

Assignment 3: Predicting insurance charges by age and BMI

Your name and student ID

July 12, 2023

Run this chunk of code to load the autograder package!

Instructions

- Solutions will be released by Friday, July 14th.
- This semester, homework assignments are for practice only and will not be turned in for marks.

Helpful hints:

- Every function you need to use was taught during lecture! So you may need to revisit the lecture code to help you along by opening the relevant files on Datahub. Alternatively, you may wish to view the code in the condensed PDFs posted on the course website. Good luck!
- Knit your file early and often to minimize knitting errors! If you copy and paste code for the slides, you are bound to get an error that is hard to diagnose. Typing out the code is the way to smooth knitting! We recommend knitting your file each time after you write a few sentences/add a new code chunk, so you can detect the source of knitting errors more easily. This will save you and the GSIs from frustration! **You must knit correctly before submitting.**
- It is good practice to not allow your code to run off the page. To avoid this, have a look at your knitted PDF and ensure all the code fits in the file. If it doesn't look right, go back to your .Rmd file and add spaces (new lines) using the return or enter key so that the code runs onto the next line.

```
library(readr)
library(dplyr)
library(ggplot2)
library(broom)
library(forcats)
```

Predicting insurance charges by age and BMI

Problem: Medical insurance charges can vary according to the complexity of a procedure or condition that requires medical treatment. You are tasked with determining how these charges are associated with age, for patients who have a body mass index (bmi) in the “normal” range (bmi between 16 and 25) who are smokers.

Plan: You have chosen to use tools to examine relationships between two variables to address the problem. In particular, scatter plots and simple linear regression.

Data: You have access to the dataset `insurance.csv`, a claims dataset from an insurance provider.

Analysis and Conclusion: In this assignment you will perform the analysis and make a conclusion to help answer the problem statement.

1. [1 point] Type one line of code to import these data into R. Assign the data to `insure_data`. Execute the code by hitting the green arrow and ensure the dataset has been saved by looking at the environment tab and viewing the data set by clicking the table icon to the right of its name.

```
insure_data <- read_csv("data/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.
```

```
insure_data
```

```
## # A tibble: 1,338 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.
## 7    46 female 33.4     1 no    southeast 8241.
## 8    37 female 27.7     3 no    northwest 7282.
## 9    37 male   29.8     2 no    northeast 6406.
## 10   60 female 25.8     0 no    northwest 28923.
## # i 1,328 more rows
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p1.R")
```

```
##
## All tests passed!
```

Execute the functions below one line at a time to get to know your dataset.

```
dim(insure_data)
```

```
## [1] 1338    7
```

```
names(insure_data)
```

```
## [1] "age"      "sex"      "bmi"      "children" "smoker"   "region"   "charges"
```

```
str(insure_data)
```

```
## spc_tbl_ [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>
```

```
head(insure_data)
```

```
## # 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.
```

2. [1 point] How many individuals are in the dataset? Assign this number to p2.

```
p2 <- nrow(insure_data)
p2
```

```
## [1] 1338
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p2.R")
```

```
##
## All tests passed!
```

3. [1 point] What are the nominal variables in the dataset? Assign the names of these variables to a vector of strings, p3.

```
p3 <- c("sex", "smoker", "region")
p3
```

```
## [1] "sex"      "smoker" "region"
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p3.R")
```

```
##
## All tests passed!
```

4. [1 point] How many ordinal variables are in the dataset? Assign the *number* of ordinal variables to p4.

```
p4 <- 0
p4
```

```
## [1] 0
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p4.R")
```

```
##
## All tests passed!
```

5. [1 point] Are there continuous variables in the dataset? Assign the names of these variables to a vector of strings, p5.

```
p5 <- c("bmi", "charges", "age")
p5
```

```
## [1] "bmi"      "charges" "age"
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p5.R")
```

```
##
```

```
## All tests passed!
```

6. [1 point] What are the discrete variables in the dataset? Assign the names of these variables to a vector of strings, p6.

```
p6 <- c("children", "age")
p6
```

```
## [1] "children" "age"
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p6.R")
```

```
##
```

```
## All tests passed!
```

Run the following code. Remind yourself what the `mutate()` function does in general, and notice that a new function called `case_when()` is also being used.

```
insure_data <- insure_data %>%  
  mutate(bmi_cat = case_when(bmi < 16 ~ "Underweight",  
                             bmi >= 16 & bmi < 25 ~ "Normal",  
                             bmi >= 25 & bmi < 30 ~ "Overweight",  
                             bmi >= 30 ~ "Obese")  
  )
```

7. What did the code above accomplish?

The above code created a new variable called `bmi_cat` that created four categories of BMI: underweight, normal, overweight, and obese, based on the continuous variable BMI.

