SDS 358 Group5 RP#3

I. Group Member

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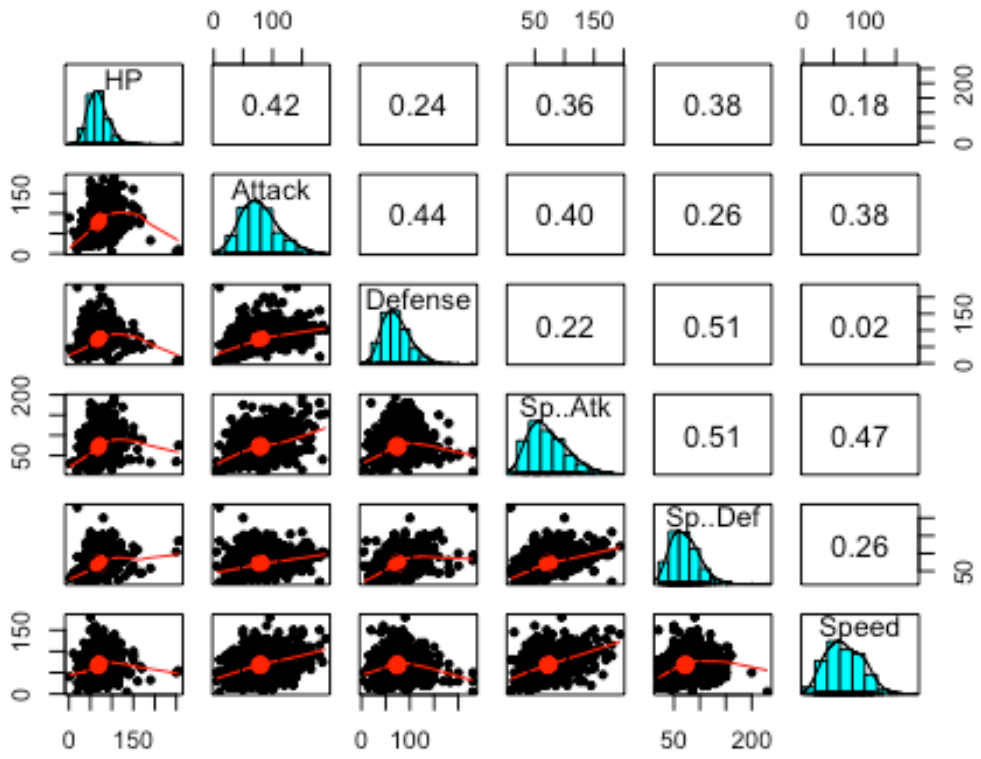
II. Loading Data

We only keep the data of five predictors and the response we need.

