# An Investigation Into the Effect of Temperature on the Elasticity of Rubber Bands

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**Abstract:** This technical report investigates and discusses the effect of temperature on the elasticity of rubber bands. Various industries use rubber bands, so understanding the performance of their elasticity under different temperature conditions can be crucial for optimizing performance. The fundamental research question of this study is: How does temperature affect the elasticity of rubber bands? To conduct this investigation, the researcher utilized a completely randomized design and assigned 50 Alliance Rubber 26649 Advantage Rubber Bands to two treatment groups: freezer and control, in their apartment's designated research area. The researcher initially measured the rubber bands at a standard room temperature of 70 ° F. Then, the researcher applied the treatment of either control or freezer (0 ° F) and measured again. The researcher then analyzed the mean difference in post-treatment and pre-treatment stretch for each treatment group to assess the effect of temperature on rubber band elasticity, using a two-sample t-test. The results of the study revealed a significant difference in the mean difference of rubber band stretch between the control and freezer groups. The study found that the control group resulted in a statistically significant and practically larger difference compared to the freezer group, indicating that cold temperatures decrease the elasticity of rubber bands. We recommend further research to validate these findings for other brands of rubber bands and different types of elastic material.

## 1. Introduction

Rubber bands are an everyday item that is quite often overlooked by the majority of people. Their elastic property plays a crucial role in many different practical applications such as in damping devices, tensioning mechanisms, and securing components during manufacturing processes. By understanding the complicated mechanics and factors that influence the elasticity of rubber bands, we can make improvements in engineering, material sciences, biomechanics, physics, and other fields. This report aims to investigate how exactly temperature affects the elasticity of rubber bands. Studies have previously been conducted that have investigated factors such as the stretching behavior of rubber bands of different sizes (Davuluri & Ravipati, 2022) [1], however, the specific influence of temperature on elasticity still has much to be discovered. Some of these prior studies have indicated that temperature can alter the physical properties of rubber bands including elasticity, and we hope to expand on and discover the exact effect of temperature on elasticity. The significance of this study lies in its potential practical improvements in the fields mentioned before. In the following section, we will present the data and methods used in this study, describing the design and data collection procedures. We will then display and discuss the results of the study and their implications. Lastly, we will discuss a summary of the findings as well as the limitations of the study and suggestions for future research.

## 2. Data & Methods

This study aimed to investigate the effect of temperature on the elasticity of rubber bands. Specifically, this study conducted a statistical analysis to find whether exposure to cold temperatures decreases the elasticity of rubber bands when compared to room temperature. This study used a completely randomized design and randomly assigned 50 Alliance Rubber 26649 Advantage Rubber Bands to two treatment groups, freezer or control, resulting in 25 replicates per treatment group. The design of the experiment is shown in Table 1 below. The freezer group was placed overnight in a standard freezer set at 0 ° F while the control group was kept overnight at room temperature set at a standard 70 ° F. All rubber bands were new and unused.

To collect data, the researcher randomly assigned each rubber band to the control or freezer treatment. The researcher collected data from April 13, 2023 - April 14, 2023, in their apartment's research area. The researcher used a standard ruler, fully stretched each rubber band at room temperature, and recorded the maximum millimeters reached. The researcher applied the assigned treatment and measured each rubber band again. After recording all measurements, the researcher calculated the differences in post-treatment and pre-treatment stretch for all rubber bands. The primary response variable of interest was the calculated difference in millimeters. To analyze the difference between treatments, the researcher conducted a two-sample t-test to compare the means between the control and freezer groups. A significance level of 0.05 was used for testing significance. Some limitations of the study include that the temperature was not directly measured and that the maximum stretch was dependent on the opinion and strength of the researcher, both of which could lead to increased unexplained variation and decreased reproducibility. Additionally, the generalization of the study can only be to Alliance Rubber 26649 Advantage Rubber Bands purchased online.

The researcher carried out the statistical analysis using R's version 4.2.2 "t.test" function (R Core Team, 2022) [2]. The researcher created the graph using the ggplot2 package in R (Wickham, 2016) [3] and the tables using the kableExtra (Zhu, 2021) [4] and broom (Robinson, Hayes, and Couch, 2023) [5] packages in R.

Table 1: Summary Statistics for Difference in Post and Pre Treatment Stretch Lengths (mm)

| Treatment | Sample Size | Mean | Median | Standard Deviation | Min | Max |
|---|---|---|---|---|---|---|
| control | 25 | 3.72 | 0 | 14.30 | -20 | 32 |
| freezer | 25 | -14.28 | -15 | 10.54 | -39 | 5 |

## 3. Results & Discussion

After collecting the data on the difference in rubber band stretch between a control group kept at room temperature and a freezer group kept at cold temperatures, the researcher used a two-sample t-test to analyze the difference in means between the two groups. The results of the t-test can be found in Tables 2 and 3. As seen in Table 2, the two-sample t-test resulted in a significant difference in the mean of the difference of the post and pre-treatment rubber band stretch between the control treatment and the freezer treatment at an alpha level of 0.05. ($t = 5.07$, $df = 48$, $p < 0.001$).

