    Male      Low     Plant Sterol        0.443835399
0.1677446    60.00000     2.64589936       0.6855981     1.52761071     0.33952817     2.7156932
42
##                     Plant Sterol   -    Female    Low     Placebo             0.454368805
0.1677446    60.00000     2.70869365       0.5801251    -1.56386501    -2.75351925    -0.3742107
76
##                                    -    Female    Low     Niacin              0.837096748
0.1677446    60.00000     4.99030441       0.0003616    -2.88115359    -4.15021404    -1.6120931
51
##                                    -    Female    Low     Plant Sterol        0.743458835
0.1677446    60.00000     4.43208734       0.0026626     2.55886682     1.31305165     3.8046819
94
##                                    -    Male      High    Placebo            -0.773058155
0.1677446    60.00000    -4.60854200       0.0014309     2.66074296     1.40783201     3.9136539
15
##                                    -    Male      High    Niacin             -0.086290889
0.1677446    60.00000    -0.51441820       1.0000000     0.29699949    -0.85914567     1.4531446
46
##                                    -    Male      High    Plant Sterol        0.089461803
0.1677446    60.00000     0.53332143       1.0000000     0.30791327    -0.84832708     1.4641536
22
##                                    -    Male      Low     Placebo             0.329162972
0.1677446    60.00000     1.96228624       1.0000000    -1.13292649    -2.30618148     0.0403285
07
##                                    -    Male      Low     Niacin              0.521574392
0.1677446    60.00000     3.10933592       0.1892139    -1.79517593    -2.99566931    -0.5946825
57
##                                    -    Male      Low     Plant Sterol        0.434577379
0.1677446    60.00000     2.59070820       0.7924411     1.49574608     0.30901617     2.6824759
90
##              Low     Placebo       -    Female    Low     Niacin              0.382727943
0.1677446    60.00000     2.28161075       1.0000000     1.31728858     0.13763214     2.4969450
27
##                                    -    Female    Low     Plant Sterol        0.289090030
0.1677446    60.00000     1.72339369       1.0000000     0.99500181    -0.17407528     2.1640788
99
