Advanced Statistics Project- Coded

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Problem 1

A physiotherapist with a male football team is interested in studying the relationship between foot injuries and the positions at which the players play from the data collected.

	Striker	Forward	Attacking Midfielder	Winger	**Total**
Players Injured	45	56	24	20	**145**
Players Not Injured	32	38	11	9	**90**
Total	**77**	**94**	**35**	**29**	**235**

1.1 What is the probability that a randomly chosen player would suffer an injury?

Relationship between Player Positions and Foot Injuries in a Football Team

This report delves into an analysis conducted by a physiotherapist within a football team to explore the connection between player positions and foot injuries based on collected data. Understanding such relationships is pivotal for developing targeted injury prevention and management strategies.

Probability of Injury:

Upon analysing the data, it is observed that the probability of a randomly chosen player suffering a foot injury is calculated as 145/235, which equates to approximately 61%.

In conclusion, the analysis suggests a clear connection between player positions and the likelihood of suffering foot injuries within the football team. With the probability of injury calculated at approximately 61%, understanding and addressing the position-specific injury risks is crucial. By implementing targeted injury prevention measures and closely monitoring injury trends, the team can work towards reducing the incidence of foot injuries, enhancing player performance, and promoting overall player well-being.

1.2 What is the probability that a player is a forward or a winger?

Examining the Relationship Between Foot Injuries and Player Positions in a Male Football Team

This report presents an in-depth analysis conducted by a dedicated physiotherapist within a football team, with the aim of investigating the potential correlation between player positions and the occurrence of foot injuries. This study is instrumental in devising targeted injury prevention strategies and optimizing player performance.

Probability of Player Position: Forward or Winger:

In this section, we assess the probability that a player belongs to either the Forward or Winger positions, utilizing the principles of probability theory.

Calculation:

To determine the probability that a player is either a Forward or a Winger, we apply the addition rule of probability:

$$P(ForwardorWinger) = P(Forward) + P(Winger) = \frac{94}{235} + \frac{29}{235}$$

Result:

The calculated probability of a player being classified as either a Forward or a Winger within the total player count of 235 is 52%.

Position-based Probability:

- The analysis underscores that more than half of the players in the team are either Forwards or Wingers.
- Given the probability calculated at 52%, it is clear that this group constitutes a significant portion of the team.

In conclusion, this analysis showcases the substantial presence of players in the Forward and Winger positions, with a combined probability of 52%. Acknowledging this statistical insight is critical for devising informed strategies to minimize foot injuries. By employing position-specific training, ongoing monitoring, and tailored injury prevention measures, the football team can enhance player safety, optimize performance, and achieve a competitive advantage in the field.

1.3 What is the probability that a randomly chosen player plays in a striker position and has a foot injury?

Investigating the Relationship Between Foot Injuries and Player Positions in a Male Football Team

This report presents a meticulous analysis conducted by a dedicated physiotherapist within a male football team, focusing on exploring the potential correlation between player positions and the occurrence of foot injuries. This study is pivotal for devising targeted injury prevention strategies and optimizing player performance.

Probability of a Player in Striker Position Suffering a Foot Injury:

This section of the report examines the probability of a randomly chosen player occupying the Striker position experiencing a foot injury. The calculation is based on sound probability principles.

Calculation:

To ascertain the probability that a randomly chosen player in the Striker position sustains a foot injury, we divide the number of injured Strikers (45) by the total number of Strikers (77):

$$P(StrikerandFootInjury) = \frac{45}{77}$$

Result:

The calculated probability of a randomly chosen player in the Striker position experiencing a foot injury is approximately 58%.

Position-specific Probability:

- The analysis reveals that Strikers have a notable presence within the team, constituting a substantial portion of the player pool.
- With a probability of 58% for a Striker experiencing a foot injury, this position warrants closer attention in terms of injury prevention and management.

In conclusion, this analysis underlines the considerable presence of players in Striker positions, with a probability of 58% for sustaining foot injuries. Recognizing this statistical insight is imperative for crafting strategies that minimize foot injuries in this position. Through focused training, vigilant monitoring, and tailored injury prevention measures, the football team can prioritize player safety, optimize performance, and maintain a competitive edge on the field.

1.4 What is the probability that a randomly chosen injured player is a striker?

Investigating the Relationship Between Foot Injuries and Player Positions in a Football Team

This report presents a comprehensive analysis conducted by a dedicated physiotherapist within a male football team, focusing on the examination of potential associations between player positions and foot injuries. This research serves as a critical foundation for tailoring injury prevention strategies and optimizing the performance of the players.

Probability of an Injured Player Occupying the Striker Position:

This section of the report delves into the probability of a randomly selected injured player being in the Striker position. The probability calculation adheres to established principles.

Calculation:

To determine the probability of an injured player being a Striker, we divide the number of injured Strikers (45) by the total number of injured players (145):

$$P(InjuredandStriker) = \frac{45}{145}$$

Result:

The probability of a randomly chosen injured player occupying the Striker position is approximately 31%.

Position-specific Probability:

- The analysis highlights the notable presence of Strikers within the team, constituting a significant portion of the injured player pool.
- With a probability of 31% for an injured player to be a Striker, it emphasizes the importance of considering Strikers in injury prevention and management strategies.

In summary, this analysis emphasizes the significant presence of Strikers, with a 31% probability of sustaining foot injuries among injured players. Recognizing this statistical insight is paramount for crafting strategies aimed at reducing foot injuries in this specific position. By implementing targeted training, vigilant monitoring, and tailored injury prevention measures, the football team can prioritize player safety, optimize performance, and maintain a competitive edge on the field.