8. [1 point] What type of variable is `bmi_cat`? Uncomment one of the choices below.

```
p8 <- 'ordinal'  
# p8 <- 'nominal'  
# p8 <- 'continuous'  
# p8 <- 'discrete'
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p8.R")
```

```
##
```

```
## All tests passed!
```


9. [1 point] Read the problem statement proposed at the beginning of this exercise. Who belongs to the population of interest? Uncomment one of the choices below.

```
p9 <- 'Smokers of normal BMI'
# p9 <- 'Smokers of overweight BMI'
# p9 <- 'Smokers who have abnormal BMI'
# p9 <- 'All people at risk of high medical charges'

# YOUR CODE HERE
```

```
. = ottr::check("tests/p9.R")
```

```
##
## All tests passed!
```

10. [1 point] Using a dplyr function, make a new dataset called `insure_subset` containing the population of interest.

```
insure_subset <- insure_data %>% filter(smoker == "yes" & bmi_cat == "Normal")
insure_subset
```

```
## # A tibble: 55 x 8
##   age sex      bmi children smoker region    charges bmi_cat
##   <dbl> <chr> <dbl>    <dbl> <chr>  <chr>      <dbl> <chr>
## 1    53 female  22.9         1 yes    southeast 23245. Normal
## 2    20 female  22.4         0 yes    northwest 14712. Normal
## 3    28 male    24.0         3 yes    southeast 17663. Normal
## 4    27 female  24.8         0 yes    southeast 16578. Normal
## 5    45 male    22.9         2 yes    northwest 21099. Normal
## 6    56 male    20.0         0 yes    northeast 22413. Normal
## 7    38 male    19.3         0 yes    southwest 15821. Normal
## 8    32 female  17.8         2 yes    northwest 32734. Normal
## 9    42 female  23.4         0 yes    northeast 19965. Normal
## 10   48 male    24.4         0 yes    southeast 21224. Normal
## # i 45 more rows
```

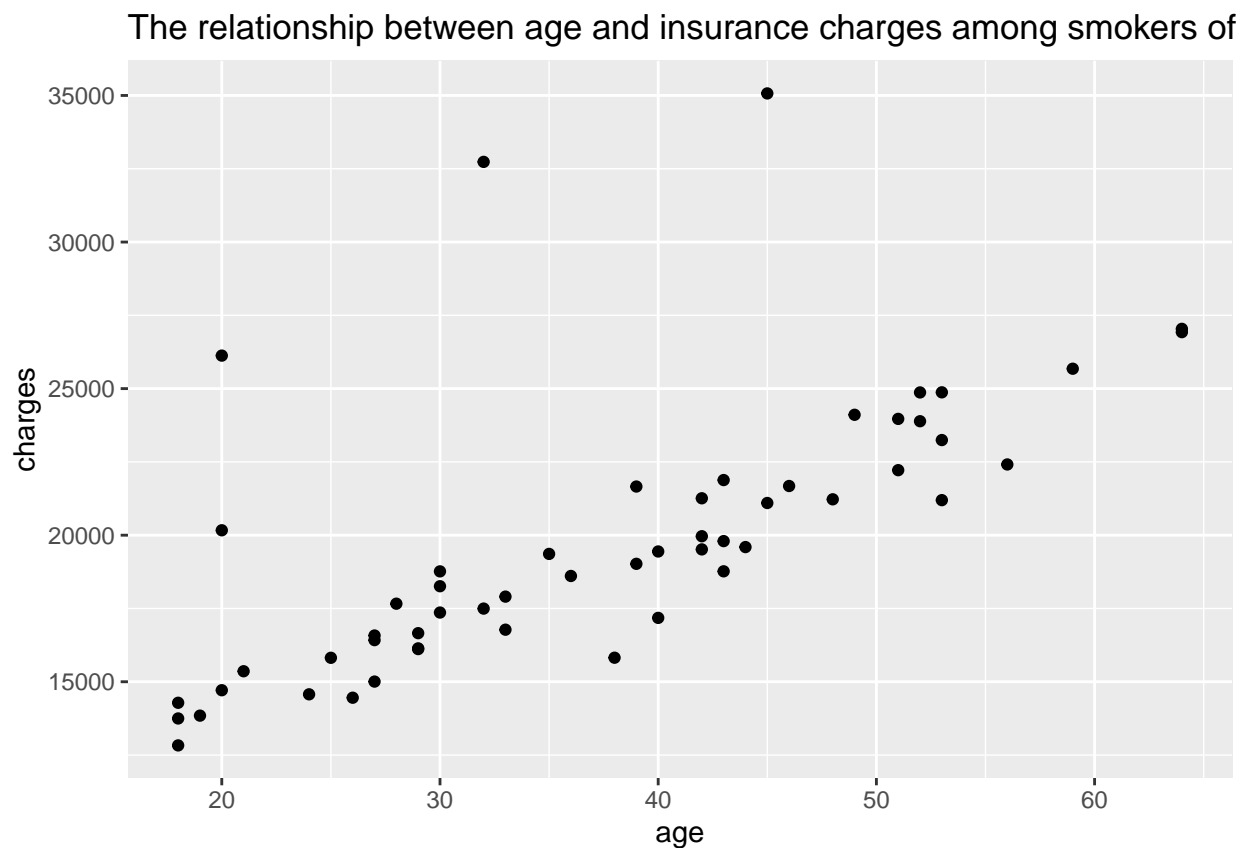
```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p10.R")
```

```
##
## All tests passed!
```