##                                    -    Male      High    Placebo            -1.227426960
0.1677446    60.00000    -7.31723566    < .0000001     4.22460798     2.83578903     5.613426922
##                                    -    Male      High    Niacin             -0.540659694
0.1677446    60.00000    -3.22311186       0.1354170    -1.86086450    -3.06468843    -0.6570405
67
##                                    -    Male      High    Plant Sterol       -0.364907001
0.1677446    60.00000    -2.17537223       1.0000000    -1.25595174    -2.43337546    -0.0785280
23
##                                    -    Male      Low     Placebo            -0.125205833
0.1677446    60.00000    -0.74640742       1.0000000    -0.43093852    -1.58848877     0.7266117
22
##                                    -    Male      Low     Niacin              0.067205587
0.1677446    60.00000     0.40064227       1.0000000     0.23131092    -0.92433370     1.3869555
```

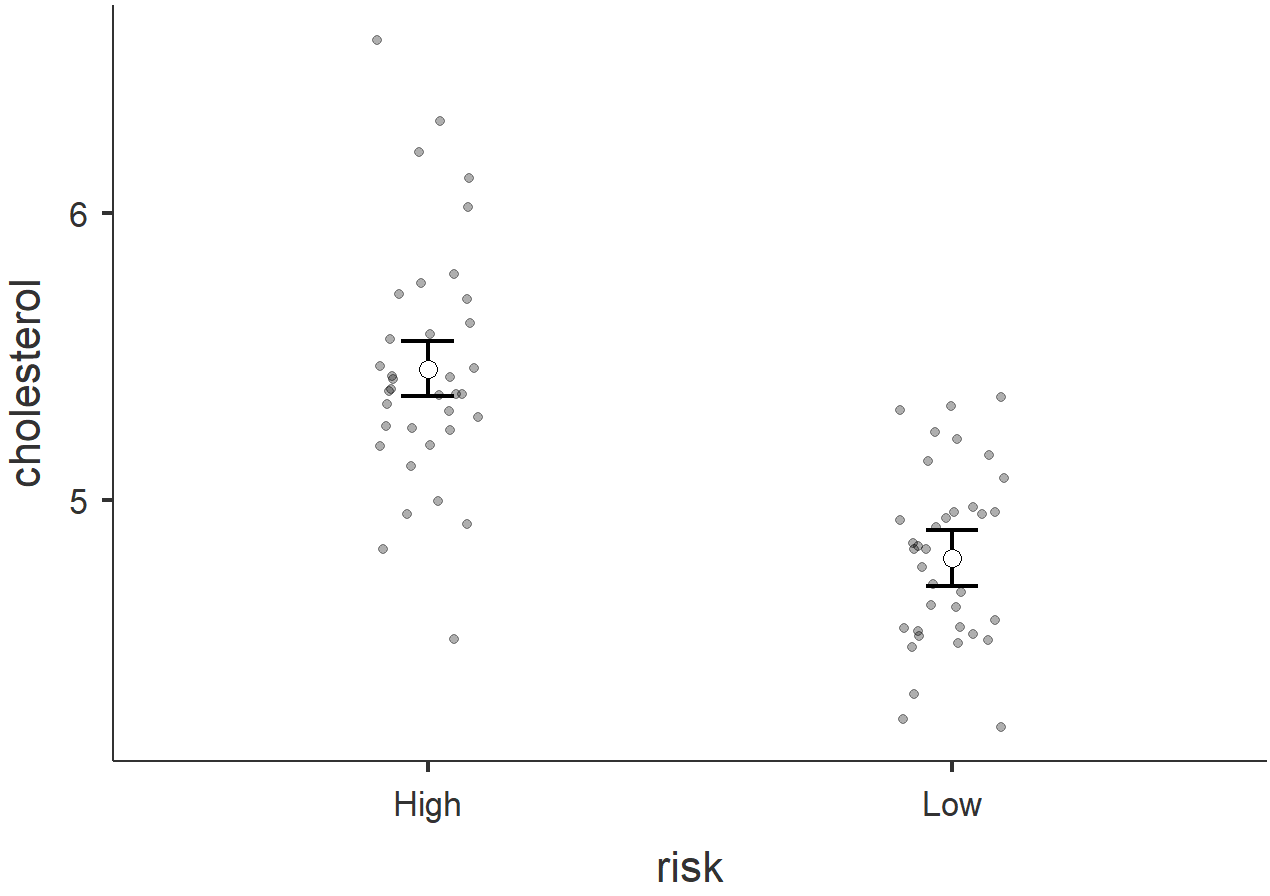
```
38
##                                   -    Male      Low     Plant Sterol       -0.019791425
0.1677446    60.00000    -0.11798545       1.0000000    -0.06811893    -1.22305840     1.0868205
38
##                     Niacin        -    Female    Low     Plant Sterol       -0.093637913
0.1677446    60.00000    -0.55821707       1.0000000    -0.32228677    -1.47865773     0.8340841
81
##                                   -    Male      High    Placebo            -1.610154903
0.1677446    60.00000    -9.59884641    < .0000001     5.54189656     4.00638710     7.077406015
##                                   -    Male      High    Niacin             -0.923387637
0.1677446    60.00000    -5.50472261       0.0000535     3.17815308     1.88566737     4.4706387
91
##                                   -    Male      High    Plant Sterol       -0.747634944
0.1677446    60.00000    -4.45698298       0.0024407    -2.57324032    -3.82004226    -1.3264383
92
##                                   -    Male      Low     Placebo            -0.507933776
0.1677446    60.00000    -3.02801817       0.2392865     1.74822711     0.55004623     2.9464079
77
##                                   -    Male      Low     Niacin             -0.315522356
0.1677446    60.00000    -1.88096849       1.0000000    -1.08597766    -2.25775142     0.0857961
01
##                                   -    Male      Low     Plant Sterol       -0.402519368
0.1677446    60.00000    -2.39959620       1.0000000    -1.38540751    -2.56766298    -0.2031520