Correlation Matrix Plot

```
pairs.panels(data, method = "pearson")
```



Interaction Analysis

```
# Calculate the interaction term:
data <- data %>%
  mutate(def.spdf = Defense*Sp..Def)
```

```r
# Fit the regression model with 2 predictors and the interaction effect
reg2 <- lm(HP~Attack+Defense+Sp..Atk+Sp..Def+Speed + def.spdf, data)
# Display the summary table for the regression model
summary(reg2)
```

```
##
## Call:
## lm(formula = HP ~ Attack + Defense + Sp..Atk + Sp..Def + Speed +
##     def.spdf, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -55.941 -12.305  -3.212   7.876 176.944
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 10.7982541  4.3522909   2.481 0.013306 *
## Attack       0.2764647  0.0294542   9.386  < 2e-16 ***
## Defense      0.2187298  0.0585761   3.734 0.000202 ***
## Sp..Atk      0.0817300  0.0304205   2.687 0.007368 **
## Sp..Def      0.6102262  0.0668753   9.125  < 2e-16 ***
## Speed       -0.1021945  0.0314174  -3.253 0.001191 **
## def.spdf    -0.0038912  0.0006321  -6.156 1.19e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.31 on 793 degrees of freedom
## Multiple R-squared:  0.3088, Adjusted R-squared:  0.3035
## F-statistic: 59.04 on 6 and 793 DF,  p-value: < 2.2e-16
```

```r
# Calculate the interaction term:
data <- data %>%
  mutate(spat.spdf = Sp..Atk*Sp..Def)
# Fit the regression model with 2 predictors and the interaction effect
reg3 <- lm(HP~Attack+Defense+Sp..Atk+Sp..Def+Speed + spat.spdf, data)
# Display the summary table for the regression model
summary(reg3)
```

```
##
## Call:
## lm(formula = HP ~ Attack + Defense + Sp..Atk + Sp..Def + Speed +
##     spat.spdf, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -61.837 -12.263  -2.847   8.237 189.587
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 28.7018963  4.6641158   6.154 1.20e-09 ***
```

```
## Attack       0.2962777  0.0299643   9.888  < 2e-16 ***
## Defense     -0.0866873  0.0327698  -2.645  0.00832 **
## Sp..Atk      0.1570769  0.0697717   2.251  0.02464 *
## Sp..Def      0.3058496  0.0665541   4.596 5.02e-06 ***
## Speed       -0.0967130  0.0322776  -2.996  0.00282 **
## spat.spdf   -0.0005749  0.0007663  -0.750  0.45333
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.81 on 793 degrees of freedom
## Multiple R-squared:  0.2763, Adjusted R-squared:  0.2708
## F-statistic: 50.45 on 6 and 793 DF,  p-value: < 2.2e-16
```

```
# Calculate the interaction term:
data <- data %>%
  mutate(atk.df = Attack*Defense)
# Fit the regression model with 2 predictors and the interaction effect
reg4 <- lm(HP~Attack+Defense+Sp..Atk+Sp..Def+Speed + atk.df, data)
# Display the summary table for the regression model
summary(reg4)
```

```
##
## Call:
## lm(formula = HP ~ Attack + Defense + Sp..Atk + Sp..Def + Speed +
##     atk.df, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -61.560 -12.584  -2.988   8.564 178.113
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 44.0424026  4.5324101   9.717  < 2e-16 ***
## Attack       0.1128202  0.0598085   1.886 0.059612 .
## Defense     -0.2764196  0.0633693  -4.362 1.46e-05 ***
## Sp..Atk      0.1110967  0.0305416   3.638 0.000293 ***
## Sp..Def      0.2781959  0.0370529   7.508 1.62e-13 ***
## Speed       -0.0898969  0.0319077  -2.817 0.004962 **
## atk.df       0.0023514  0.0006659   3.531 0.000438 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.64 on 793 degrees of freedom
## Multiple R-squared:  0.287,  Adjusted R-squared:  0.2816
## F-statistic: 53.19 on 6 and 793 DF,  p-value: < 2.2e-16
```

```
# Calculate the interaction term:
data <- data %>%
  mutate(spat.speed = Sp..Atk*Speed)
# Fit the regression model with 2 predictors and the interaction effect
```

```
reg5 <- lm(HP~Attack+Defense+Sp..Atk+Sp..Def+Speed + spat.speed, data)
# Display the summary table for the regression model
summary(reg5)
```

```
##
## Call:
## lm(formula = HP ~ Attack + Defense + Sp..Atk + Sp..Def + Speed +
##     spat.speed, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -59.497 -12.175  -2.768   7.901 191.643
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 25.5282930  4.6140764   5.533 4.29e-08 ***
## Attack       0.2940241  0.0299486   9.818  < 2e-16 ***
## Defense     -0.0826107  0.0325360  -2.539  0.01131 *
## Sp..Atk      0.2058801  0.0662220   3.109  0.00194 **
## Sp..Def      0.2563528  0.0373995   6.854 1.44e-11 ***
## Speed       -0.0053298  0.0632473  -0.084  0.93286
## spat.speed  -0.0011913  0.0007296  -1.633  0.10290
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.78 on 793 degrees of freedom
## Multiple R-squared:  0.2782, Adjusted R-squared:  0.2727
## F-statistic: 50.93 on 6 and 793 DF,  p-value: < 2.2e-16
```

The significant interactions are Attack*Defense and Defense*SpecialAttack.

