Ametop Alone vs. Ametop and Vapocoolant Spray to Reduce IV Insertion Pain for Pediatric Patients

Dr. Louis Scheepers
Investigator and Pediatric Anesthesiologist, BC Children's Hospital, Clinical Associate Professor, Department of Anesthesiology, Pharmacology & Therapeutics, Faculty of Medicine, UBC

STAT 450: Case Studies in Statistics
Instructors: Keegan Korthauer, Melissa Lee, Rodolfo Lourenzutti
Teaching Assistant: Jonathan Agyeman
Students: Fabiola Grace, Maggie Ruan, Runhe Guo, Yimin You
Department of Statistics, The University of British Columbia

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Summary

This study aims to improve pain management for pediatric patients during intravenous (IV) insertions, a common yet distressing procedure. It investigates the effectiveness of two treatments: Ametop gel as a standalone treatment and the combination of Ametop and vapocoolant spray. A randomized controlled experiment is used to assess the pain levels of pediatric patients during IV insertions after receiving either Ametop gel alone or a combination of Ametop gel and vapocoolant spray. A two-sample t-test is used to compare changes in pain levels between the two treatment groups, and a linear regression is performed to examine the association between age and pain level. The two-sample t-test indicates that adding vapocoolant spray significantly reduces the discomfort of IV insertions in pediatric patients. The regression analysis reveals more pain for younger children and the addition of vapocoolant spray decreases the pain much more for younger children. The evaluation of the number of IV attempts and side effects shows that adding vapocoolant spray does not increase the number of IV attempts. Overall, the combination of Ametop and vapocoolant spray is more effective than Ametop alone, particularly for younger children.

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1. Introduction

Intravenous (IV) insertion is an essential medical procedure that is frequently associated with discomfort and pain, particularly in pediatric patients. To mitigate this, BC Children's Hospital currently utilizes Ametop gel, a topical anesthetic that numbs the skin prior to needle insertion, to alleviate pain and ease the process. Despite its efficacy, Ametop gel alone may not suffice, especially in individuals with heightened sensitivity to pain. The hospital is considering the additional use of a vapocoolant spray. This spray acts rapidly to cool and numb the skin and is hypothesized to provide better pain relief during IV insertions.

To evaluate the effectiveness of adding a vapocoolant spray to Ametop gel, we summarized two research questions and formulated the corresponding statistical analysis. The objectives are as follows:

- Does the addition of a vapocoolant spray to Ametop reduce pediatric discomfort during IV insertions more than Ametop alone? To assess this, the mean difference in pain levels experienced by pediatric patients is examined when using Ametop alone versus the combination of Ametop with a vapocoolant spray during IV insertions.
- Does age and randomization group (control vs. study) affect the pain level during IV insertions? To examine this, the relationship between patient age and randomization group to the pain level is analyzed.

Furthermore, we aim to analyze whether the use of vapocoolant spray affects the number of IV attempts and to assess the incidence of side effects among pediatric patients. The following sections detail the data description, statistical methods, and the results derived from our analysis.

2. Data description

Data were collected from 240 pediatric patients undergoing intravenous (IV) insertion. Some participants withdrew from the study for reasons such as itchiness from Ametop and conversion to inhalation induction. We excluded 17 observations that withdrew from the study, focusing solely on the remaining 223 observations.

The dataset has several key variables, categorized as follows:

- **Patient Demographics:** This includes variables such as age and gender. Age (5-16 years old) is particularly important for determining if responses to pain management strategies vary among different pediatric age groups.
- **Randomization Groups:** Patients are randomly assigned to one of two groups: Group 1, receiving Ametop alone (the control group), and Group 2, receiving both Ametop and the vapocoolant spray (the study group). This randomization is essential for assessing the comparative effectiveness of the two treatment approaches.
- **FPS-R Scores:** Patients' pain levels are rated using the Faces Pain Scales-Revised scale from 0 (no pain) to 10 (worst pain possible), offering a measurable discomfort level during IV insertion. This score determines the primary outcome, that is, the effectiveness of different treatment approaches.
- **Number of IV Attempts:** This variable represents the number of attempts needed for a successful IV insertion, reflecting the procedural difficulty and its potential correlation with patient discomfort.
- **Side Effects:** Side effects, including the appearance of redness, sensations of itchiness, puffiness, or pain, are recorded to check if participants' experience of any severe adverse reactions to the treatment.
- **Observer Scores:** During data collection, observer scores are also recorded, where the patients' discomfort is observed by a nurse on a 3-point scale: 'none,' 'slight pain,' or 'severe pain.' This validates the primary outcome, FPS-R Scores, ensuring a reliable pain assessment in children who might not fully understand the FPS-R pictogram provided. In the subsequent statistical analysis, we will concentrate on FPS-R Scores and not on the observer scores.

Other than these variables, there are nine controlled variables, encompassing specifications such as an age range of 5-16 years and whether the patient has a needle phobia, to guarantee that participants' eligibility in accordance with the criteria.

3. Methods

Several statistical methods are employed to address our research objectives. A two-sample t-test is used to assess the primary objective of comparing the difference in mean FPS-R scores between the control and study groups. For the first secondary objective, a linear regression analysis is performed to explore the relationship between age and randomization groups on FPS-R scores. To illustrate the second secondary objective, a bar graph is presented depicting the number of IV attempts across the two groups. Lastly, a pie chart is used to display the distribution of side effects among all participants, addressing the third secondary objective.

3.1 Main Objective: To assess the mean difference in pain levels experienced by pediatric patients when using Ametop alone versus the combination of Ametop with a vapocoolant spray during IV insertions

The exploratory data analysis examines the distribution of the target response variable, the FPS-R scores. Figure 1 displays comparative boxplots for the control and study groups, illustrating the distribution of these FPS-R scores.

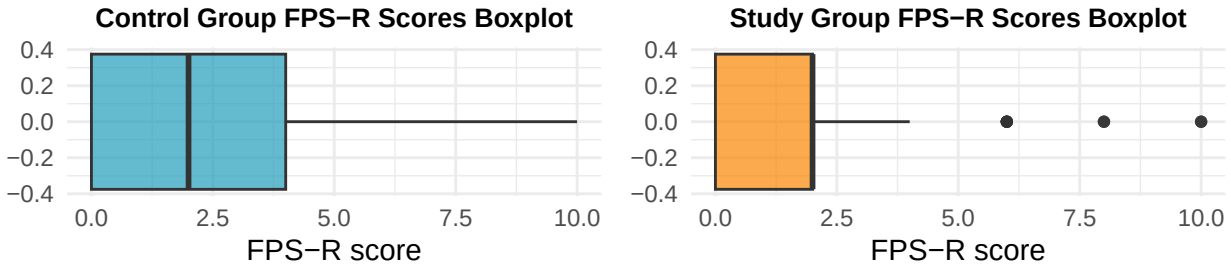


Figure 1: FPS-R Scores Boxplots of Control (Ametop) and Study (Ametop + Spray) Group

Figure 1 shows that the median FPS-R score for both the control and study groups is 2. The study group displays a higher concentration of scores at FPS-R scores 0 and 2, resulting in a right-skewed distribution, and FPS-R scores 6 and above are considered outliers.

The two-sample t-test is used to assess whether the addition of vapocoolant spray reduces discomfort. This test is applied under the assumption that the differences between the means of the control and study groups follow a normal distribution. Although the dataset itself is not normally distributed, the sample size is large enough that, according to the Central Limit Theorem (CLT), the t-test can still be used. The null hypothesis asserts that the mean FPS-R scores for both groups are the same, while the alternative hypothesis is that the mean FPS-R score is lower for the study group that is using the vapocoolant spray. Consequently, a one-sided t-test is used, and the level of significance is set at 5%.

3.2 Secondary Objective 1: To determine the relationship between age and randomization (control and study) groups on FPS-R scores

A linear regression analysis is employed to address the second statistical question concerning the impact of age and randomization (study and control) groups on FPS-R scores. This approach explores the relationship between age, the randomization group, and the combined effect of both age and the randomization group on the FPS-R scores. To construct the model, the assumptions underlying linear regression are tested. These assumptions include linearity, independence, homoscedasticity, and normality of residuals. The QQ plot shows a heavy tailed distribution that indicates that the data do not appear to be exactly normally distributed. However, since the focus is on inference rather than prediction, and considering the Central Limit Theorem (CLT) assumption, we proceeded with the use of linear regression for our analysis. The statistical significance of the model coefficients is assessed with a p-value threshold of 5% significance level.

