MLMs

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Basic modeling idea:

Predicting Match outcome based on Success-Score (difference), Possession & opponent quality with the team identity as a random factor
Team as random intercept seems necessary, as results are probable to correlate within teams (i.e. some teams just win more!). Random slopes for possession could be realistic - some studies showed that better teams profit more from possession. Random slope for opponent quality has no theoretical basis. All teams are expected to perform worse (compared to their average performance, i.e. random intercept) against stronger opponents. Random slopes for the Success-Score are also unneccessary. All teams are hypothesized to profit from Success-Scores and the variance shared with possession that might count against this argument is accounted for by the possession predictor. Is it an issue if I have symmetrical points (the two teams for each match?!)

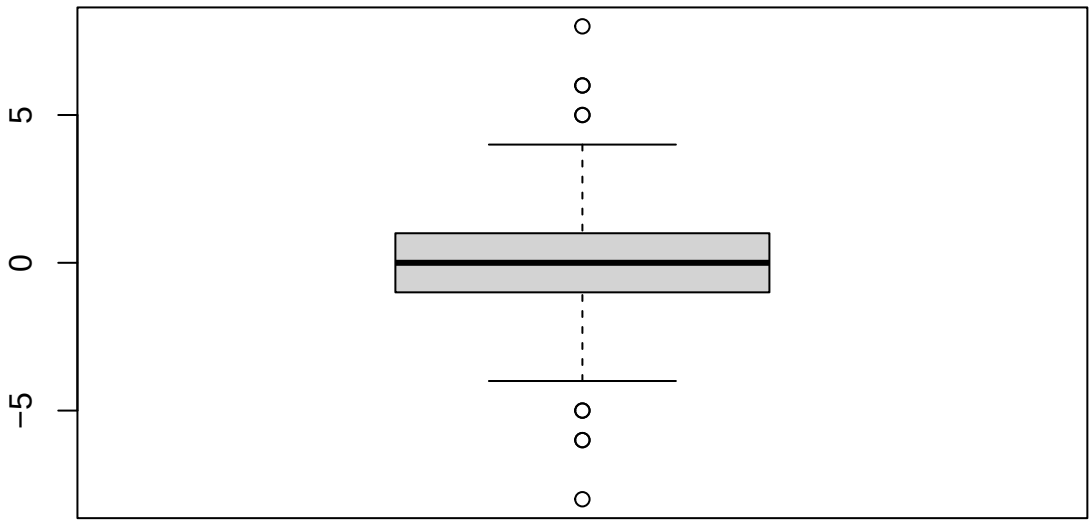
$$MO = (\beta_0 + u_{0t}) + \beta_{ass} \times ASS_{it} + \beta_{oq} \times OQ_{it} + (\beta_p + u_{pt}) \times P_{it}$$

with:
MO = match outcome
β_0 = overall intercept
u_0t = the random intercept, the team specific deviation from overall intercept
β = the overall slope for each predictor
u_{xyt} = the random slope of team t for predictor xy / team t's deviation from overall slope
ASS = Average Success Score
OQ = opponent quality
P = possession
i = the match
t = the team

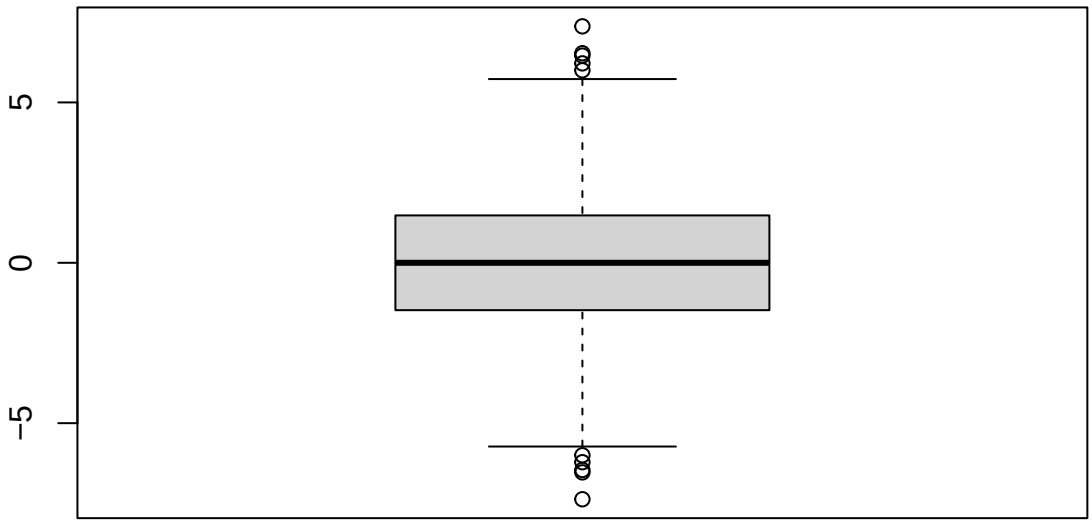
16m_100s

Descriptive

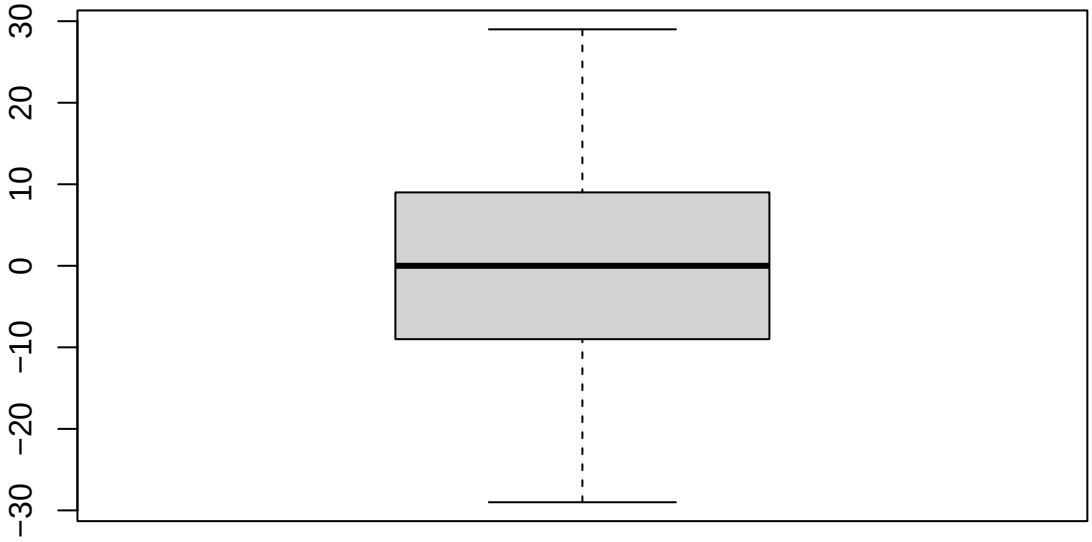
```
boxplot(df$Outcome_num)
```



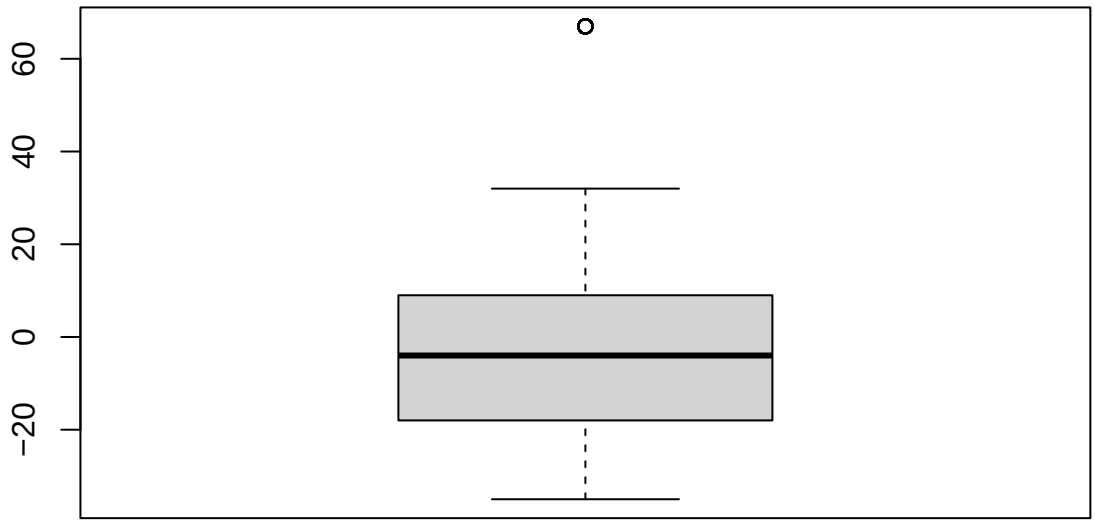

```
boxplot(df$ASS_16m_100s_diff)
```




```
boxplot(df$possession_zero)
```



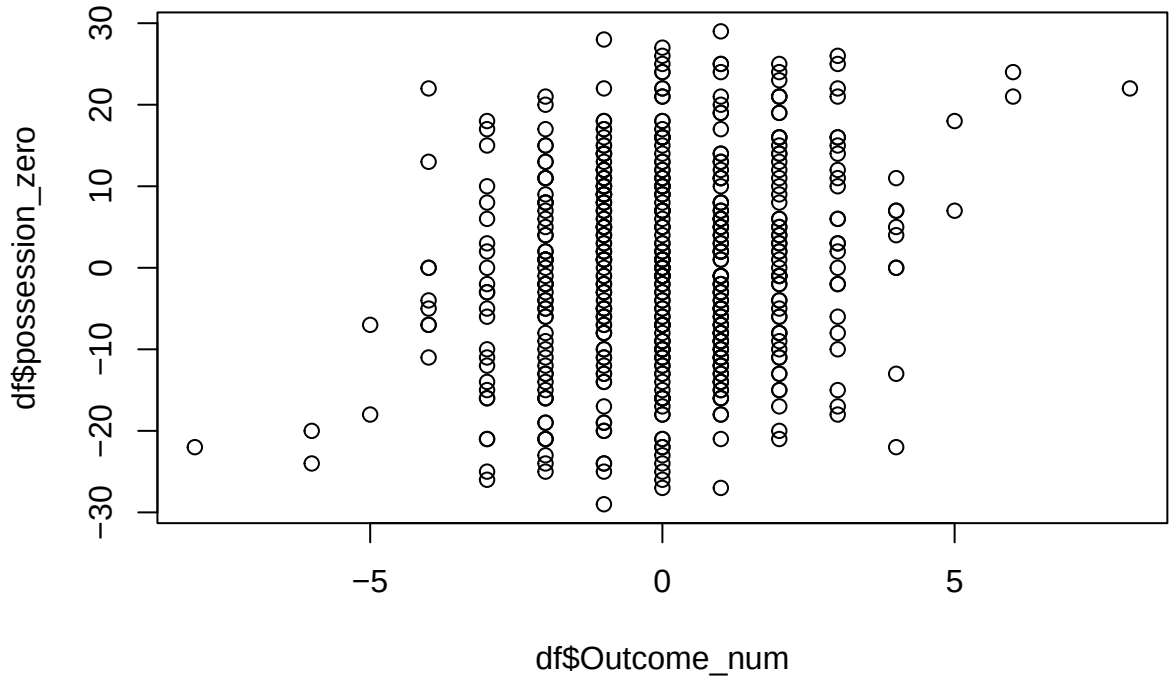

```
boxplot(df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$possession_zero
## t = 4.5167, df = 504, p-value = 7.831e-06
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1119941 0.2795989
## sample estimates:
##       cor
## 0.1972373
```

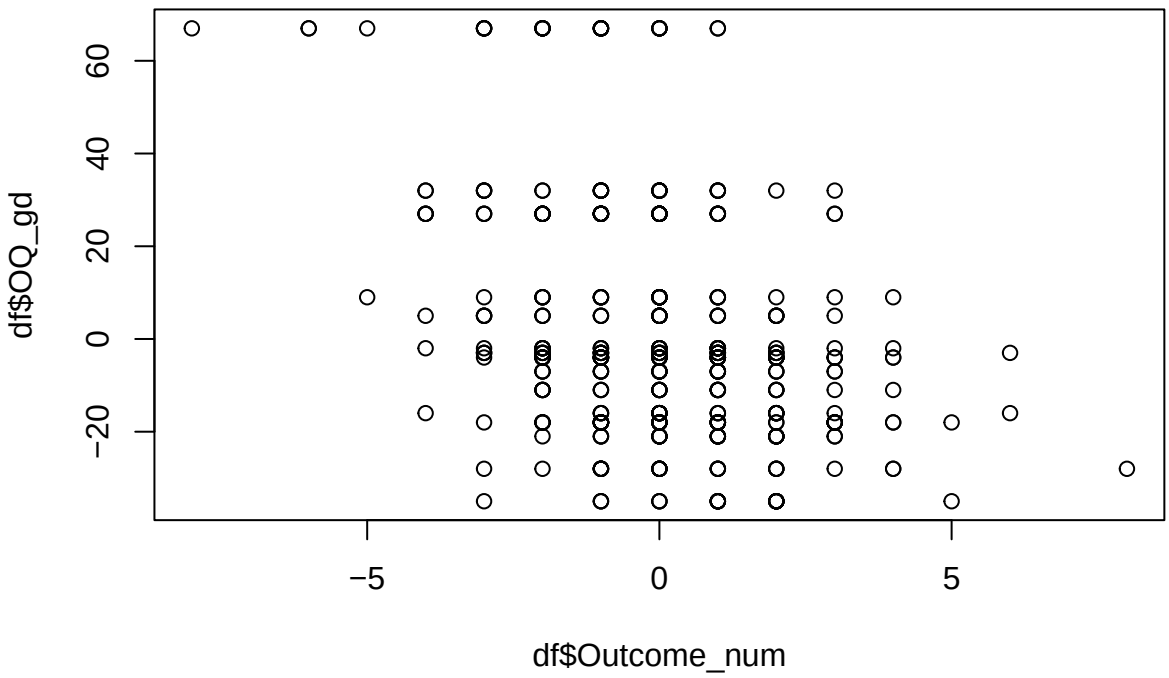
```
plot(df$Outcome_num, df$possession_zero)
```




```
cor.test(df$Outcome_num, df$OQ_gd)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$OQ_gd
## t = -9.2557, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4532666 -0.3040926
## sample estimates:
##        cor
## -0.3811578
```

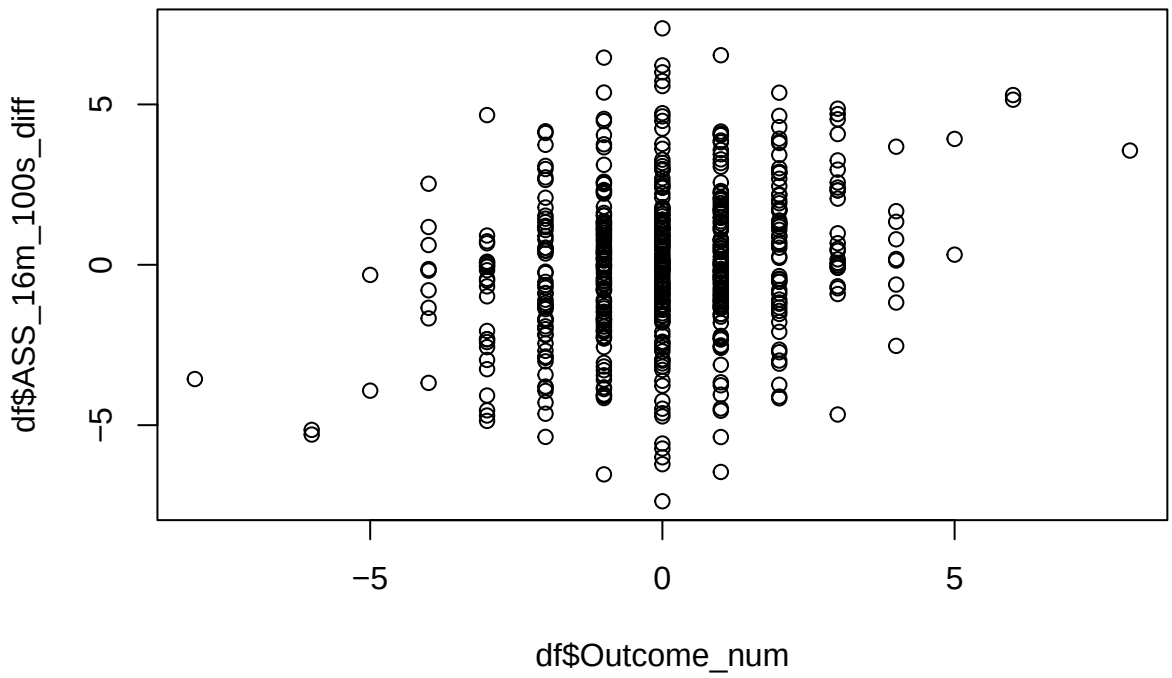
```
plot(df$Outcome_num, df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$ASS_16m_100s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$ASS_16m_100s_diff
## t = 6.0868, df = 504, p-value = 2.283e-09
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1785866 0.3410703
## sample estimates:
##       cor
## 0.2616816
```

```
plot(df$Outcome_num, df$ASS_16m_100s_diff)
```




```
cor.test(df$OQ_gd, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$possession_zero
## t = -12.359, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.5464574 -0.4124298
## sample estimates:
##        cor
## -0.4822607
```

```
cor.test(df$OQ_gd, df$ASS_16m_100s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$ASS_16m_100s_diff
## t = -9.1874, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4510285 -0.3015373
```

```
## sample estimates:
##        cor
## -0.3787506
```

```
cor.test(df$possession_zero, df$ASS_16m_100s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$possession_zero and df$ASS_16m_100s_diff
## t = 22.65, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.6641929 0.7509196
## sample estimates:
##       cor
## 0.7102409
```

Diagnostics

```
fullmod <- lmer(Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (1+possession_zero|Team), da
```

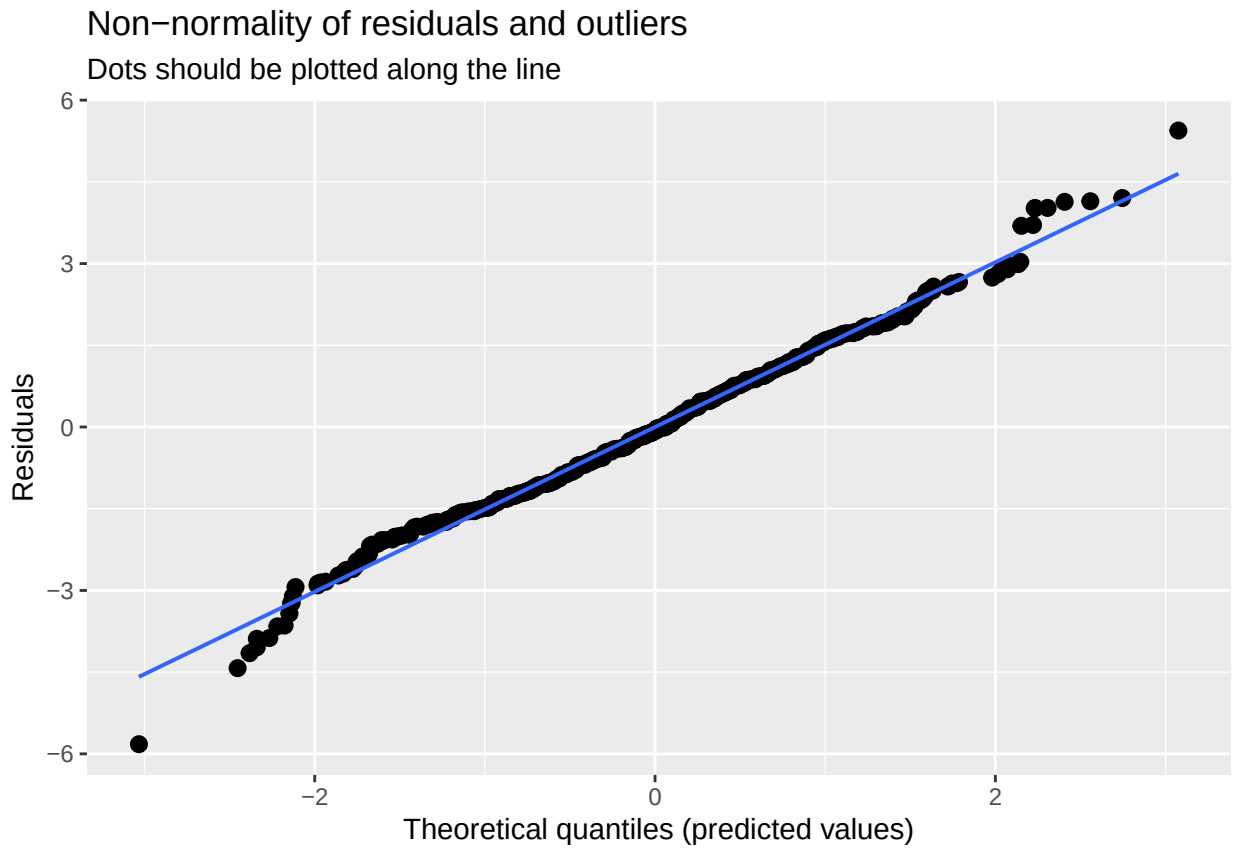
```
## boundary (singular) fit: see help('isSingular')
```

```
vif(fullmod)
```

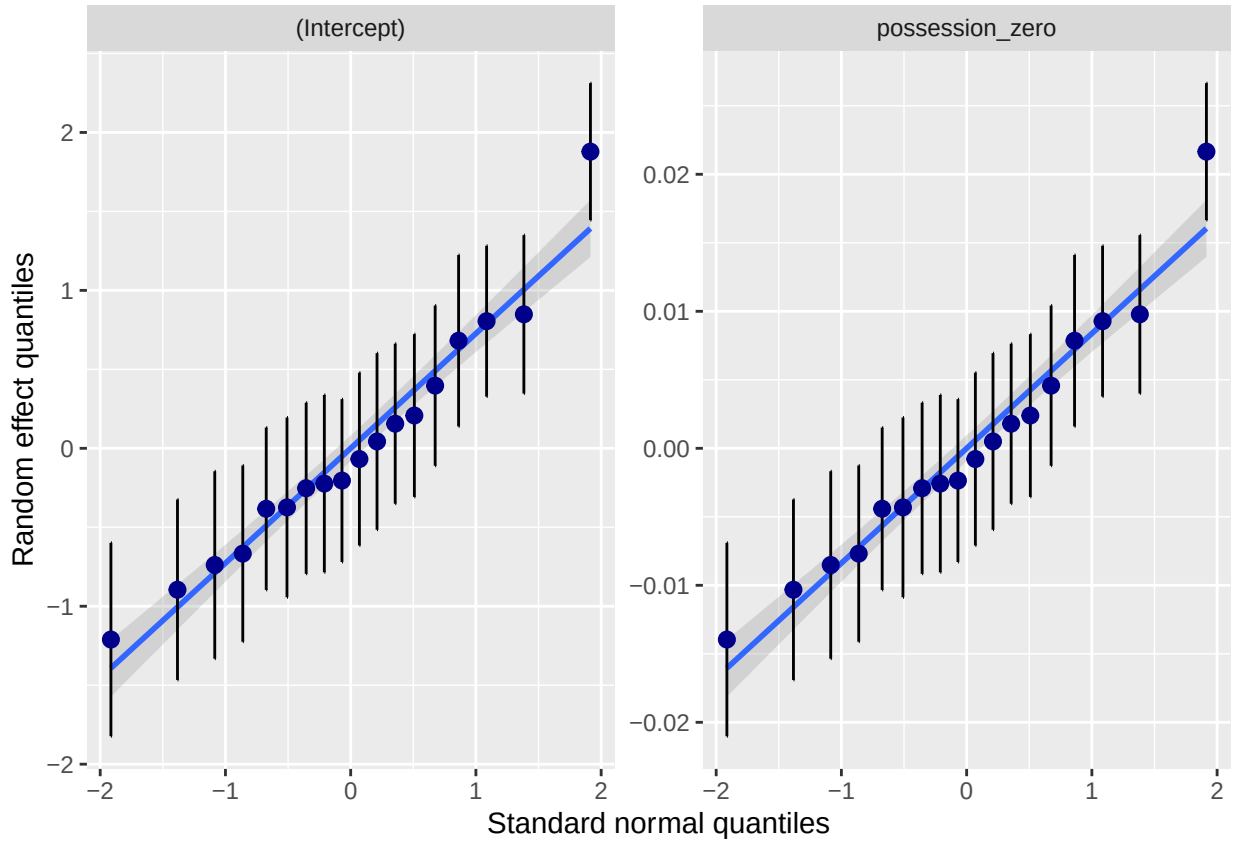
```
## ASS_16m_100s_diff   possession_zero             OQ_gd
##          1.670941          1.962260          1.378506
```

```
sjPlot::plot_model(fullmod, type = 'diag')
```

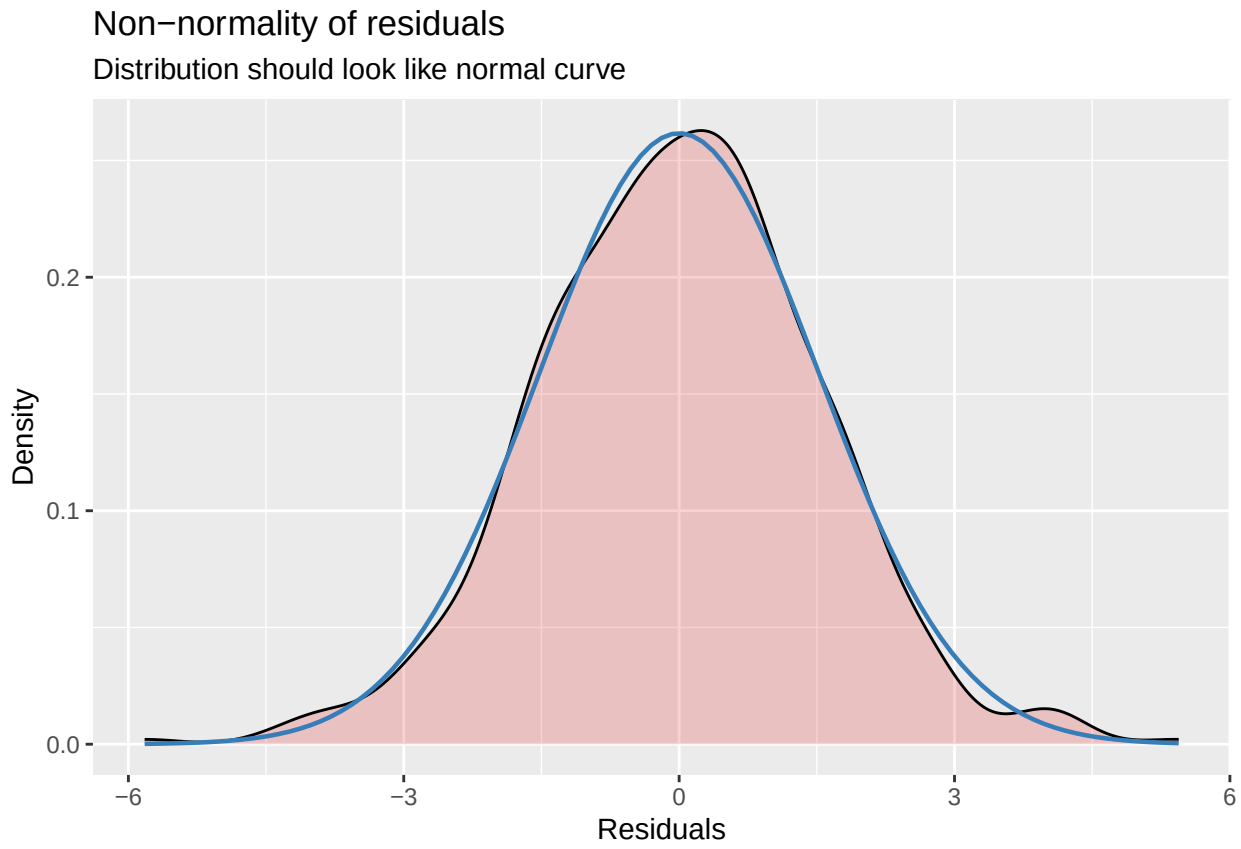
```
## Warning in checkMatrixPackageVersion(): Package version inconsistency detected.
## TMB was built with Matrix version 1.5.4.1
## Current Matrix version is 1.5.1
## Please re-install 'TMB' from source using install.packages('TMB', type = 'source') or ask CRAN for a

## [[1]]

## `geom_smooth()` using formula = 'y ~ x'
```