Model Selection

```
#stepwise regression forward selection
data <- data %>%
mutate(atk.df = Attack*Defense, def.spdf = Defense*Sp..Def)
FitStart <-lm(HP ~1, data)
FitAll <- lm(HP~Attack+Defense+Sp..Atk+Sp..Def+Speed + def.spdf +atk.df,
 data)
step(FitStart,direction="forward", scope =formula(FitAll))
```

```
## Start:  AIC=5185.06
## HP ~ 1
##
##             Df Sum of Sq    RSS    AIC
## + Attack     1     92945 428018 5029.8
## + atk.df     1     81017 439947 5051.8
## + Sp..Def    1     74720 446243 5063.2
## + Sp..Atk    1     68412 452551 5074.4
## + def.spdf   1     36915 484049 5128.3
## + Defense    1     29913 491050 5139.8
```

```
## + Speed     1     16129 504835 5161.9
## <none>                  520963 5185.1
##
## Step:  AIC=5029.85
## HP ~ Attack
##
##            Df Sum of Sq    RSS    AIC
## + Sp..Def   1     39985 388034 4953.4
## + Sp..Atk   1     23493 404526 4986.7
## + def.spdf  1      9023 418996 5014.8
## + atk.df    1      3746 424272 5024.8
## + Defense   1      1904 426114 5028.3
## <none>                  428018 5029.8
## + Speed     1       136 427883 5031.6
##
## Step:  AIC=4953.39
## HP ~ Attack + Sp..Def
##
##            Df Sum of Sq    RSS    AIC
## + def.spdf  1   13639.9 374394 4926.8
## + Sp..Atk   1    4934.8 383099 4945.1
## + Defense   1    2844.7 385189 4949.5
## <none>                  388034 4953.4
## + Speed     1     589.4 387444 4954.2
## + atk.df    1      76.3 387957 4955.2
##
## Step:  AIC=4926.76
## HP ~ Attack + Sp..Def + def.spdf
##
##           Df Sum of Sq    RSS    AIC
## + atk.df   1   10923.4 363470 4905.1
## + Defense  1    7997.2 366397 4911.5
## + Speed    1    3904.9 370489 4920.4
## + Sp..Atk  1    1843.9 372550 4924.8
## <none>                 374394 4926.8
##
## Step:  AIC=4905.07
## HP ~ Attack + Sp..Def + def.spdf + atk.df
##
##           Df Sum of Sq    RSS    AIC
## + Speed    1   2696.59 360774 4901.1
## + Sp..Atk  1   1823.00 361647 4903.1
## <none>                 363470 4905.1
## + Defense  1    364.44 363106 4906.3
##
## Step:  AIC=4901.12
## HP ~ Attack + Sp..Def + def.spdf + atk.df + Speed
##
##           Df Sum of Sq    RSS    AIC
## + Sp..Atk  1    3643.4 357130 4895.0
```

```
## <none>                 360774 4901.1
## + Defense  1     332.2 360442 4902.4
##
## Step:  AIC=4895
## HP ~ Attack + Sp..Def + def.spdf + atk.df + Speed + Sp..Atk
##
##           Df Sum of Sq    RSS    AIC
## <none>                 357130 4895.0
## + Defense  1    183.74 356947 4896.6

##
## Call:
## lm(formula = HP ~ Attack + Sp..Def + def.spdf + atk.df + Speed +
##     Sp..Atk, data = data)
##
## Coefficients:
## (Intercept)       Attack      Sp..Def     def.spdf       atk.df
   Speed
##   24.893443     0.121892     0.577826    -0.003343     0.002059    -
0.099120
##     Sp..Atk
##    0.085953

#stepwise regression backward selection
step(FitAll,direction="backward", scope =formula(FitStart))

## Start:  AIC=4896.58
## HP ~ Attack + Defense + Sp..Atk + Sp..Def + Speed + def.spdf +
##     atk.df
##
##            Df Sum of Sq    RSS    AIC
## - Defense   1       184 357130 4895.0
## <none>                  356947 4896.6
## - Attack    1      2597 359544 4900.4
## - atk.df    1      3157 360104 4901.6
## - Sp..Atk   1      3495 360442 4902.4
## - Speed     1      4440 361387 4904.5
## - def.spdf  1     14523 371470 4926.5
## - Sp..Def   1     35914 392861 4971.3
##
## Step:  AIC=4895
## HP ~ Attack + Sp..Atk + Sp..Def + Speed + def.spdf + atk.df
##
##            Df Sum of Sq    RSS    AIC
## <none>                  357130 4895.0
## - Attack    1      2638 359769 4898.9
## - Sp..Atk   1      3643 360774 4901.1
## - Speed     1      4517 361647 4903.1
## - atk.df    1      9306 366436 4913.6
```

```
## - def.spdf  1     23253 380383 4943.5
## - Sp..Def   1     41709 398840 4981.4

##
## Call:
## lm(formula = HP ~ Attack + Sp..Atk + Sp..Def + Speed + def.spdf +
##     atk.df, data = data)
##
## Coefficients:
## (Intercept)       Attack      Sp..Atk      Sp..Def        Speed
def.spdf
##   24.893443     0.121892     0.085953     0.577826    -0.099120    -
0.003343
##      atk.df
##    0.002059
```

The results indicate that we should include all predictors expcept the Defense in the model. However, by the hierarchy principle, since we include the interaction term Defense*Attack, we have to include the Defense in our model.