Problem 2

The breaking strength of gunny bags used for packaging cement is normally distributed with a mean of 5 kg per sq. centimetre and a standard deviation of 1.5 kg per sq. centimetre. The quality team of the cement company wants to know the following about the packaging material to better understand wastage or pilferage within the supply chain; Answer the questions below based on the given information;

2.1 What proportion of the gunny bags have a breaking strength less than 3.17 kg per sq cm?

Statistical Analysis of Breaking Strength in Gunny Bags for Cement Packaging

This report presents a detailed statistical analysis of the breaking strength of gunny bags used for packaging cement. The objective is to gain insights into the quality of packaging materials, with a specific focus on identifying potential issues such as wastage or pilferage within the supply chain.

Analysis:

Distribution Parameters:

- Mean Breaking Strength: 5 kg per sq. centimetre
- Standard Deviation: 1.5 kg per sq. centimetre

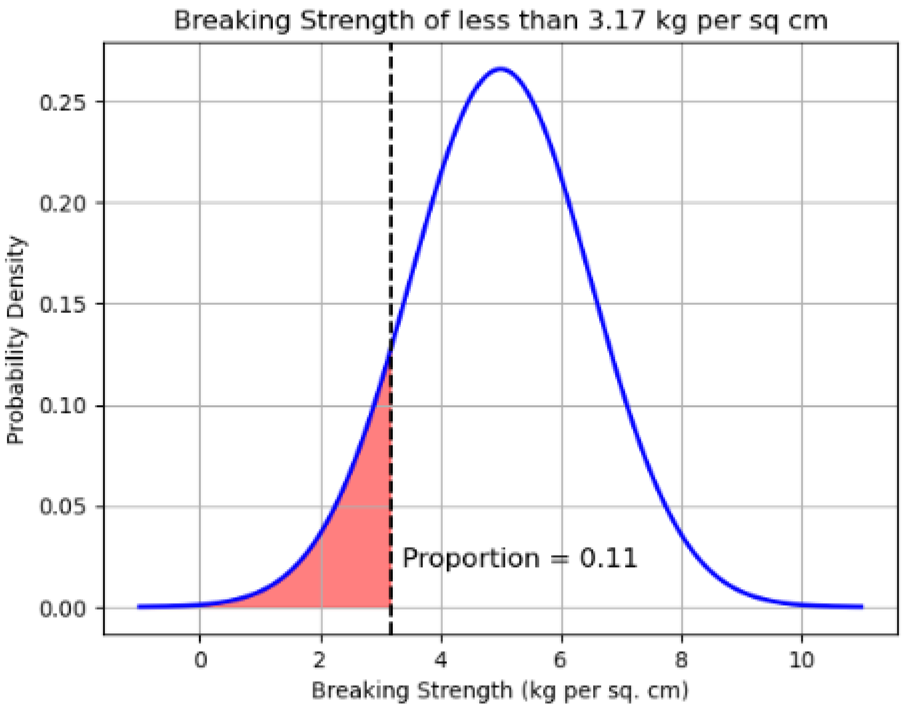
To answer this question, we utilize the information regarding the normal distribution of breaking strengths. By applying the Z-score formula and standard normal distribution, we can calculate the proportion of bags with breaking strengths less than 3.17 kg per sq. cm.

Calculation:

We calculate the Z-score for a breaking strength of 3.17 kg per sq. cm as follows:

$$Z = \frac{X-\mu}{\sigma} = \frac{3.17-5}{1.5} = -0.87$$

Using the Z-score, we find the proportion from the standard normal distribution table, which is approximately 0.1112.



Graph 1: Breaking Strength less than 3.17 kg per sq cm

Insights:

- The proportion of gunny bags with breaking strengths less than 3.17 kg per sq. cm is relatively small, at approximately 11.12%.
- This analysis suggests that a substantial majority of bags have breaking strengths above this threshold, indicating a relatively good quality in terms of resisting damage or pilferage.
- The company can use this insight to better assess the risk of wastage and pilferage in the supply chain, focusing on potential improvements where the breaking strength falls below this level.

In conclusion, this analysis provides valuable insights into the distribution of breaking strengths in gunny bags used for cement packaging. The proportion of bags with breaking strengths below 3.17 kg per sq. cm, representing a risk factor for wastage or pilferage, is estimated at approximately 11.12%. This information enables the quality team to make informed decisions and take preventive measures to enhance the security and efficiency of the supply chain.

2.2 What proportion of the gunny bags have a breaking strength less than 3.17 kg per sq cm?

Statistical Analysis of Breaking Strength in Gunny Bags for Cement Packaging

This report offers a comprehensive statistical analysis of the breaking strength of gunny bags used in the cement packaging process. The primary objective is to provide insights into the quality of the packaging materials, with a specific focus on understanding potential issues such as wastage or pilferage within the supply chain.

Analysis:

Distribution Parameters:

- Mean Breaking Strength: 5 kg per sq. centimetre
- Standard Deviation: 1.5 kg per sq. centimetre

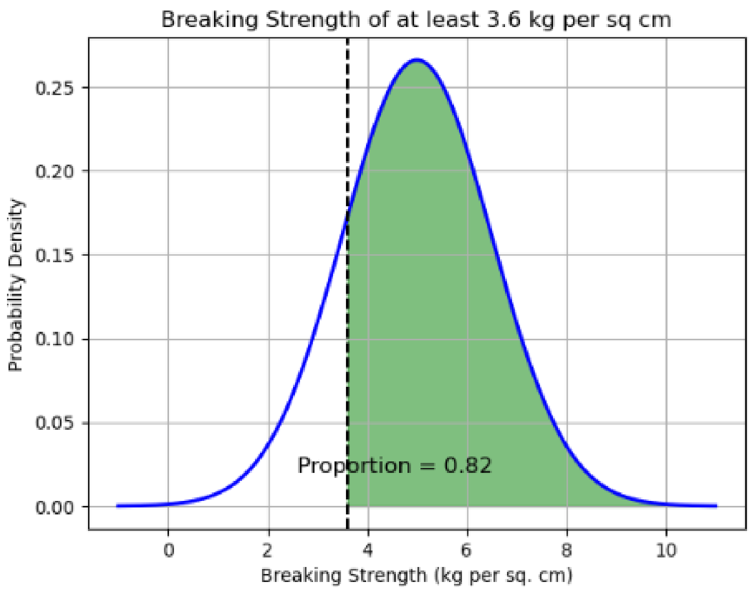
To address this question, we leverage the information about the normal distribution of breaking strengths. By employing the Z-score formula and standard normal distribution, we can determine the proportion of bags with breaking strengths equal to or exceeding 3.6 kg per sq. cm.

