Systolic Blood Pressure Case Study

MAS II Sample Questions Supplemental Material

A. Case Study Description

This is a hierarchical modeling problem.

The modeling problem is to evaluate the effect of a variety of treatments which are given in different hospitals with different doctors. The treatment result is recorded at the patient level of detail and the outcome at the end of the time period is known for all patients that entered the study with a uniform beginning and ending time period for all patients.

The treatment affects systolic blood pressure. The hospital and doctor can affect the treatment outcome. Not all hospitals and doctors that could use this treatment are included in the data set used to evaluate the different treatments.

For each patient, you are given the beginning systolic pressure, the hospital number, the doctor number within hospital, the treatment (in numeric category) , the ending systolic pressure and the change in systolic pressure.

Some exploratory data output and some potential models along with the output from those models is shown.

B. Create Exploratory Data Output

This section is included to allow the candidate to understand the nature of the data underlying the modeling output.

Input data set

The first table shown is sample of the input data set which displays only the first ten records. The Treatment number is shown in the first column. Later columns in the data set show potential groupings for the eight treatments that are shown with separate potential treatment groups for both the mean effect and the standard errors: mean_grp_X or var_grp_X. The linear mixed models to be reviewed require that the variables by transformed from numeric to categorical groups to inform the statistical routines that 1 is really just a category “1” and there is no cardinal ordering of the treatments or treatment groups with an “F” inserted in the variable name to clarify that particular variable has been transformed from numeric to categorical. For example, Mean_F_G_1 is the variable for treatments grouped for use in estimating the mean effect for treatments placed in group one with that numerical assignment transformed into a categorical variable.

```
## # A tibble: 1,680 x 21
##    Treatment hospital doctor beg_systolic end_systolic mean_grp_1
##        <int>    <int>  <int>        <dbl>        <dbl>      <int>
##  1         1        0      0        160.         155.           1
##  2         2        0      0        115.         113.           0
##  3         3        0      0        126.         123.           1
##  4         4        0      0        100.0         96.7          1
##  5         5        0      0        139.         140.           1
##  6         6        0      0        131.         128.           1
##  7         7        0      0        128.         126.           1
##  8         8        0      0        117.         113.           1
##  9         1        0      1        164.         162.           1
## 10         2        0      1        139.         135.           0
##    var_grp_1 change_systolic Doctor_F Hospital_F Treatment_F Mean_F_G_1
##        <int>           <dbl> <fct>    <fct>      <fct>       <fct>
##  1         0           -5.66 0        0          1           1
##  2         0           -2.37 0        0          2           0
##  3         0           -2.98 0        0          3           1
##  4         0           -3.33 0        0          4           1
##  5         1            1.36 0        0          5           1
##  6         1           -2.48 0        0          6           1
##  7         1           -2.23 0        0          7           1
##  8         1           -4.07 0        0          8           1
##  9         0           -2.02 1        0          1           1
## 10         0           -3.65 1        0          2           0
##    Var_F_G_1 var_grp_2 var_grp_3 mean_grp_2 mean_grp_3 Mean_F_G_2
##    <fct>         <dbl>     <dbl>      <dbl>      <dbl> <fct>
##  1 0               0.        0.         1.         1. 1
##  2 0               1.        0.         0.         0. 0
##  3 0               1.        1.         1.         1. 1
##  4 0               1.        1.         1.         2. 1
##  5 1               2.        1.         1.         3. 1
##  6 1               2.        2.         1.         2. 1
##  7 1               2.        2.         1.         3. 1
##  8 1               2.        3.         2.         3. 2
##  9 0               0.        0.         1.         1. 1
## 10 0               1.        0.         0.         0. 0
##    Var_F_G_2 Mean_F_G_3 Var_F_G_3
##    <fct>     <fct>      <fct>
##  1 0         1          0
##  2 1         0          0
##  3 1         1          1
##  4 1         2          1
##  5 2         3          1
##  6 2         2          2
##  7 2         3          2
```

```
##  8 2         3          3
##  9 0         1          0
## 10 1         0          0
## # ... with 1,670 more rows
```

Summary of the input data set

The table below shows for each column in the input data set statistics that display the characteristics of the values in that column.

```
##    Treatment       hospital      doctor     beg_systolic
##  Min.   :1.00   Min.   : 0   Min.   :0.0   Min.   : 62.69
##  1st Qu.:2.75   1st Qu.: 5   1st Qu.:2.0   1st Qu.:106.41
##  Median :4.50   Median :10   Median :4.5   Median :119.78
##  Mean   :4.50   Mean   :10   Mean   :4.5   Mean   :119.96
##  3rd Qu.:6.25   3rd Qu.:15   3rd Qu.:7.0   3rd Qu.:133.32
##  Max.   :8.00   Max.   :20   Max.   :9.0   Max.   :183.60
##
##   end_systolic     mean_grp_1      var_grp_1   change_systolic
##  Min.   : 52.2   Min.   :0.000   Min.   :0.0   Min.   :-17.7001
##  1st Qu.:102.1   1st Qu.:1.000   1st Qu.:0.0   1st Qu.: -7.2384
##  Median :116.2   Median :1.000   Median :0.5   Median : -3.8417
##  Mean   :116.1   Mean   :0.875   Mean   :0.5   Mean   : -3.8600
##  3rd Qu.:129.7   3rd Qu.:1.000   3rd Qu.:1.0   3rd Qu.: -0.4965
##  Max.   :184.6   Max.   :1.000   Max.   :1.0   Max.   : 11.2164
##
##     Doctor_F     Hospital_F    Treatment_F  Mean_F_G_1 Var_F_G_1
##  0      :168   0      :  80   1      :210   0: 210     0:840
##  1      :168   1      :  80   2      :210   1:1470     1:840
##  2      :168   2      :  80   3      :210
##  3      :168   3      :  80   4      :210
##  4      :168   4      :  80   5      :210
##  5      :168   5      :  80   6      :210
##  (Other):672   (Other):1200   (Other):420
##    var_grp_2       var_grp_3      mean_grp_2   mean_grp_3    Mean_F_G_2
##  Min.   :0.000   Min.   :0.00   Min.   :0    Min.   :0.000   0: 210
##  1st Qu.:1.000   1st Qu.:0.75   1st Qu.:1    1st Qu.:1.000   1:1260
##  Median :1.500   Median :1.00   Median :1    Median :2.000   2: 210
##  Mean   :1.375   Mean   :1.25   Mean   :1    Mean   :1.875
##  3rd Qu.:2.000   3rd Qu.:2.00   3rd Qu.:1    3rd Qu.:3.000
##  Max.   :2.000   Max.   :3.00   Max.   :2    Max.   :3.000
##
##  Var_F_G_2 Mean_F_G_3 Var_F_G_3
##  0:210     0:210      0:420
##  1:630     1:420      1:630
##  2:840     2:420      2:420
##            3:630      3:210
```

This is a summary of the results of each of the treatments across all hospitals and doctors.

One should note that some of the treatments have similar effects leading to the question of are there natural groupings of the treatments when evaluating the effectiveness. Three sets of potential groups for both the mean and variance effects to be modeled in the linear mixed models as shown below were created from reviewing this table.

```
## # A tibble: 8 x 7
##   Treatment_F mean_chng med_chgn min_chgn max_chng Std_Dev_Chng
##   <fct>           <dbl>    <dbl>    <dbl>    <dbl>        <dbl>
## 1 1              -1.80    -2.00    -12.4    7.38          3.85
## 2 2               0.306    0.353    -9.98  11.2           4.03
## 3 3              -1.26    -1.14    -10.5    9.12          3.83
## 4 4              -3.27    -3.04    -14.7    5.74          3.88
## 5 5              -6.41    -6.52    -14.3    7.90          3.67
## 6 6              -4.39    -4.20    -14.9    5.61          4.07
## 7 7              -4.97    -5.00    -17.2    6.95          3.79
## 8 8              -9.09    -9.42    -17.7   -0.0202        3.55
##   Num_Observations
##              <int>
## 1              210
## 2              210
## 3              210
## 4              210
## 5              210
## 6              210
## 7              210
## 8              210
```

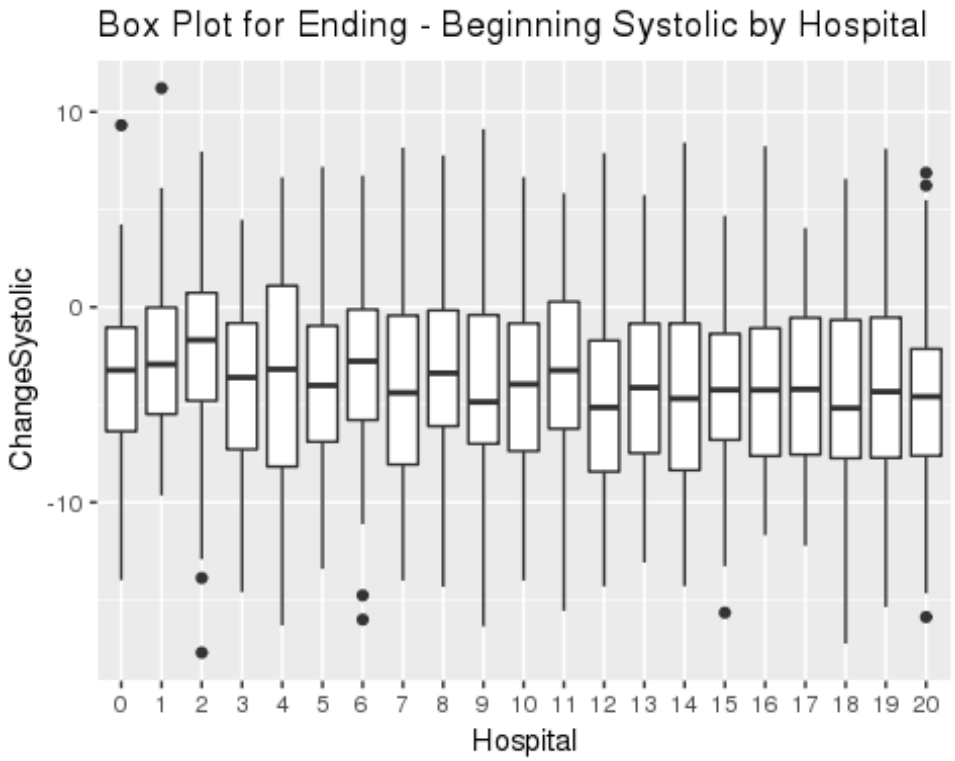
This shows a potential set of groupings for the treatment mean and variance

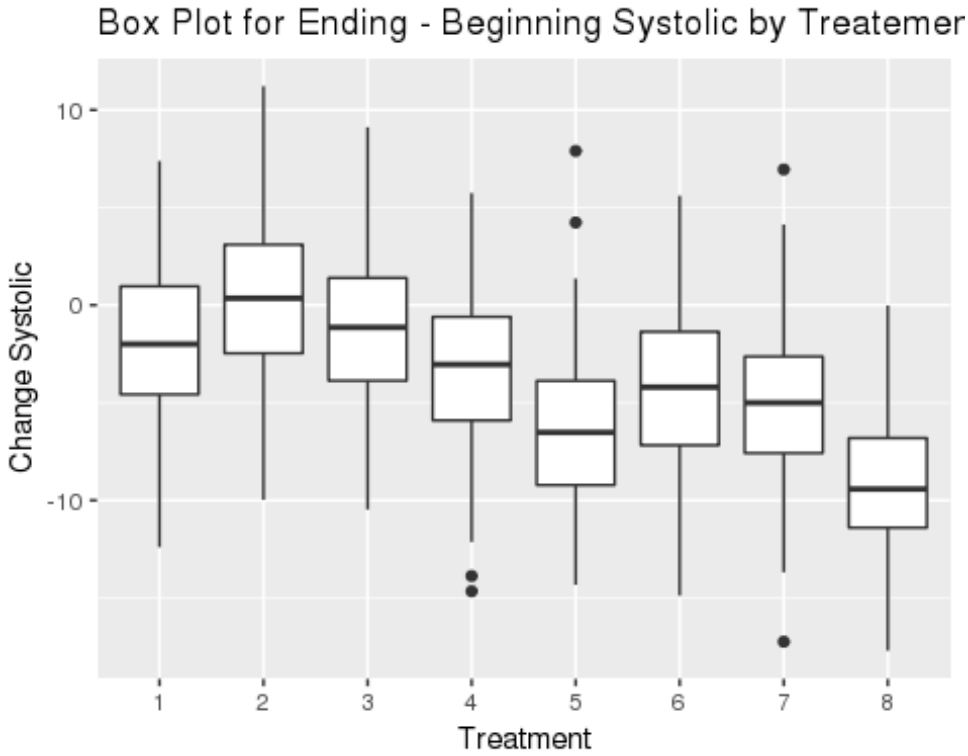
The groupings displayed will be used in subsequent models. Each treatment is mapped to three different options for either the mean or variance grouping.

```
## # A tibble: 8 x 7
##   Treatment_F Mean_F_G_1 Var_F_G_1 Mean_F_G_2 Var_F_G_2 Mean_F_G_3
##   <fct>            <dbl>     <dbl>      <dbl>     <dbl>      <dbl>
## 1 1                   1.        0.         1.        0.         1.
## 2 2                   0.        0.         0.        1.         0.
## 3 3                   1.        0.         1.        1.         1.
## 4 4                   1.        0.         1.        1.         2.
## 5 5                   1.        1.         1.        2.         3.
## 6 6                   1.        1.         1.        2.         2.
## 7 7                   1.        1.         1.        2.         3.
## 8 8                   1.        1.         2.        2.         3.
```

```
##   Var_F_G_3
##       <dbl>
## 1        0.
## 2        0.
## 3        1.
## 4        1.
## 5        1.
## 6        2.
## 7        2.
## 8        3.
```

Create Box Whisker plots of the change in systolic pressure by Treatment and then by Hospital





C. This section will display the results of fitting different models.

The items that will vary across models include:

Computation method: maximum likelihood or restricted maximum likelihood

Variance grouping with different treatments assigned different variance groups

Treatment groups with different treatments assigned to different mean treatment groups Include or exclude hospitals with doctors nested within hospital as a random effect

When there is no grouping of the eight treatments included in the study, it is called the "Full Model".

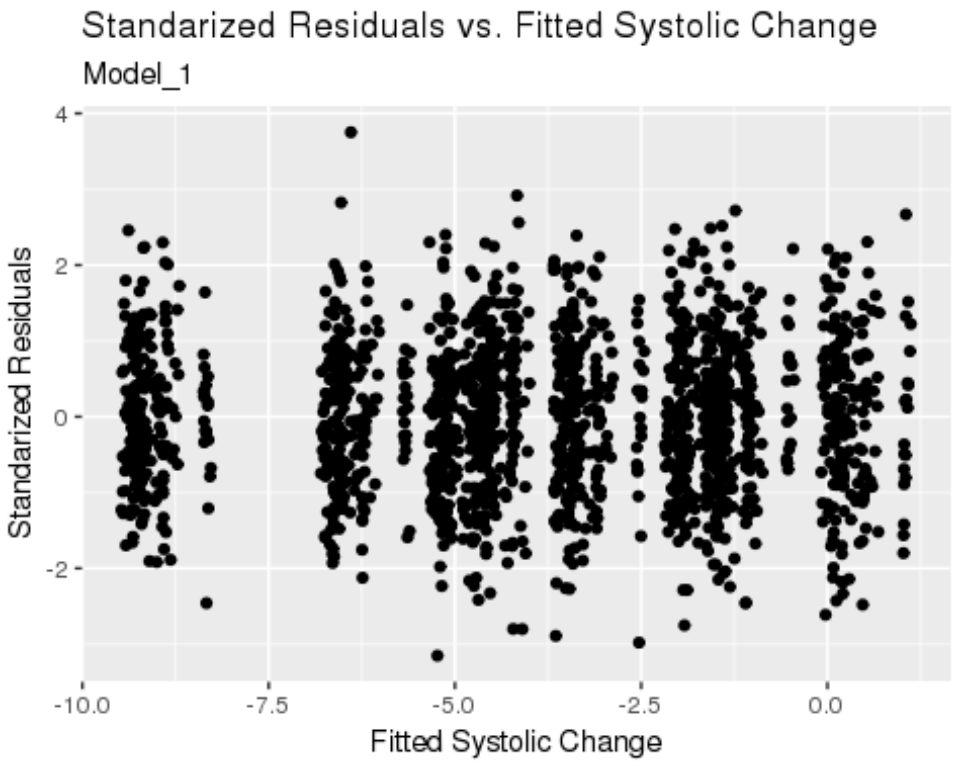
In all cases, the models were fit using the lme option within the nlme package in R. The results are displayed using the summary function to generate standardized goodness of fit statistics and the fitted betas for each model.

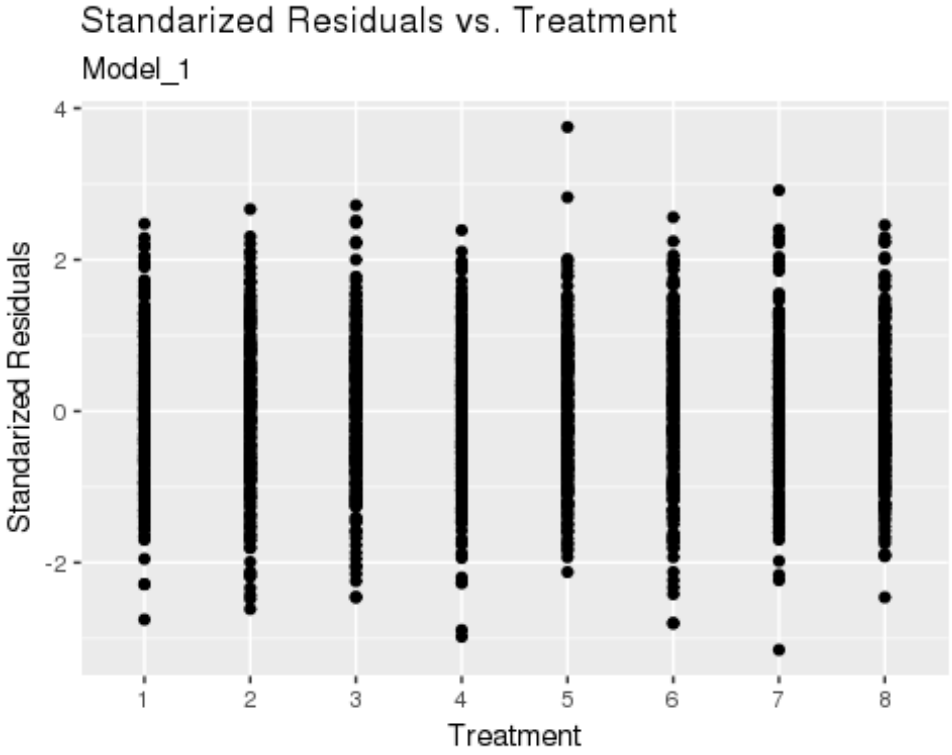
The same set of graphs displaying the behavior of the residuals will be shown for each model.

