

Exploratory Data Analysis II and Plots with R

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Section 1

Outline

Outline

- Elegant graphics for data analysis
- From univariate to bivariate analysis
- Bivariate analysis
 - Qualitative vs Qualitative
 - Qualitative vs Quantitative
 - Quantitative vs Quantitative
- Correlation
 - Definition
 - Types of correlation (Pearson, Spearman)
- Interactive and Impressive Plots

Section 2

Elegant graphics for data analysis

Elegant graphics for data analysis

- R is a powerful tool to plot your data
- Hadley Wickham introduced (2009) **ggplot2**, a grammar of graphics
- Extensions:
 - GGally, ggrepel ..
- References:
 - ggplot2 book
 - STHDA. Statistical tools for high throughput data analysis
 - R Colors

How ggplot2 works?

- Based on the Grammar of Graphics (Wilkinson 2005)
- A graphic maps data to aesthetic attributes of geometric objects
- May include statistical transformations and coordinate system

Components of ggplot2

- Layer: geoms, stats
- Scales: aesthetics like color, shapes, legend
- Coord: axes, gridlines
- Facet: to divide data into multiple plots
- Theme: font size, background colors

Installation

```
# install.packages("pacman")  
library(pacman)  
p_load(ggplot2)
```


Load diabetes database

```
library(pacman)
p_load(rio)
osteo <- rio::import("datasets/osteoporosis.csv", dec = ",")
```

First steps

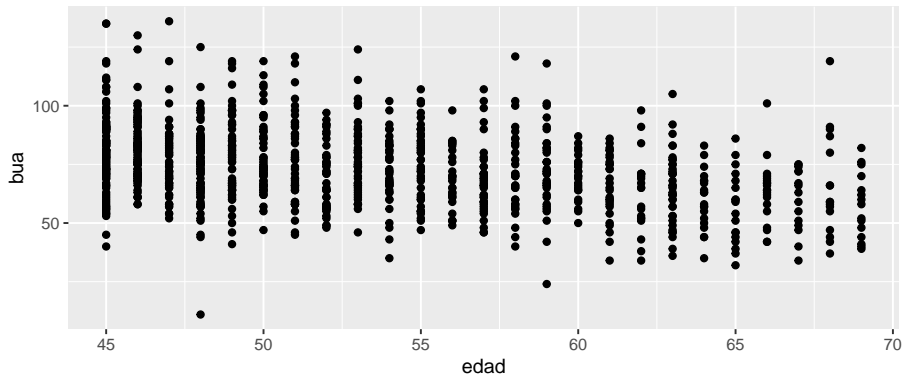
Three key components

- Data
- Aesthetic mappings between variables
- A least one layer Usually created with a geom function

```
ggplot(mpg, aes(x = displ, y = hwy)) +  
  geom_point()
```

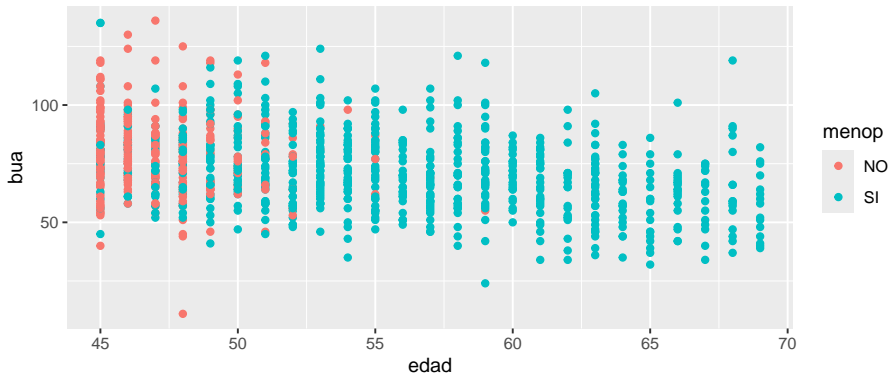
Basic Structure. Points

```
library(ggplot2)
ggplot(osteo, aes(x = edad , y = bua )) +
  geom_point()
```