3.3 Secondary Objective 2: To explore the change in the number of IV insertion attempts when using Ametop alone versus the combination of Ametop with a vapocoolant spray

To investigate whether the combination of Ametop with a vapocoolant spray increases the number of IV insertion attempts compared to the application of Ametop alone, we use summary statistics and visually analyze the data using plots. These help us understand the distribution and average number of IV attempts in both the control group (Ametop alone) and the study group (Ametop with vapocoolant spray).

3.4 Secondary Objective 3: To explore the incidence of side effects due to Ametop

The exploratory data analysis is conducted on all 240 participants of the study, including those who withdrew prior to the study's completion. This approach accounts for patients who withdrew due to experiencing side effects, thereby preserving all incidences of side effects in the dataset.

The observed side effects are categorized into four distinct groups: "Redness," "Redness and Itching," "Puffiness," and "Pain" to facilitate the quantitative analysis of side effects. The results are summarized with a pie chart and frequency table.

4. Results

This section presents the results of our data analysis. We compare the p-value to the significance level for the two-sample t-test. Then, we examine a linear regression model on the response variable, using their estimates and p-values. The results are presented in Table 1, Table 2, Figure 2, Figure 3 and Figure 4.

4.1 Main Objective: To assess the mean difference in pain levels experienced by pediatric patients when using Ametop alone versus the combination of Ametop with a vapocoolant spray during IV insertions

For the main objective, a two-sample t-test is performed on the two randomization (control and study) groups and FPS-R scores. The results of the test, including the group means, standard error, and p-value, are shown in Table 1 below.

Table 1: Control Group and Study Group Two-Sample T-Test

Control Group Mean	Study Group Mean	Standard Error	P-value
2.6909	1.9292	0.3779	0.02258

The mean FPS-R score for the group with Ametop alone is 2.6909, while the mean FPS-R score for the group with the combination of Ametop and vapocoolant spray is 1.9292. The test yields a p-value of 0.02258, which is below the 5% significance threshold. This allows us to reject the null hypothesis at the 5% significance level, indicating a difference in the mean FPS-R scores between the control and study groups. These results support the hypothesis that adding vapocoolant spray may reduce discomfort in pediatric patients.

4.2 Secondary Objective 1: To determine the relationship between age and randomization (control and study) groups on FPS-R scores

For the second statistical question, a linear regression model is built using age, randomization group, and the combined effect of both age and randomization group to find their relationship with the FPS-R scores. The results of the linear regression model are shown in Table 2 below.

Table 2: Linear Regression Model Output

Term	Estimate	Standard Error	P-value
(Intercept)	4.1459	0.7175	$< .0001$
Age	-0.1640	0.0751	0.0301
Study Group	-1.6818	1.0279	0.1032
Age:Study Group	0.1098	0.1024	0.2847

Our findings indicate that age is a significant factor in FPS-R scores, as suggested by the p-value in Table 2. The model suggests that older children experience less pain during IV insertion. With each additional year of age, the FPS-R scores decrease by an average of 0.1640 in the control group and by an average of 0.0542 in the study group.

Compared to the control group, children in the study group experienced a greater decrease in FPS-R scores by an average of 1.6818. This matches our earlier findings for the main objective that vapocoolant spray is effective in reducing pain levels in IV insertions for children.

Although the estimates for the randomization group and the interaction between age and the randomization group are not statistically significant, they still provide valuable insights. From the estimates in Table 2, a linear regression model is created which represents the average FPS-R scores among children according to their age and group allocation, as depicted in Figure 2.

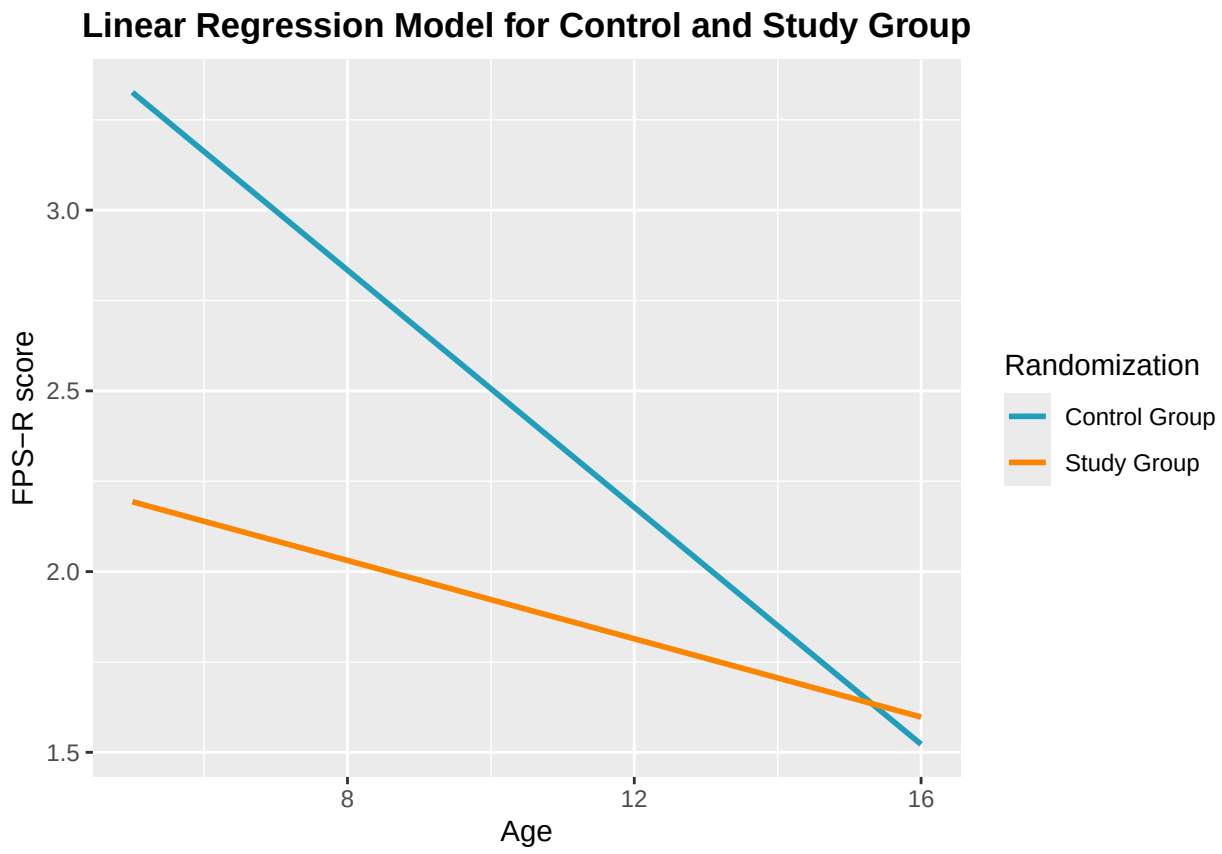


Figure 2: Linear Regression Model for Control and Study Group

Figure 2 shows that, on average, the study group experiences less pain compared to the control group, which exhibits a much steeper decrease in FPS-R scores. As age increases, the gap in FPS-R score reductions between the study and control groups narrows, suggesting that the vapocoolant spray is more effective in reducing pain for younger children. Notably, the two lines intersect at around age 15, indicating that the efficacy of the vapocoolant spray in reducing pain may not be as pronounced in children aged 15 and 16.

4.3 Secondary Objective 2: To explore the change in the number of IV insertion attempts when using Ametop alone versus the combination of Ametop with a vapocoolant spray

Figure 3 below represents the number of IV insertion attempts in the control group compared to the study group with vapocoolant spray.