11. [3 points] Make a scatter plot of the relationship between age and insurance charges for the population of interest. Give your plot an informative title.

```
p11 <- ggplot(insure_subset, aes(x = age, y = charges)) +  
  geom_point() +  
  labs(title = "The relationship between age and insurance charges among smokers of normal BMI")  
p11
```



```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p11.R")
```

```
##
```

```
## All tests passed!
```

12. [2 points] Run a linear regression model on the relationship between age and charges. Think about which variable is explanatory (X) and which is response (Y). Assign the regression model to the object `insure_mod` and uncomment the line of code below the model to tidy the output.

```
insure_model <- lm(formula = charges ~ age, data = insure_subset)
insure_model
```

```
##
## Call:
## lm(formula = charges ~ age, data = insure_subset)
##
## Coefficients:
## (Intercept)          age
##      10656.1         246.1
```

```
# tidy(insure_model)
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p12.R")
```

```
##
## All tests passed!
```

13. [1 point] Interpret the slope parameter in the context of this problem.

For every year increase in age, medical charges increase by \$246.14.

14. [1 point] Interpret the intercept parameter.

The model predicts that the insurance charged would be \$10,656.14 for a person of aged 0.

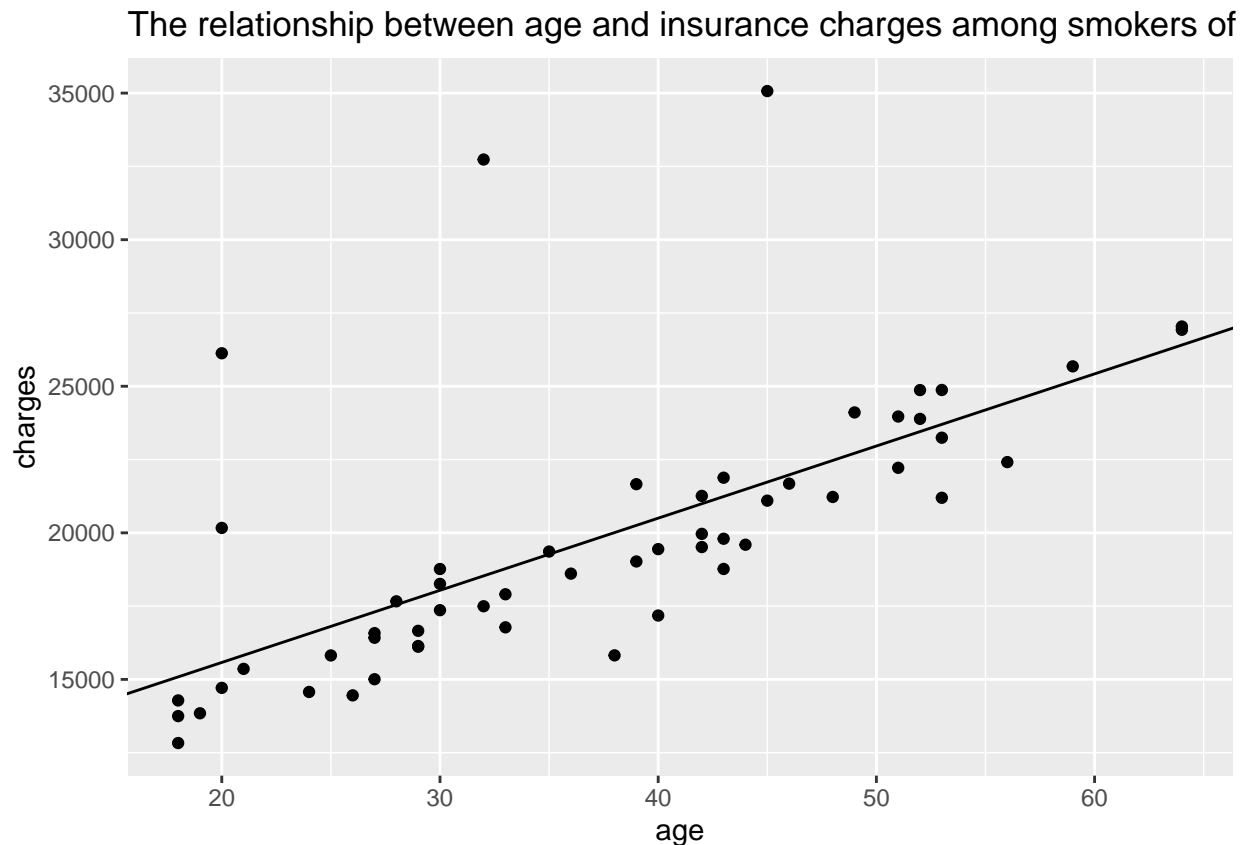
15. [1 point] Does the intercept make sense in this context?