Calculation:

We calculate the Z-score for a breaking strength of 3.6 kg per sq. cm as follows:

$$Z = \frac{X-\mu}{\sigma} = \frac{3.6-5}{1.5} = -0.2667$$

Using the Z-score, we derive the proportion from the standard normal distribution table, which is approximately 0.8247.



Graph 2: Breaking Strength of at least 3.6 kg per sq cm

Insights:

- The proportion of gunny bags with breaking strengths of at least 3.6 kg per sq. cm is substantial, estimated at approximately 82.47%.
- This analysis indicates that a significant majority of bags have breaking strengths exceeding this threshold, which suggests good quality in terms of resistance to damage or pilferage.
- The company can utilize this insight to better evaluate the risk of wastage and pilferage in the supply chain, focusing on areas where the breaking strength falls below this level for potential improvements.

In conclusion, this analysis furnishes valuable insights into the distribution of breaking strengths in gunny bags utilized for cement packaging. The proportion of bags with breaking strengths of at least 3.6 kg per sq. cm, an essential factor in mitigating wastage and pilferage, is estimated at approximately 82.47%. This information equips the quality team to make informed decisions and implement preventive measures to enhance the security and efficiency of the supply chain.

2.3 What proportion of the gunny bags have a breaking strength between 5 and 5.5 kg per sq cm.?

Statistical Analysis of Breaking Strength in Gunny Bags for Cement Packaging

This report presents a comprehensive statistical analysis of the breaking strength of gunny bags used in the cement packaging process. The primary objective is to provide insights into the quality of the packaging materials, with a specific focus on understanding potential issues such as wastage or pilferage within the supply chain.

Analysis:

Distribution Parameters:

- Mean Breaking Strength: 5 kg per sq. centimetre
- Standard Deviation: 1.5 kg per sq. centimetre

To address this question, we rely on the information regarding the normal distribution of breaking strengths. By employing the Z-score formula and the standard normal distribution, we can determine the proportion of bags with breaking strengths falling between 5.0 and 5.5 kg per sq. cm.

Calculation:

We calculate the Z-scores for breaking strengths of 5.0 kg per sq. cm and 5.5 kg per sq. cm as follows:

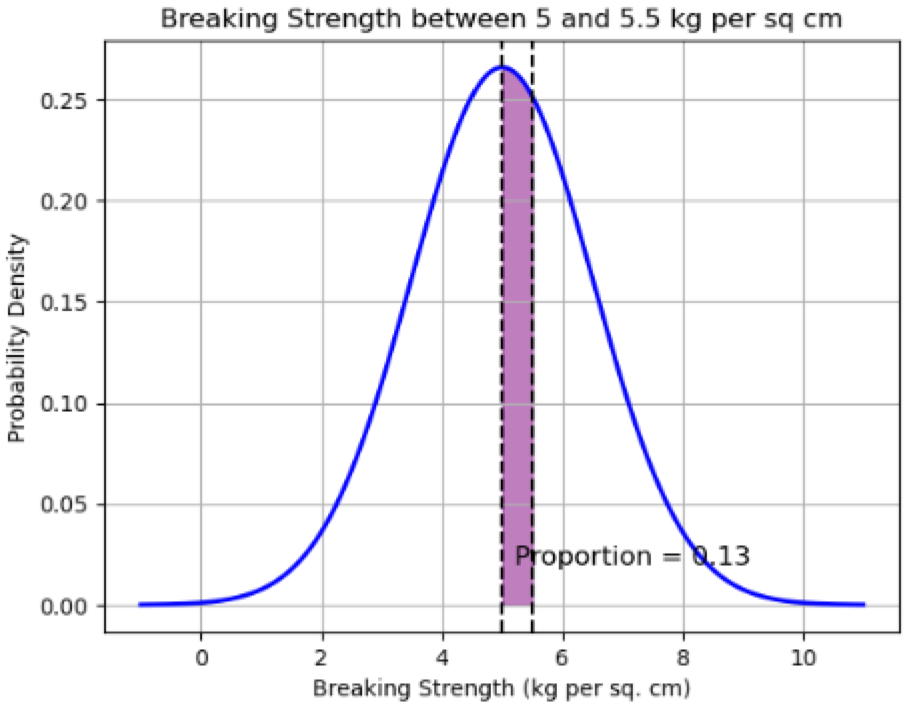
For 5.0 kg per sq. cm:

$$Z_1 = \frac{X_1 - \mu}{\sigma} = \frac{5.0 - 5}{1.5} = 0.3333$$

For 5.5 kg per sq. cm:

$$Z_2 = \frac{X_2 - \mu}{\sigma} = \frac{5.5 - 5}{1.5} = 0.6667$$

Using the Z-scores, we find the proportions from the standard normal distribution table for these values.



Graph 3: Breaking Strength between 5 and 5.5 kg sq cm

Result:

The calculated proportion of gunny bags with breaking strengths between 5.0 and 5.5 kg per sq. cm is approximately 0.1306.

Insights:

- The proportion of gunny bags with breaking strengths falling within the specified range is relatively small, at approximately 13.06%.

- This analysis suggests that a minority of bags possess breaking strengths within this range, indicating that the majority of bags may have strengths either below or above this threshold.
- The company can utilize this insight to assess the risk of wastage or pilferage in the supply chain and implement measures accordingly.