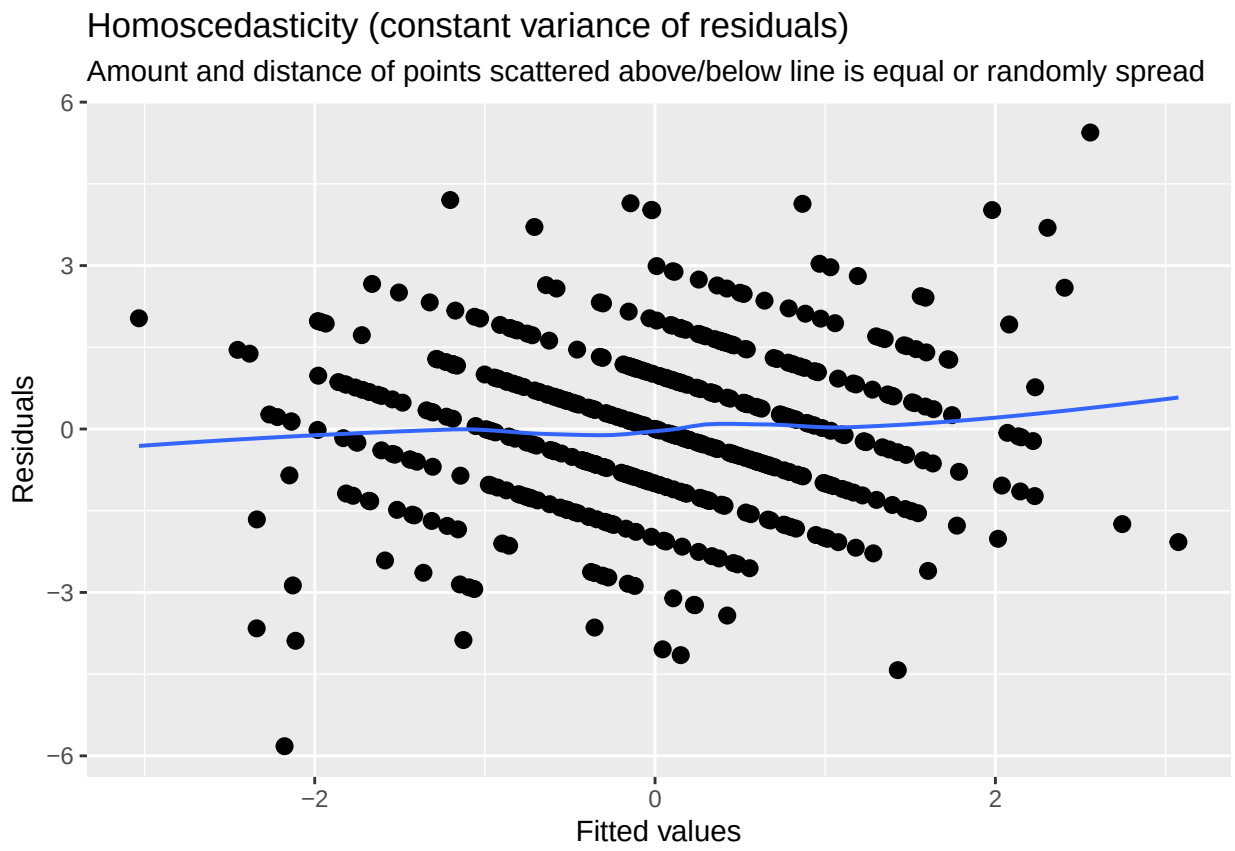

```
##
## [[2]]
## [[2]]$Team

## `geom_smooth()` using formula = 'y ~ x'
```


(Intercept)
possession_zero
Random effect quantiles
Standard normal quantiles
2
1
0
−1
−2
0.02
0.01
0.00
−0.01
−0.02
−2
−1
0
1
2

```
##
##
## [[3]]
```




```
##
## [[4]]

## `geom_smooth()` using formula = 'y ~ x'
```



Inference

```
summary(fullmod)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (1 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1931.1   1964.9   -957.5   1915.1      498
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.7634 -0.6683 -0.0006  0.6077  3.5174
##
## Random effects:
##  Groups   Name            Variance  Std.Dev. Corr
##  Team     (Intercept)     5.911e-01 0.768841
##           possession_zero 7.855e-05 0.008863 1.00
##  Residual                 2.394e+00 1.547218
## Number of obs: 506, groups:  Team, 18
```

```
##
## Fixed effects:
##                      Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.053297   0.193994  15.097675  -0.275 0.787245
## ASS_16m_100s_diff   0.153116   0.041629 496.527468   3.678 0.000261 ***
## possession_zero    -0.057843   0.009740 219.350820  -5.938 1.12e-08 ***
## OQ_gd              -0.035127   0.003353 500.049703 -10.476  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_16 pssss_
## ASS_16_100_  0.001
## possessn_zr  0.213 -0.549
## OQ_gd        0.004  0.076  0.392
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')
```

```
PS <- lmer(Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (1|Team), data = df,  REML = FALS
summary(PS)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (1 |
##     Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1928.7   1954.1   -958.4   1916.7      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6796 -0.6489  0.0085  0.6292  3.6073
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Team     (Intercept) 0.6871   0.8289
##  Residual             2.3910   1.5463
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                      Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)       -9.169e-04  2.072e-01  1.607e+01  -0.004 0.996523
## ASS_16m_100s_diff  1.545e-01  4.161e-02  4.967e+02   3.712 0.000229 ***
## possession_zero   -5.881e-02  9.524e-03  5.048e+02  -6.175 1.36e-09 ***
## OQ_gd             -3.513e-02  3.356e-03  4.999e+02 -10.469  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_16 pssss_
## ASS_16_100_ -0.001
## possessn_zr -0.002 -0.555
## OQ_gd       -0.005  0.080  0.403
```

```r
anova(PS, fullmod)
```

```
## Data: df
## Models:
## PS: Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (1 | Team)
## fullmod: Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## PS         6 1928.7 1954.1 -958.36   1916.7
## fullmod    8 1931.1 1964.9 -957.53   1915.1 1.6653  2     0.4349
```

```r
RI<- lmer(Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (0+possession_zero|Team), data = d
summary(RI)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (0 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1958.9   1984.3   -973.5   1946.9      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6372 -0.7005  0.0550  0.5878  3.3498
##
## Random effects:
##  Groups   Name            Variance Std.Dev.
##  Team     possession_zero 0.001052 0.03244
##  Residual                 2.652979 1.62880
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.087437   0.079380 464.634683  -1.102 0.271249
## ASS_16m_100s_diff   0.156954   0.042503 501.232705   3.693 0.000246 ***
## possession_zero    -0.032423   0.011885  49.054322  -2.728 0.008818 **
## OQ_gd              -0.030721   0.003434 501.982367  -8.946  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_16 pssss_
## ASS_16_100_  0.013
## possessn_zr  0.025 -0.472
## OQ_gd        0.014  0.069  0.269
```

```r
anova(RI, fullmod)
```

```
## Data: df
## Models:
## RI: Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (0 + possession_zero | Team)
```

```
## fullmod: Outcome_num ~ ASS_16m_100s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## RI         6 1958.9 1984.3 -973.46   1946.9
## fullmod    8 1931.1 1964.9 -957.53   1915.1 31.867  2  1.202e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
coef(RI)
```

```
## $Team
##                           (Intercept) ASS_16m_100s_diff possession_zero
## 1. FC Köln                -0.08743702         0.1569544     -0.04317594
## 1. FSV Mainz 05           -0.08743702         0.1569544     -0.03969799
## Bayer 04 Leverkusen       -0.08743702         0.1569544     -0.04652415
## Borussia Dortmund         -0.08743702         0.1569544     -0.02094313
## Borussia Mönchengladbach -0.08743702         0.1569544     -0.05157077
## Eintracht Frankfurt       -0.08743702         0.1569544     -0.02764397
## FC Augsburg               -0.08743702         0.1569544     -0.01601545
## FC Bayern München         -0.08743702         0.1569544      0.05509977
## FC Ingolstadt 04          -0.08743702         0.1569544     -0.03013744
## FC Schalke 04             -0.08743702         0.1569544     -0.05638082
## Hamburger SV              -0.08743702         0.1569544     -0.02858719
## Hertha BSC                -0.08743702         0.1569544     -0.04692409
## RB Leipzig                -0.08743702         0.1569544     -0.05243748
## Sport-Club Freiburg       -0.08743702         0.1569544     -0.05683469
## SV Darmstadt 98           -0.08743702         0.1569544     -0.01476145
## SV Werder Bremen          -0.08743702         0.1569544     -0.05286795
## TSG 1899 Hoffenheim       -0.08743702         0.1569544     -0.02335316
## VfL Wolfsburg             -0.08743702         0.1569544     -0.03085164
##                                OQ_gd
## 1. FC Köln                -0.03072052
## 1. FSV Mainz 05           -0.03072052
## Bayer 04 Leverkusen       -0.03072052
## Borussia Dortmund         -0.03072052
## Borussia Mönchengladbach -0.03072052
## Eintracht Frankfurt       -0.03072052
## FC Augsburg               -0.03072052
## FC Bayern München         -0.03072052
## FC Ingolstadt 04          -0.03072052
## FC Schalke 04             -0.03072052
## Hamburger SV              -0.03072052
## Hertha BSC                -0.03072052
## RB Leipzig                -0.03072052
## Sport-Club Freiburg       -0.03072052
## SV Darmstadt 98           -0.03072052
## SV Werder Bremen          -0.03072052
## TSG 1899 Hoffenheim       -0.03072052
## VfL Wolfsburg             -0.03072052
##
## attr(,"class")
## [1] "coef.mer"
```

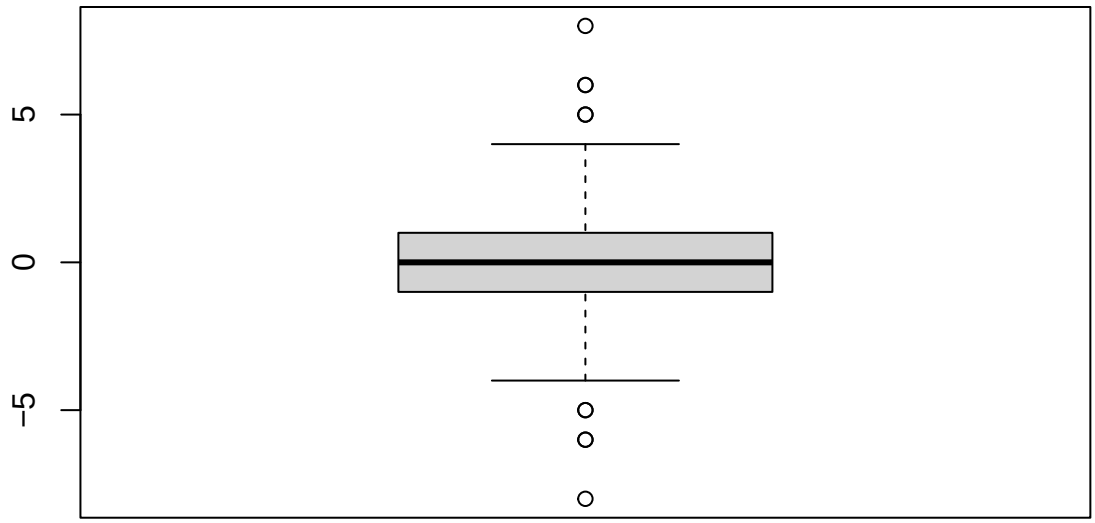
```r
coef(PS)
```

```
## $Team
##                           (Intercept) ASS_16m_100s_diff possession_zero
## 1. FC Köln                -0.02880894         0.1544685      -0.0588067
## 1. FSV Mainz 05           -0.42191824         0.1544685      -0.0588067
## Bayer 04 Leverkusen        0.13938897         0.1544685      -0.0588067
## Borussia Dortmund          0.89338343         0.1544685      -0.0588067
## Borussia Mönchengladbach   0.19991634         0.1544685      -0.0588067
## Eintracht Frankfurt       -0.33661677         0.1544685      -0.0588067
## FC Augsburg               -0.76907734         0.1544685      -0.0588067
## FC Bayern München          2.18205979         0.1544685      -0.0588067
## FC Ingolstadt 04          -0.92737600         0.1544685      -0.0588067
## FC Schalke 04              0.40315011         0.1544685      -0.0588067
## Hamburger SV              -0.70026310         0.1544685      -0.0588067
## Hertha BSC                -0.29344207         0.1544685      -0.0588067
## RB Leipzig                 0.69493523         0.1544685      -0.0588067
## Sport-Club Freiburg       -0.39309646         0.1544685      -0.0588067
## SV Darmstadt 98           -1.16737875         0.1544685      -0.0588067
## SV Werder Bremen          -0.10096957         0.1544685      -0.0588067
## TSG 1899 Hoffenheim        0.89740314         0.1544685      -0.0588067
## VfL Wolfsburg             -0.28779398         0.1544685      -0.0588067
##                                OQ_gd
## 1. FC Köln                -0.03512832
## 1. FSV Mainz 05           -0.03512832
## Bayer 04 Leverkusen       -0.03512832
## Borussia Dortmund         -0.03512832
## Borussia Mönchengladbach  -0.03512832
## Eintracht Frankfurt       -0.03512832
## FC Augsburg               -0.03512832
## FC Bayern München         -0.03512832
## FC Ingolstadt 04          -0.03512832
## FC Schalke 04             -0.03512832
## Hamburger SV              -0.03512832
## Hertha BSC                -0.03512832
## RB Leipzig                -0.03512832
## Sport-Club Freiburg       -0.03512832
## SV Darmstadt 98           -0.03512832
## SV Werder Bremen          -0.03512832
## TSG 1899 Hoffenheim       -0.03512832
## VfL Wolfsburg             -0.03512832
##
## attr(,"class")
## [1] "coef.mer"
```

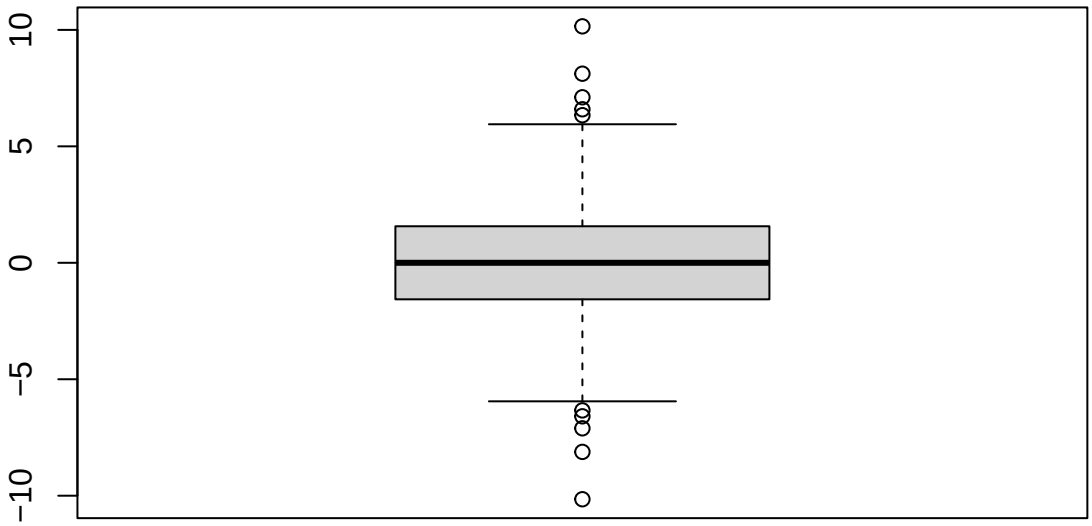
16m_300s

Descriptives

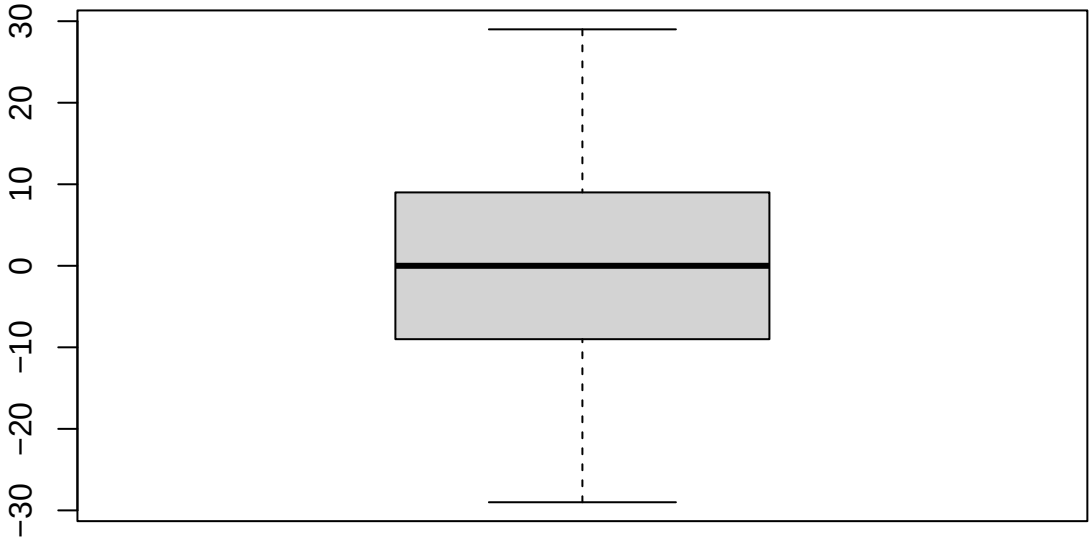
```r
boxplot(df$Outcome_num)
```



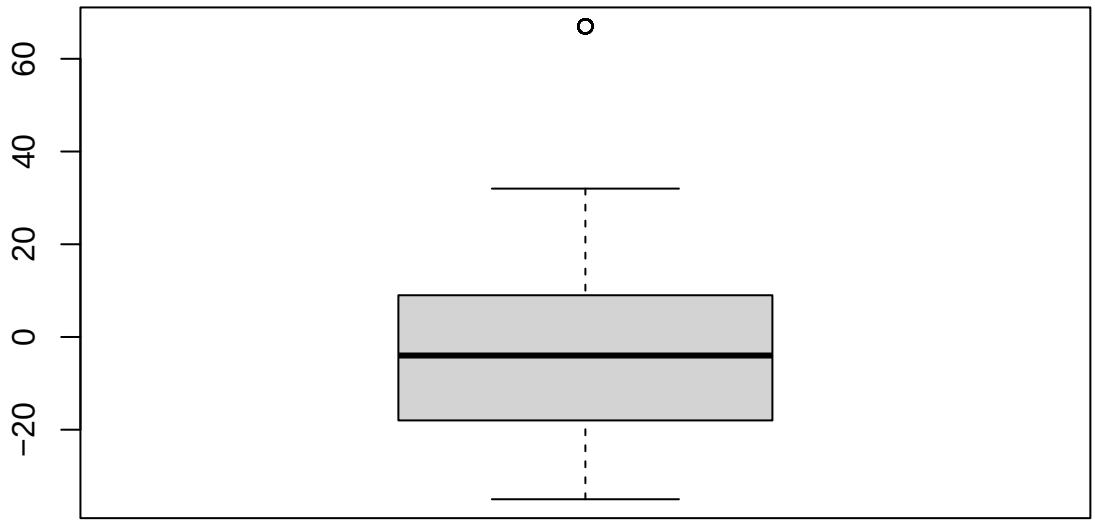

```r
boxplot(df$ASS_16m_300s_diff)
```




```
boxplot(df$possession_zero)
```




```
boxplot(df$OQ_gd)
```




```r
cor.test(df$Outcome_num, df$possession_zero)
```

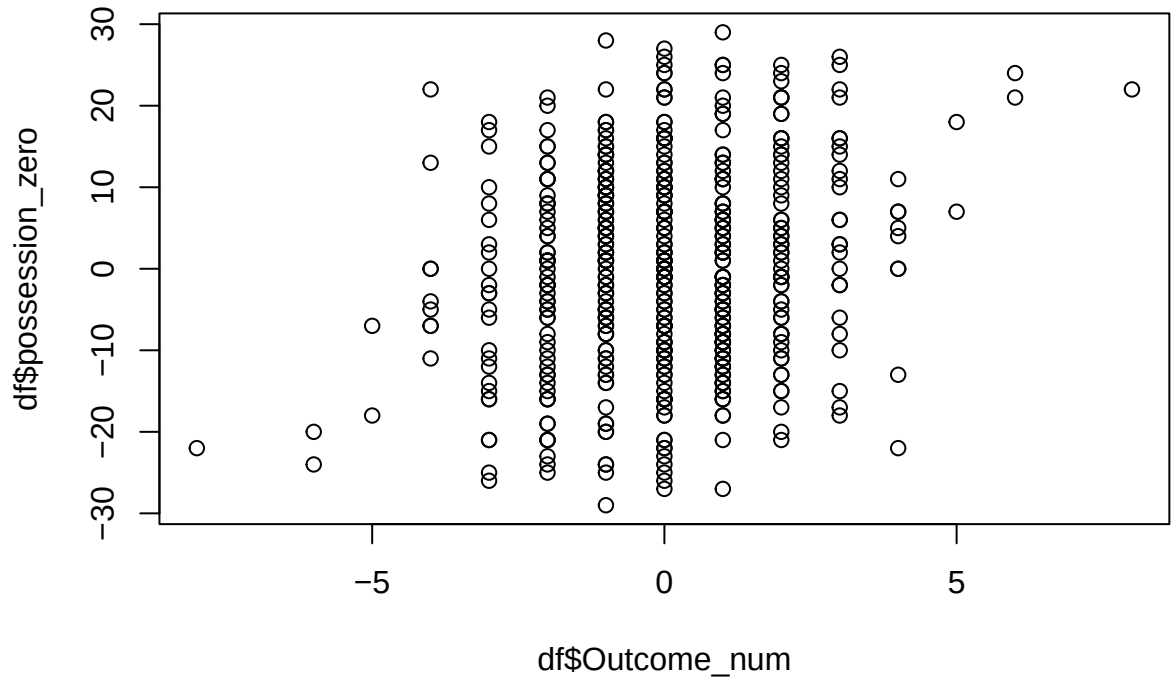
```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$possession_zero
## t = 4.5167, df = 504, p-value = 7.831e-06
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1119941 0.2795989
## sample estimates:
##       cor
## 0.1972373
```

```r
cor.test(df$Outcome_num, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$possession_zero
## t = 4.5167, df = 504, p-value = 7.831e-06
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1119941 0.2795989
```

```
## sample estimates:
##       cor
## 0.1972373
```

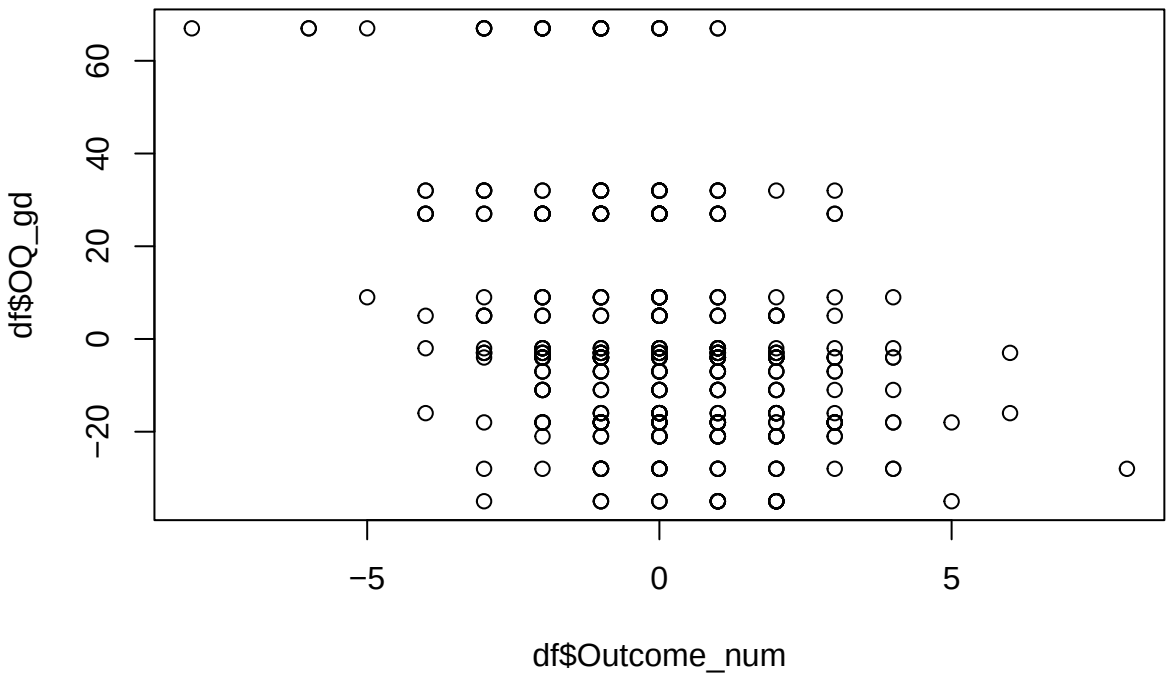
```
plot(df$Outcome_num, df$possession_zero)
```




```
cor.test(df$Outcome_num, df$OQ_gd)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$OQ_gd
## t = -9.2557, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4532666 -0.3040926
## sample estimates:
##       cor
## -0.3811578
```

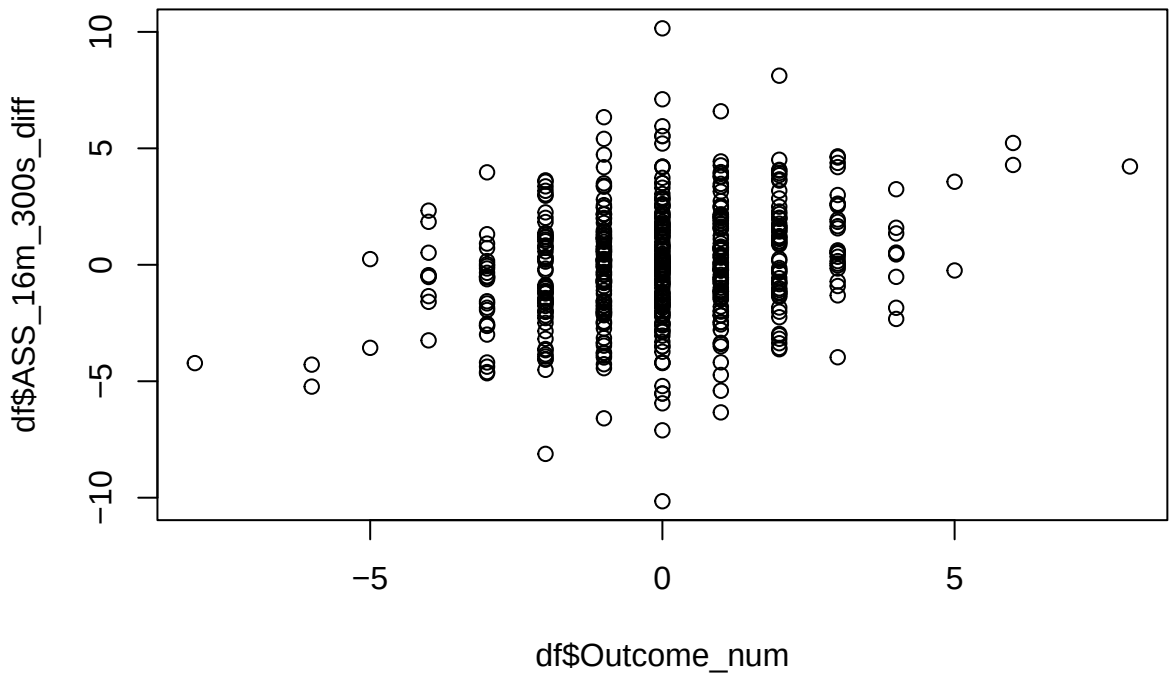
```
plot(df$Outcome_num, df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$ASS_16m_300s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$ASS_16m_300s_diff
## t = 6.0306, df = 504, p-value = 3.162e-09
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1762441 0.3389314
## sample estimates:
##       cor
## 0.2594273
```

```
plot(df$Outcome_num, df$ASS_16m_300s_diff)
```




```
cor.test(df$OQ_gd, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$possession_zero
## t = -12.359, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.5464574 -0.4124298
## sample estimates:
##        cor
## -0.4822607
```

```
cor.test(df$OQ_gd, df$ASS_16m_300s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$ASS_16m_300s_diff
## t = -8.6846, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4342967 -0.2825022
```

```
## sample estimates:
##        cor
## -0.3607864
```

```
cor.test(df$possession_zero, df$ASS_16m_300s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$possession_zero and df$ASS_16m_300s_diff
## t = 19.953, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.6126156 0.7103443
## sample estimates:
##       cor
## 0.6643096
```

Diagnostics

```
fullmod <- lmer(Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (1+possession_zero|Team), da
```

```
## boundary (singular) fit: see help('isSingular')
```