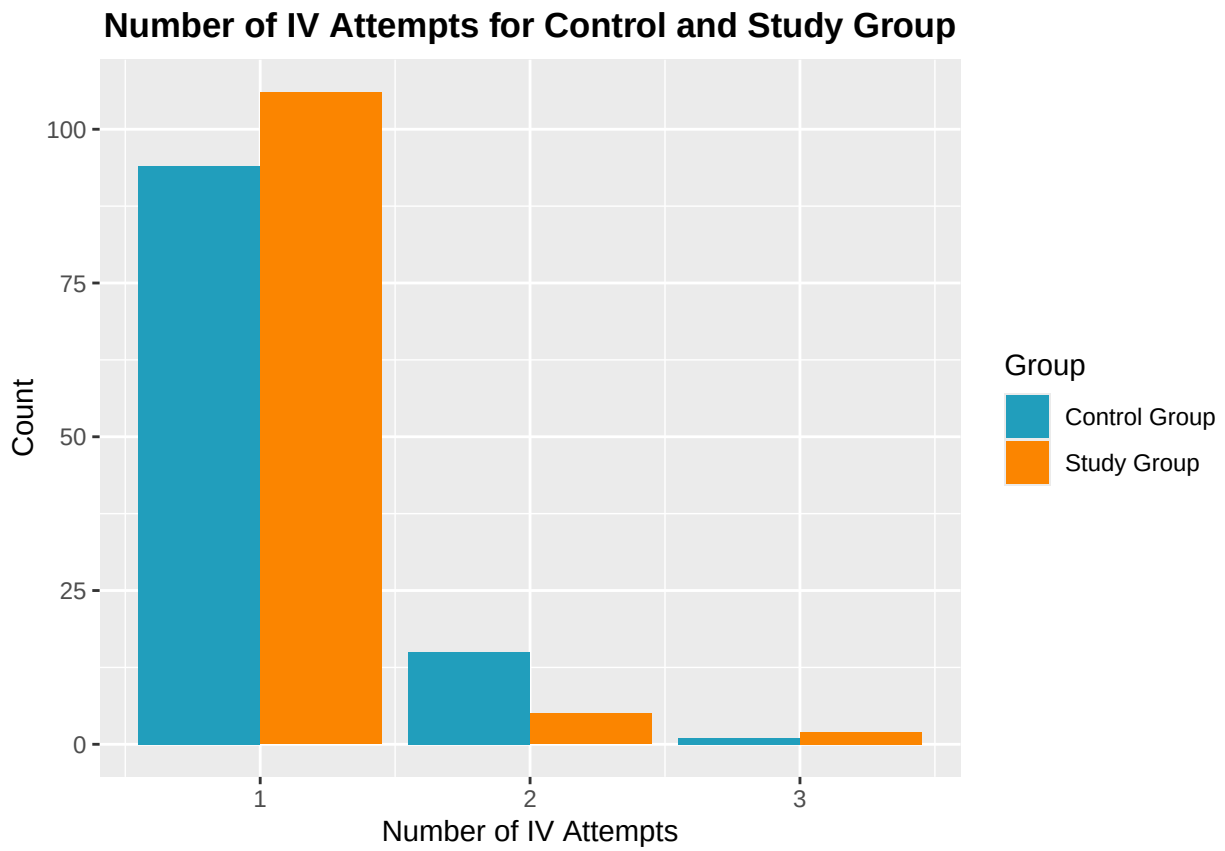


Figure 3: Number of IV Attempts for Control and Study Group

Figure 3 shows that, for the distribution of IV attempts, both groups exhibit comparable patterns, with the majority of instances in both groups having a single IV attempt. Quantitatively, the study group, with vapocoolant spray, has an average of 1.08 IV attempts. This is marginally lower than the control group's average of 1.155 attempts, where only Ametop is applied. We thus conclude that there is no increase in the number of IV attempts for the study group when the vapocoolant spray is added.

In summary, through the analysis of simple summary plots and calculation of mean attempts, it becomes evident that the introduction of the vapocoolant spray does not result in an elevated number of IV attempts when combined with Ametop.

4.4 Secondary Objective 3: To explore the incidence of side effects due to Ametop

First, we want to know the proportions of patients experiencing side effects. Our findings indicate that there are 12 out of 240 patients from the dataset that experience side effects. This finding is shown in Figure 4 pie chart.

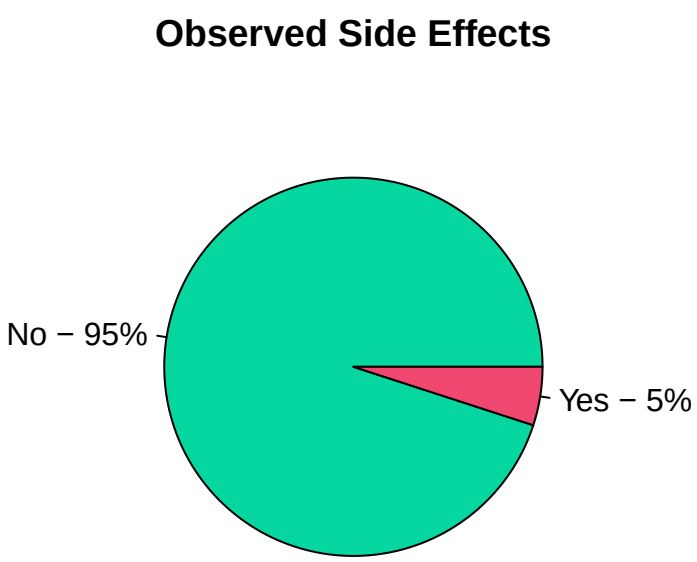


Figure 4: Proportion of Observed Side Effects

As illustrated in Figure 4, 95% of the patients experience no side effects, and 5% of patients experience side effects.

Then, we want to understand the type of side effects present. Table 3 below shows the categorization of the side effects based on the description given in the dataset.

Table 3: Side Effects Category

Side Effects Description	Category
Slight redness of skin from ametop	Redness
Some redness on skin, more than usual	Redness
vey mild pink and pruritic skin.	Redness + Itching
complained of pain on the spray.	Pain
slightly puffy hands after ametop removal	Puffiness
pink skin and very mild itching	Redness + Itching
redness from ametop	Redness
quite red & itchy skin from ametop. Underlying eczema.	Redness + Itching
redness at ametop site. Not painful or pruritic.	Redness
redness & raised area under ametop	Redness
quite itchy from ametop. Redness.	Redness + Itching
Slight redness from ametop. No pruritis.	Redness

The totals for each category in Table 3 are summarized in Table 4.

Table 4: Frequency Table of Side Effects

Category	Frequency
Pain	1
Puffiness	1
Redness only	6
Redness + Itching	4

As shown in Table 3 and Table 4, the most common side effect reported by patients is redness, either alone or accompanied by itching.

5. Conclusion

5.1 Conclusion

The study investigates whether the addition of a vapocoolant spray significantly reduces IV insertion pain for pediatric patients compared to using only Ametop gel. The results indicate that combining Ametop gel with the vapocoolant spray benefits pediatric patients during IV insertions. The combination of Ametop and vapocoolant spray significantly reduces discomfort in pediatric patients. This combination is particularly effective in younger children and may not be necessary for children aged 15 and 16. Additionally, the addition of spray does not increase the number of IV attempts. In terms of side effects, 95% of patients report no adverse effects from Ametop. Among the 5% of patients experiencing side effects, the most common side effect is redness, either alone or accompanied by itching.

5.2 Limitation

The base pain level was neither set nor recorded during data collection. If the patient was experiencing a headache or other body ache, it might have affected how they felt during the IV insertion, which could bias their choice of FPS-R scores.

It is possible that several factors influenced the FPS-R scores. Some factors such as age, number of IV attempts, and the practitioner's role may significantly impact the FPS-R scores reported by the patients. However, if we restrict these variables within the current dataset, it would result in an insufficient amount of data for robust analysis.

5.3 Recommendation

Based on the limitation, future research could explore this research on a more controlled set of variables. Specifically, studies could target children within a specific age group or a narrower age range, limiting other factors to a single IV attempt and practitioners with similar levels of experience. This approach provides a more precise understanding of how the addition of vapocoolant spray reduces IV insertion pain and leads to more definitive conclusions.

References

Rogers TL, Ostrow CL. The use of EMLA cream to decrease venipuncture pain in children. Journal of Pediatric Nursing. 2004 Feb 1;19(1):33-9.

