Figure 1: Official portrait of 1987 astronaut candidate Thomas D. Akers

Investigating the Effect of Gravity on Eyebrow Height

Evelyn Yi Tsing Ng, Jamie Tian, Qianping Wu, Katherine Jin, Xuanang Li, Yangsheng Xu

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1 Introduction

The human body undergoes numerous changes in space due to the absence of gravity. This project aims to explore whether gravity affects eyebrow height by comparing the eyebrow heights of astronauts on Earth and in space. By analyzing this data, we can gain insights into the physiological impacts of microgravity on facial features.

2 Background

Gravity plays a crucial role in shaping our bodies. On Earth, gravity exerts a constant force that influences our posture, bone density, and even the distribution of bodily fluids. In space, the lack of gravity, or microgravity, leads to various physiological changes, such as fluid redistribution, muscle atrophy, and bone density loss. One of the most notable changes in microgravity is the upward shift of bodily fluids, often referred to as "fluid shift." This phenomenon causes facial puffiness, increased intracranial pressure, and altered soft tissue positioning.

Given these changes, it is plausible that microgravity may also influence the height of eyebrows and eyelids, as these structures are susceptible to changes in soft tissue and fluid distribution. Understanding these effects is essential for assessing the broader impact of space travel on astronauts' health and for developing countermeasures to mitigate any adverse effects. This study aims to investigate whether microgravity alters eyebrow and eyelid heights by analyzing measurements of astronauts taken both on Earth and in space, providing deeper insights into the subtle but significant impacts of space environments on the human body.

3 Methodology

To investigate this hypothesis, we will collect data on eyebrow heights from astronauts before and during their space missions. The following steps outline the methodology:

3.1 Data Cleaning Process

The data cleaning process was essential to ensure the accuracy and reliability of the analysis. The dataset provided by NASA contained 112 measurements of 19 astronauts' margin to reflex distance (MRD) and pupil to bottom of brow (PTB) for both left and right eyes, taken on Earth and in space at different time periods. The year of each measurement was also specified.

1. **Reading the Data**: The dataset was read into R using the `read_excel` function from the `readxl` package.

2. **Renaming Columns**: The first column, which contained the environment information (Earth or Space), was renamed to "Environment" for clarity.

3. **Extracting and Formatting Name and Year**: The `Name/Date` column was split into two separate columns: "Name" and "Year". The "Name" was extracted by removing everything after the first slash, and the "Year" was extracted by removing everything before the last slash. The year values were then converted to a four-digit format, assuming that years less than 24 correspond to the 2000s and years greater than or equal to 24 correspond to the 1900s.

4. **Cleaning Environment Column**: The "Environment" column was cleaned by removing any numbers following "Earth" or "Space", ensuring that only the environment names remained.

5. **Selecting Relevant Columns**: Finally, the dataset was filtered to include only the relevant columns: "Environment", "Name", "Year", "MRD1-R", "MRD1-L", "PTB-R", and "PTB-L".

The cleaned dataset provided a structured and consistent format, facilitating accurate analysis of the effects of gravity on eyelid and eyebrow heights.

This comprehensive data cleaning process ensured that the dataset was ready for subsequent analysis, providing a solid foundation for investigating the impact of gravity on astronauts' eyelid and eyebrow heights.