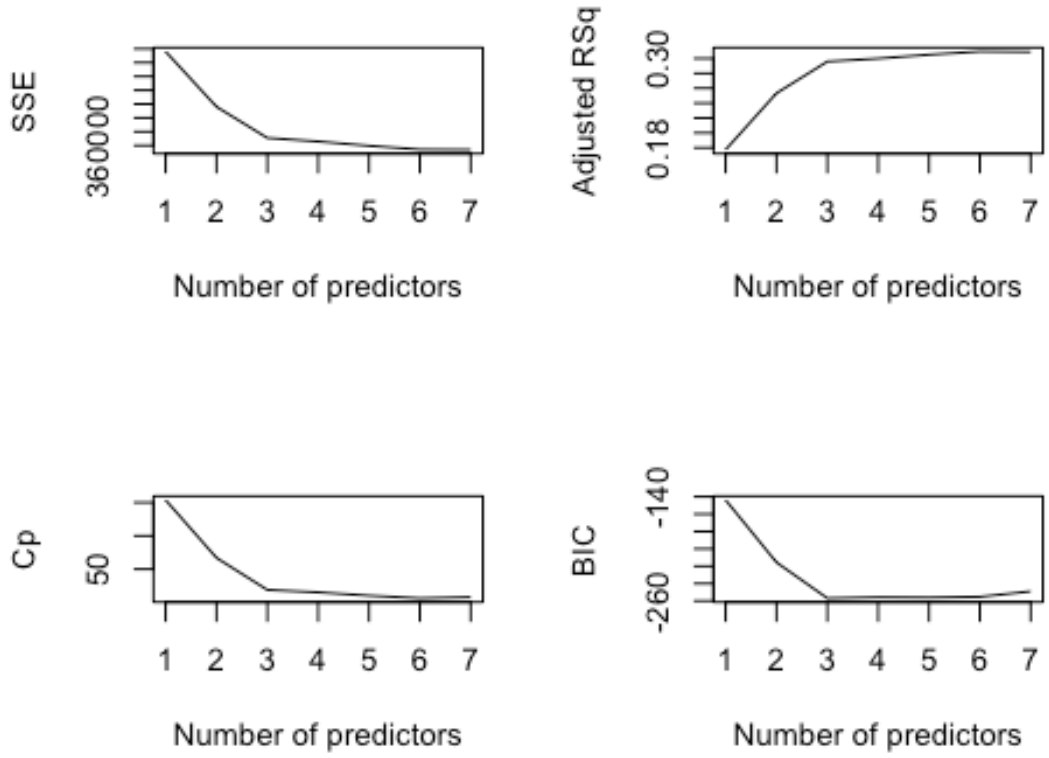
```
#best subset regression
models <- regsubsets(HP~Attack+Defense+Sp..Atk+Sp..Def+Speed + def.spdf
 +atk.df, data, nvmax =7)
summary(models)

## Subset selection object
## Call: regsubsets.formula(HP ~ Attack + Defense + Sp..Atk + Sp..Def +

##     Speed + def.spdf + atk.df, data, nvmax = 7)
## 7 Variables  (and intercept)
##          Forced in Forced out
## Attack       FALSE      FALSE
## Defense      FALSE      FALSE
## Sp..Atk      FALSE      FALSE
## Sp..Def      FALSE      FALSE
## Speed        FALSE      FALSE
## def.spdf     FALSE      FALSE
## atk.df       FALSE      FALSE
## 1 subsets of each size up to 7
## Selection Algorithm: exhaustive
##          Attack Defense Sp..Atk Sp..Def Speed def.spdf atk.df
## 1  ( 1 ) "*"    " "     " "     " "     " "   " "      " "
## 2  ( 1 ) "*"    " "     " "     "*"     " "   " "      " "
## 3  ( 1 ) " "    " "     " "     "*"     " "   "*"      "*"
## 4  ( 1 ) " "    " "     "*"     "*"     " "   "*"      "*"
## 5  ( 1 ) " "    " "     "*"     "*"     "*"   "*"      "*"
## 6  ( 1 ) "*"    " "     "*"     "*"     "*"   "*"      "*"
## 7  ( 1 ) "*"    "*"     "*"     "*"     "*"   "*"      "*"

models.sum <-summary(models)
par(mfrow =c(2,2))
```

```
# SSE
plot(models.sum$rss, xlab ="Number of predictors", ylab ="SSE", type ="
l")
# R2
plot(models.sum$adjr2, xlab ="Number of predictors", ylab ="Adjusted RS
q", type ="l")
# Mallow's Cp
plot(models.sum$cp, xlab ="Number of predictors", ylab ="Cp", type ="l")
# BIC
plot(models.sum$bic, xlab ="Number of predictors", ylab ="BIC", type ="
l")
```



The best subset selection method indicates that we shall use the model with seven predictors since the model has highest Adjusted R^2 and lowest SSE and C_p, although the BIC of the model is a little bit higher.