51
##                     Plant Sterol  -    Male      High    Placebo            -1.516516990
0.1677446    60.00000    -9.04062934    < .0000001     5.21960979     3.72223036     6.716989214
##                                   -    Male      High    Niacin             -0.829749724
0.1677446    60.00000    -4.94650555       0.0004243     2.85586631     1.58871313     4.1230194
88
##                                   -    Male      High    Plant Sterol       -0.653997031
0.1677446    60.00000    -3.89876592       0.0162708     2.25095355     1.02511758     3.4767895
21
##                                   -    Male      Low     Placebo            -0.414295863
0.1677446    60.00000    -2.46980110       1.0000000     1.42594033     0.24207906     2.6098016
02
##                                   -    Male      Low     Niacin             -0.221884443
0.1677446    60.00000    -1.32275142       1.0000000     0.76369089    -0.39957049     1.9269522
70
##                                   -    Male      Low     Plant Sterol       -0.308881455
0.1677446    60.00000    -1.84137914       1.0000000    -1.06312074    -2.23419541     0.1079539
23
##    Male      High    Placebo        -    Male      High    Niacin              0.686767266
0.1677446    60.00000     4.09412380       0.0084900     2.36374348     1.13084903     3.5966379
17
##                                   -    Male      High    Plant Sterol        0.862519959
0.1677446    60.00000     5.14186343       0.0002072     2.96865623     1.69288903     4.2444234
34
##                                   -    Male      Low     Placebo             1.102221127
0.1677446    60.00000     6.57082824       0.0000009     3.79366945     2.44696820     5.1403707
10
##                                   -    Male      Low     Niacin              1.294632547
0.1677446    60.00000     7.71787792    < .0000001     4.45591890     3.04320236     5.868635437
```

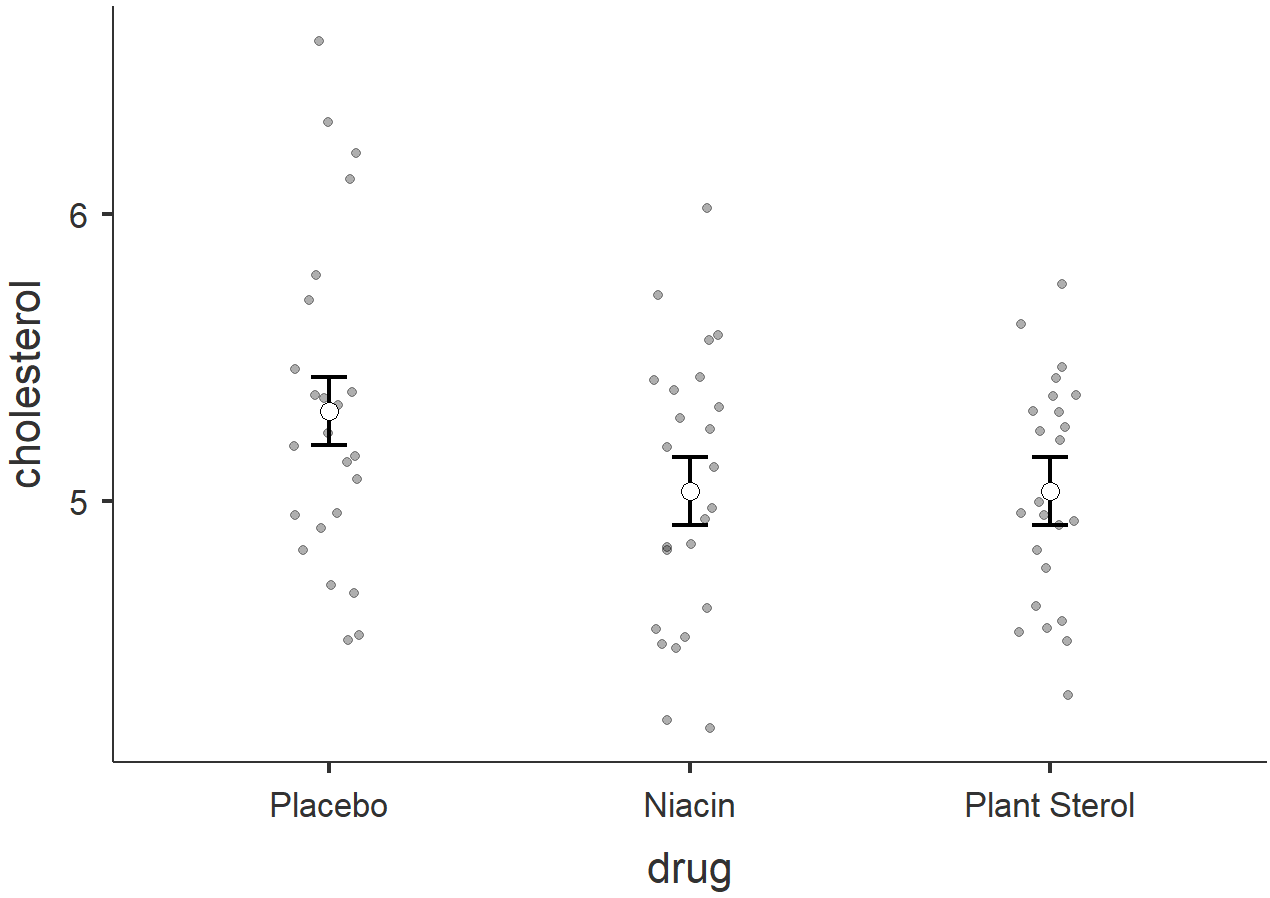
```
##                                   -    Male      Low     Plant Sterol        1.207635535
0.1677446    60.00000     7.19925020    < .0000001     4.15648904     2.77454041     5.538437675
##                      Niacin       -    Male      High    Plant Sterol        0.175752693
0.1677446    60.00000     1.04773963       1.0000000     0.60491276    -0.55523008     1.7650555