Table 2: Two Sample t-test

| Mean Control | Mean Freezer | DF | t-stat | p-value |
|---|---|---|---|---|
| 3.72 | -14.28 | 48 | 5.07 | <0.001 |

*Note:*

Null: Mean of Freezer = Mean of Control

Table 3: 95% Confidence Interval

| Estimate | Lower | Upper |
|---|---|---|
| 18 | 10.858 | 25.142 |

*Note:*

Interval represents the range of values for the difference in means between Treatment 1 (Control) and Treatment 2 (Freezer).

These results are further supported by the 95% confidence interval for the difference in means between the control and freezer treatments, shown in Table 3. As seen by these results, the control treatment resulted in a difference in rubber band stretch that was significantly larger than the freezer treatment. Specifically, we are 95% confident that the mean difference in the post-to-pre-treatment stretch in the control group is between 10.858 and 25.142 millimeters larger than that of the freezer group. The observed difference between groups of 18 mm is quite large and practically significant. To put this difference in perspective, since an unstretched rubber band is approximately 75 mm, the control group was able to stretch about a quarter of an unstretched rubber band more than the freezer group. This difference can be visually interpreted by the boxplots provided in Figure 1.

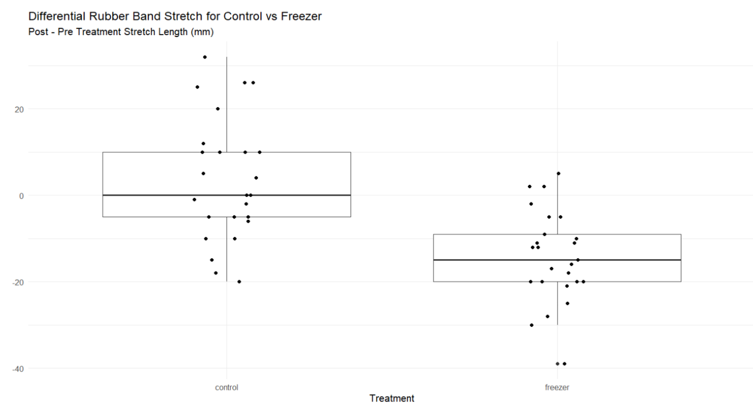


Fig. 1. Box plots of post-pre stretch for each treatment, revealing reduced elasticity in the freezer group

As seen in Figure 1, the median of the control treatment group is quite a bit higher than the freezer treatment group and the entire IQR (interquartile range) of the control treatment group is above the IQR of the freezer treatment group. However, it is still important to note that there is a large overlap between the data points of the two groups, indicating variability. Due to the usage of random assignment and selection, the results of the study are causal. There is sufficient evidence to say that cold temperature decreases the elasticity of rubber bands, which supports the researcher's initial hypothesis that exposure to cold temperatures would reduce the elasticity of rubber bands. However, it is still important to recognize the limitations of the study. We can only generalize these results to Alliance Rubber 26649 Advantage Rubber Bands purchased online. Further research is needed to determine if similar effects occur for other brands of rubber bands and possibly other types of elastic material. Additionally, the researcher in this study did not directly measure the temperature or standardize the stretch method, which could be reasons for the large variability in the study and potentially introduced bias. Further research should be conducted to validate the results that perhaps focus on minimizing the sources of bias that were introduced in this study.

## 4. Conclusion

This study aimed to investigate the effect of temperature on the elasticity of rubber bands. Using a completely randomized design, the researcher assigned 50 Alliance Rubber 26649 Advantage Rubber Bands to two treatment groups of freezer and control. The researcher initially measured the rubber bands at room temperature, then applied one of the treatments and measured the rubber bands again. The researcher then analyzed the difference in post-treatment and pre-treatment stretch using a two-sample t-test. The results of this study have provided valuable insight into the effect of temperature on the elasticity of rubber bands. The study found compelling evidence, indicated by the two-sample t-test and 95% confidence interval, that cold temperature reduces the elasticity of rubber bands compared to room temperature. These findings support the initial hypothesis. Due to the usage of random assignment, we can infer causality from the results of this study. The observed result displays practical significance since on average, the difference in the control group in the study was a quarter of a non-stretched rubber band more than the freezer group. Changes in the elasticity of the observed level would make a significant impact on many of the current applications of elastic rubber bands. These results suggest that manufacturers should consider the impact of temperature on rubber bands when selecting or utilizing rubber bands to ensure optimal performance. Since generalizing the results of this study are limited to Alliance Rubber 26649 Advantage Rubber Bands purchased online, further research is needed to validate the results across different brands and types of elastic materials. Future studies should aim to minimize potential sources of bias and possibly incorporate direct temperature measurements to reduce unexplained variability and increase the reproducibility and accuracy of the findings. The implications of this study extend beyond the scope, and it is our hope that with future research we can reduce costs and optimize performance in industries that heavily rely on elastic rubber bands.