Diagnostic

```
reg <- lm(HP~ Attack+Defense+Sp..Atk+Sp..Def+Speed+def.spdf+atk.df, dat
a)
summary(reg)

##
## Call:
```

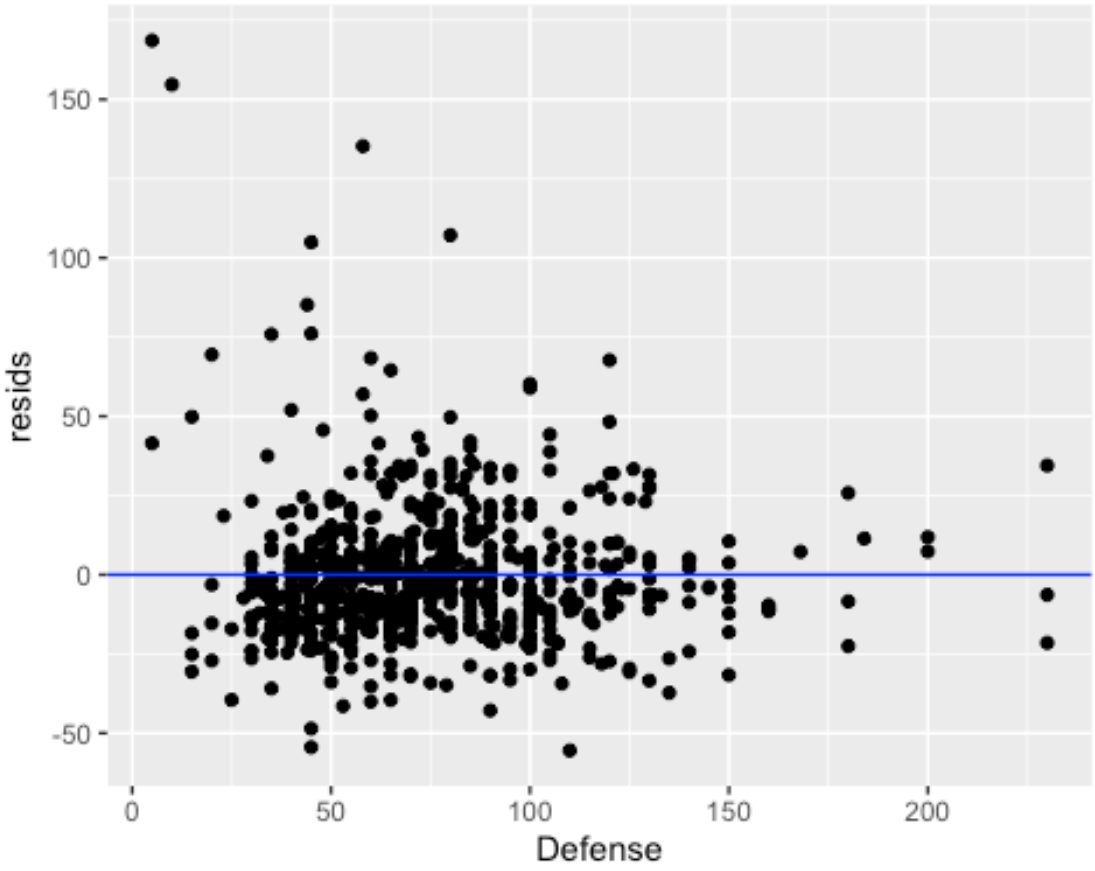
```
## lm(formula = HP ~ Attack + Defense + Sp..Atk + Sp..Def + Speed +
##     def.spdf + atk.df, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -55.501 -12.449  -3.104   8.226 168.619
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 21.5865299  5.9508702   3.627 0.000305 ***
## Attack       0.1413511  0.0588795   2.401 0.016594 *
## Defense      0.0544028  0.0852043   0.638 0.523334
## Sp..Atk      0.0844415  0.0303233   2.785 0.005485 **
## Sp..Def      0.5965252  0.0668242   8.927  < 2e-16 ***
## Speed       -0.0983456  0.0313329  -3.139 0.001760 **
## def.spdf    -0.0036215  0.0006380  -5.677 1.93e-08 ***
## atk.df       0.0017514  0.0006617   2.647 0.008286 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.23 on 792 degrees of freedom
## Multiple R-squared:  0.3148, Adjusted R-squared:  0.3088
## F-statistic: 51.99 on 7 and 792 DF,  p-value: < 2.2e-16
```