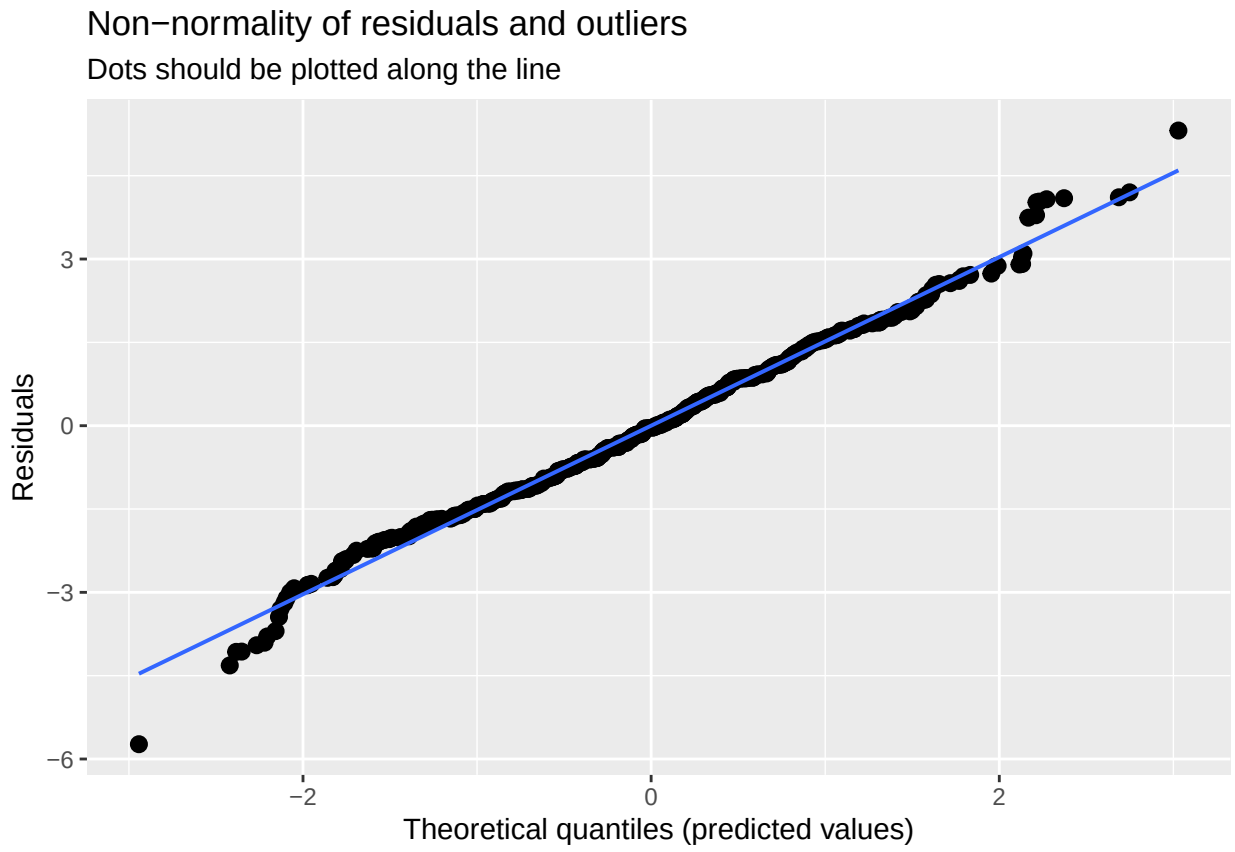
```
vif(fullmod)
```

```
## ASS_16m_300s_diff   possession_zero             OQ_gd
##          1.506743          1.804863          1.374530
```

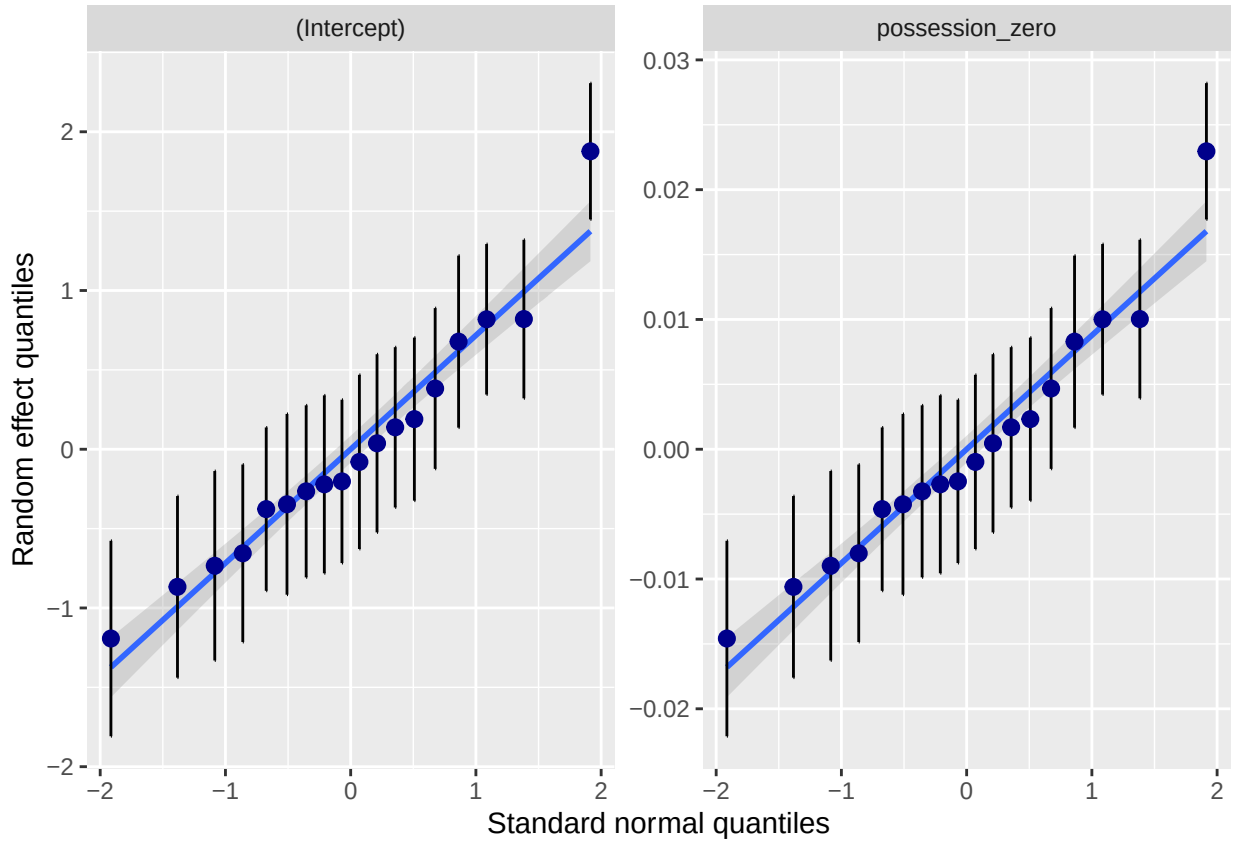
```
sjPlot::plot_model(fullmod, type = 'diag')
```

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

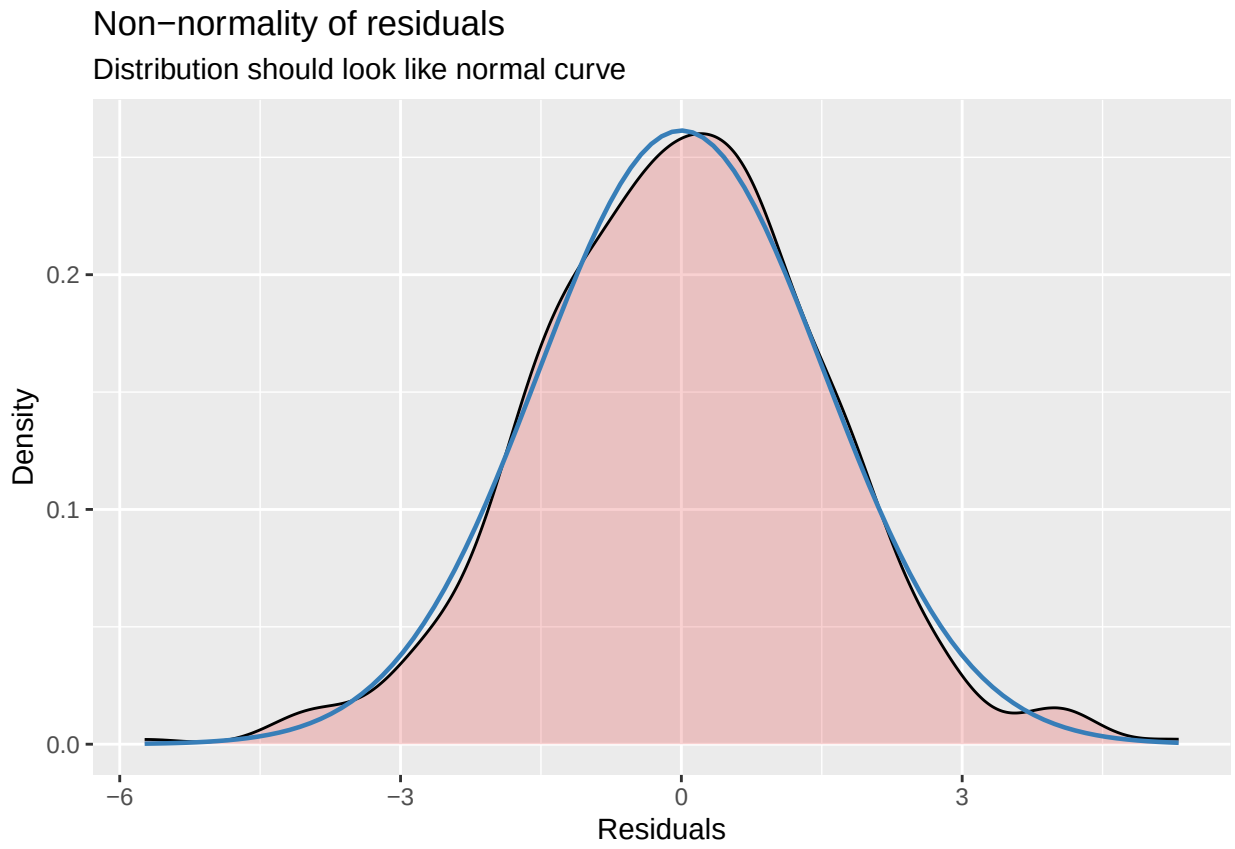
```
## `geom_smooth()` using formula = 'y ~ x'
```



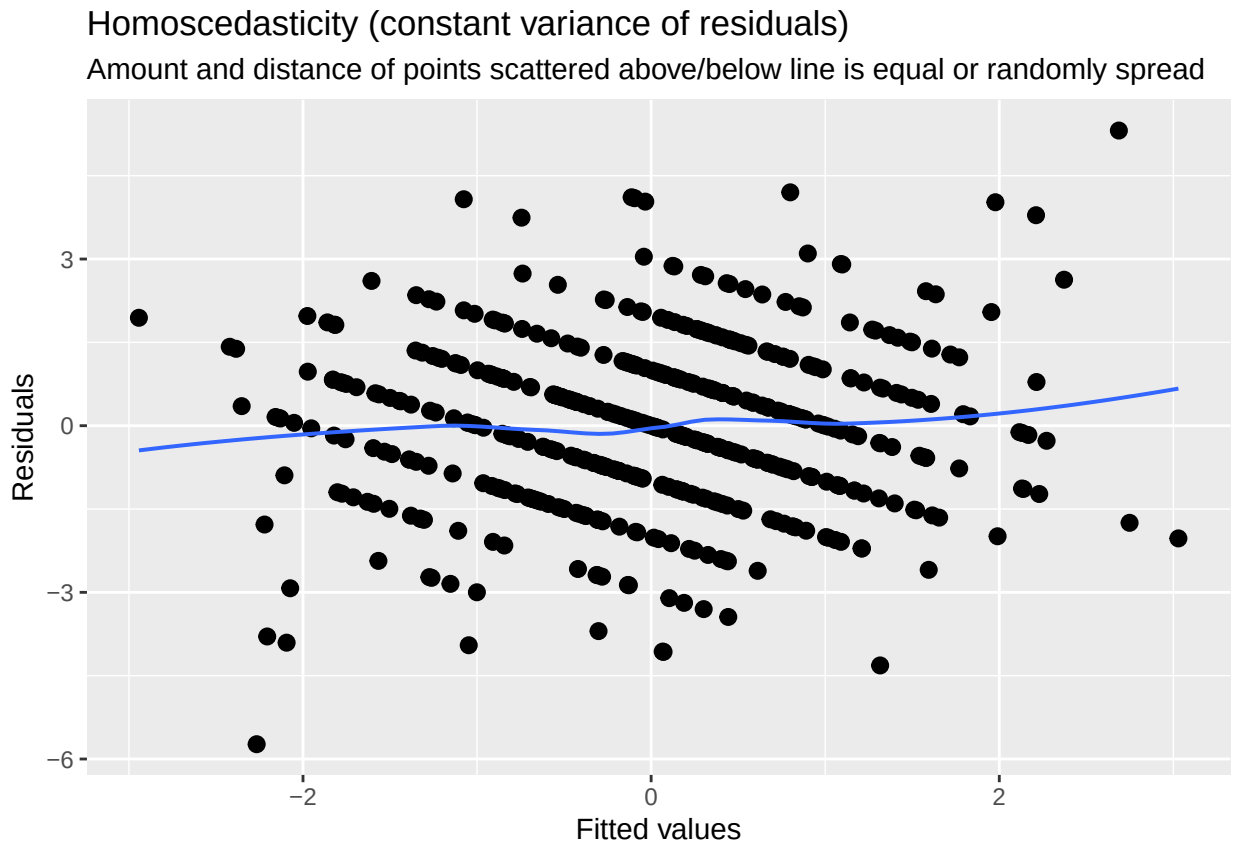

```
##
## [[2]]
## [[2]]$Team

## `geom_smooth()` using formula = 'y ~ x'
```


(Intercept)
possession_zero
Random effect quantiles
Standard normal quantiles
2
1
0
−1
−2
0.03
0.02
0.01
0.00
−0.01
−0.02
−2
−1
0
1
2

```
##
##
## [[3]]
```




```
##
## [[4]]

## `geom_smooth()` using formula = 'y ~ x'
```



Inference

```
summary(fullmod)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (1 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1931.8   1965.6   -957.9   1915.8      498
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.7020 -0.6893  0.0136  0.6126  3.4303
##
## Random effects:
##  Groups   Name            Variance  Std.Dev. Corr
##  Team     (Intercept)     5.804e-01 0.761813
##           possession_zero 8.682e-05 0.009318 1.00
##  Residual                 2.399e+00 1.548854
## Number of obs: 506, groups:  Team, 18
```

```
##
## Fixed effects:
##                      Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.056014   0.192486  15.000558  -0.291 0.775033
## ASS_16m_300s_diff   0.136491   0.038254 493.875035   3.568 0.000395 ***
## possession_zero    -0.054504   0.009389 190.823098  -5.805 2.64e-08 ***
## OQ_gd              -0.035133   0.003356 500.122813 -10.469  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_16 pssss_
## ASS_16_300_  0.001
## possessn_zr  0.232 -0.493
## OQ_gd        0.004  0.076  0.412
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')
```

```
PS<- lmer(Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (1|Team), data = df,  REML = FALSE
summary(PS)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (1 |
##     Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1929.7   1955.0   -958.8   1917.7      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6154 -0.6532  0.0127  0.6241  3.5239
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Team     (Intercept) 0.6845   0.8273
##  Residual             2.3959   1.5479
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                      Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)       -8.732e-04  2.068e-01  1.605e+01  -0.004 0.996684
## ASS_16m_300s_diff  1.368e-01  3.823e-02  4.945e+02   3.579 0.000379 ***
## possession_zero   -5.544e-02  9.143e-03  5.036e+02  -6.063 2.62e-09 ***
## OQ_gd             -3.515e-02  3.359e-03  4.999e+02 -10.465  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_16 pssss_
## ASS_16_300_ -0.001
## possessn_zr -0.002 -0.498
## OQ_gd       -0.005  0.080  0.426
```

```r
anova(PS, fullmod)
```

```
## Data: df
## Models:
## PS: Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (1 | Team)
## fullmod: Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## PS         6 1929.7 1955.0 -958.84   1917.7
## fullmod    8 1931.8 1965.6 -957.91   1915.8 1.8467  2     0.3972
```

```r
RI<- lmer(Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (0+possession_zero|Team), data = d
summary(RI)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (0 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1958.4   1983.7   -973.2   1946.4      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5806 -0.7113  0.0447  0.5919  3.2665
##
## Random effects:
##  Groups   Name            Variance Std.Dev.
##  Team     possession_zero 0.001075 0.03279
##  Residual                 2.648607 1.62745
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.090664   0.079365 466.410583  -1.142 0.253888
## ASS_16m_300s_diff   0.148540   0.039377 501.633171   3.772 0.000181 ***
## possession_zero    -0.030416   0.011637  43.976748  -2.614 0.012220 *
## OQ_gd              -0.030714   0.003432 501.815423  -8.950  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_16 pssss_
## ASS_16_300_  0.004
## possessn_zr  0.031 -0.424
## OQ_gd        0.013  0.069  0.278
```

```r
anova(RI, fullmod)
```

```
## Data: df
## Models:
## RI: Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (0 + possession_zero | Team)
```

```
## fullmod: Outcome_num ~ ASS_16m_300s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## RI         6 1958.3 1983.7 -973.18   1946.3
## fullmod    8 1931.8 1965.6 -957.91   1915.8 30.524  2  2.354e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
coef(RI)
```

```
## $Team
##                           (Intercept) ASS_16m_300s_diff possession_zero
## 1. FC Köln                -0.09066378         0.1485399     -0.04248152
## 1. FSV Mainz 05           -0.09066378         0.1485399     -0.03659203
## Bayer 04 Leverkusen       -0.09066378         0.1485399     -0.04568720
## Borussia Dortmund         -0.09066378         0.1485399     -0.01747604
## Borussia Mönchengladbach -0.09066378         0.1485399     -0.04996184
## Eintracht Frankfurt       -0.09066378         0.1485399     -0.02552094
## FC Augsburg               -0.09066378         0.1485399     -0.01338464
## FC Bayern München         -0.09066378         0.1485399      0.05851963
## FC Ingolstadt 04          -0.09066378         0.1485399     -0.02854764
## FC Schalke 04             -0.09066378         0.1485399     -0.05284534
## Hamburger SV              -0.09066378         0.1485399     -0.02740548
## Hertha BSC                -0.09066378         0.1485399     -0.04603331
## RB Leipzig                -0.09066378         0.1485399     -0.05002357
## Sport-Club Freiburg       -0.09066378         0.1485399     -0.05557267
## SV Darmstadt 98           -0.09066378         0.1485399     -0.01285965
## SV Werder Bremen          -0.09066378         0.1485399     -0.05105221
## TSG 1899 Hoffenheim       -0.09066378         0.1485399     -0.02096917
## VfL Wolfsburg             -0.09066378         0.1485399     -0.02958921
##                                OQ_gd
## 1. FC Köln                -0.03071438
## 1. FSV Mainz 05           -0.03071438
## Bayer 04 Leverkusen       -0.03071438
## Borussia Dortmund         -0.03071438
## Borussia Mönchengladbach -0.03071438
## Eintracht Frankfurt       -0.03071438
## FC Augsburg               -0.03071438
## FC Bayern München         -0.03071438
## FC Ingolstadt 04          -0.03071438
## FC Schalke 04             -0.03071438
## Hamburger SV              -0.03071438
## Hertha BSC                -0.03071438
## RB Leipzig                -0.03071438
## Sport-Club Freiburg       -0.03071438
## SV Darmstadt 98           -0.03071438
## SV Werder Bremen          -0.03071438
## TSG 1899 Hoffenheim       -0.03071438
## VfL Wolfsburg             -0.03071438
##
## attr(,"class")
## [1] "coef.mer"
```

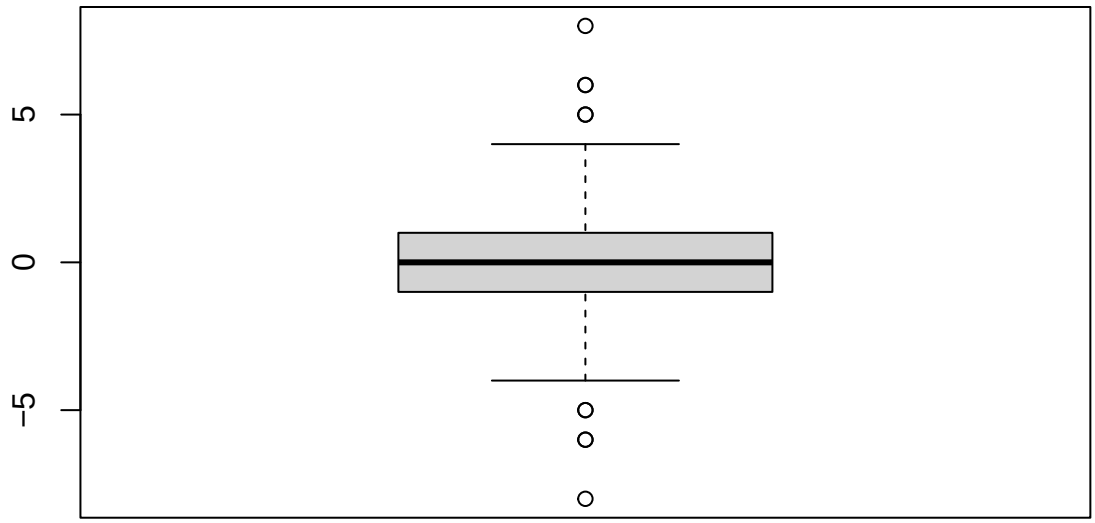
```
coef(PS)
```

```
## $Team
##                           (Intercept) ASS_16m_300s_diff possession_zero
## 1. FC Köln                -0.03539783         0.1368328     -0.05543775
## 1. FSV Mainz 05           -0.40023768         0.1368328     -0.05543775
## Bayer 04 Leverkusen        0.12116044         0.1368328     -0.05543775
## Borussia Dortmund          0.91582425         0.1368328     -0.05543775
## Borussia Mönchengladbach   0.18121766         0.1368328     -0.05543775
## Eintracht Frankfurt       -0.33976940         0.1368328     -0.05543775
## FC Augsburg               -0.77039410         0.1368328     -0.05543775
## FC Bayern München          2.20316171         0.1368328     -0.05543775
## FC Ingolstadt 04          -0.90128667         0.1368328     -0.05543775
## FC Schalke 04              0.38664067         0.1368328     -0.05543775
## Hamburger SV              -0.69059907         0.1368328     -0.05543775
## Hertha BSC                -0.30672123         0.1368328     -0.05543775
## RB Leipzig                 0.69276978         0.1368328     -0.05543775
## Sport-Club Freiburg       -0.38787745         0.1368328     -0.05543775
## SV Darmstadt 98           -1.15089139         0.1368328     -0.05543775
## SV Werder Bremen          -0.11380259         0.1368328     -0.05543775
## TSG 1899 Hoffenheim        0.86937522         0.1368328     -0.05543775
## VfL Wolfsburg             -0.28889062         0.1368328     -0.05543775
##                                 OQ_gd
## 1. FC Köln                -0.03515056
## 1. FSV Mainz 05           -0.03515056
## Bayer 04 Leverkusen       -0.03515056
## Borussia Dortmund         -0.03515056
## Borussia Mönchengladbach  -0.03515056
## Eintracht Frankfurt       -0.03515056
## FC Augsburg               -0.03515056
## FC Bayern München         -0.03515056
## FC Ingolstadt 04          -0.03515056
## FC Schalke 04             -0.03515056
## Hamburger SV              -0.03515056
## Hertha BSC                -0.03515056
## RB Leipzig                -0.03515056
## Sport-Club Freiburg       -0.03515056
## SV Darmstadt 98           -0.03515056
## SV Werder Bremen          -0.03515056
## TSG 1899 Hoffenheim       -0.03515056
## VfL Wolfsburg             -0.03515056
##
## attr(,"class")
## [1] "coef.mer"
```

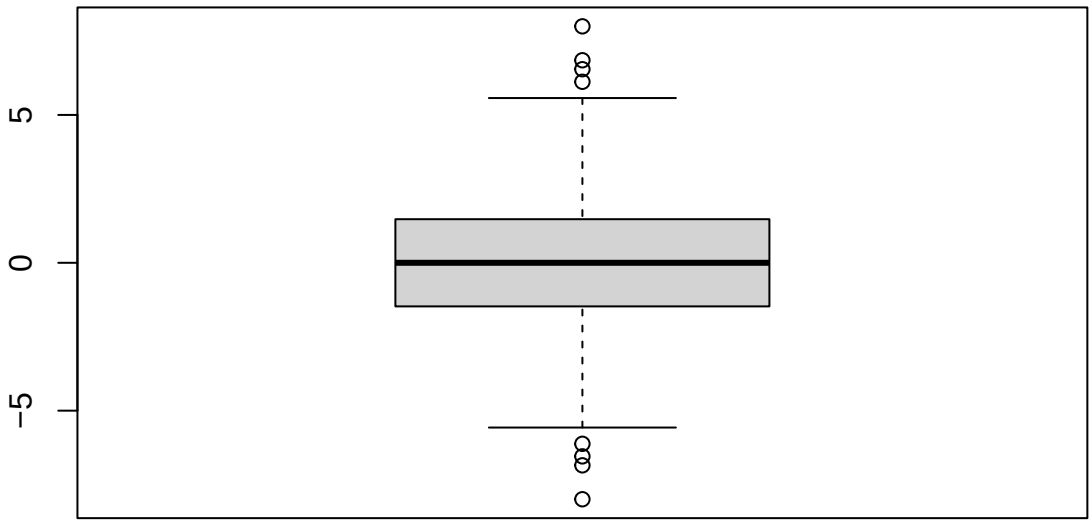
16m_500s

Descriptives

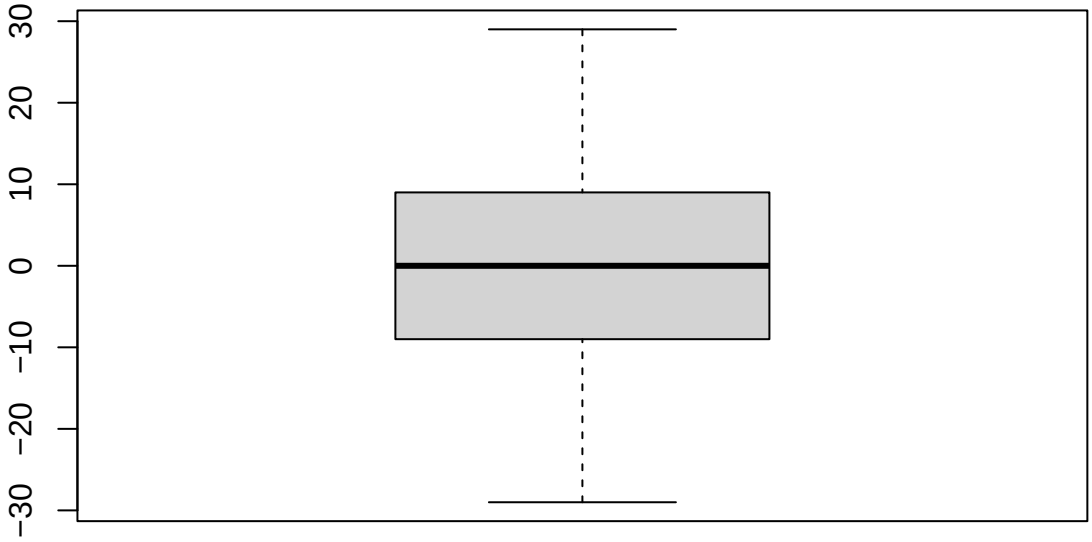
```r
boxplot(df$Outcome_num)
```



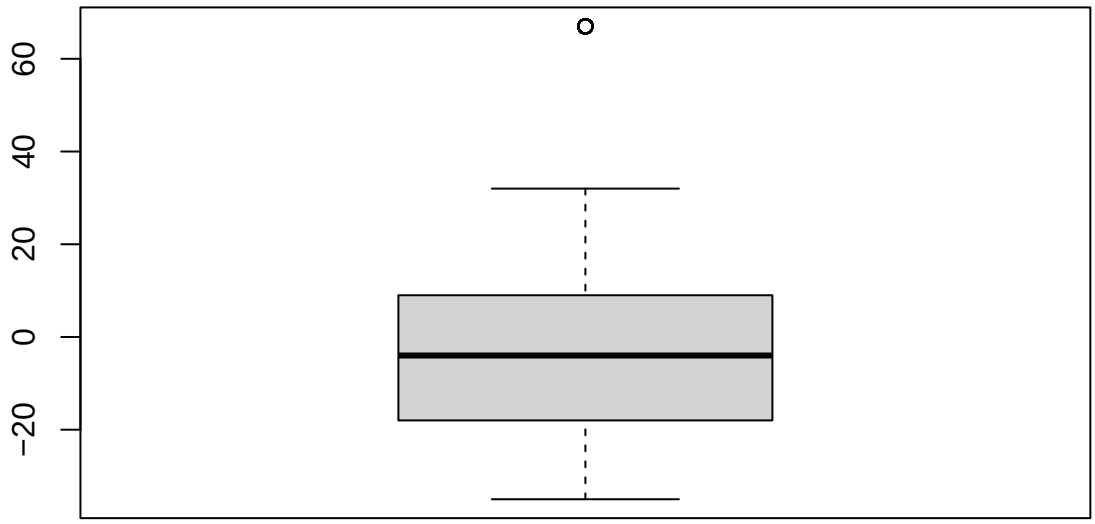

```r
boxplot(df$ASS_16m_500s_diff)
```




```
boxplot(df$possession_zero)
```



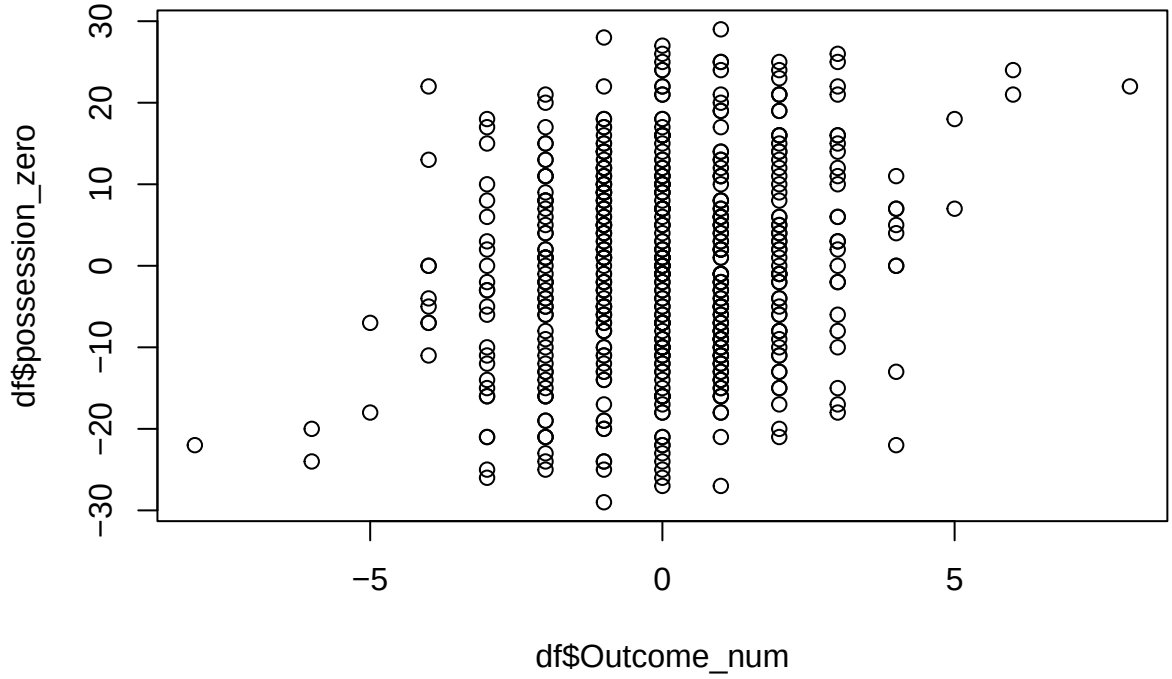

```
boxplot(df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$possession_zero
## t = 4.5167, df = 504, p-value = 7.831e-06
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1119941 0.2795989
## sample estimates:
##       cor
## 0.1972373
```

