Indian Statistical Institute, Kolkata

Project for 'Statistical Methods - III'

Bachelor of Statistics (Hons.), 2023-26

Gender Parity in Precision Sports: A Statistical Analysis of Olympic Archery and Shooting

Nishant Lamboria
BS2334

Advisor/Instructor:
Dr. Ayanendranath Basu
Professor, Interdisciplinary Statistical Research Unit

Friday, November 8, 2024

Contents

Abstract

This project investigates gender parity in Olympic precision sports, specifically focusing on archery and shooting. Unlike many physically demanding sports, archery and shooting are skill-driven events where factors such as focus, precision, and control play a larger role than physical strength. Using Olympic finals data, I compare the performance of male and female athletes to assess differences in outcomes. Statistical analyses, including mean comparison tests and tests for proportions, are applied to identify any significant performance gaps between genders. Results suggest that in precision sports like archery and shooting, male and female athletes perform at comparable levels, suggesting that skill-intensive sports show minimal gender disparities. This study contributes to a broader understanding of gender parity in sports and highlights events where skill can overshadow physical differences, promoting greater inclusivity in competitive sports.

1 Data

This study focuses on three Olympic events: **Shooting 10m Air Pistol**, **Shooting 10m Air Rifle**, and **Archery (Individual)**. Data were collected from the official Olympic finals results, specifically analyzing each shot's score.

For the Shooting 10m Air Pistol and 10m Air Rifle events, data were obtained from the finals, which feature eight athletes per event for each gender. Each final consists of 150 shots in total for both men and women. In these events, scores range from 0.0 to 10.9, recorded to one decimal place, allowing for fine distinctions in precision. By analyzing scores at this detailed level, we capture a comprehensive view of performance consistency and precision under competitive conditions.

In the Archery Individual event, the Olympic finals are structured as one-on-one elimination matches. Since these matches provide fewer total observations, data were taken from the quarterfinal rounds, thereby maintaining a sample size of eight athletes per gender. Archery scores are recorded as integer values ranging from 0 to 10. This approach yields over 100 individual shot scores for both men and women, allowing for robust statistical comparisons.

2 Exploration

Starting with basic summary statistics for each event, as shown in the tables below. For each gender, the measures mean, median, variance, standard deviation, minima, maxima and range are reported. These descriptive statistics provide a preliminary view of the central tendency and variability, or the lack thereof, in performance across genders and events.

Group	Mean	Median	Variance	SD	Min	Max	Range
Men	9.91	9.90	0.26	0.51	8.30	10.80	2.50
Women	9.93	10.00	0.33	0.57	7.90	10.80	2.90

Table 1: Summary Statistics for **10m Air Pistol Shooting**

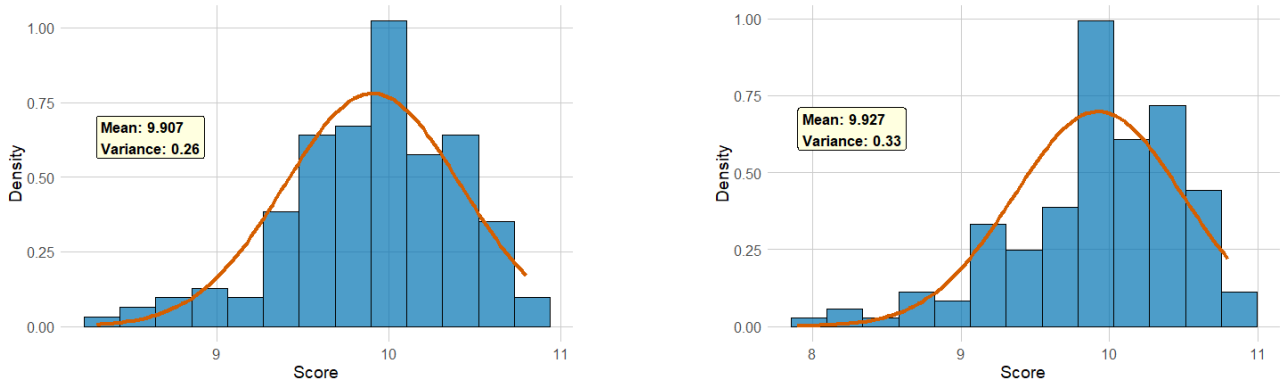
Group	Mean	Median	Variance	SD	Min	Max	Range
Men	10.42	10.50	0.09	0.31	9.30	10.90	1.60
Women	10.42	10.50	0.09	0.30	9.60	10.90	1.30