Appendix

For client

Two-Sample T-Test

Let x_i be the value for one of the response variables in our sample. $x_1, x_2, ..., x_{223}$ are considered as IID sample of size n = 223.

H_0: The mean FPS-R scores for the control and study groups are the same.

H_a: The mean FPS-R score is lower for the study group which is using the vapocoolant spray.

$\bar{x}$ is the sample mean and is the estimate of the response variable, and the s_x is the sample standard deviation.

The formula for the two-sample t-test is:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\frac{s_x}{\sqrt{n}}}$$

We calculated the result using a one-sided test in R, and it is displayed in Table 1.

Linear Regression Model

Our model to test the relationship between age and randomization (control and study) groups on FPS-R scores is as follows:

$$Y = 4.1459 - 0.1640X_1 - 1.6818X_2 + 0.1098X_1 * X_2 + \epsilon$$

where ϵ follows $N(0, \sigma^2)$, Y = FPS-R scores, X_1 = Age, and

$$X_2 = \begin{cases} 1 & \text{if the patient is in the study group} \\ 0 & \text{if the patient is in the control group} \end{cases}$$

From the linear regression, we can get the estimated coefficient and the p-value through R-codes that are presented in Table 2. Using the equation, we can calculate fitted values, which are the predicted values of the FPS-R scores using the data that is used to create the model, to create Figure 2.

For mentor

Data cleaning

```
# Read data
file_path <- "../data/Ametop-PE data(new-Alex)(1control 2study).xlsx"
original_data <- read_excel(file_path)

# Save original data for side effects analysis
data <- original_data

# Remove withdrawn patients
data <- data[data$`Withdrawn after consent?` != "Yes", ]

# Remove unnecessary variables
data <- select(data,
               -`Elective surgery requiring IV?`,
               -`ASA I or II?`,
               -`Aged 5-16?`,
               -`Any allergies to Ametop, Pain Ease, or Tagederm adhesive?`,
               -`Ametop placed at least 30min before estimated IV start time?`,
               -`Receiving sedative pre-medication / anxiolytics?`,
               -`Needle phobia?`,
               -`Planned inhalation induction?`,
               -`Developmental delay or unable to interpret FPS-R?`,
               -`Time Ametop applied`,
               -`Time Ametop removed`,
               -`Time of skin puncture`,
               -`Record ID`,
               -`Complete?`,
               -`Withdrawn after consent?`,
               -`Reason for withdrawal`,
               -`Other reason for withdrawal`)
```

```
# Check for missing values in all columns except 'Notes' and 'Observed side effects'
missing_values_summary <- data %>%
  select(-Notes, -`Observed side effects`) %>%
  summarise_all(~sum(is.na(.)))

# No missing values found
print(missing_values_summary)
```

```
## # A tibble: 1 x 11
##   Randomization   Age   Sex Practitioner `Duration of Ametop`
##           <int> <int> <int>        <int>                <int>
## 1             0     0     0            0                    0
## # i 6 more variables: `Time between Ametop and skin puncture` <int>,
## #   `Reaction to skin puncture` <int>, `Number of IV attempts` <int>,
## #   `FPS-R score` <int>, `Needle gauge` <int>,
## #   `Any side effects observed?` <int>
```

```r
# Shorten the data
data$`Reaction to skin puncture` <- gsub("^(Slight|Severe).*", "\\1 Pain",
                                         data$`Reaction to skin puncture`)

# Verify the changes
table(data$`Reaction to skin puncture`)
```

```
##
##        None Severe Pain Slight Pain
##         158           5          60
```

Data preprocessing

```r
# Create new variables for the dataset

# Create 'Observer Number'
data$`Observer Number` <- case_when(
  data$`Reaction to skin puncture` == "None" ~ 1,
  data$`Reaction to skin puncture` == "Slight Pain" ~ 2,
  data$`Reaction to skin puncture` == "Severe Pain" ~ 3
)

# Create 'FPS-R Number'
data$`FPS-R Number` <- case_when(
  data$`FPS-R score` %in% c(0, 2) ~ 1,
  data$`FPS-R score` %in% c(4, 6) ~ 2,
  data$`FPS-R score` %in% c(8, 10) ~ 3
)

# Create 'Match Responses'
data$`Match Responses` <- ifelse(data$`Observer Number` == data$`FPS-R Number`, "Yes", "No")

# Create data subset for match data
data_subset <- data[data$`Match Responses` == 'Yes',]
```

```r
# Verify data
head(data)
```

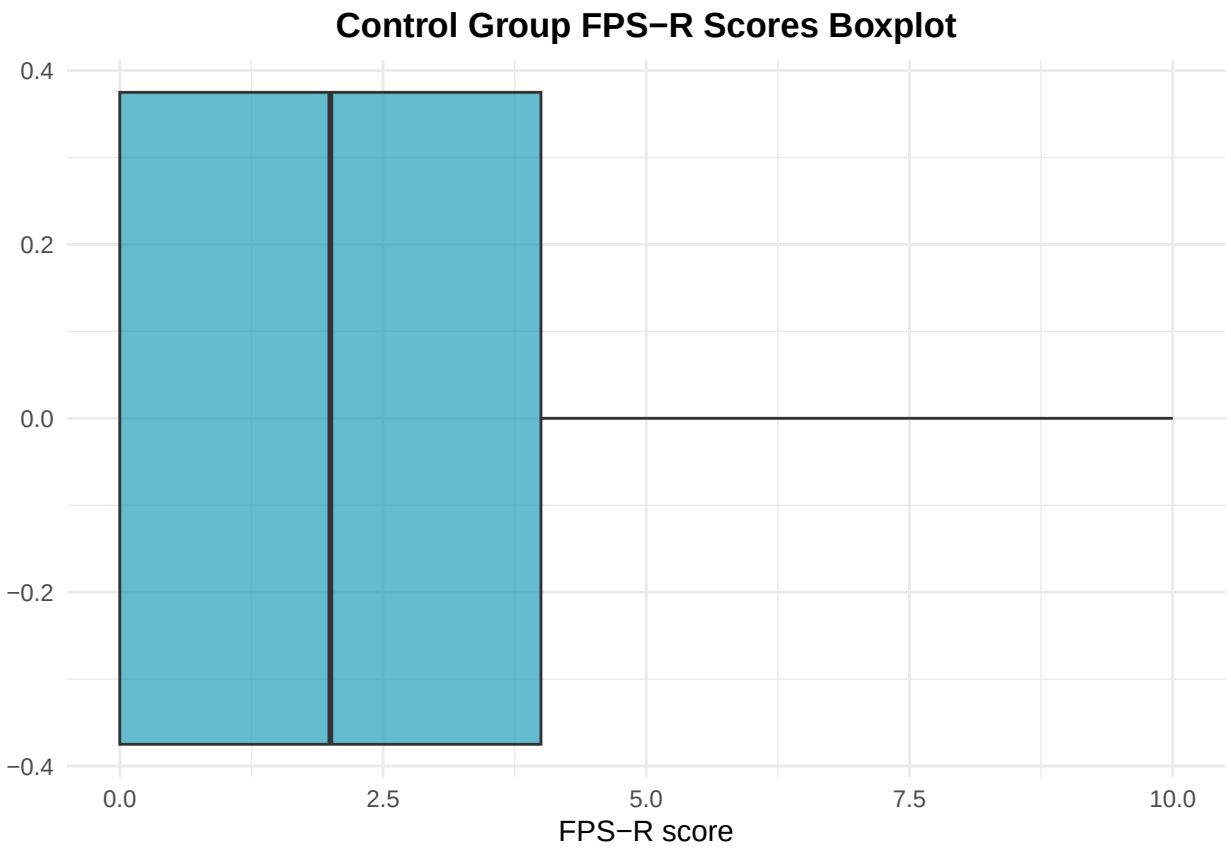
```
## # A tibble: 6 x 16
##   Randomization   Age Sex    Practitioner ‘Duration of Ametop‘
##           <dbl> <dbl> <chr>  <chr>                       <dbl>
## 1             2     6 Female Resident                       50
## 2             1     9 Female Anesthetist                    60
## 3             2     7 Male   Resident                       48
## 4             1     8 Female Anesthetist                    37
## 5             1     9 Male   Resident                       60
## 6             1     6 Female Anesthetist                    34
## # i 11 more variables: ‘Time between Ametop and skin puncture‘ <dbl>,
## #   ‘Reaction to skin puncture‘ <chr>, ‘Number of IV attempts‘ <dbl>,
## #   ‘FPS-R score‘ <dbl>, ‘Needle gauge‘ <dbl>,
## #   ‘Any side effects observed?‘ <chr>, ‘Observed side effects‘ <chr>,
```

```
## #   Notes <chr>, `Observer Number` <dbl>, `FPS-R Number` <dbl>,
## #   `Match Responses` <chr>
```