No because being 0 years old is non sensical. Further, the minimum age in the dataset is 18, so extrapolation to 0 is not supported by the data. (student can say either of these items or both.)

16. [1 point] Add the line of best fit to your scatterplot by copying and pasting the plot's code from question 11 in the chunk below and adding a geom that can be used to add a regression line.

```
p16 <- ggplot(insure_subset, aes(x = age, y = charges)) +  
  geom_point() +  
  labs(title = "The relationship between age and insurance charges among smokers of normal BMI") +  
  geom_abline(intercept = 10656.1, slope = 246.1)
```

p16



```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p16.R")
```

```
##
```

```
## All tests passed!
```

17. [2 points] What do you notice about the fit of the line in terms of the proportion of points above vs. below the line? Why do you think that is?

The line seems high. There is a large proportion of points below the line. That's because there exists some notable outliers above the line which don't follow the linear trend of the data points.

Run the following `filter()` function in the chunk below.

```
insure_smaller_subset <- insure_subset %>%  
  filter(charges < 30000 & ! (charges > 25000 & age == 20))
```

18. [2 points] How many individuals were removed? Who were they?

Three individuals were removed. They were the “y outliers”, the two people with the highest charges in the dataset and a third person who was 20 years old with a charge > \$25,000.

19. [2 points] Run a regression model on `insure_smaller_subset` between charges and age. Assign the model to `insure_better_model` and analyze the output using the `tidy()` function.

```
insure_better_model <- lm(formula = charges ~ age, data = insure_smaller_subset)
# tidy(insure_better_model)

# YOUR CODE HERE
```