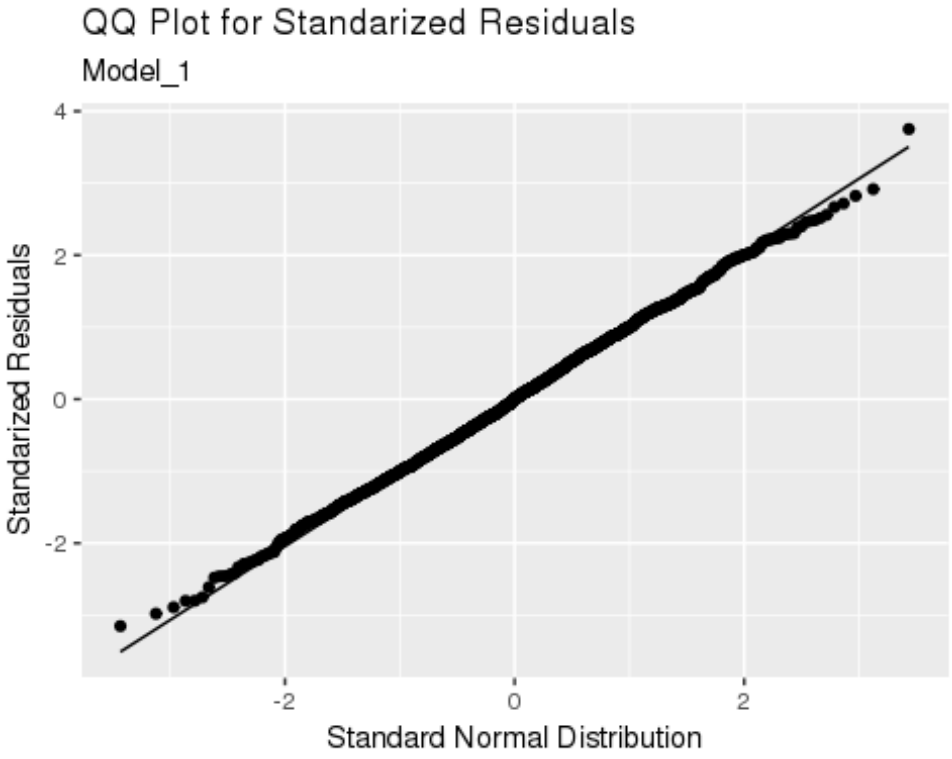
The models will be numbered and the definition of the model will precede the model output.

Create Model 1

Model Definition: Computation method: restricted maximum likelihood Variance grouping: None Treatment group definition: Full model Random Effect: Include hospitals with doctors nested within hospital

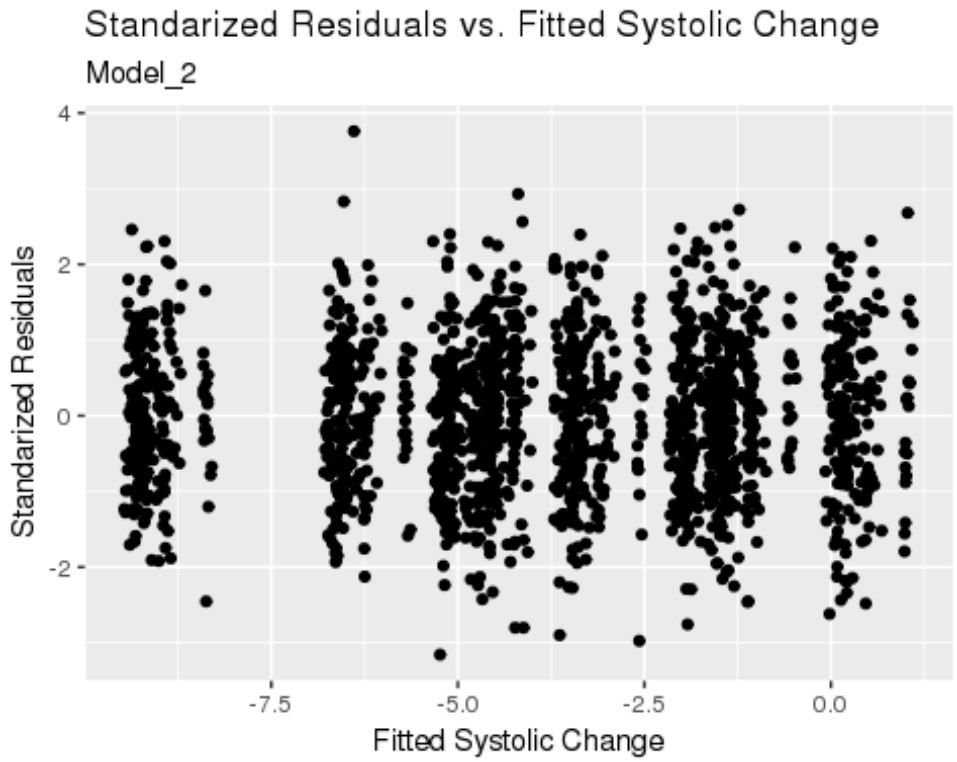


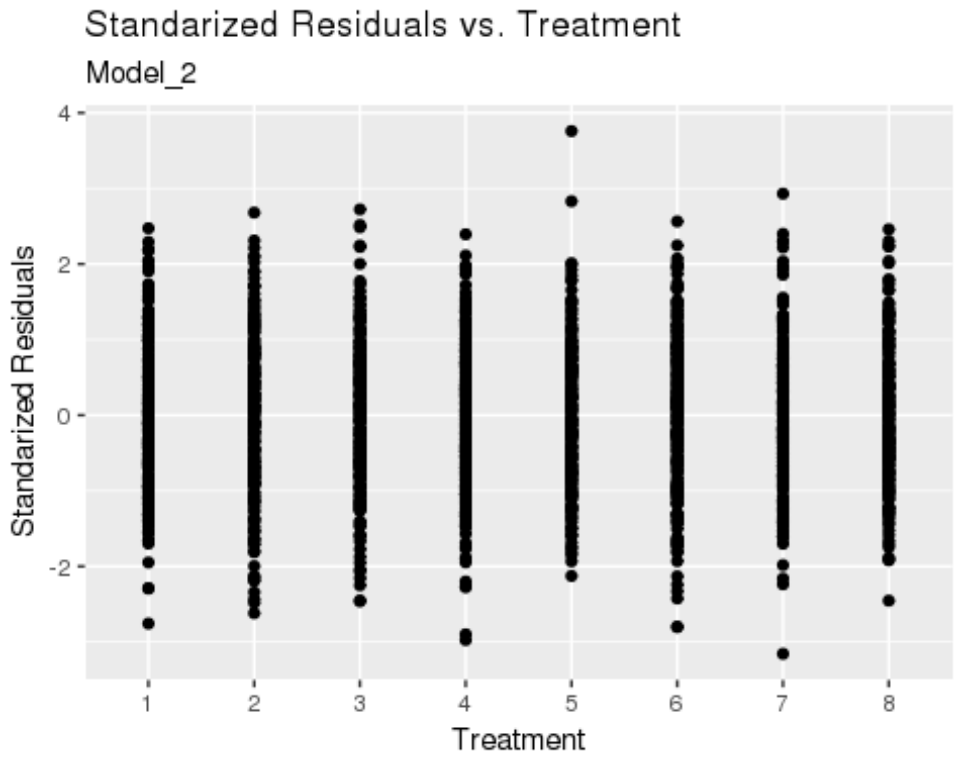

Standarized Residuals vs. Treatment
Model_1
Standarized Residuals
4
2
0
-2
1
2
3
4
5
6
7
8
Treatment

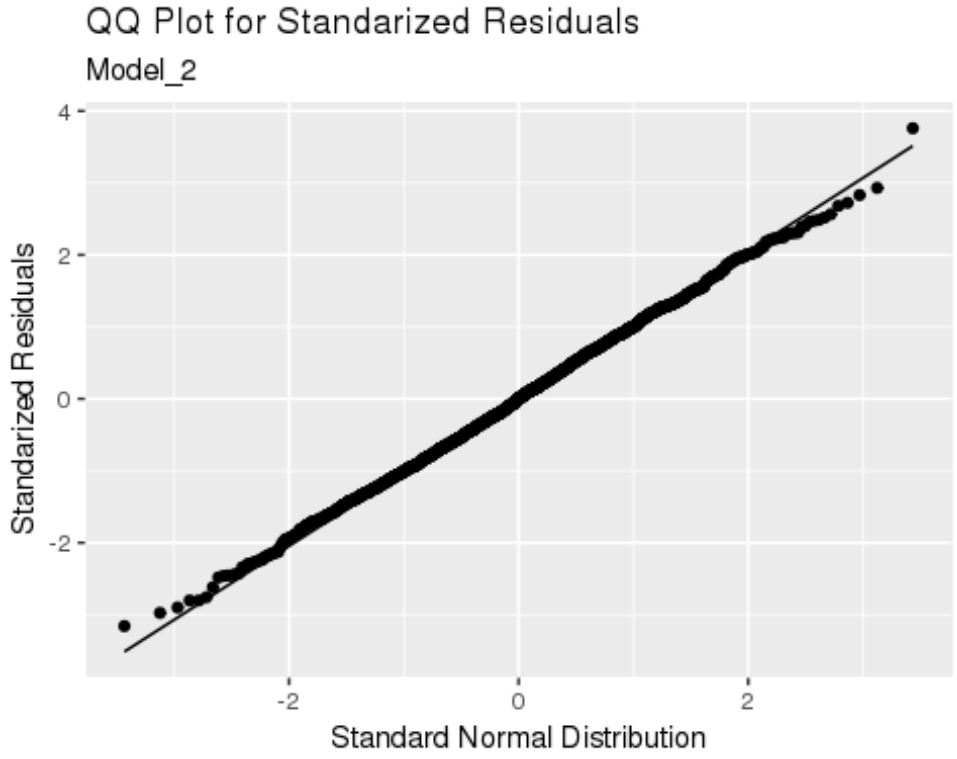

QQ Plot for Standarized Residuals
Model_1
Standarized Residuals
4
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 2

Model Definition: Computation method: maximum likelihood Variance grouping: None Treatment group definition: Full model Random Effect: Include hospitals with doctors nested within hospital

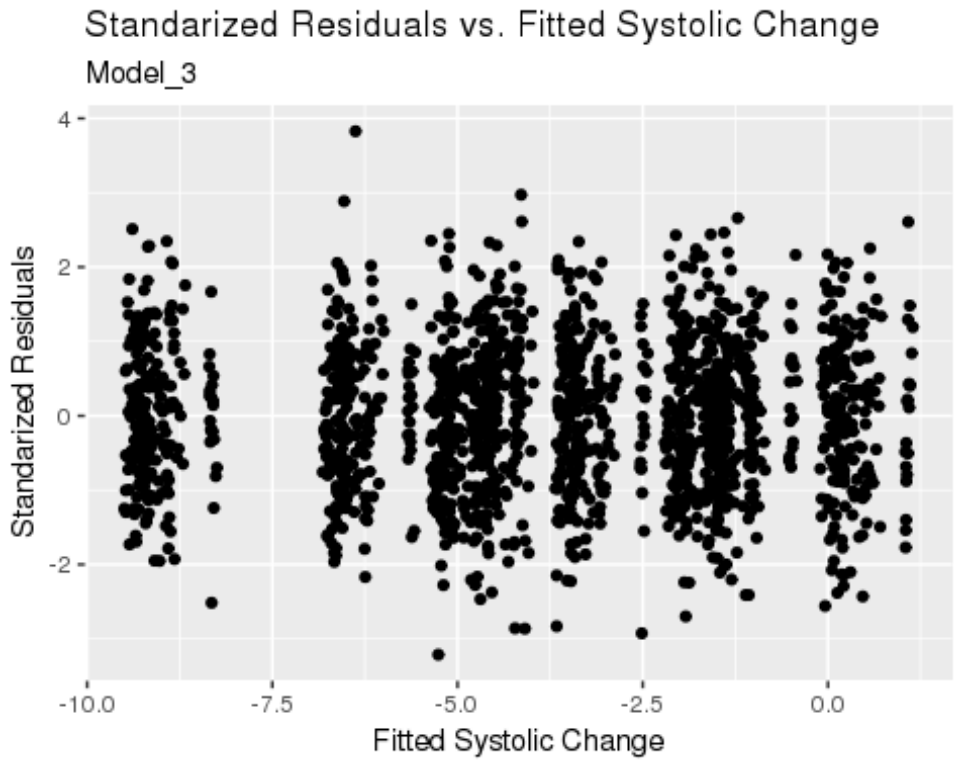


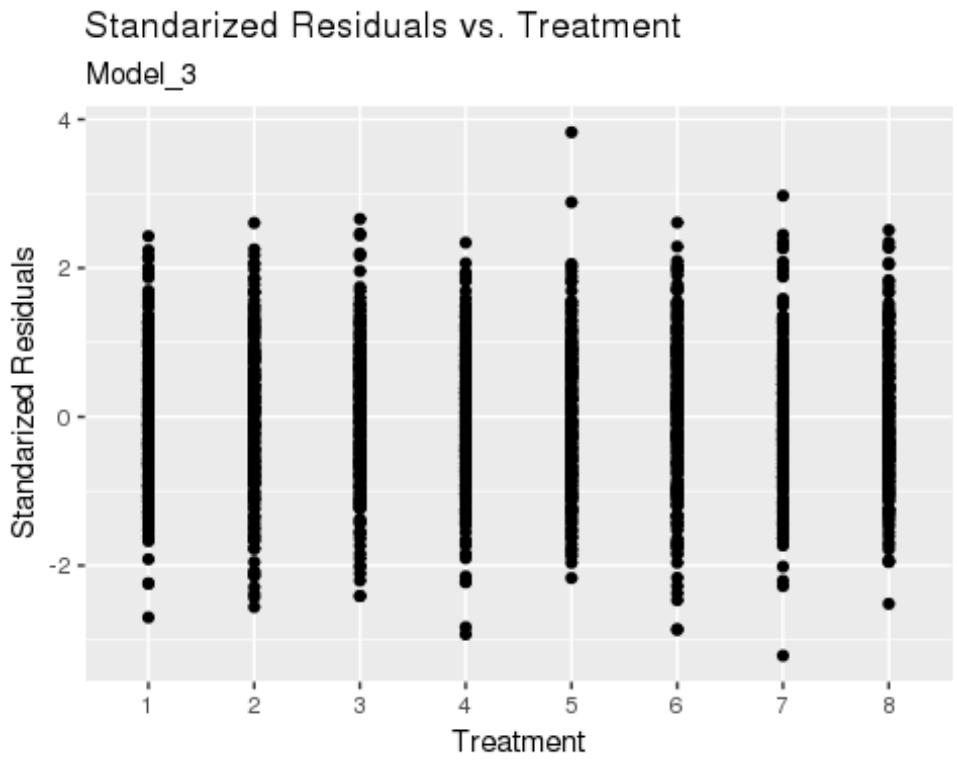

Standarized Residuals vs. Treatment
Model_2
Standarized Residuals
4
2
0
-2
1
2
3
4
5
6
7
8
Treatment

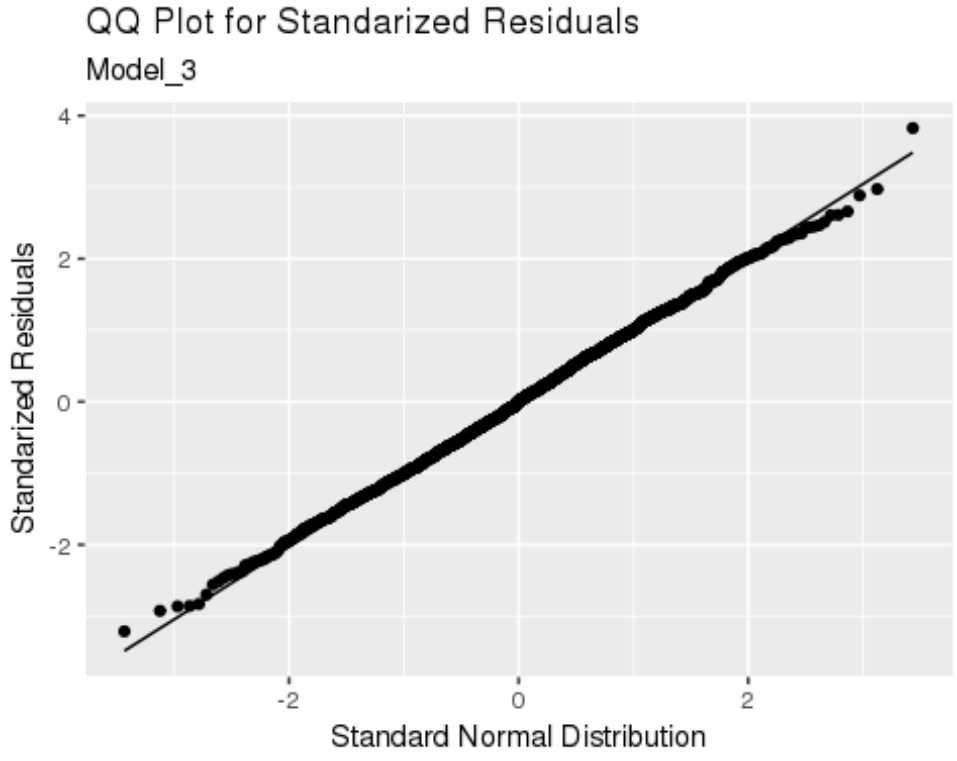

QQ Plot for Standarized Residuals
Model_2
Standarized Residuals
4
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 3

Model Definition: Computation method: restricted maximum likelihood Variance grouping: Variance Group #1 Treatment group definition: Full model Random Effect: Include hospitals with doctors nested within hospital

