

Health Insurance: Data Exploration & Linear Model

Rebecca Nguyen

The purpose of this final project is to explore the health insurance data set and predict insurance charges based on several determinants.

Healthcare should be easily accessible and affordable for all regardless of our medical history. It is a fundamental right that everyone should have. We see many countries offering free, universal healthcare, such as Mexico, Canada, and the UK. Yet, the US seems to lag behind even though we are a highly-developed country.

That being said, we all know about that rumor that US health insurance prices are based off of the presence of medical conditions, or drug use, to name a couple. But is it actually true? Are these health insurance companies deliberately jacking up prices and making money off of us for not being “healthy”? What significant factors greatly affect how much we are charged for health insurance? This is what I would like to explore through this data set.

Load appropriate packages/csv file

```
library(tidyverse)

## -- Attaching packages ----- tidyverse 1.3.1 --
## v ggplot2 3.3.5      v purrr   0.3.4
## v tibble  3.1.4      v dplyr   1.0.7
## v tidyr   1.1.3      v stringr 1.4.0
## v readr   2.0.1      v forcats 0.5.1

## -- Conflicts ----- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
insurance_df <- read_csv('insurance.csv')

## Rows: 1338 Columns: 7

## -- Column specification -----
## Delimiter: ","
## chr (3): sex, smoker, region
## dbl (4): age, bmi, children, charges

##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

Data Exploration

```
head(insurance_df)
```

```
## # A tibble: 6 x 7
##   age sex      bmi children smoker region    charges
##   <dbl> <chr> <dbl>    <dbl> <chr>  <chr>      <dbl>
## 1    19 female  27.9        0 yes   southwest 16885.
## 2    18 male   33.8        1 no    southeast 1726.
## 3    28 male   33          3 no    southeast 4449.
## 4    33 male   22.7        0 no    northwest 21984.
## 5    32 male   28.9        0 no    northwest 3867.
## 6    31 female 25.7        0 no    southeast 3757.

str(insurance_df)

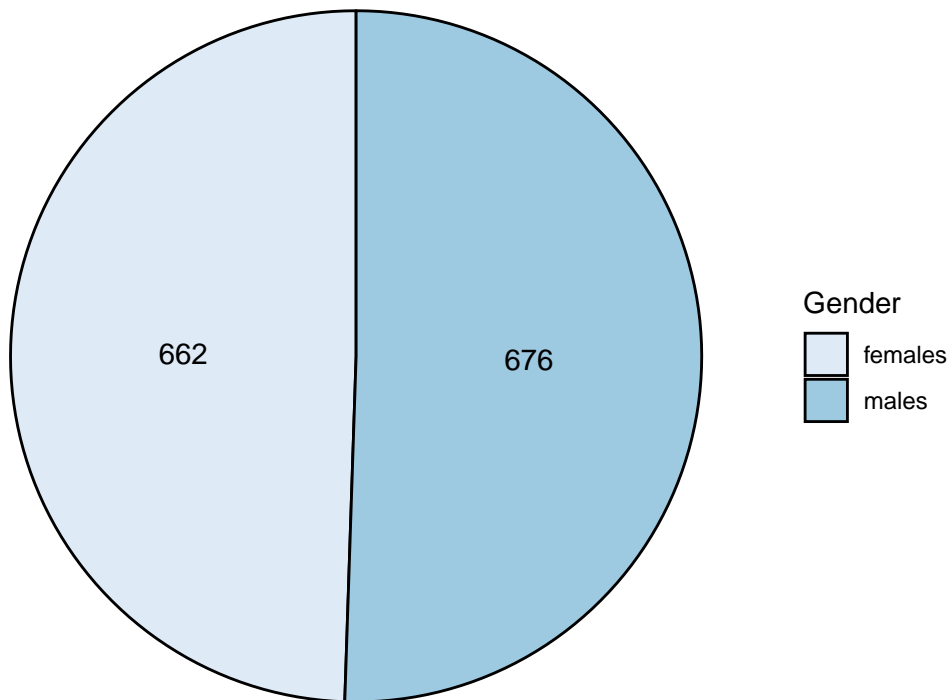
## spec_tbl_df [1,338 x 7] (S3: spec_tbl_df/tbl_df/tbl/data.frame)
##  $ age      : num [1:1338] 19 18 28 33 32 31 46 37 37 60 ...
##  $ sex      : chr [1:1338] "female" "male" "male" "male" ...
##  $ bmi      : num [1:1338] 27.9 33.8 33 22.7 28.9 ...
##  $ children: num [1:1338] 0 1 3 0 0 0 1 3 2 0 ...
##  $ smoker   : chr [1:1338] "yes" "no" "no" "no" ...
##  $ region   : chr [1:1338] "southwest" "southeast" "southeast" "northwest" ...
##  $ charges  : num [1:1338] 16885 1726 4449 21984 3867 ...
##  - attr(*, "spec")=
##    .. cols(
##    ..   age = col_double(),
##    ..   sex = col_character(),
##    ..   bmi = col_double(),
##    ..   children = col_double(),
##    ..   smoker = col_character(),
##    ..   region = col_character(),
##    ..   charges = col_double()
##    .. )
##  - attr(*, "problems")=<externalptr>

1338 observations
7 variables:
numerical: age, bmi, children, charges | character: sex, smoker, region

table(insurance_df$sex)

##
## female    male
##    662    676

gender_num <- data.frame(value = c(662, 676),
                          Gender = c("females", "males"))
ggplot(gender_num, aes(x = "", y = value, fill = Gender)) +
  geom_col(color = "black") +
  geom_text(aes(label = value),
            position = position_stack(vjust = 0.5)) +
  coord_polar(theta = "y") +
  scale_fill_brewer() +
  theme_void()
```



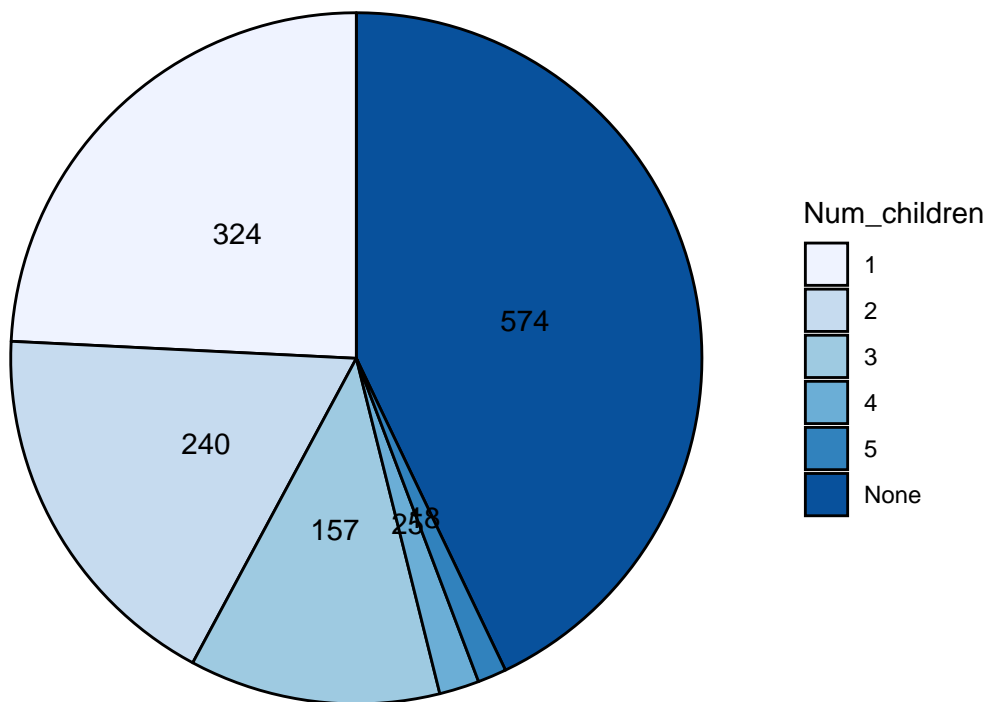
```
insurance_df %>%
  group_by(sex) %>%
  summarize(avg = mean(age, na.rm = TRUE), sd = sd(age, na.rm = TRUE))
```