Table 2: Summary Statistics for **10m Air Rifle Shooting**

Group	Mean	Median	Variance	SD	Min	Max	Range
Men	9.27	9.00	0.67	0.82	6	10	4
Women	9.20	9.00	0.80	0.89	5	10	5

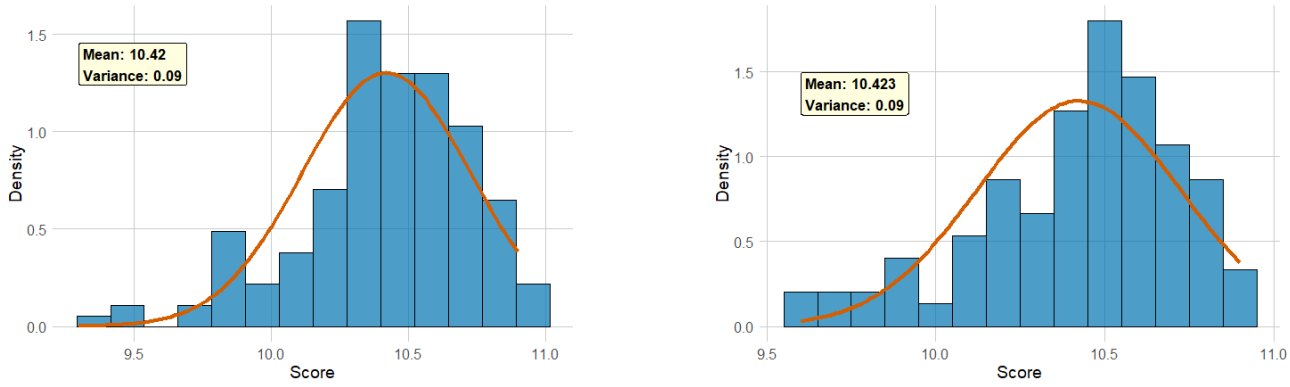
Table 3: Summary Statistics for **Archery**

To understand score distributions, I used histograms and density plots for each shooting event.



(a) Men (b) Women

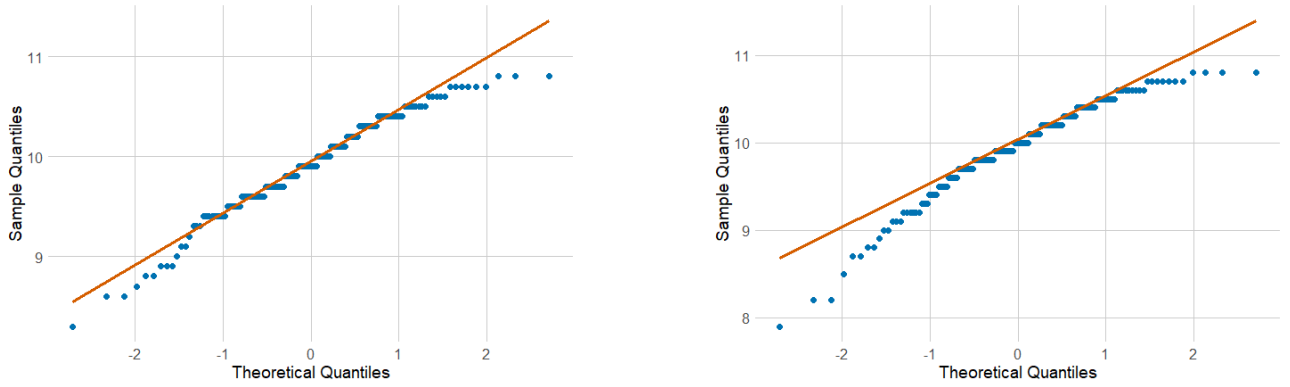
Figure 2.1: Histogram plots fitted with Normal Density for Pistol Shooting