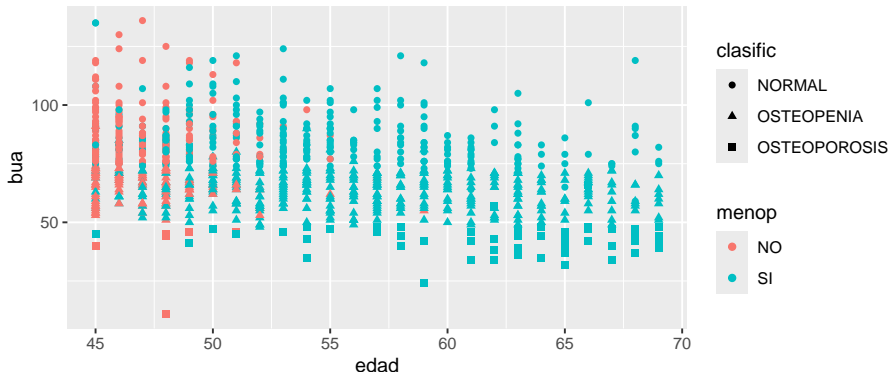
Basic Structure. Points + color

```
ggplot(osteo, aes(x = edad , y = bua , color = menop)) +  
  geom_point()
```



Basic Structure. Points + color + shape

```
ggplot(osteo, aes(x = edad , y = bua , color = menop, shape =  
  geom_point()
```



Section 3

From Univariate to Bivariate Analysis

From Univariate to Bivariate Analysis

- Elegant graphics for data analysis
- **From univariate to bivariate analysis**
- Bivariate analysis
 - Qualitative vs Qualitative
 - Qualitative vs Quantitative
 - Quantitative vs Quantitative
- Correlation
 - Definition
 - Types of correlation (Pearson, Spearman)
- Extra

Section 4

From Univariate to Bivariate Analysis

From Univariate to Bivariate Analysis

- Univariate: analysis of one variable
- Bivariate: check for relationships between two variables

Questions to consider

If there are more than one variable in the dataset it could be interesting to guess if:

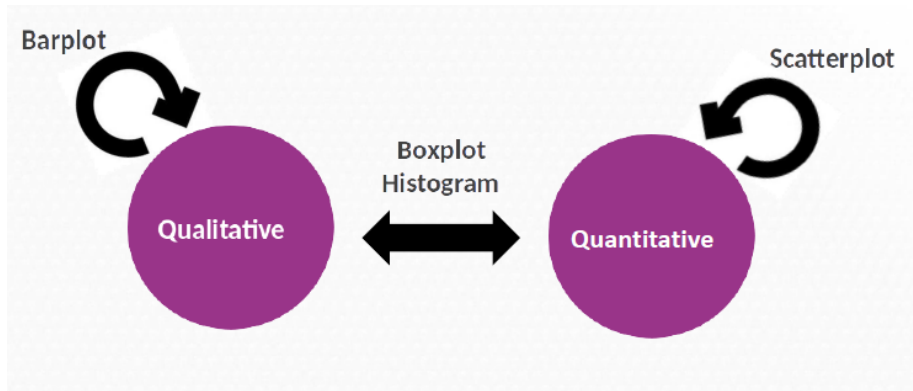
- Does a relation exist?
- How important is it?
- What is the direction?

Section 5

Bivariate Analysis

Types

Some plots to study the relationship between two variables. . .



Definition

- Bivariate analysis explores the relationship between two variables.
- The approach depends on whether the variables are numerical or categorical.

Qualitative vs Qualitative

- Use contingency tables
- Chi-squared test for independence

Example data

```
library(rio)
library(gmodels)
```

```
CrossTable(osteo$grupedad, osteo$clasific, prop.c = FALSE, prop.r = FALSE)
```

```
##
```

```
##
```

```
##      Cell Contents
```

```
## |-----|
```

```
## |                                     N |
```

```
## |      N / Table Total |
```