```
## # A tibble: 2 x 3
##   sex      avg    sd
##   <chr> <dbl> <dbl>
## 1 female 39.5  14.1
## 2 male  38.9  14.1
```

```
table(insurance_df$children)
```

```
##
##  0  1  2  3  4  5
## 574 324 240 157 25 18
```

```
children_num <- data.frame(value = c(574, 324, 240, 157, 25, 18),
                           Num_children = c("None", 1, 2, 3, 4, 5))
ggplot(children_num, aes(x = "", y = value, fill = Num_children)) +
  geom_col(color = "black") +
  geom_text(aes(label = value),
            position = position_stack(vjust = 0.5)) +
  coord_polar(theta = "y") +
  scale_fill_brewer() +
  theme_void()
```



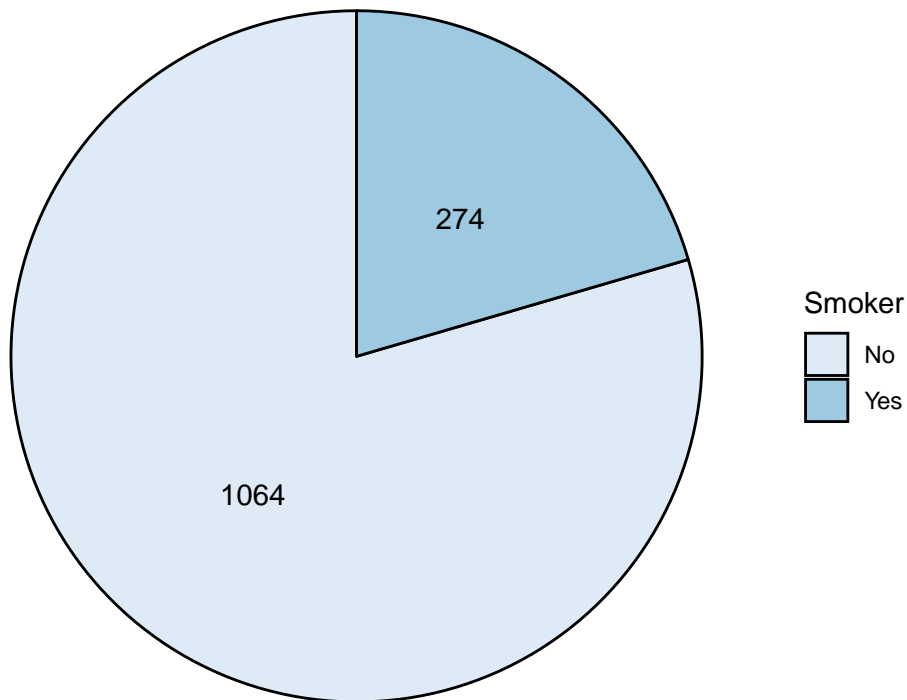
```
table(insurance_df$smoker)
```

```
##
```

```
## no yes
```

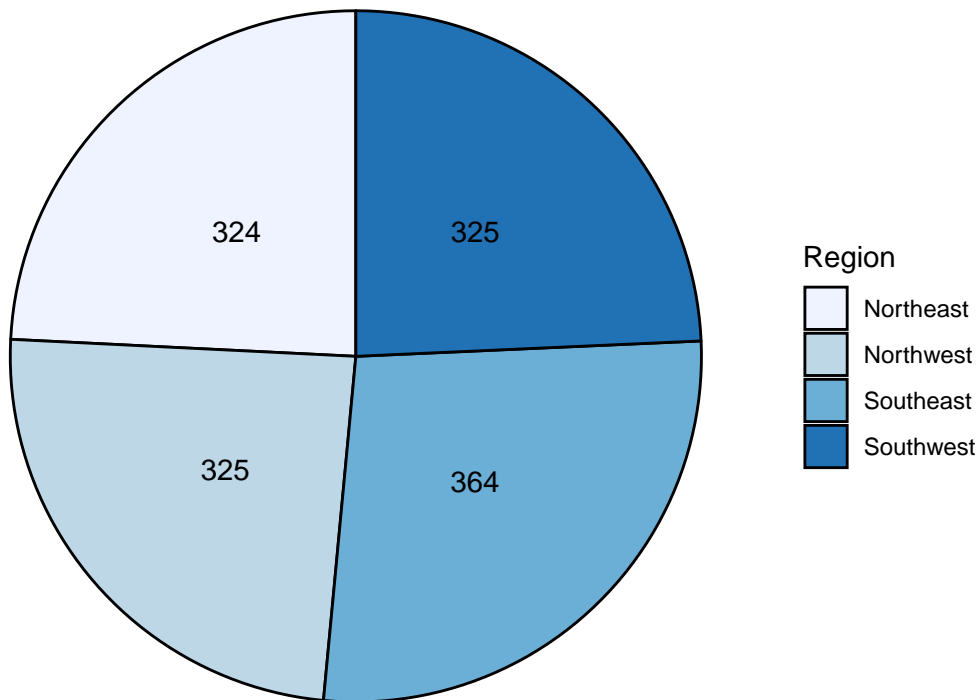
```
## 1064 274
```

```
smoke_num <- data.frame(value = c(1064, 274),
                        Smoker = c("No", "Yes"))
ggplot(smoke_num, aes(x = "", y = value, fill = Smoker)) +
  geom_col(color = "black") +
  geom_text(aes(label = value),
            position = position_stack(vjust = 0.5)) +
  coord_polar(theta = "y") +
  scale_fill_brewer() +
  theme_void()
```



