

QUARTILE

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QUARTILE

Primary Disciplinary Field(s): Statistics, Data Analysis, Psychometrics, Economics

1. Core Definition

A **quartile** is a type of quantile that divides a rank-ordered data set into four subsets, each containing 25% of the total observations. These subsets are defined by three specific data points--the first quartile (Q1), the second quartile (Q2), and the third quartile (Q3)--which represent the 25th, 50th, and 75th percentiles, respectively. Quartiles are fundamental tools in descriptive statistics, providing a robust measure of data spread and central tendency that is less susceptible to extreme outliers than the arithmetic mean. They are particularly valuable when analyzing distributions that are skewed or non-normal, offering a clear snapshot of where the bulk of the data lies and how observations are distributed around the median.

The concept essentially involves partitioning a sorted list of scores or measurements into four manageable blocks. The **first quartile (Q1)** marks the boundary below which the lowest 25% of the data falls. The **second quartile (Q2)** is synonymous with the **median**, separating the bottom 50% from the top 50% of the dataset. Finally, the **third quartile (Q3)** delineates the point below which 75% of the observations reside, meaning the top 25% of scores exceed this value. For example, stating that "John's scores were consistently in the second quartile" implies that his performance ranked between the 26th and 50th percentile of the tested population, performing better than the lowest 25% but not achieving the level of the upper 50%. This method of segmentation allows researchers to quickly identify performance clusters and assess variability across different segments of a population without relying on assumptions of data symmetry.

Understanding quartiles is crucial for grasping related statistical concepts like the **Interquartile Range (IQR)**, which is the difference between Q3 and Q1. The IQR represents the spread of the middle 50% of the data set and is the standard metric used to describe the variability of the central distribution. Unlike the standard deviation, which relies on the squared distance of every data point from the mean, the IQR is a measure of statistical dispersion based entirely on the positional values of the quartiles. This positional dependence makes it highly useful in fields such as quality control, financial analysis, and psychometric testing where robustness against anomalous or extreme values is a major priority.

2. Historical Context and Development

While statistical concepts relating to central tendency have been utilized for centuries, the formalization and widespread application of quantiles, including quartiles, gained significant traction during the late 19th and early 20th centuries as descriptive statistics became standardized.

The broader field of statistics, heavily influenced by foundational figures like Sir Francis Galton and Karl Pearson, sought robust methods for describing large sets of data, particularly in biological, social, and psychological sciences. Prior to the systematic use of quartiles, researchers relied heavily on the mean and the range, measures which proved inadequate for accurately describing asymmetric or non-normal distributions commonly encountered in real-world data.

The conceptual groundwork for quartiles rests on the percentile system. While a percentile divides the data into 100 parts, a quartile simplifies this categorization into four major blocks, offering an easily interpretable summary of distribution characteristics. The formal adoption of the median (Q2) as a standard measure of central tendency often preceded the generalized use of Q1 and Q3, primarily because the median is intuitively easier to locate and calculate. The subsequent incorporation of the full set of quartiles facilitated the development of non-parametric statistics--methods that do not rely on strict assumptions about the underlying distributional shape of the data, such as normality. This shift was pivotal in expanding the utility of statistics beyond purely theoretical mathematical applications and into complex, empirical data analysis, where distributions are frequently irregular or heavily skewed.

The visual representation of quartiles was profoundly popularized by the introduction of the **Box-and-Whisker Plot** (or Box Plot) by American mathematician John W. Tukey in 1977. Tukey's innovation provided a simple, yet highly effective, graphic method for displaying the five-number summary (minimum, Q1, median, Q3, maximum), making the interquartile range and the location of potential outliers immediately visible. This development cemented the quartile's position as a cornerstone tool in exploratory data analysis (EDA), allowing practitioners across diverse fields--from epidemiology and climate science to finance and educational testing--to communicate complex distribution characteristics effectively and efficiently to non-specialist audiences.