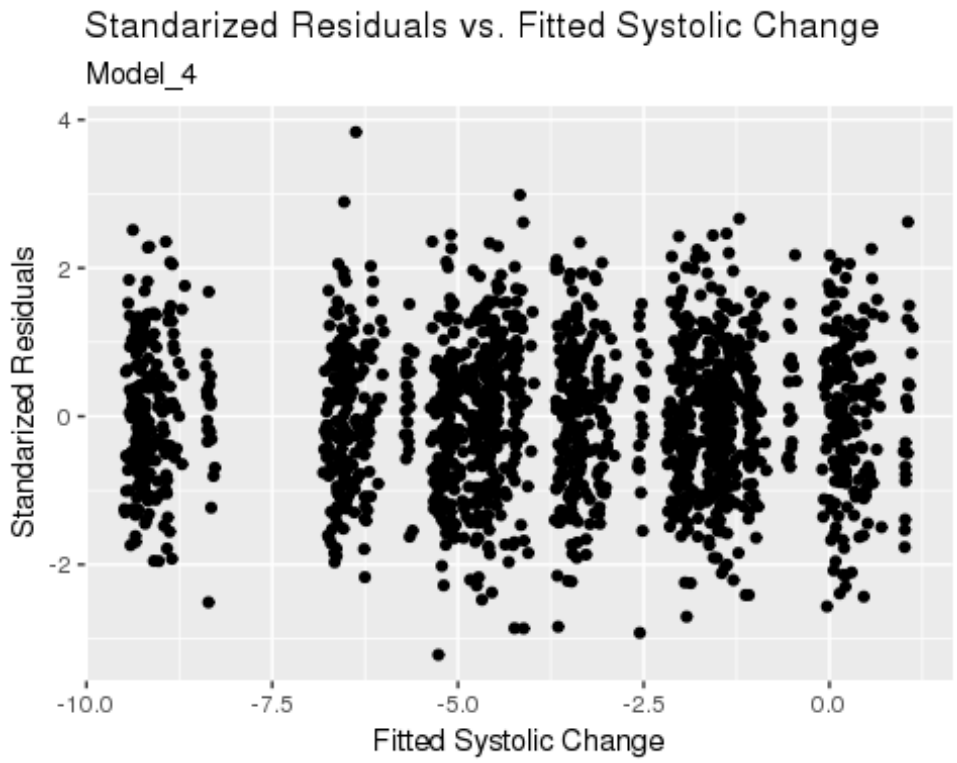


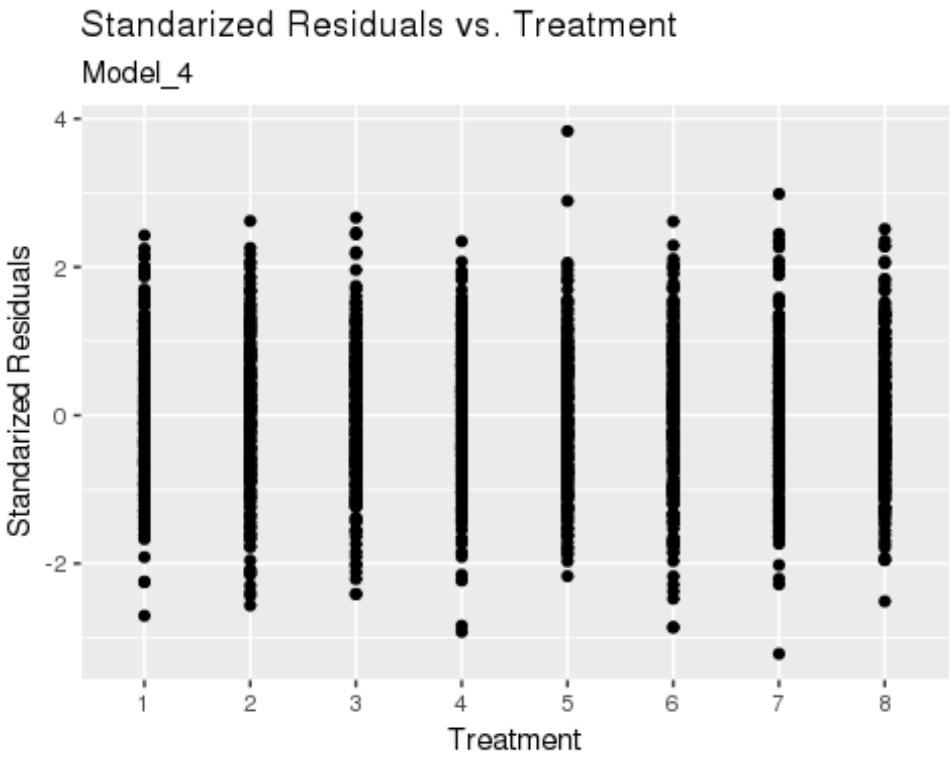

Standarized Residuals vs. Treatment
Model_3
Standarized Residuals
4
2
0
-2
1
2
3
4
5
6
7
8
Treatment

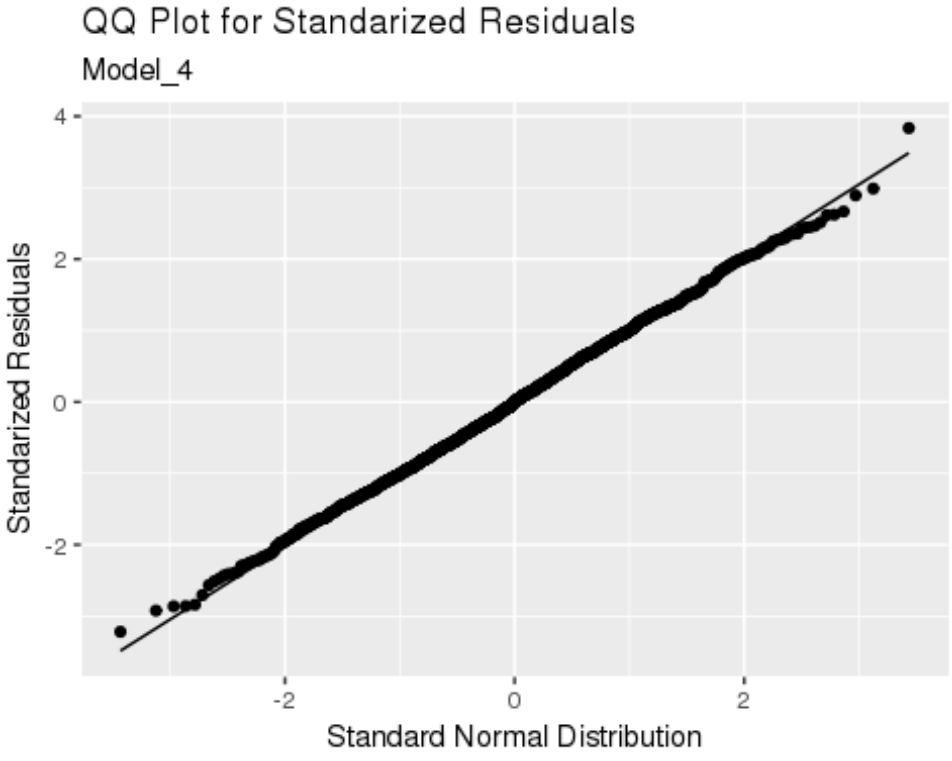

QQ Plot for Standarized Residuals
Model_3
Standarized Residuals
4
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 4

Model Definition: Computation method: maximum likelihood Variance grouping: Variance Group #1 Treatment group definition: Full model Random Effect: Include hospitals with doctors nested within hospital

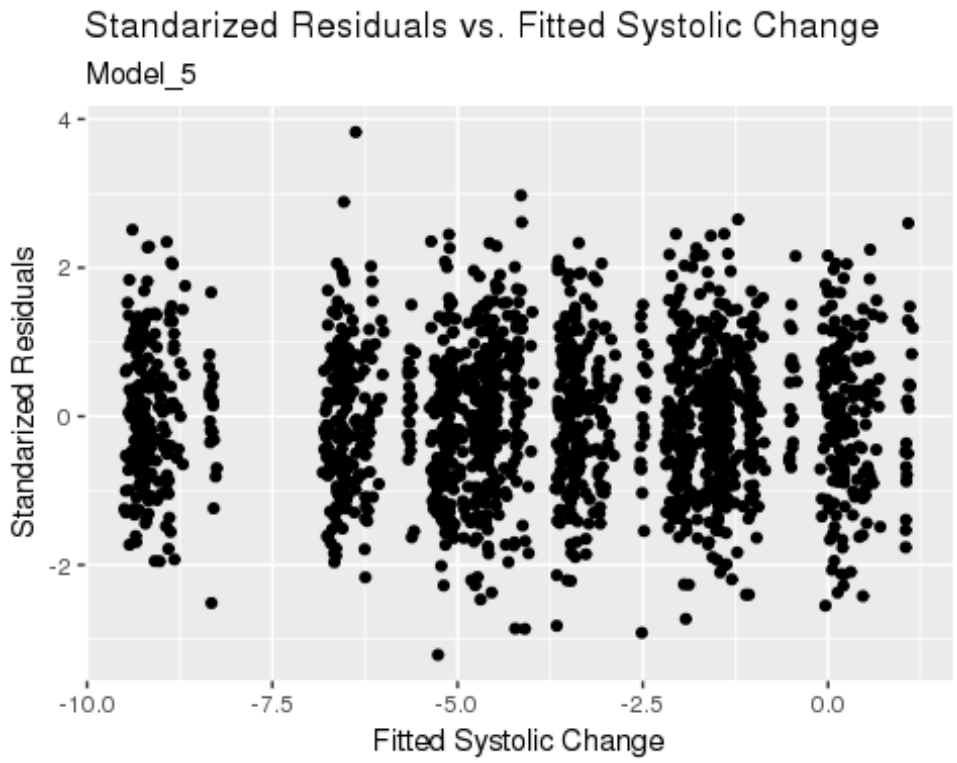


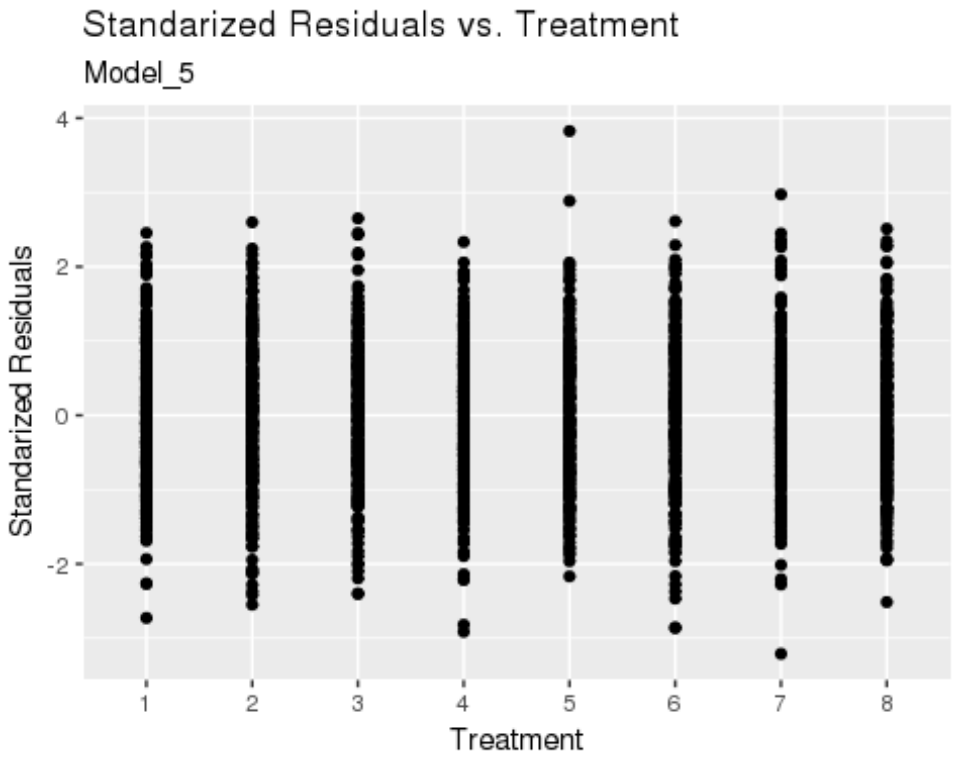

Standarized Residuals vs. Treatment
Model_4
Standarized Residuals
4
2
0
-2
1
2
3
4
5
6
7
8
Treatment

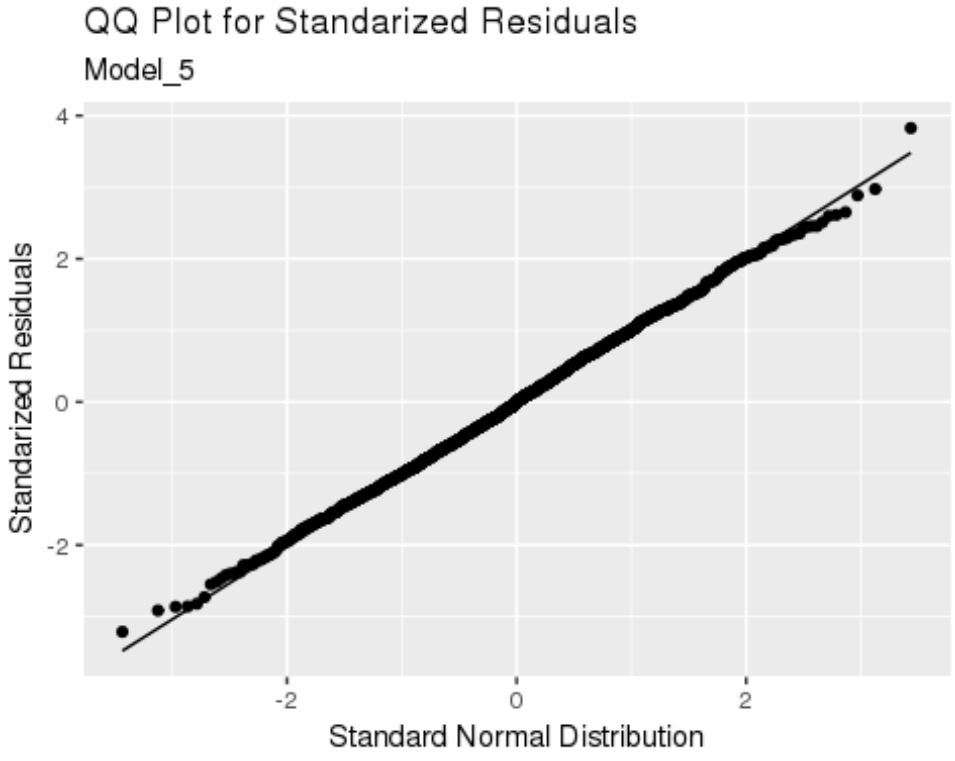

QQ Plot for Standarized Residuals
Model_4
Standarized Residuals
4
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 5

Model Definition: Computation method: restricted maximum likelihood Variance grouping: Group #2 Treatment group definition: Full model Random Effect: Include hospitals with doctors nested within hospital

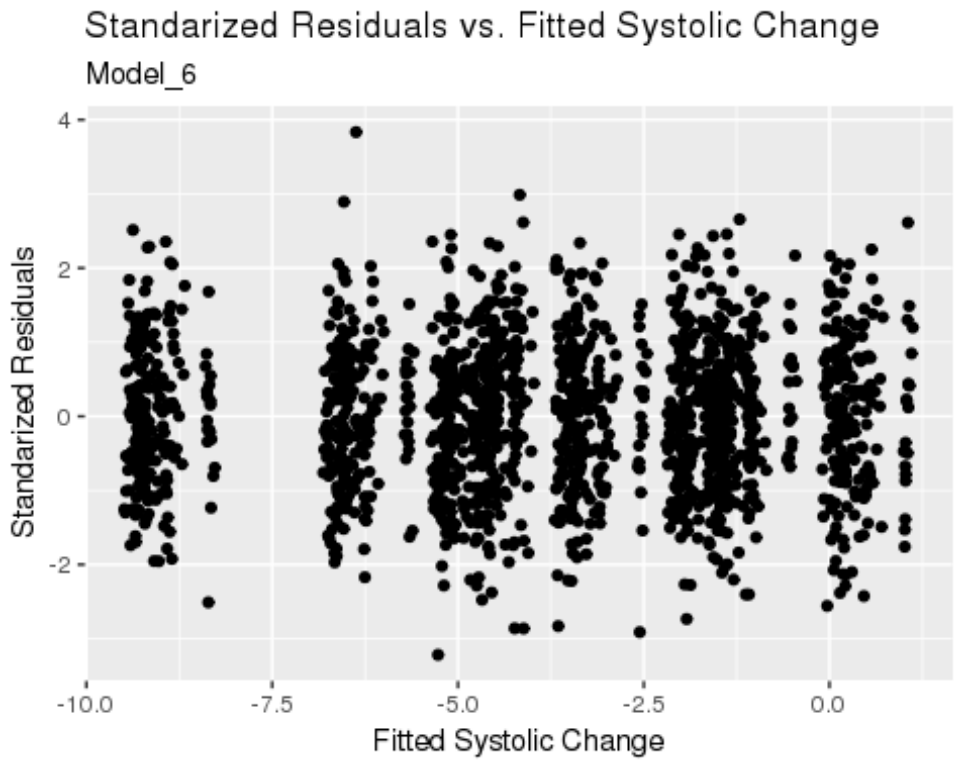


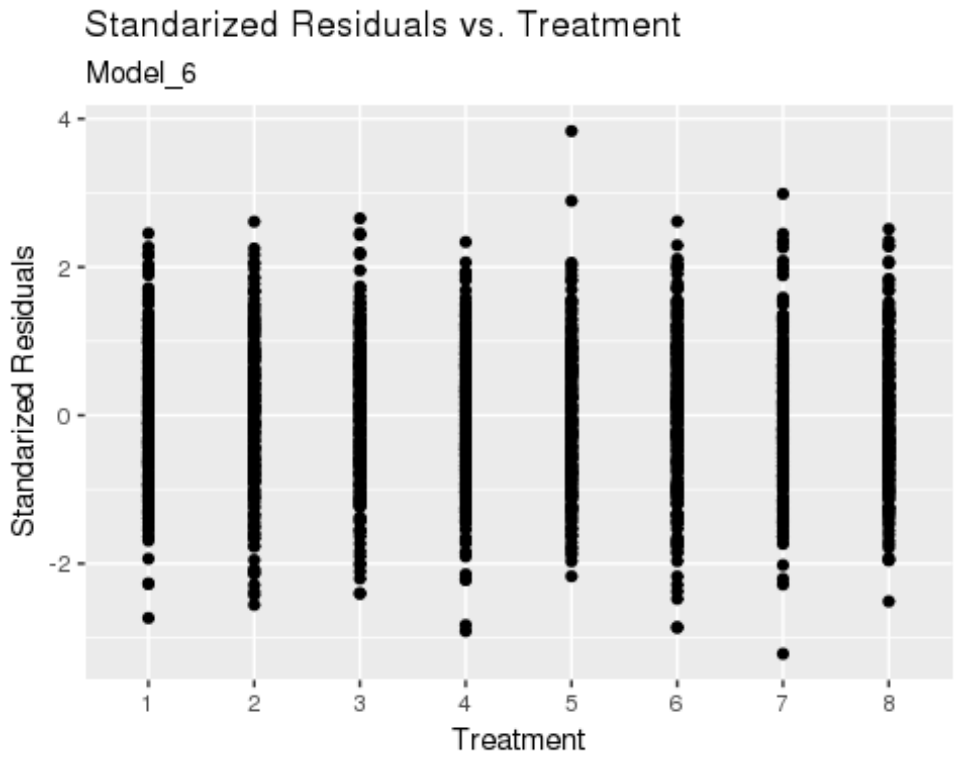

Standarized Residuals vs. Treatment
Model_5
Standarized Residuals
4
2
0
-2
1
2
3
4
5
6
7
8
Treatment

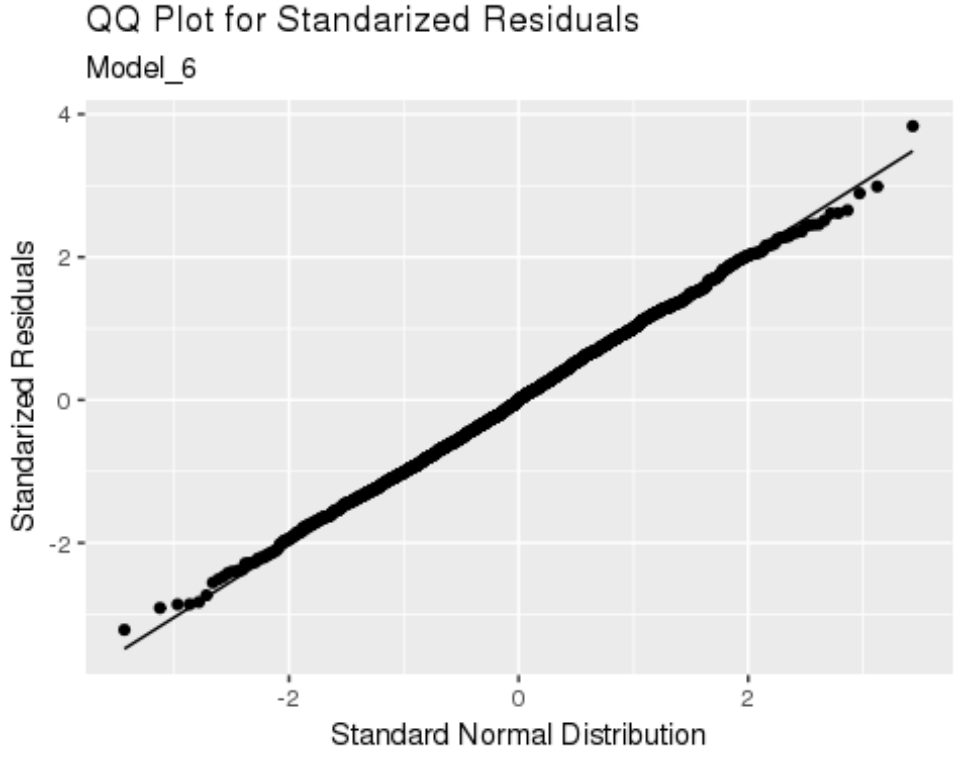

QQ Plot for Standarized Residuals
Model_5
Standarized Residuals
4
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 6