```
table(insurance_df$region)
```

```
##
## northeast northwest southeast southwest
##      324      325      364      325
region_num <- data.frame(value = c(324, 325, 364, 325),
                          Region = c("Northeast", "Northwest", "Southeast",
                                     "Southwest"))
ggplot(region_num, aes(x = "", y = value, fill = Region)) +
  geom_col(color = "black") +
  geom_text(aes(label = value),
            position = position_stack(vjust = 0.5)) +
  coord_polar(theta = "y") +
  scale_fill_brewer() +
  theme_void()
```



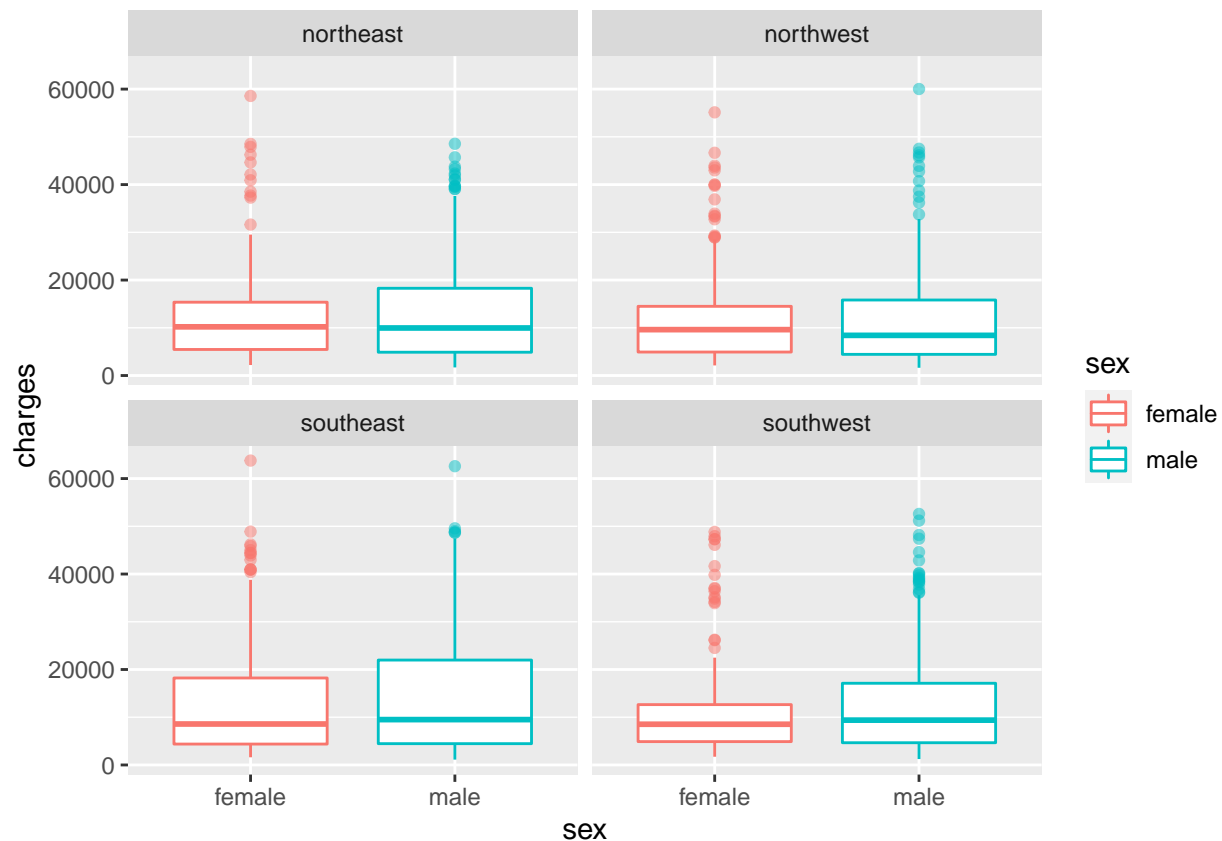
```
mean(insurance_df$charges)
```

```
## [1] 13270.42
```

The overall average insurance charge is \$13,270.42

Sex vs. Charges Significance

```
sex_plot <- insurance_df %>%  
  ggplot(aes(x = sex, y = charges, color = sex)) +  
  facet_wrap(~ region) +  
  geom_boxplot(outlier.alpha = 0.5)  
sex_plot
```



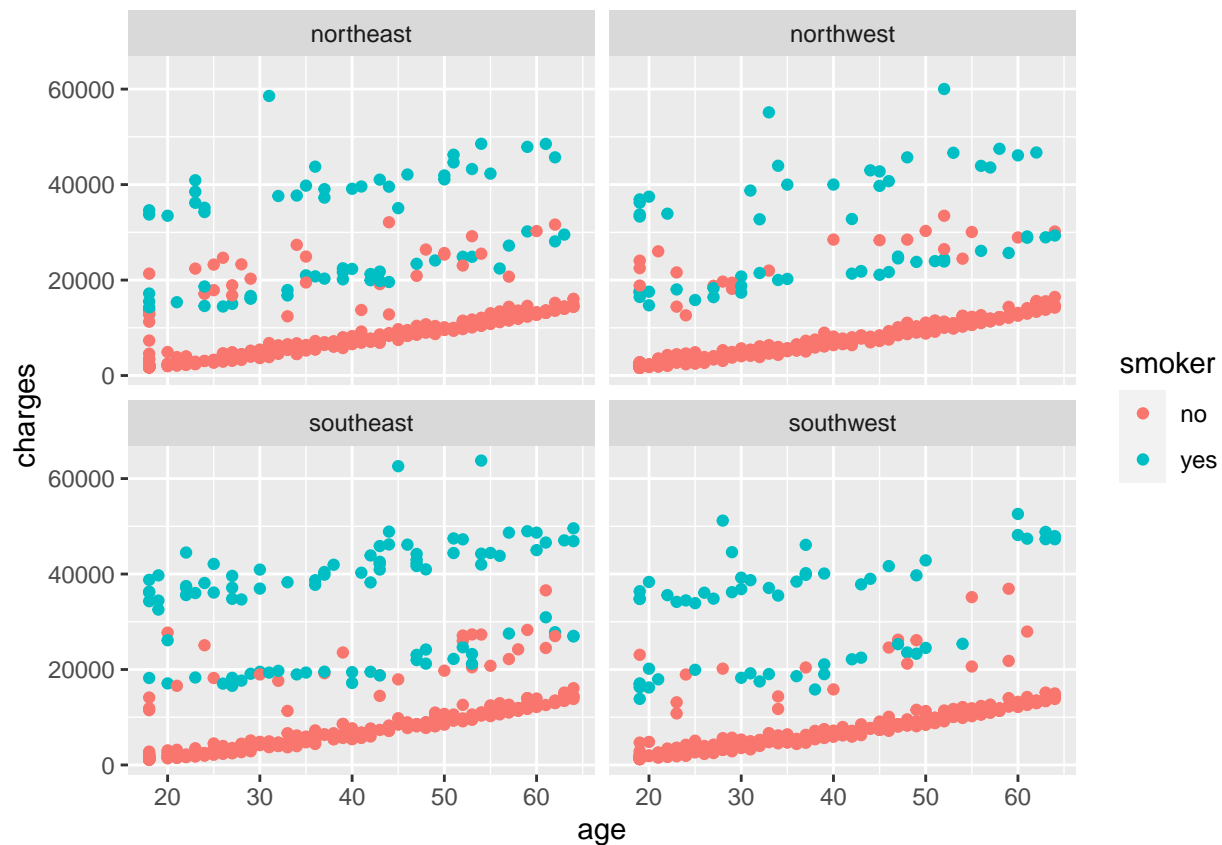
```
sex_sum <- insurance_df %>%
  group_by(sex) %>%
  summarize(avg = mean(charges, na.rm = TRUE), sd = sd(charges, na.rm = TRUE))
sex_sum
```

```
## # A tibble: 2 x 3
##   sex      avg      sd
##   <chr>  <dbl>  <dbl>
## 1 female 12570. 11129.
## 2 male  13957. 12971.
```

The boxplots illustrate how there is no apparent bias between gender and insurance charges. Regardless of gender, the mean insurance charges are relatively similar as are the median charges per region.

Age vs. Charges Significance

```
age_plot <- insurance_df %>%
  ggplot(aes(x = age, y = charges, color = smoker)) +
  facet_wrap(~ region) +
  geom_point()
age_plot
```