3. Calculation and Methodology

Calculating quartiles reliably requires two primary procedural steps: first, ordering the entire data set from the lowest value to the highest; second, determining the position of the quartile based on the total number of observations (N). However, a key challenge in statistical practice is that there are multiple recognized methods for calculating the exact numerical value of Q1 and Q3, often leading to minor differences in results depending on the specific formula adopted by statistical software packages (such as R, Excel, or SPSS). These discrepancies typically arise when handling small sample sizes or when deciding whether to include or exclude the median in the subsets used to calculate the outer quartiles.

The second quartile, Q2, is the easiest to calculate as it is simply the **median**. If N is an odd number, the median is the single middle value in the ordered list. If N is an even number, the median is the arithmetic average of the two middle values. Once the median is established, the

calculation of Q1 and Q3 involves finding the median of the respective halves. One common approach, often referred to as the **Tukey method** or inclusive method, defines Q1 as the median of the lower half of the data (including Q2 if N is odd) and Q3 as the median of the upper half (also including Q2 if N is odd). This method is highly intuitive and widely taught in introductory statistics courses.

Conversely, some statistical software utilizes more rigorous formulas based on specific percentile position indices (often following international standards, such as the R-methods). These methods typically calculate the position (L) of the p -th percentile using a formula like $L = p/100 \times (N+1)$ or similar variations. For example, to find Q3 (the 75th percentile), $L = 0.75(N+1)$. If this calculated position L is an integer, the quartile value is simply the value at that position. If L is not an integer (i.e., it falls between two observed data points), **linear interpolation** must be applied to estimate the quartile value. The choice of calculation method is not merely academic; inconsistencies in quartile calculation across different academic studies or financial reports can lead to minor, yet consequential, discrepancies in reported IQR and outlier thresholds, emphasizing the necessity of clearly documenting the methodology used in published analysis.

4. Key Characteristics and the Five-Number Summary

The fundamental utility of quartiles is demonstrated through their ability to distill the essential characteristics of a data distribution into a simple, standardized structure known as the **five-number summary**. This summary provides a rapid, comprehensive overview of data location, spread, and shape, making it an essential prerequisite for initial data inspection and subsequent advanced analysis. The five core components of this summary are the Minimum value, the First Quartile (Q1), the Median (Q2), the Third Quartile (Q3), and the Maximum value.

The **Minimum** and **Maximum** values establish the absolute boundaries of the data set, defining the full range of observations captured. Q2 (the Median) serves as the primary non-parametric measure of central tendency. Crucially, the five-number summary ensures that the distance between the Minimum and Q1, Q1 and Q2, Q2 and Q3, and Q3 and the Maximum, each theoretically contains exactly 25% of the data observations. By visually or numerically comparing the lengths of these four segments, analysts can instantaneously infer the skewness and concentration of the distribution. For instance, if the distance between Q3 and the Maximum is significantly larger than the distance between the Minimum and Q1, the data exhibits a positive (right) skew, meaning the upper 25% of scores are more widely dispersed than the lower 25%.

In applied contexts such as standardized testing, these summary characteristics are vital for immediate interpretation. If the first quartile score in a large cohort is 50, researchers know that 25% of the students scored 50 or below. If the median is 70 and the third quartile is 85, a researcher is aware that the central 50% of students scored between 50 and 85, providing a much

richer description of performance variance than the average score alone. This robustness allows researchers to draw meaningful conclusions about the spread of achievement regardless of whether the distribution adheres to a perfect normal curve, which is a rare idealization in psychological and educational data.

5. The Interquartile Range (IQR) and Outlier Detection

The most significant derived statistic utilizing quartiles is the **Interquartile Range (IQR)**, calculated simply as the difference between the third quartile (Q3) and the first quartile (Q1): $IQR = Q3 - Q1$. The IQR quantifies the spread of the central 50% of the data, effectively neutralizing the influence of the most extreme 25% of scores at either end. Because it focuses exclusively on the core distribution, the IQR is considered a highly **resistant measure of variability**, meaning it is minimally affected by outliers, unlike the standard deviation, which can be dramatically inflated by a few extreme values.