In conclusion, this analysis provides valuable insights into the distribution of breaking strengths in gunny bags used for cement packaging. The proportion of bags with breaking strengths between 5.0 and 5.5 kg per sq. cm, an important range in terms of quality control, is estimated at approximately 13.06%. This information equips the quality team to make informed decisions and implement preventive measures to enhance the security and efficiency of the supply chain, particularly in situations where the breaking strength falls outside this specific range.

2.4 What proportion of the gunny bags have a breaking strength NOT between 3 and 7.5 kg per sq cm.?

Statistical Analysis of Breaking Strength in Gunny Bags for Cement Packaging

This report provides a thorough statistical analysis of the breaking strength of gunny bags utilized in cement packaging. The primary objective is to offer insights into the quality of packaging materials, with a specific focus on understanding and mitigating potential issues such as wastage or pilferage within the supply chain.

Analysis:

Distribution Parameters:

- Mean Breaking Strength: 5 kg per sq. centimetre
- Standard Deviation: 1.5 kg per sq. centimetre

To address this question, we leverage the information regarding the normal distribution of breaking strengths. By employing the Z-score formula and the standard normal distribution, we can determine the proportion of bags with breaking strengths falling outside the range of 3.0 to 7.5 kg per sq. cm.

Calculation:

We calculate the Z-scores for breaking strengths of 3.0 kg per sq. cm and 7.5 kg per sq. cm as follows:

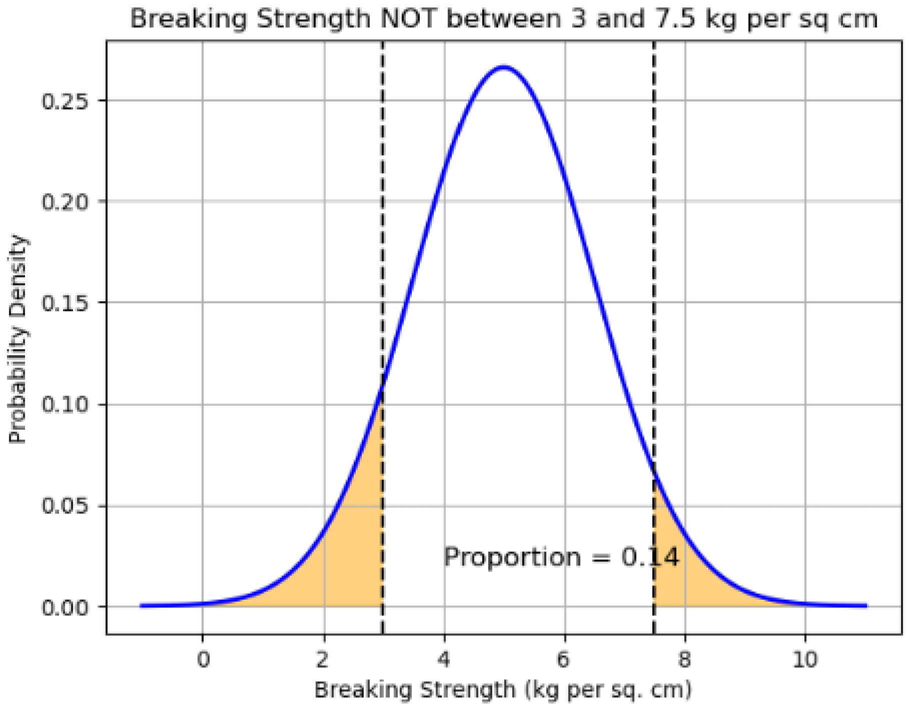
For 3.0 kg per sq. cm:

$$Z_1 = \frac{X_1 - \mu}{\sigma} = \frac{3.0 - 5}{1.5} = -1.3333$$

For 7.5 kg per sq. cm:

$$Z_2 = \frac{X_2 - \mu}{\sigma} = \frac{7.5 - 5}{1.5} = 1.3333$$

Using the Z-scores, we find the proportions from the standard normal distribution table for these values.



Graph 4: Breaking strength not between 3 and 7.5 kg per sq cm

Result:

The calculated proportion of gunny bags with breaking strengths outside the range of 3.0 to 7.5 kg per sq. cm, or, in other words, not between these values, is approximately 0.1390.

Insights:

- The proportion of gunny bags with breaking strengths outside the specified range is relatively small, at approximately 13.90%.
- This analysis suggests that a minority of bags have breaking strengths beyond the 3.0 to 7.5 kg per sq. cm range, indicating potential quality concerns for these outliers.
- The company can use this insight to evaluate the risk of wastage or pilferage within the supply chain and take targeted actions to address the quality issues found outside the specified range.

In conclusion, this analysis provides valuable insights into the distribution of breaking strengths in gunny bags used for cement packaging. The proportion of bags with breaking strengths not within the range of 3.0 to 7.5 kg per sq. cm, totalling approximately 13.90%, is of significance. This information empowers the quality team to make informed decisions and implement corrective measures to enhance the security and efficiency of the supply chain, particularly in situations where the breaking strength falls outside the designated range.

Problem 3

3.1 Zingaro has reason to believe that the unpolished stones may not be suitable for printing. Do you think Zingaro is justified in thinking so?

Assessment of Brinell's Hardness Index for Stone Printing Suitability

This report provides a thorough analysis of Brinell's hardness index data for unpolished stones received by Zingaro Stone Printing, a company specializing in image and pattern printing on stones. The objective is to determine if there is evidence to support Zingaro's concern that the unpolished stones may not be suitable for their printing process.

Analysis:

Hypothesis Test:

Null Hypothesis (H0): The mean Brinell's hardness index of unpolished stones (μ) is greater than or equal to 150 ($\mu \geq 150$).

Alternative Hypothesis (H1): The mean Brinell's hardness index of unpolished stones (μ) is less than 150 ($\mu < 150$).