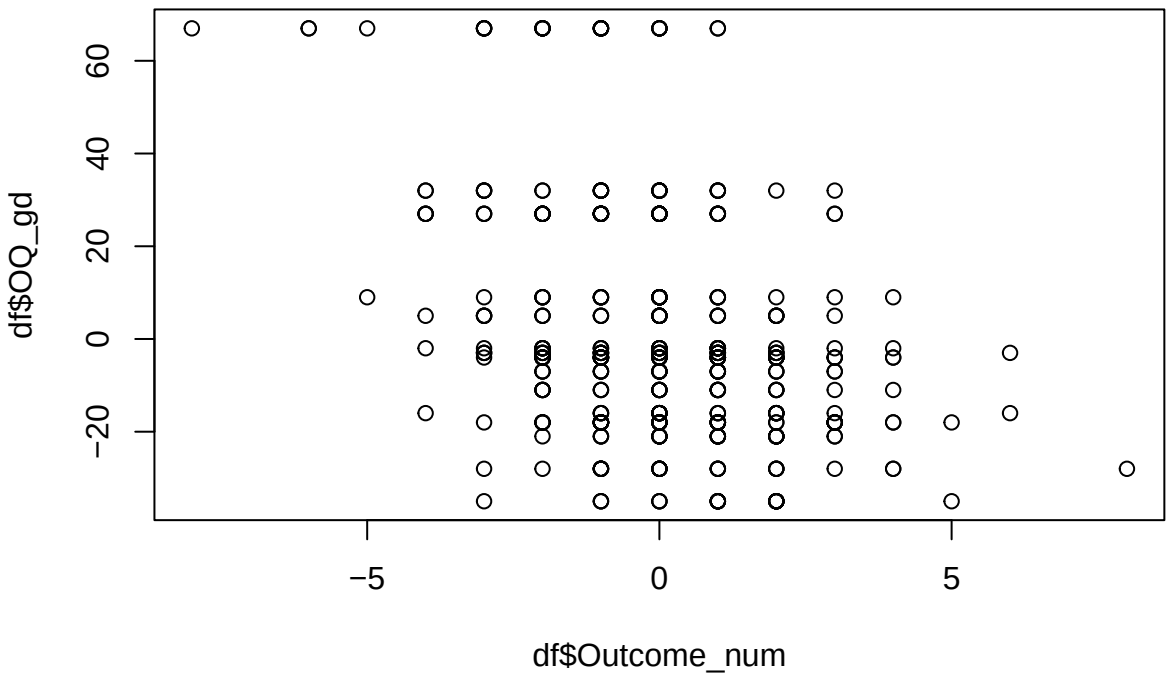
```
plot(df$Outcome_num, df$possession_zero)
```




```
cor.test(df$Outcome_num, df$OQ_gd)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$OQ_gd
## t = -9.2557, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4532666 -0.3040926
## sample estimates:
##        cor
## -0.3811578
```

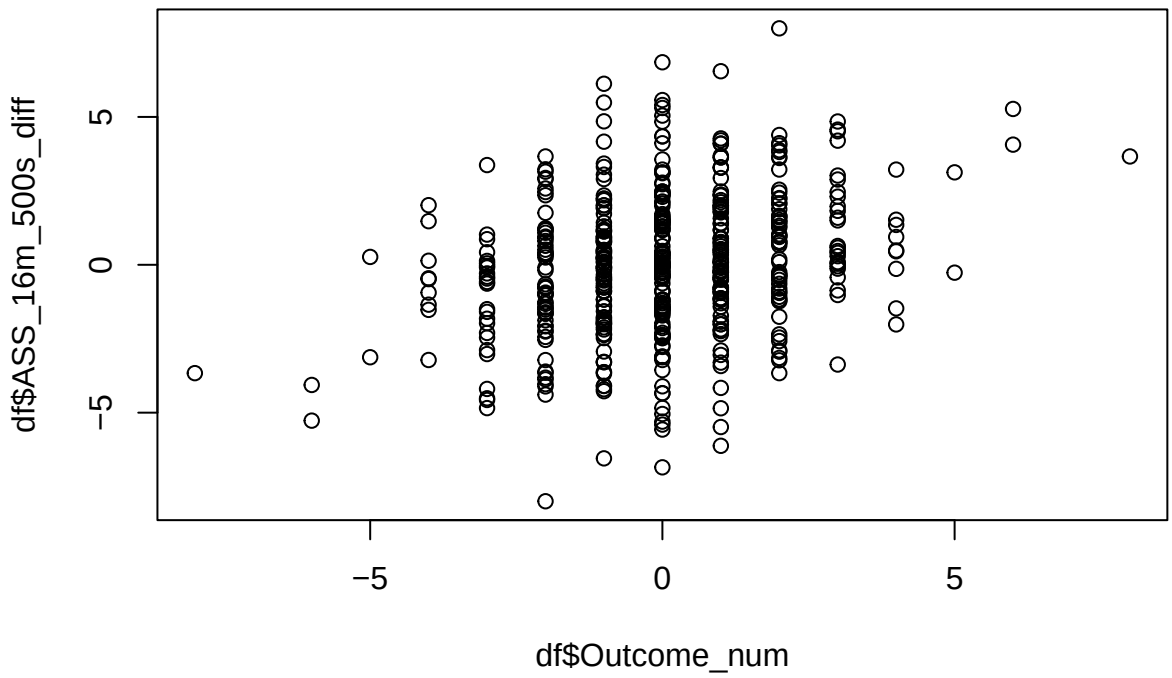
```
plot(df$Outcome_num, df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$ASS_16m_500s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$ASS_16m_500s_diff
## t = 6.4965, df = 504, p-value = 1.976e-10
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1955411 0.3565022
## sample estimates:
##       cor
## 0.2779718
```

```
plot(df$Outcome_num, df$ASS_16m_500s_diff)
```




```
cor.test(df$OQ_gd, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$possession_zero
## t = -12.359, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.5464574 -0.4124298
## sample estimates:
##        cor
## -0.4822607
```

```
cor.test(df$OQ_gd, df$ASS_16m_500s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$ASS_16m_500s_diff
## t = -8.9634, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4436276 -0.2931028
```

```
## sample estimates:
##        cor
## -0.3707979
```

```
cor.test(df$possession_zero, df$ASS_16m_500s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$possession_zero and df$ASS_16m_500s_diff
## t = 19.703, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.6073799 0.7061888
## sample estimates:
##      cor
## 0.659625
```

Diagnostics

```
fullmod <- lmer(Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (1+possession_zero|Team), da
```

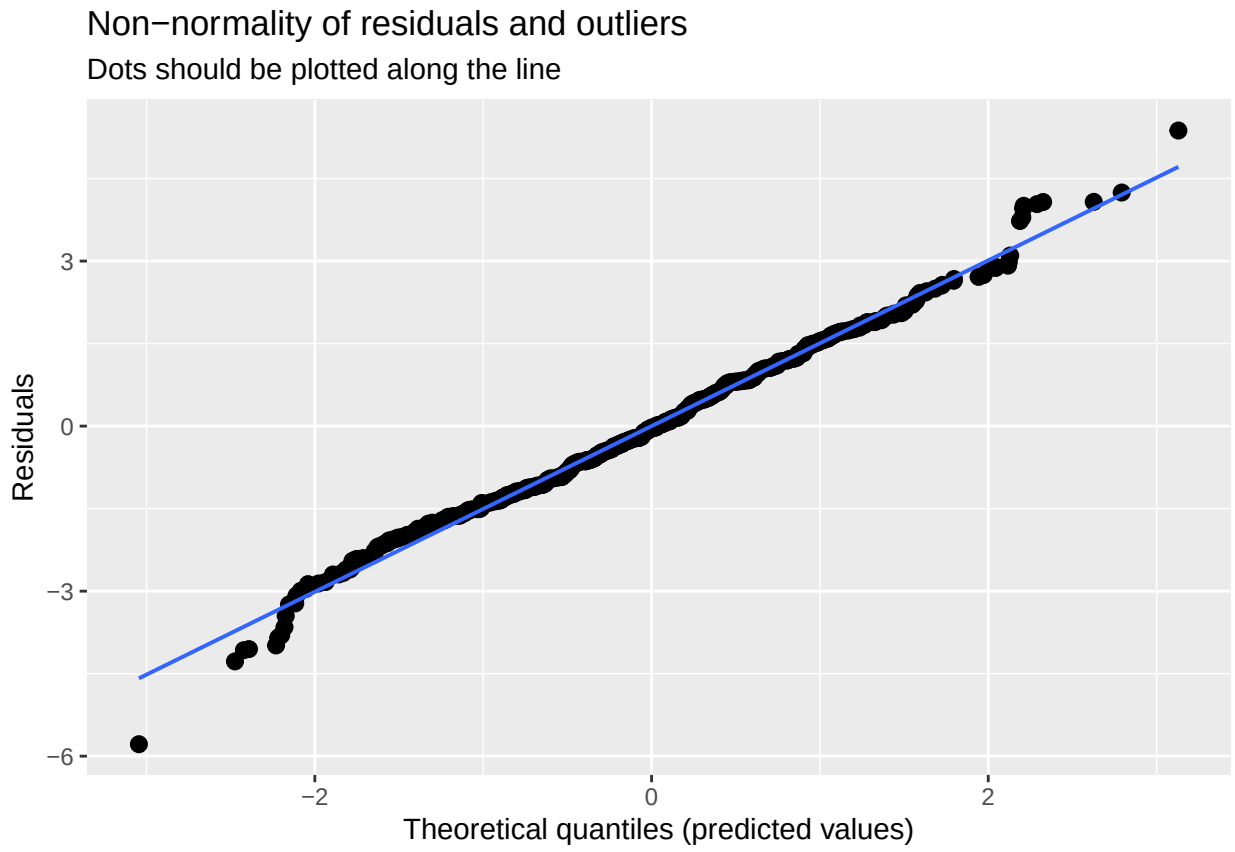
```
## boundary (singular) fit: see help('isSingular')
```

```
vif(fullmod)
```

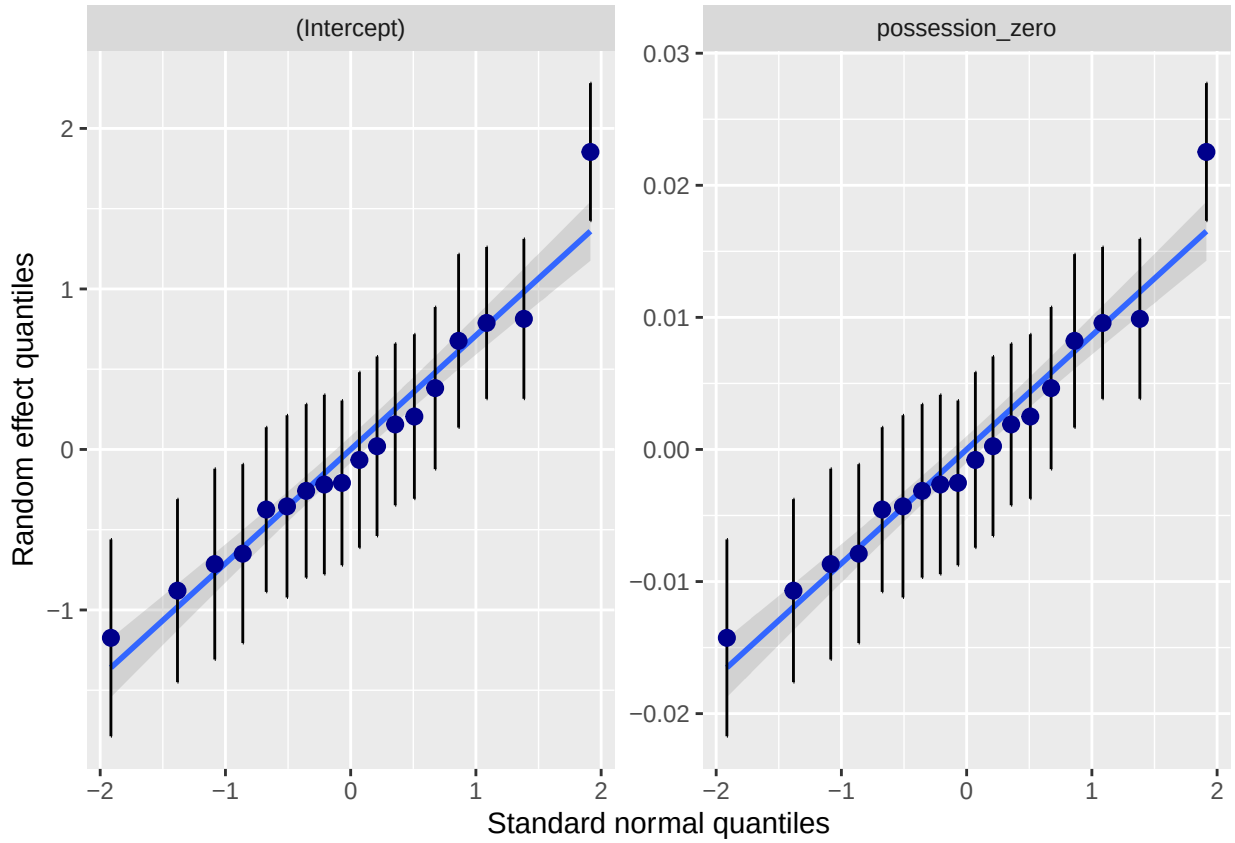
```
## ASS_16m_500s_diff   possession_zero             OQ_gd
##          1.496897          1.773798          1.380998
```

```
sjPlot::plot_model(fullmod, type = 'diag')
```

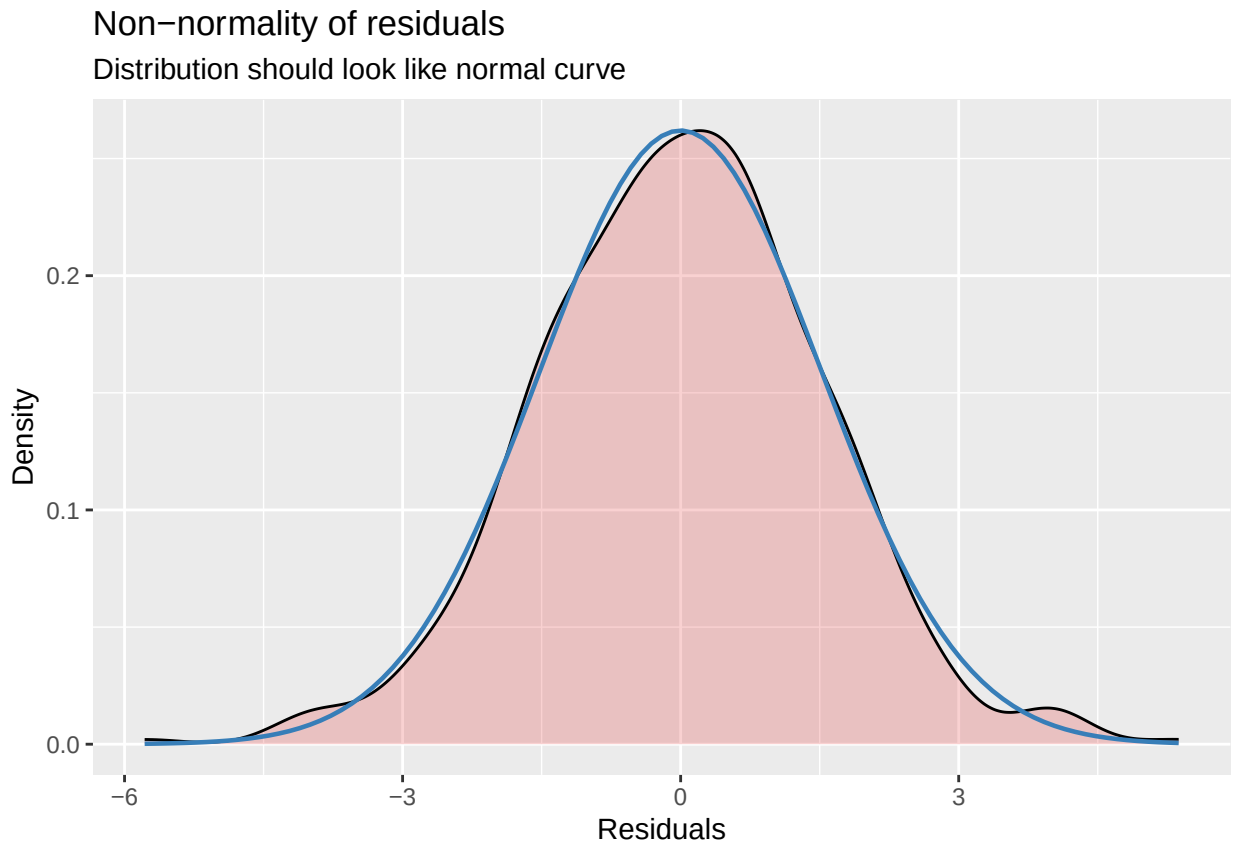
```
## [[1]]

## `geom_smooth()` using formula = 'y ~ x'
```



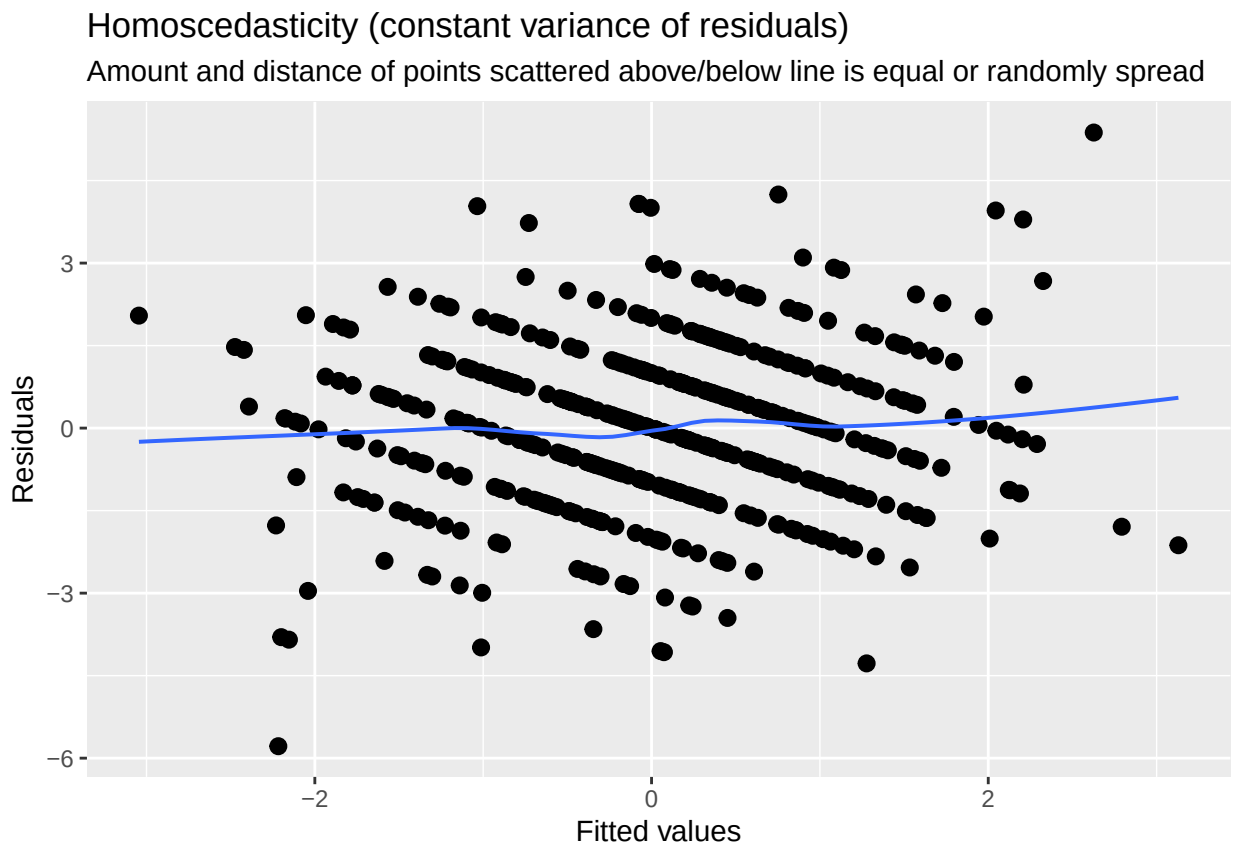

```
##
## [[2]]
## [[2]]$Team

## `geom_smooth()` using formula = 'y ~ x'
```


(Intercept)
possession_zero
Random effect quantiles
Standard normal quantiles
2
1
0
−1
0.03
0.02
0.01
0.00
−0.01
−0.02
−2
−1
0
1
2

```
##
##
## [[3]]
```




```
##
## [[4]]

## `geom_smooth()` using formula = 'y ~ x'
```



Inference

```
summary(fullmod)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (1 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1929.3   1963.1   -956.7   1913.3      498
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.7421 -0.6885  0.0142  0.6205  3.4770
##
## Random effects:
##  Groups   Name            Variance  Std.Dev. Corr
##  Team     (Intercept)     5.688e-01 0.754221
##           possession_zero 8.401e-05 0.009166 1.00
##  Residual                 2.388e+00 1.545400
## Number of obs: 506, groups:  Team, 18
```

```
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.054929   0.190760  14.968738  -0.288 0.777336
## ASS_16m_500s_diff   0.157278   0.040195 495.308915   3.913 0.000104 ***
## possession_zero    -0.055258   0.009271 191.121016  -5.960 1.19e-08 ***
## OQ_gd              -0.034716   0.003355 500.423335 -10.347  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_16 pssss_
## ASS_16_500_  0.002
## possessn_zr  0.231 -0.479
## OQ_gd        0.004  0.099  0.405
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')
```

```
PS<- lmer(Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (1|Team), data = df,  REML = FALSE
summary(PS)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (1 |
##     Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1927.1   1952.5   -957.6   1915.1      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6567 -0.6473  0.0168  0.6321  3.5704
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Team     (Intercept) 0.6693   0.8181
##  Residual             2.3853   1.5444
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)       -8.622e-04  2.047e-01  1.601e+01  -0.004    0.997
## ASS_16m_500s_diff  1.578e-01  4.017e-02  4.958e+02   3.929 9.74e-05 ***
## possession_zero   -5.618e-02  9.033e-03  5.034e+02  -6.219 1.05e-09 ***
## OQ_gd             -3.473e-02  3.358e-03  5.003e+02 -10.340  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_16 pssss_
## ASS_16_500_ -0.001
## possessn_zr -0.002 -0.484
## OQ_gd       -0.005  0.103  0.419
```

```r
anova(PS, fullmod)
```

```
## Data: df
## Models:
## PS: Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (1 | Team)
## fullmod: Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## PS         6 1927.1 1952.5 -957.56   1915.1
## fullmod    8 1929.3 1963.1 -956.66   1913.3 1.8022  2     0.4061
```

```r
RI<- lmer(Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (0+possession_zero|Team), data = d
summary(RI)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (0 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1955.2   1980.6   -971.6   1943.2      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6226 -0.6953  0.0455  0.5888  3.3147
##
## Random effects:
##  Groups   Name            Variance Std.Dev.
##  Team     possession_zero 0.001048 0.03237
##  Residual                 2.633435 1.62279
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.088572   0.079092 465.096183  -1.120  0.26335
## ASS_16m_500s_diff   0.171987   0.041170 501.673583   4.178 3.48e-05 ***
## possession_zero    -0.031619   0.011484  43.545395  -2.753  0.00857 **
## OQ_gd              -0.030310   0.003427 502.061934  -8.844  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_16 pssss_
## ASS_16_500_  0.008
## possessn_zr  0.029 -0.415
## OQ_gd        0.014  0.090  0.273
```

```r
anova(RI, fullmod)
```

```
## Data: df
## Models:
## RI: Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (0 + possession_zero | Team)
```

```
## fullmod: Outcome_num ~ ASS_16m_500s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## RI         6 1955.2 1980.6 -971.61   1943.2
## fullmod    8 1929.3 1963.1 -956.66   1913.3 29.906  2  3.207e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
coef(RI)
```

```
## $Team
##                           (Intercept) ASS_16m_500s_diff possession_zero
## 1. FC Köln                -0.08857162         0.1719872     -0.04323670
## 1. FSV Mainz 05           -0.08857162         0.1719872     -0.03730423
## Bayer 04 Leverkusen       -0.08857162         0.1719872     -0.04622500
## Borussia Dortmund         -0.08857162         0.1719872     -0.02027224
## Borussia Mönchengladbach -0.08857162         0.1719872     -0.05067402
## Eintracht Frankfurt       -0.08857162         0.1719872     -0.02620483
## FC Augsburg               -0.08857162         0.1719872     -0.01508383
## FC Bayern München         -0.08857162         0.1719872      0.05594263
## FC Ingolstadt 04          -0.08857162         0.1719872     -0.02994659
## FC Schalke 04             -0.08857162         0.1719872     -0.05324634
## Hamburger SV              -0.08857162         0.1719872     -0.02855369
## Hertha BSC                -0.08857162         0.1719872     -0.04760829
## RB Leipzig                -0.08857162         0.1719872     -0.05048980
## Sport-Club Freiburg       -0.08857162         0.1719872     -0.05696201
## SV Darmstadt 98           -0.08857162         0.1719872     -0.01388796
## SV Werder Bremen          -0.08857162         0.1719872     -0.05236008
## TSG 1899 Hoffenheim       -0.08857162         0.1719872     -0.02239907
## VfL Wolfsburg             -0.08857162         0.1719872     -0.03063744
##                                OQ_gd
## 1. FC Köln                -0.03030974
## 1. FSV Mainz 05           -0.03030974
## Bayer 04 Leverkusen       -0.03030974
## Borussia Dortmund         -0.03030974
## Borussia Mönchengladbach -0.03030974
## Eintracht Frankfurt       -0.03030974
## FC Augsburg               -0.03030974
## FC Bayern München         -0.03030974
## FC Ingolstadt 04          -0.03030974
## FC Schalke 04             -0.03030974
## Hamburger SV              -0.03030974
## Hertha BSC                -0.03030974
## RB Leipzig                -0.03030974
## Sport-Club Freiburg       -0.03030974
## SV Darmstadt 98           -0.03030974
## SV Werder Bremen          -0.03030974
## TSG 1899 Hoffenheim       -0.03030974
## VfL Wolfsburg             -0.03030974
##
## attr(,"class")
## [1] "coef.mer"
```