97
##                                   -    Male      Low     Placebo             0.415453861
0.1677446    60.00000     2.47670444       1.0000000    -1.42992598    -2.61394753    -0.2459044
25
##                                   -    Male      Low     Niacin              0.607865281
0.1677446    60.00000     3.62375413       0.0395561     2.09217542     0.87575423     3.3085966
12
##                                   -    Male      Low     Plant Sterol        0.520868269
0.1677446    60.00000     3.10512641       0.1915447     1.79274557     0.59237330     2.9931178
39
##                      Plant Sterol -    Male      Low     Placebo             0.239701168
0.1677446    60.00000     1.42896481       1.0000000    -0.82501322    -1.98967001     0.3396435
73
##                                   -    Male      Low     Niacin              0.432112589
0.1677446    60.00000     2.57601450       0.8233307    -1.48726266    -2.67363701    -0.3008883
14
##                                   -    Male      Low     Plant Sterol        0.345115576
0.1677446    60.00000     2.05738678       1.0000000     1.18783281     0.01276855     2.3628970
75
##              Low      Placebo      -    Male      Low     Niacin              0.192411420
0.1677446    60.00000     1.14704968       1.0000000     0.66224944    -0.49893700     1.8234358
87
##                                   -    Male      Low     Plant Sterol        0.105414408
0.1677446    60.00000     0.62842197       1.0000000     0.36281959    -0.79395165     1.5195908
31
##                      Niacin       -    Male      Low     Plant Sterol       -0.086997013
0.1677446    60.00000    -0.51862772       1.0000000    -0.29942985    -1.45559591     0.8567362
07
##  ------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------
------
##    Note. Comparisons are based on estimated marginal means
##
##
##  ESTIMATED MARGINAL MEANS
##
##  GENDER
##
##  Estimated Marginal Means - gender
##  ---------------------------------------------------------------
##    gender    Mean        SE            Lower       Upper
##  ---------------------------------------------------------------
##    Female    4.991067    0.04842370    4.894205    5.087929
##    Male      5.266663    0.04842370    5.169802    5.363525
##  ---------------------------------------------------------------
##
##
##  RISK
```