## References


1. S. Davuluri and A. Ravipati, "A study on the stretching behavior of rubber bands," https://emerginginvestigators.org/articles/a-study-on-the-stretching-behavior-of-rubber-bands (2022).
2. R Core Team, *R: A language and environment for statistical computing*, R Foundation for Statistical Computing, Vienna, Austria (2022).
3. H. Wickham, *ggplot2: Elegant Graphics for Data Analysis* (Springer-Verlag New York, 2016).
4. H. Zhu, *kableExtra: Construct Complex Table with 'kable' and Pipe Syntax* (2021). R package version 1.3.4.
5. D. Robinson, A. Hayes, and S. Couch, *broom: Convert Statistical Objects into Tidy Tibbles* (2023). R package version 1.0.3.


[1–5]

## Appendix

### *Appendix A: Research Protocol*

The following is the research protocol that was used for this study:
1. Get your 50 Alliance Rubber 26649 Advantage Rubber Bands.
2. Write a number 1-50 on 50 small pieces of paper. Evens will be assigned to the freezer and odds will be assigned to the control. Flip the papers over and randomly assign them to each rubber band. Mark the rubber band with its number.
3. Stretch the rubber bands over a large piece of paper. Using a pen mark the starting point, stretch the rubber band fully, and mark the furthest point reached by the fully stretched rubber band. (May need two people) I define a fully stretched rubber band as a rubber band that is stretched until I cannot comfortably stretch the rubber band any notable amount.
4. Using a standard ruler or meter stick on your phone, measure the distance between the two points in millimeters.
5. Repeat steps 2 and 3 for each of the 50 rubber bands, recording the maximum length reached for that numbered rubber band.
6. Apply each treatment for all 50 rubber bands, leaving 25 at room temperature for the control group and putting the other 25 rubber bands in the freezer for the cold group.
7. Set a timer for an hour.
8. After 1 hour, repeat steps 2 and 3 once again and record the final maximum length reached. Due to the time that it takes to measure the rubber bands and the fact that the temperature might be lost, keep the individual cold rubber bands in the freezer until it is time to measure each one.
9. Calculate the difference in millimeters between the final maximum stretched length and the initial length. (final - initial)
10. Conduct a two-sample t-test to compare the means between the control and freezer groups.
11. Analyze the results and draw conclusions based on the statistical analysis.

### *Appendix B: Collected Data*

The following is the table of all collected data on the difference in rubber band stretch for the control and freezer treatment groups (found on next page):

| ID | TRT | PreTRTLen (mm) | PostTRTLen (mm) | Diff |
|---|---|---|---|---|
| 1 | control | 230 | 235 | 5 |
| 2 | freezer | 200 | 180 | -20 |
| 3 | control | 202 | 228 | 26 |
| 4 | freezer | 190 | 169 | -21 |
| 5 | control | 179 | 173 | -6 |
| 6 | freezer | 210 | 205 | -5 |
| 7 | control | 170 | 182 | 12 |
| 8 | freezer | 180 | 168 | -12 |
| 9 | control | 225 | 220 | -5 |
| 10 | freezer | 209 | 200 | -9 |
| 11 | control | 215 | 215 | 0 |
| 12 | freezer | 230 | 210 | -20 |
| 13 | control | 228 | 210 | -18 |
| 14 | freezer | 235 | 225 | -10 |
| 15 | control | 220 | 230 | 10 |
| 16 | freezer | 210 | 199 | -11 |
| 17 | control | 200 | 190 | -10 |
| 18 | freezer | 190 | 188 | -2 |
| 19 | control | 218 | 198 | -20 |
| 20 | freezer | 250 | 220 | -30 |
| 21 | control | 230 | 225 | -5 |
| 22 | freezer | 198 | 170 | -28 |
| 23 | control | 200 | 190 | -10 |
| 24 | freezer | 190 | 175 | -15 |
| 25 | control | 185 | 180 | -5 |
| 26 | freezer | 200 | 184 | -16 |
| 27 | control | 190 | 190 | 0 |
| 28 | freezer | 238 | 199 | -39 |
| 29 | control | 186 | 190 | 4 |
| 30 | freezer | 200 | 180 | -20 |
| 31 | control | 210 | 195 | -15 |
| 32 | freezer | 200 | 205 | 5 |
| 33 | control | 184 | 183 | -1 |
| 34 | freezer | 210 | 198 | -12 |
| 35 | control | 190 | 200 | 10 |
| 36 | freezer | 210 | 190 | -20 |
| 37 | control | 189 | 215 | 26 |
| 38 | freezer | 198 | 200 | 2 |
| 39 | control | 189 | 187 | -2 |
| 40 | freezer | 237 | 220 | -17 |
| 41 | control | 198 | 230 | 32 |
| 42 | freezer | 220 | 195 | -25 |
| 43 | control | 210 | 230 | 20 |
| 44 | freezer | 195 | 190 | -5 |
| 45 | control | 185 | 195 | 10 |
| 46 | freezer | 178 | 160 | -18 |
| 47 | control | 190 | 215 | 25 |
| 48 | freezer | 218 | 220 | 2 |
| 49 | control | 190 | 200 | 10 |
| 50 | freezer | 219 | 208 | -11 |