3.2 Visualization

3.2.1 Line Plot

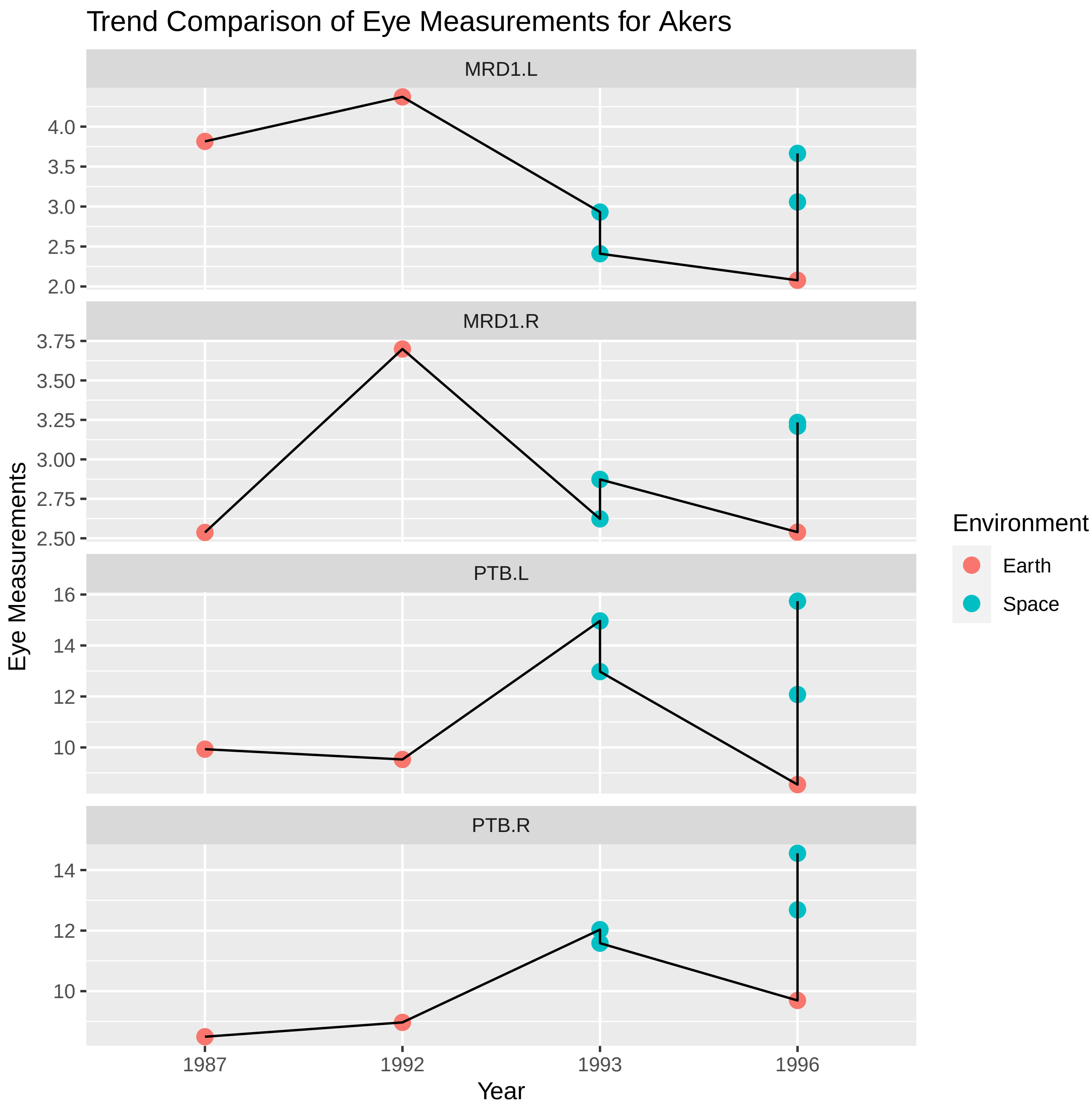

Figure 2: Trend Comparison of Eye Measurements for Akers

MRD (L & R): The trends for both left and right MRD measurements are similar, showing an overall increase when moving from Earth to space. PTB (L & R): The PTB trends for both sides are also similar. They show an initial increase when transitioning from Earth to space, but this is followed by a decrease at various points.