(a) Men (b) Women

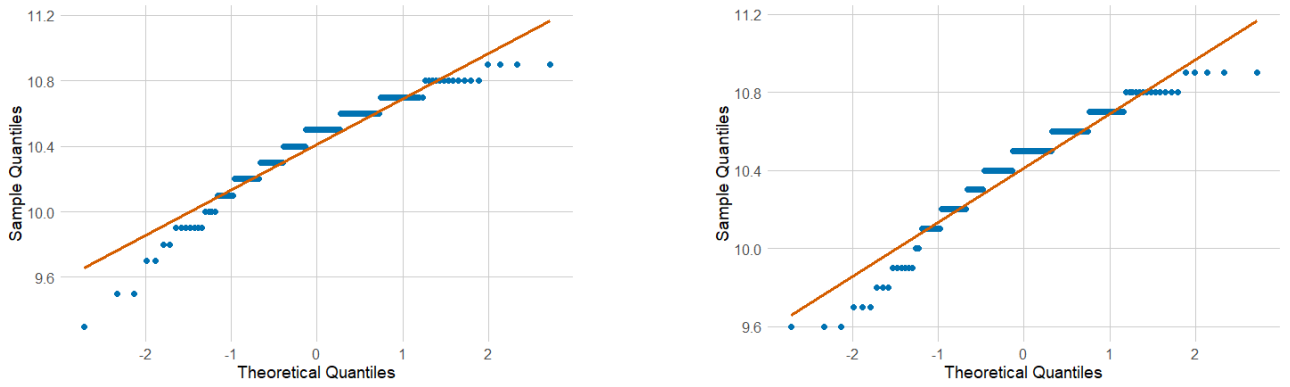
Figure 2.2: Histogram plots fitted with Normal Density for Rifle Shooting

The histograms and density plots suggest a tendency toward normal distribution in the score data. To further fortify this assumption, I generated Q-Q plots for a more detailed assessment of the distribution's conformity to normality.



(a) Men (b) Women

Figure 2.3: QQ-plots for Pistol Shooting



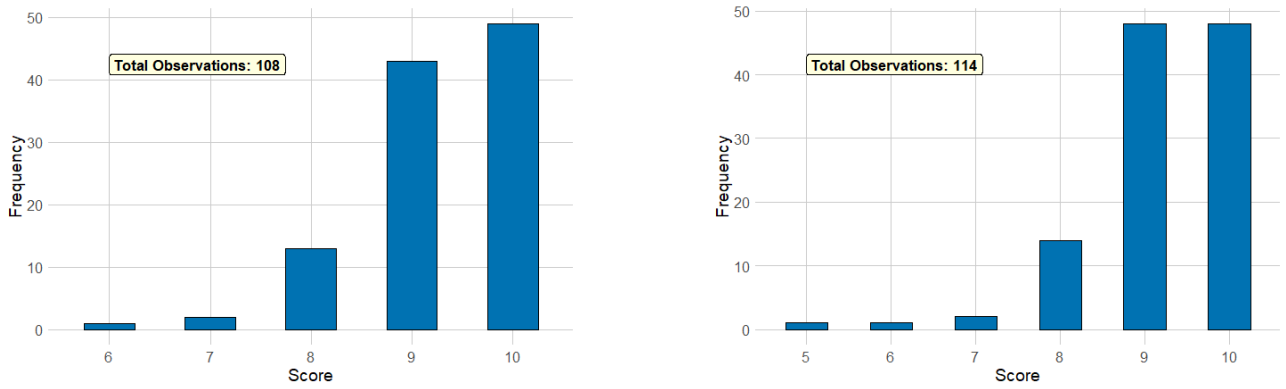
(a) Men (b) Women

Figure 2.4: QQ-plots for Rifle Shooting

The Q-Q plots demonstrate a good fit, indicating that the assumption of asymptotic normality

holds for these datasets. This validation supports the development of appropriate test statistics for my analysis.

However, the archery data is highly discrete with a limited sample space, making it inappropriate to attempt fitting a normal distribution. Instead, I visualized the data using bar graphs to better represent the score distribution.