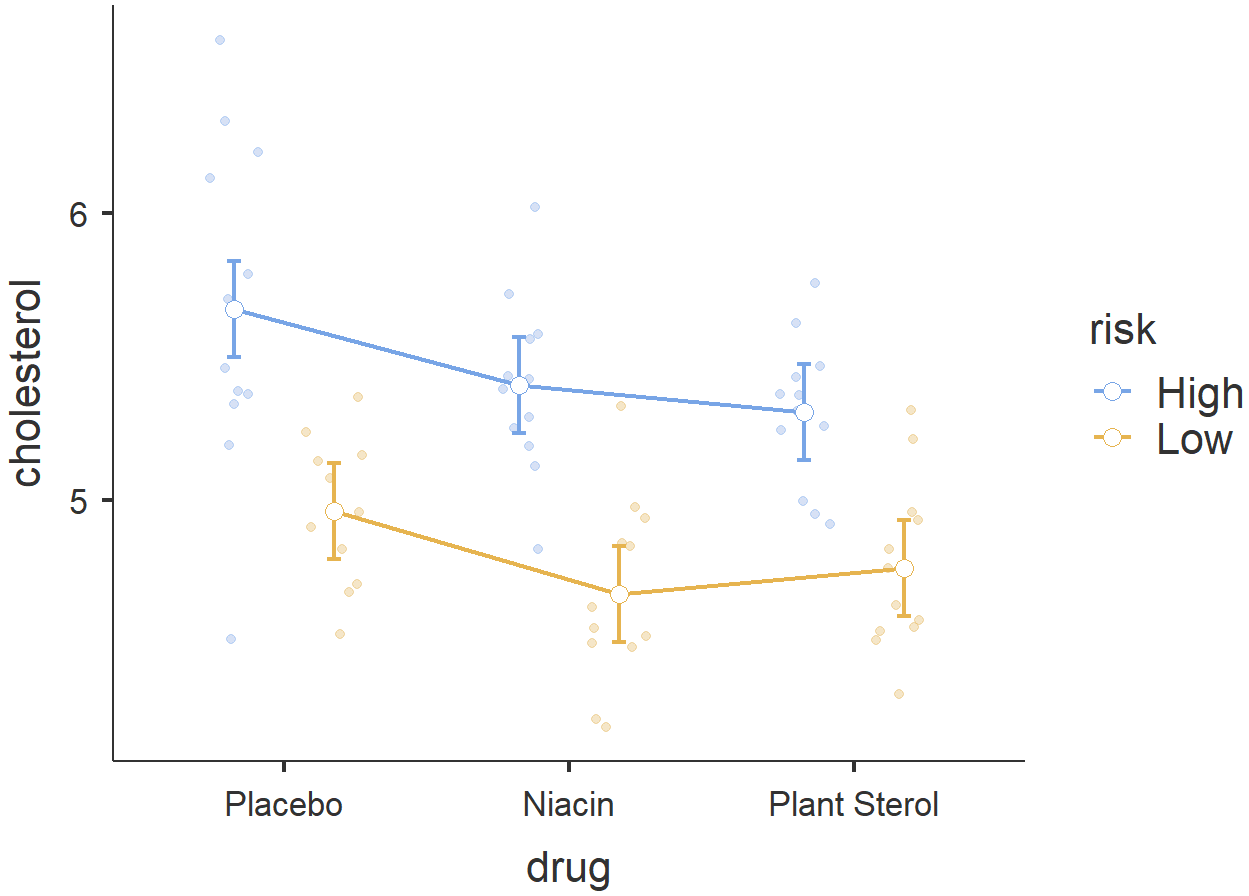
```
##
##  Estimated Marginal Means - risk
##  ──────────────────────────────────────────────────────────────
##    risk    Mean        SE            Lower       Upper
##  ──────────────────────────────────────────────────────────────
##    High    5.458536    0.04842370    5.361674    5.555397
##    Low     4.799195    0.04842370    4.702333    4.896057
##  ──────────────────────────────────────────────────────────────
##
##
##  DRUG
##
##  Estimated Marginal Means - drug
##  ──────────────────────────────────────────────────────────────────────
##    drug            Mean        SE            Lower       Upper
##  ──────────────────────────────────────────────────────────────────────
##    Placebo         5.314115    0.05930668    5.195484    5.432746
##    Niacin          5.036787    0.05930668    4.918156    5.155418
##    Plant Sterol    5.035693    0.05930668    4.917062    5.154325
##  ──────────────────────────────────────────────────────────────────────
##
##
##  DRUG:RISK
##
##  Estimated Marginal Means - drug:risk
##  ──────────────────────────────────────────────────────────────────────────────
##    risk    drug            Mean        SE            Lower       Upper
##  ──────────────────────────────────────────────────────────────────────────────
##    High    Placebo         5.667427    0.08387231    5.499658    5.835197
##            Niacin          5.400342    0.08387231    5.232573    5.568112
##            Plant Sterol    5.307837    0.08387231    5.140067    5.475607
##    Low     Placebo         4.960802    0.08387231    4.793033    5.128572
##            Niacin          4.673232    0.08387231    4.505463    4.841002
##            Plant Sterol    4.763550    0.08387231    4.595780    4.931320
##  ──────────────────────────────────────────────────────────────────────────────
##
##
##  DRUG:GENDER
##
##  Estimated Marginal Means - drug:gender
##  ──────────────────────────────────────────────────────────────────────────────
##    gender    drug            Mean        SE            Lower       Upper
##  ──────────────────────────────────────────────────────────────────────────────
##    Female    Placebo         5.053714    0.08387231    4.885944    5.221484
##              Niacin          4.938649    