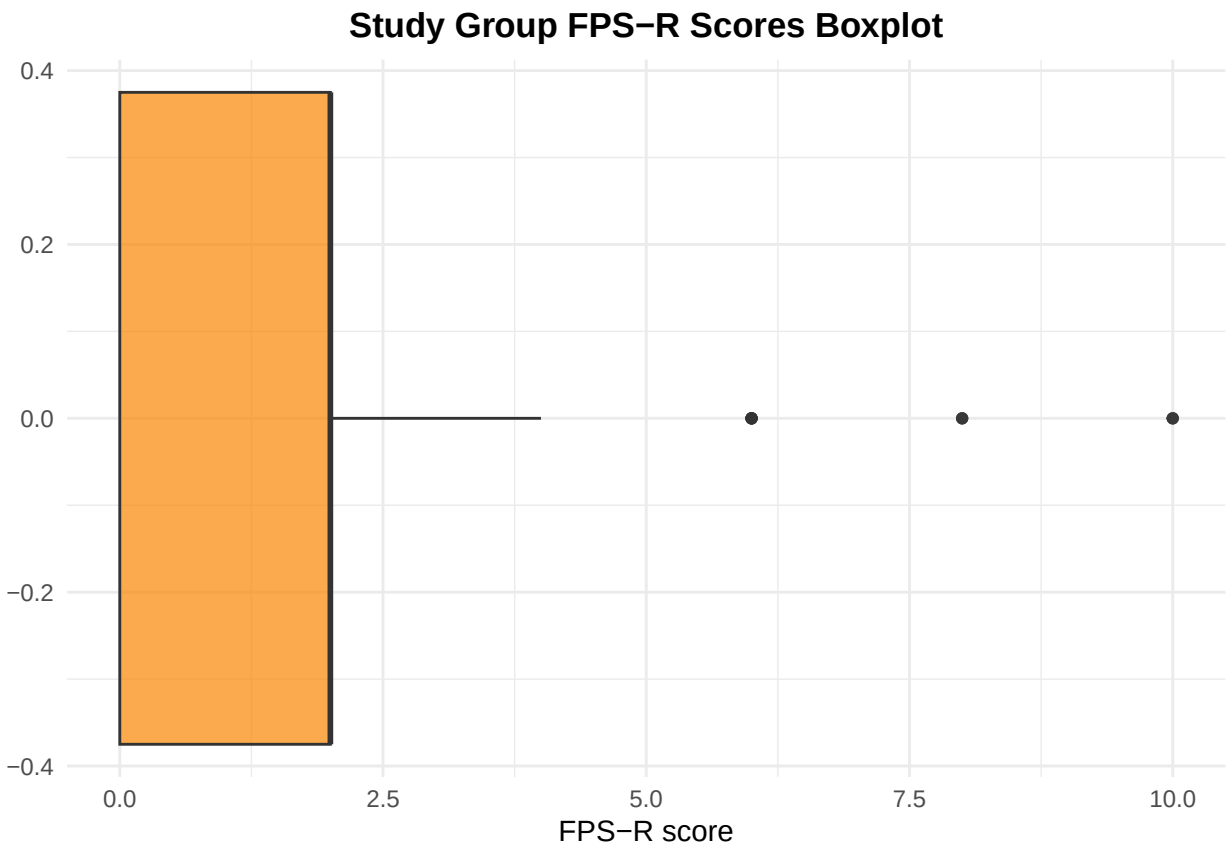
Main Objective

```
# Boxplots
plot1 <- data %>% filter(Randomization == 1) %>%
  ggplot(aes(`FPS-R score`, fill = "Control Group")) +
  geom_boxplot(alpha = 0.7) +
  labs(title = "Control Group FPS-R Scores Boxplot") +
  scale_fill_manual(values = c("Control Group" = "#219ebc")) +
  theme_minimal() +
  theme(plot.title = element_text(hjust = 0.5, face = "bold"), legend.position = "none")

plot2 <- data %>% filter(Randomization == 2) %>%
  ggplot(aes(`FPS-R score`, fill = "Study Group")) +
  geom_boxplot(alpha = 0.7) +
  labs(title = "Study Group FPS-R Scores Boxplot") +
  scale_fill_manual(values = c("Study Group" = "#fb8500")) +
  theme_minimal() +
  theme(plot.title = element_text(hjust = 0.5, face = "bold"), legend.position = "none")

plot1
```

Boxplots


Control Group FPS−R Scores Boxplot
0.4
0.2
0.0
−0.2
−0.4
0.0
2.5
5.0
7.5
10.0
FPS−R score

```
plot2
```




```
# Create a table to count matches
table <- table(data$`Observer Number`, data$`FPS-R Number`)

# Name the rows and columns to reflect the desired format
rownames(table) <- c("1", "2", "3")
colnames(table) <- c("1", "2", "3")

# Output the 3x3 table
cat("Contingency Table of FPS-R Number vs. Observer Number\n")
```

Table

```
## Contingency Table of FPS-R Number vs. Observer Number
```

```
cat("Rows: FPS-R Number\n")
```

```
## Rows: FPS-R Number
```

```
cat("Columns: Observer Number\n\n")
```

```
## Columns: Observer Number
```

```r
print(table)
```

```
##
##       1   2   3
##   1 135  20   3
##   2  24  24  12
##   3   0   0   5
```

```r
# Perform t-test
t_test <- t.test(data[data$Randomization == 2, ]$`FPS-R score`,
                 data[data$Randomization == 1, ]$`FPS-R score`,
                 alternative = c("less"))
print(t_test)
```

T-tests

```
##
##  Welch Two Sample t-test
##
## data:  data[data$Randomization == 2, ]$`FPS-R score` and data[data$Randomization == 1, ]$`FPS-R score
## t = -2.0155, df = 204.03, p-value = 0.02258
## alternative hypothesis: true difference in means is less than 0
## 95 percent confidence interval:
##        -Inf -0.1372509
## sample estimates:
## mean of x mean of y
##  1.929204  2.690909
```

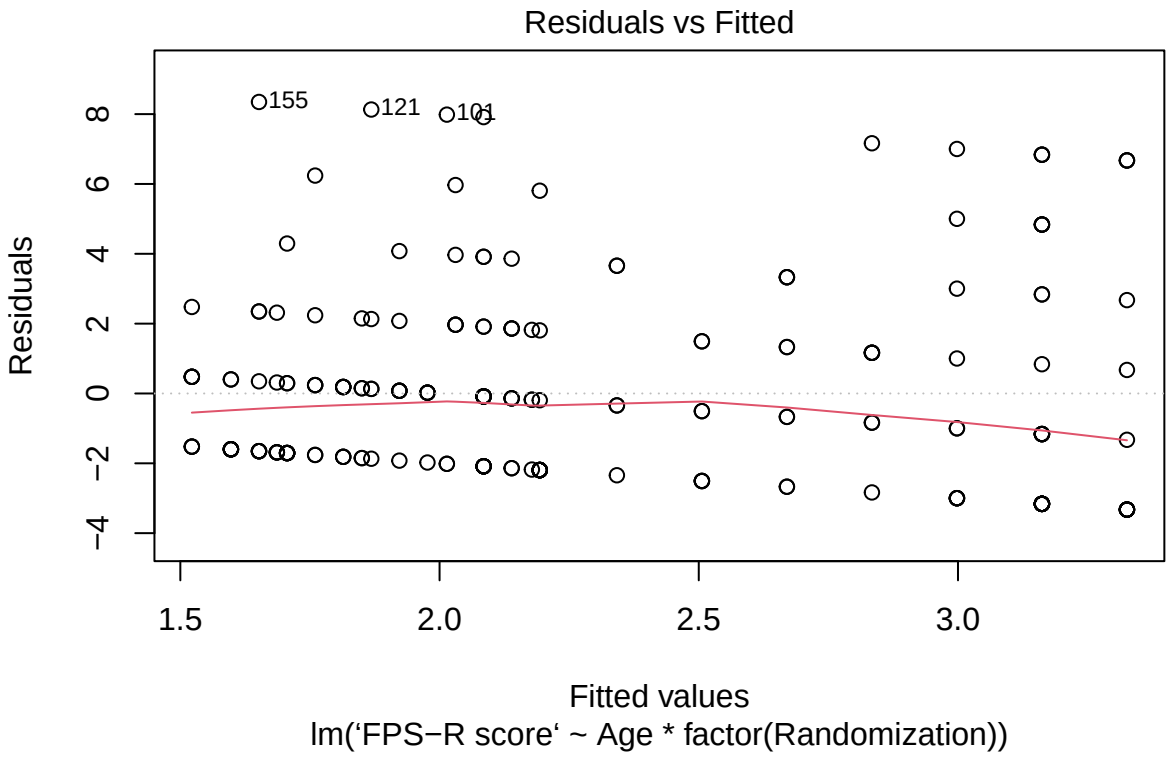
```r
# Conclusion: We should only reject the null hypothesis based on the full dataset.
```