```
cor(insurance_df$age, insurance_df$charges)
```

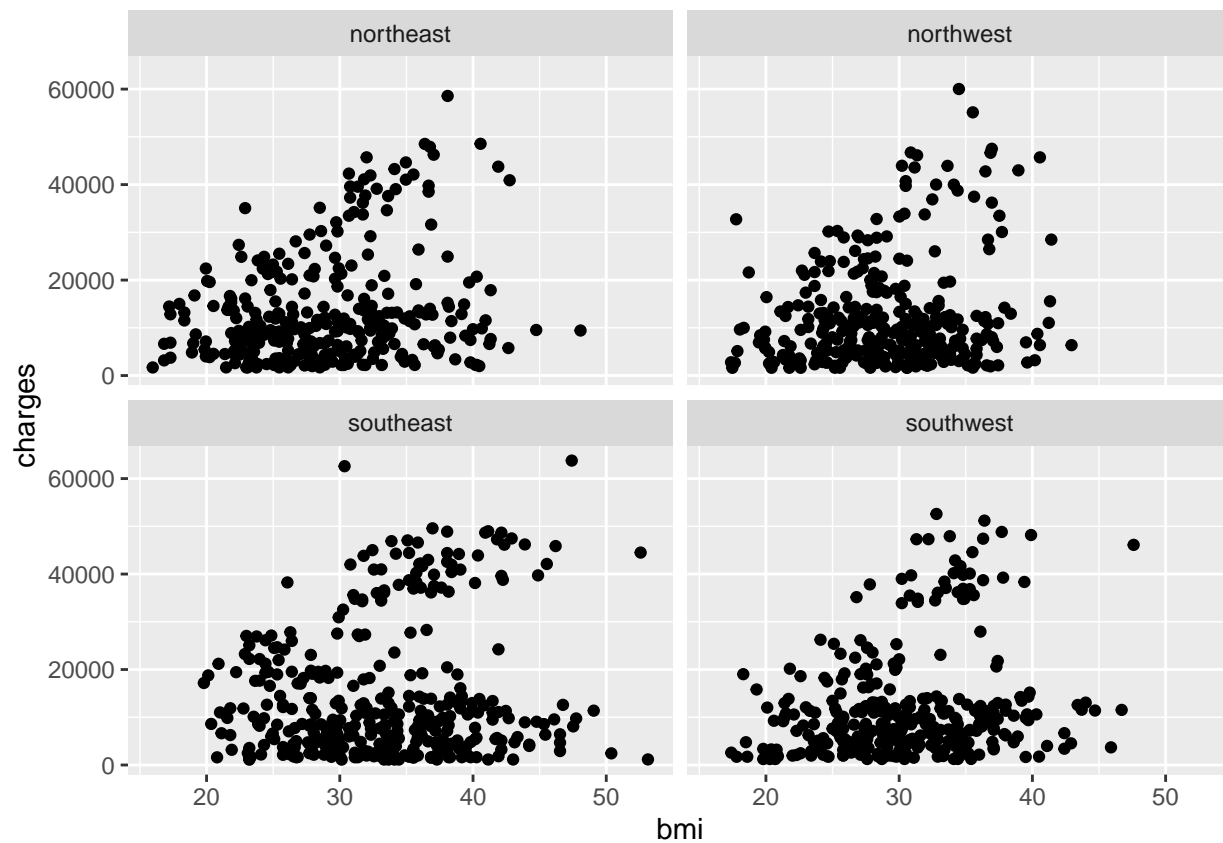
```
## [1] 0.2990082
```

Based on the scatter plots, there seems to be a positive, linear relationship between age and insurance charges. As age increases, so does the health insurance. There also seems to be 2 distinct levels above the baseline that indicates being a smoker results in elevated charges. Other unexplored factors could also contribute to this phenomenon, such as the type of insurance.

However, the correlation coefficient indicates a weak to moderate linear relation between age and insurance charges.

BMI vs. Charges Significance

```
BMI_plot <- insurance_df %>%
  ggplot(aes(x = bmi, y = charges)) +
  facet_wrap(~ region) +
  geom_point()
BMI_plot
```

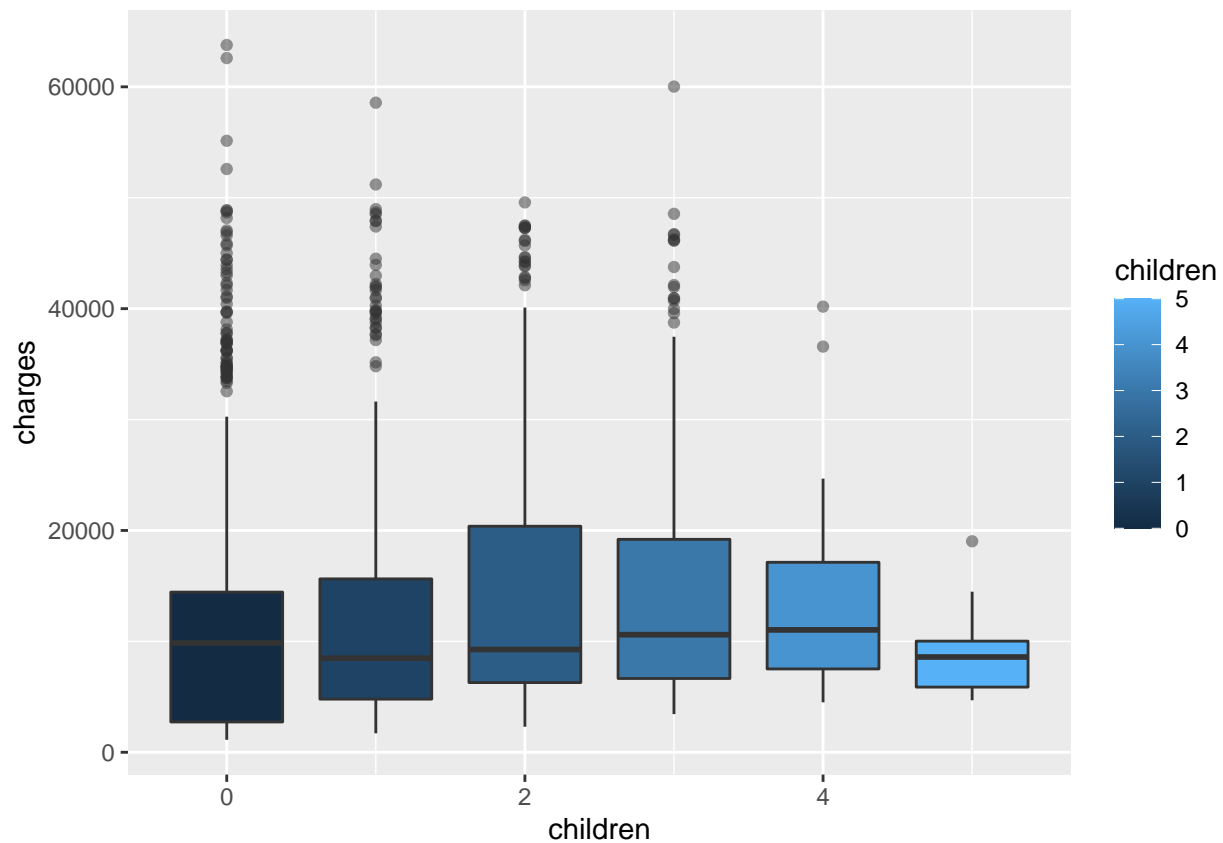
```
cor(insurance_df$bmi, insurance_df$charges)
```

```
## [1] 0.198341
```

Based on the scatter plots and correlation coefficient, there appears to be a weak, positive linear relationship between BMI and insurance charges. However, NE & NW look similar to each other as well as SE & SW.

Children vs. Charges Significance