Model Definition: Computation method: maximum likelihood Variance grouping: Variance Group #2 Treatment group definition: Full model Random Effect: Include hospitals with doctors nested within hospital

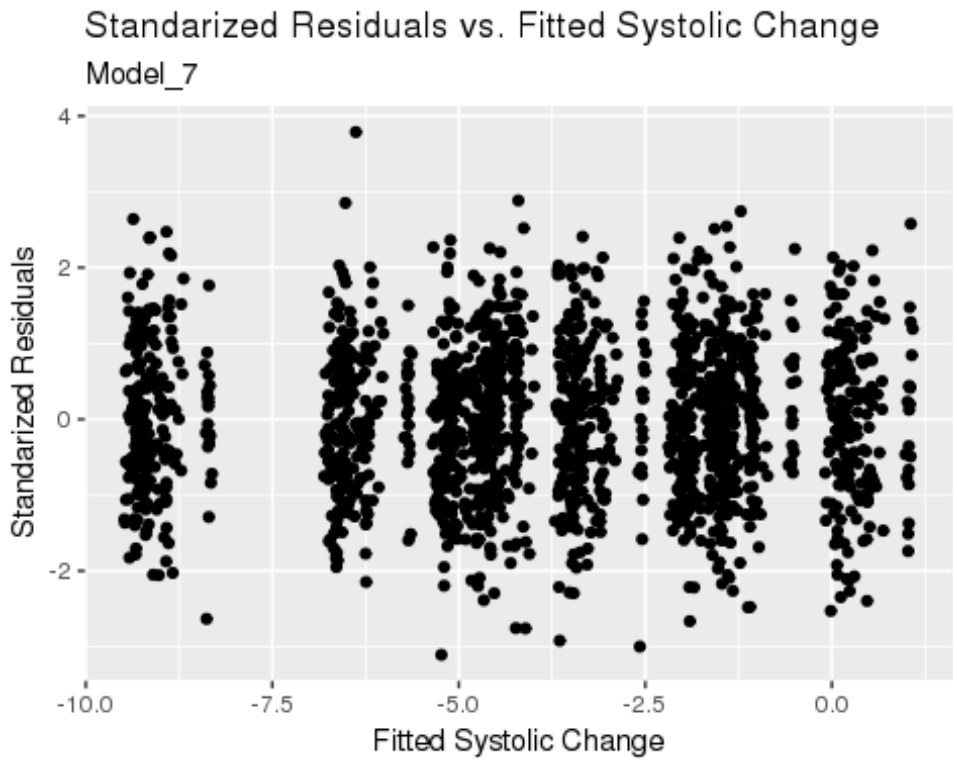


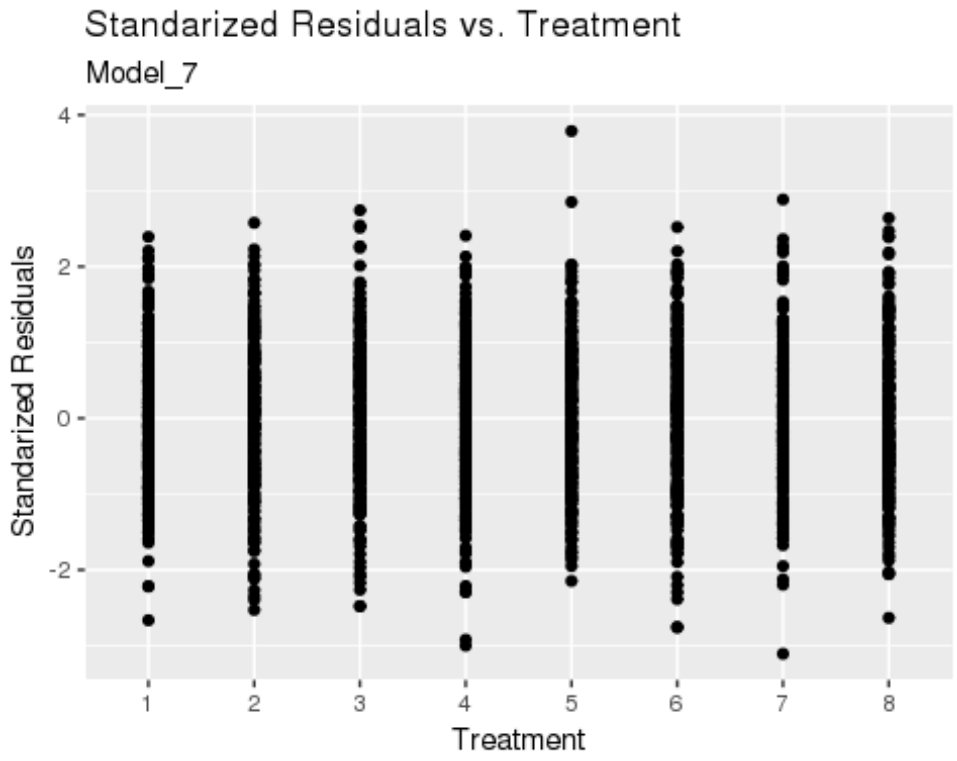

Standarized Residuals vs. Treatment
Model_6
Standarized Residuals
4
2
0
-2
1
2
3
4
5
6
7
8
Treatment

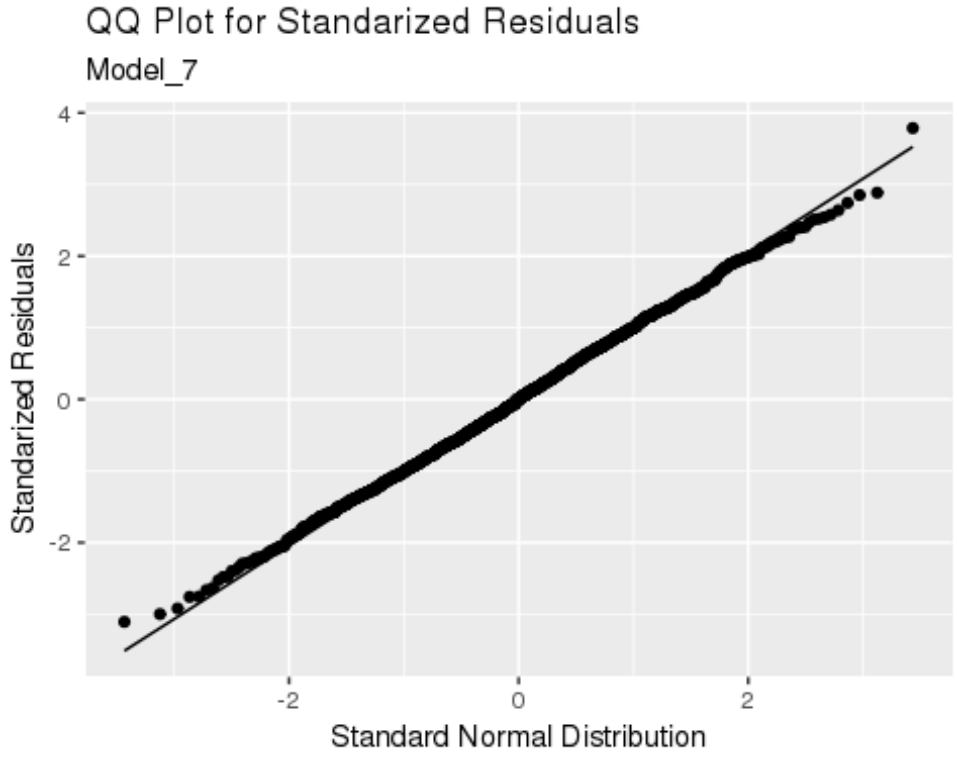

QQ Plot for Standarized Residuals
Model_6
Standarized Residuals
4
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 7

Model Definition: Computation method: restricted maximum likelihood Variance grouping: Variance Group #3 Treatment group definition: Full model Random Effect: Include hospitals with doctors nested within hospital

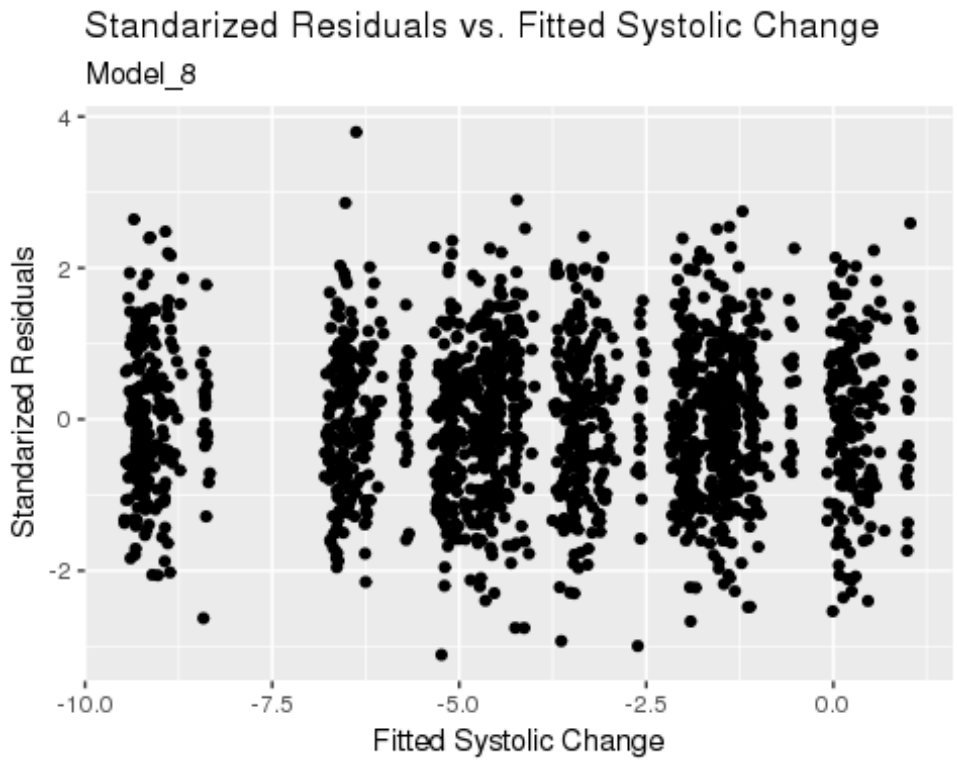


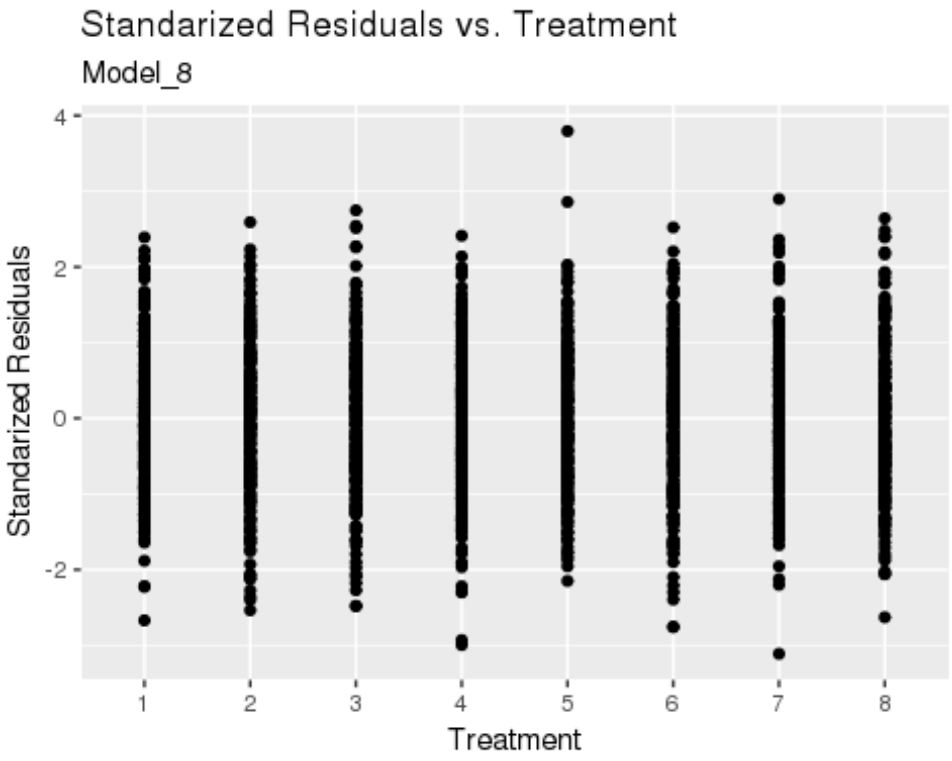

Standarized Residuals vs. Treatment
Model_7
Standarized Residuals
4
2
0
-2
1
2
3
4
5
6
7
8
Treatment

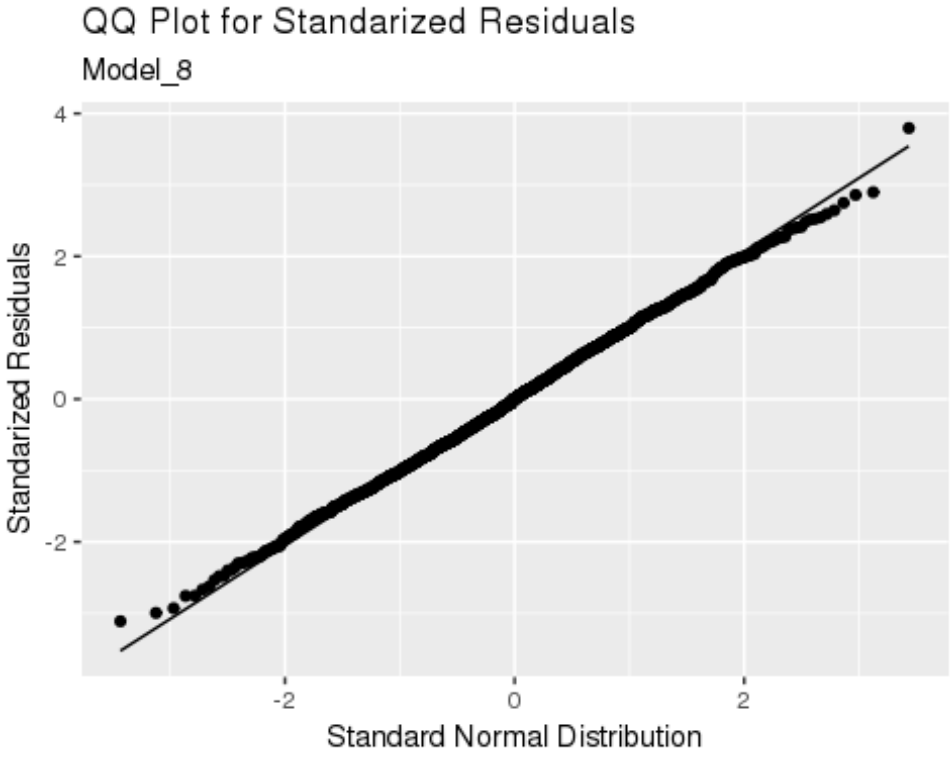

QQ Plot for Standarized Residuals
Model_7
Standarized Residuals
4
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 8

Model Definition: Computation method: maximum likelihood Variance grouping: Variance Group #3 Treatment group definition: Full model Random Effect: Include hospitals with doctors nested within hospital

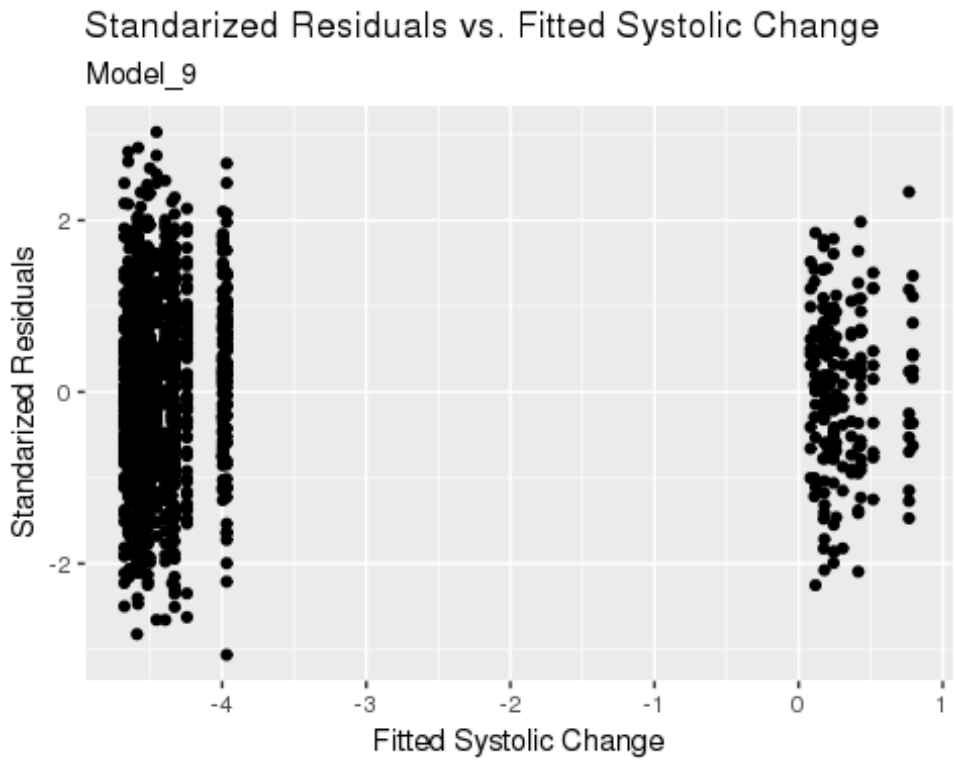


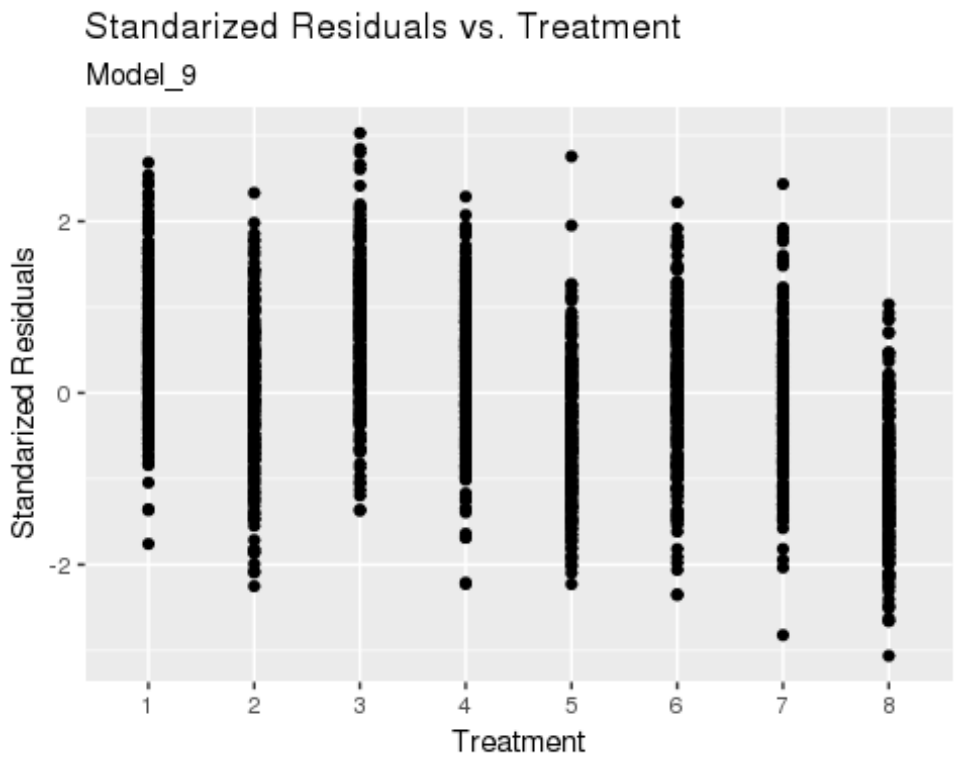

Standarized Residuals vs. Treatment
Model_8
Standarized Residuals
4
2
0
-2
1
2
3
4
5
6
7
8
Treatment