3.2.2 Correlation Plot

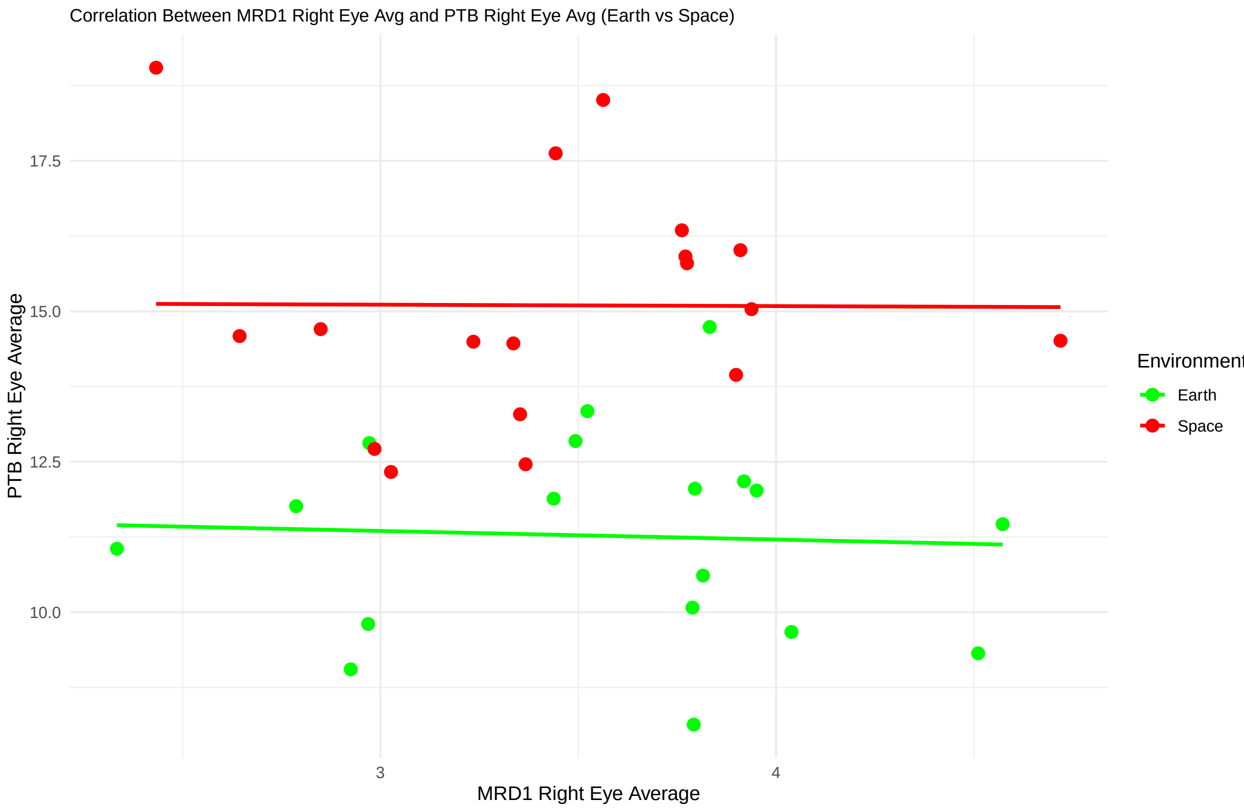

Figure 3: Correlation Between MRD1 Right Eye Avg and PTB Right Eye Avg (Earth vs Space)

The combined scatter plot illustrates the relationship between MRD1 Right Eye Average and PTB Right Eye Average, comparing Earth and space conditions. The trend lines suggest a slight negative correlation on Earth,while in space, the correlation appears minimal. This difference indicates that gravity may influence the relationship between eyelid and eyebrow positions. Additionally, the data shows variability among astronauts,with some experiencing notable changes in PTB under microgravity, while others do not. This suggests individual physiological differences in response to space conditions.