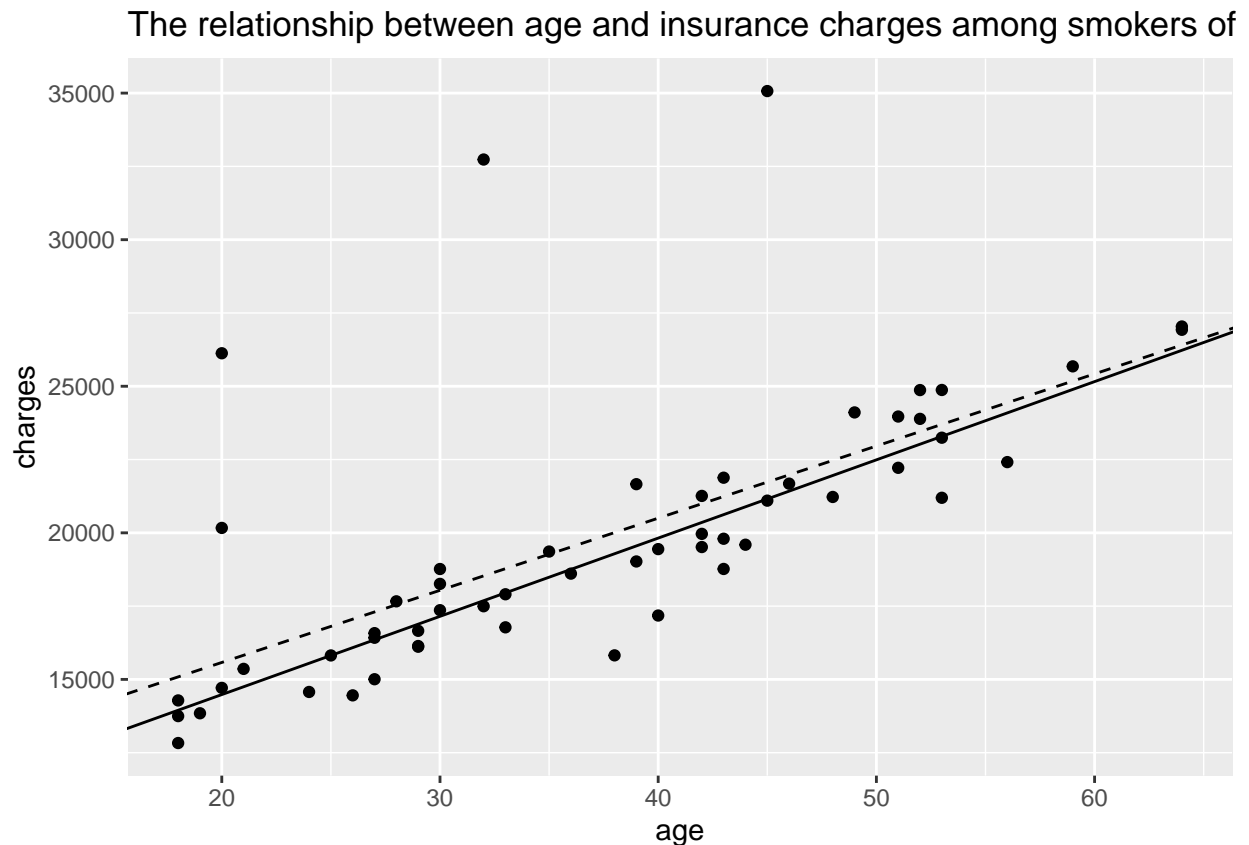
```
. = ottr::check("tests/p19.R")
```

```
##
```

```
## All tests passed!
```

20. [2 points] Add the new regression line to your ggplot from question 16. Keep the original regression line on the plot for comparison. To distinguish the lines, change the color, line type, or line width of one of the lines.

```
p20 <- ggplot(insure_subset, aes(x = age, y = charges)) +
  geom_point() +
  labs(title = "The relationship between age and insurance charges among smokers of normal BMI") +
  geom_abline(intercept = 10656.1, slope = 246.1, lty = 2) +
  geom_abline(intercept = 9144.1, slope = 266.9) # YOUR CODE HERE
p20
```



```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p20.R")
```

```
##
## All tests passed!
```


21. [1 point] Calculate the r-squared value for `insure_model` and assign this value to `insure_model_r2`.

```
insure_model_r2 <- glance(insure_model) %>% pull(r.squared)
insure_model_r2
```

```
## [1] 0.449261
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p21.R")
```

```
##
```

```
## All tests passed!
```

22. [1 point] Calculate the r-squared value for `insure_better_model` using a function learned in class. Assign this value to `insure_better_model_r2`.

```
insure_better_model_r2 <- glance(insure_better_model) %>% pull(r.squared)
insure_better_model_r2
```

```
## [1] 0.8477642
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p22.R")
```

```
##
```

```
## All tests passed!
```

23. [2 points] Calculate the correlation coefficient between age and charges using `insure_subset`. Also calculate the squared correlation coefficient. You should use `summarize()` to create a dataframe of these two values and name the two variables `corr` and `corr_sq`, respectively. What do you notice about the relationship between the correlation coefficient and r-squared values that you calculated earlier?

```
p23 <- insure_subset %>% summarize(corr = cor(age, charges), corr_sq = corr^2)
p23
```

```
## # A tibble: 1 x 2
##   corr corr_sq
##   <dbl>   <dbl>
## 1 0.670   0.449
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p23.R")
```

```
##
## All tests passed!
```