```
child_plot <- insurance_df %>%
  ggplot(aes(x = children, y = charges, fill = children, group = children)) +
  geom_boxplot(outlier.alpha = 0.5)
child_plot
```



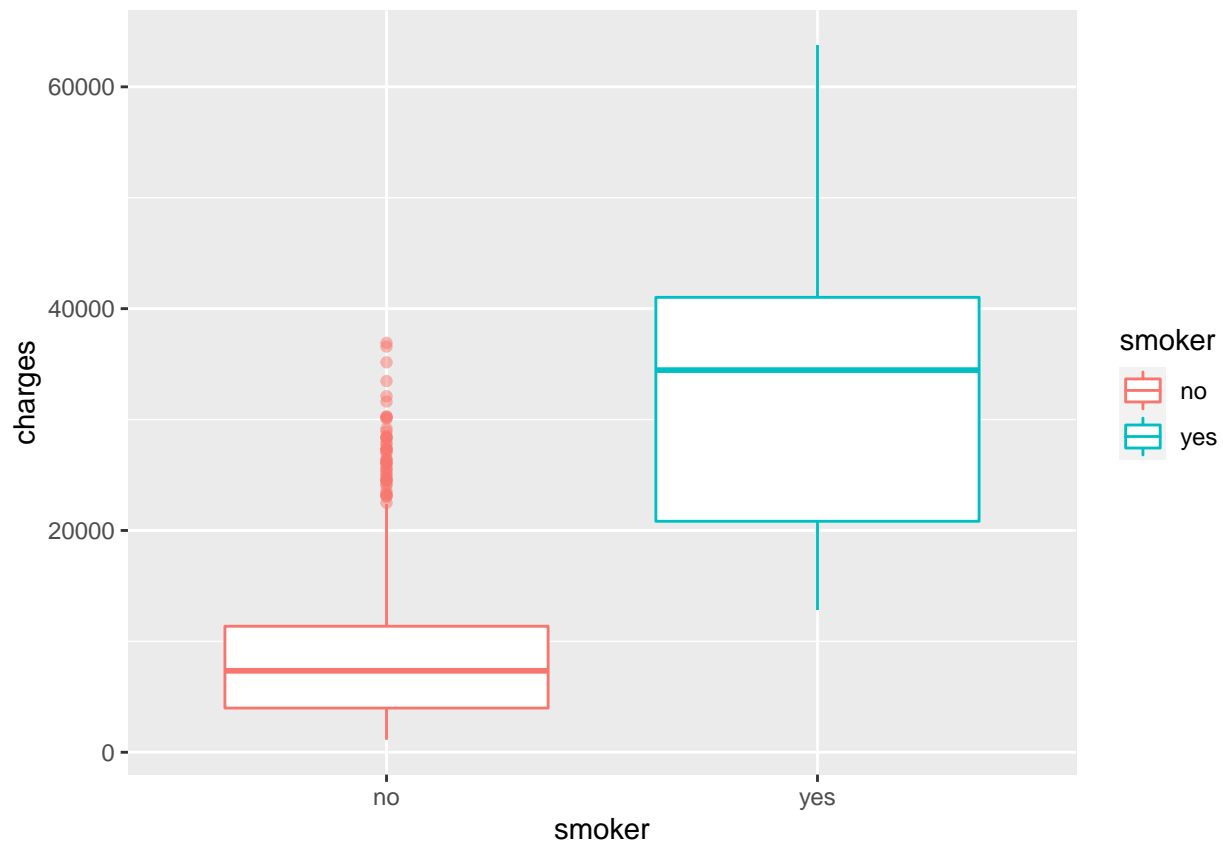
```
cor(insurance_df$children, insurance_df$charges)
```

```
## [1] 0.06799823
```

Based on the box plot & correlation coefficient, there is no correlation between the number of offsprings & insurance charges.

Smoker vs. Charges Significance

```
smoke_plot <- insurance_df %>%
  ggplot(aes(x = smoker, y = charges, color = smoker)) +
  geom_boxplot(outlier.alpha = 0.5)
smoke_plot
```

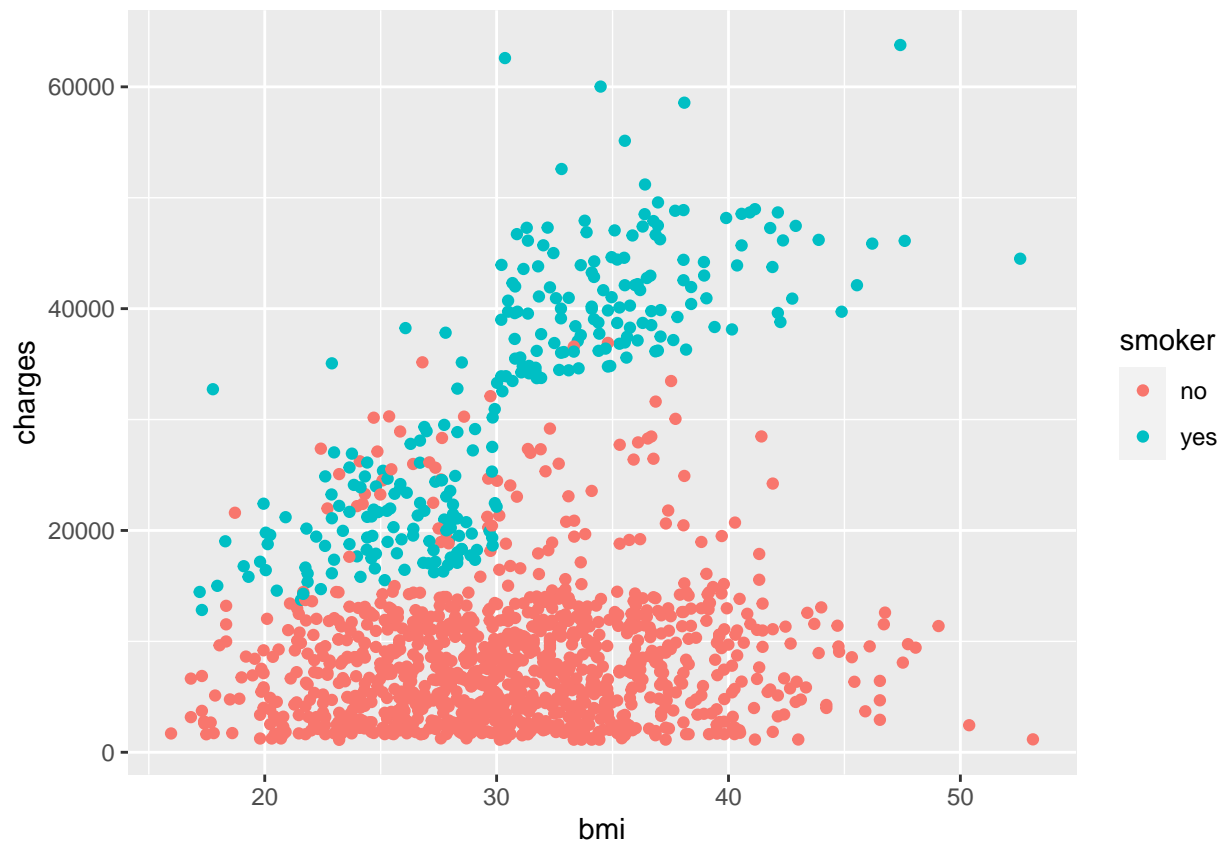