0.08387231    4.770879    5.106418
##              Plant Sterol    4.980839    0.08387231    4.813069    5.148608
##    Male      Placebo         5.574516    0.08387231    5.406746    5.742285
##              Niacin          5.134926    0.08387231    4.967157    5.302696
##              Plant Sterol    5.090548    0.08387231    4.922779    5.258318
##  ──────────────────────────────────────────────────────────────────────────────
##
##
```

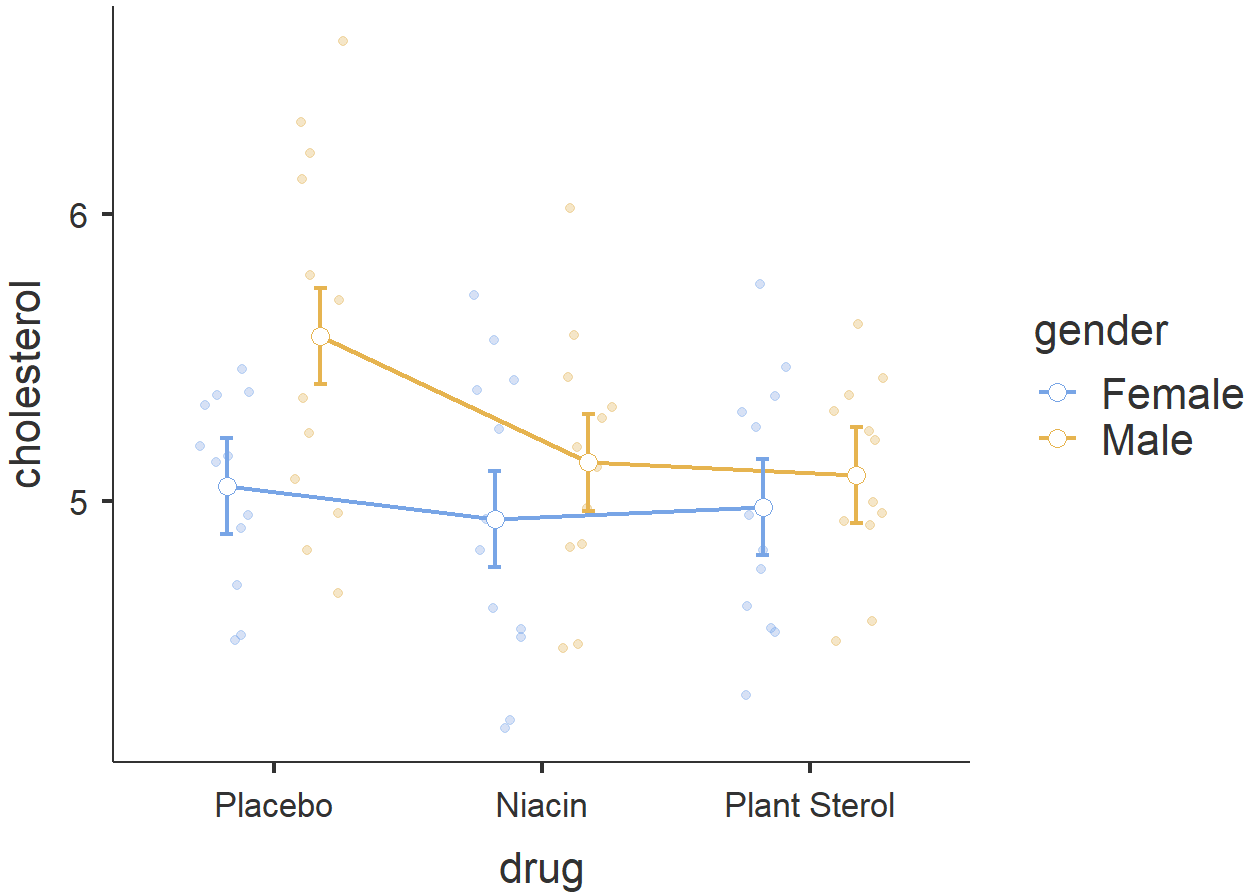
```
##  DRUG:GENDER:RISK
##
##  Estimated Marginal Means - drug:gender:risk
##  ──────────────────────────────────────────────────────────────────────────────
##    risk    gender    drug           Mean       SE          Lower      Upper
##  ──────────────────────────────────────────────────────────────────────────────
##    High    Female    Placebo        5.209229   0.1186134   4.971967   5.446491
##                      Niacin         5.361826   0.1186134   5.124564   5.599088
##                      Plant Sterol   5.352568   0.1186134   5.115306   5.589830
##            Male      Placebo        6.125626   0.1186134   5.888364   6.362888
##                      Niacin         5.438859   0.1186134   5.201597   5.676121
##                      Plant Sterol   5.263106   0.1186134   5.025844   5.500368
##    Low     Female    Placebo        4.898199   0.1186134   4.660937   5.135461
##                      Niacin         4.515471   0.1186134   4.278209   4.752733
##                      Plant Sterol   4.609109   0.1186134   4.371847   4.846371
##            Male      Placebo        5.023405   0.1186134   4.786143   5.260667
##                      Niacin         4.830994   0.1186134   4.593732   5.068256
##                      Plant Sterol   4.917991   0.1186134   4.680729   5.155253
##  ──────────────────────────────────────────────────────────────────────────────
```

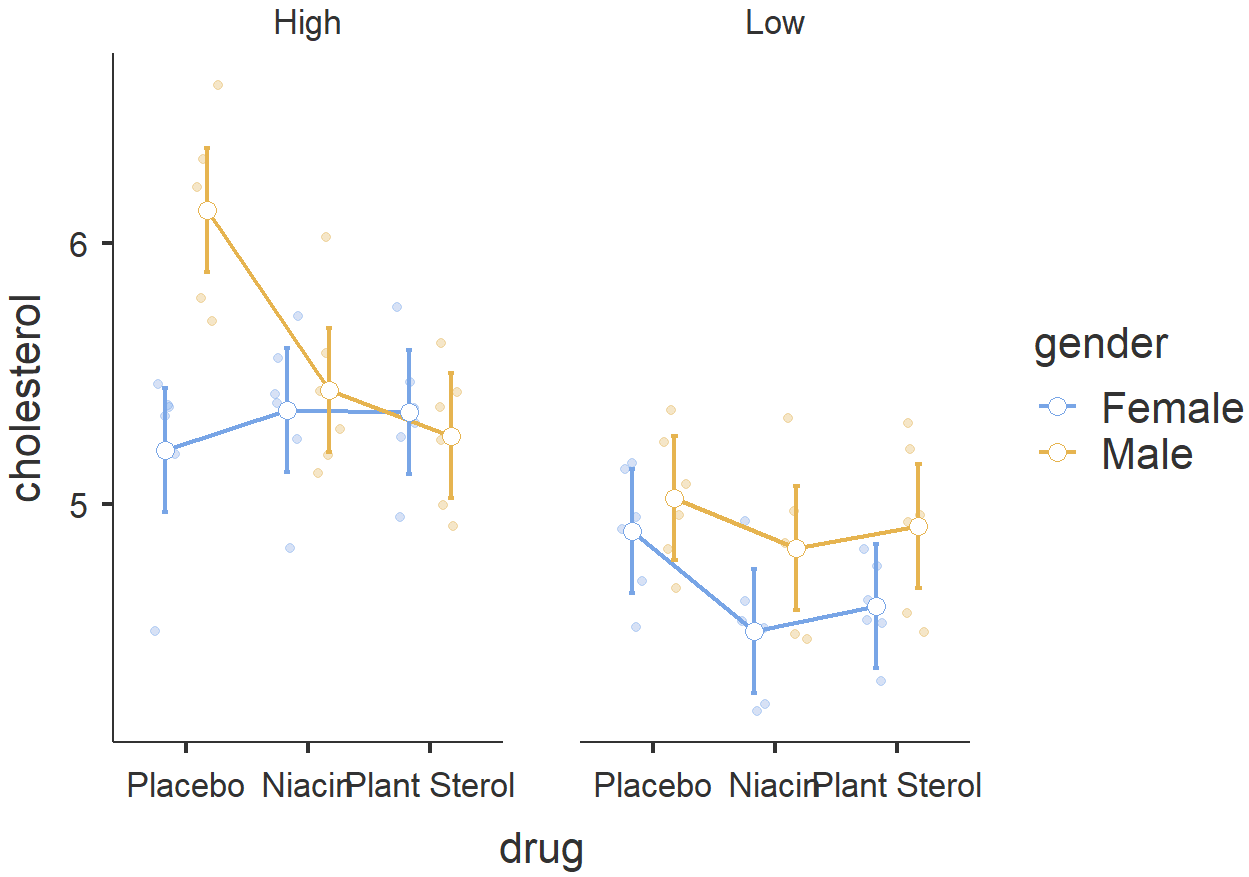

cholesterol
6
5
Female
Male
gender


cholesterol
6
5
High
Low
risk


cholesterol
6
5
Placebo
Niacin
Plant Sterol
drug


cholesterol
6
5
Placebo
Niacin
Plant Sterol
drug
risk
High
Low


cholesterol
6
5
Placebo
Niacin
Plant Sterol
drug
gender
Female
Male


High
Low
cholesterol
6
5
Placebo
Niacin
Plant Sterol
drug
gender
Female
Male

```
# Simple two-way interaction effect check Risk and Drug across Gender
model <- lm(cholesterol~drug*gender*risk, dat)