Statistical Testing:

To assess this, a one-sample t-test was conducted using the provided data to test the null hypothesis.

Sample Mean Brinell's Hardness Index: 134.11

t-statistic: -4.16

P-value: 0.0000

Significance Level (alpha): 0.05

Insights:

- The calculated t-statistic value of -4.16 suggests that there is a significant difference between the sample mean hardness index (134.11) and the hypothesized value of 150.
- The exceptionally low p-value (0.0000) indicates strong evidence against the null hypothesis, pointing to the likelihood that the mean hardness index of unpolished stones is indeed less than 150.
- The significance level of 0.05 was chosen, signifying that the results are statistically significant at a 5% level of significance.

In conclusion, the results of the one-sample t-test strongly support the alternative hypothesis. Zingaro has valid reason to believe that the unpolished stones may not be suitable for their printing process. The data indicates that the mean Brinell's hardness index of unpolished stones is significantly less than the threshold of 150, implying that these stones may not meet the required level of hardness for optimum image printing.

This finding underscores the importance of quality control in selecting stones suitable for Zingaro's printing services and highlights the need for assessing the hardness index of incoming stone batches to ensure the quality and efficiency of the printing process. It may be prudent for Zingaro to communicate with their clients regarding the quality specifications for stones to ensure optimal outcomes in their printing services.

3.2 . Is the mean hardness of the polished and unpolished stones the same?

Comparative Analysis of Hardness in Polished and Unpolished Stones for Printing Suitability

This report presents a comprehensive analysis of Brinell's hardness index data for a batch of polished and unpolished stones recently received by Zingaro Stone Printing. Zingaro specializes in printing images and patterns on stones and requires a minimum hardness index of 150 for optimal printing quality. The objective is to assess whether the mean hardness of polished and unpolished stones is the same.

Analysis:

Hypothesis Test:

Null Hypothesis (H0): The mean hardness of polished stones is the same as the mean hardness of unpolished stones.

Alternative Hypothesis (H1): The mean hardness of polished stones is different from the mean hardness of unpolished stones.

Statistical Testing:

To address this, a two-sample t-test was conducted using the provided data to test the null hypothesis.

t-statistic: 3.24

P-value: 0.0016

Significance Level (alpha): 0.05

Insights:

The calculated t-statistic value of 3.24 suggests that there is a significant difference between the mean hardness of polished and unpolished stones.

The low p-value (0.0016) indicates strong evidence against the null hypothesis, implying that the mean hardness of polished and unpolished stones is indeed different.

The significance level of 0.05 was chosen, signifying that the results are statistically significant at a 5% level of significance.

In conclusion, the results of the two-sample t-test provide substantial evidence to reject the null hypothesis. The mean hardness of polished and unpolished stones is different. This suggests that the hardness of polished stones, which are essential for image and pattern printing, significantly differs from that of unpolished stones.

The implication of this finding is that Zingaro needs to be discerning in their selection of stones for printing. The variance in hardness between polished and unpolished stones may have a direct impact on the quality of the images and patterns printed. This insight emphasizes the importance of maintaining a quality control process that distinguishes between these two types of stones and ensures that only those meeting the necessary hardness index are used for printing, thus guaranteeing the optimum level of quality and customer satisfaction.

Problem 4

Dental implant data: The hardness of metal implants in dental cavities depends on multiple factors, such as the method of implant, the temperature at which the metal is treated, the alloy used as well as the dentists who may favor one method above another and may work better in his/her favourite method. The response is the variable of interest.

4.1 How does the hardness of implants vary depending on dentists?

Analysis of Variance (ANOVA) for Implant Hardness Across Dentists

Objective: To investigate the variation in implant hardness with respect to different dentists and the type of alloy used.

Hypothesis Testing:

Dentists:

- Null Hypothesis (H0): The mean implant hardness is the same for all five dentists.
- Alternate Hypothesis (H1): At least one pair of dentists have significantly different mean implant hardness.

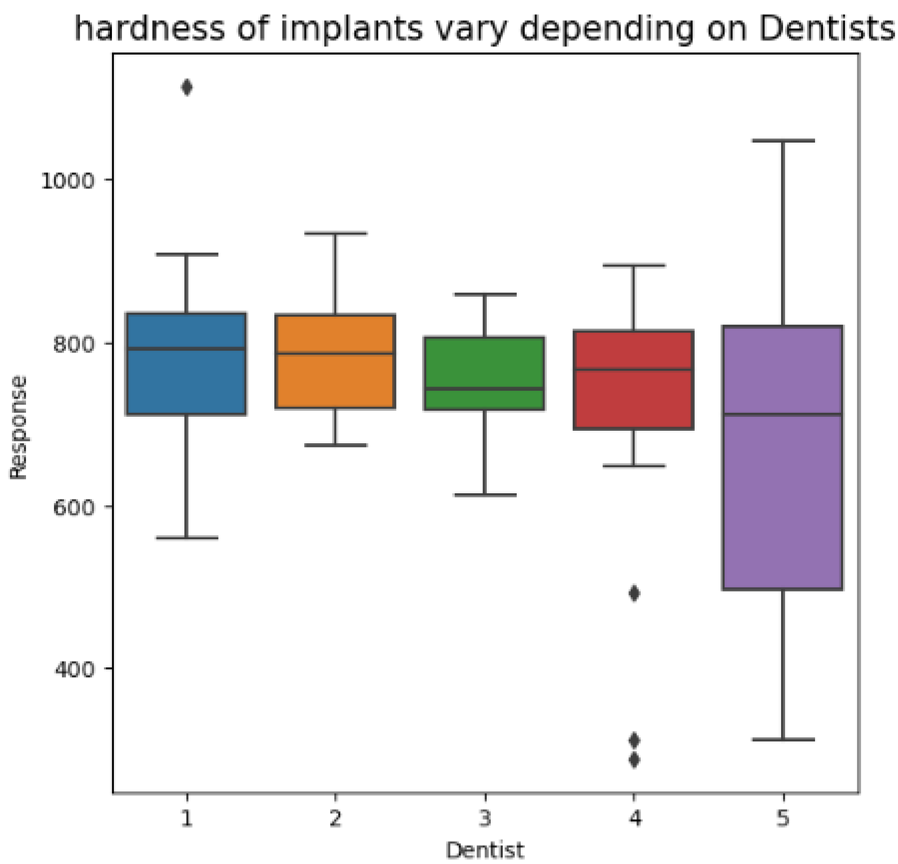
Alloy:

- Null Hypothesis (H0): The mean implant hardness is the same for both types of alloys.