24. [2 points] Calculate the correlation coefficient between age and charges using the smaller dataset `insure_smaller_subset`. Also calculate the squared correlation coefficient. You should use `summarize()` to create a dataframe of these two values and name the two variables `corr` and `corr_sq`, respectively. What do you notice about the relationship between the correlation coefficient and r-squared values that you calculated earlier?

```
p24 <- insure_smaller_subset %>% summarize(corr = cor(age, charges), corr_sq = corr^2)
p24
```

```
## # A tibble: 1 x 2
##   corr corr_sq
##   <dbl>   <dbl>
## 1 0.921   0.848
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p24.R")
```

```
##
## All tests passed!
```

Your supervisor asks you to extend your analysis to consider other smokers with BMIs classified as overweight or obese. In particular, she wanted to know if the relationship between age and medical charges is different for different BMI groups. You can use data visualization coupled with your skills in linear regression to help answer this question.

25. [1 point] Make a new dataframe called `insure_smokers` that includes smokers of any BMI from the original `insure_data` dataset.

```
insure_smokers <- insure_data %>% filter(smoker == "yes")
insure_smokers
```

```
## # A tibble: 274 x 8
##   age sex    bmi children smoker region    charges bmi_cat
##   <dbl> <chr> <dbl>    <dbl> <chr>  <chr>    <dbl> <chr>
## 1   19 female 27.9        0 yes   southwest 16885. Overweight
## 2   62 female 26.3        0 yes   southeast 27809. Overweight
## 3   27 male  42.1        0 yes   southeast 39612. Obese
## 4   30 male  35.3        0 yes   southwest 36837. Obese
## 5   34 female 31.9        1 yes   northeast 37702. Obese
## 6   31 male  36.3        2 yes   southwest 38711. Obese
## 7   22 male  35.6        0 yes   southwest 35586. Obese
## 8   28 male  36.4        1 yes   southwest 51195. Obese
## 9   35 male  36.7        1 yes   northeast 39774. Obese
## 10  60 male  39.9        0 yes   southwest 48173. Obese
## # i 264 more rows
```

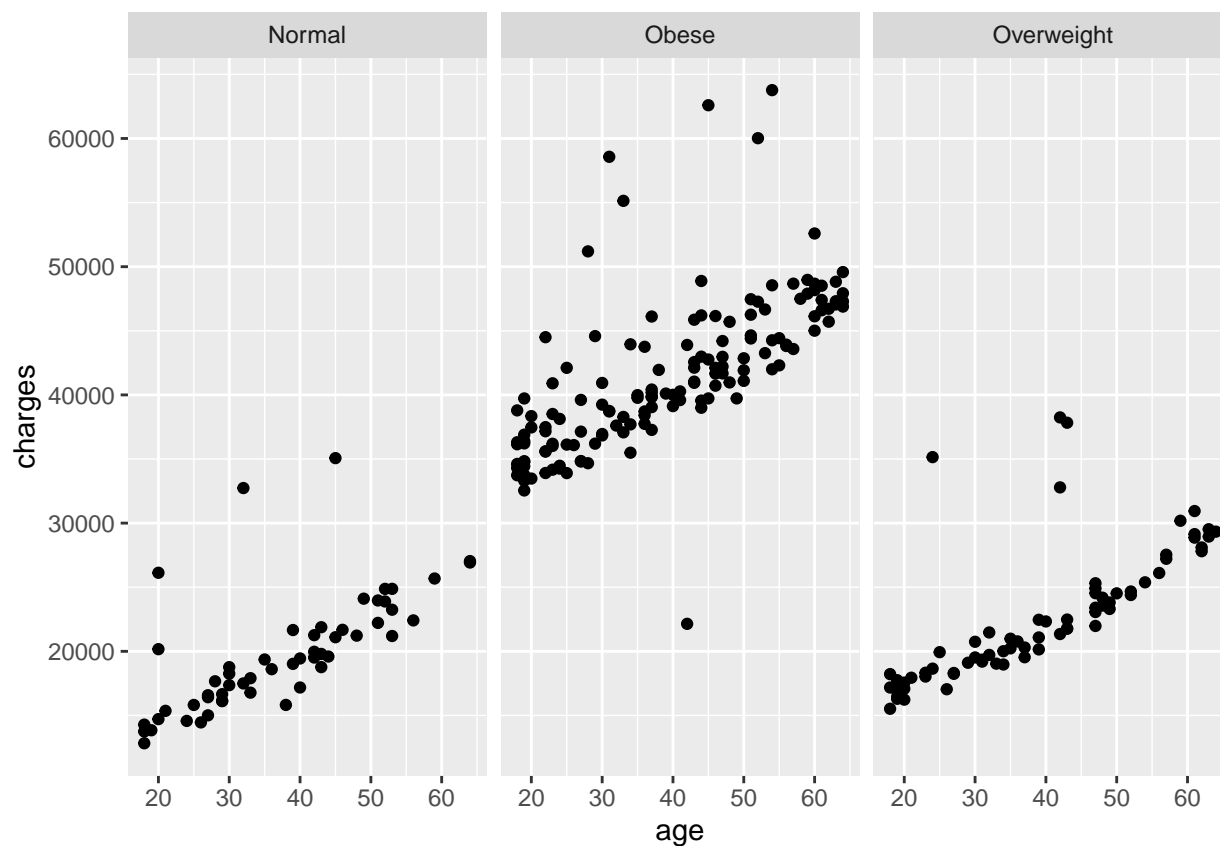
```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p25.R")
```

```
##
## All tests passed!
```