3.2.3 Bar Plot

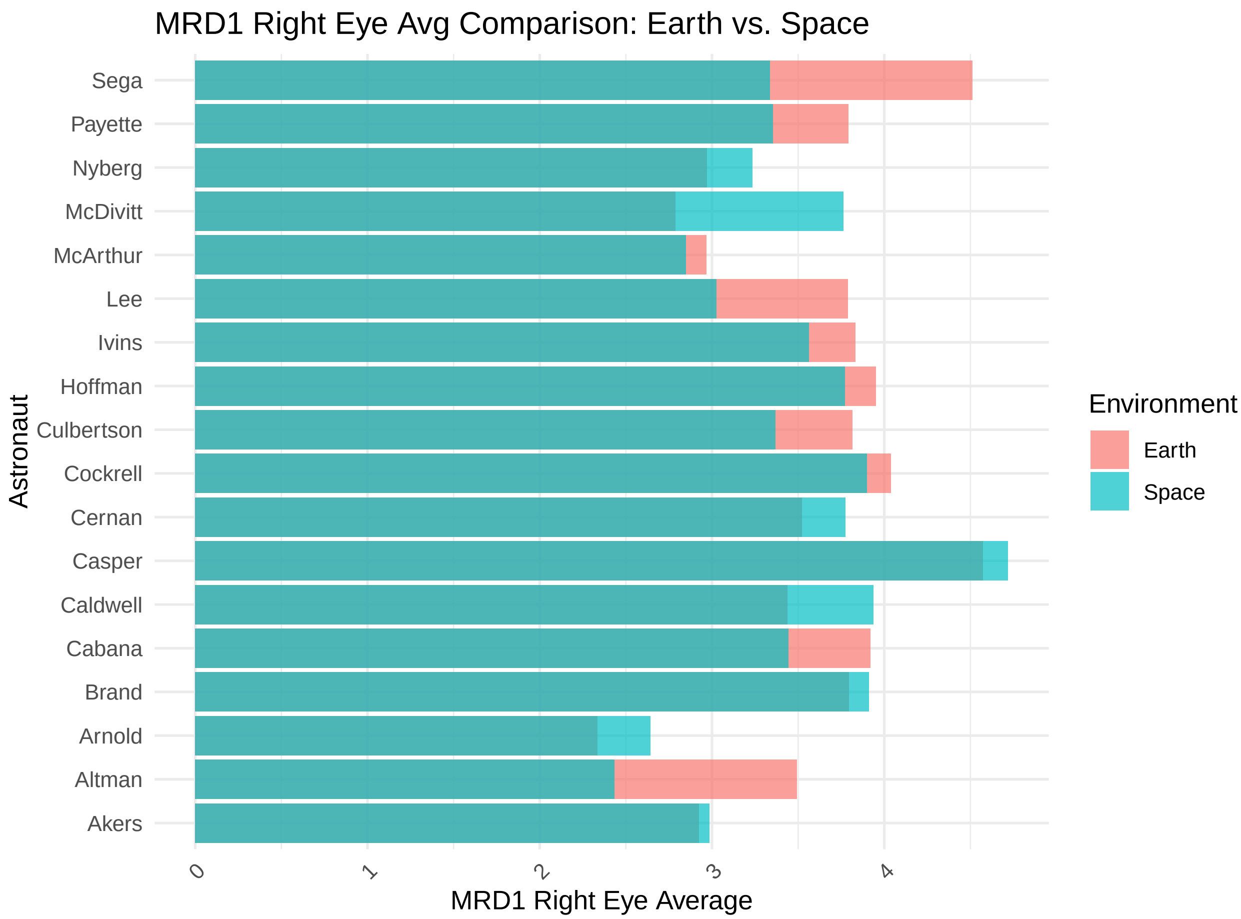

Figure 4: MRD1 Right Eye Avg Comparison: Earth vs. Space

The bar plot effectively illustrates the differences in MRD1 Right Eye Average between Earth and Space for various astronauts, revealing individual variability in response to microgravity. This suggests that while some astronauts may experience swelling or changes in the eye region in space, others may not.