```
smoke_sum <- insurance_df %>%
  group_by(smoker) %>%
  summarize(avg = mean(charges, na.rm = TRUE), sd = sd(charges, na.rm = TRUE))
smoke_sum
```

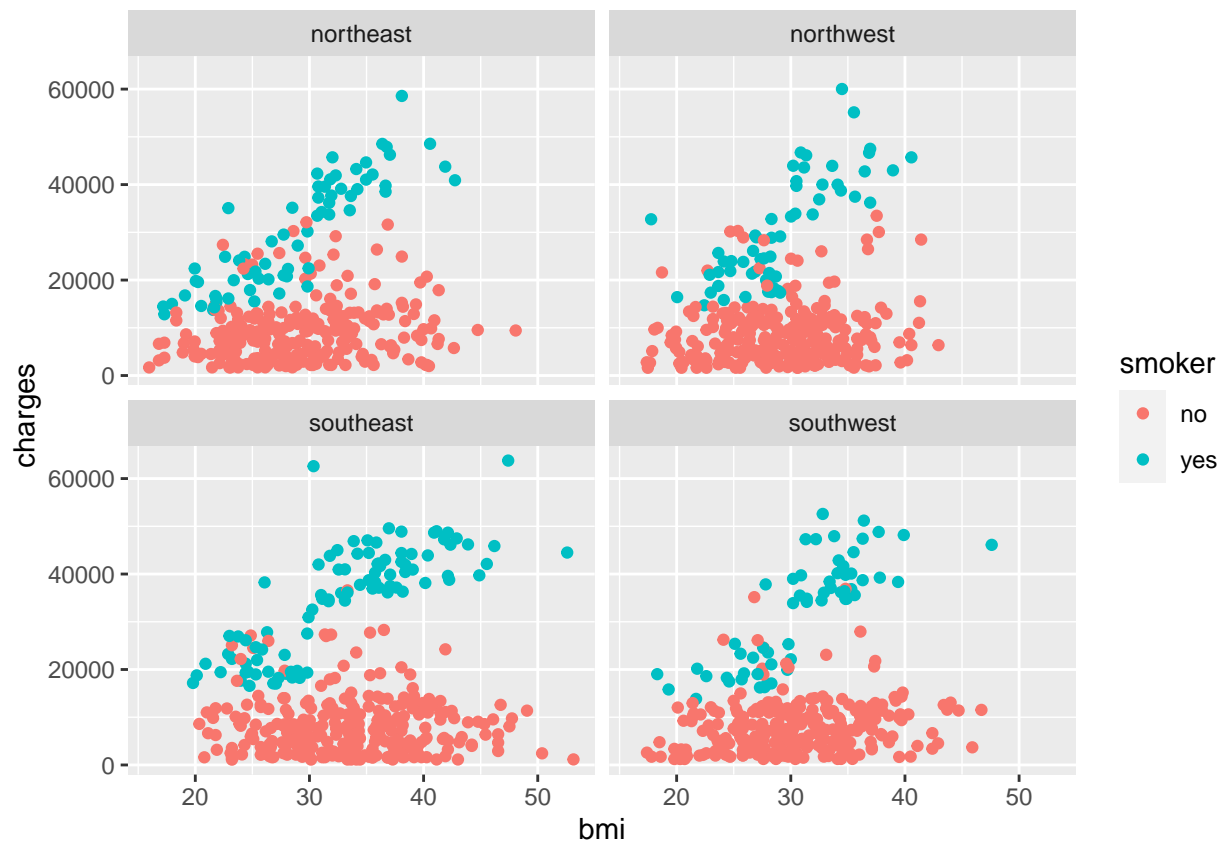
```
## # A tibble: 2 x 3
##   smoker    avg    sd
##   <chr>   <dbl> <dbl>
## 1 no      8434.  5994.
## 2 yes    32050. 11542.
```

This box plot illustrates a startling, significant difference between smoker status and health insurance charges. A smoker is expected to pay on average \$32,050, whereas a non-smoker is expected to pay on average \$8,434. That is a \$23,616 difference!

```
smokebmi_plot <- insurance_df %>%
  ggplot(aes(x = bmi, y = charges, color = smoker)) +
  geom_point()
smokebmi_plot
```



```
insurance_df %>%  
  ggplot(aes(x = bmi, y = charges, color = smoker)) +  
  facet_wrap(~ region) +  
  geom_point()
```



These scatter plots indicate a positive, moderate linear relation between being a smoker as well as obese (> 30 BMI) and health insurance charges. Health insurance increases as the BMI of a smoker increases. It is apparent that the base charges of smokers are higher than their counterparts. It is rather evident when visualizing per region.

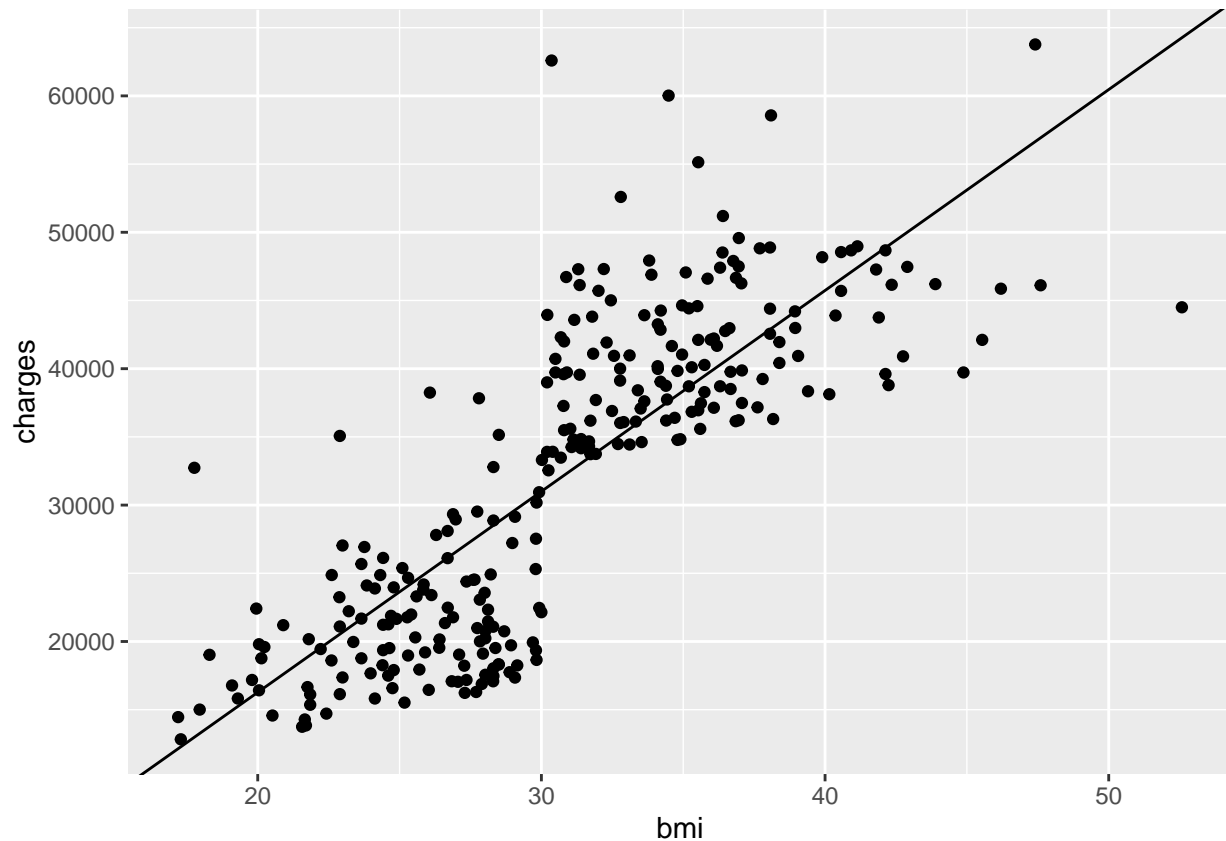
```
bmismc <- insurance_df %>%
  filter(smoker == "yes") %>%
  select(bmi, charges)
bmismc
```