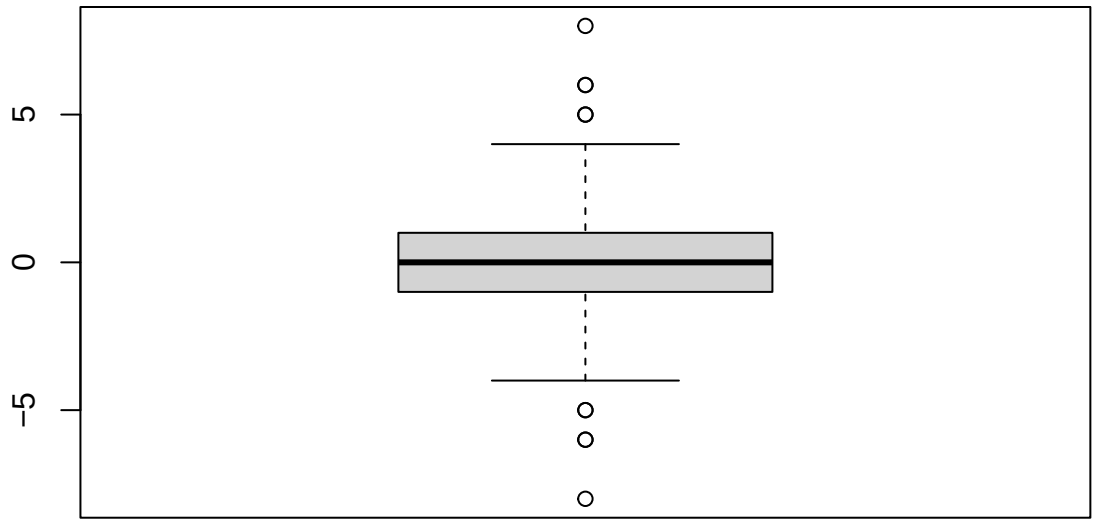
```
coef(PS)
```

```
## $Team
##                           (Intercept) ASS_16m_500s_diff possession_zero
## 1. FC Köln                -0.04955952         0.1578459     -0.05618187
## 1. FSV Mainz 05           -0.40725564         0.1578459     -0.05618187
## Bayer 04 Leverkusen        0.14153366         0.1578459     -0.05618187
## Borussia Dortmund          0.88142218         0.1578459     -0.05618187
## Borussia Mönchengladbach   0.19868491         0.1578459     -0.05618187
## Eintracht Frankfurt       -0.33640692         0.1578459     -0.05618187
## FC Augsburg               -0.75109578         0.1578459     -0.05618187
## FC Bayern München          2.17123571         0.1578459     -0.05618187
## FC Ingolstadt 04          -0.91228362         0.1578459     -0.05618187
## FC Schalke 04              0.38584298         0.1578459     -0.05618187
## Hamburger SV              -0.68362099         0.1578459     -0.05618187
## Hertha BSC                -0.29720988         0.1578459     -0.05618187
## RB Leipzig                 0.69107458         0.1578459     -0.05618187
## Sport-Club Freiburg       -0.38314396         0.1578459     -0.05618187
## SV Darmstadt 98           -1.13502412         0.1578459     -0.05618187
## SV Werder Bremen          -0.09852369         0.1578459     -0.05618187
## TSG 1899 Hoffenheim        0.86260185         0.1578459     -0.05618187
## VfL Wolfsburg             -0.29379172         0.1578459     -0.05618187
##                                OQ_gd
## 1. FC Köln                -0.03472597
## 1. FSV Mainz 05           -0.03472597
## Bayer 04 Leverkusen       -0.03472597
## Borussia Dortmund         -0.03472597
## Borussia Mönchengladbach  -0.03472597
## Eintracht Frankfurt       -0.03472597
## FC Augsburg               -0.03472597
## FC Bayern München         -0.03472597
## FC Ingolstadt 04          -0.03472597
## FC Schalke 04             -0.03472597
## Hamburger SV              -0.03472597
## Hertha BSC                -0.03472597
## RB Leipzig                -0.03472597
## Sport-Club Freiburg       -0.03472597
## SV Darmstadt 98           -0.03472597
## SV Werder Bremen          -0.03472597
## TSG 1899 Hoffenheim       -0.03472597
## VfL Wolfsburg             -0.03472597
##
## attr(,"class")
## [1] "coef.mer"
```

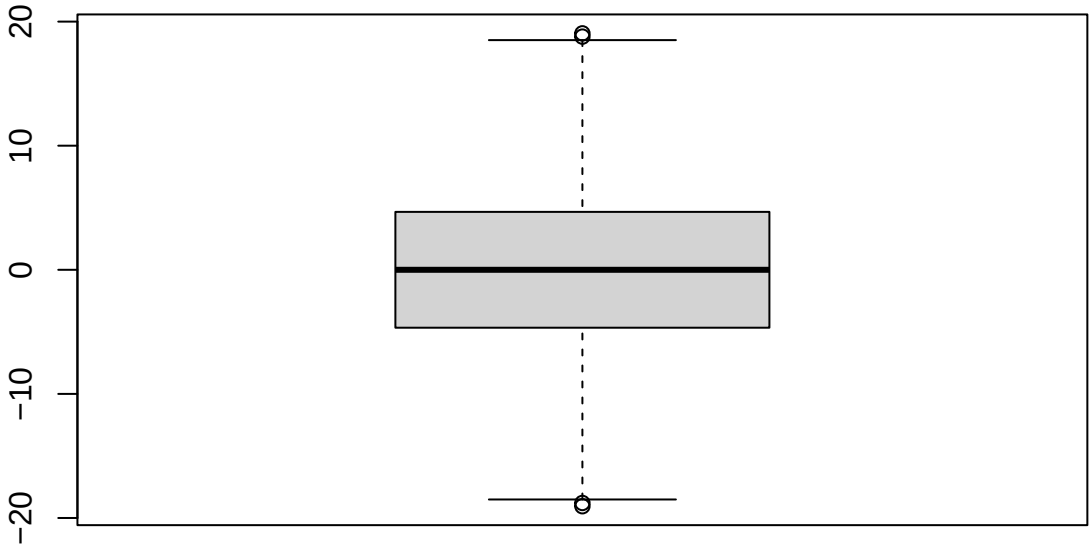
30m_100s

Descriptive

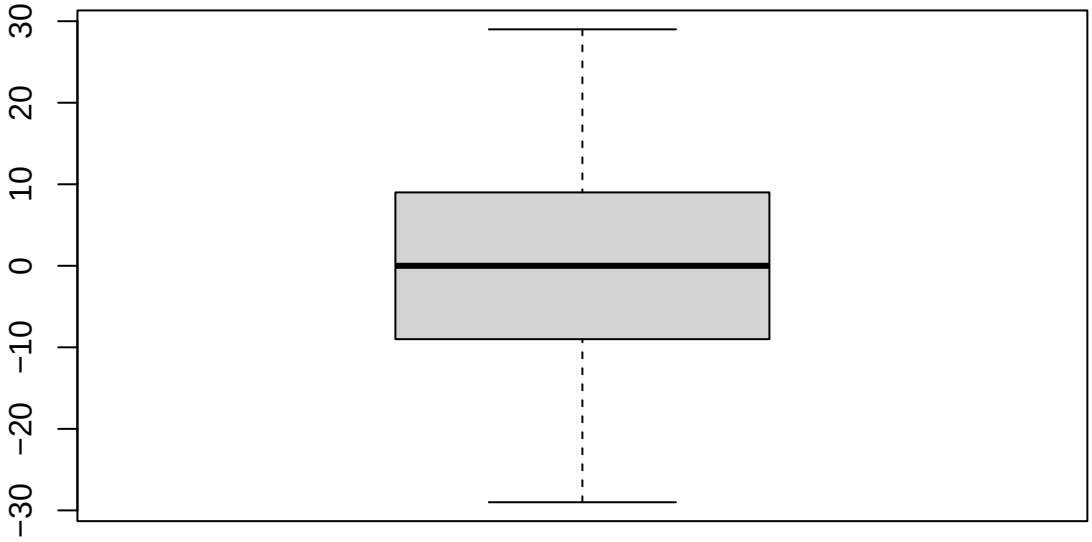
```r
boxplot(df$Outcome_num)
```



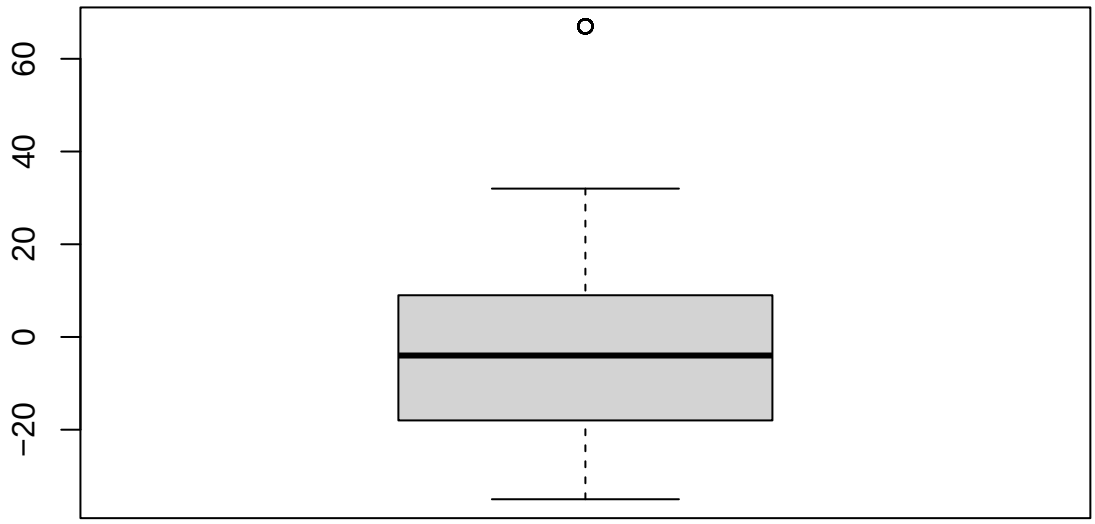

```r
boxplot(df$ASS_30m_100s_diff)
```




```
boxplot(df$possession_zero)
```



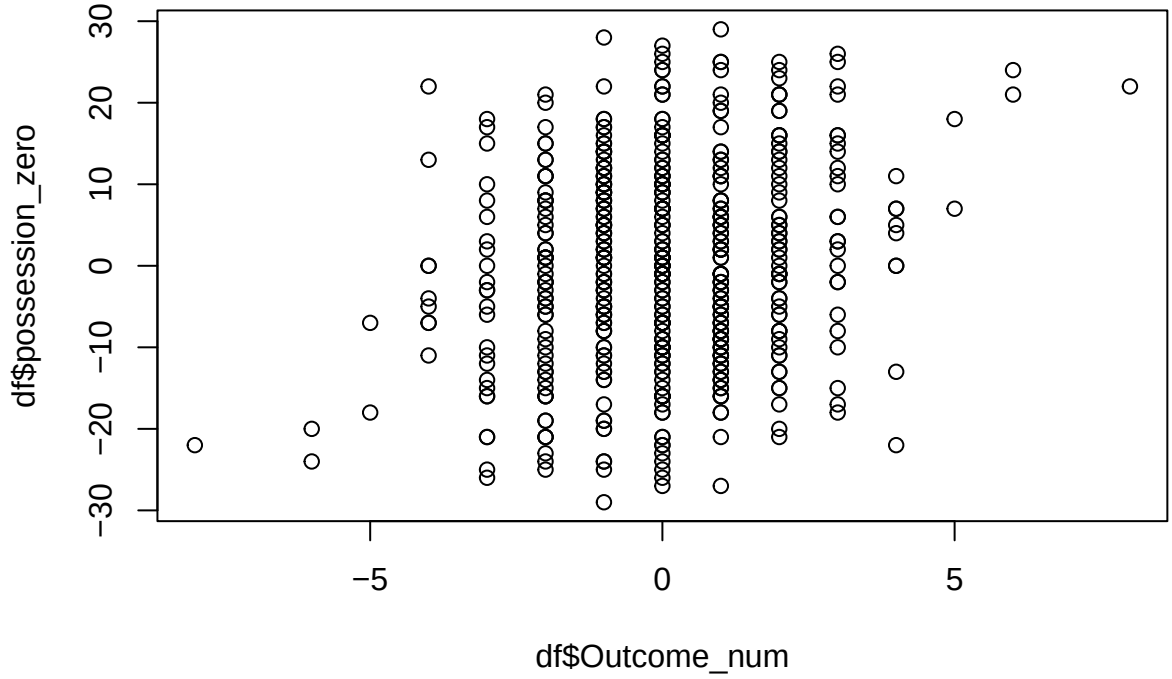

```
boxplot(df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$possession_zero
## t = 4.5167, df = 504, p-value = 7.831e-06
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1119941 0.2795989
## sample estimates:
##       cor
## 0.1972373
```

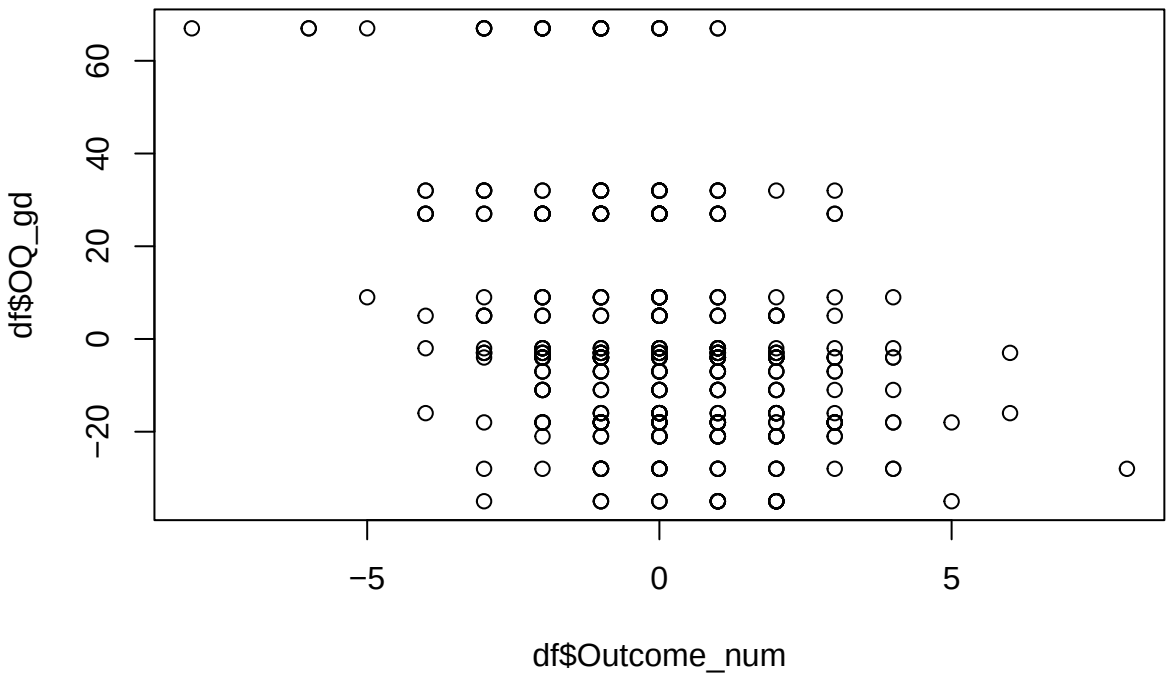
```
plot(df$Outcome_num, df$possession_zero)
```




```
cor.test(df$Outcome_num, df$OQ_gd)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$OQ_gd
## t = -9.2557, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4532666 -0.3040926
## sample estimates:
##        cor
## -0.3811578
```

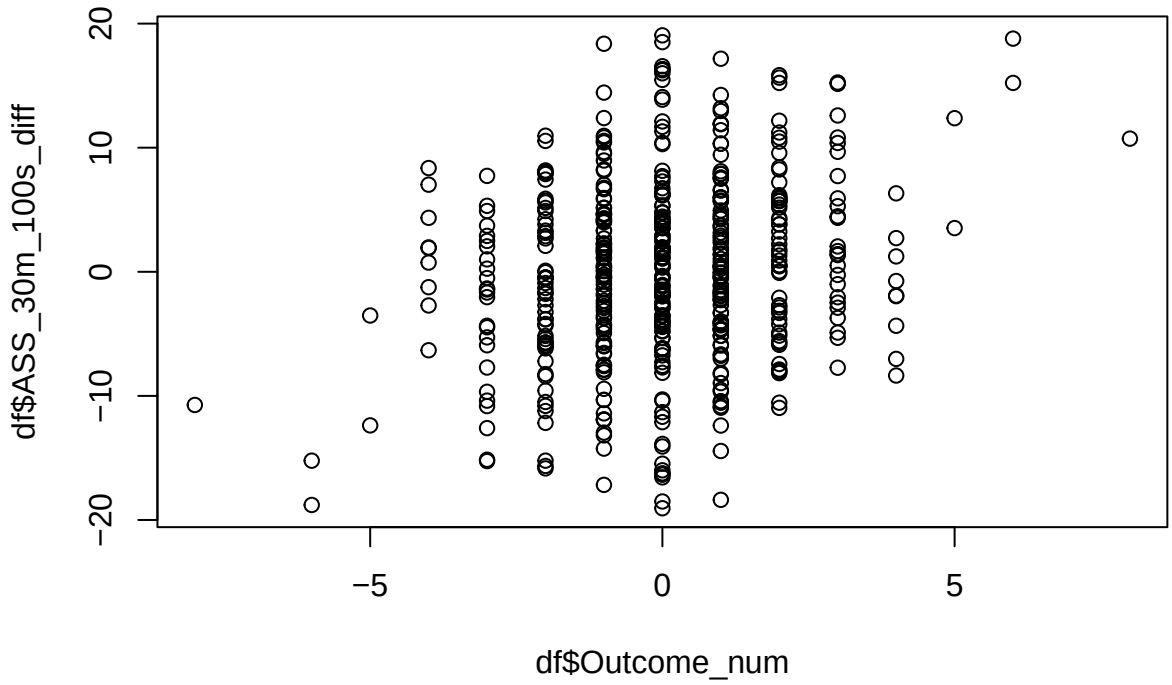
```
plot(df$Outcome_num, df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$ASS_30m_100s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$ASS_30m_100s_diff
## t = 5.2653, df = 504, p-value = 2.075e-07
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1440394 0.3093524
## sample estimates:
##       cor
## 0.2283411
```

```
plot(df$Outcome_num, df$ASS_30m_100s_diff)
```




```
cor.test(df$OQ_gd, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$possession_zero
## t = -12.359, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.5464574 -0.4124298
## sample estimates:
##       cor
## -0.4822607
```

```
cor.test(df$OQ_gd, df$ASS_30m_100s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$ASS_30m_100s_diff
## t = -9.1996, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4514277 -0.3019929
```

```
## sample estimates:
##        cor
## -0.3791799
```

```
cor.test(df$possession_zero, df$ASS_30m_100s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$possession_zero and df$ASS_30m_100s_diff
## t = 26.371, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.7222197 0.7957990
## sample estimates:
##       cor
## 0.7614512
```

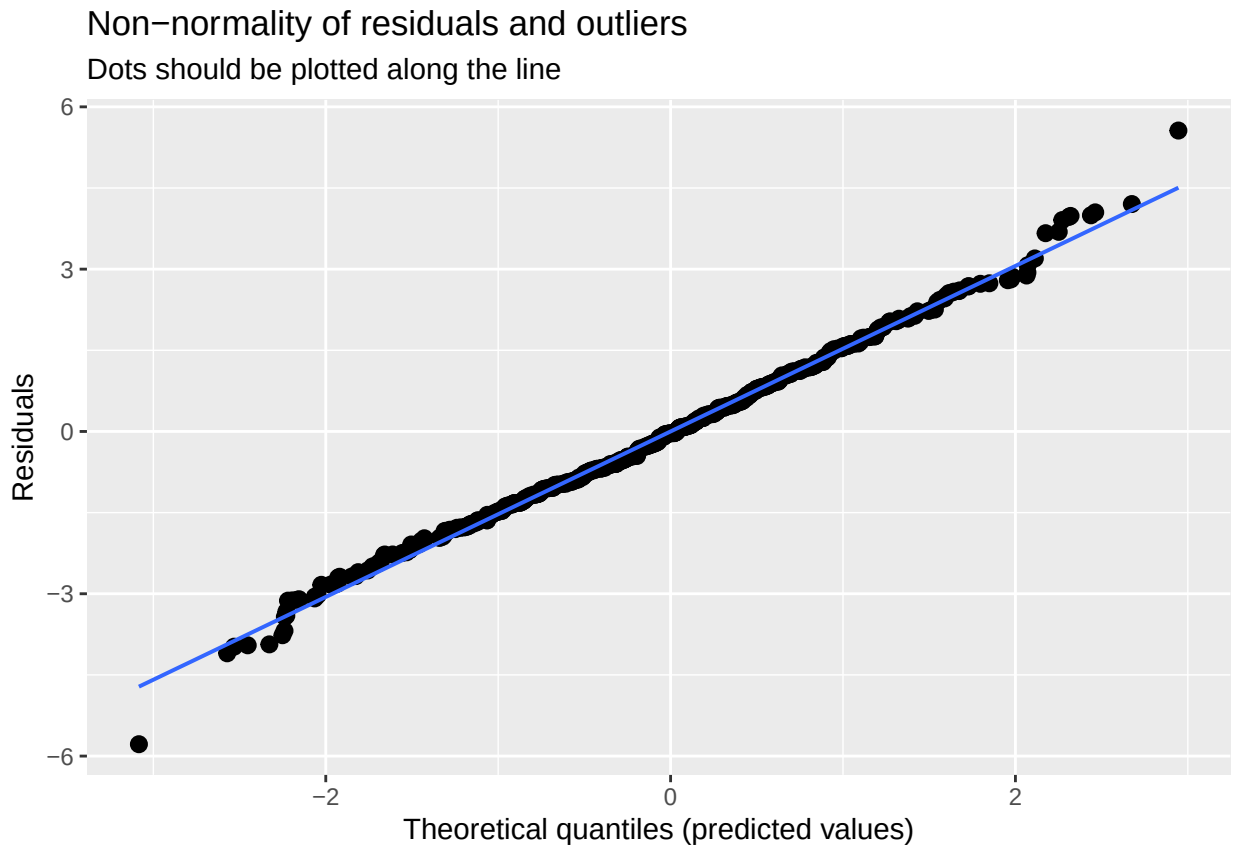
Diagnostics

```
fullmod <- lmer(Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (1+possession_zero|Team), da
vif(fullmod)
```

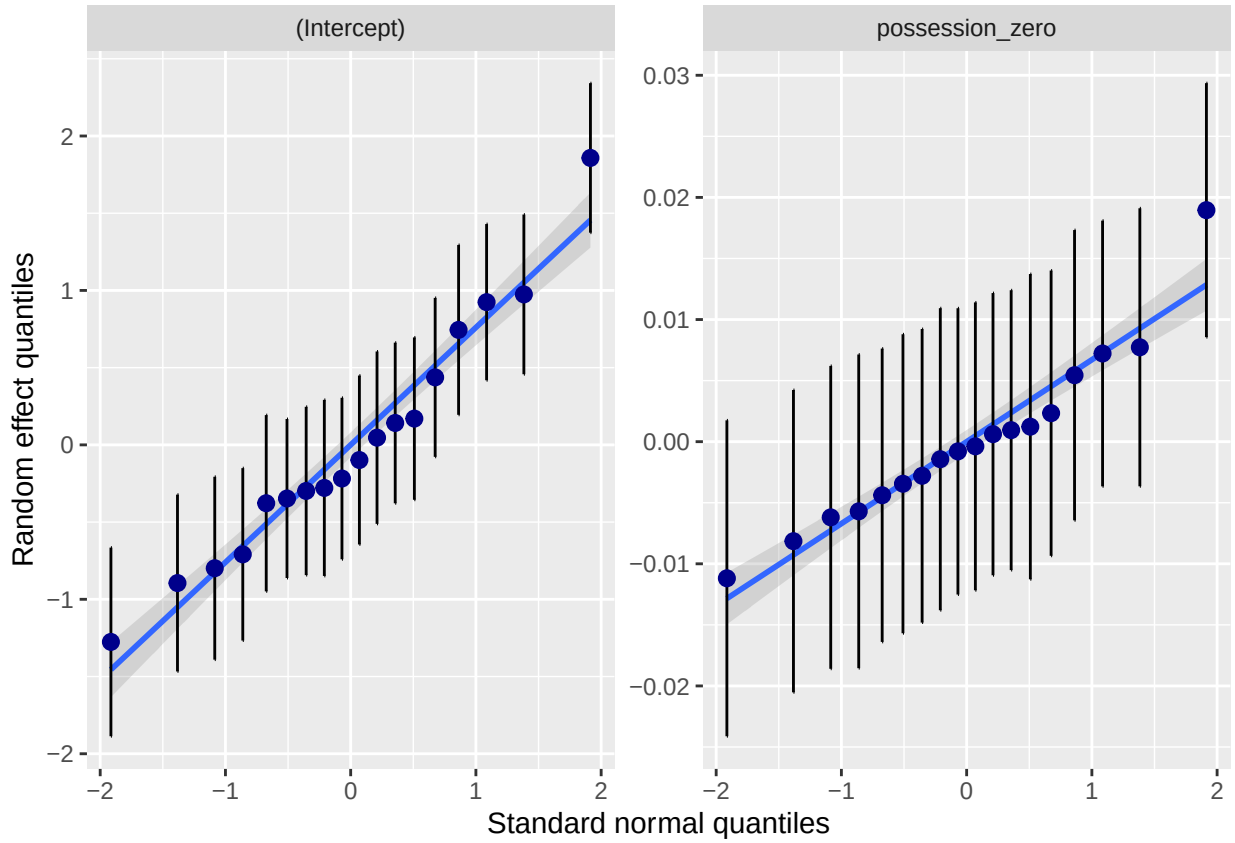
```
## ASS_30m_100s_diff   possession_zero             OQ_gd
##          1.972396          2.298661          1.372308
```

```
sjPlot::plot_model(fullmod, type = 'diag')
```

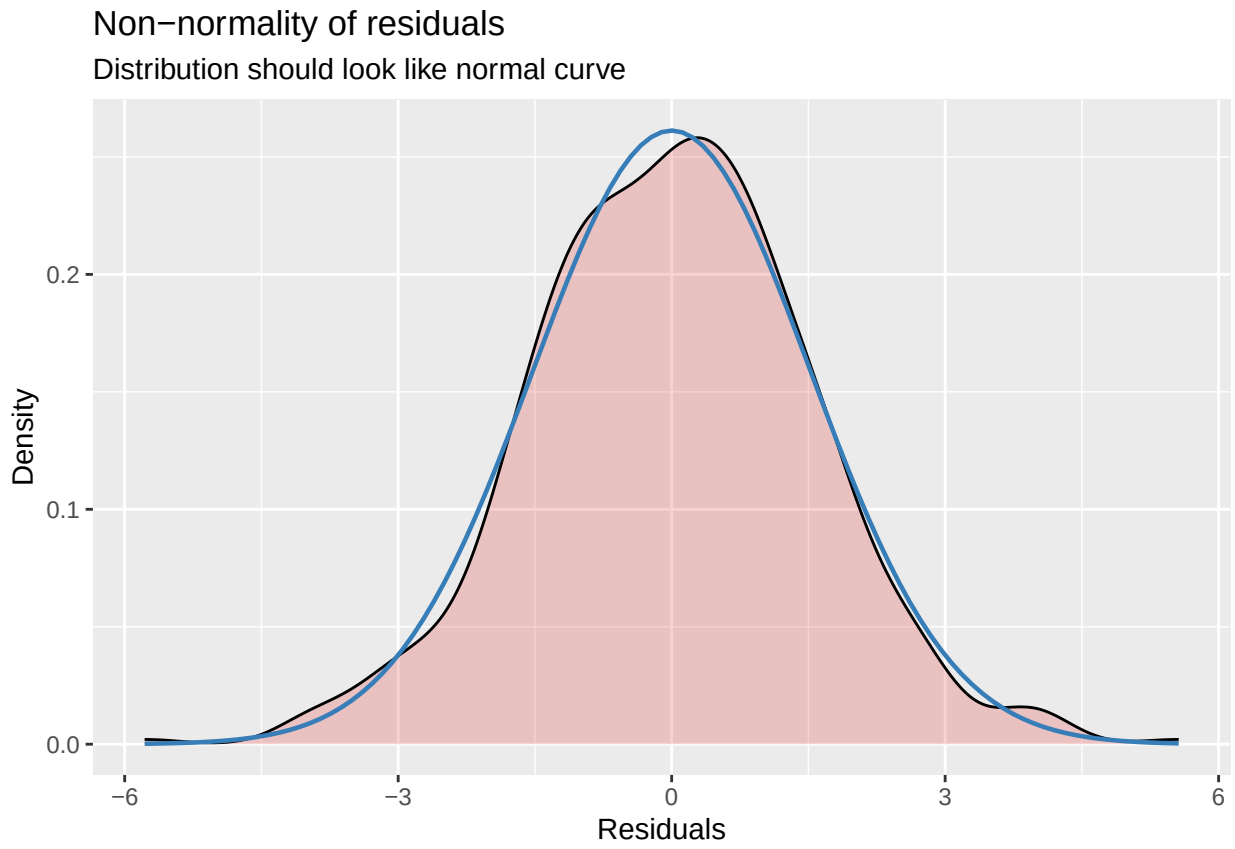
```
## [[1]]

## `geom_smooth()` using formula = 'y ~ x'
```



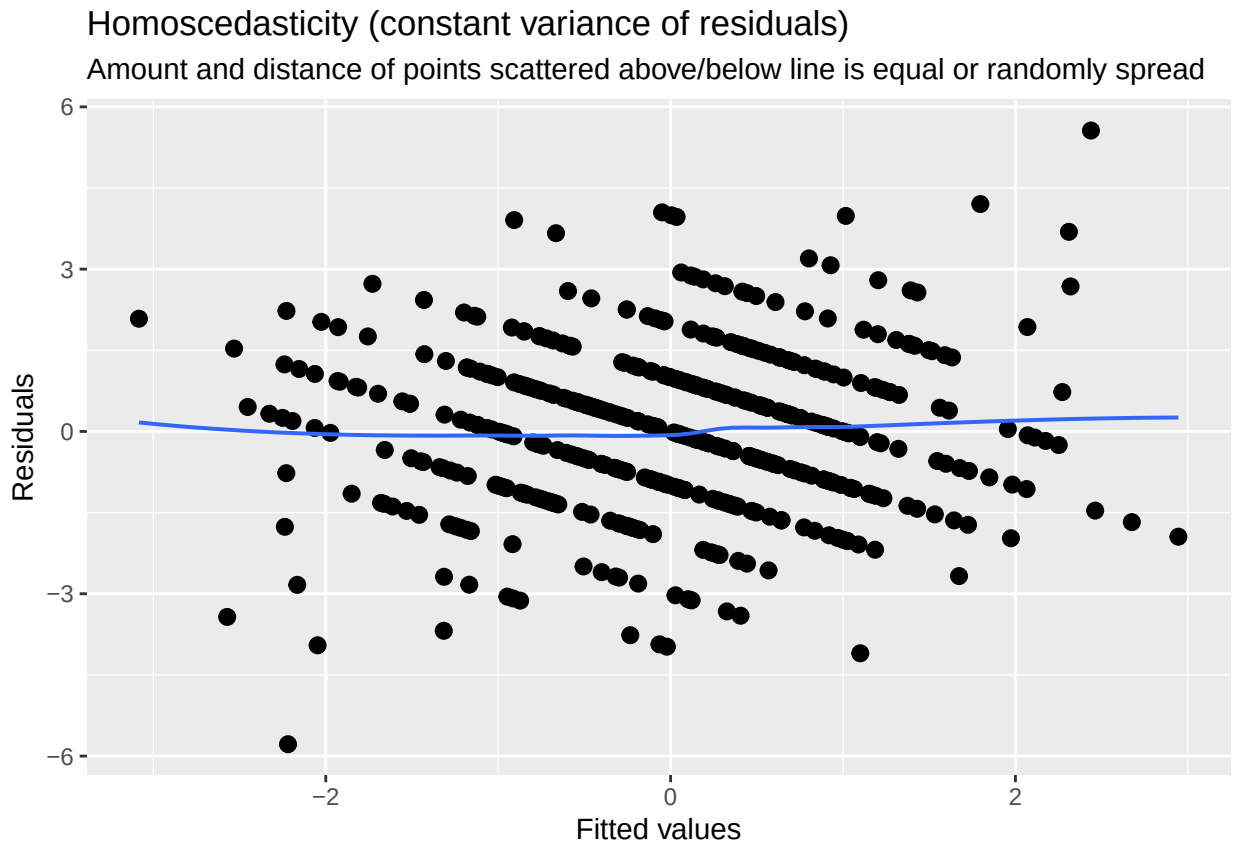

```
##
## [[2]]
## [[2]]$Team

## `geom_smooth()` using formula = 'y ~ x'
```


