Effects of Vitamin C on Tooth Growth in Guinea Pigs

Karen Yong

21 October 2015

Overview

In this study, we are going to analyze the ToothGrowth dataset which contains data on the length of odontoblasts (cells responsible for tooth growth) in 60 guinea pigs. Each animal received one of three dose levels of vitamin C (0.5, 1, and 2 mg/day) by one of two delivery methods, (orange juice or ascorbic acid (a form of vitamin C and coded as VC).

Exploring the Data

First, we load the 'ToothGrowth' dataset:

```
## 'data.frame':    60 obs. of  3 variables:
##  $ len : num  4.2 11.5 7.3 5.8 6.4 10 11.2 11.2 5.2 7 ...
##  $ supp: Factor w/ 2 levels "OJ","VC": 2 2 2 2 2 2 2 2 2 2 ...
##  $ dose: num  0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 ...
```

```
##    len supp dose
## 1  4.2   VC  0.5
## 2 11.5   VC  0.5
## 3  7.3   VC  0.5
## 4  5.8   VC  0.5
## 5  6.4   VC  0.5
## 6 10.0   VC  0.5
```

The ToothGrowth dataset consists of 60 observations and 3 variables:
- **len:** Tooth length in millimeters (numeric variable)
- **supp:** Supplement type (factor variable with 2 levels OJ and VC)
- **dose:** Dose in milligrams (numeric variable)

Basic Summary of Data

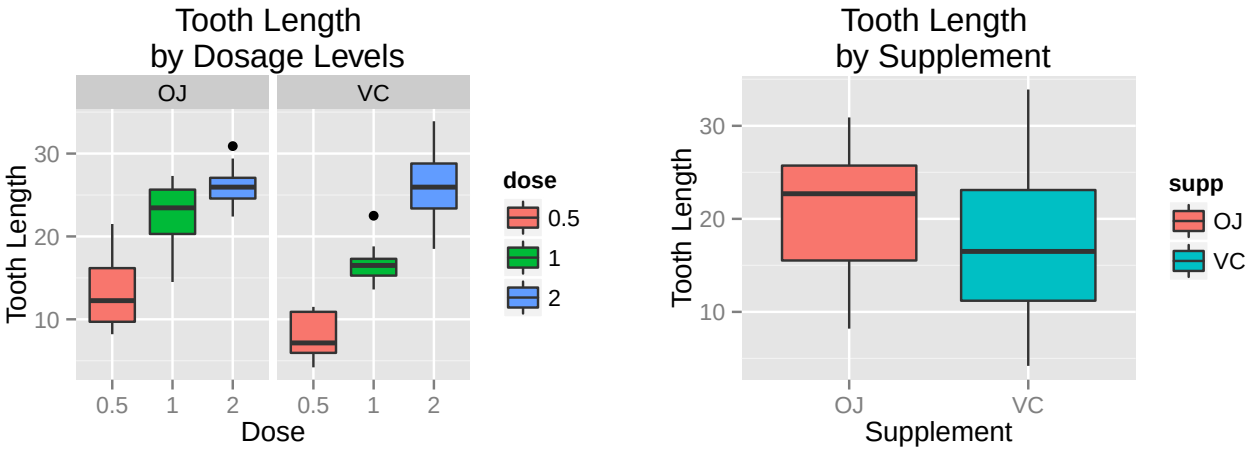
```
##       len        supp     dose
##  Min.   : 4.20   OJ:30   0.5:20
##  1st Qu.:13.07   VC:30   1  :20
##  Median :19.25           2  :20
##  Mean   :18.81
##  3rd Qu.:25.27
##  Max.   :33.90
```

The summary shows that the average tooth length for the sample of guinea pigs is **18.813** millimeters and a calculated standard deviation of **7.649** millimeters.

```
##
##      0.5  1  2
##   OJ  10 10 10
##   VC  10 10 10
```

From the table above, we can see that the 60 pigs were evenly treated in groups of 10 for each of the three dose levels of vitamin (0.5, 1 and 2 mg/day) and each delivery method (orange juice or ascorbic acid).

The plots below show tooth length differences across the OJ and VC groups by dosage level and supplement type:



The **"Tooth Length by Dosage Levels"** boxplot shows a notable positive interaction between the tooth length and dosage levels given to the guinea pigs. Meanwhile, the **"Tooth Length by Supplement"** boxplot indicates that in general, guinea pigs which received orange juice have a greater average tooth length than those which received ascorbic acid.