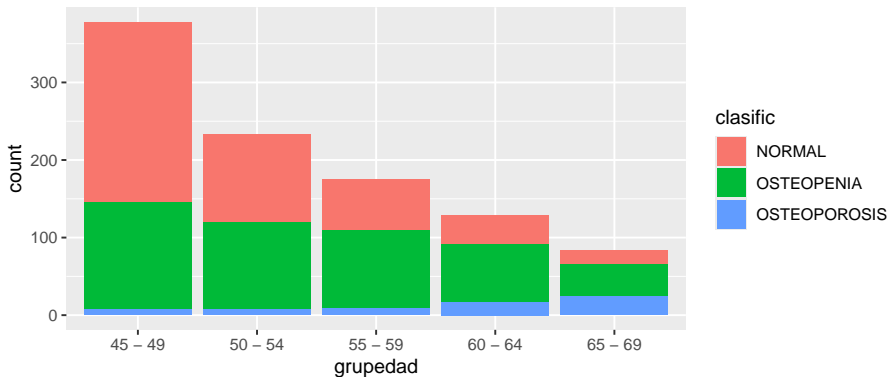
```
## |-----|
```

```
##
```

Barplots

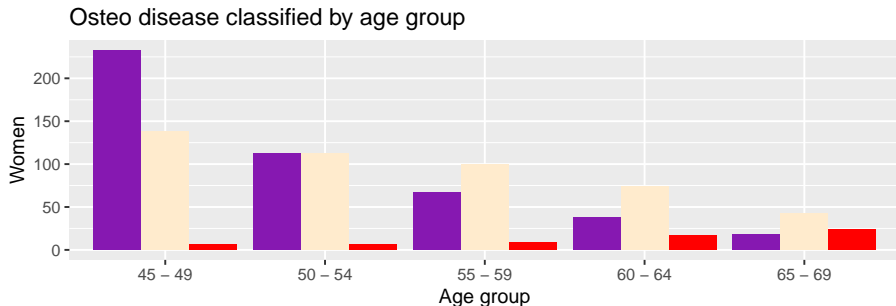
- We can use bar plots to explore the relationship.
- Example: **grupedad vs clasific**

```
ggplot(osteo, aes(x = grupedad, fill = clasific)) +  
  geom_bar()
```



Customizing

```
p <- ggplot(osteos, aes(x = grouped, fill = clasific)) +  
  geom_bar(position = "dodge") +  
  scale_fill_manual(values=c("#8618b1", "blanchedalmond", "red")) +  
  theme(legend.position="bottom") +  
  labs(x = "Age group", y = "Women", title = "Osteo disease cl")  
p
```



clasific NORMAL OSTEOPENIA OSTEOPOROSIS

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Qualitative vs Quantitative

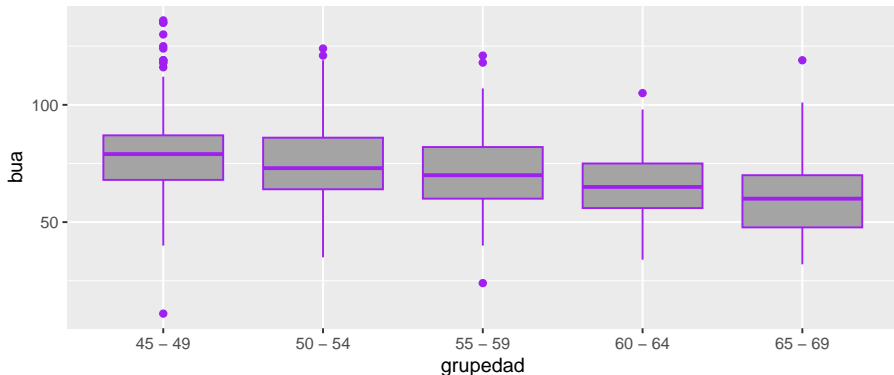
- One qualitative and one quantitative variable
- Use table of means or boxplots

```
library(dplyr)
osteo %>%
  group_by(grupedad) %>%
  summarize(mean_bua = mean(bua, na.rm = TRUE))
```

```
## # A tibble: 5 x 2
##   grupedad mean_bua
##   <chr>      <dbl>
## 1 45 - 49      78.8
## 2 50 - 54      75.1
## 3 55 - 59      71.4
## 4 60 - 64      64.9
## 5 65 - 69      60.7
```