(a) Men (b) Women

Figure 2.5: Bar plots for Archery

The bar plots suggest that a multinomial distribution would be a more suitable fit for this dataset. This approach allows for the construction of logical tests based on the observed frequency of scores, facilitating a more robust statistical analysis.

3 Tests

In the shooting events, I treat the combined data from the eight players in each event as a single sample drawn from an asymptotic normal distribution. This approach effectively represents the performance of an average athlete in that category, enabling a comparison between the average male and female shooters at the Olympic finals level.

I then employ a two-sample t-test, with the null hypothesis being H_0*: there is no difference between the mean scores of male and female shooters*, tested against a two-sided alternative.

In the case of the archery events, I also use combined data to represent the average archer's

performance at the Olympic finals level. I assume that scores for both genders follow a multinomial distribution, with the null hypothesis stated as H_0*: there is no difference between the parameters of male and female archers*, again tested against a two-sided alternative.

I assume that every shot of an archer takes one of the four values, $\{10, 9, 8, \text{O}\}$, where O represents the collection of all scores ≤ 7 which are grouped into a single bin due to an insufficient number of individual observations. So, let X represent the male frequency vector and Y represent the female frequency vector. Suppose that $X \sim \textit{Multinomial}(108, \vec{p})$, where $\vec{p}$ represents the unknown probability parameters for the male scores. Similarly, $Y \sim \textit{Multinomial}(114, \vec{q})$, where $\vec{q}$ represents the unknown probability parameters for the female scores.

The null hypothesis can now be expressed as $\text{H}_0 : \vec{p} = \vec{q}$. Let the components of $\vec{p}$ be denoted by $[p_1, p_2, p_3, 1 - p_1 - p_2 - p_3]$, and similarly for $\vec{q}$. To test for $\text{H}_{01} : p_1 = q_1$, we can consider the $\hat{p_1} = X_1$ and $\hat{q_1} = Y_1$, allowing for an asymptotic z-test for proportions. This test can be repeated for $\text{H}_{02} : p_2 = q_2$ and $\text{H}_{03} : p_3 = q_3$ by evaluating the indicator function at 9 and 8 respectively.

4 Results

The following summarizes the t-tests performed for the shooting events, executed using R.

Statistic	Value
t-statistic	-0.33
Degrees of Freedom	294.38
p-value	**0.74**
Mean (Men)	9.91
Mean (Women)	9.93

(a) 10m Air Pistol

Statistic	Value
t-statistic	-0.10
Degrees of Freedom	297.90
p-value	**0.92**
Mean (Men)	10.42
Mean (Women)	10.42

(b) 10m Air Rifle

Table 4: t-test Results for the Shooting Events

The most notable observation is the exceedingly high ***p-value*** in both tests, which indicates a significant inability to reject the null hypothesis.

A similar trend is observed in the z-tests for proportions in the Archery event, again making it difficult to reject the null hypothesis by a significant margin. The test results are summarized in the tables below.

Statistic	$H_{01} : p_1 = q_1$	$H_{02} : p_2 = q_2$	$H_{03} : p_3 = q_3$
Z-statistic	0.49	-0.35	-0.06
p-value	**0.62**	**0.73**	**0.96**
Proportion (Men)	0.45	0.40	0.12
Proportion (Women)	0.42	0.42	0.12

Table 5: Asymptotic z-test Results for Archery

5 Conclusion

Overall, my findings suggest that in skill-intensive, precision sports like shooting and archery, male and female athletes perform equivalently at the Olympic finals level. This conclusion highlights the importance of skill and focus over physical attributes in these sports and underscores the potential for gender inclusivity and even mixed-gender formats in such events. The project demonstrates the effectiveness of using statistical methods to evaluate performance data in various sports contexts, offering a framework for further studies on gender performance comparisons. Future research could extend this analysis to additional events or examine psychological and environmental factors that contribute to performance parity in precision-based sports.

References

[1] 10m Air Pistol Men - Finals Results [link]

[2] 10m Air Pistol Women - Finals Results [link]

[3] 10m Air Rifle Men - Finals Results [link]

[4] 10m Air Rifle Women - Finals Results [link]

[5] Official Archery Results Book [link]

[6] Code [link]