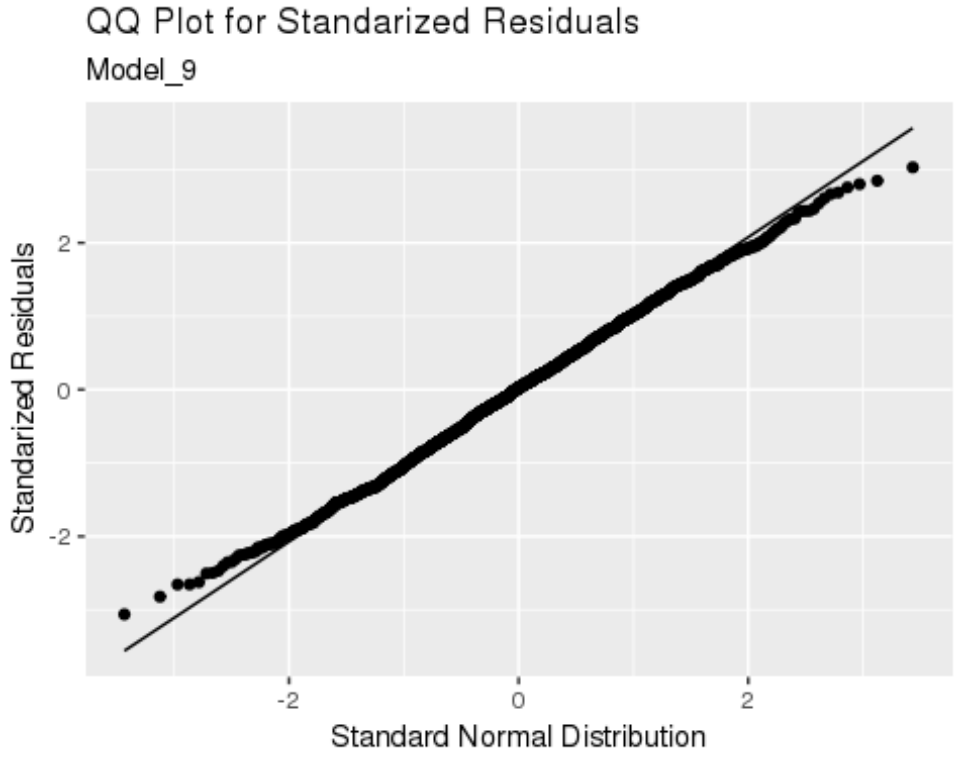

QQ Plot for Standarized Residuals
Model_8
Standarized Residuals
4
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 9

Model Definition: Computation method: restricted maximum likelihood Variance grouping: None Treatment group definition: Mean group #1 Random Effect: Include hospitals with doctors nested within hospital

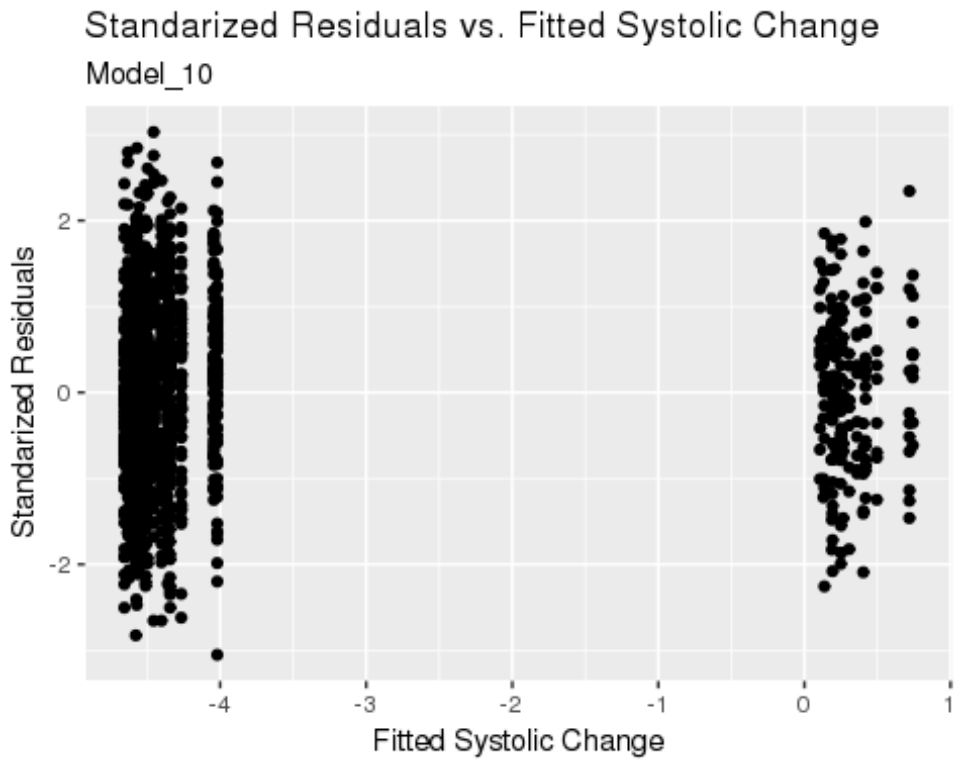


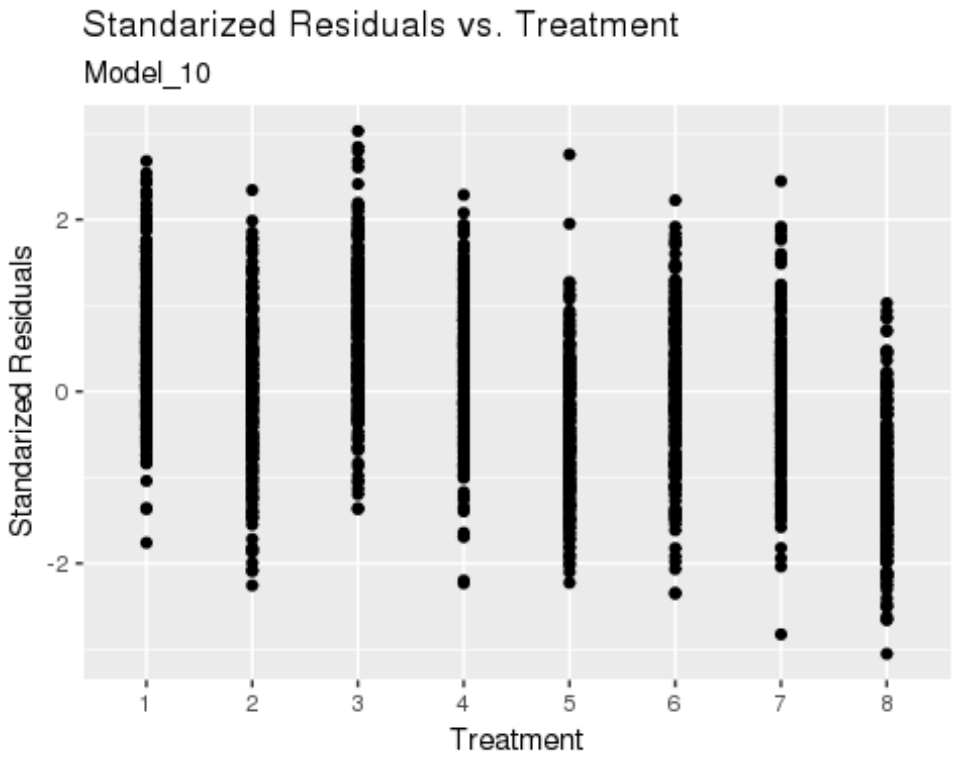

Standarized Residuals vs. Treatment
Model_9
Standarized Residuals
2
0
-2
1
2
3
4
5
6
7
8
Treatment

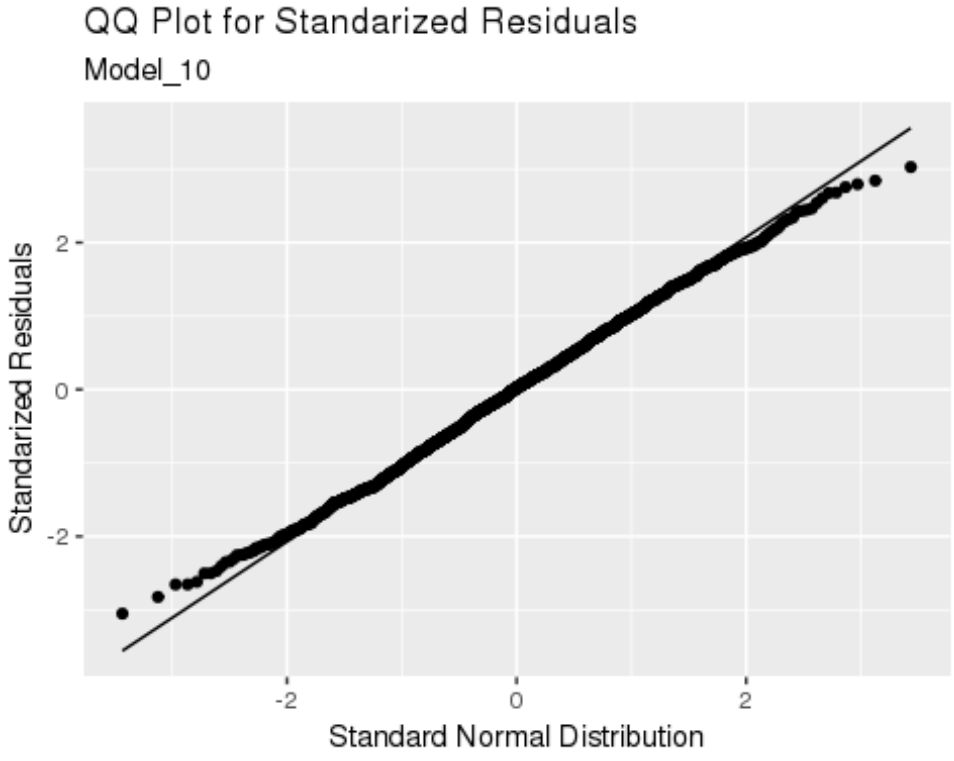

QQ Plot for Standarized Residuals
Model_9
Standarized Residuals
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 10

Model Definition: Computation method: maximum likelihood Variance grouping: None Treatment group definition: Full model Random Effect: Include hospitals with doctors nested within hospital

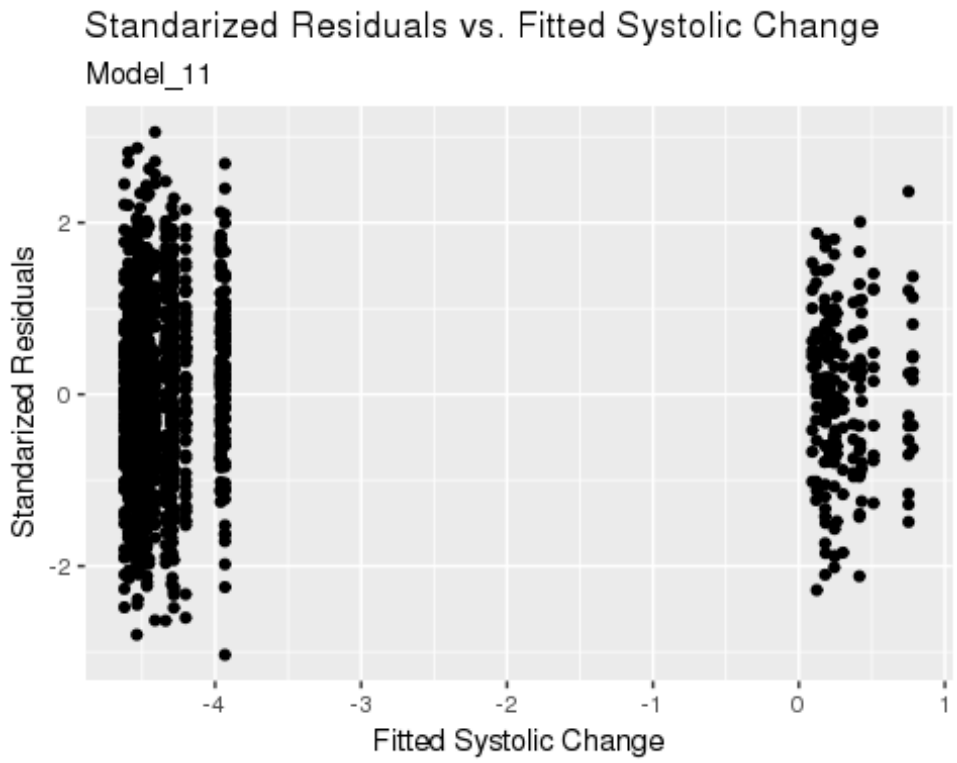


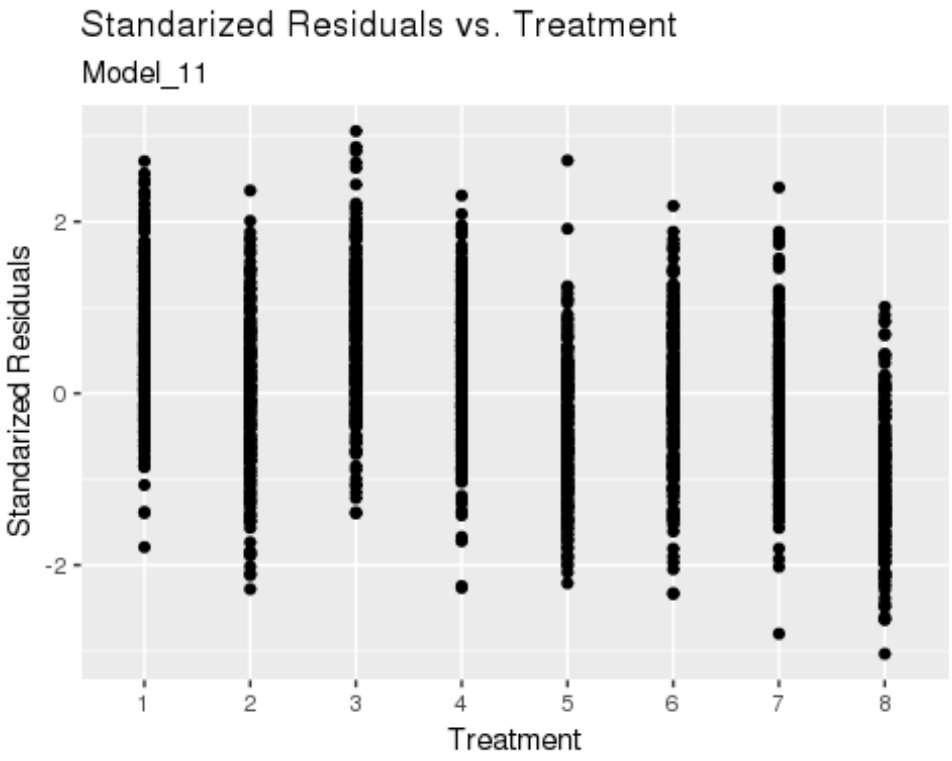

Standarized Residuals vs. Treatment
Model_10
Standarized Residuals
2
0
-2
1
2
3
4
5
6
7
8
Treatment

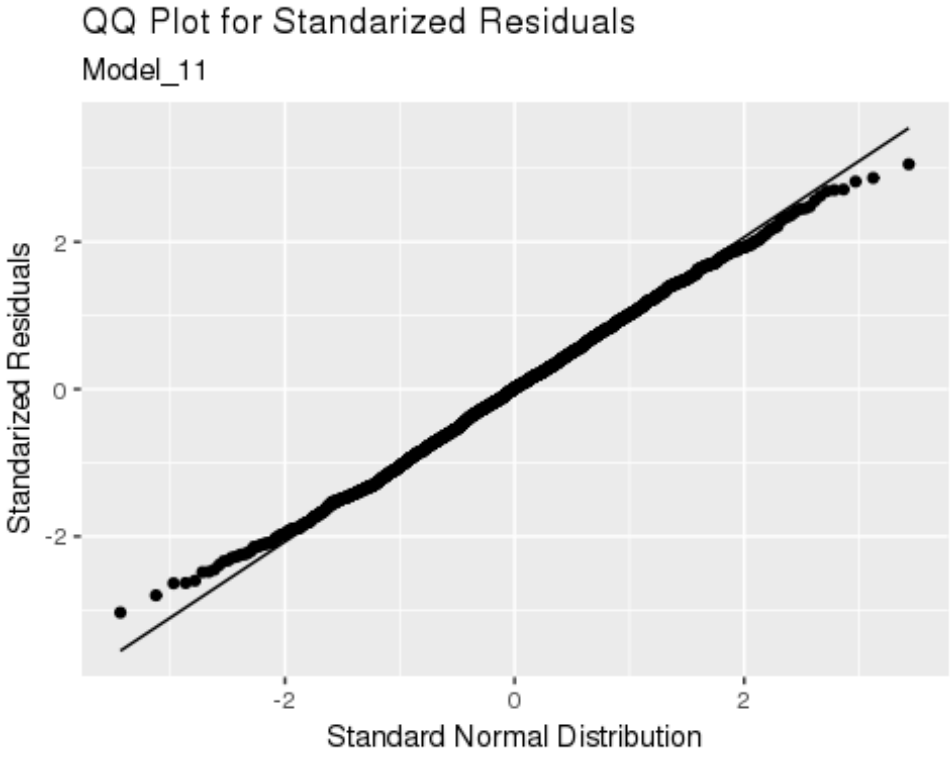

QQ Plot for Standarized Residuals
Model_10
Standarized Residuals
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 11

Model Definition: Computation method: restricted maximum likelihood Variance grouping: Variance Group #1 Treatment group definition: Mean Group #1 Random Effect: Include hospitals with doctors nested within hospital