sie.check <- dat %>%
  group_by(risk) %>%
  anova_test(dv = cholesterol,
             between = c(gender,drug),
             error = model)%>%
  get_anova_table() %>%
  adjust_pvalue(method = "bonferroni")
sie.check
```

```
## # A tibble: 6 × 9
##   risk  Effect        DFn   DFd      F       p `p<.05`   ges   p.adj
##   <fct> <chr>       <dbl> <dbl>  <dbl>   <dbl> <chr>   <dbl>   <dbl>
## 1 High  gender          1    60  9.68  0.003   "*"     0.139 0.018
## 2 High  drug            2    60  4.96  0.01    "*"     0.142 0.06
## 3 High  gender:drug     2    60 10.3   0.00014 "*"     0.256 0.00084
## 4 Low   gender          1    60  6.66  0.012   "*"     0.1   0.072
## 5 Low   drug            2    60  3.07  0.054   ""      0.093 0.324
## 6 Low   gender:drug     2    60  0.415 0.662   ""      0.014 1
```

```
# Simple simple main effects
ssme.check <- dat %>%
  group_by(gender,risk) %>%
  anova_test(dv = cholesterol,
             between = drug,
             error = model)%>%
  get_anova_table() %>%
  adjust_pvalue(method = "bonferroni")
ssme.check
```

```
## # A tibble: 4 × 10
##   gender risk  Effect   DFn   DFd     F         p `p<.05`   ges     p.adj
##   <fct>  <fct> <chr>  <dbl> <dbl> <dbl>     <dbl> <chr>   <dbl>     <dbl>
## 1 Female High  drug       2    60  0.52 0.597     ""      0.017 1
## 2 Female Low   drug       2    60  2.83 0.067     ""      0.086 0.268
## 3 Male   High  drug       2    60 14.8  0.0000061 "*"     0.33  0.0000244
## 4 Male   Low   drug       2    60  0.66 0.521     ""      0.022 1
```

Factorial ANOVA Visualization

```
pwc <- dat %>%
  group_by(gender, risk) %>%
  emmeans_test(cholesterol ~ drug, p.adjust.method = "bonferroni")
pwc
```

```
## # A tibble: 12 × 11
##    gender risk  term  .y.         group1  group2    df statistic       p   p.adj
##  * <fct>  <fct> <chr> <chr>       <chr>   <chr>  <dbl>     <dbl>   <dbl>   <dbl>
##  1 Female High  drug  cholesterol Placebo Niacin    60   -0.910  3.67e-1 1   e+0
##  2 Female High  drug  cholesterol Placebo Plant…    60   -0.855  3.96e-1 1   e+0
##  3 Female High  drug  cholesterol Niacin  Plant…    60    0.0552 9.56e-1 1   e+0
##  4 Female Low   drug  cholesterol Placebo Niacin    60    2.28   2.61e-2 7.82e-2
##  5 Female Low   drug  cholesterol Placebo Plant…    60    1.72   9.00e-2 2.70e-1
##  6 Female Low   drug  cholesterol Niacin  Plant…    