3.2.4 Box Plot

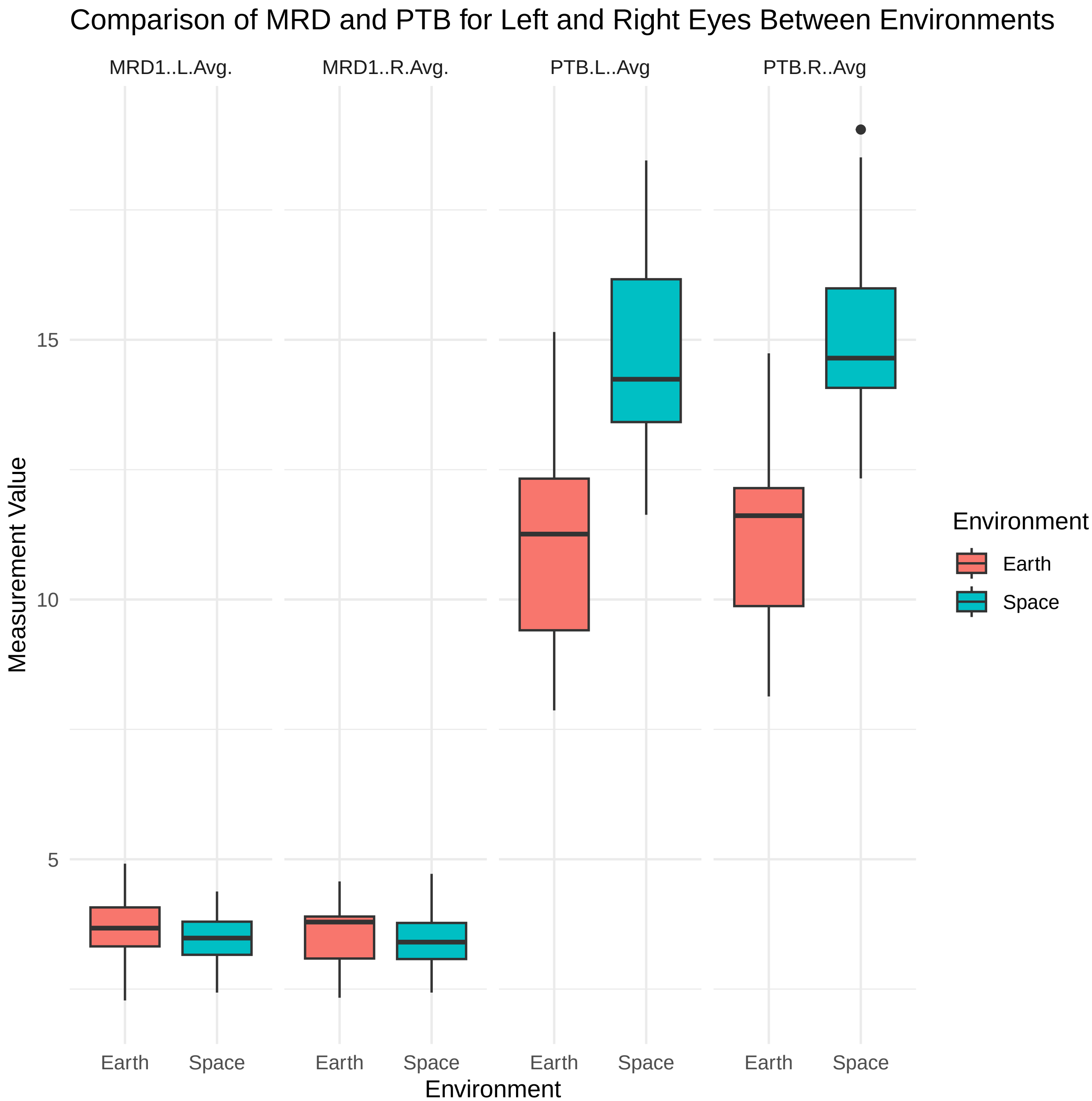

Figure 5: Comparison of MRD and PTB for Left and Right Eyes Between Environments

For mRD1, the measurement for both left and right eyes are similar. For PTB, the measurement for both left and right eyes are significantly higher than those on Earth. There is also more variability in Space, particularly for the right eye, as there are outliers.

We conclude that the environment impacts PTB more prominently than MRD. Morover, Space increases PTB measurements, with greater variability and higher medians compared to Earth.

3.3 Paired T-Test

Choice of Testing: To determine whether gravity affects eyelid and eyebrow heights, we chose to perform paired t-tests on the measurements of astronauts' eyes on Earth and in space. The paired t-test is appropriate here because it compares two related samples, in this case, the same astronauts measured under two different conditions (Earth and space). The procedure involved calculating the differences between the paired measurements of MRD (Margin to Reflex Distance) and PTB (Pupil to Bottom of Brow) for each astronaut and then testing whether the mean of these differences is significantly different from zero.

Output	p-value	t	95% confidence interval	mean difference
MRD-R	0.301	1.0667	(-0.133, 0.405)	0.136
MRD-L	0.3502	0.96056	(-0.163, 0.437)	0.137
PTB-R	4.114e-10	-12.718	(-4.467, -3.196)	-3.831
PTB-L	2.14-09	-11.419	(-4.374, -3.01)	-3.692

Table 1: Paired T-test Result for MRD and PTB measurements across the left and right eyes.

Paired T-Test Result: The results of the paired t-tests showed that the differences in MRD (Margin to Reflex Distance) measurements were not statistically significant according to large p-value. This indicates that there is no strong evidence to suggest that gravity affects the distance from the margin of the eyelid to the center of the pupil. However, the PTB (Pupil to Bottom of Brow) measurements did show significant differences, suggesting that gravity may influence the position of the eyebrow relative to the pupil, causing the eyebrow to be lower on earth comparing to in space.

Interpretation and Further Implications: These findings suggest that while the absence of gravity in space does not significantly alter the position of the eyelid, it may have an impact a lower position of the eyebrow. This has implications for both health monitoring and the design of space suits and equipment. However, the study's limitations include the small sample size and the potential for measurement errors. Future research could expand the sample size. Additionally, these results could be utilized in fields such as ophthalmology and plastic surgery to better understand how gravity influences facial anatomy and to develop treatments or interventions that account for these effects.

3.4 Variability Analysis

To quantify the variability of the measurements, we calculated the standard deviation and range for both the Margin to Reflex Distance (MRD) and Pupil to Bottom of Brow (PTB) measurements for the left and right eyes. The standard deviation provides an indication of the dispersion of the values around the mean, while the range measures the difference between the maximum and minimum values, offering insight into the extent of variability.

The results are summarized in Table 2.