- Alternate Hypothesis (H1): The mean implant hardness is significantly different for the two types of alloys.

Initial Data examination:

Upon examining the data, it is evident that the means of implant hardness for the five different dentists are not identical.



Graph 5: Hardness of implants vary depending on Dentists

Assumption Checking:

Before conducting ANOVA, we need to ensure the assumptions of normality and homogeneity of variance are met.

1. Shapiro-Wilk's Test for Dentist:

- Null Hypothesis (H0): Implant hardness for each dentist follows a normal distribution.
- Alternate Hypothesis (H1): Implant hardness for each dentist does not follow a normal distribution.

The Shapiro-Wilk's test yielded a very small p-value (1.1794428473876906e-06), indicating that the implant hardness distribution for each dentist does not follow a normal distribution.

2. Levene's Test for Homogeneity of Variance for Dentist Variable:

- The null hypothesis assumes that the variances of implant hardness for different dentists are equal.

The test statistic was inconclusive (nan) with a p-value of nan, suggesting that the variance in implant hardness across different dentists is not homogeneous.

3. Shapiro-Wilk's Test for Alloy:

- Null Hypothesis (H0): Implant hardness for each type of alloy follows a normal distribution.
- Alternate Hypothesis (H1): Implant hardness for each type of alloy does not follow a normal distribution.

Similar to the dentists, the Shapiro-Wilk's test also indicated a very small p-value (1.3392246838404842e-13), demonstrating that implant hardness for each type of alloy does not follow a normal distribution.

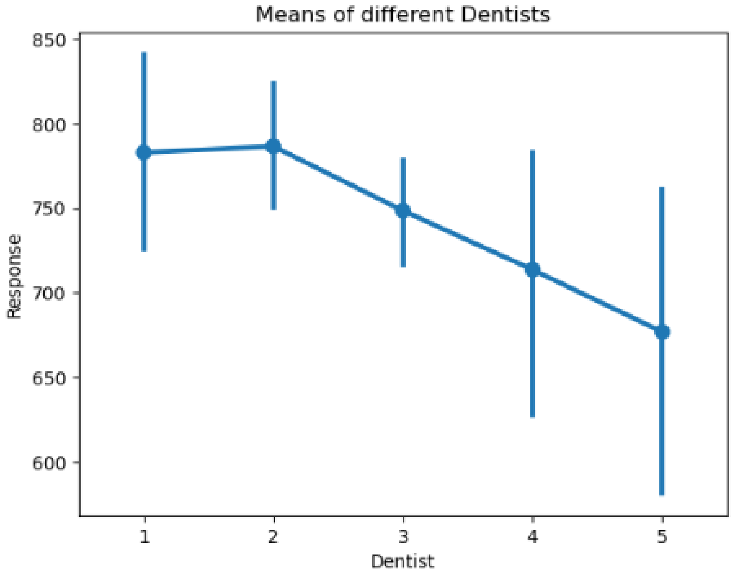
4. Levene's Test for Homogeneity of Variance for Alloy Variable:

- The null hypothesis assumes that the variances of implant hardness for different types of alloys are equal.

The test statistic was inconclusive (nan) with a p-value of nan, suggesting that the variance in implant hardness across different types of alloys is not homogeneous.

ANOVA Test:

To test the significance of differences among means, an ANOVA test was conducted. Categorical conversion of variables was necessary, as ANOVA only accepts categorical variables. The p-value from this test for dentists was 0.11%, indicating no significant difference in implant hardness among the different dentists.



Graph 6: Means of different levels of Dentists

Conclusion:

At a 5% significance level, we failed to reject the null hypothesis. This suggests that there is no significant difference in implant hardness among the various dentists.

Insights:

The analysis did not identify any specific dentist whose implant hardness significantly differed from the others.

These findings indicate that implant hardness does not significantly depend on the dentist performing the procedure.

Please note that a post-hoc analysis, such as Tukey's HSD test, may help identify any pairwise differences among the means, but this is not explicitly covered in the current analysis.

4.2 How does the hardness of implants vary depending on methods?

Analysis of Variance (ANOVA) for Implant Hardness Across Methods

Objective: To investigate the variation in implant hardness based on different methods used in dental procedures.

Hypothesis Testing:

Methods:

- Null Hypothesis (H0): The mean implant hardness is the same for all three methods.

- Alternate Hypothesis (H1): At least one pair of methods has significantly different mean implant hardness.