(Intercept)
possession_zero
Random effect quantiles
Standard normal quantiles
2
1
0
−1
−2
0.03
0.02
0.01
0.00
−0.01
−0.02
−2
−1
0
1
2

```
##
##
## [[3]]
```




```
##
## [[4]]

## `geom_smooth()` using formula = 'y ~ x'
```



Inference

```
summary(fullmod)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (1 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1935.5   1969.3   -959.7   1919.5      498
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.7268 -0.6597  0.0259  0.6385  3.5855
##
## Random effects:
##  Groups   Name            Variance  Std.Dev. Corr
##  Team     (Intercept)     6.386e-01 0.799128
##           possession_zero 8.222e-05 0.009067 0.78
##  Residual                 2.406e+00 1.551194
## Number of obs: 506, groups:  Team, 18
```

```
##
## Fixed effects:
##                      Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.043793   0.200912  14.493696  -0.218  0.83049
## ASS_30m_100s_diff   0.047430   0.015614 490.410777   3.038  0.00251 **
## possession_zero    -0.059280   0.010626  60.839614  -5.579 5.92e-07 ***
## OQ_gd              -0.035788   0.003357 492.779428 -10.660  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_30 pssss_
## ASS_30_100_ -0.001
## possessn_zr  0.155 -0.635
## OQ_gd        0.001  0.036  0.378
```

```
PS<- lmer(Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (1|Team), data = df,  REML = FALSE
summary(PS)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (1 |
##     Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1932.5   1957.8   -960.2   1920.5      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6558 -0.6668  0.0095  0.6218  3.6620
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Team     (Intercept) 0.7207   0.8489
##  Residual             2.4057   1.5510
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                      Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.001203   0.211697  16.145525  -0.006  0.99554
## ASS_30m_100s_diff   0.049155   0.015591 501.490461   3.153  0.00171 **
## possession_zero    -0.060615   0.010405 505.224629  -5.825 1.02e-08 ***
## OQ_gd              -0.035778   0.003359 499.377023 -10.653  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_30 pssss_
## ASS_30_100_ -0.002
## possessn_zr -0.001 -0.645
## OQ_gd       -0.005  0.038  0.388
```

```r
anova(PS, fullmod)
```

```
## Data: df
## Models:
## PS: Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (1 | Team)
## fullmod: Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## PS         6 1932.5 1957.8 -960.24   1920.5
## fullmod    8 1935.5 1969.3 -959.73   1919.5 1.0231  2     0.5996
```

```r
RI<- lmer(Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (0+possession_zero|Team), data = d
summary(RI)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (0 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1967.8   1993.2   -977.9   1955.8      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6033 -0.7110  0.0297  0.5976  3.3819
##
## Random effects:
##  Groups   Name            Variance Std.Dev.
##  Team     possession_zero 0.001025 0.03202
##  Residual                 2.702452 1.64391
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                     Estimate Std. Error        df t value Pr(>|t|)
## (Intercept)        -0.08417    0.08005 460.49471  -1.051   0.2936
## ASS_30m_100s_diff   0.03379    0.01572 505.11992   2.149   0.0321 *
## possession_zero    -0.02592    0.01240  58.45303  -2.089   0.0410 *
## OQ_gd              -0.03123    0.00346 502.23311  -9.025   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_30 pssss_
## ASS_30_100_  0.036
## possessn_zr  0.011 -0.539
## OQ_gd        0.014  0.044  0.268
```

```r
anova(RI, fullmod)
```

```
## Data: df
## Models:
## RI: Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (0 + possession_zero | Team)
```

```
## fullmod: Outcome_num ~ ASS_30m_100s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## RI         6 1967.8 1993.2 -977.90   1955.8
## fullmod    8 1935.5 1969.3 -959.73   1919.5 36.345  2  1.282e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
coef(RI)
```

```
## $Team
##                           (Intercept) ASS_30m_100s_diff possession_zero
## 1. FC Köln                -0.08416652         0.0337941    -0.034377255
## 1. FSV Mainz 05           -0.08416652         0.0337941    -0.035911624
## Bayer 04 Leverkusen       -0.08416652         0.0337941    -0.037567613
## Borussia Dortmund         -0.08416652         0.0337941    -0.012886410
## Borussia Mönchengladbach -0.08416652         0.0337941    -0.046932179
## Eintracht Frankfurt       -0.08416652         0.0337941    -0.021108333
## FC Augsburg               -0.08416652         0.0337941    -0.008245153
## FC Bayern München         -0.08416652         0.0337941     0.058522882
## FC Ingolstadt 04          -0.08416652         0.0337941    -0.025434770
## FC Schalke 04             -0.08416652         0.0337941    -0.050706308
## Hamburger SV              -0.08416652         0.0337941    -0.021030023
## Hertha BSC                -0.08416652         0.0337941    -0.038831244
## RB Leipzig                -0.08416652         0.0337941    -0.044712196
## Sport-Club Freiburg       -0.08416652         0.0337941    -0.051585733
## SV Darmstadt 98           -0.08416652         0.0337941    -0.008616220
## SV Werder Bremen          -0.08416652         0.0337941    -0.045385573
## TSG 1899 Hoffenheim       -0.08416652         0.0337941    -0.017169597
## VfL Wolfsburg             -0.08416652         0.0337941    -0.024503042
##                                 OQ_gd
## 1. FC Köln                -0.03122931
## 1. FSV Mainz 05           -0.03122931
## Bayer 04 Leverkusen       -0.03122931
## Borussia Dortmund         -0.03122931
## Borussia Mönchengladbach -0.03122931
## Eintracht Frankfurt       -0.03122931
## FC Augsburg               -0.03122931
## FC Bayern München         -0.03122931
## FC Ingolstadt 04          -0.03122931
## FC Schalke 04             -0.03122931
## Hamburger SV              -0.03122931
## Hertha BSC                -0.03122931
## RB Leipzig                -0.03122931
## Sport-Club Freiburg       -0.03122931
## SV Darmstadt 98           -0.03122931
## SV Werder Bremen          -0.03122931
## TSG 1899 Hoffenheim       -0.03122931
## VfL Wolfsburg             -0.03122931
##
## attr(,"class")
## [1] "coef.mer"
```

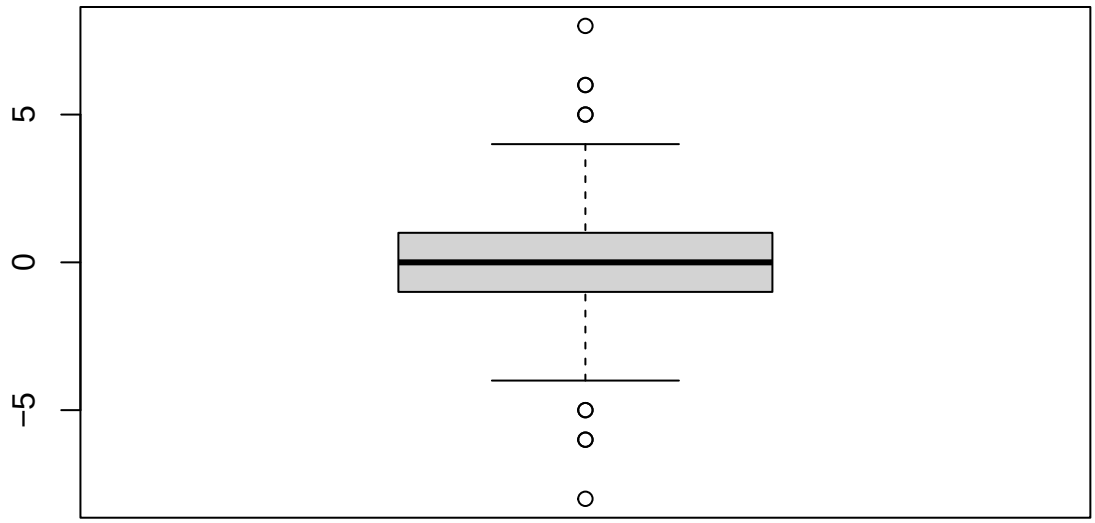
```r
coef(PS)
```

```
## $Team
##                           (Intercept) ASS_30m_100s_diff possession_zero
## 1. FC Köln                -0.02036982        0.04915485     -0.06061547
## 1. FSV Mainz 05           -0.41408108        0.04915485     -0.06061547
## Bayer 04 Leverkusen        0.11735744        0.04915485     -0.06061547
## Borussia Dortmund          0.99336034        0.04915485     -0.06061547
## Borussia Mönchengladbach   0.15833715        0.04915485     -0.06061547
## Eintracht Frankfurt       -0.37224064        0.04915485     -0.06061547
## FC Augsburg               -0.82980996        0.04915485     -0.06061547
## FC Bayern München          2.12447992        0.04915485     -0.06061547
## FC Ingolstadt 04          -0.92074990        0.04915485     -0.06061547
## FC Schalke 04              0.44031415        0.04915485     -0.06061547
## Hamburger SV              -0.73876594        0.04915485     -0.06061547
## Hertha BSC                -0.33376322        0.04915485     -0.06061547
## RB Leipzig                 0.75055049        0.04915485     -0.06061547
## Sport-Club Freiburg       -0.34984341        0.04915485     -0.06061547
## SV Darmstadt 98           -1.23868690        0.04915485     -0.06061547
## SV Werder Bremen          -0.12295726        0.04915485     -0.06061547
## TSG 1899 Hoffenheim        1.01858320        0.04915485     -0.06061547
## VfL Wolfsburg             -0.28336083        0.04915485     -0.06061547
##                                 OQ_gd
## 1. FC Köln                -0.03577763
## 1. FSV Mainz 05           -0.03577763
## Bayer 04 Leverkusen       -0.03577763
## Borussia Dortmund         -0.03577763
## Borussia Mönchengladbach  -0.03577763
## Eintracht Frankfurt       -0.03577763
## FC Augsburg               -0.03577763
## FC Bayern München         -0.03577763
## FC Ingolstadt 04          -0.03577763
## FC Schalke 04             -0.03577763
## Hamburger SV              -0.03577763
## Hertha BSC                -0.03577763
## RB Leipzig                -0.03577763
## Sport-Club Freiburg       -0.03577763
## SV Darmstadt 98           -0.03577763
## SV Werder Bremen          -0.03577763
## TSG 1899 Hoffenheim       -0.03577763
## VfL Wolfsburg             -0.03577763
##
## attr(,"class")
## [1] "coef.mer"
```

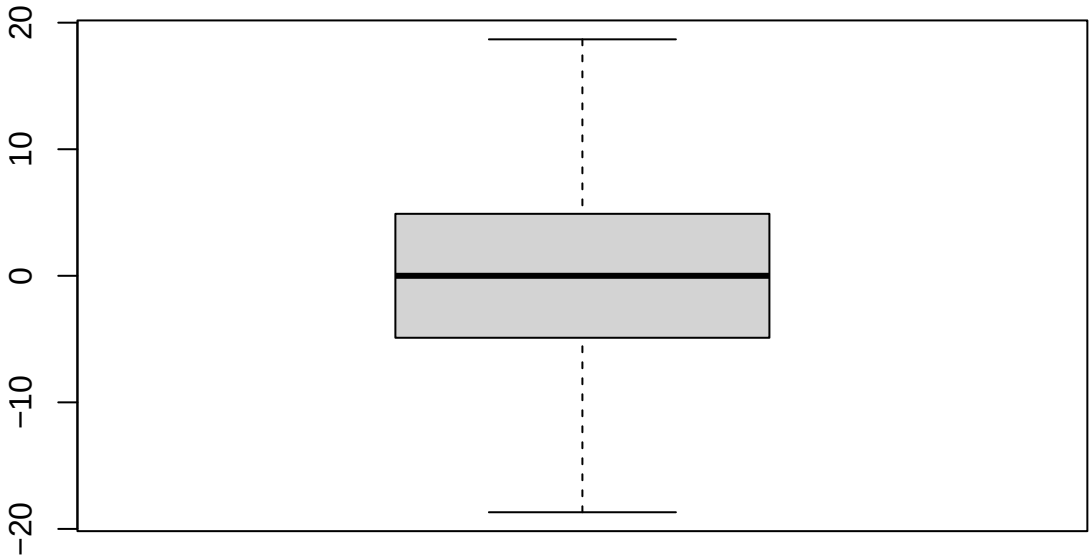
30m_300s

Descriptive

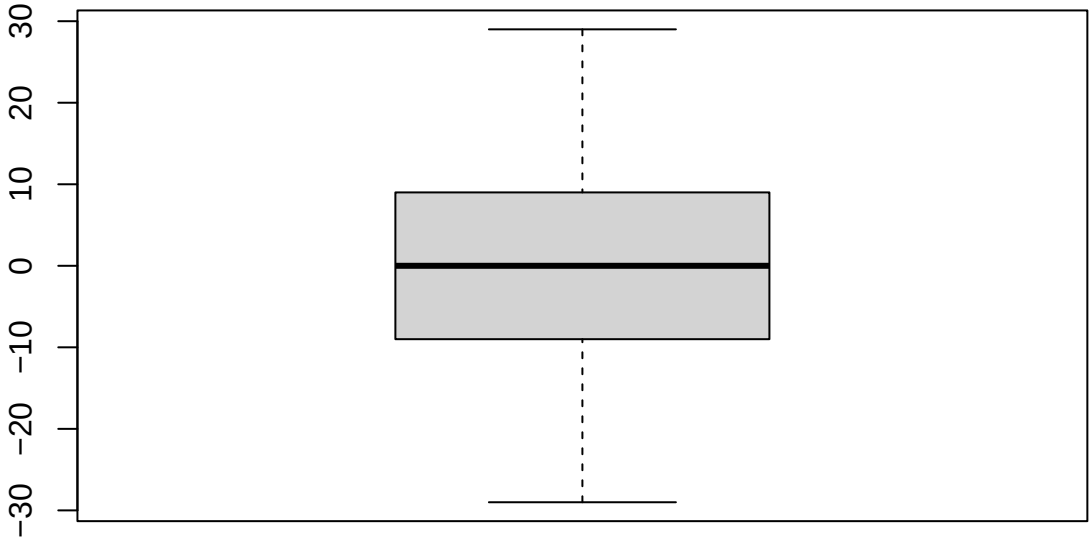
```r
boxplot(df$Outcome_num)
```



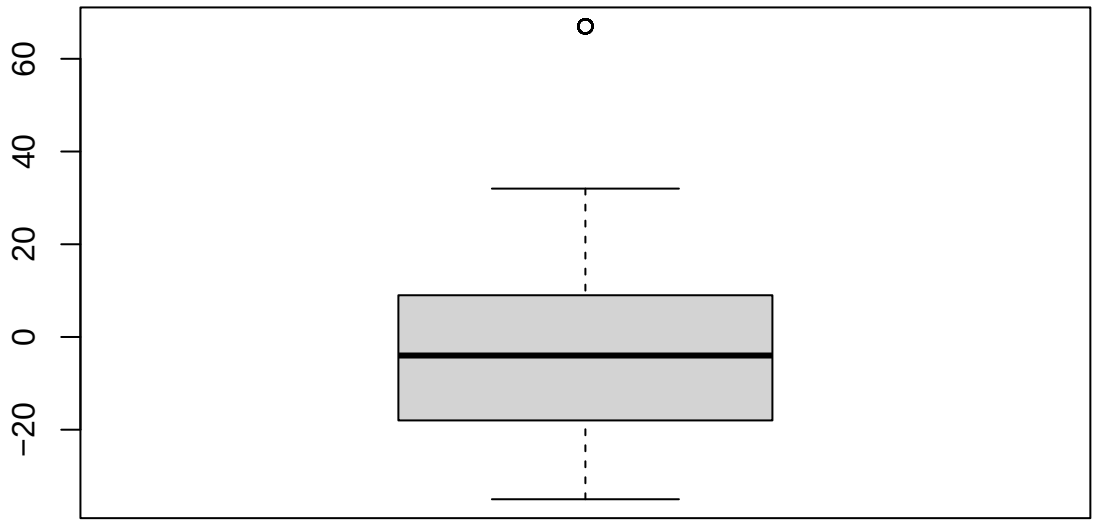

```r
boxplot(df$ASS_30m_300s_diff)
```




```
boxplot(df$possession_zero)
```



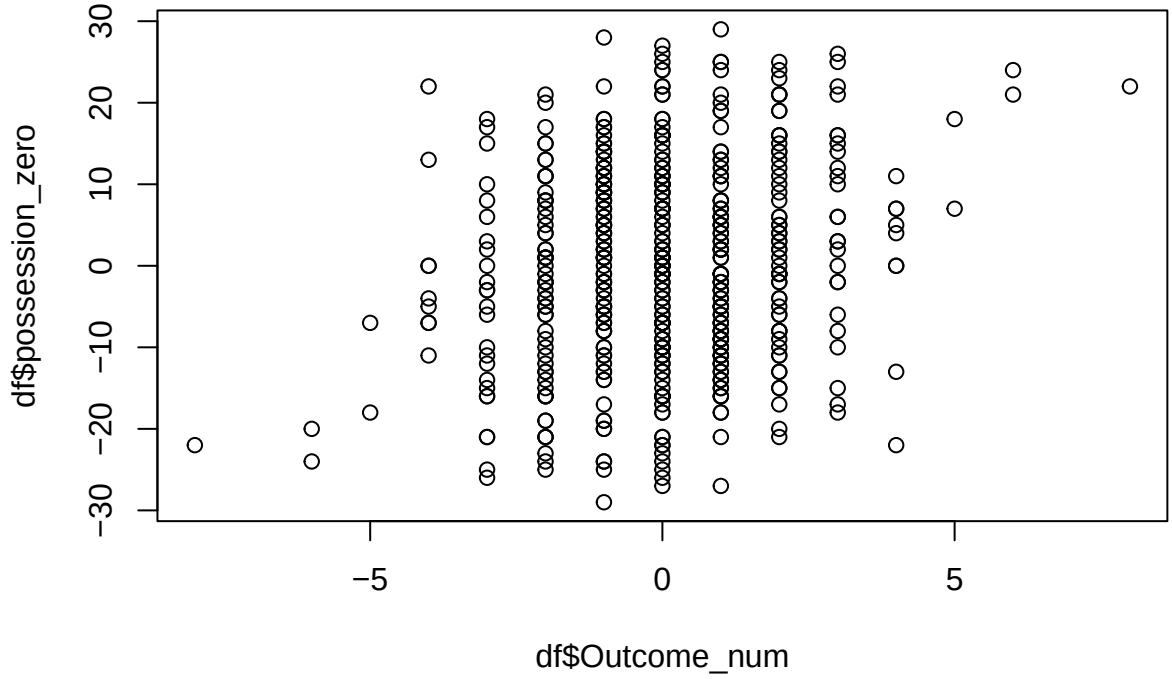

```
boxplot(df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$possession_zero
## t = 4.5167, df = 504, p-value = 7.831e-06
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1119941 0.2795989
## sample estimates:
##       cor
## 0.1972373
```

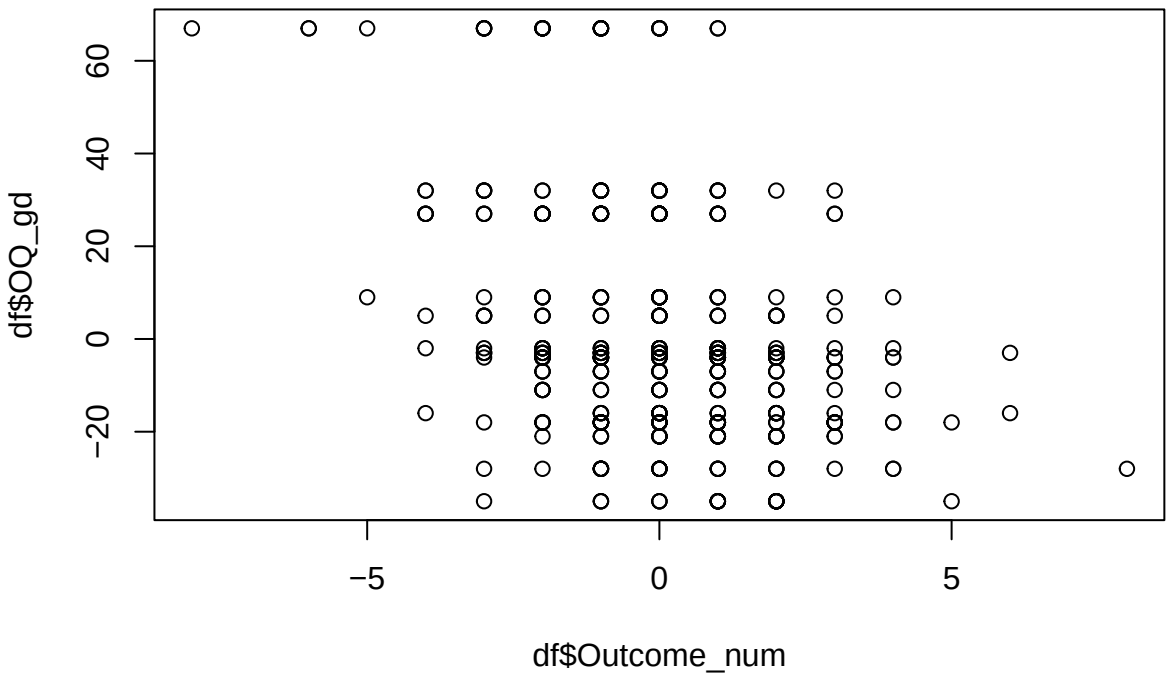
```
plot(df$Outcome_num, df$possession_zero)
```




```
cor.test(df$Outcome_num, df$OQ_gd)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$OQ_gd
## t = -9.2557, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4532666 -0.3040926
## sample estimates:
##       cor
## -0.3811578
```

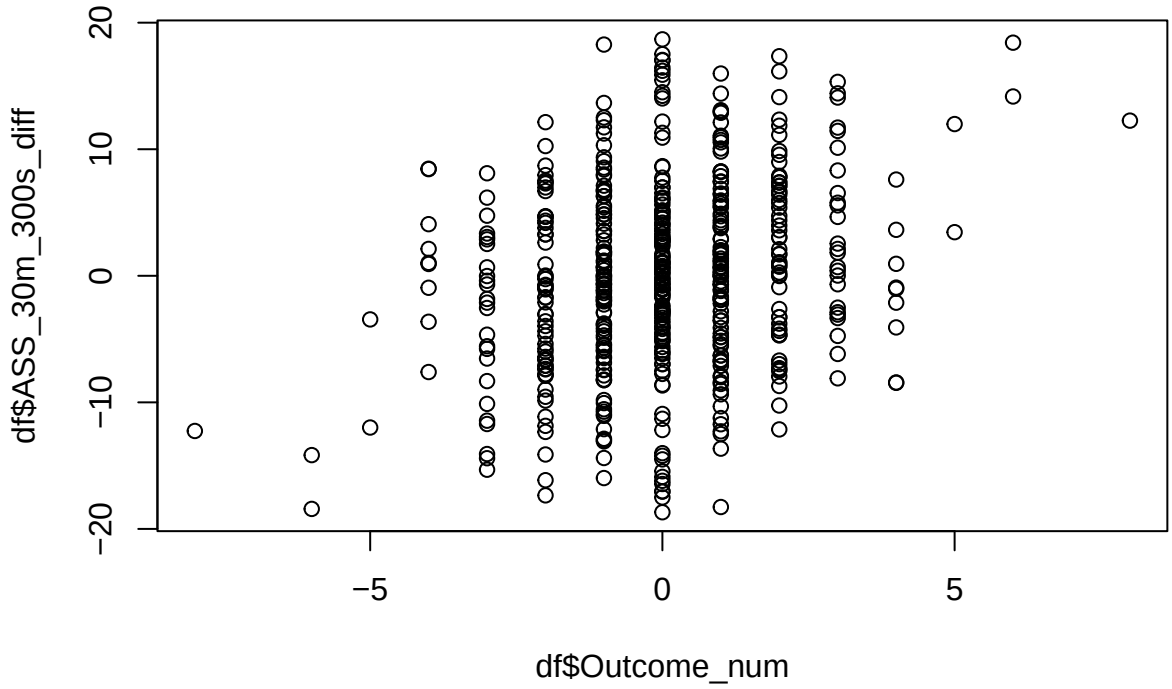
```
plot(df$Outcome_num, df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$ASS_30m_300s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$ASS_30m_300s_diff
## t = 5.6359, df = 504, p-value = 2.902e-08
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1597088 0.3237842
## sample estimates:
##       cor
## 0.2434877
```

```
plot(df$Outcome_num, df$ASS_30m_300s_diff)
```




```
cor.test(df$OQ_gd, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$possession_zero
## t = -12.359, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.5464574 -0.4124298
## sample estimates:
##       cor
## -0.4822607
```

```
cor.test(df$OQ_gd, df$ASS_30m_300s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$ASS_30m_300s_diff
## t = -9.1335, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4492567 -0.2995159
```

```
## sample estimates:
##        cor
## -0.3768457
```

```
cor.test(df$possession_zero, df$ASS_30m_300s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$possession_zero and df$ASS_30m_300s_diff
## t = 25.282, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.7066410 0.7838289
## sample estimates:
##       cor
## 0.7477505
```

Diagnostics

```
fullmod <- lmer(Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (1+possession_zero|Team), da
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## unable to evaluate scaled gradient
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## Model failed to converge: degenerate Hessian with 1 negative eigenvalues
```

```
## Warning: Model failed to converge with 1 negative eigenvalue: -4.8e+03
```

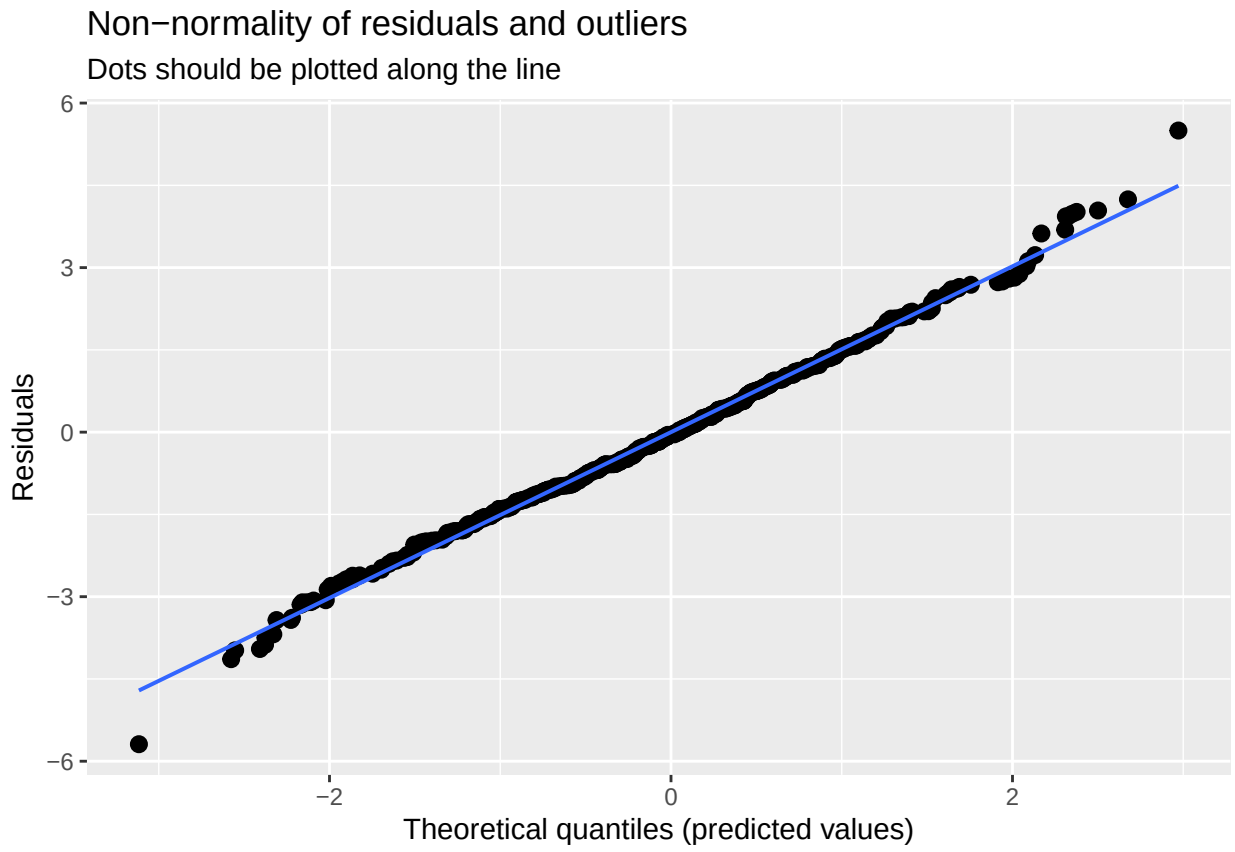
```
vif(fullmod)
```

```
## ASS_30m_300s_diff   possession_zero             OQ_gd
##          1.919197          2.256099          1.388593
```