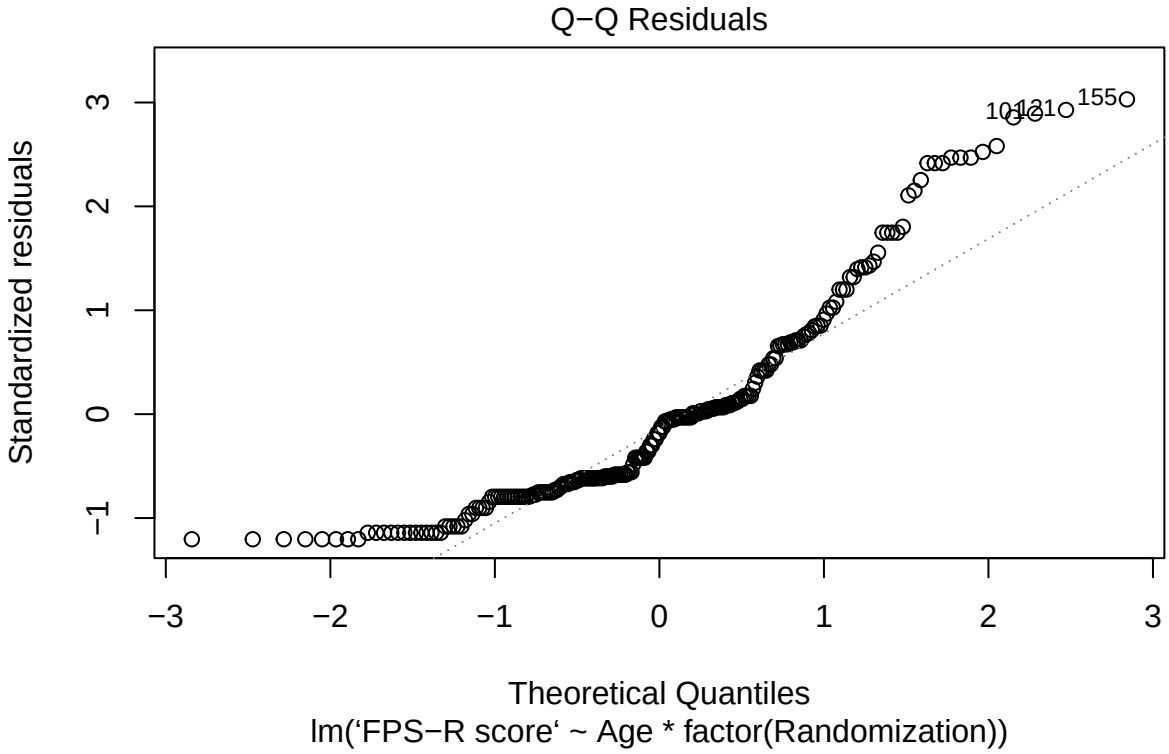
Secondary Objective 1: Linear Regression of Age * Randomization Group

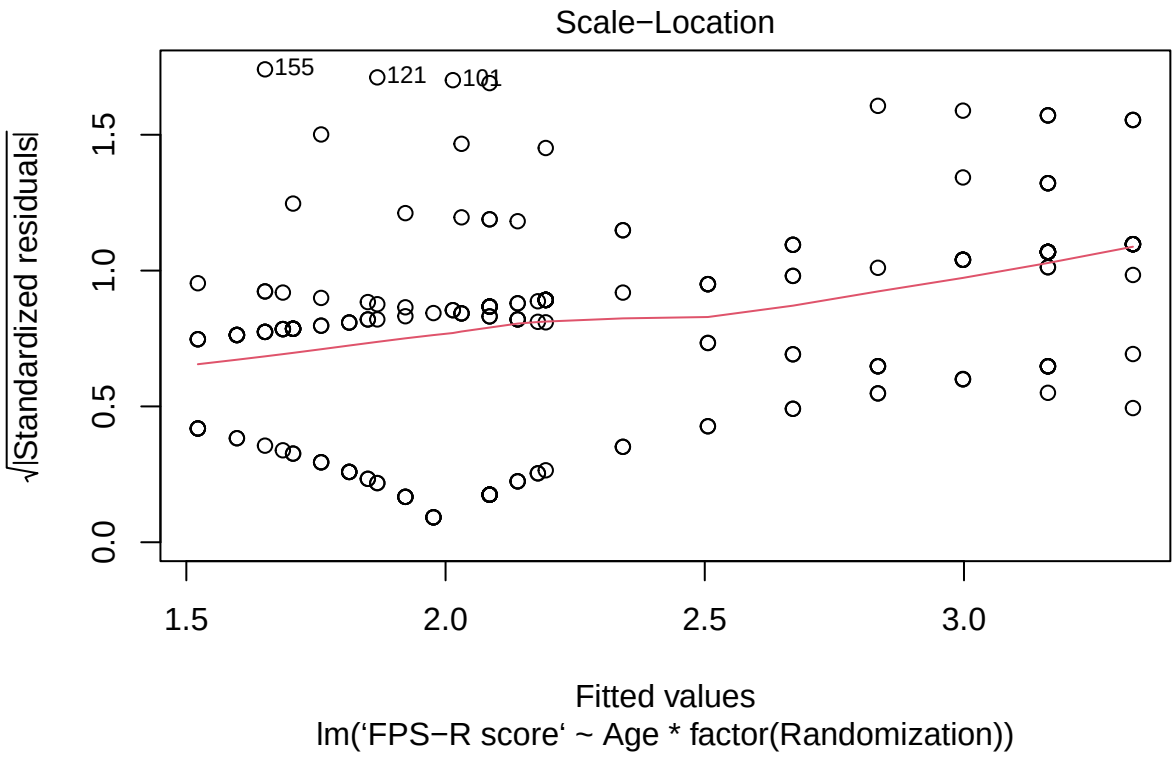
```r
lm_age <- lm(`FPS-R score` ~ Age * factor(Randomization), data = data)
tidy(summary(lm_age))
```

