**Introduction**

For this activity, you will be exploring data from the 2023 Boston Marathon by analyzing the result times of the finishing runners. Focusing on the single quantitative variable of result times in seconds, you will examine both visualizations and summary statistics to make key conclusions. The incorporation of z-scores will allow for comparisons to be made between two subsets of the data by determining performances of top finishers.

**Learning Goals**

By the end of the activity, you will be able to:

* Analyze structures and distributions of histograms
* Use basic summary statistics to assess center and spread
* Calculate further relevant metrics for quantitative data
* Determine which metrics are most relevant to your data
* Calculate and compare z-scores for individual cases

**Data**

The data below shows the top 6 finishers of the 2023 Boston Marathon. In addition to the **name** of the runner, the **finish\_net\_sec** variable shows the race result time of the runner that is timed from when they cross the starting gate at the beginning of the race to the finish line. The full data (boston\_marathon\_2023.csv) is available on the GitHub repo associated with this module and contains many more variables associated with the runner information and times.

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Description automatically generated**

**Methods**

For this activity, students will primarily use basic concepts of histograms and boxplots to analyze distributions. Students will also require formulas for deviation, IQR, standard deviation, fences, and z-score. For r users, summary statistics can be calculated using the summary() and var() commands.

**Exercises**

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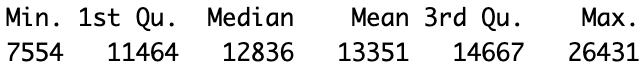
1. Consider the histogram above comprised of race results times in seconds with 20 bins. How would it change if it had 5 bins? What about 100 bins?

*If it had 5 bins, it would condense to 5 columns that group together thousands more of times. With 100 we would have 100 different time groups and the histogram would be much wider.*

1. How would you describe the shape of the histogram?

*Slightly right-skewed and unimodal.*

*Summary statistics for result times (seconds) of all finishers of the race.*

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1. Calculate the deviation of a result time of 16000 seconds.

*16000 – 13351 = 2649*

1. The variance of the sample is 6,892,160. Calculate the standard deviation and provide an interpretation.

Standard Deviation: s*qrt(6892160) = 2625.292*

*Interpretation: On average, the race times vary by 2625.292 seconds around the mean race time.*

1. What is the value of the interquartile range (IQR)?

*14667 – 11464 = 3203*

1. **Using your answer to the previous question, determine the values of the upper and lower fence.**

*Q3 + 1.5 \* IQR = Upper fence*

*Q1 – 1.5 \* IQR = Lower fence*

*14667 + 1.5\*3203 = 19471.5*

*11464 – 1.5\*3203 = 6659.5*

1. Is a time of 19500 seconds an outlier? What about a time of 7100 seconds?

*Yes, a time of 19500**seconds is an outlier because it exceeds the upper fence.*

*No, a time of 7100 seconds is not an outlier because it is greater than the lower fence and less than the upper fence.*

1. The mean and standard deviation of only men’s results can be found below. Using this information, calculate the z-score of the top male finisher who completed the race in 7554 seconds. Provide an interpretation of the result.

**Mean Standard Deviation**

12745.52 2619.31

*Z-score = (7554 - 12745.52) / 2619.31 = -1.98*

*The result time of the top male finisher is -1.98 standard deviations away from the mean time for all men.*

1. The mean and standard deviation of only women’s results can be found below. Using this information, calculate the z-score of the top female finisher who completed the race in 8498 seconds. Provide an interpretation of the result.

**Mean Standard Deviation**

14155.68 2408.28

*Z-score = (8498 - 14155.6) /* 2408.28 = -2.35

*The result time of the top female finisher is -2.35 standard deviations away from the mean time for all men.*

1. Based on your answers to the previous two questions, determine which top finisher had the more remarkable result in relation to their respective field.

*The top female finisher had the more remarkable result in relation to their field because their z-score was comparatively larger than that of the male finisher.*