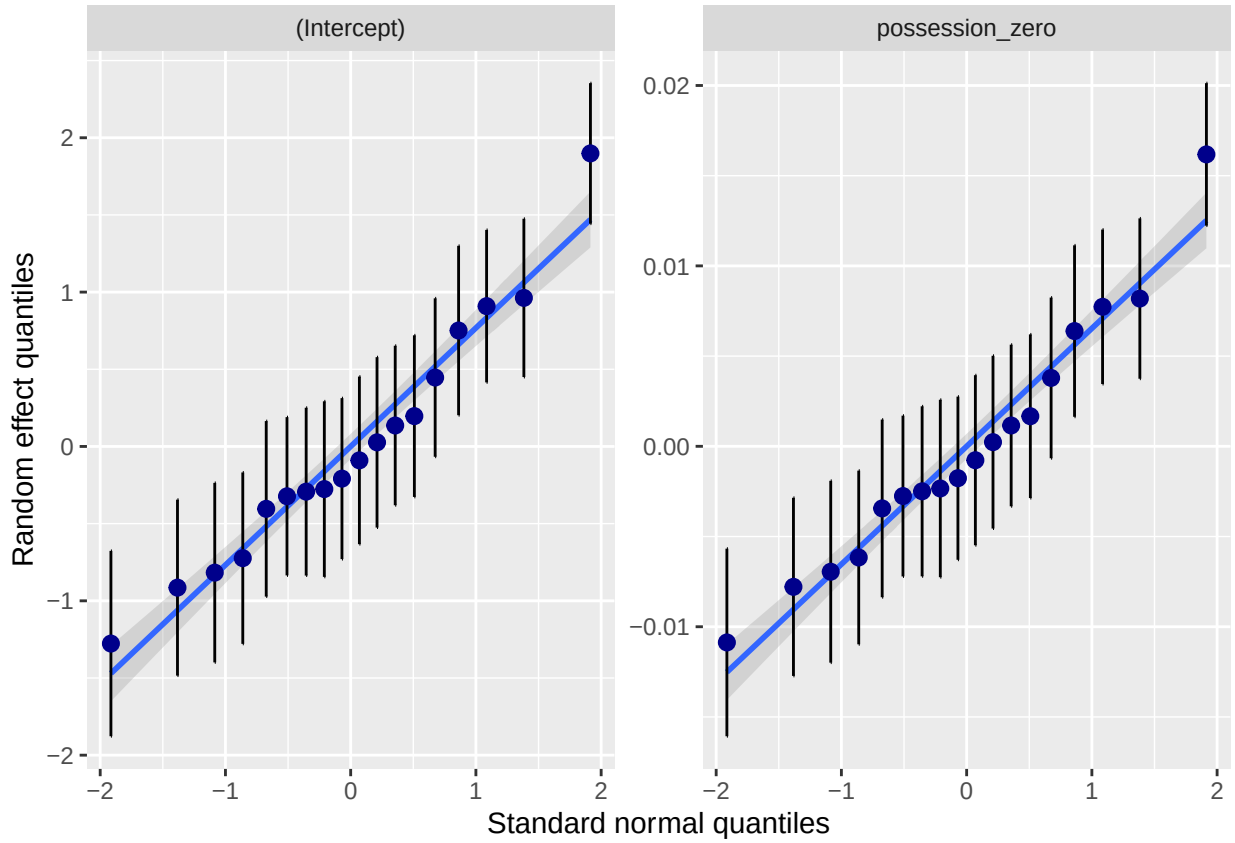
```
sjPlot::plot_model(fullmod, type = 'diag')
```

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

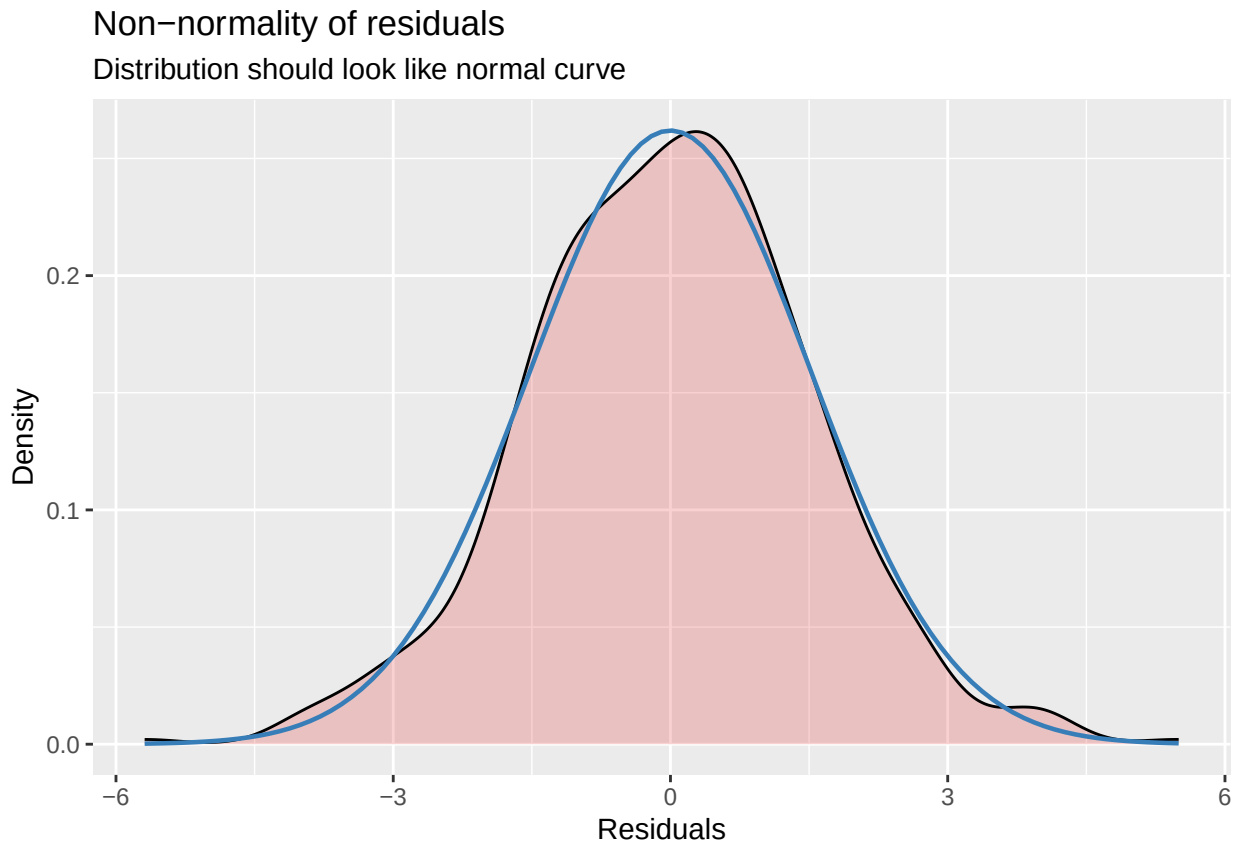
```
## `geom_smooth()` using formula = 'y ~ x'
```



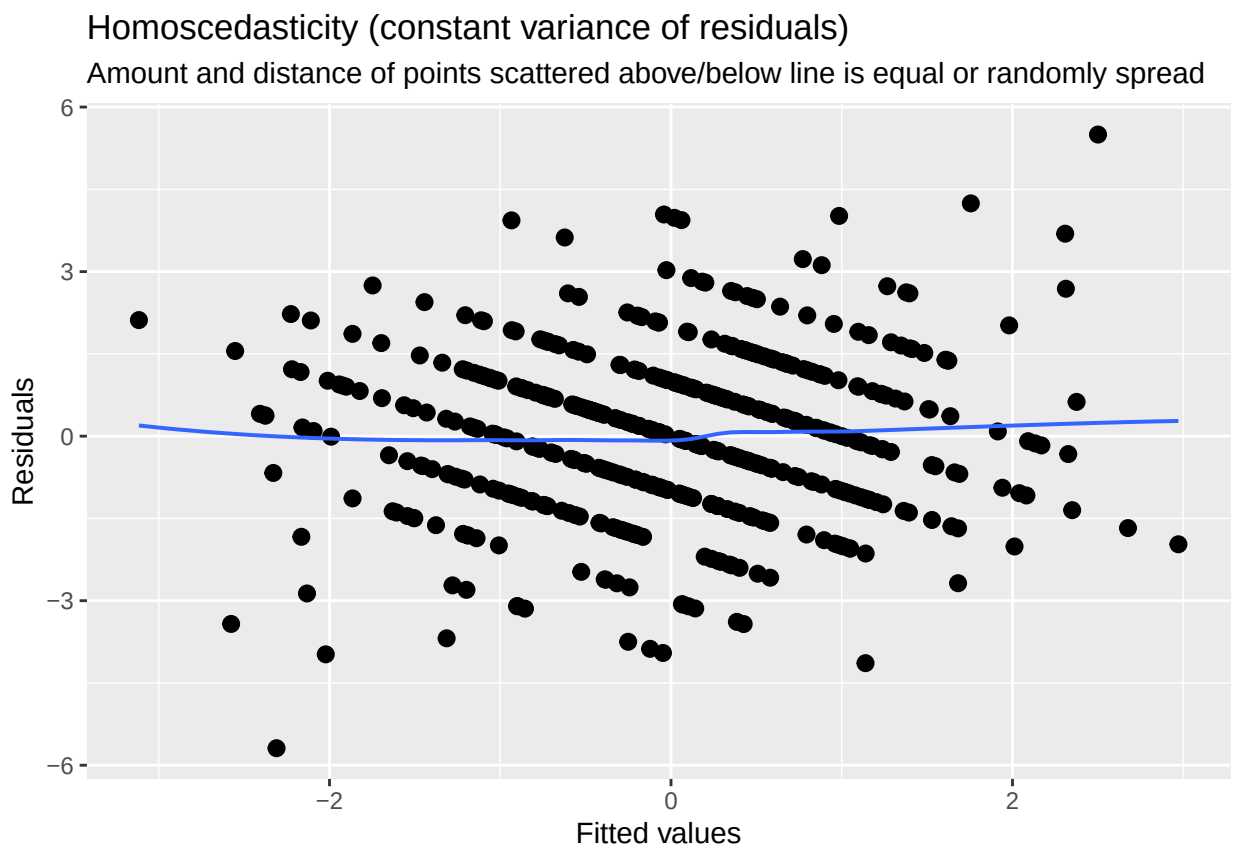

```
##
## [[2]]
## [[2]]$Team

## `geom_smooth()` using formula = 'y ~ x'
```


(Intercept)
possession_zero
Random effect quantiles
Standard normal quantiles
2
1
0
−1
−2
0.02
0.01
0.00
−0.01
−2
−1
0
1
2

```
##
##
## [[3]]
```




```
##
## [[4]]

## `geom_smooth()` using formula = 'y ~ x'
```



Inference

```
summary(fullmod)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (1 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1931.8   1965.6   -957.9   1915.8      498
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6800 -0.6749  0.0234  0.6203  3.5566
##
## Random effects:
##  Groups   Name            Variance  Std.Dev. Corr
##  Team     (Intercept)     6.468e-01 0.804219
##           possession_zero 4.708e-05 0.006861 1.00
##  Residual                 2.391e+00 1.546153
## Number of obs: 506, groups:  Team, 18
```

```
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.042135   0.201749  15.344917  -0.209  0.83731
## ASS_30m_300s_diff   0.053131   0.014727 497.994737   3.608  0.00034 ***
## possession_zero    -0.061912   0.010278 303.161562  -6.024 4.93e-09 ***
## OQ_gd              -0.035680   0.003346 499.270036 -10.662  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_30 pssss_
## ASS_30_300_ -0.001
## possessn_zr  0.157 -0.621
## OQ_gd        0.001  0.041  0.388
## optimizer (nloptwrap) convergence code: 0 (OK)
## unable to evaluate scaled gradient
## Model failed to converge: degenerate  Hessian with 1 negative eigenvalues
```

```
PS<- lmer(Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (1|Team), data = df,  REML = FALSE
summary(PS)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (1 |
##     Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1928.7   1954.1   -958.4   1916.7      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6103 -0.6776  0.0107  0.6056  3.6260
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Team     (Intercept) 0.7207   0.8489
##  Residual             2.3873   1.5451
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.001443   0.211609  16.154609  -0.007 0.994643
## ASS_30m_300s_diff   0.054604   0.014704 500.172963   3.714 0.000227 ***
## possession_zero    -0.063084   0.010153 505.076007  -6.213 1.09e-09 ***
## OQ_gd              -0.035670   0.003346 499.309041 -10.659  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_30 pssss_
## ASS_30_300_ -0.002
## possessn_zr -0.001 -0.625
```

```
## OQ_gd       -0.005  0.041  0.395
```

```
anova(PS, fullmod)
```

```
## Data: df
## Models:
## PS: Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (1 | Team)
## fullmod: Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## PS         6 1928.7 1954.1 -958.36   1916.7
## fullmod    8 1931.8 1965.6 -957.88   1915.8 0.9703  2     0.6156
```

```
RI<- lmer(Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (0+possession_zero|Team), data = d
summary(RI)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (0 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1964.7   1990.0   -976.3   1952.7      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5770 -0.7048  0.0165  0.6127  3.3601
##
## Random effects:
##  Groups   Name            Variance Std.Dev.
##  Team     possession_zero 0.001014 0.03185
##  Residual                 2.686142 1.63895
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.082584   0.079794 460.080318  -1.035   0.3012
## ASS_30m_300s_diff   0.041570   0.014909 504.313566   2.788   0.0055 **
## possession_zero    -0.029249   0.012190  55.668104  -2.399   0.0198 *
## OQ_gd              -0.031084   0.003451 502.256731  -9.008   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_30 pssss_
## ASS_30_300_  0.034
## possessn_zr  0.012 -0.521
## OQ_gd        0.014  0.049  0.270
```

```
anova(RI, fullmod)
```

```
## Data: df
```

```
## Models:
## RI: Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (0 + possession_zero | Team)
## fullmod: Outcome_num ~ ASS_30m_300s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## RI         6 1964.7 1990.0 -976.34   1952.7
## fullmod    8 1931.8 1965.6 -957.88   1915.8 36.938  2  9.531e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
coef(RI)
```

```
## $Team
##                           (Intercept) ASS_30m_300s_diff possession_zero
## 1. FC Köln                 -0.0825841        0.04156988     -0.03786602
## 1. FSV Mainz 05            -0.0825841        0.04156988     -0.03946379
## Bayer 04 Leverkusen        -0.0825841        0.04156988     -0.04095852
## Borussia Dortmund          -0.0825841        0.04156988     -0.01730789
## Borussia Mönchengladbach   -0.0825841        0.04156988     -0.05002099
## Eintracht Frankfurt        -0.0825841        0.04156988     -0.02376627
## FC Augsburg                -0.0825841        0.04156988     -0.01178463
## FC Bayern München          -0.0825841        0.04156988      0.05434293
## FC Ingolstadt 04           -0.0825841        0.04156988     -0.02877555
## FC Schalke 04              -0.0825841        0.04156988     -0.05372121
## Hamburger SV               -0.0825841        0.04156988     -0.02442724
## Hertha BSC                 -0.0825841        0.04156988     -0.04217836
## RB Leipzig                 -0.0825841        0.04156988     -0.04816023
## Sport-Club Freiburg        -0.0825841        0.04156988     -0.05500058
## SV Darmstadt 98            -0.0825841        0.04156988     -0.01123017
## SV Werder Bremen           -0.0825841        0.04156988     -0.04864305
## TSG 1899 Hoffenheim        -0.0825841        0.04156988     -0.01972800
## VfL Wolfsburg              -0.0825841        0.04156988     -0.02779259
##                                OQ_gd
## 1. FC Köln                -0.03108365
## 1. FSV Mainz 05           -0.03108365
## Bayer 04 Leverkusen       -0.03108365
## Borussia Dortmund         -0.03108365
## Borussia Mönchengladbach -0.03108365
## Eintracht Frankfurt       -0.03108365
## FC Augsburg               -0.03108365
## FC Bayern München         -0.03108365
## FC Ingolstadt 04          -0.03108365
## FC Schalke 04             -0.03108365
## Hamburger SV              -0.03108365
## Hertha BSC                -0.03108365
## RB Leipzig                -0.03108365
## Sport-Club Freiburg       -0.03108365
## SV Darmstadt 98           -0.03108365
## SV Werder Bremen          -0.03108365
## TSG 1899 Hoffenheim       -0.03108365
## VfL Wolfsburg             -0.03108365
##
## attr(,"class")
## [1] "coef.mer"
```

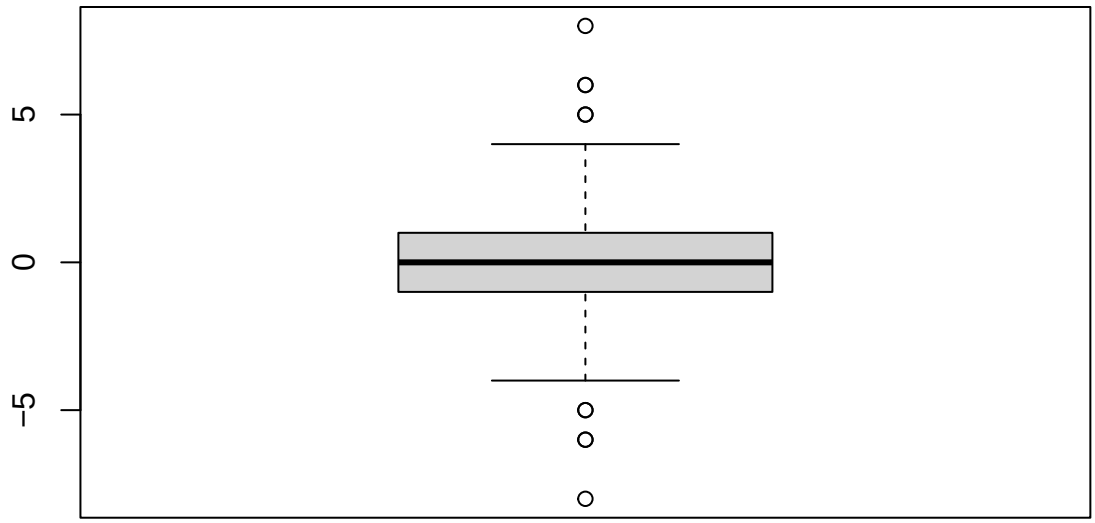
```r
coef(PS)
```

```
## $Team
##                           (Intercept) ASS_30m_300s_diff possession_zero
## 1. FC Köln                -0.03237281        0.05460419     -0.06308408
## 1. FSV Mainz 05           -0.43746977        0.05460419     -0.06308408
## Bayer 04 Leverkusen        0.11312716        0.05460419     -0.06308408
## Borussia Dortmund          0.98469408        0.05460419     -0.06308408
## Borussia Mönchengladbach   0.19012613        0.05460419     -0.06308408
## Eintracht Frankfurt       -0.37124957        0.05460419     -0.06308408
## FC Augsburg               -0.83344603        0.05460419     -0.06308408
## FC Bayern München          2.11719771        0.05460419     -0.06308408
## FC Ingolstadt 04          -0.93814957        0.05460419     -0.06308408
## FC Schalke 04              0.45233104        0.05460419     -0.06308408
## Hamburger SV              -0.75033761        0.05460419     -0.06308408
## Hertha BSC                -0.32662763        0.05460419     -0.06308408
## RB Leipzig                 0.75876569        0.05460419     -0.06308408
## Sport-Club Freiburg       -0.32869726        0.05460419     -0.06308408
## SV Darmstadt 98           -1.23922476        0.05460419     -0.06308408
## SV Werder Bremen          -0.11683588        0.05460419     -0.06308408
## TSG 1899 Hoffenheim        1.00539861        0.05460419     -0.06308408
## VfL Wolfsburg             -0.27320070        0.05460419     -0.06308408
##                                OQ_gd
## 1. FC Köln                -0.03566972
## 1. FSV Mainz 05           -0.03566972
## Bayer 04 Leverkusen       -0.03566972
## Borussia Dortmund         -0.03566972
## Borussia Mönchengladbach  -0.03566972
## Eintracht Frankfurt       -0.03566972
## FC Augsburg               -0.03566972
## FC Bayern München         -0.03566972
## FC Ingolstadt 04          -0.03566972
## FC Schalke 04             -0.03566972
## Hamburger SV              -0.03566972
## Hertha BSC                -0.03566972
## RB Leipzig                -0.03566972
## Sport-Club Freiburg       -0.03566972
## SV Darmstadt 98           -0.03566972
## SV Werder Bremen          -0.03566972
## TSG 1899 Hoffenheim       -0.03566972
## VfL Wolfsburg             -0.03566972
##
## attr(,"class")
## [1] "coef.mer"
```

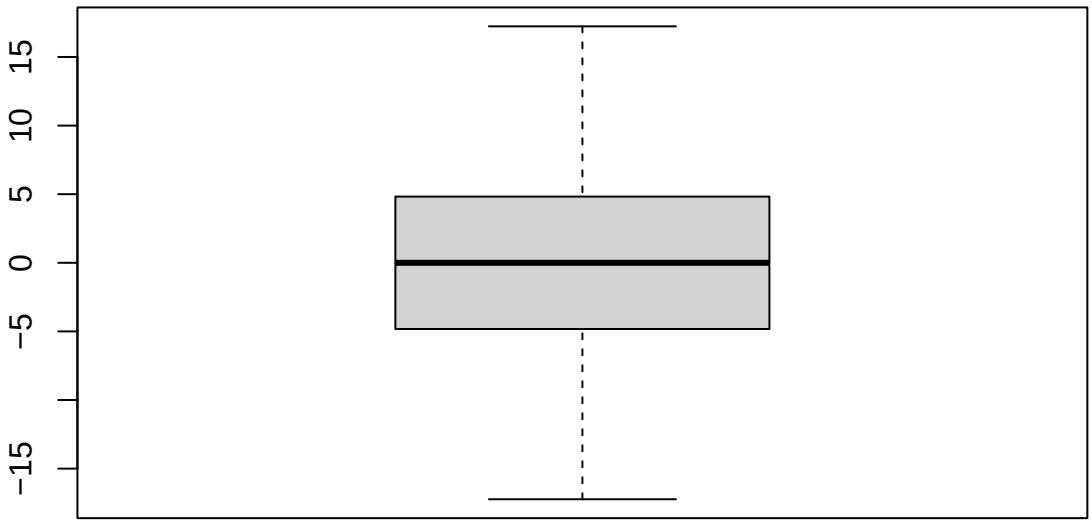
30m_500s

Descriptive

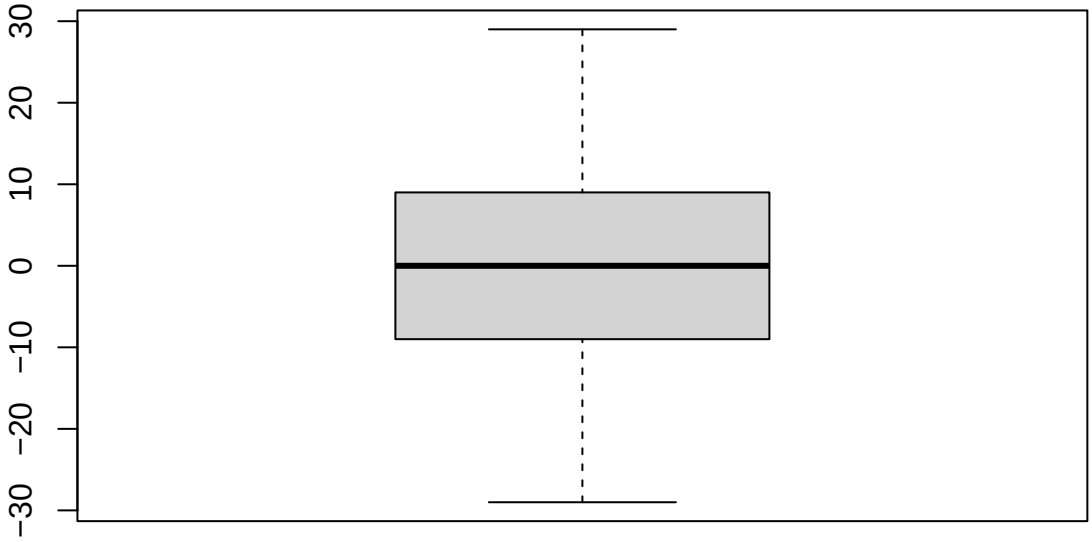
```r
boxplot(df$Outcome_num)
```



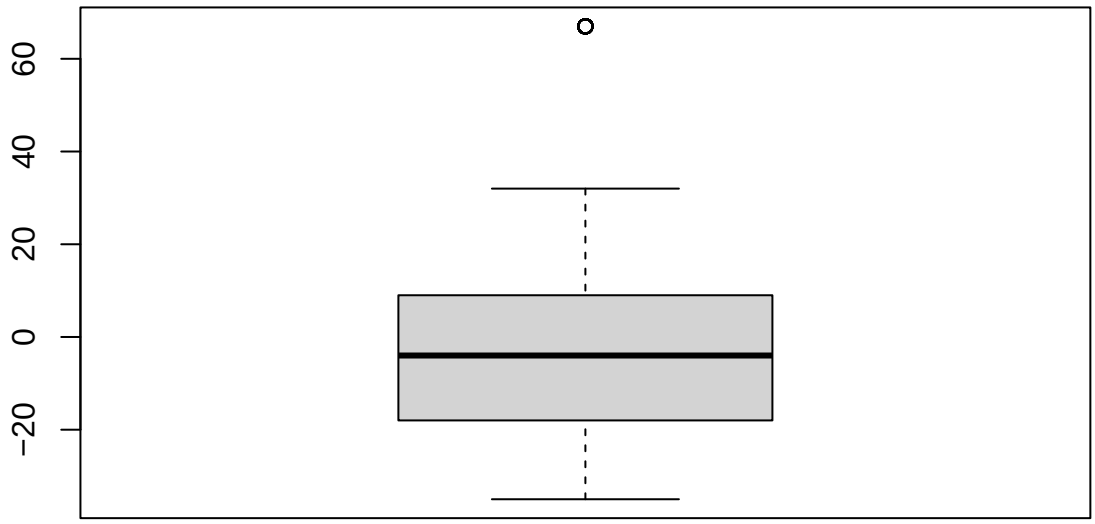

```r
boxplot(df$ASS_30m_500s_diff)
```




```
boxplot(df$possession_zero)
```



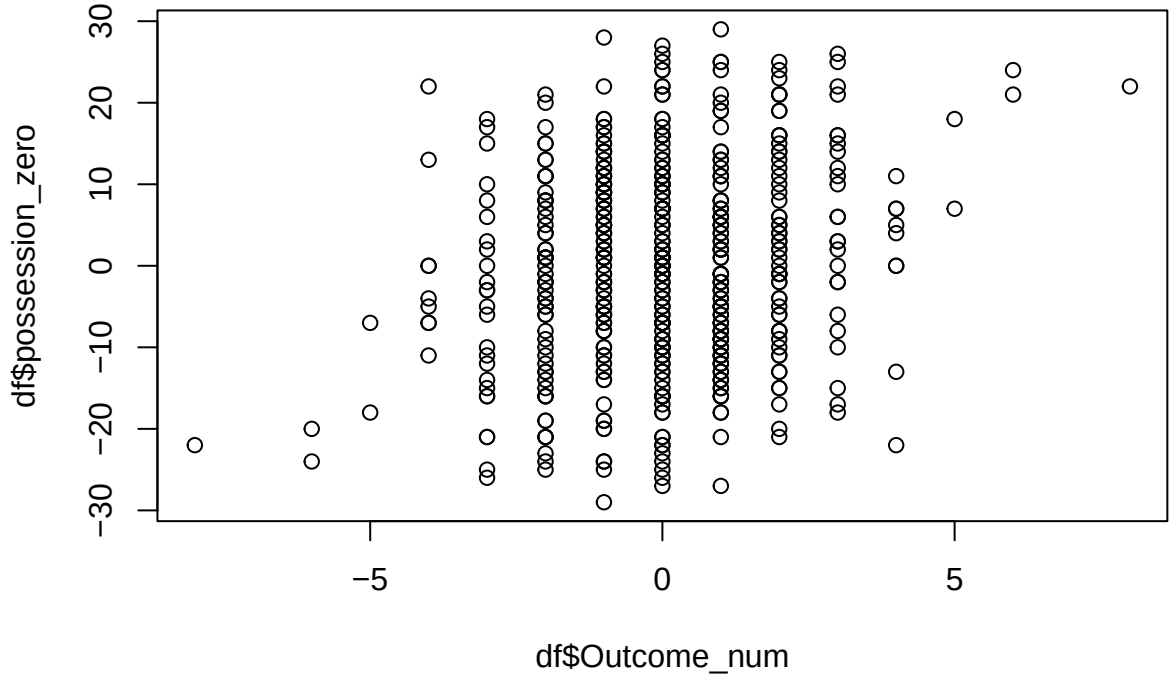

```
boxplot(df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$possession_zero
## t = 4.5167, df = 504, p-value = 7.831e-06
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1119941 0.2795989
## sample estimates:
##       cor
## 0.1972373
```