26. [1 point] Make a scatterplot that examines the relationship between age and charges for normal, overweight, and obese individuals in three side by side plots. A `facet_` command may help you.

```
p26 <- ggplot(insure_smokers, aes(x = age, y = charges)) +  
  geom_point() +  
  facet_wrap(~ bmi_cat)  
p26
```



```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p26.R")
```

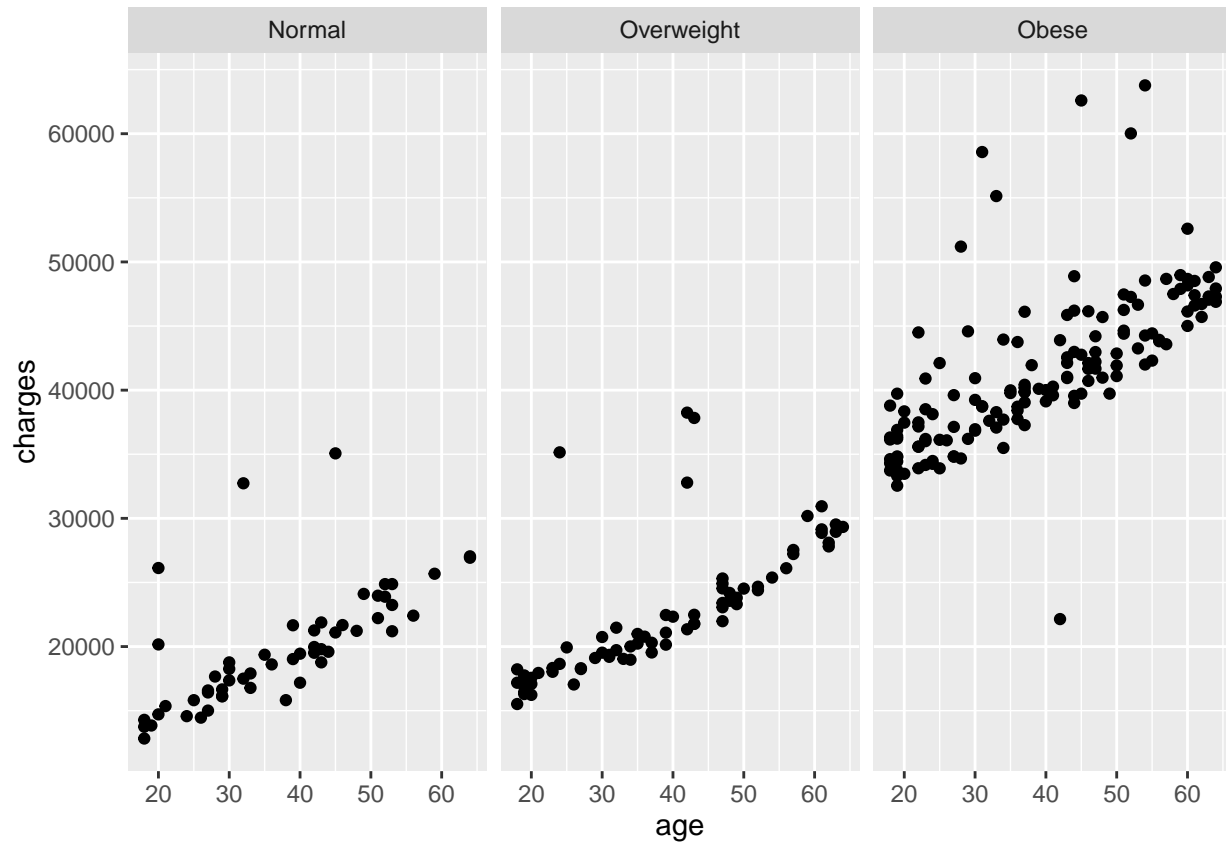
```
##  
## All tests passed!
```

The plot above automatically displays the BMI categories alphabetically. Run the chunk below to assign a different order to the values of `bmi_cat`.

```
insure_smokers <- insure_smokers %>%  
  mutate(bmi_cat_ordered = forcats::fct_relevel(bmi_cat, "Normal", "Overweight", "Obese"))
```