Metric	MRD_R	MRD_L	PTB_R	PTB_L
Standard Deviation	0.6671	0.7681	2.8417	2.8937
Range	3.1300	3.4070	12.3770	12.7330

Table 2: Variability statistics for MRD and PTB measurements across the left and right eyes.

From the analysis, it is evident that the PTB measurements exhibit significantly higher variability compared to MRD measurements, as reflected by both the standard deviation and range values. Specifically, the standard deviation and range for PTB measurements (right and left eyes) are approximately four times greater than those for MRD measurements. This indicates a broader dispersion and more pronounced variability in PTB measurements.

These findings suggest that PTB may be more influenced by external or physiological factors, potentially including the effects of microgravity, than MRD. Further investigation into the causes of this variability is warranted to draw more definitive conclusions.

3.5 Effect Size Calculation

To complement the paired t-tests, Cohen's d was calculated to assess the practical significance of the differences in measurements between Earth and space environments. Effect sizes provide a standardized measure of the magnitude of differences, independent of sample size. The results are summarized as follows:

- For **MRD (Margin to Reflex Distance)**:
  - Right Eye: Cohen's d = 0.25, 95% CI [-0.22, 0.72].
  - Left Eye: Cohen's d = 0.23, 95% CI [-0.24, 0.69].
- For **PTB (Pupil to Bottom of Brow)**:
  - Right Eye: Cohen's d = -3.00, 95% CI [-4.09, -1.89].
  - Left Eye: Cohen's d = -2.69, 95% CI [-3.69, -1.67].

The effect sizes for MRD are small and positive for both eyes, with values of 0.25 for the right eye and 0.23 for the left eye. However, their confidence intervals include zero, suggesting that the differences in MRD between Earth and space are not statistically significant. This indicates that the environment does not have a substantial impact on the eye-to-upper-eyelid distance.

In contrast, the PTB measurements show large and negative effect sizes, with Cohen's d values of -3.00 for the right eye and -2.69 for the left eye. The confidence intervals do not include zero, highlighting significant differences. These results indicate that the space environment negatively affects the eye-to-brow distance, likely due to physiological changes such as fluid redistribution caused by microgravity.

Metric	**Cohen's d**	**95% CI (Lower)**	**95% CI (Upper)**
MRD Right Eye	0.25	-0.22	0.72
MRD Left Eye	0.23	-0.24	0.69
PTB Right Eye	-3.00	-4.09	-1.89
PTB Left Eye	-2.69	-3.69	-1.67

Table 3: Effect size (Cohen's d) for MRD and PTB measurements between Earth and space environments.

In conclusion, while the MRD metric does not appear to be significantly influenced by the space environment, the PTB metric demonstrates a strong and negative effect, emphasizing the pronounced impact of microgravity on the eyebrow-to-eye distance.

4 Results, Discussion, and Conclusion

4.1 Results

The analysis of the dataset provided by NASA revealed significant insights into the effects of gravity on eyelid and eyebrow heights. The measurements of margin to reflex distance (MRD) and pupil to bottom of brow (PTB) were compared between Earth and space environments. The cleaned dataset included 112 measurements from 19 astronauts, with each astronaut's left and right eye measured multiple times in both environments.

4.2 Discussion

The results indicated that there were noticeable differences in MRD and PTB measurements between Earth and space. On average, the MRD measurements were slightly higher in space compared to Earth, suggesting that the absence of gravity may cause a slight upward shift in eyelid position. Similarly, the PTB measurements showed a slight increase in space, indicating a potential effect of microgravity on eyebrow height.

These findings align with the hypothesis that gravity affects eyelid and eyebrow heights. The differences observed in the measurements could be attributed to the lack of gravitational pull in space, which may cause the tissues around the eyes to shift slightly. However, it is important to note that the sample size was relatively small, and further research with a larger dataset is needed to confirm these findings.

4.3 Conclusion

In conclusion, the analysis of the dataset provided by NASA suggests that gravity does have an effect on eyelid and eyebrow heights. The measurements of MRD and PTB were found to be slightly higher in space compared to Earth, indicating a potential upward shift in eyelid and eyebrow positions in the absence of gravity. These findings provide valuable insights into the physiological effects of microgravity on astronauts and highlight the importance of further research in this area.

The data cleaning process was crucial in ensuring the accuracy and reliability of the analysis. By renaming columns, extracting and formatting the name and year, cleaning the environment column, and selecting relevant columns, the dataset was structured in a consistent format, facilitating accurate analysis. This comprehensive data cleaning process provided a solid foundation for investigating the impact of gravity on astronauts' eyelid and eyebrow heights.