60   -0.558  5.79e-1 1   e+0
##  7 Male   High  drug  cholesterol Placebo Niacin    60    4.09   1.29e-4 3.86e-4
##  8 Male   High  drug  cholesterol Placebo Plant…    60    5.14   3.14e-6 9.42e-6
##  9 Male   High  drug  cholesterol Niacin  Plant…    60    1.05   2.99e-1 8.97e-1
## 10 Male   Low   drug  cholesterol Placebo Niacin    60    1.15   2.56e-1 7.68e-1
## 11 Male   Low   drug  cholesterol Placebo Plant…    60    0.628  5.32e-1 1   e+0
## 12 Male   Low   drug  cholesterol Niacin  Plant…    60   -0.519  6.06e-1 1   e+0
## # ℹ 1 more variable: p.adj.signif <chr>
```

```
pwc %>% filter(gender == "Male", risk == "High")
```

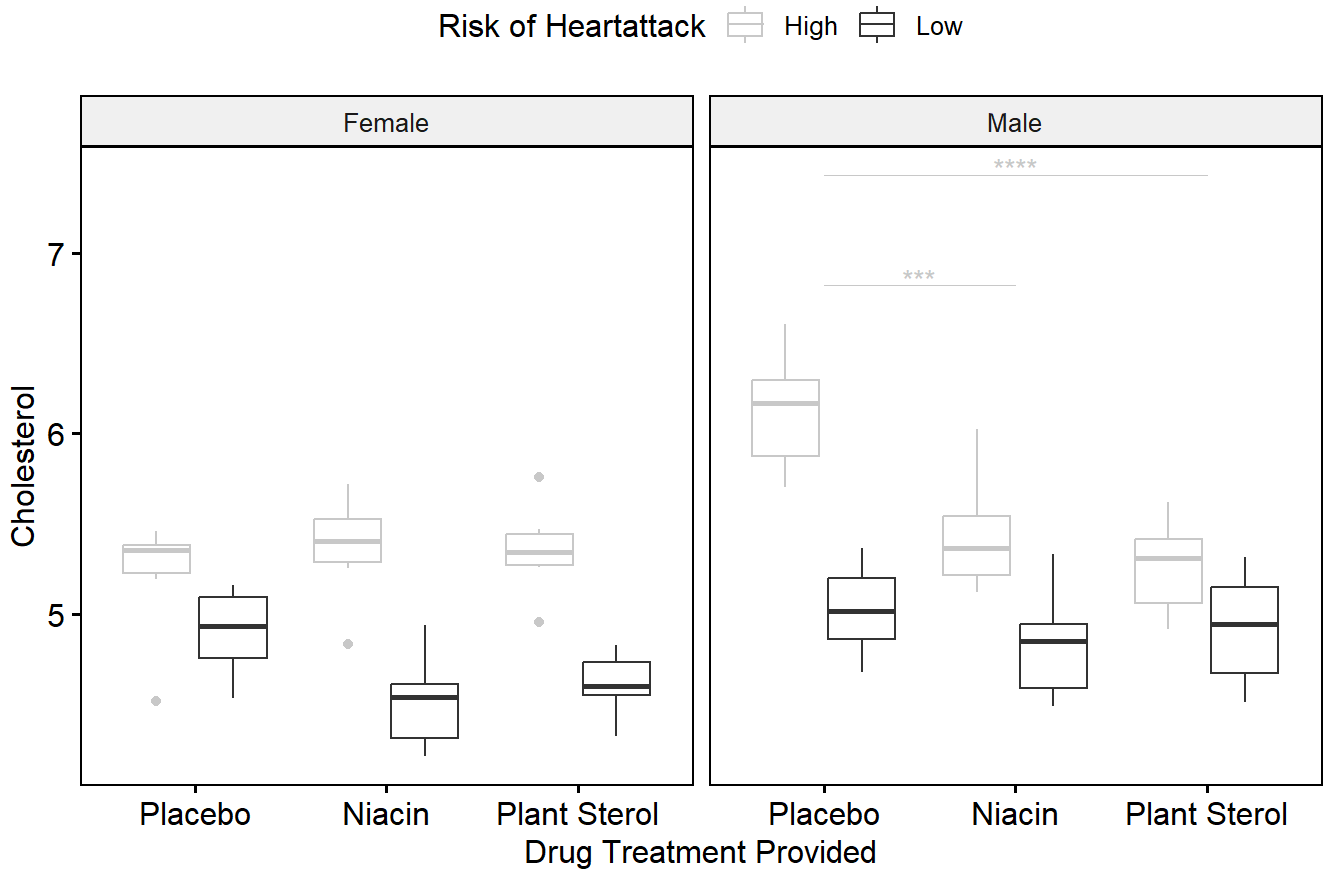
```
## # A tibble: 3 × 11
##   gender risk  term  .y.         group1  group2     df statistic       p   p.adj
##   <fct>  <fct> <chr> <chr>       <chr>   <chr>   <dbl>     <dbl>   <dbl>   <dbl>
## 1 Male   High  drug  cholesterol Placebo Niacin     60      4.09 1.29e-4 3.86e-4
## 2 Male   High  drug  cholesterol Placebo Plant …    60      5.14 3.14e-6 9.42e-6
## 3 Male   High  drug  cholesterol Niacin  Plant …    60      1.05 2.99e-1 8.97e-1
## # ℹ 1 more variable: p.adj.signif <chr>
```

```
get_emmeans(pwc) %>% filter(gender == "Male", risk == "High")
```

```
## # A tibble: 3 × 9
##   gender risk  drug         emmean    se    df conf.low conf.high method
##   <fct>  <fct> <fct>         <dbl> <dbl> <dbl>    <dbl>     <dbl> <chr>
## 1 Male   High  Placebo        6.13 0.119    60     5.89      6.36 Emmeans test
## 2 Male   High  Niacin         5.44 0.119    60     5.20      5.68 Emmeans test
## 3 Male   High  Plant Sterol   5.26 0.119    60     5.03      5.50 Emmeans test
```

```
pwc <- pwc %>% add_xy_position(x = "drug")
pwc.filtered <- pwc %>% filter(gender == "Male", risk == "High")

ggboxplot(dat,
          x = "drug",
          y = "cholesterol",
          color = "risk",
          palette = "grey",
          facet.by = "gender") +
  stat_pvalue_manual(pwc.filtered,
                     color = "risk",
                     hide.ns = TRUE,
                     tip.length = 0,
                     step.increase = 0.1,
                     step.group.by = "gender") +
  labs(x = "Drug Treatment Provided",
       y = "Cholesterol",
       color = "Risk of Heartattack",
       caption = get_pwc_label(pwc))
```



pwc: **Emmeans test**; p.adjust: **Bonferroni**