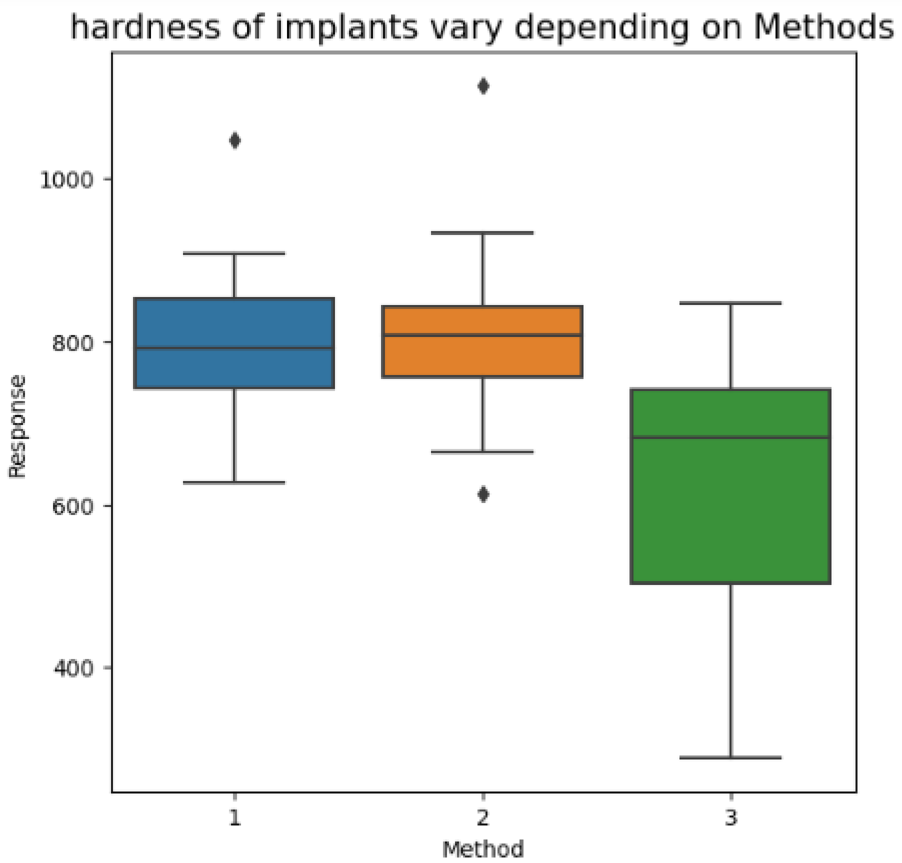
Alloy:

- Null Hypothesis (H0): The mean implant hardness is the same for both types of alloys.

- Alternate Hypothesis (H1): The mean implant hardness is significantly different for the two types of alloys.

Initial Data Examination:

- An initial examination of the data reveals the means of implant hardness differ across the different methods.



Graph 7: Hardness of implants vary depending on Methods

Assumption Checking:

Before conducting ANOVA, it is essential to ensure that the assumptions of normality and homogeneity of variance are met.

1. Shapiro-Wilk's Test for Methods:

- Null Hypothesis (H0): Implant hardness for each method follows a normal distribution.

- Alternate Hypothesis (H1): Implant hardness for each method does not follow a normal distribution.

The Shapiro-Wilk's test resulted in a very small p-value (6.475901481728386e-10), suggesting that the implant hardness distribution for each method does not follow a normal distribution.

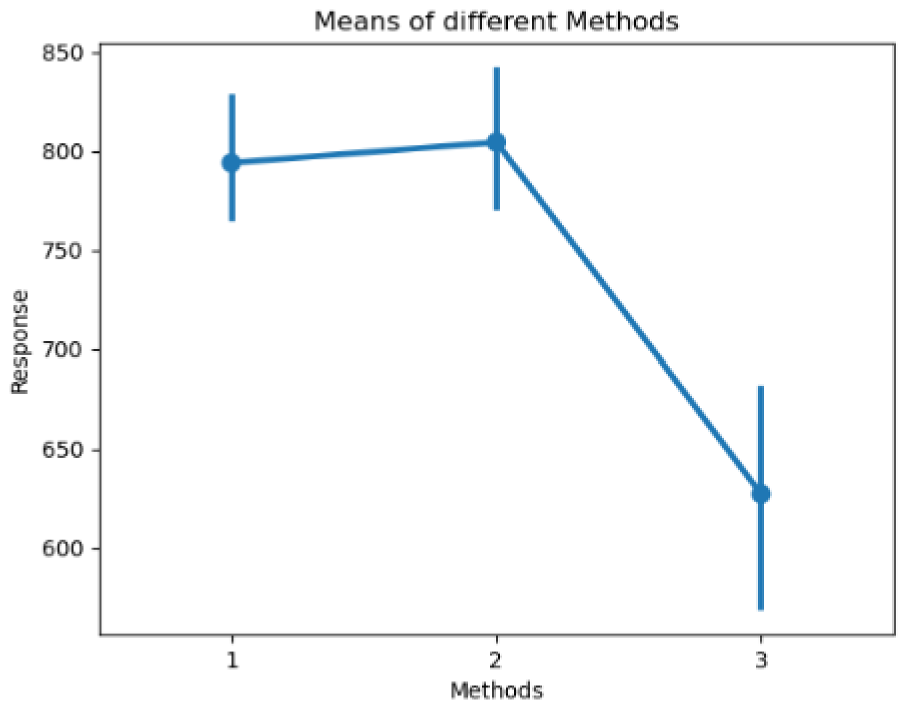
2. Levene's Test for Homogeneity of Variance for Method Variable:

- The null hypothesis assumes that the variances of implant hardness for different methods are equal.

The test statistic was inconclusive (nan) with a p-value of nan, indicating that the variance in implant hardness across different methods is not homogeneous.

ANOVA Test:

To test the significance of differences among means, an ANOVA test was conducted. Categorical conversion of variables was necessary, as ANOVA only accepts categorical variables. The p-value from this test for methods was found to be less than the significance level.



Graph 8: Means of different Methods

Conclusion:

With a p-value less than the chosen significance level, we reject the null hypothesis. This suggests that there is a significant difference in implant hardness among the different methods used.

Insights:

- The analysis confirms that at least one pair of methods significantly differs in implant hardness.

- The method employed during dental procedures has a significant impact on implant hardness.

While the ANOVA test shows that implant hardness depends on the method used, further post-hoc analysis, such as Tukey's HSD test, can be applied to identify which specific pairs of methods exhibit significant differences in mean implant hardness. This will provide more detailed insights into the impact of individual methods.