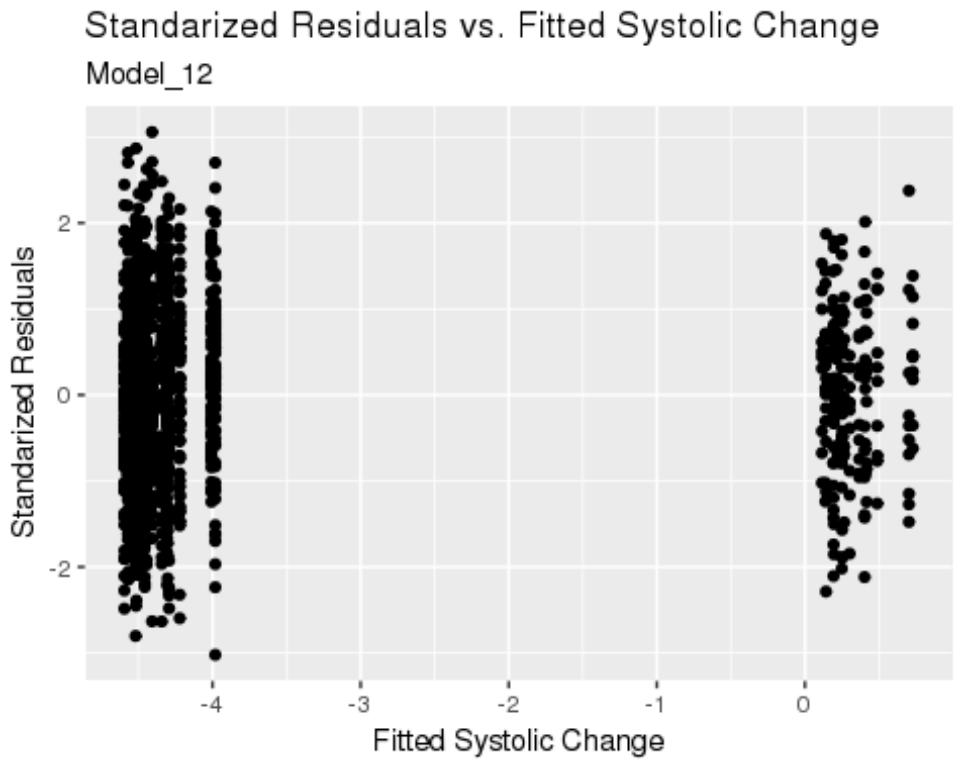


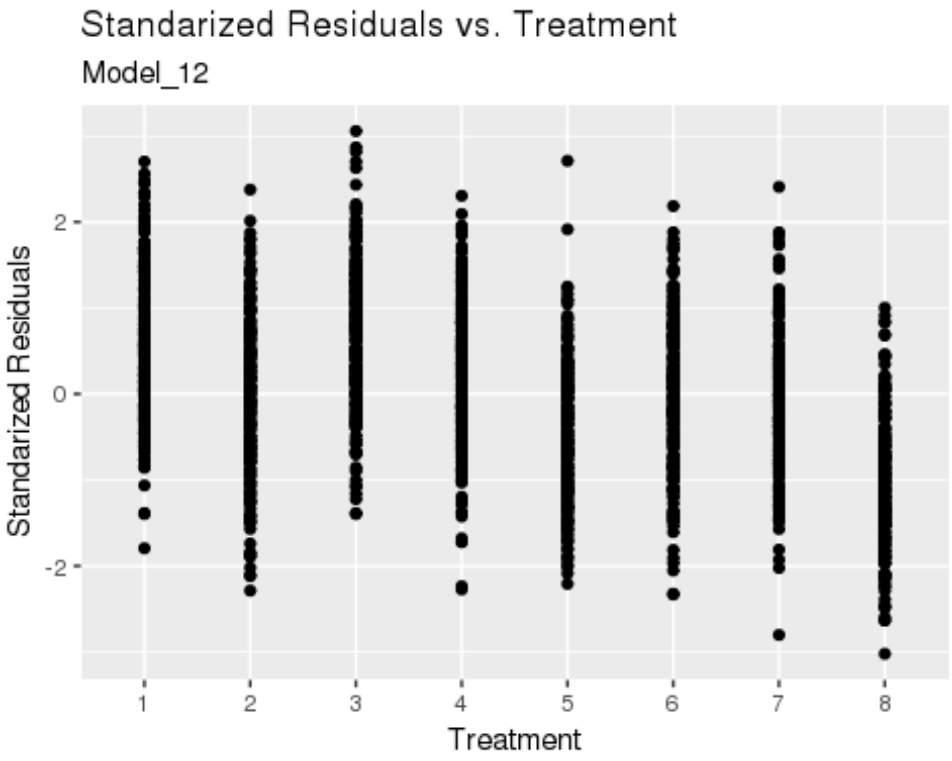

Standarized Residuals vs. Treatment
Model_11
Standarized Residuals
2
0
-2
1
2
3
4
5
6
7
8
Treatment

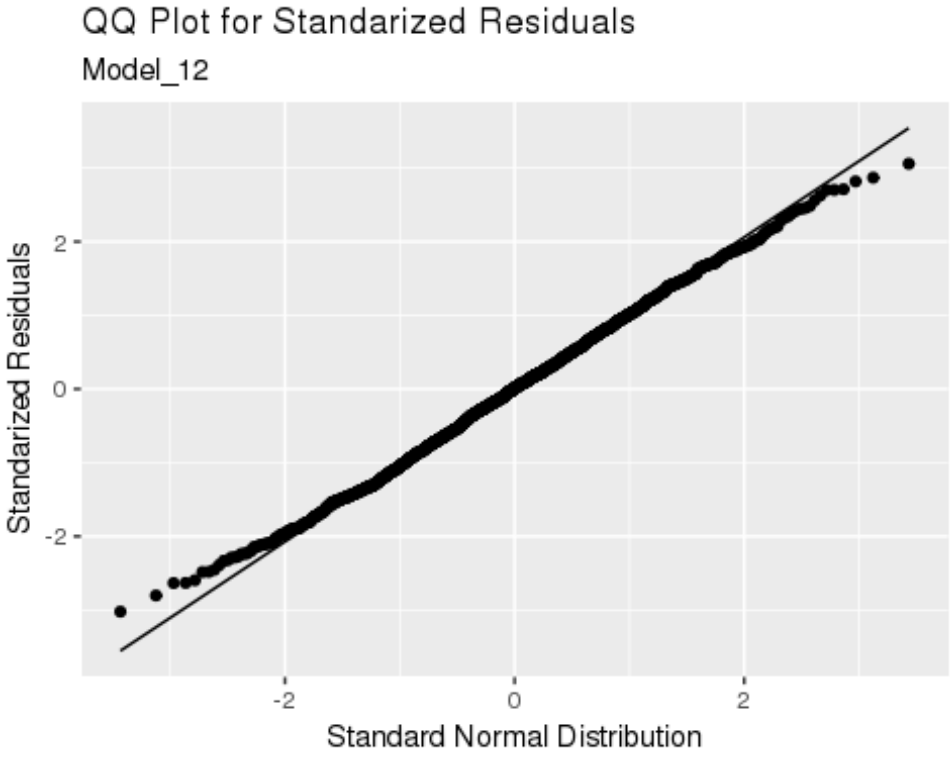

QQ Plot for Standarized Residuals
Model_11
Standarized Residuals
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 12

Model Definition: Computation method: maximum likelihood Variance grouping: Variance Group #1 Treatment group definition: Mean Group #1 Random Effect: Include hospitals with doctors nested within hospital

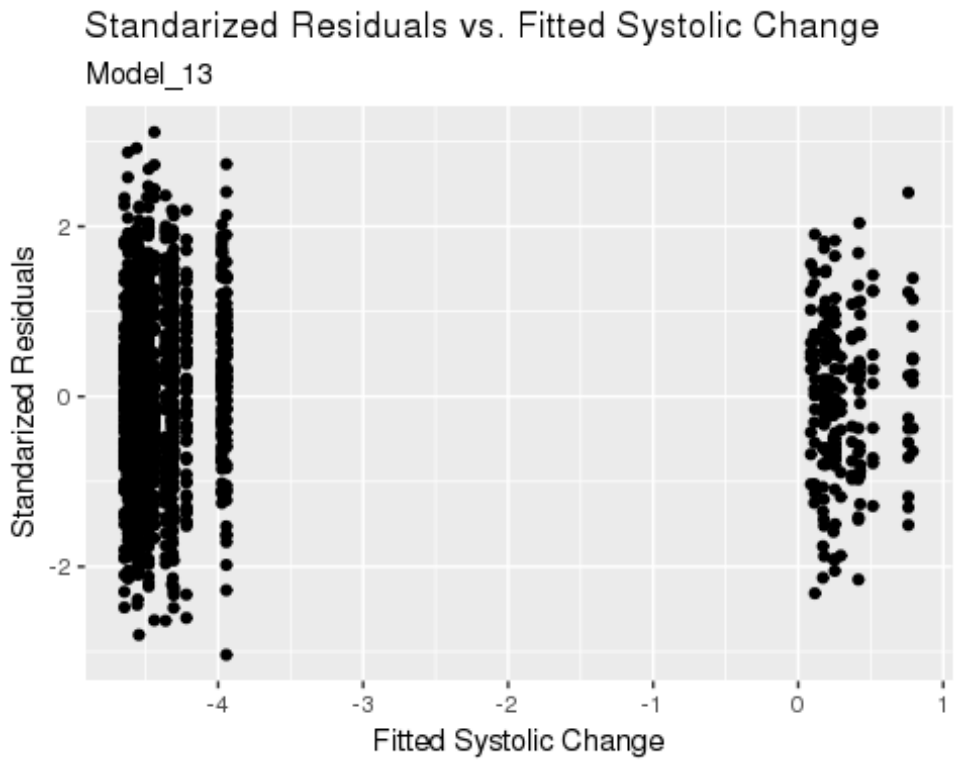


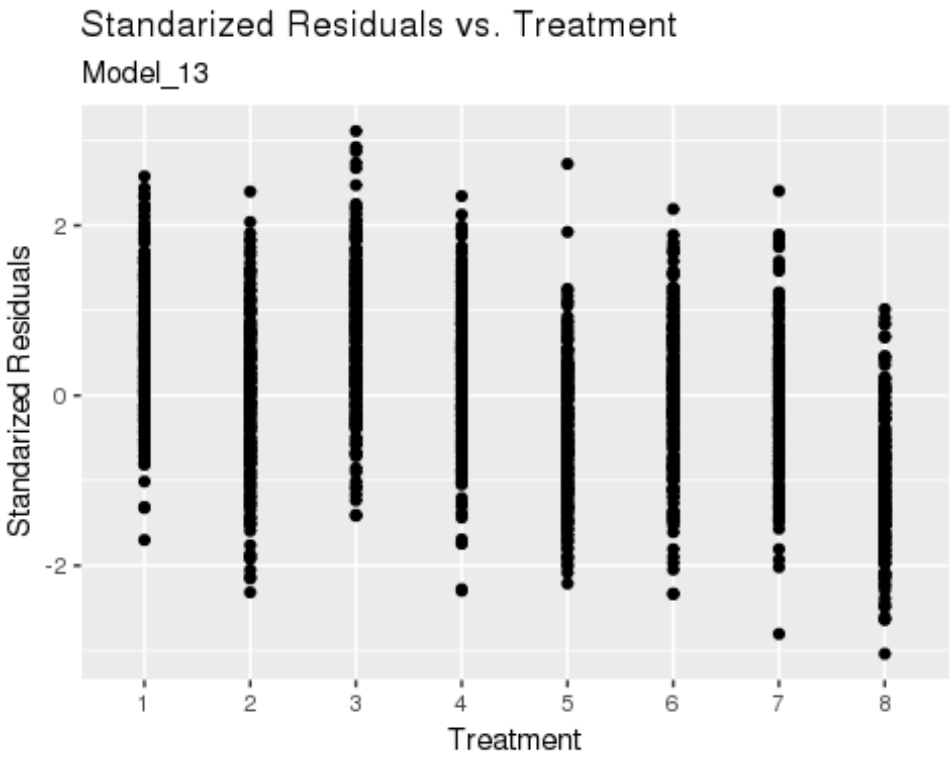

Standarized Residuals vs. Treatment
Model_12
Standarized Residuals
2
0
-2
1
2
3
4
5
6
7
8
Treatment

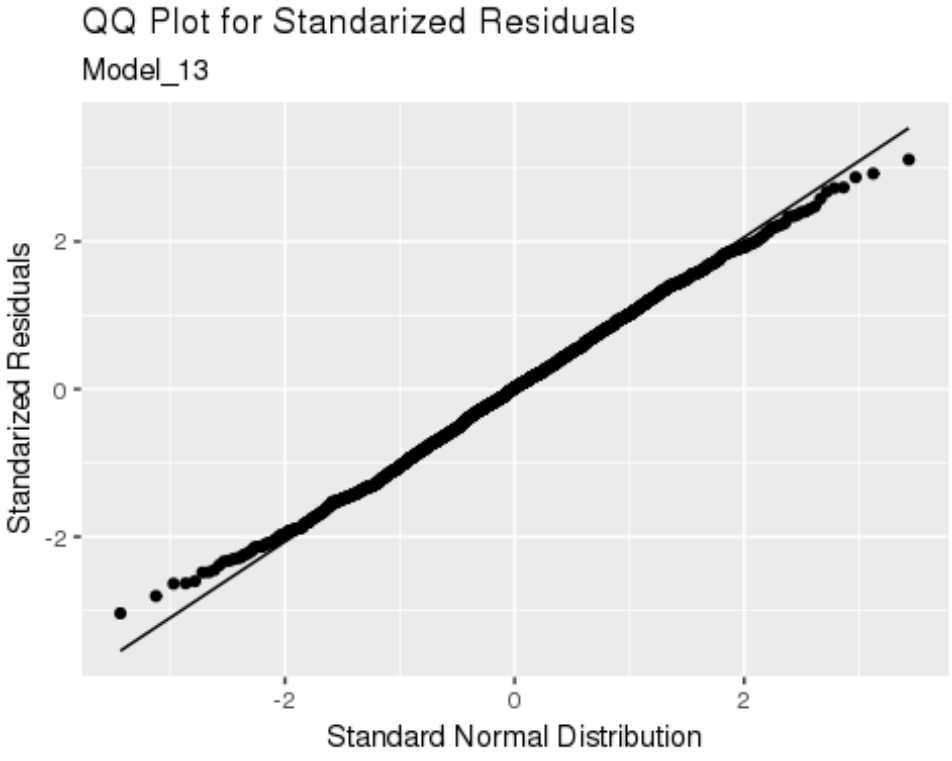

QQ Plot for Standarized Residuals
Model_12
Standarized Residuals
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 13

Model Definition: Computation method: restricted maximum likelihood Variance grouping: Group #2 Treatment group definition: Mean Group #1 Random Effect: Include hospitals with doctors nested within hospital

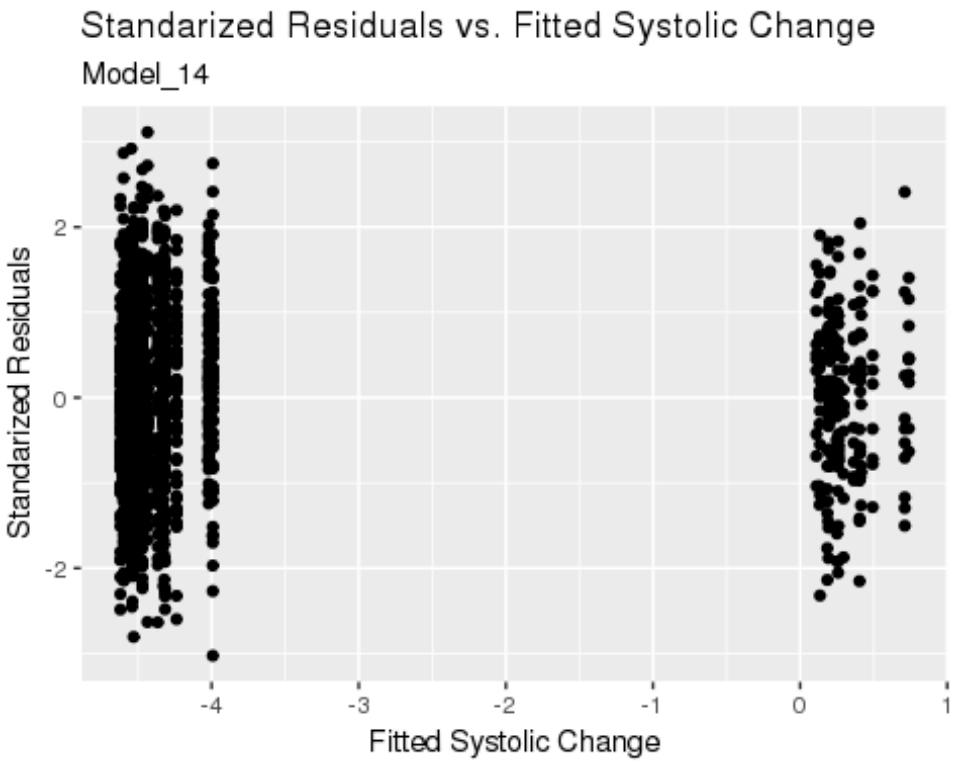


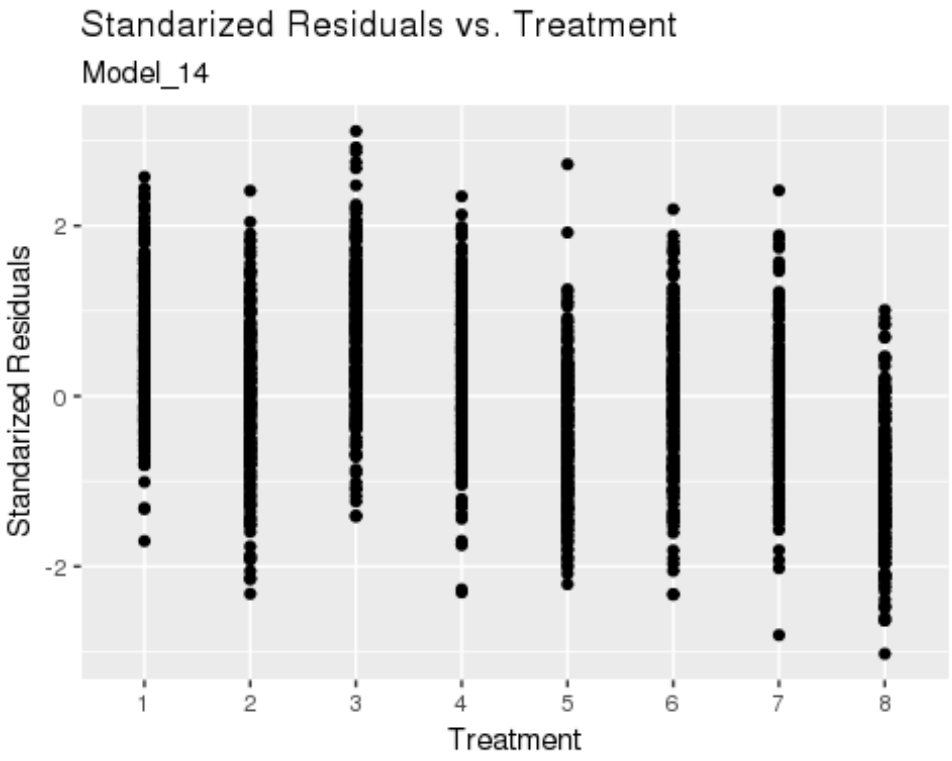

Standarized Residuals vs. Treatment
Model_13
Standarized Residuals
2
0
-2
1
2
3
4
5
6
7
8
Treatment