We decide to choose the model $HP = 21.687 + 0.141Attack + 0.054Defense + 0.084SpecialAttack + 0.597SpecilDefense - 0.098Speed - 0.0036Defense * SpecialDefense + 0.002Attack * Defense$

Residual Plot

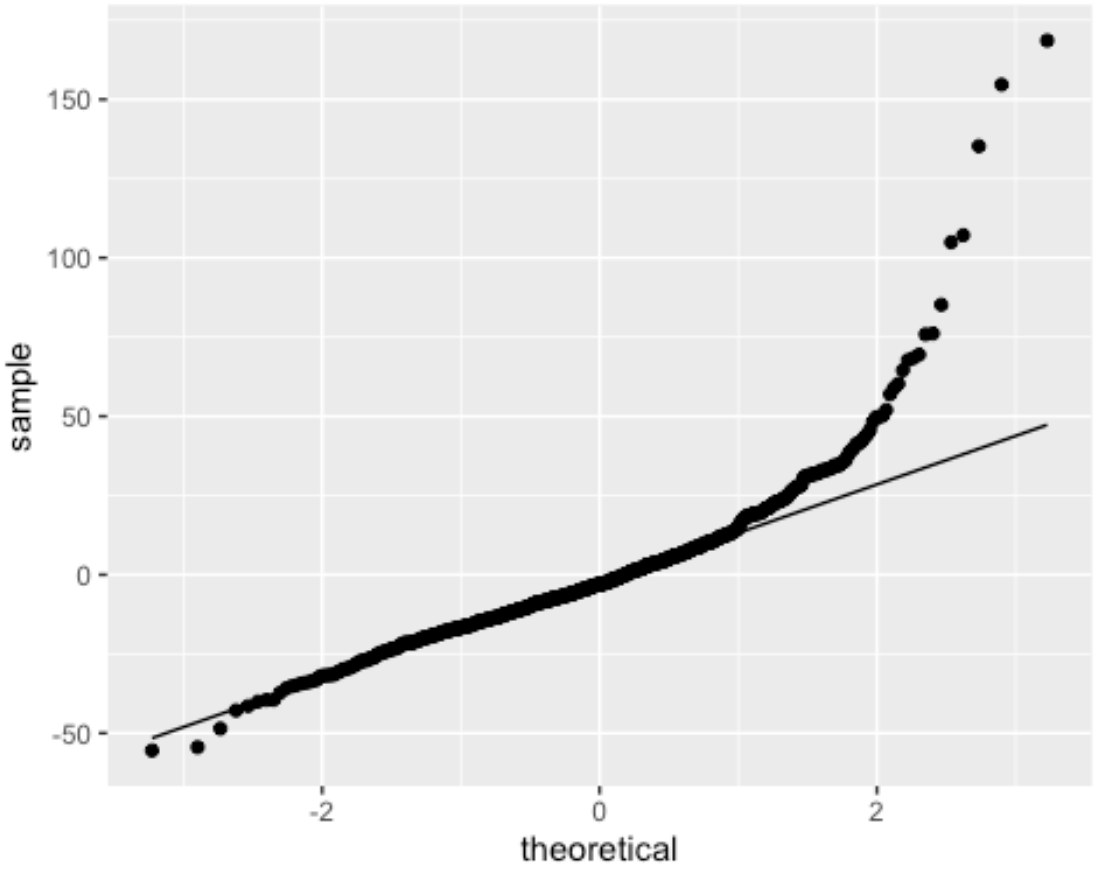
```
data$resids <- residuals(reg)
data$predicted <- predict(reg)

ggplot(data, aes(x=Defense, y=resids)) +
  geom_point() + geom_hline(color='blue', yintercept = 0)
```



The residual plot shows that the model does not violate the linearity condition. However the condition of equal variance is not met. Moreover, there are some outliers.

```
ggplot(data, aes(sample=resids)) +
  stat_qq() + stat_qq_line()
```



From the normal probability plot, we can see that the normal assumption of the normality of the errors seems to be approximately met except some outliers on the right tail. Therefore, we shall consider a log transformation on the response.