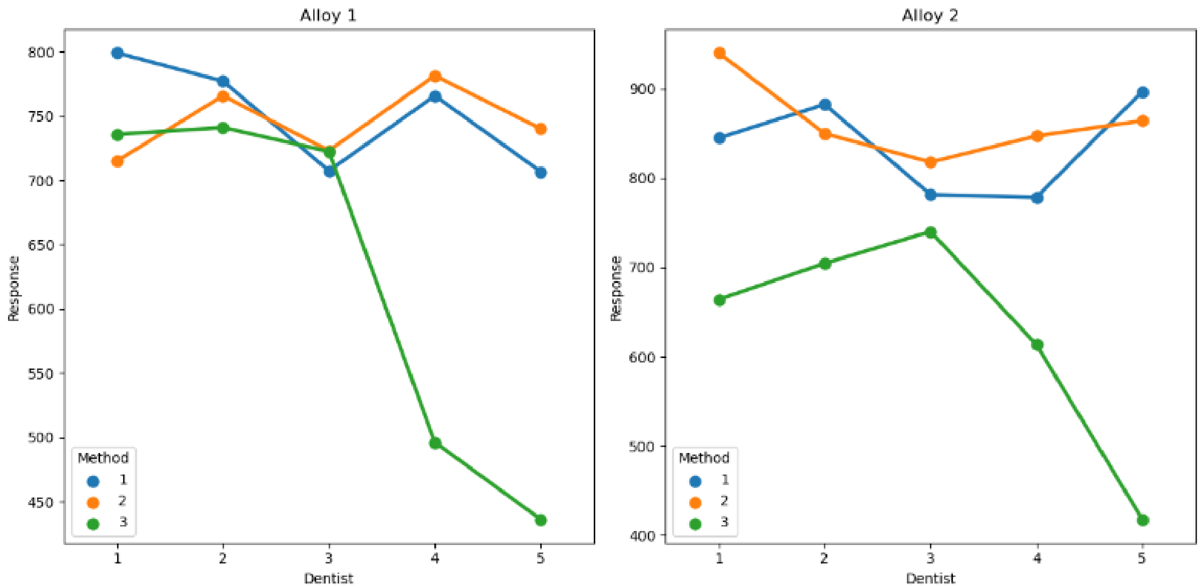
4.3 What is the interaction effect between the dentist and method on the hardness of dental implants for each type of alloy?

Assessment of Interaction Effects Between Dentist and Method on Implant Hardness for Each Alloy Type

Objective: The objective is to evaluate the interaction effects between the dentist and method for the hardness of dental implants, considering each type of alloy separately.

Analysis:

Interaction effects between the dentist and method for the hardness of dental implants were assessed by creating interaction plots for each type of alloy. The plots are designed to visualize how the implant hardness varies across different combinations of dentist and method.



Graph 9: Interactions effects between Dentist and Method on Implant Hardness for each Alloy type

Insights:

For Alloy 1:

- **Dentist 1:** Interaction is observed between Method 1 and 2.
- **Dentist 3:** Interaction effects are evident for all three methods.

For Alloy 2:

- **Dentist 2, 3, and 5:** Interaction is observed between Method 1 and 2.
- **For all Dentists:** Method 3 does not exhibit any interaction effect.

These findings provide valuable insights into the relationship between dentists, methods, and implant hardness for each type of alloy. It is essential to consider these interaction effects when making decisions related to dental implant procedures, as they can impact the final hardness of the implants, potentially affecting patient outcomes and satisfaction.

4.4 How does the hardness of implants vary depending on dentists and methods together?

Assessment of Hardness Variation in Dental Implants: Dentists, Methods, and Alloy Types

Objective: The objective is to evaluate the impact of different factors, including Dentist, Method, and Alloy type, on the hardness of dental implants. We consider their individual effects, potential interactions, and pairwise comparisons.

Analysis:

Step 1: Null and Alternate Hypotheses

- **Null Hypothesis (H0):** There is no significant difference in the means of implant hardness based on Dentist, Method, and Alloy type.
- **Alternate Hypothesis (H1):** At least one of these factors (Dentist, Method, Alloy) or their interactions has a significant effect on implant hardness.

Step 2: Assumption Check

- **Normality:** The normality assumption is validated using the Shapiro-Wilk test. The results indicate that most combinations of Dentists and Methods follow a normal distribution.
- **Homogeneity of Variance:** Levene's test is applied to check for homogeneity of variance, revealing that the variances are not equal (heteroscedasticity).

Step 3: Conduct Two-Way ANOVA and Compute P-Value

- The Two-Way ANOVA is conducted to assess the effects of Dentist, Method, and Alloy type on implant hardness.
- The obtained p-value is less than the significance level (typically 0.05), leading to the rejection of the null hypothesis. This suggests that at least one factor or interaction has a significant impact on implant hardness.

Step 4: Identify Significant Differences

Post-hoc tests, such as Tukey HSD, are performed to determine which specific combinations of Dentists and Methods are different from each other.

Interpretations are made based on the adjusted p-values for each pair.

Insights:

Alloy 1:

- Significant differences are observed between various Dentist and Method combinations. For example, '1-1' vs. '4-3,' '2-2' vs. '4-3,' '3-3' vs. '5-3,' and '5-1' vs. '5-3' exhibit significant differences in implant hardness.

Alloy 2:

- In the case of Alloy 2, the comparisons do not reveal significant differences between Dentists and Methods.

These findings indicate that the combination of Dentist and Method influences implant hardness differently for Alloy 1, whereas Alloy 2 appears to be less sensitive to such combinations. Understanding these distinctions is essential for optimizing implant procedures and ensuring consistent outcomes in dental implantation.

It's important to note that post-hoc tests help identify precisely which pairs exhibit significant differences. These results provide valuable insights for dental practitioners and researchers seeking to improve implant hardness control. Further investigations may focus on understanding the specific reasons behind these observed differences and their clinical implications.