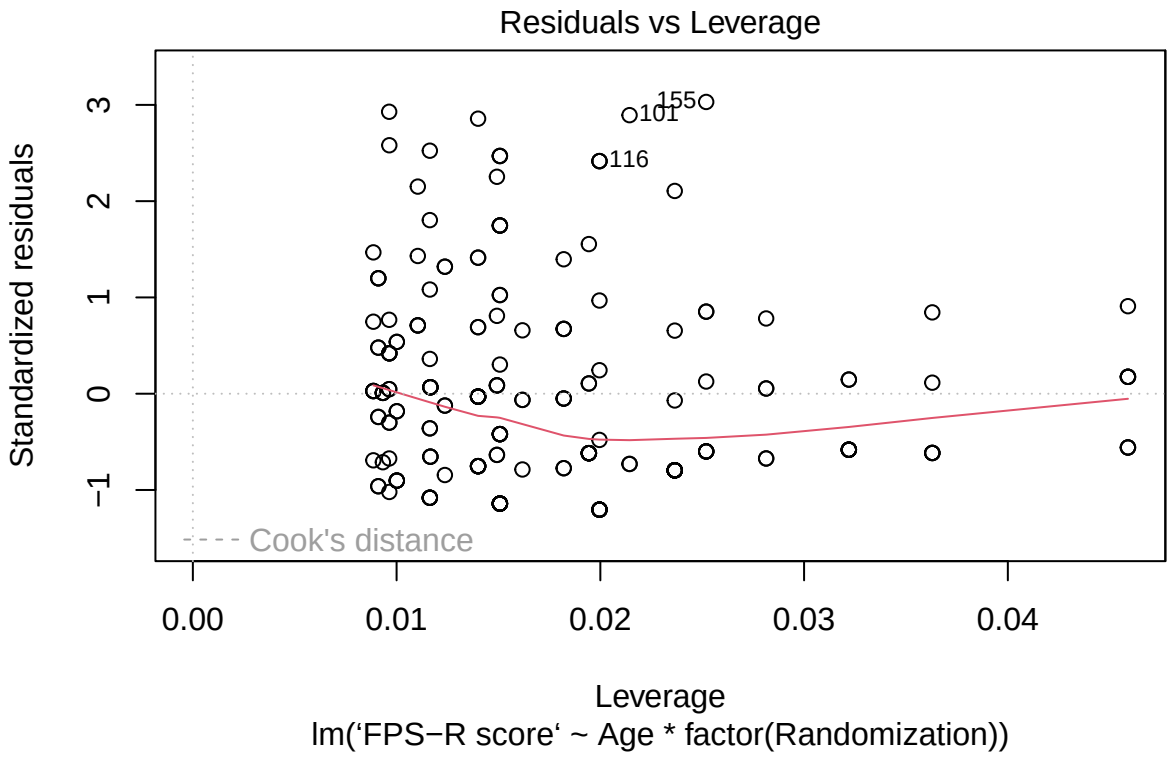
```
## # A tibble: 4 x 5
##   term                        estimate std.error statistic      p.value
##   <chr>                          <dbl>     <dbl>     <dbl>        <dbl>
## 1 (Intercept)                    4.15     0.718       5.78 0.0000000258
## 2 Age                           -0.164    0.0751     -2.18 0.0301
## 3 factor(Randomization)2        -1.68     1.03       -1.64 0.103
## 4 Age:factor(Randomization)2     0.110    0.102       1.07 0.285
```

```r
plot(lm_age)
```


Residuals vs Fitted
Residuals
Fitted values
lm(‘FPS−R score‘ ~ Age * factor(Randomization))
155
121
101
8
6
4
2
0
−2
−4
1.5
2.0
2.5
3.0

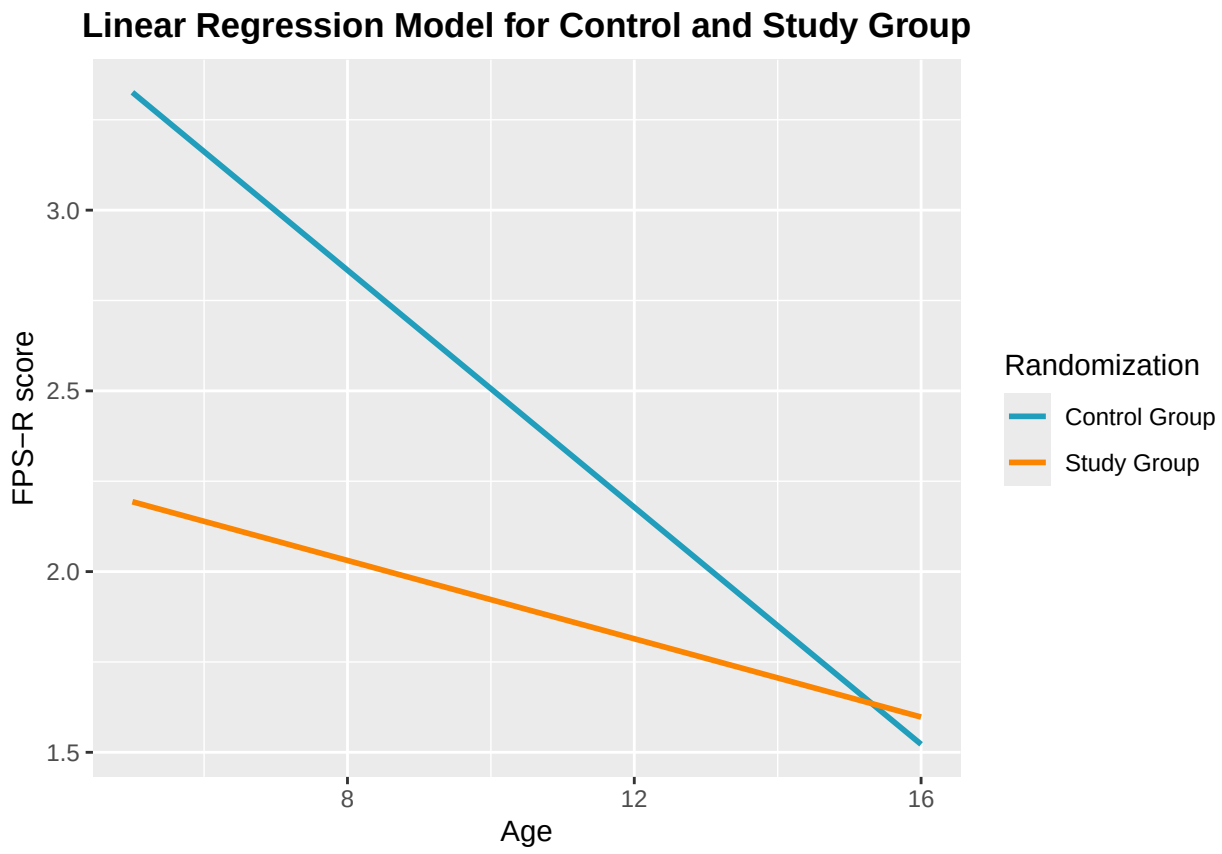

Q−Q Residuals
Standardized residuals
Theoretical Quantiles
lm(‘FPS−R score‘ ~ Age * factor(Randomization))
155


Scale−Location
155
121
101
√|Standardized residuals|
0.0
0.5
1.0
1.5
1.5
2.0
2.5
3.0
Fitted values
lm(‘FPS−R score‘ ~ Age * factor(Randomization))




```
# Plot the linear regression line
ggplot(data, aes(x = Age, y = `FPS-R score`, color = factor(Randomization))) +
  # Add the regression line
  geom_smooth(method = "lm", se = FALSE) +
  # Set plot labels
  xlab("Age") +
  ylab("FPS-R score") +
  labs(color = "Randomization", title = "Linear Regression Model for Control and Study Group") +
  scale_color_manual(values = c("#219ebc", "#fb8500"),
                     labels = c("Control Group", "Study Group")) +
  theme(plot.title = element_text(hjust = 0.5, face = "bold"))
```

```
## ‘geom_smooth()‘ using formula = ’y ~ x’
```



Secondary Objective 2: Number of IV Attempts Analysis

```
# Summary statistics
data_control <- data[data$`Randomization` == 1,]
data_study <- data[data$`Randomization` == 2,]
summary(data_control$`Number of IV attempts`)
```