27. [1 point] Re-run your code from question 26, but facet using `bmi_cat_ordered`.

```
p27 <- ggplot(insure_smokers, aes(x = age, y = charges)) +  
  geom_point() +  
  facet_wrap(~bmi_cat_ordered)  
p27
```



```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p27.R")
```

```
##
```

```
## All tests passed!
```

28. [3 points] Run a separate linear model for each BMI group. To do this, you will need to subset your data into the three groups of interest. Call your models `normal_mod`, `overweight_mod`, `obese_mod`. Use the `tidy()` function to display the output from each model.

```
## subset your data here

# '<<<<YOUR CODE HERE>>>>'
# '<<<<YOUR CODE HERE>>>>'
# '<<<<YOUR CODE HERE>>>>'

## generate your models

insure_smokers_normal <- insure_smokers %>% filter(bmi_cat == "Normal")
insure_smokers_overweight <- insure_smokers %>% filter(bmi_cat == "Overweight")
insure_smokers_obese <- insure_smokers %>% filter(bmi_cat == "Obese")

normal_mod <- lm(charges ~ age, data = insure_smokers_normal)
overweight_mod <- lm(charges ~ age, data = insure_smokers_overweight)
obese_mod <- lm(charges ~ age, data = insure_smokers_obese)

tidy(normal_mod)
```

```
## # A tibble: 2 x 5
##   term          estimate std.error statistic      p.value
##   <chr>          <dbl>    <dbl>    <dbl>    <dbl>
## 1 (Intercept)   10656.    1471.     7.24 0.00000000184
## 2 age           246.      37.4     6.58 0.0000000217
```

```
tidy(overweight_mod)
```

```
## # A tibble: 2 x 5
##   term          estimate std.error statistic  p.value
##   <chr>          <dbl>    <dbl>    <dbl>   <dbl>
## 1 (Intercept)   12400.    1176.    10.5 3.01e-16
## 2 age           264.      28.9     9.16 1.07e-13
```

```
tidy(obese_mod)
```

```
## # A tibble: 2 x 5
##   term          estimate std.error statistic  p.value
##   <chr>          <dbl>    <dbl>    <dbl>   <dbl>
## 1 (Intercept)   30558.    1093.    28.0 7.96e-60
## 2 age           281.      26.2    10.7 5.05e-20
```

```
. = ottr::check("tests/p28.R")
```

```
##
## All tests passed!
```

For the next three problems, use the models to predict medical charges for a 20-year old by weight category. You don't need an R function to make these predictions, just the output from the models. Show your work for each calculation.

29. [1 point] Predict the medical charges for a 20 year old with a normal BMI.

```
p29 <- 10656.1 + 246.1 * 20
p29
```

```
## [1] 15578.1
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p29.R")
```

```
##
## All tests passed!
```

30. [1 point] Predict the medical charges for a 20 year old with an overweight BMI.

```
p30 <- 12399.7 + 264.2 * 20
p30
```

```
## [1] 17683.7
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p30.R")
```

```
##
## All tests passed!
```

31. [1 point] Predict the medical charges for a 20 year old with an obese BMI.

```
p31 <- 30558.1 + 281.2 * 20
p31
```

```
## [1] 36182.1
```

```
# YOUR CODE HERE
```

```
. = ottr::check("tests/p31.R")
```

```
##
## All tests passed!
```

32. [3 points] In three sentences maximum, comment on (1) the direction of the association, (2) how much the slopes vary across the BMI groups, and (3) how much the predicted medical charges for a 20-year old varies by BMI category.

There was a positive association between age and medical charges for normal, overweight, and obese individuals. The relationship was of similar magnitude for each BMI group, though the slope increased in magnitude for overweight and obese individuals, implying that a steeper relationship for overweight individuals, and even steeper for obese individuals vs. normal BMI individuals. For a given age, obese individuals had much higher charges than overweight and normal weight individuals.

END