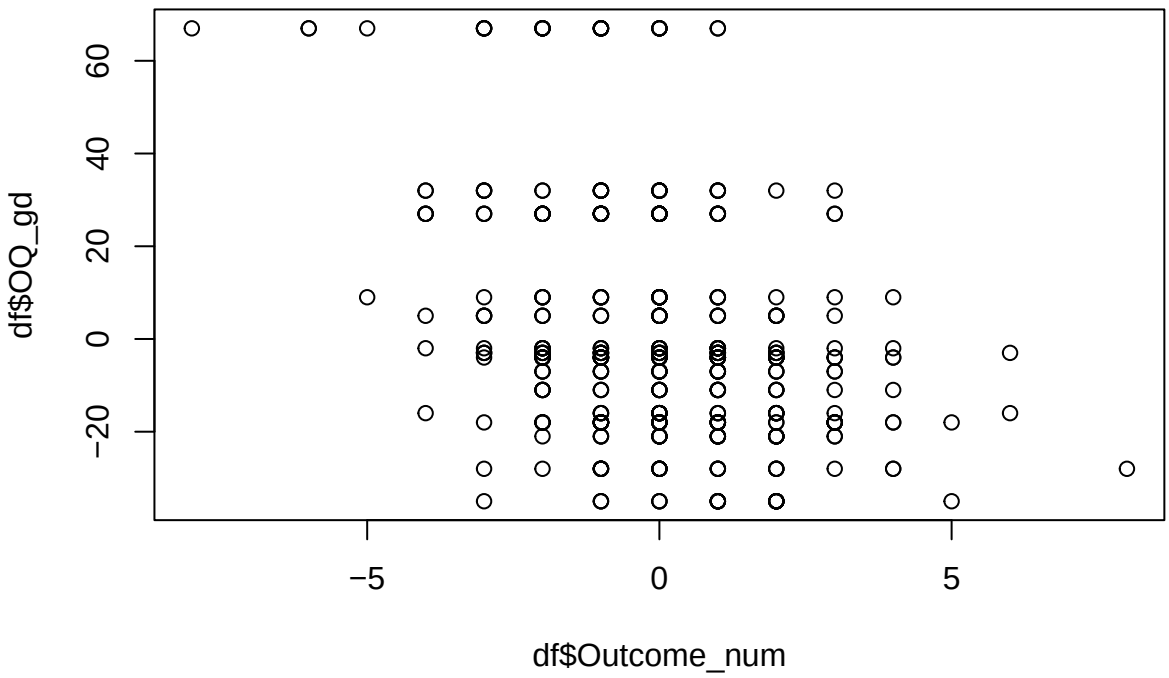
```
plot(df$Outcome_num, df$possession_zero)
```




```
cor.test(df$Outcome_num, df$OQ_gd)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$OQ_gd
## t = -9.2557, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4532666 -0.3040926
## sample estimates:
##        cor
## -0.3811578
```

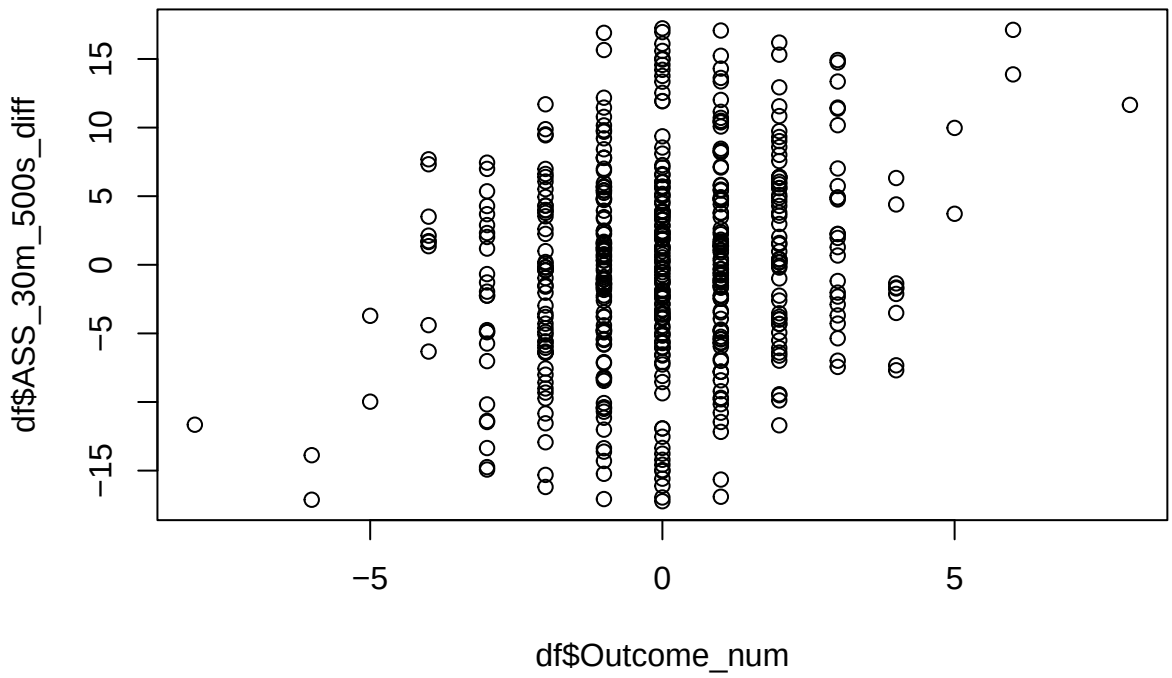
```
plot(df$Outcome_num, df$OQ_gd)
```




```
cor.test(df$Outcome_num, df$ASS_30m_500s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$Outcome_num and df$ASS_30m_500s_diff
## t = 5.068, df = 504, p-value = 5.654e-07
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1356401 0.3015849
## sample estimates:
##       cor
## 0.2202052
```

```
plot(df$Outcome_num, df$ASS_30m_500s_diff)
```




```
cor.test(df$OQ_gd, df$possession_zero)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$possession_zero
## t = -12.359, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.5464574 -0.4124298
## sample estimates:
##        cor
## -0.4822607
```

```
cor.test(df$OQ_gd, df$ASS_30m_500s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$OQ_gd and df$ASS_30m_500s_diff
## t = -9.2155, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4519511 -0.3025903
```

```
## sample estimates:
##        cor
## -0.3797428
```

```
cor.test(df$possession_zero, df$ASS_30m_500s_diff)
```

```
##
##  Pearson's product-moment correlation
##
## data:  df$possession_zero and df$ASS_30m_500s_diff
## t = 25.608, df = 504, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.7114113 0.7875004
## sample estimates:
##       cor
## 0.7519495
```

Diagnostics

```
fullmod <- lmer(Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (1+possession_zero|Team), da
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## Model failed to converge with max|grad| = 0.036353 (tol = 0.002, component 1)
```

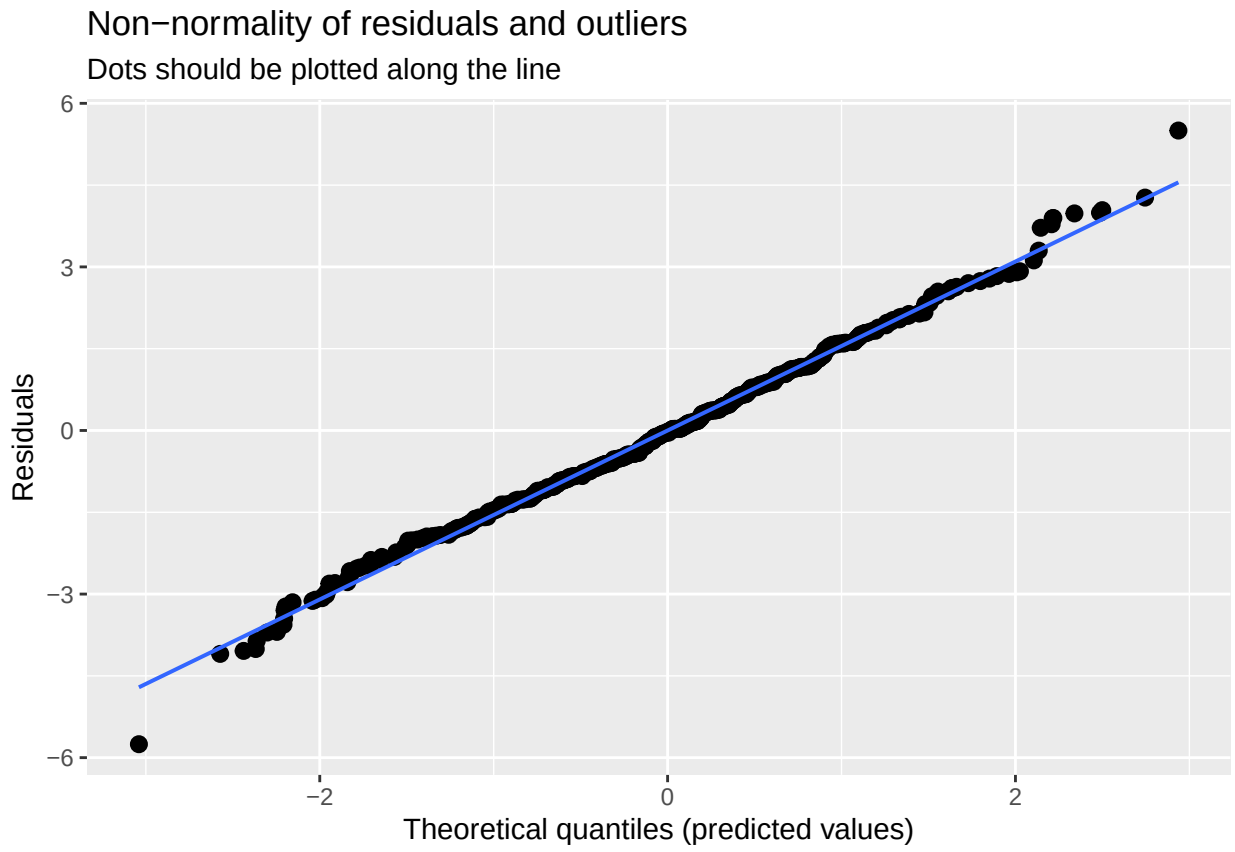
```
vif(fullmod)
```

```
## ASS_30m_500s_diff   possession_zero             OQ_gd
##          1.913411          2.227189          1.369123
```

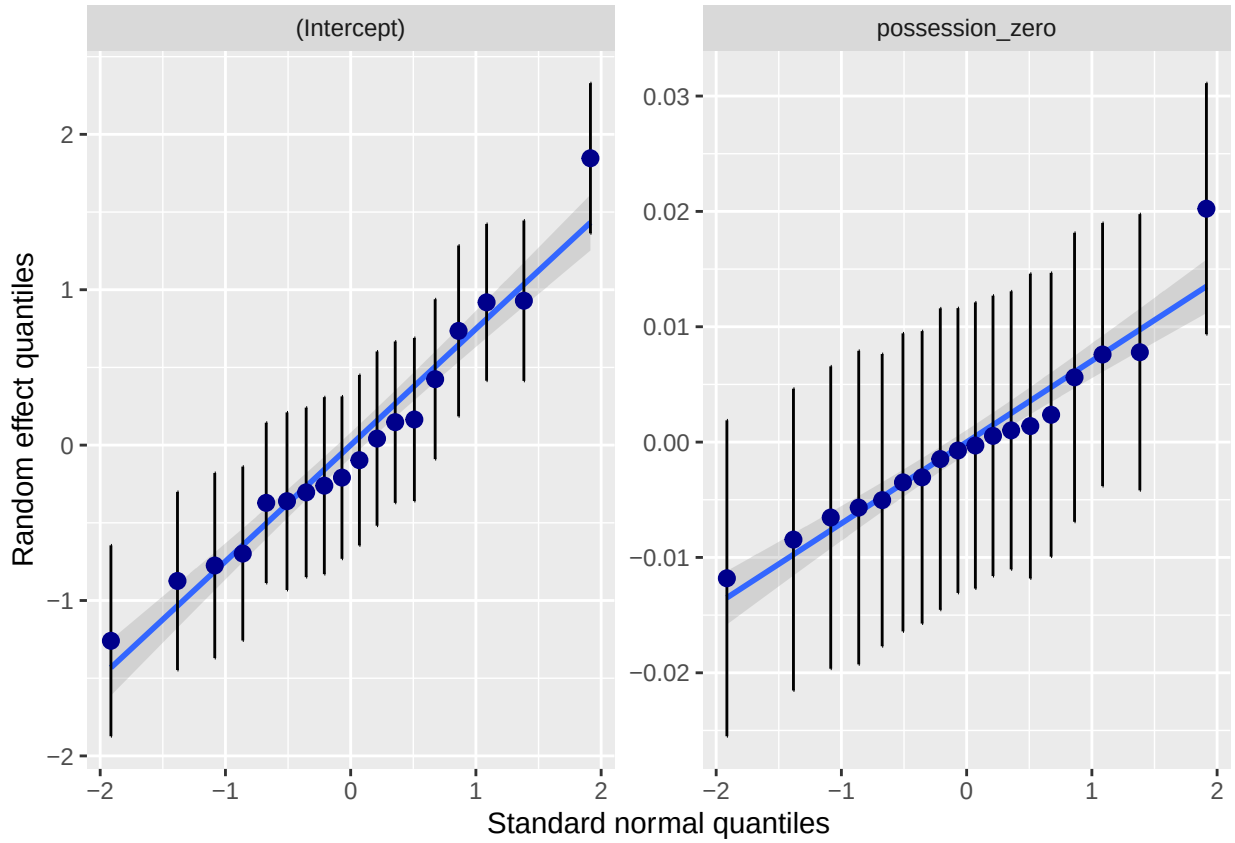
```
sjPlot::plot_model(fullmod, type = 'diag')
```

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

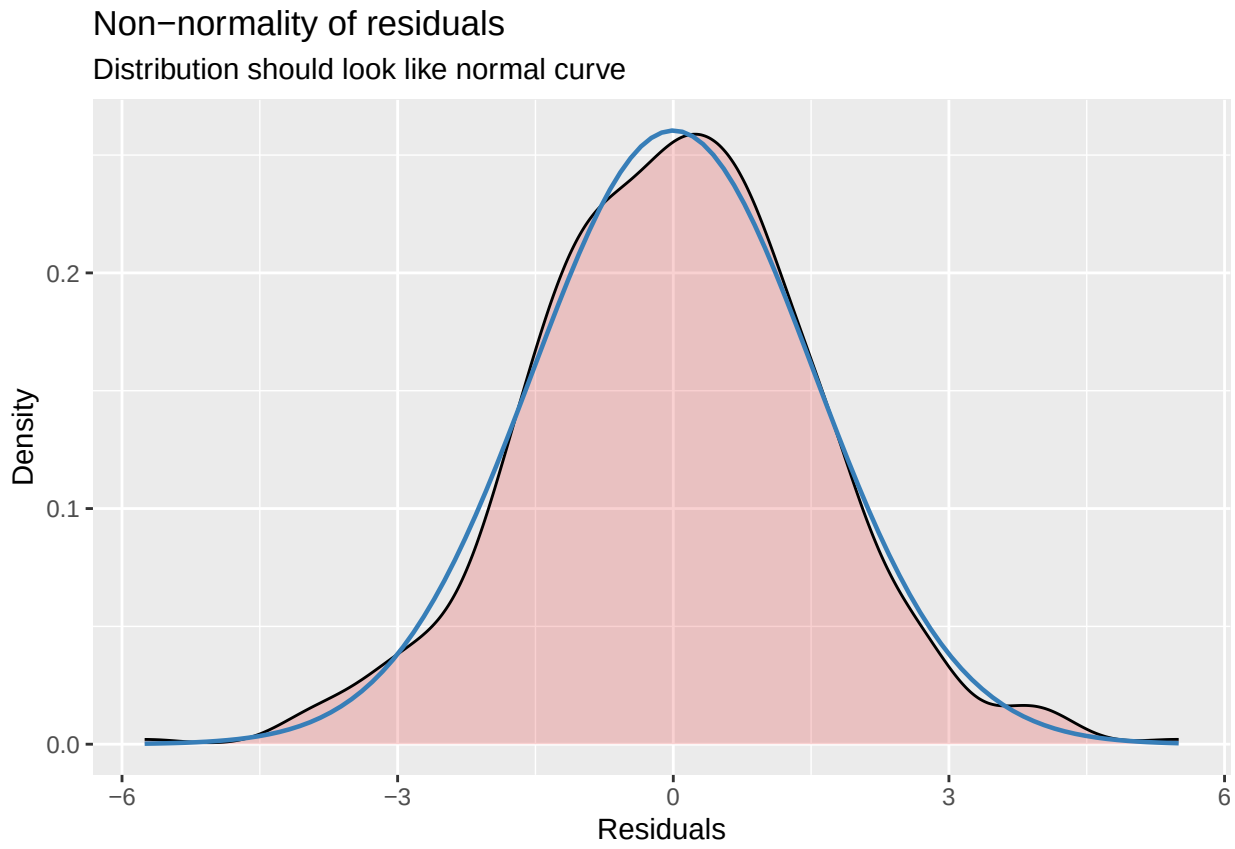
```
## `geom_smooth()` using formula = 'y ~ x'
```



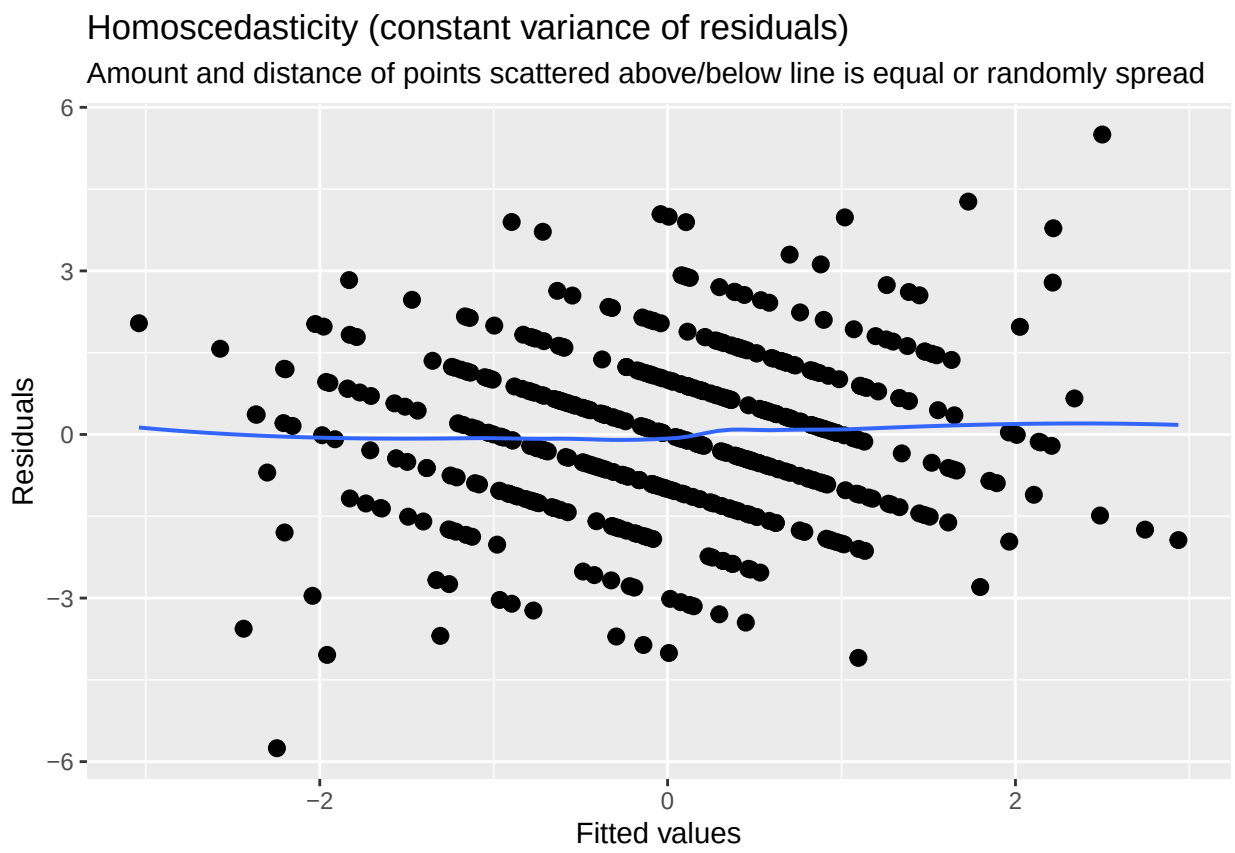

```
##
## [[2]]
## [[2]]$Team

## `geom_smooth()` using formula = 'y ~ x'
```


(Intercept)
possession_zero
Random effect quantiles
Standard normal quantiles
2
1
0
−1
−2
0.03
0.02
0.01
0.00
−0.01
−0.02

```
##
##
## [[3]]
```




```
##
## [[4]]

## `geom_smooth()` using formula = 'y ~ x'
```



Inference

```
summary(fullmod)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (1 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1938.2   1972.0   -961.1   1922.2      498
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6964 -0.6565  0.0201  0.6349  3.5339
##
## Random effects:
##  Groups   Name            Variance  Std.Dev. Corr
##  Team     (Intercept)     6.114e-01 0.781893
##           possession_zero 9.042e-05 0.009509 0.77
##  Residual                 2.423e+00 1.556543
## Number of obs: 506, groups:  Team, 18
```

```
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.045745   0.197222  14.690888  -0.232    0.820
## ASS_30m_500s_diff   0.039624   0.015715 496.096588   2.521    0.012 *
## possession_zero    -0.054920   0.010528  55.421687  -5.216 2.81e-06 ***
## OQ_gd              -0.035719   0.003369 492.166006 -10.603  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_30 pssss_
## ASS_30_500_ -0.001
## possessn_zr  0.164 -0.622
## OQ_gd        0.002  0.044  0.378
## optimizer (nloptwrap) convergence code: 0 (OK)
## Model failed to converge with max|grad| = 0.036353 (tol = 0.002, component 1)
```

```
PS<- lmer(Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (1|Team), data = df,  REML = FALSE
summary(PS)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (1 |
##     Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1935.3   1960.7   -961.7   1923.3      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6211 -0.6631  0.0031  0.6218  3.6116
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Team     (Intercept) 0.7161   0.8462
##  Residual             2.4202   1.5557
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.000932   0.211158  16.115338  -0.004  0.99653
## ASS_30m_500s_diff   0.041619   0.015686 501.697314   2.653  0.00822 **
## possession_zero    -0.056643   0.010293 504.867103  -5.503 5.94e-08 ***
## OQ_gd              -0.035754   0.003370 499.482309 -10.611  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_30 pssss_
## ASS_30_500_ -0.002
## possessn_zr -0.001 -0.632
## OQ_gd       -0.005  0.045  0.389
```

```r
anova(PS, fullmod)
```

```
## Data: df
## Models:
## PS: Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (1 | Team)
## fullmod: Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## PS         6 1935.3 1960.7 -961.66   1923.3
## fullmod    8 1938.2 1972.0 -961.11   1922.2 1.0996  2     0.5771
```

```r
RI<- lmer(Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (0+possession_zero|Team), data = d
summary(RI)
```

```
## Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's
##   method [lmerModLmerTest]
## Formula: Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (0 +
##     possession_zero | Team)
##    Data: df
##
##      AIC      BIC   logLik deviance df.resid
##   1969.4   1994.8   -978.7   1957.4      500
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5877 -0.7010  0.0254  0.6071  3.3502
##
## Random effects:
##  Groups   Name            Variance Std.Dev.
##  Team     possession_zero 0.001033 0.03214
##  Residual                 2.710792 1.64645
## Number of obs: 506, groups:  Team, 18
##
## Fixed effects:
##                     Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)        -0.084542   0.080208 460.363513  -1.054   0.2924
## ASS_30m_500s_diff   0.027325   0.015782 504.848041   1.731   0.0840 .
## possession_zero    -0.022729   0.012301  56.264835  -1.848   0.0699 .
## OQ_gd              -0.031242   0.003467 502.292366  -9.010   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) ASS_30 pssss_
## ASS_30_500_  0.042
## possessn_zr  0.008 -0.524
## OQ_gd        0.015  0.053  0.266
```

```r
anova(RI, fullmod)
```

```
## Data: df
## Models:
## RI: Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (0 + possession_zero | Team)
```

```
## fullmod: Outcome_num ~ ASS_30m_500s_diff + possession_zero + OQ_gd + (1 + possession_zero | Team)
##         npar    AIC    BIC  logLik deviance Chisq Df Pr(>Chisq)
## RI         6 1969.4 1994.8 -978.70   1957.4
## fullmod    8 1938.2 1972.0 -961.11   1922.2 35.18  2  2.295e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
coef(RI)
```

```
## $Team
##                           (Intercept) ASS_30m_500s_diff possession_zero
## 1. FC Köln                -0.08454235        0.02732476    -0.030226640
## 1. FSV Mainz 05           -0.08454235        0.02732476    -0.032539834
## Bayer 04 Leverkusen       -0.08454235        0.02732476    -0.034447598
## Borussia Dortmund         -0.08454235        0.02732476    -0.009523313
## Borussia Mönchengladbach -0.08454235        0.02732476    -0.044033204
## Eintracht Frankfurt       -0.08454235        0.02732476    -0.018662420
## FC Augsburg               -0.08454235        0.02732476    -0.004618681
## FC Bayern München         -0.08454235        0.02732476     0.062516937
## FC Ingolstadt 04          -0.08454235        0.02732476    -0.021900217
## FC Schalke 04             -0.08454235        0.02732476    -0.047103172
## Hamburger SV              -0.08454235        0.02732476    -0.018328953
## Hertha BSC                -0.08454235        0.02732476    -0.035706818
## RB Leipzig                -0.08454235        0.02732476    -0.042110670
## Sport-Club Freiburg       -0.08454235        0.02732476    -0.048725750
## SV Darmstadt 98           -0.08454235        0.02732476    -0.006103570
## SV Werder Bremen          -0.08454235        0.02732476    -0.041538865
## TSG 1899 Hoffenheim       -0.08454235        0.02732476    -0.014865879
## VfL Wolfsburg             -0.08454235        0.02732476    -0.021198310
##                                 OQ_gd
## 1. FC Köln                -0.03124178
## 1. FSV Mainz 05           -0.03124178
## Bayer 04 Leverkusen       -0.03124178
## Borussia Dortmund         -0.03124178
## Borussia Mönchengladbach -0.03124178
## Eintracht Frankfurt       -0.03124178
## FC Augsburg               -0.03124178
## FC Bayern München         -0.03124178
## FC Ingolstadt 04          -0.03124178
## FC Schalke 04             -0.03124178
## Hamburger SV              -0.03124178
## Hertha BSC                -0.03124178
## RB Leipzig                -0.03124178
## Sport-Club Freiburg       -0.03124178
## SV Darmstadt 98           -0.03124178
## SV Werder Bremen          -0.03124178
## TSG 1899 Hoffenheim       -0.03124178
## VfL Wolfsburg             -0.03124178
##
## attr(,"class")
## [1] "coef.mer"
```

```r
coef(PS)
```

```
## $Team
##                           (Intercept) ASS_30m_500s_diff possession_zero
## 1. FC Köln                -0.03285935         0.0416195     -0.05664297
## 1. FSV Mainz 05           -0.40203396         0.0416195     -0.05664297
## Bayer 04 Leverkusen        0.12535912         0.0416195     -0.05664297
## Borussia Dortmund          0.99899947         0.0416195     -0.05664297
## Borussia Mönchengladbach   0.15611119         0.0416195     -0.05664297
## Eintracht Frankfurt       -0.35692503         0.0416195     -0.05664297
## FC Augsburg               -0.81848187         0.0416195     -0.05664297
## FC Bayern München          2.14150028         0.0416195     -0.05664297
## FC Ingolstadt 04          -0.90770188         0.0416195     -0.05664297
## FC Schalke 04              0.42986918         0.0416195     -0.05664297
## Hamburger SV              -0.73220398         0.0416195     -0.05664297
## Hertha BSC                -0.34213681         0.0416195     -0.05664297
## RB Leipzig                 0.74714844         0.0416195     -0.05664297
## Sport-Club Freiburg       -0.37300519         0.0416195     -0.05664297
## SV Darmstadt 98           -1.22679531         0.0416195     -0.05664297
## SV Werder Bremen          -0.12564273         0.0416195     -0.05664297
## TSG 1899 Hoffenheim        0.97928834         0.0416195     -0.05664297
## VfL Wolfsburg             -0.27726534         0.0416195     -0.05664297
##                                 OQ_gd
## 1. FC Köln                -0.03575353
## 1. FSV Mainz 05           -0.03575353
## Bayer 04 Leverkusen       -0.03575353
## Borussia Dortmund         -0.03575353
## Borussia Mönchengladbach  -0.03575353
## Eintracht Frankfurt       -0.03575353
## FC Augsburg               -0.03575353
## FC Bayern München         -0.03575353
## FC Ingolstadt 04          -0.03575353
## FC Schalke 04             -0.03575353
## Hamburger SV              -0.03575353
## Hertha BSC                -0.03575353
## RB Leipzig                -0.03575353
## Sport-Club Freiburg       -0.03575353
## SV Darmstadt 98           -0.03575353
## SV Werder Bremen          -0.03575353
## TSG 1899 Hoffenheim       -0.03575353
## VfL Wolfsburg             -0.03575353
##
## attr(,"class")
## [1] "coef.mer"
```