Boxplots

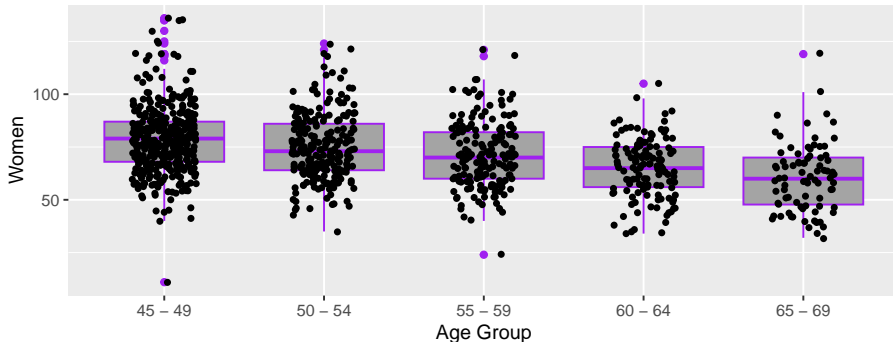
```
bp <- ggplot(osteo, aes(x = grupedad, y = bua)) +  
  geom_boxplot(fill = '#A4A4A4', color = "purple")  
bp
```



Customizing

```
bp + geom_jitter(shape = 16, position = position_jitter(0.2))  
  labs(x = "Age Group", y = "Women", title = "Osteo disease cl
```

Osteo disease classified by age group



Quantitative vs Quantitative

- Scatter plots are useful to show correlation or pattern.
- Example: **edad vs bua**

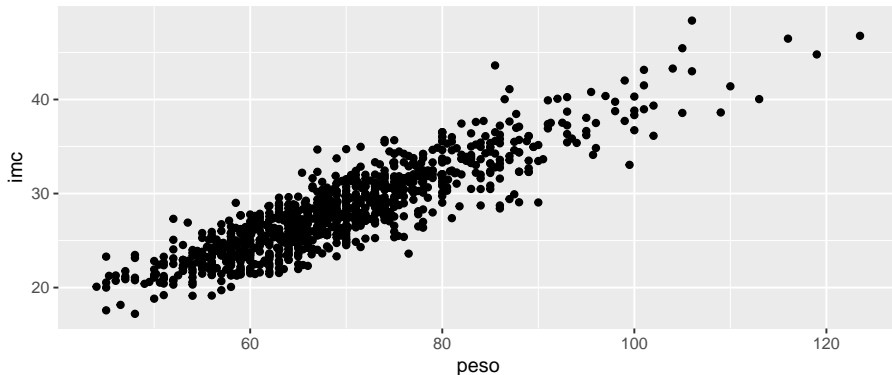
Example data

```
head(osteo[, c("peso", "imc")], n = 10)
```

```
##      peso  imc
## 1  70.0 24.80
## 2  53.0 22.94
## 3  64.0 25.64
## 4  78.0 30.09
## 5  56.0 22.72
## 6  63.5 21.97
## 7  86.0 33.18
## 8  61.5 22.87
## 9  60.5 24.23
## 10 64.0 28.83
```

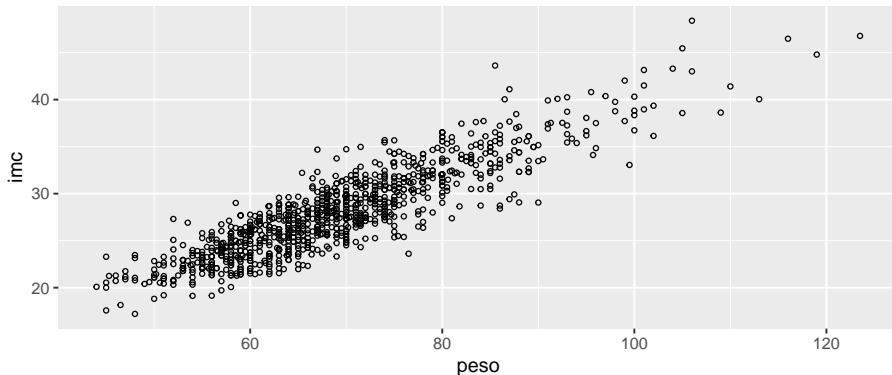
Scatterplot

```
ggplot(osteo, aes(x = peso, y = imc)) +  
  geom_point()
```