Log Transformation on Response

```
data <- data %>%
  mutate(lnHP = log(HP))

reg_ln_old <- lm(lnHP ~ Attack+Defense+Sp..Atk+Sp..Def+Speed+def.spdf+a
tk.df, data)
summary(reg_ln_old)
```

```
##
## Call:
## lm(formula = lnHP ~ Attack + Defense + Sp..Atk + Sp..Def + Speed +
##     def.spdf + atk.df, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.9457 -0.1561 -0.0027  0.1522  1.3330
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept)  3.238e+00  8.827e-02  36.679  < 2e-16 ***
## Attack       3.500e-03  8.734e-04   4.007 6.73e-05 ***
## Defense      3.734e-03  1.264e-03   2.954 0.003229 **
## Sp..Atk      1.605e-03  4.498e-04   3.569 0.000379 ***
## Sp..Def      9.049e-03  9.912e-04   9.129  < 2e-16 ***
## Speed       -1.081e-03  4.648e-04  -2.326 0.020294 *
## def.spdf    -6.367e-05  9.463e-06  -6.729 3.29e-11 ***
## atk.df       8.522e-06  9.815e-06   0.868 0.385497
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3149 on 792 degrees of freedom
## Multiple R-squared:  0.348,  Adjusted R-squared:  0.3423
## F-statistic:  60.4 on 7 and 792 DF,  p-value: < 2.2e-16
```

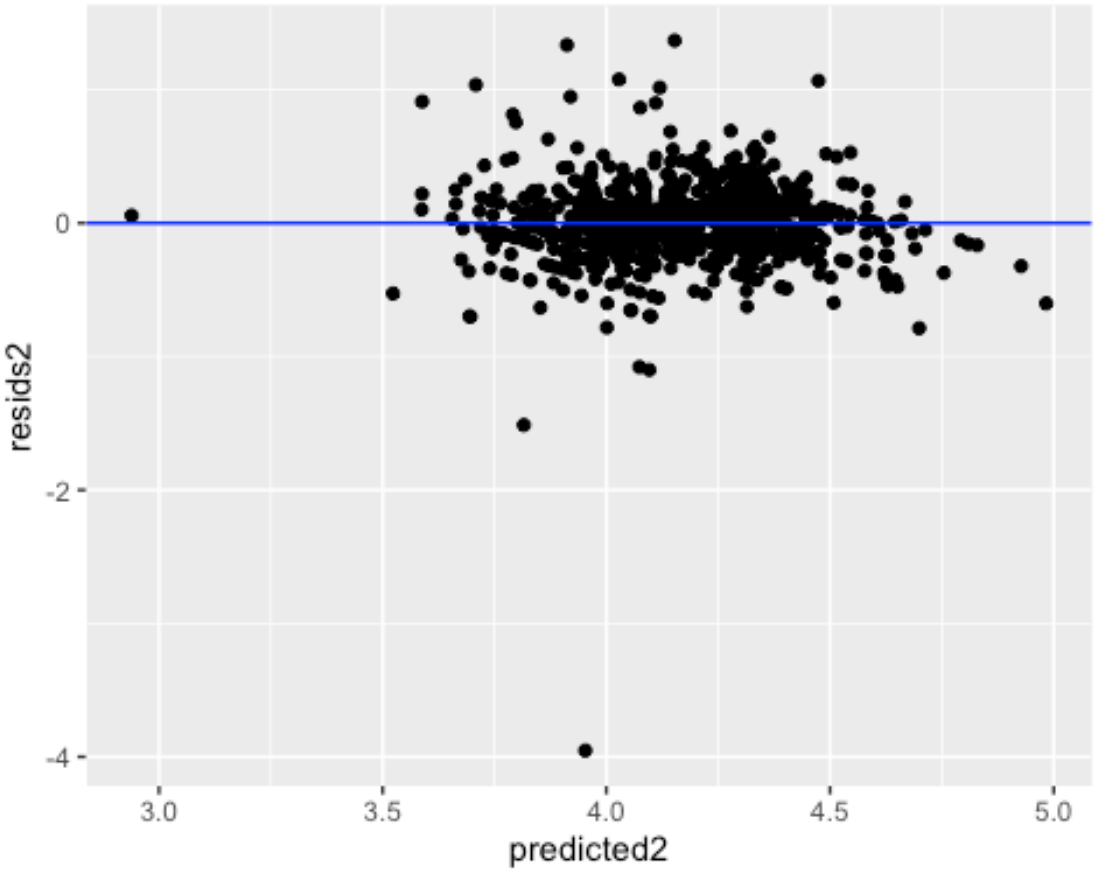
```
reg_ln <- lm(lnHP ~ Attack+Defense+Sp..Atk+Sp..Def+Speed+def.spdf, data)
summary(reg_ln)
```

```
##
## Call:
## lm(formula = lnHP ~ Attack + Defense + Sp..Atk + Sp..Def + Speed +
##     def.spdf, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.9529 -0.1550  0.0003  0.1488  1.3690
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  3.185e+00  6.431e-02  49.532  < 2e-16 ***
## Attack       4.157e-03  4.352e-04   9.552  < 2e-16 ***
## Defense      4.533e-03  8.655e-04   5.238 2.08e-07 ***
## Sp..Atk      1.592e-03  4.495e-04   3.543 0.000419 ***
## Sp..Def      9.116e-03  9.881e-04   9.225  < 2e-16 ***
## Speed       -1.100e-03  4.642e-04  -2.369 0.018086 *
## def.spdf    -6.499e-05  9.340e-06  -6.958 7.25e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3149 on 793 degrees of freedom
## Multiple R-squared:  0.3474, Adjusted R-squared:  0.3425
## F-statistic: 70.36 on 6 and 793 DF,  p-value: < 2.2e-16
```

```
data$resids2 <- residuals(reg_ln)
data$predicted2 <- predict(reg_ln)
```