```
## # A tibble: 274 x 2
##   bmi charges
##   <dbl>   <dbl>
## 1  27.9  16885.
## 2  26.3  27809.
## 3  42.1  39612.
## 4  35.3  36837.
## 5  31.9  37702.
## 6  36.3  38711
## 7  35.6  35586.
## 8  36.4  51195.
## 9  36.7  39774.
## 10 39.9  48173.
## # ... with 264 more rows
```

```
lm(charges~bmi, bmismc)
```

```
##
## Call:
```

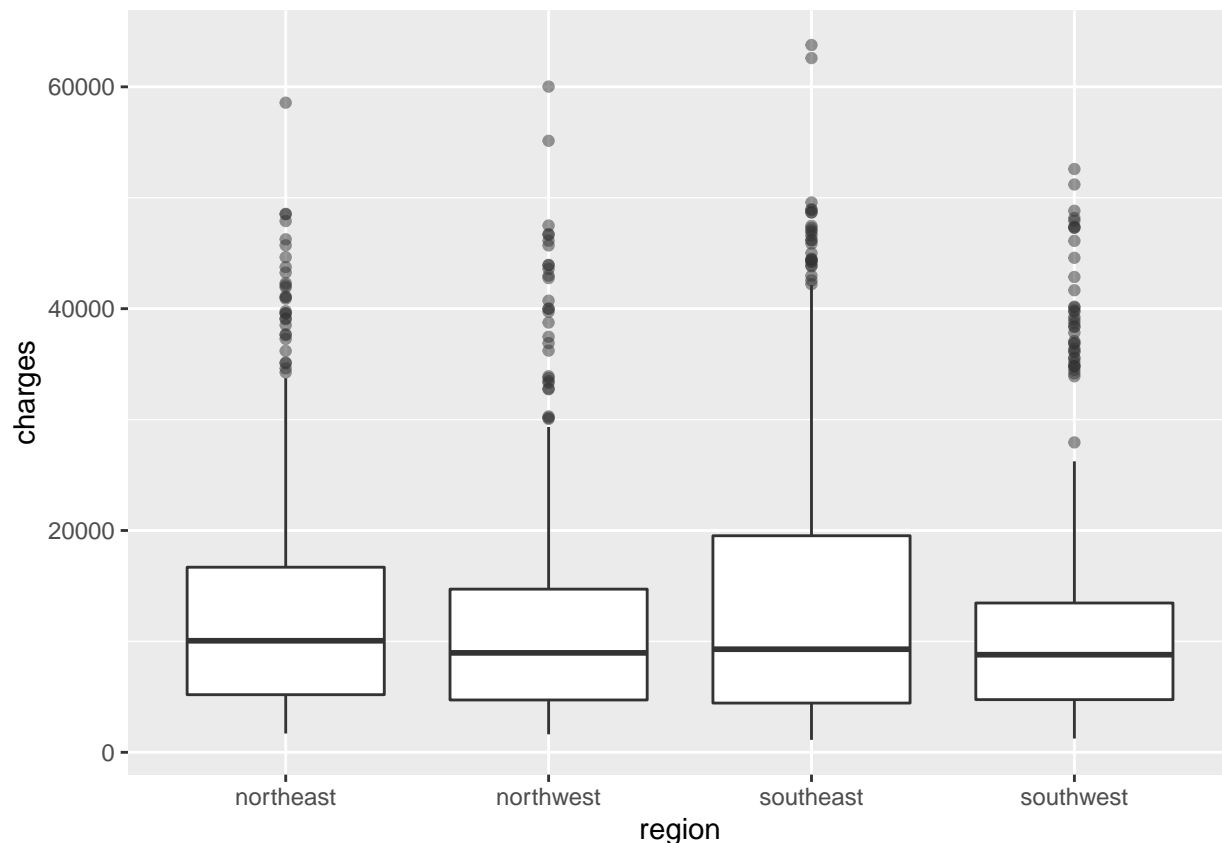
```
## lm(formula = charges ~ bmi, data = bmismc)
##
## Coefficients:
## (Intercept)      bmi
##      -13187      1473
lm_bmismcplot <- bmismc %>%
  ggplot(aes(bmi, charges)) +
  geom_point() +
  geom_abline(intercept = -13187, slope = 1473)
lm_bmismcplot
```



As a smoker by default, one unit increase in BMI results in 1473 increase in charges.

Region vs. Charges Significance

```
region_plot <- insurance_df %>%
  ggplot(aes(x = region, y = charges)) +
  geom_boxplot(outlier.alpha = 0.5)
region_plot
```



```
region_sum <- insurance_df %>%
  group_by(region) %>%
  summarize(avg = mean(charges, na.rm = TRUE), sd = sd(charges, na.rm = TRUE))
region_sum
```

```
## # A tibble: 4 x 3
##   region      avg      sd
##   <chr>      <dbl> <dbl>
## 1 northeast 13406. 11256.
## 2 northwest 12418. 11072.
## 3 southeast 14735. 13971.
## 4 southwest 12347. 11557.
```

Based on the box plot and summary, there is very weak relation between region and insurance. Regardless of location, the mean & median insurance charges are relatively similar. However, the east seems to charge a bit more than the west. The southeast being the most expensive.

From this data exploration, we can conclude that age and BMI alongside smoker play a significant role in health insurance charges. Sex, children, and region do not significantly affect health insurance charges.

Linear Regression Model

```
linear_model_insurance <- lm(charges~., insurance_df)
linear_model_insurance
```

```
##
```

```
## Call:
## lm(formula = charges ~ ., data = insurance_df)
##
## Coefficients:
##      (Intercept)          age      sexmale          bmi
##      -11938.5        256.9       -131.3        339.2
##      children      smokeryes regionnorthwest regionsoutheast
##      475.5        23848.5       -353.0       -1035.0
## regionsouthwest
##      -960.1
```

```
summary(linear_model_insurance)
```

```
##
## Call:
## lm(formula = charges ~ ., data = insurance_df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -11304.9  -2848.1   -982.1   1393.9  29992.8
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -11938.5     987.8  -12.086 < 2e-16 ***
## age             256.9       11.9   21.587 < 2e-16 ***
## sexmale        -131.3     332.9   -0.394 0.693348
## bmi             339.2       28.6   11.860 < 2e-16 ***
## children       475.5      137.8    3.451 0.000577 ***
## smokeryes     23848.5     413.1   57.723 < 2e-16 ***
## regionnorthwest -353.0     476.3   -0.741 0.458769
## regionsoutheast -1035.0     478.7   -2.162 0.030782 *
## regionsouthwest -960.0     477.9   -2.009 0.044765 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6062 on 1329 degrees of freedom
## Multiple R-squared:  0.7509, Adjusted R-squared:  0.7494
## F-statistic: 500.8 on 8 and 1329 DF,  p-value: < 2.2e-16
```

Based on the summary, the most significant factors are age, BMI, children, & smoker. The least significant is the regions. Sex holds no significance in relation to charges. The p-value for sexmale is big, so let's take it out.