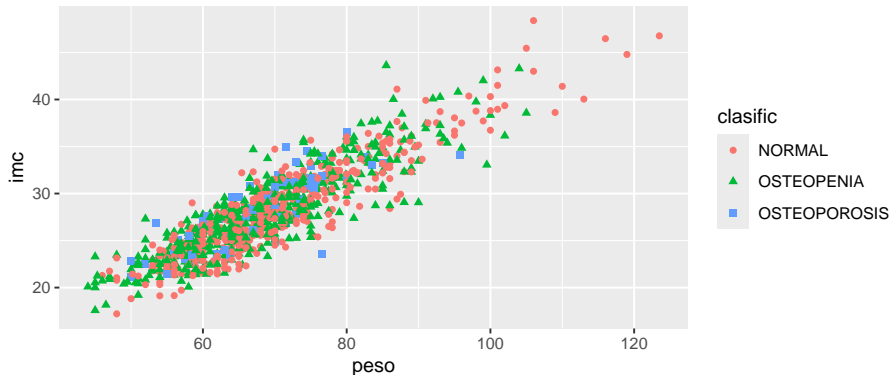
Customizing

```
ggplot(osteo, aes(x = peso, y = imc)) +  
  geom_point(size = 1, shape = 1)
```



Add information

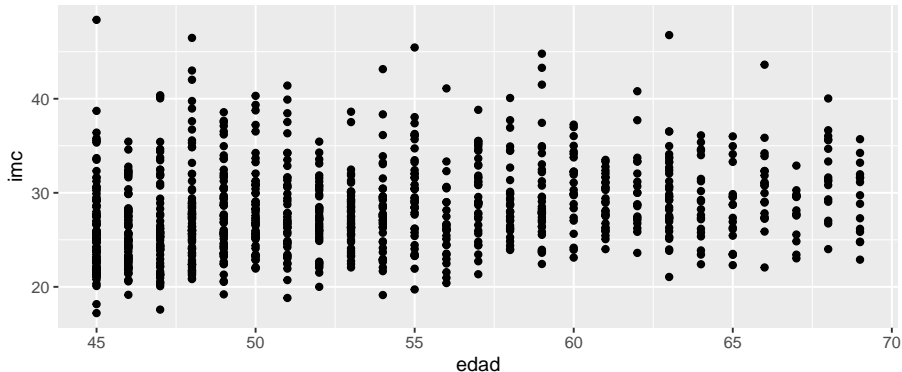
```
ggplot(osteo, aes(x = peso, y = imc, color = clasific, shape =  
  geom_point())
```



Other relation

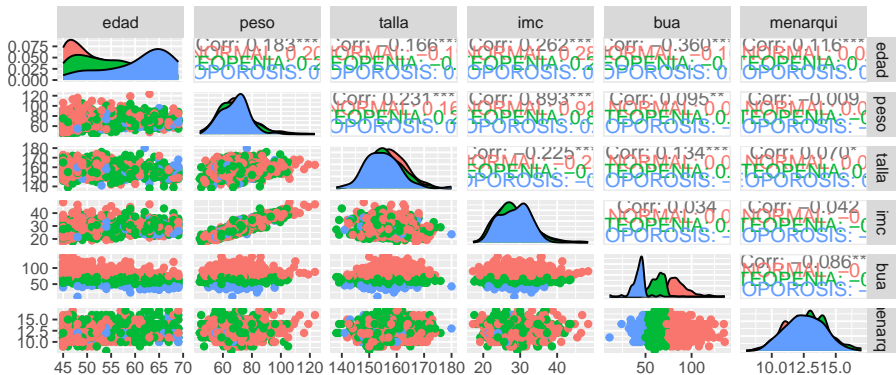
But not always the correlation is good!

```
ggplot(osteo, aes(x = edad, y = imc)) +  
  geom_point()
```



