Vitamin C promotes Tooth Growth in Guinea Pigs

MOHAMMAD SHADAN

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SYNOPSIS

Tests were performed on 60 different guinea pigs and response in the length of odontoblasts (cells responsible for tooth growth) were observed (URL)
- 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, OJ or ascorbic acid, VC (a form of vitamin C)

1. Load the ToothGrowth data and perform some basic exploratory data analysis

```
data(ToothGrowth)                    #Loading dataset ToothGrowth
tg <- as.data.frame(ToothGrowth)
tg$dose <- as.factor(tg$dose)        #Converting "dose" to factor variable
```

Exploratory Data Analysis

Variation in Length of odontoblasts cells based on Dosage (mg/day) :
- For Dosage of 0.5 and 1, Mean length is more for Orange Juice compared to Ascorbic Acid
- For Dosage of 2.0, Mean length is almost same for Orange Juice and Ascorbic Acid

Refer Code 1 and Figure 1 in APPENDIX for R Script and Plot on which the above observations are based

Variation in Length of odontoblasts cells based on Delivery Method (OJ or VC) :
- For Orange Juice as well as Ascorbic Acid the Mean length increases as the dosage amount is increased from 0.5 to 2 mg/day

Refer Code 2 and Figure 2 in APPENDIX for R Script and Plot on which the above observations are based

Please note, similar results will be reflected by Hypothesis Tests also

2. Provide a basic summary of the data.

```
summary(tg)    #Summary of ToothGrowth Dataset
```

```
##       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
```

```
str(tg)        #Dimension and Field Type Details
```

```
## '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: Factor w/ 3 levels "0.5","1","2": 1 1 1 1 1 1 1 1 1 1 ...
```

3. Use confidence intervals and/or hypothesis tests to compare tooth growth by supp and dose

Assumptions :
- Variances are unequal
- Test subjects are not Paired (as tests were done on 60 different Guinea Pigs)
- Distribution is Normal

Null Hpothesis, H0 : Mean of Length are same i.e. Difference of mean is Zero and thus effects of Delivery Methods(supp) or Dosage are same
Alternate Hypothesis, Ha : Mean of Length are not same i.e. Difference of mean is not Zero and thus effects of Delivery Methods(supp) or Dosage are different

Considering 95 % Confidence Interval,
if **pValue > 0.05** : we accept the Null Hypothesis, thus delivery methods or dosage have almost same effect on Tooth Growth
if **pValue < 0.05** : we reject the Null Hypothesis, thus delivery methods or dosage have different effect on Tooth Growth

Firstly, comparing Tooth Growth by Dose (0.5, 1, 2 mg/day)

```
#Subsetting the data based on pair of two dose each, (0.5, 1), (0.5,2), (1,2)
dose0.51 <- subset(tg, tg$dose==c(0.5,1))
dose0.52 <- subset(tg, tg$dose==c(0.5,2))
dose12   <- subset(tg, tg$dose==c(1,2))
```

Compare effect of dose level 0.5 and 1 mg/day on Tooth Growth

```
ttest0.51 <- t.test(dose0.51$len~dose0.51$dose, conf = 0.95, paired = FALSE, var.equal = FALSE);
cat("p.value :", ttest0.51$p.value, " |   Conf. Interval : ", ttest0.51$conf.int)
```

```
## p.value : 0.0002951967  |   Conf. Interval :  -14.43327 -5.20673
```

Since pValue < 0.05, we reject the Null Hypothesis, thus both dose levels have different effect on Tooth Growth

Compare effect of dose level 0.5 and 2 mg/day on Tooth Growth

```
ttest0.52 <- t.test(dose0.52$len~dose0.52$dose, conf = 0.95, paired = FALSE, var.equal = FALSE)
cat("p.value :", ttest0.52$p.value, " |   Conf. Interval : ", ttest0.52$conf.int)
```

```
## p.value : 9.361615e-07  |   Conf. Interval :  -19.72833 -10.93167
```

Since pValue < 0.05, we reject the Null Hypothesis, thus both dose levels have different effect on Tooth Growth

Compare effect of dose level 1 and 2 mg/day on Tooth Growth

```
ttest12 <- t.test(dose12$len~dose12$dose, conf = 0.95, paired = FALSE, var.equal = FALSE)
cat("p.value :", ttest12$p.value, " |   Conf. Interval : ", ttest12$conf.int)
```

```
## p.value : 0.001709878  |   Conf. Interval :  -10.89999 -2.980007
```

Since pValue < 0.05, we reject the Null Hypothesis, thus both dose levels have different effect on Tooth Growth

Secondly, comparing Tooth Growth by Supp (Delivery Method, Orange Juice(OJ) and Ascorbic Acid (VC))

```
#Subsetting Data based on dosage
supp0.5 <- subset(tg, tg$dose==.5); supp1   <- subset(tg, tg$dose==1);
supp2   <- subset(tg, tg$dose==2)
```

Comparing effect of OJ and VC on Tooth Growth at Dosage of .5 mg/day

```
ttest0.5 <- t.test(supp0.5$len~supp0.5$supp, conf = 0.95, paired = FALSE, var.equal = FALSE);
cat("p.value :", ttest0.5$p.value, " |   Conf. Interval : ", ttest0.5$conf.int)
```

```
## p.value : 0.006358607  |   Conf. Interval :  1.719057 8.780943
```