```
linear_model_insurance2 <- lm(charges~.-sex, insurance_df)
linear_model_insurance2
```

```
##
## Call:
## lm(formula = charges ~ . - sex, data = insurance_df)
##
## Coefficients:
##      (Intercept)          age          bmi      children
##      -11990.3        257.0        338.7        474.6
##      smokeryes regionnorthwest regionsoutheast regionsouthwest
##      23836.3       -352.2       -1034.4       -959.4
```



```
summary(linear_model_insurance2)
```

```
##
## Call:
## lm(formula = charges ~ . - sex, data = insurance_df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -11367.2  -2835.4   -979.7   1361.9  29935.5
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -11990.27    978.76  -12.250 < 2e-16 ***
## age           256.97     11.89   21.610 < 2e-16 ***
## bmi           338.66     28.56   11.858 < 2e-16 ***
## children      474.57    137.74    3.445 0.000588 ***
## smokeryes     23836.30   411.86   57.875 < 2e-16 ***
## regionnorthwest -352.18    476.12  -0.740 0.459618
## regionsoutheast -1034.36   478.54  -2.162 0.030834 *
## regionsouthwest -959.37   477.78  -2.008 0.044846 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6060 on 1330 degrees of freedom
## Multiple R-squared:  0.7509, Adjusted R-squared:  0.7496
## F-statistic: 572.7 on 7 and 1330 DF,  p-value: < 2.2e-16
```

The multiple R-squared: 0.7509 tells us this linear regression model decently explains the data.

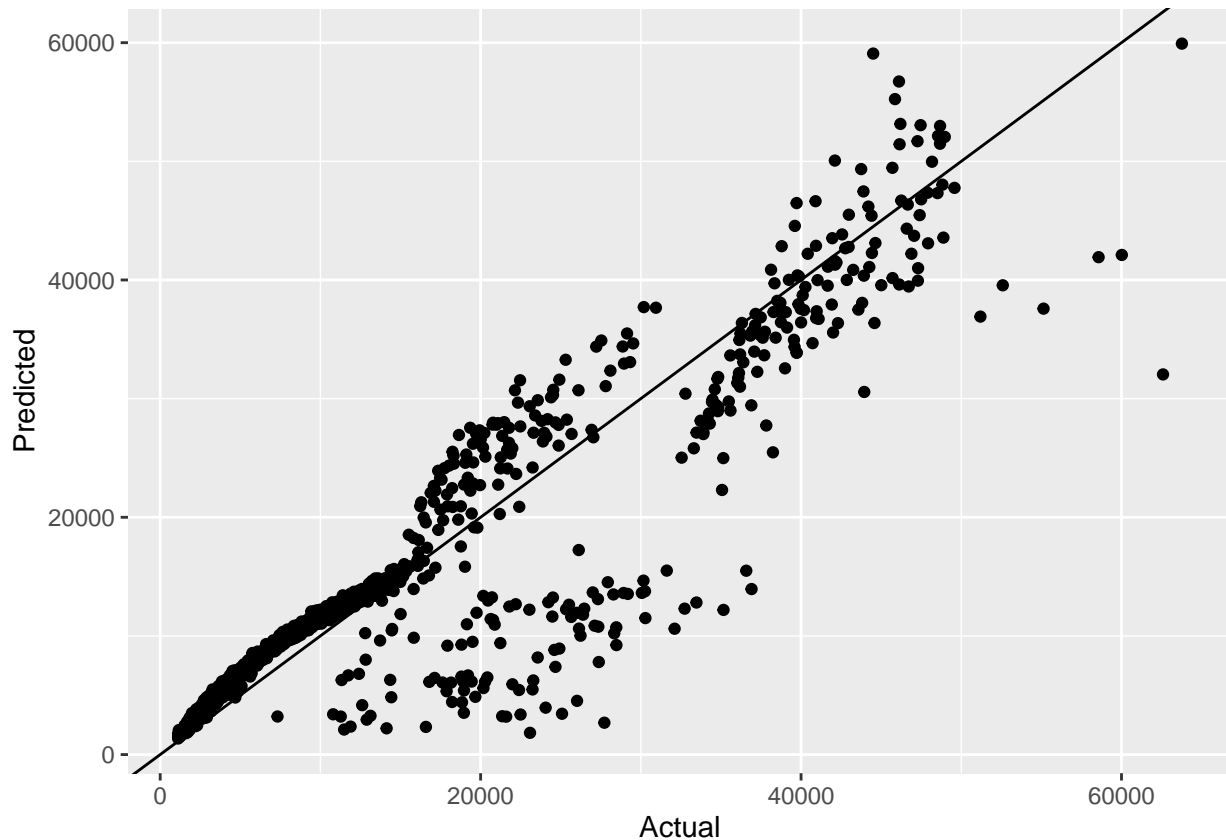
```
lm_test <- lm(charges ~.+bmi*smoker, insurance_df)
summary(lm_test)
```

```
##
## Call:
## lm(formula = charges ~ . + bmi * smoker, data = insurance_df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -14580.7  -1857.2  -1360.8   -475.7  30552.4
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -2223.454    865.611  -2.569  0.01032 *
## age           263.620     9.516   27.703 < 2e-16 ***
## sexmale      -500.146    266.518  -1.877  0.06079 .
## bmi           23.533     25.601    0.919  0.35814
## children      516.403    110.179    4.687 3.06e-06 ***
## smokeryes    -20415.611  1648.277  -12.386 < 2e-16 ***
## regionnorthwest -585.478    380.859  -1.537  0.12447
## regionsoutheast -1210.131   382.750  -3.162  0.00160 **
## regionsouthwest -1231.108   382.218  -3.221  0.00131 **
## bmi:smokeryes   1443.096     52.647   27.411 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 4846 on 1328 degrees of freedom
## Multiple R-squared:  0.8409, Adjusted R-squared:  0.8398
## F-statistic: 780 on 9 and 1328 DF,  p-value: < 2.2e-16
```

By including the synergistic effect of BMI & smoker to LM, the new multiple R-squared increased to 0.840, which directly translates to a better model.

```
lm_predict <- predict(lm_test, insurance_df)
test <- data.frame("Predicted" = lm_predict, "Actual" = insurance_df$charges)
ggplot(test, aes(Actual, Predicted)) + geom_point() + geom_abline()
```



After adjusting the LM, we can see the model being the best fit for the data.

Prediction Application

```
age = 60
sex = "female"
bmi = 35
children = 2
smoker = "yes"
region = "northeast"
single_obs <- data.frame(age = 60,
                          sex = "female",
                          bmi = 35,
                          children = 2,
                          smoker = "yes",
                          region = "northeast")
single_obs
```

```
##   age    sex bmi children smoker   region
## 1  60 female 35         2    yes northeast
```

```
predict(lm_test, single_obs)
```

```
##           1
## 45542.98
```

\$45,503.18 is our prediction.

Challenges

A significant challenge that I faced while working on this project was the data visualization interpretation. I had difficulty analyzing the plots I created, such as identifying patterns in the graphs and determining what factors may have caused a certain graph to appear that way. For example, initially, I colored the data points of the “Age vs. Charges Significance” graph to show the gender of each point. When looking at it, I did not understand why there were various levels above the apparent baseline. I tinkered with the color feature and found coloring the data points to show smoker status to really explain why the points were the way they were. Being a smoker results in a significant increase in charges throughout life. Other unexplored variables could also explain why there are more levels to the graph, such as the type of insurance.