Multiple plots

```
library(GGally)
ggpairs(osteo, columns = c("edad", "peso", "talla", "imc", "bua", "menarquia"),
        ggplot2::aes(colour = clasific))
```



Section 6

Exercise I

Exercise I

Load the diabetes dataset

Study relation between `mort` and `tabac`

- **Build a contingency table between `mort` and `tabac`.**
- **Visualize the relationship between `mort` and `tabac`.**

Study relation between `mort` and `bmi`

- **Calculate Mean, median, and standard deviation of `bmi` by categories of `mort`.**
- **Visualize the relationship between `bmi` by `mort` status**

Study relation between `bmi` and `edad`

- **Visualize the relationship between age and BMI.**

Is there a relationship between the variables?

Section 7

Correlation

Main characteristics

Correlation analysis allows

- To study the way of relation between the two variables
- To quantify the intensity of relation

Correlation is not causation one thing does not causes the other

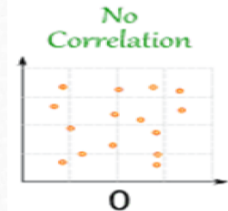
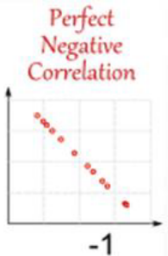
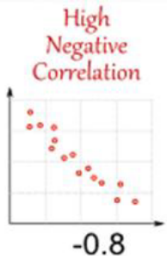
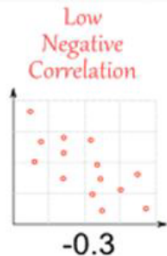
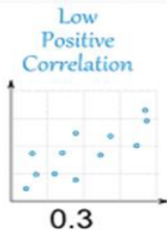
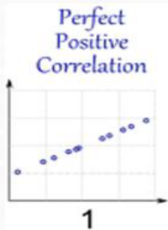
In the correlation analysis, the two variables have the same weight

The correlation coefficient measures the strength of a linear relation

Concepts

- Correlation quantifies strength and direction of relationship
- r from -1 to 1
 - $r > 0$: direct
 - $r < 0$: inverse
 - $r = 0$: no relation

Types correlation. Pearson



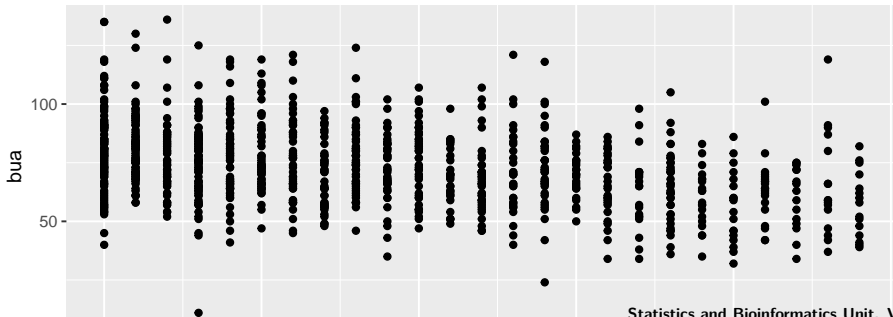
Pearson

```
cor(osteo$bua, osteo$edad, method = "pearson")
```

```
## [1] -0.3601883
```

Don't forget to look the graphic!!

```
ggplot(osteo, aes(x = edad, y = bua)) +  
  geom_point()
```



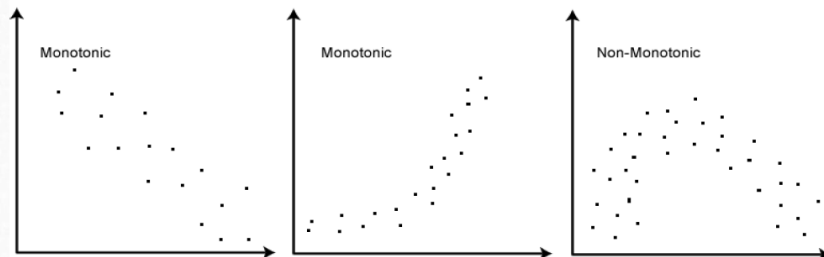
Spearman

- Pearson correlation coefficient is severely affected by outliers and if the relation is not linear

→ Better to use Spearman correlation coefficient (use the ranks between the numbers instead the values) to calculate the correlation coefficient

- Evaluates the monotonic relationship between the variables (not the linear relationship as Pearson does).