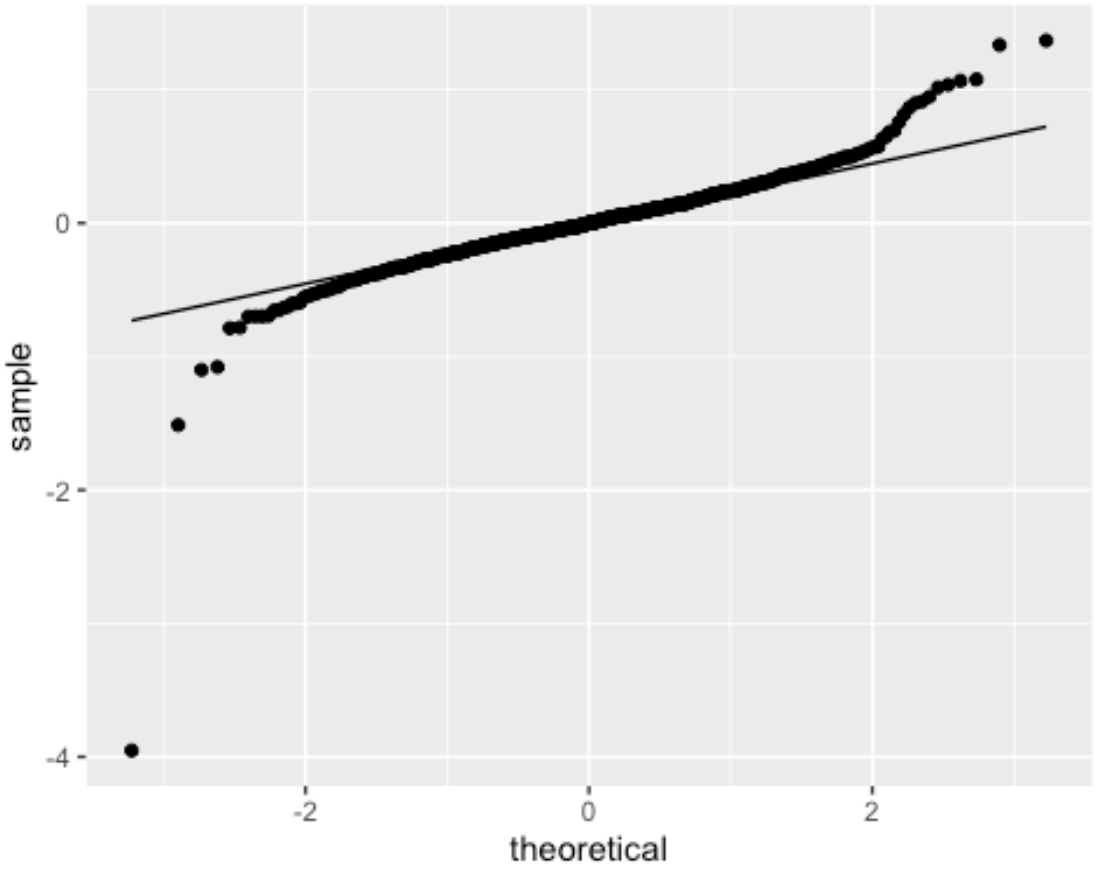
After the log transformation for y, the atk.df has p-value larger than 0.05, so we omitted it from the model and did diagnostic analysis.

```
ggplot(data, aes(x=predicted2, y=resids2)) +
  geom_point() + geom_hline(color='blue', yintercept = 0)
```



The residual plot indicates that the conditions of constant variance for error terms and linearity are met, except some outliers.

```
ggplot(data, aes(sample=resids2)) +
  stat_qq() + stat_qq_line()
```



The assumption of the normality of the errors seems to be approximately met and is better than the previous model.

Reference

[1]Barradas, A. (2016, August 29). Pokemon with stats. Retrieved October 13, 2020, from https://www.kaggle.com/abcsds/pokemon