Effect of Vitamin C dose and delivery method on guinea pig tooth growth

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1 Synopsis

In this report, we analyze the effect of vitamin C dose amount and delivery method through supplements on the tooth growth of guinea pigs. Through hypothesis testing, we find that:

1. Increasing the dose of vitamin C increases the tooth growth.
2. The delivery method for vitamin C does not affect tooth growth.

2 Exploratory Data Analysis

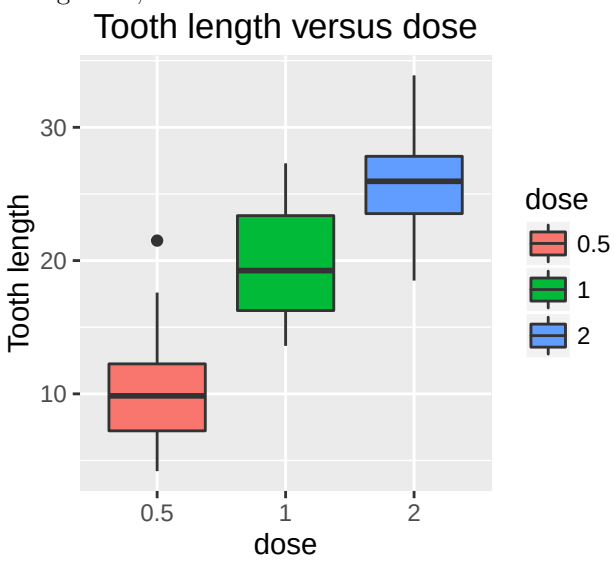
Let's first load the data and get some basic information from the data set. We also transform the dose variable to a factor, which will be easier to use later on.

```
## '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 ...
##  $ delivery: Factor w/ 2 levels "OJ","VC": 2 2 2 2 2 2 2 2 2 2 ...
##  $ dose    : Factor w/ 3 levels "0.5","1","2": 1 1 1 1 1 1 1 1 1 1 ...
```

We are looking at 60 observations of tooth length where there are 2 delivery methods (orange juice (OJ) and ascorbic acid (VC)) and 3 dose levels (0.5, 1, 2).

2.1 Visualisation of the effect of dose and the delivery method on tooth growth

As shown in Figure 1, there might be an effect of the dose amount on the tooth growth. As shown in Figure 2, there does not seem to be much of an effect of the delivery method on tooth growth.



For each delivery method, let's look at the effect of the dose on the tooth growth.

Our exploratory analysis seems to indicate that increasing the dose amount increases the tooth length. Using orange juice might boost the tooth length at lower doses compared to ascorbic acid but that effect looks like it dissappears for a dose of 2 mg.

3 Questions and Key Assumptions

Our analysis will seek to answer two questions:

1. Does the dose amount change the tooth growth?
2. Does the delivery method change the tooth growth?

For our analysis to hold, we make the following key assumptions about the data:

- We are dealing with independent random populations with different variances.
- All the guinea pigs used in this experiment are similar.
- The experiments were done as a double-blind test (the experimenters did not know which guinea pigs received which treatments).

4 Hypothesis Tests

4.1 Does the dose amount change the tooth growth?

The null hypothesis is that the dose amount does not affect the tooth growth, i.e. for the difference doses, the difference in the means is zero. The alternative the is that the dose amount does affect the tooth growth. We perform hypothesis testing between each of the difference doses to see if we can reject the null hypothesis.

- Testing the difference of means between dose 0.5 mg and 1 mg:

```
dose_test12 <- t.test(len ~ dose, data = df[df$dose %in% c(0.5,1),],
                      paired = FALSE, var.equal = FALSE)
```

The resulting confidence interval is [-11.9837813, -6.2762187] and does not contain zero.

- Testing the difference of means between dose 1 mg and 2 mg:

```
dose_test23 <- t.test(len ~ dose, data = df[df$dose %in% c(1,2),],
                      paired = FALSE,var.equal = FALSE)
```

The resulting confidence interval is [-8.9964805, -3.7335195] and does not contain zero.

- Testing the difference of means between dose 0.5 mg and 2 mg:

```
dose_test13 <- t.test(len ~ dose, data = df[df$dose %in% c(0.5,2),],
                      paired = FALSE, var.equal = FALSE)
```

The resulting confidence interval is [-18.1561665, -12.8338335] and does not contain zero.

None of the confidence intervals contain zero so we can reject the null hypothesis. Increasing the dose does indeed increase the tooth growth.

4.2 Does the delivery method change the tooth growth?

The null hypothesis is that the delivery method does not affect the tooth growth, i.e. the difference in the means is zero. The alternative then is that the delivery method does affect the tooth growth. We perform hypothesis testing to see if we can reject the null hypothesis:

```
delivery_test <- t.test(len ~ delivery, data = df, paired = F, var.equal = F)
```

The resulting confidence interval is [-0.1710156, 7.5710156]. Since this interval contains zero, we can not reject the null hypothesis. This means that the delivery method does not affect tooth growth.

5 Conclusions

Under our assumptions, we can answer both our questions:

1. Increasing the dose of vitamin C increases the tooth growth.
2. The delivery method for vitamin C does not affect tooth growth.

6 Appendix

The version history of this document can be found at the GitHub repository page. Here is the full code used in this document.

```
## ----echo = FALSE, message=FALSE, warning=FALSE--------------------------
library(dplyr)
library(ggplot2)
df <- ToothGrowth
df <- df %>%
    mutate(dose = as.factor(dose)) %>%
    rename(delivery = supp)
str(df)

## ----echo = FALSE, fig.cap="Tooth length versus dose"---------------------
ggplot(data=df, aes(x=dose,y=len)) +
    geom_boxplot(aes(fill=dose)) +
    labs(x = "dose",
         y="Tooth length",
         title="Tooth length versus dose");

## ----echo = FALSE,  fig.cap="tooth length versus delivery method"--------
ggplot(data=df, aes(x=delivery,y=len)) +
    geom_boxplot(aes(fill=delivery)) +
    labs(x = "delivery",
         y="Tooth length",
         title="Tooth length versus delivery");

## ----echo = FALSE---------------------------------------------------------
ggplot(data=df, aes(x=dose,y=len)) +
    geom_boxplot(aes(fill=dose)) +
    facet_wrap(~ delivery) +
    labs(x = "delivery",
         y="Tooth length",
         title="Boxplot of tooth length");

## -------------------------------------------------------------------------
dose_test12 <- t.test(len ~ dose, data = df[df$dose %in% c(0.5,1),],
                      paired = FALSE, var.equal = FALSE)

## -------------------------------------------------------------------------
dose_test23 <- t.test(len ~ dose, data = df[df$dose %in% c(1,2),],
                      paired = FALSE,var.equal = FALSE)

## -------------------------------------------------------------------------
dose_test13 <- t.test(len ~ dose, data = df[df$dose %in% c(0.5,2),],
                      paired = FALSE, var.equal = FALSE)

## -------------------------------------------------------------------------
delivery_test <- t.test(len ~ delivery, data = df, paired = F, var.equal = F)

## ----code=readLines(knitr::purl('./tooth_growth.Rmd', documentation = 1)), eval = FALSE----
## NA
```