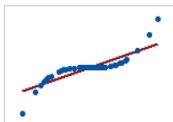
→ The variables tend to change together but not necessarily at a constant rate



Types of correlation



Pearson = +1, Spearman = +1



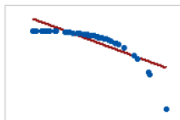
Pearson = +0.851, Spearman = +1



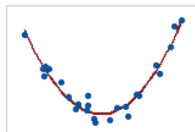
Pearson = -0.093, Spearman = -0.093



Pearson = -1, Spearman = -1



Pearson = -0.799, Spearman = -1



Coefficient of 0

Always examine a **scatterplot** to determine the form of the relationship

Example

```
cor(osteo$bua, osteo$edad, method = "spearman")
```

```
## [1] -0.3540295
```

Correlation Matrix

```
cor(osteo[, c("edad", "peso", "talla", "imc", "bua", "menarquie")])
```

```
##              edad              peso              talla              imc
## edad      1.0000000  0.182629245 -0.16635268  0.26173285 -0.3601883
## peso      0.1826292  1.000000000  0.23110585  0.89278635  0.094678365
## talla     -0.1663527  0.231105848  1.00000000 -0.22546438  0.13350207
## imc       0.2617329  0.892786346 -0.22546438  1.00000000 -0.04160766
## bua       -0.3601883  0.094678365  0.13350207  0.03415938  1.00000000
## menarquie 0.1159013 -0.008526465  0.07000284 -0.04160766 -0.085935539
##
##              menarquie
## edad      0.115901253
## peso     -0.008526465
## talla     0.070002843
## imc      -0.041607661
## bua      -0.085935539
## menarquie 1.000000000
```

Section 8

Summary

Summary

- Use `geom_bar` for categorical-categorical
- Use `geom_boxplot` for categorical-numerical
- Use `geom_point` for numerical-numerical
- Always include clear labels and titles

Section 9

Exercises II

Exercises II

- Calculate Pearson and Spearman correlations between `edat` and `bmi`.

Scatter plot of `edat` vs `bmi` colored by `CHD` status.

- Calculate the correlation between all pairs of numerical variables.
- Use the `GGally` package to visualize all pairwise relationships between variables using the `ggpairs()` function.

Section 10

Interactive and Impressive Plots

Interactive Scatter Plot with Tooltips

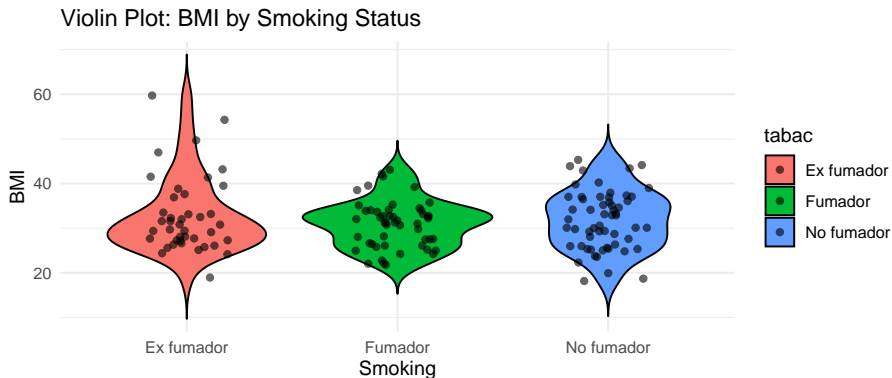
```
p_load(plotly)

p1 <- ggplot(diab, aes(x = edat, y = bmi, color = tabac, label = edat)) +
  geom_point(size = 3) +
  labs(title = "BMI vs Age (colored by Smoking)", x = "Age", y = "BMI")

# ggplotly(p1, tooltip = c("x", "y", "label", "color"))
```