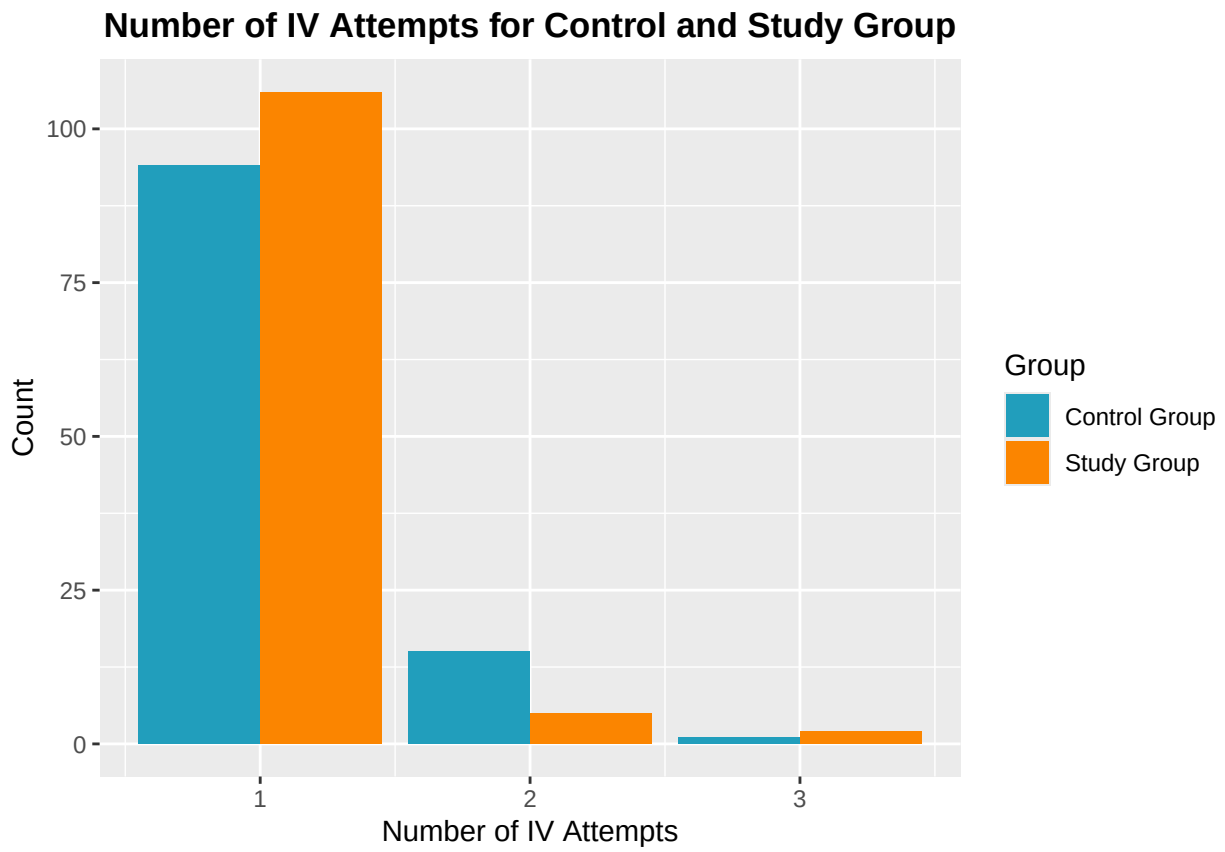
```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   1.000   1.000   1.000   1.155   1.000   3.000
```

```
summary(data_study$`Number of IV attempts`)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    1.00    1.00    1.00    1.08    1.00    3.00
```

```
# Mean for study group decreases instead

# Bar Chart for IV attempts
bar <- data %>%
  mutate(Group = ifelse(Randomization == 1, "Control Group", "Study Group")) %>%
  ggplot(aes(x = `Number of IV attempts`, fill = Group)) +
  geom_bar(position = "dodge") +
```

```
  scale_fill_manual(values = c("Control Group" = "#219ebc", "Study Group" = "#fb8500")) +
  labs(title = "Number of IV Attempts for Control and Study Group", x = "Number of IV Attempts",
    y = "Count", fill = "Group"
  ) +
    theme(
    plot.title = element_text(hjust = 0.5, face = "bold")
  )

print(bar)
```



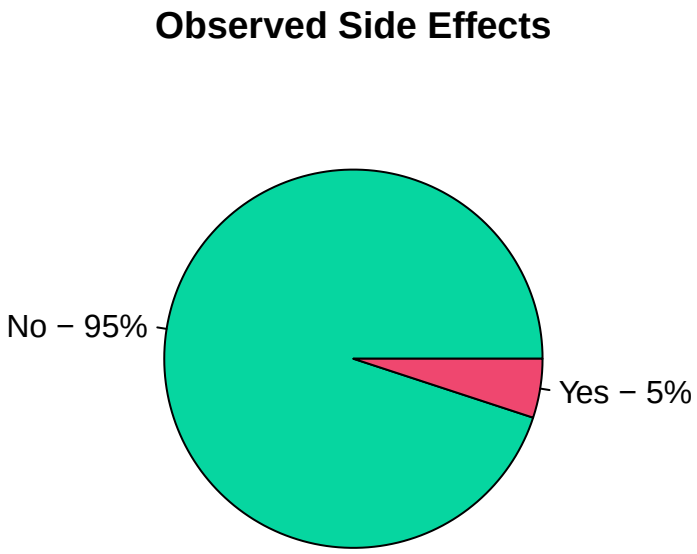

```
# No need further testing, from EDA we can see that the study group
# didn't increase number of IV attempts (in fact, it decreases)
# (note: we did try doing t-test for confirmation and we can't reject null)
```

Secondary Objective 3: Side Effects

```
# Pie chart draw function with percentages
draw_pie_chart <- function(all_categories, title) {
  # Count the occurrences of each category
  category_counts <- table(all_categories)

  # Calculate the percentage for each category
```

```r
  percentages <- round(category_counts / sum(category_counts) * 100, 1)

  # Create labels that include both the category name and the percentage
  labels <- paste(names(category_counts), " - ", percentages, "%", sep="")

  pie(category_counts,
      main = title,
      col = c("#06d6a0", "#ef476f"),
      labels = labels,
      cex = 1.0)
}

# Summarize "Any side effects observed?" column
side_effects_observed_summary <- data.frame(original_data$`Any side effects observed?`)

# Create a pie chart for the observed side effects
draw_pie_chart(side_effects_observed_summary, "Observed Side Effects")
```

Pie chart for Observed side effects




```r
# Define the categorization function
categorize_effects <- function(effect) {
  effect_lower <- tolower(effect)
  categories <- list(
    Redness = "red|redness|pink",
```

```
    Itching = "itchy|pruritic|pruritis|itching",
    Pain = "pain|painful",
    Puffiness = "puffy"
  )

  identified_categories <- character(0)

  # Negation patterns
  pattern_start <- "\\b(no|not)\\s+("
  pattern_middle <- ")\\b|(no|not)\\s+\\w+\\s+or\\s+("
  pattern_end <- ")"

  for (category_name in names(categories)) {
    symptom_pattern <- categories[[category_name]]

    # Check for the symptom but exclude if negated
    if (grepl(symptom_pattern, effect_lower)) {
      negation_pattern <- paste0(
        pattern_start, symptom_pattern, pattern_middle, symptom_pattern, pattern_end)
      if (!grepl(negation_pattern, effect_lower)) {
        identified_categories <- c(identified_categories, category_name)
      }
    }
  }

  # Return "Other" if no category is found
  if (length(identified_categories) == 0) {
    return("Other")
  }

  return(identified_categories)
}
```

```
# Get the side effects data
side_effects_data <- na.omit(data.frame(SideEffects = original_data$`Observed side effects`))
side_effects_data$Category <- sapply(side_effects_data$SideEffects, function(effect) {
  category <- categorize_effects(effect)
  paste(category, collapse = " + ")
})
print(side_effects_data)
```

Frequency table for observed side effects

```
##                                             SideEffects          Category
## 2                     Slight redness of skin from ametop           Redness
## 20                  Some redness on skin, more than usual           Redness
## 76                       vey mild pink and pruritic skin. Redness + Itching
## 82                       complained of pain on the spray.              Pain
## 85               slightly puffy hands after ametop removal         Puffiness
## 118                       pink skin and very mild itching Redness + Itching
```

```
## 192                                    redness from ametop           Redness
## 198 quite red & itchy skin from ametop. Underlying eczema. Redness + Itching
## 207       redness at ametop site. Not painful or pruritic.           Redness
## 211                       redness & raised area under ametop           Redness
## 222                        quite itchy from ametop. Redness. Redness + Itching
## 238                Slight redness from ametop. No pruritis.           Redness
```

```r
# Frequency table
table(side_effects_data$Category)
```

```
##
##              Pain         Puffiness           Redness Redness + Itching
##                 1                 1                 6                 4
```