Hypothesis Tests and Confidence Intervals

Analysis of Dosage Levels

Null Hypothesis: Increasing the dosage level does not increase the tooth length

We will compare the dosage levels by using t-tests to check on our null hypothesis.

Test 1: Increase dosage from 0.5 to 1.0

```
##
##  Welch Two Sample t-test
##
## data:  dose.0.5$len and dose.1.0$len
## t = -6.4766, df = 37.986, p-value = 1.268e-07
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -11.983781  -6.276219
## sample estimates:
## mean of x mean of y
##    10.605    19.735
```

Test 2: Increase dosage from 1.0 to 2.0

```
##
##  Welch Two Sample t-test
##
```

```
## data:  dose.1.0$len and dose.2.0$len
## t = -4.9005, df = 37.101, p-value = 1.906e-05
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -8.996481 -3.733519
## sample estimates:
## mean of x mean of y
##    19.735    26.100
```

Conclusion from Tests 1 and 2

Test 1 resulted in a confidence interval of **-11.9837813, -6.2762187** (which does not contain zero) and a p-value of **1.268301e-07** which is smaller than 0.05. Test 2 resulted in a confidence interval of **-8.9964805, -3.7335195** (which also does not contain zero) and a p-value of **1.90643e-05** which is smaller than 0.05.

These 2 results indicate that we **can** reject the null hypothesis and conclude that increasing the dosage level **does** increase the tooth length.

Analysis of Supplement Types

Null Hypothesis: Vitamin C supplements alone do not have an effect on tooth length

```
##
##  Welch Two Sample t-test
##
## data:  len by supp
## t = 1.9153, df = 55.309, p-value = 0.06063
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.1710156  7.5710156
## sample estimates:
## mean in group OJ mean in group VC
##         20.66333         16.96333
```

Conclusion from Test

This test resulted in a confidence interval of **-0.1710156, 7.5710156** (which contains zero) and a p-value of **0.06063451** which is larger than 0.05.

This indicates that we **cannot** reject the null hypothesis that Vitamin C supplements alone do not have an effect on tooth length.

Assumptions

The following assumptions were made when running the tests:

- We are working with Independent and Identically Distributed (IID) samples and members of the sample population (i.e. 60 guinea pigs) are representative of the entire population of guinea pigs.
- We are working with non-paired data and as such, we are performing a non-paired test.
- The variances are not equal and therefore we are not using pooled variances to estimate the variance, instead the Welch approximation is used.

Appendix

The codes to the report can be found here.

```
#Exploring the Data - load required libraries
library(dplyr)
library(ggplot2)
library(grid)
library(gridExtra)

#Load dataset and explore data
data("ToothGrowth")           #load dataset
str(ToothGrowth)
ToothGrowth$dose <- as.factor(ToothGrowth$dose)   #convert dose from num to factor
head(ToothGrowth)

#Basic summary of data and calculate standard deviation for tooth length
summary(ToothGrowth)
avg.len <- round(mean(ToothGrowth$len), 3)
sd.len <- round(sd(ToothGrowth$len), 3)

#Create table of test subjects by delivery methods and dosage levels
table(ToothGrowth$supp, ToothGrowth$dose)

#Plot 2 boxplots - Tooth Length by Dosage Levels & Tooth Length by Supplement Type
gdose <- ggplot (ToothGrowth, aes(dose,len, fill=dose)) + geom_boxplot()
          + labs(x="Dose", y="Tooth Length",title="Tooth Length \n by Dosage Levels")
          + facet_grid(.~supp)

gsupp <- ggplot(ToothGrowth, aes(supp,len,fill=supp))+geom_boxplot()
          + labs(x="Supplement", y="Tooth Length",title="Tooth Length \n by Supplement")

grid.arrange(gdose, gsupp, ncol=2)

#Create subsets for each dosage level
dose.0.5 <- filter(ToothGrowth, dose == 0.5)
dose.1.0 <- filter(ToothGrowth, dose == 1.0)
dose.2.0 <- filter(ToothGrowth, dose == 2.0)

#T-test for effects of dosage level on tooth length
##Test 1 - Increase dosage from 0.5 to 1.0
test1 <- t.test(dose.0.5$len, dose.1.0$len, paired=F, var.equal=F)
test1
##Test 2 - INcrease dosage from 1.0 to 2.0
test2 <- t.test(dose.1.0$len, dose.2.0$len, paired=F, var.equal=F)
test2

#T-test for effects of supplements on tooth length
test3 <- t.test(len ~ supp, data = ToothGrowth, paired=F, var.equal=F)
test3
```