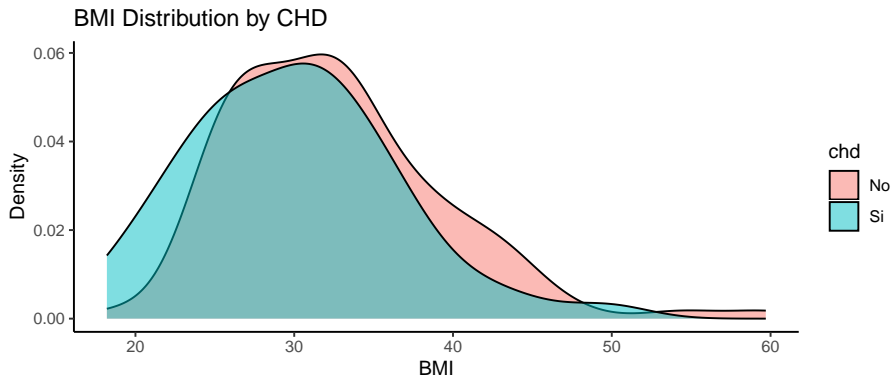
Violin Plot for BMI by Smoking Status

```
ggplot(diab, aes(x = tabac, y = bmi, fill = tabac)) +  
  geom_violin(trim = FALSE, color = "black") +  
  geom_jitter(width = 0.2, alpha = 0.6) +  
  labs(title = "Violin Plot: BMI by Smoking Status", x = "Smoking Status") +  
  theme_minimal()
```



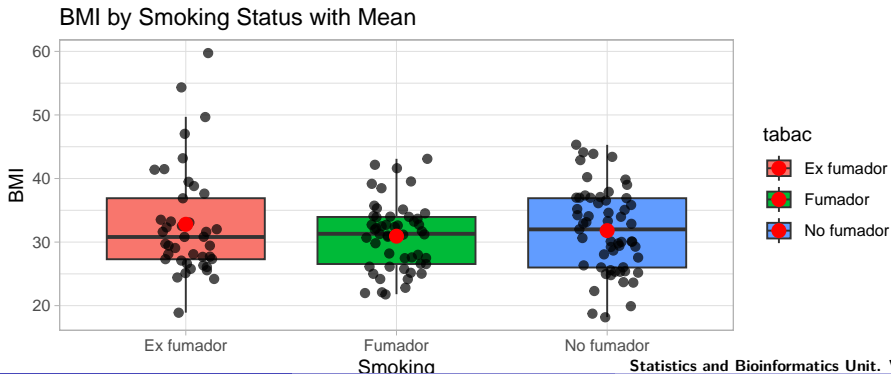
Density Plot by CHD Status

```
ggplot(diab, aes(x = bmi, fill = chd)) +  
  geom_density(alpha = 0.5) +  
  labs(title = "BMI Distribution by CHD", x = "BMI", y = "Density") +  
  theme_classic()
```



Boxplot + Points + Mean Line

```
ggplot(diab, aes(x = tabac, y = bmi, fill = tabac)) +  
  geom_boxplot(outlier.shape = NA) +  
  geom_jitter(width = 0.15, color = "black", size = 2, alpha = 0.5) +  
  stat_summary(fun = mean, geom = "point", shape = 20, size = 100, color = "red") +  
  labs(title = "BMI by Smoking Status with Mean", x = "Smoking") +  
  theme_light()
```



Section 11

Geospatial Visualization

World Map with Countries Colored

```
p_load(maps)

# Load world map data
world <- map_data("world")

# Plot a basic world map
ggplot(world, aes(x = long, y = lat, group = group)) +
  geom_polygon(fill = "lightblue", color = "white") +
  labs(title = "Basic World Map") +
  theme_minimal()
```

Basic World Map



Section 12

Summary

Summary

- Use `plotly` for interactive visualizations
- `GGally::ggpairs` offers compact overviews
- Combine multiple `ggplot2` layers for clarity and emphasis