Since pValue < 0.05, we reject the Null Hypothesis, thus both delivery methods have different effect on Tooth Growth

Comparing effect of OJ and VC on Tooth Growth at Dosage of 1 mg/day

```
ttest1 <- t.test(supp1$len~supp1$supp, conf = 0.95, paired = FALSE, var.equal = FALSE);
cat("p.value :", ttest1$p.value, " |   Conf. Interval : ", ttest1$conf.int)
```

```
## p.value : 0.001038376  |   Conf. Interval :  2.802148 9.057852
```

Since pValue < 0.05, we reject the Null Hypothesis, thus both delivery methods have different effect on Tooth Growth

Comparing effect of OJ and VC on Tooth Growth at Dosage of 2 mg/day

```
ttest2 <- t.test(supp2$len~supp2$supp, conf = 0.95, paired = FALSE, var.equal = FALSE);
cat("p.value :", ttest2$p.value, " |   Conf. Interval : ", ttest2$conf.int)
```

```
## p.value : 0.9638516  |   Conf. Interval :  -3.79807 3.63807
```

Since pValue > 0.05, we accept the Null Hypothesis, thus both delivery methods almost same effect on Tooth Growth

4. State your conclusions and the assumptions needed for your conclusions

Assumptions :
- Since tests were done on 60 different Guinea Pigs thus they are considered independent (not Paired)
- Variances are unequal
- Normal Distribution is considered

Conlcusion based on Exploratory Analysis and Hypothesis Test :
- Mean length of odontoblasts cells is more when delivery method is Orange Juice (OJ) compared to Ascorbic Acid (VC) when Dosage of 0.5 and 1 mg/day is given
- Mean length of odontoblasts cells is almost same for Orange Juice and Ascorbic Acid when Dosage of 2.0 mg/day is given
- Given Orange Juice or Ascorbic Acid the Cell length increases as the dosage amount is increased from 0.5 to 2 mg/day

Report Analysis was based on elaboration of the below points as advised in the assigment :
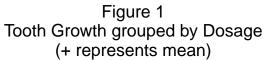* Load the ToothGrowth data and perform some basic exploratory data analyses
* Provide a basic summary of the data
* Use confidence intervals and/or hypothesis tests to compare tooth growth by supp and dose
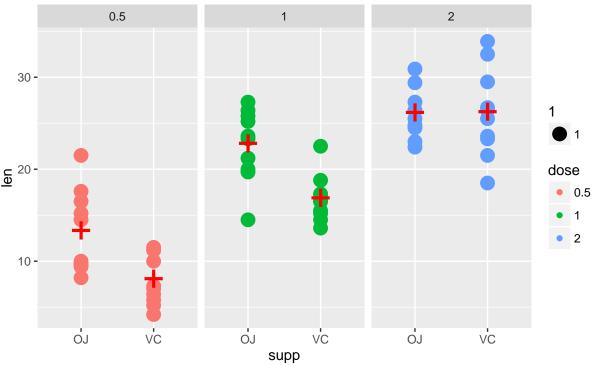* State your conclusions and the assumptions needed for your conclusions

Below are Codes and Plots used to deduce observations for Exploratory Data Analysis on Page 1:

Code 1

```r
p <- ggplot(tg, aes(x=supp, y=len, col=dose))
p <- p + geom_point(aes(size=1))
p <- p + facet_grid(.~dose)
p <- p + stat_summary(fun.y=mean, geom="point", shape="+", size=9, col = "red")
p <- p + labs(title="Figure 1\n Tooth Growth grouped by Dosage \n(+ represents mean)")
```
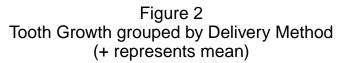
Figure 1

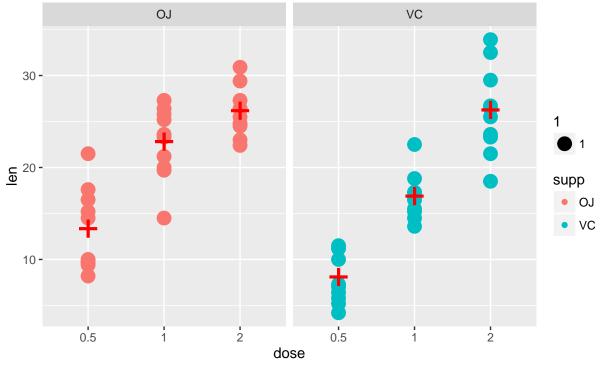Variation in Cell Length based on of Dosage (mg/day) :
- For Dosage of 0.5 and 1, Mean length is more for Orange Juice (OJ) compared to Ascorbic Acid (VC) - For Dosage of 2.0, Mean length is almost same for Orange Juice and Ascorbic Acid

Code 2

```
q <- ggplot(tg, aes(x=dose, y=len, col=supp))
q <- q + geom_point(aes(size=1))
q <- q + facet_grid(.~supp)
q <- q + stat_summary(fun.y=mean, geom="point", shape="+", size=9, col = "red")
q <- q + labs(title="Figure 2\n Tooth Growth grouped by Delivery Method \n(+ represents mean)")
```

Figure 2

Figure 2
Tooth Growth grouped by Delivery Method
(+ represents mean)

Variation of Cell Length based on Delivery Method (OJ or VC) :
- For Orange Juice as well as Ascorbic Acid the Mean length increases as the dosage amount is increased
from 0.5 to 2 mg/day