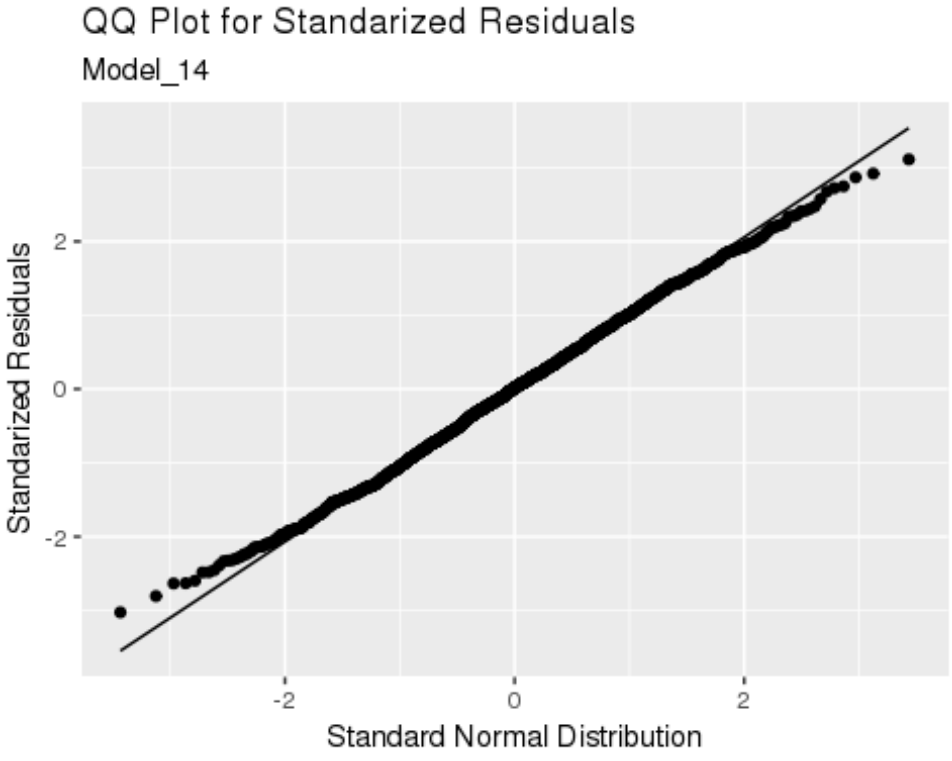

QQ Plot for Standarized Residuals
Model_13
Standarized Residuals
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 14

Model Definition: Computation method: maximum likelihood Variance grouping: Variance Group #2 Treatment group definition: Mean Group #1 Random Effect: Include hospitals with doctors nested within hospital

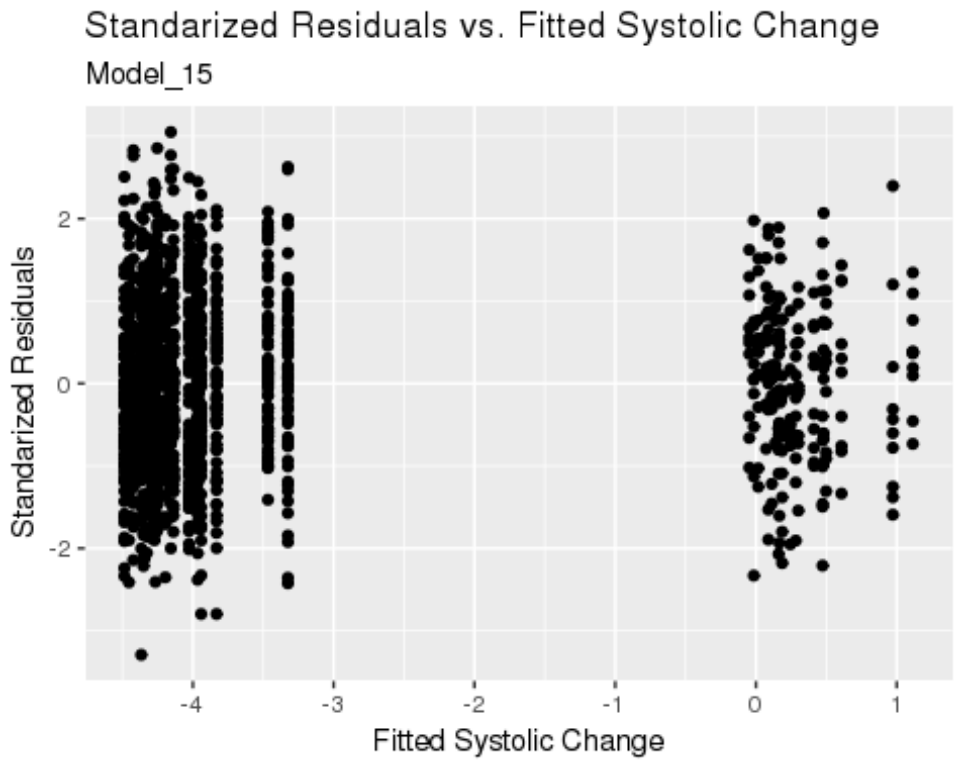


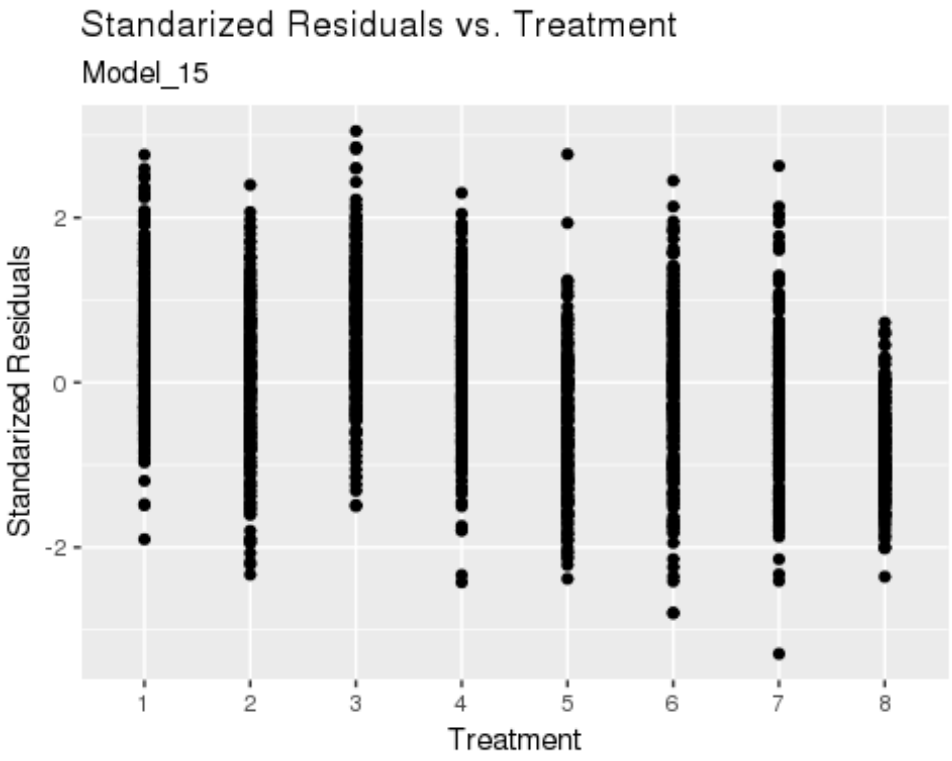

Standarized Residuals vs. Treatment
Model_14
Standarized Residuals
2
0
-2
1
2
3
4
5
6
7
8
Treatment

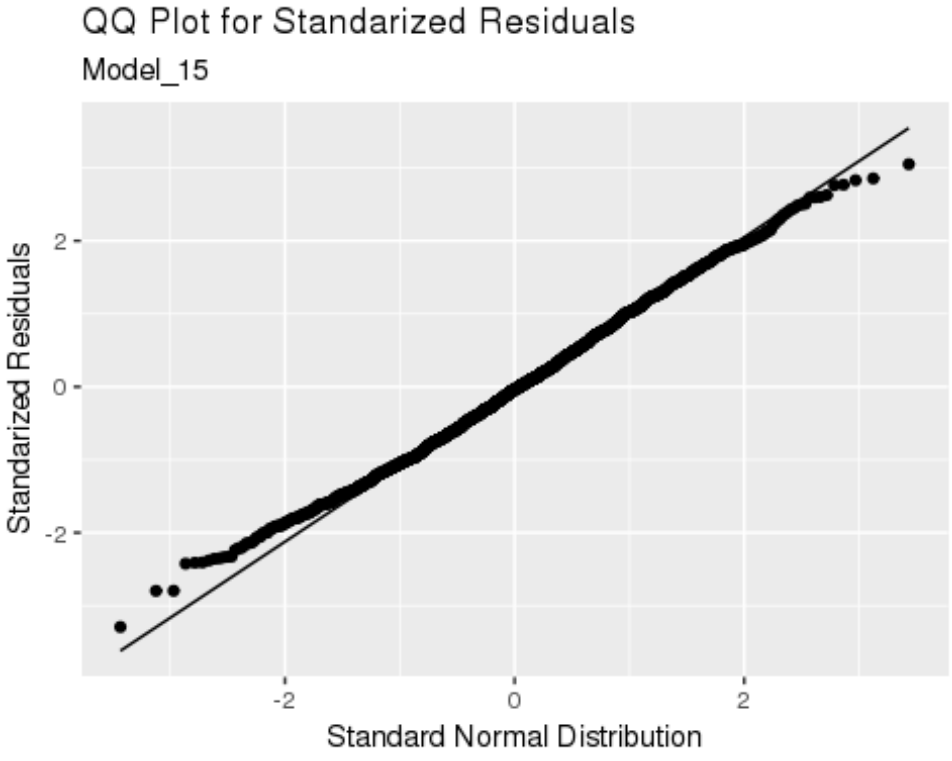

QQ Plot for Standarized Residuals
Model_14
Standarized Residuals
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 15

Model Definition: Computation method: restricted maximum likelihood Variance grouping: Variance Group #3 Treatment group definition: Mean Group #1 Random Effect: Include hospitals with doctors nested within hospital

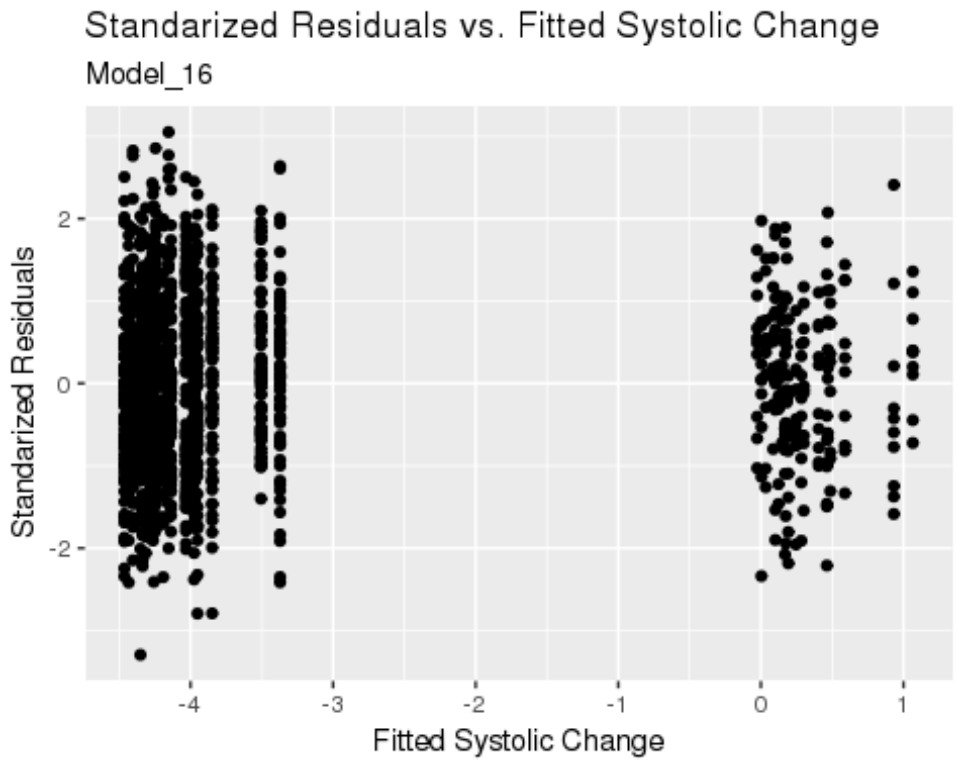


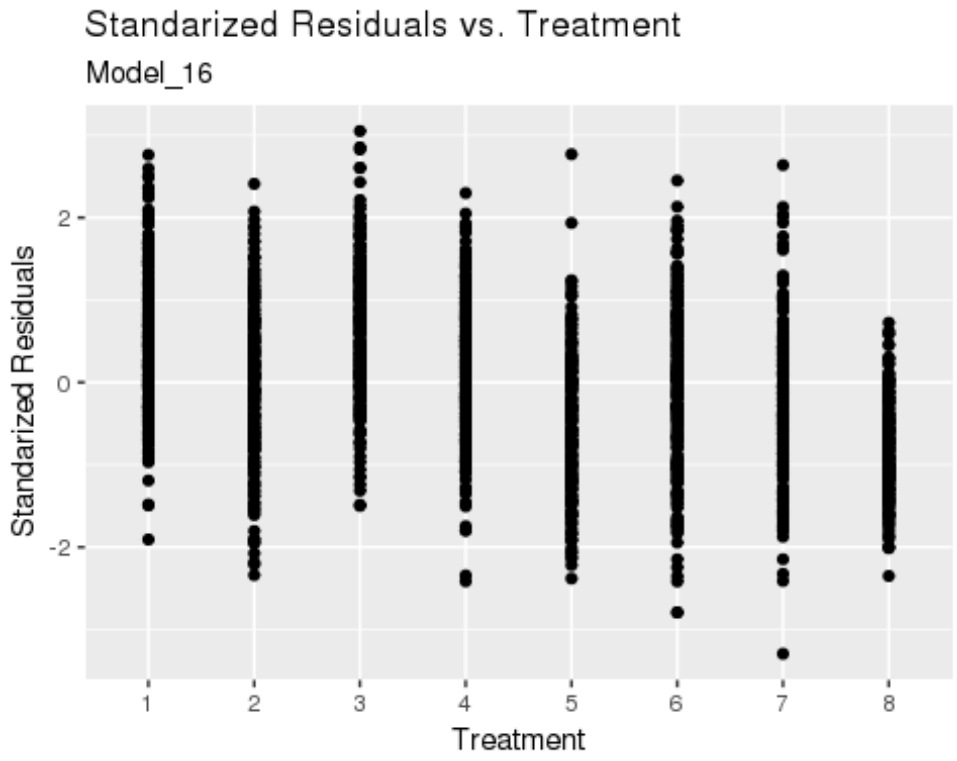

Standarized Residuals vs. Treatment
Model_15
Standarized Residuals
2
0
-2
1
2
3
4
5
6
7
8
Treatment

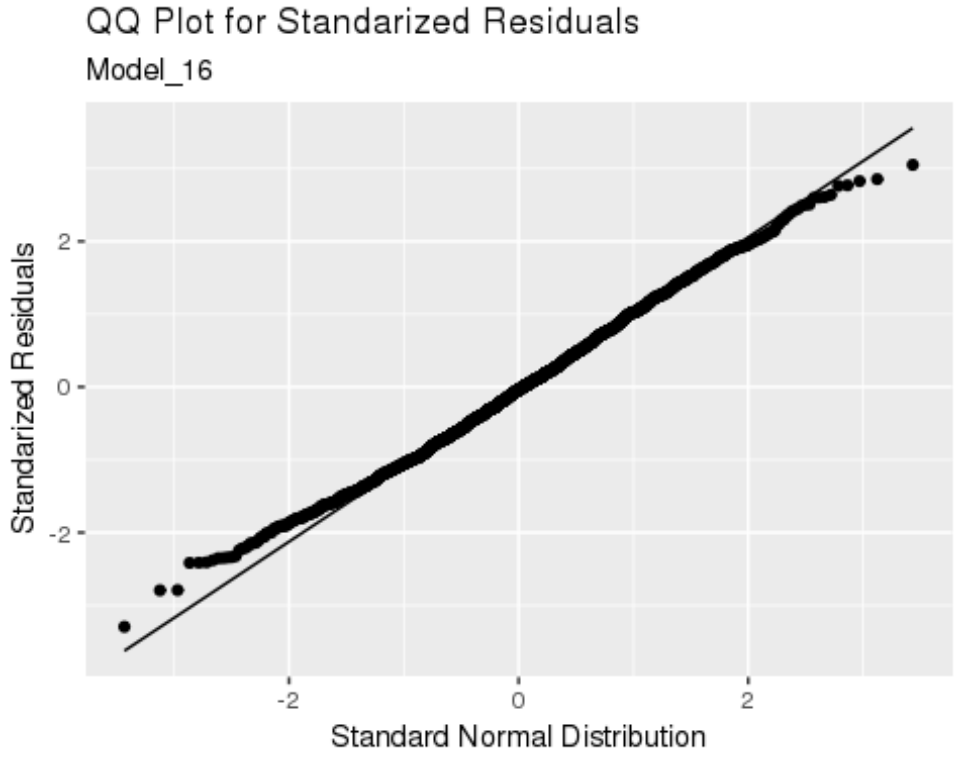

QQ Plot for Standarized Residuals
Model_15
Standarized Residuals
2
0
-2
-2
0
2
Standard Normal Distribution

Create Model 16

Model Definition: Computation method: maximum likelihood Variance grouping: Variance Group #3 Treatment group definition: Mean Group #1 Random Effect: Include hospitals with doctors nested within hospital




Standarized Residuals vs. Treatment
Model_16
Standarized Residuals
2
0
-2
1
2
3
4
5
6
7
8
Treatment


QQ Plot for Standarized Residuals
Model_16
Standarized Residuals
2
0
-2
-2
0
2
Standard Normal Distribution

D. Standardized goodness of fit statistics and fitted betas

Model 1 Results

```
## Linear mixed-effects model fit by REML
##  Data: systolic_g
##        AIC      BIC    logLik
##   9300.655 9360.294 -4639.327
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4307059
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##         (Intercept) Residual
## StdDev:    0.187263 3.810025
##
## Fixed effects: change_systolic ~ Treatment_F
##                  Value Std.Error   DF    t-value p-value
## (Intercept)  -1.795012 0.2795101 1463  -6.421992  0.0000
## Treatment_F2  2.101111 0.3718204 1463   5.650875  0.0000
## Treatment_F3  0.533483 0.3718204 1463   1.434788  0.1516
## Treatment_F4 -1.476657 0.3718204 1463  -3.971425  0.0001
## Treatment_F5 -4.615913 0.3718204 1463 -12.414362  0.0000
## Treatment_F6 -2.595449 0.3718204 1463  -6.980384  0.0000
## Treatment_F7 -3.172534 0.3718204 1463  -8.532437  0.0000
## Treatment_F8 -7.294017 0.3718204 1463 -19.617043  0.0000
##  Correlation:
##              (Intr) Trt_F2 Trt_F3 Trt_F4 Trt_F5 Trt_F6 Trt_F7
## Treatment_F2 -0.665
## Treatment_F3 -0.665  0.500
## Treatment_F4 -0.665  0.500  0.500
## Treatment_F5 -0.665  0.500  0.500  0.500
## Treatment_F6 -0.665  0.500  0.500  0.500  0.500
## Treatment_F7 -0.665  0.500  0.500  0.500  0.500  0.500
## Treatment_F8 -0.665  0.500  0.500  0.500  0.500  0.500  0.500
##
## Standardized Within-Group Residuals:
##          Min           Q1          Med           Q3          Max
## -3.151350691 -0.690631589  0.001801036  0.687151529  3.751340359
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 2 Results

```
## Linear mixed-effects model fit by maximum likelihood
##  Data: systolic_g
##        AIC      BIC    logLik
##   9294.656 9354.348 -4636.328
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4097239
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##         (Intercept) Residual
## StdDev:   0.2090384 3.800944
##
## Fixed effects: change_systolic ~ Treatment_F
##                 Value Std.Error   DF    t-value p-value
## (Intercept)  -1.795012 0.2781484 1463  -6.453430  0.0000
## Treatment_F2  2.101111 0.3718205 1463   5.650874  0.0000
## Treatment_F3  0.533483 0.3718205 1463   1.434788  0.1516
## Treatment_F4 -1.476657 0.3718205 1463  -3.971424  0.0001
## Treatment_F5 -4.615913 0.3718205 1463 -12.414359  0.0000
## Treatment_F6 -2.595449 0.3718205 1463  -6.980382  0.0000
## Treatment_F7 -3.172534 0.3718205 1463  -8.532435  0.0000
## Treatment_F8 -7.294017 0.3718205 1463 -19.617038  0.0000
##  Correlation:
##              (Intr) Trt_F2 Trt_F3 Trt_F4 Trt_F5 Trt_F6 Trt_F7
## Treatment_F2 -0.668
## Treatment_F3 -0.668  0.500
## Treatment_F4 -0.668  0.500  0.500
## Treatment_F5 -0.668  0.500  0.500  0.500
## Treatment_F6 -0.668  0.500  0.500  0.500  0.500
## Treatment_F7 -0.668  0.500  0.500  0.500  0.500  0.500
## Treatment_F8 -0.668  0.500  0.500  0.500  0.500  0.500  0.500
##
## Standardized Within-Group Residuals:
##          Min           Q1          Med           Q3          Max
## -3.157968766 -0.690475844  0.002506614  0.689894226  3.759326289
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                     210
```

Model 3 Results

```
## Linear mixed-effects model fit by REML
##  Data: systolic_g
##        AIC     BIC    logLik
##   9301.299 9366.36 -4638.649
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4394142
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##         (Intercept) Residual
## StdDev:   0.2047342 3.885634
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_1
##  Parameter estimates:
##         0         1
## 1.0000000 0.9600076
## Fixed effects: change_systolic ~ Treatment_F
##                  Value Std.Error   DF    t-value p-value
## (Intercept)  -1.795012 0.2851142 1463  -6.295764  0.0000
## Treatment_F2  2.101111 0.3791991 1463   5.540917  0.0000
## Treatment_F3  0.533483 0.3791991 1463   1.406869  0.1597
## Treatment_F4 -1.476657 0.3791991 1463  -3.894147  0.0001
## Treatment_F5 -4.615913 0.3716939 1463 -12.418588  0.0000
## Treatment_F6 -2.595449 0.3716939 1463  -6.982760  0.0000
## Treatment_F7 -3.172534 0.3716939 1463  -8.535341  0.0000
## Treatment_F8 -7.294017 0.3716939 1463 -19.623721  0.0000
##  Correlation:
##              (Intr) Trt_F2 Trt_F3 Trt_F4 Trt_F5 Trt_F6 Trt_F7
## Treatment_F2 -0.665
## Treatment_F3 -0.665  0.500
## Treatment_F4 -0.665  0.500  0.500
## Treatment_F5 -0.678  0.510  0.510  0.510
## Treatment_F6 -0.678  0.510  0.510  0.510  0.520
## Treatment_F7 -0.678  0.510  0.510  0.510  0.520  0.520
## Treatment_F8 -0.678  0.510  0.510  0.510  0.520  0.520  0.520
##
## Standardized Within-Group Residuals:
##          Min           Q1          Med           Q3          Max
## -3.212146733 -0.684307656  0.003524133  0.684495444  3.826598621
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                     210
```

Model 4 Results

```
## Linear mixed-effects model fit by maximum likelihood
##  Data: systolic_g
##       AIC      BIC    logLik
##   9295.31 9360.429 -4635.655
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4183657
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##         (Intercept) Residual
## StdDev:   0.2246463   3.8759
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_1
##  Parameter estimates:
##        0        1
## 1.000000 0.960247
## Fixed effects: change_systolic ~ Treatment_F
##                  Value Std.Error   DF    t-value p-value
## (Intercept)  -1.795012 0.2837157 1463  -6.326797  0.0000
## Treatment_F2  2.101111 0.3791530 1463   5.541591  0.0000
## Treatment_F3  0.533483 0.3791530 1463   1.407040  0.1596
## Treatment_F4 -1.476657 0.3791530 1463  -3.894621  0.0001
## Treatment_F5 -4.615913 0.3716931 1463 -12.418613  0.0000
## Treatment_F6 -2.595449 0.3716931 1463  -6.982774  0.0000
## Treatment_F7 -3.172534 0.3716931 1463  -8.535359  0.0000
## Treatment_F8 -7.294017 0.3716931 1463 -19.623761  0.0000
##  Correlation:
##              (Intr) Trt_F2 Trt_F3 Trt_F4 Trt_F5 Trt_F6 Trt_F7
## Treatment_F2 -0.668
## Treatment_F3 -0.668  0.500
## Treatment_F4 -0.668  0.500  0.500
## Treatment_F5 -0.682  0.510  0.510  0.510
## Treatment_F6 -0.682  0.510  0.510  0.510  0.520
## Treatment_F7 -0.682  0.510  0.510  0.510  0.520  0.520
## Treatment_F8 -0.682  0.510  0.510  0.510  0.520  0.520  0.520
##
## Standardized Within-Group Residuals:
##          Min           Q1          Med           Q3          Max
## -3.218461886 -0.684686643  0.003120456  0.684527669  3.834278498
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                     210
```

Model 5 Results

```
## Linear mixed-effects model fit by REML
##  Data: systolic_g
##        AIC      BIC    logLik
##   9303.232 9373.715 -4638.616
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4391219
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##         (Intercept) Residual
## StdDev:   0.2043875 3.842886
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_2
##  Parameter estimates:
##         0         1         2
## 1.0000000 1.0148160 0.9706957
## Fixed effects: change_systolic ~ Treatment_F
##                  Value Std.Error   DF    t-value p-value
## (Intercept)  -1.795012 0.2823189 1463  -6.358100  0.0000
## Treatment_F2  2.101111 0.3778157 1463   5.561206  0.0000
## Treatment_F3  0.533483 0.3778157 1463   1.412020  0.1582
## Treatment_F4 -1.476657 0.3778157 1463  -3.908405  0.0001
## Treatment_F5 -4.615913 0.3695732 1463 -12.489849  0.0000
## Treatment_F6 -2.595449 0.3695732 1463  -7.022829  0.0000
## Treatment_F7 -3.172534 0.3695732 1463  -8.584320  0.0000
## Treatment_F8 -7.294017 0.3695732 1463 -19.736327  0.0000
##  Correlation:
##              (Intr) Trt_F2 Trt_F3 Trt_F4 Trt_F5 Trt_F6 Trt_F7
## Treatment_F2 -0.659
## Treatment_F3 -0.659  0.493
## Treatment_F4 -0.659  0.493  0.493
## Treatment_F5 -0.674  0.504  0.504  0.504
## Treatment_F6 -0.674  0.504  0.504  0.504  0.515
## Treatment_F7 -0.674  0.504  0.504  0.504  0.515  0.515
## Treatment_F8 -0.674  0.504  0.504  0.504  0.515  0.515  0.515
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.21082407 -0.68192046  0.00305779  0.68466789  3.82591848
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 6 Results

```
## Linear mixed-effects model fit by maximum likelihood
##  Data: systolic_g
##        AIC      BIC    logLik
##   9297.243 9367.789 -4635.622
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4180693
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##         (Intercept) Residual
## StdDev:   0.2243367 3.833071
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_2
##  Parameter estimates:
##         0         1         2
## 1.0000000 1.0148817 0.9709859
## Fixed effects: change_systolic ~ Treatment_F
##                  Value Std.Error   DF    t-value p-value
## (Intercept)  -1.795012 0.2808955 1463  -6.390318  0.0000
## Treatment_F2  2.101111 0.3777636 1463   5.561973  0.0000
## Treatment_F3  0.533483 0.3777636 1463   1.412215  0.1581
## Treatment_F4 -1.476657 0.3777636 1463  -3.908945  0.0001
## Treatment_F5 -4.615913 0.3695637 1463 -12.490171  0.0000
## Treatment_F6 -2.595449 0.3695637 1463  -7.023010  0.0000
## Treatment_F7 -3.172534 0.3695637 1463  -8.584540  0.0000
## Treatment_F8 -7.294017 0.3695637 1463 -19.736835  0.0000
##  Correlation:
##              (Intr) Trt_F2 Trt_F3 Trt_F4 Trt_F5 Trt_F6 Trt_F7
## Treatment_F2 -0.662
## Treatment_F3 -0.662  0.493
## Treatment_F4 -0.662  0.493  0.493
## Treatment_F5 -0.677  0.504  0.504  0.504
## Treatment_F6 -0.677  0.504  0.504  0.504  0.515
## Treatment_F7 -0.677  0.504  0.504  0.504  0.515  0.515
## Treatment_F8 -0.677  0.504  0.504  0.504  0.515  0.515  0.515
##
## Standardized Within-Group Residuals:
##          Min           Q1          Med           Q3          Max
## -3.217175106 -0.683870891  0.002868699  0.684755910  3.833637003
##
## Number of Observations: 1680
## Number of Groups:
##                Hospital_F Doctor_F %in% Hospital_F
##                        21                      210
```

Model 7 Results

```
## Linear mixed-effects model fit by REML
##  Data: systolic_g
##        AIC      BIC    logLik
##   9303.271 9379.175 -4637.635
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4237209
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##         (Intercept) Residual
## StdDev:   0.2055382 3.941013
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_3
##  Parameter estimates:
##         0         1         2         3
## 1.0000000 0.9565403 0.9806869 0.8981365
## Fixed effects: change_systolic ~ Treatment_F
##                  Value Std.Error   DF    t-value p-value
## (Intercept)  -1.795012 0.2875945 1463  -6.241467  0.0000
## Treatment_F2  2.101111 0.3846035 1463   5.463057  0.0000
## Treatment_F3  0.533483 0.3763389 1463   1.417561  0.1565
## Treatment_F4 -1.476657 0.3763389 1463  -3.923742  0.0001
## Treatment_F5 -4.615913 0.3763389 1463 -12.265310  0.0000
## Treatment_F6 -2.595449 0.3809077 1463  -6.813854  0.0000
## Treatment_F7 -3.172534 0.3809077 1463  -8.328880  0.0000
## Treatment_F8 -7.294017 0.3655402 1463 -19.954077  0.0000
##  Correlation:
##              (Intr) Trt_F2 Trt_F3 Trt_F4 Trt_F5 Trt_F6 Trt_F7
## Treatment_F2 -0.669
## Treatment_F3 -0.683  0.511
## Treatment_F4 -0.683  0.511  0.522
## Treatment_F5 -0.683  0.511  0.522  0.522
## Treatment_F6 -0.675  0.505  0.516  0.516  0.516
## Treatment_F7 -0.675  0.505  0.516  0.516  0.516  0.510
## Treatment_F8 -0.704  0.526  0.538  0.538  0.538  0.531  0.531
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.10698726 -0.68414823  0.00284928  0.69816803  3.78725057
##
## Number of Observations: 1680
## Number of Groups:
##                Hospital_F Doctor_F %in% Hospital_F
##                        21                      210
```

Model 8 Results

```
## Linear mixed-effects model fit by maximum likelihood
##  Data: systolic_g
##       AIC      BIC   logLik
##   9297.24 9373.212 -4634.62
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4024908
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##         (Intercept) Residual
## StdDev:   0.2254259  3.93075
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_3
##  Parameter estimates:
##         0         1         2         3
## 1.0000000 0.9567178 0.9813402 0.8980579
## Fixed effects: change_systolic ~ Treatment_F
##                  Value Std.Error   DF    t-value p-value
## (Intercept)  -1.795012 0.2862194 1463  -6.271453  0.0000
## Treatment_F2  2.101111 0.3845186 1463   5.464264  0.0000
## Treatment_F3  0.533483 0.3762892 1463   1.417749  0.1565
## Treatment_F4 -1.476657 0.3762892 1463  -3.924261  0.0001
## Treatment_F5 -4.615913 0.3762892 1463 -12.266931  0.0000
## Treatment_F6 -2.595449 0.3809479 1463  -6.813134  0.0000
## Treatment_F7 -3.172534 0.3809479 1463  -8.327999  0.0000
## Treatment_F8 -7.294017 0.3654452 1463 -19.959264  0.0000
##  Correlation:
##              (Intr) Trt_F2 Trt_F3 Trt_F4 Trt_F5 Trt_F6 Trt_F7
## Treatment_F2 -0.672
## Treatment_F3 -0.686  0.511
## Treatment_F4 -0.686  0.511  0.522
## Treatment_F5 -0.686  0.511  0.522  0.522
## Treatment_F6 -0.678  0.505  0.516  0.516  0.516
## Treatment_F7 -0.678  0.505  0.516  0.516  0.516  0.509
## Treatment_F8 -0.707  0.526  0.538  0.538  0.538  0.531  0.531
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.11220205 -0.68621500  0.00228202  0.70233058  3.79550328
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 9 Results

```
## Linear mixed-effects model fit by REML
##  Data: systolic_g
##        AIC      BIC    logLik
##   9827.508 9854.635 -4908.754
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.3453025
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##          (Intercept) Residual
## StdDev: 0.0003007451 4.483215
##
## Fixed effects: change_systolic ~ Mean_F_G_1
##                 Value Std.Error   DF   t-value p-value
## (Intercept)  0.306099 0.3184154 1469   0.96132  0.3365
## Mean_F_G_11 -4.761266 0.3307318 1469 -14.39616  0.0000
##  Correlation:
##             (Intr)
## Mean_F_G_11 -0.909
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.06281455 -0.69786832  0.01980658  0.70120039  3.02804047
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 10 Results

```
## Linear mixed-effects model fit by maximum likelihood
##  Data: systolic_g
##        AIC      BIC    logLik
##   9824.908 9852.041 -4907.454
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.3189744
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##          (Intercept) Residual
## StdDev: 0.0002603604 4.481864
##
## Fixed effects: change_systolic ~ Mean_F_G_1
##                 Value Std.Error   DF    t-value p-value
## (Intercept)  0.306099 0.3172028 1469   0.964995  0.3347
## Mean_F_G_11 -4.761266 0.3308290 1469 -14.391923  0.0000
##  Correlation:
##             (Intr)
## Mean_F_G_11 -0.913
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.05245211 -0.69892727  0.01811467  0.69929735  3.02894758
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 11 Results

```
## Linear mixed-effects model fit by REML
##  Data: systolic_g
##        AIC      BIC    logLik
##   9829.197 9861.749 -4908.598
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:    0.339177
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##          (Intercept) Residual
## StdDev: 0.0002962927 4.429278
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_1
##  Parameter estimates:
##        0        1
## 1.000000 1.024438
## Fixed effects: change_systolic ~ Mean_F_G_1
##                 Value Std.Error   DF    t-value p-value
## (Intercept)  0.306099 0.3144830 1469   0.973341  0.3305
## Mean_F_G_11 -4.712562 0.3273176 1469 -14.397521  0.0000
##  Correlation:
##             (Intr)
## Mean_F_G_11 -0.908
##
## Standardized Within-Group Residuals:
##          Min           Q1          Med           Q3          Max
## -3.034153841 -0.701279435  0.009167059  0.693319171  3.054950743
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 12 Results

```
## Linear mixed-effects model fit by maximum likelihood
##  Data: systolic_g
##        AIC      BIC    logLik
##   9826.564 9859.123 -4907.282
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.3123439
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##          (Intercept) Residual
## StdDev: 0.0002966376  4.42522
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_1
##  Parameter estimates:
##        0        1
## 1.000000 1.025706
## Fixed effects: change_systolic ~ Mean_F_G_1
##                 Value Std.Error   DF    t-value p-value
## (Intercept)  0.306099 0.3130697 1469   0.977735  0.3284
## Mean_F_G_11 -4.710059 0.3272415 1469 -14.393219  0.0000
##  Correlation:
##             (Intr)
## Mean_F_G_11 -0.911
##
## Standardized Within-Group Residuals:
##          Min           Q1          Med           Q3          Max
## -3.022341292 -0.703547675  0.008108789  0.690143342  3.057114859
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 13 Results

```
## Linear mixed-effects model fit by REML
##  Data: systolic_g
##        AIC      BIC    logLik
##   9829.826 9867.804 -4907.913
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.3427984
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##          (Intercept) Residual
## StdDev: 0.0002593762 4.658418
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_2
##  Parameter estimates:
##         0         1         2
## 1.0000000 0.9361625 0.9722146
## Fixed effects: change_systolic ~ Mean_F_G_1
##                 Value Std.Error   DF    t-value p-value
## (Intercept)  0.306099 0.3100978 1469   0.987105  0.3238
## Mean_F_G_11 -4.733408 0.3229824 1469 -14.655314  0.0000
##  Correlation:
##             (Intr)
## Mean_F_G_11 -0.904
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.03755031 -0.70021263  0.01264186  0.69096616  3.10924631
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 14 Results

```
## Linear mixed-effects model fit by maximum likelihood
##  Data: systolic_g
##        AIC      BIC    logLik
##   9827.172 9865.158 -4906.586
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.3161544
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##          (Intercept) Residual
## StdDev: 0.0002635953 4.655886
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_2
##  Parameter estimates:
##         0         1         2
## 1.0000000 0.9357249 0.9730321
## Fixed effects: change_systolic ~ Mean_F_G_1
##                 Value Std.Error   DF    t-value p-value
## (Intercept)  0.306099 0.3086342 1469   0.991787  0.3215
## Mean_F_G_11 -4.731102 0.3228822 1469 -14.652719  0.0000
##  Correlation:
##             (Intr)
## Mean_F_G_11 -0.908
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.02578036 -0.70152243  0.01121081  0.68979562  3.11162255
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 15 Results

```
## Linear mixed-effects model fit by REML
##  Data: systolic_g
##        AIC      BIC    logLik
##   9775.293 9818.696 -4879.647
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4481821
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##          (Intercept) Residual
## StdDev: 0.0003459471 4.273901
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_3
##  Parameter estimates:
##         0         1         2         3
## 1.0000000 1.0184239 0.9150174 1.4268349
## Fixed effects: change_systolic ~ Mean_F_G_1
##                 Value Std.Error   DF    t-value p-value
## (Intercept)  0.306099 0.3107204 1469   0.985128  0.3247
## Mean_F_G_11 -4.438794 0.3159520 1469 -14.048948  0.0000
##  Correlation:
##             (Intr)
## Mean_F_G_11 -0.886
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.29229104 -0.74060466 -0.03778026  0.66677221  3.05016798
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```

Model 16 Results

```
## Linear mixed-effects model fit by maximum likelihood
##  Data: systolic_g
##        AIC      BIC    logLik
##   9772.763 9816.176 -4878.382
##
## Random effects:
##  Formula: ~1 | Hospital_F
##         (Intercept)
## StdDev:   0.4239019
##
##  Formula: ~1 | Doctor_F %in% Hospital_F
##          (Intercept) Residual
## StdDev: 0.0003514082 4.267697
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Var_F_G_3
##  Parameter estimates:
##         0         1         2         3
## 1.0000000 1.0197313 0.9168706 1.4288039
## Fixed effects: change_systolic ~ Mean_F_G_1
##                 Value Std.Error   DF    t-value p-value
## (Intercept)  0.306099 0.3088690 1469   0.991032  0.3218
## Mean_F_G_11 -4.437553 0.3157367 1469 -14.054597  0.0000
##  Correlation:
##             (Intr)
## Mean_F_G_11 -0.89
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.29435208 -0.73974381 -0.04173015  0.67041968  3.05010782
##
## Number of Observations: 1680
## Number of Groups:
##               Hospital_F Doctor_F %in% Hospital_F
##                       21                      210
```