This characteristic makes the IQR the preferred measure of dispersion when analyzing data that is known or suspected to contain extreme values, whether those values stem from legitimate rare events, measurement errors, or data entry mistakes. Its resistance allows researchers to obtain a clearer perspective on the typical variability within a population without distortion from anomalous points. Furthermore, the IQR forms the standardized basis for John Tukey's method for detecting potential **outliers**. An observation is generally flagged as a potential mild outlier if it lies outside the range defined by calculated fences:

Lower Fence: $Q1 - (1.5 \text{ times } IQR)$

Upper Fence: $Q3 + (1.5 \text{ times } IQR)$

Observations falling even further outside this 1.5 IQR range--typically beyond $Q1 - (3 \text{ times } IQR)$ or $Q3 + (3 \text{ times } IQR)$ --are often termed extreme outliers. This methodology provides a statistically rigorous, data-driven framework for identifying scores that warrant further investigation, either for potential data cleaning procedures or for recognizing genuinely unusual phenomena within the sample population. The visual representation of these fences is seamlessly integrated into the Box-and-Whisker Plot, where the whiskers typically extend only to the most extreme data point within the 1.5 IQR fences, and any points beyond are plotted individually to highlight their outlying status.

6. Applications in Research and Industry

Quartiles are employed across virtually every quantitative discipline due to their robust nature, high interpretability, and resilience when facing non-normal distributions. In **Psychometrics** and educational research, quartiles are essential for norming scores on standardized tests and assessing student performance relative to their peers. They help educators establish clear

performance benchmarks, allowing them to determine quickly if a student's achievement falls into the bottom quartile (suggesting a need for targeted intervention) or the top quartile (suggesting advanced mastery). University admissions offices, for instance, frequently report the interquartile range of admitted student GPA or entrance exam scores to communicate the typical academic rigor required for acceptance.

In **Financial Analysis**, quartiles are utilized extensively to evaluate investment performance, often in combination with portfolio risk assessment. Fund managers routinely categorize the returns of competing funds into quartiles to determine relative market standing--a fund consistently performing in the fourth quartile (top 25% of performers) is highly sought after by investors. In macroeconomics, critical data like income distribution is almost always reported using quartiles (income brackets), which clearly illustrates economic inequality and the differential spread of wealth across various population segments, providing objective metrics for policy evaluation.

Furthermore, in **Quality Control** and manufacturing, the IQR serves as a crucial indicator of process stability and precision. If the IQR of a manufactured part's diameter is large, it signals high variability in the production process, potentially leading to increased defect rates. By diligently monitoring the quartiles of key measurements over time, engineers can detect subtle process drift long before it impacts overall quality and maintain tighter product specifications. In clinical medicine, quartiles assist in establishing reliable reference ranges for biological markers and clinical outcomes, providing crucial thresholds against which individual patient values can be compared to assess health status and treatment effectiveness.

7. Debates and Calculation Conventions

Despite the conceptual uniformity of the quartile--the division of data into four equal blocks--a notable statistical debate persists regarding the precise numerical calculation methods for Q1 and Q3, particularly when dealing with smaller data sets. Unlike the median (Q2), which possesses a universally accepted definition, the exact positioning and interpolation strategy for the outer quartiles are not strictly standardized across all major statistical programming environments. This ambiguity stems from the fact that when the total number of data points (N) is not perfectly divisible by four, locating the single data point that definitively fulfills the 25% or 75% criterion requires adopting an arbitrary convention or interpolation strategy.

The most commonly used calculation conventions are broadly categorized into several families, including the inclusive method (or Mendenhall and Sincich Method), the exclusive method (or Moore and McCabe Method), and various interpolation-based methods (e.g., the nine R-type formulas standardized in some statistical computing languages). The inclusive method includes the median within both the lower and upper halves when calculating Q1 and Q3, while the exclusive method strictly omits the median from both halves. If a statistical report fails to specify which

method was employed, replication of results, especially with non-symmetrical small samples, can become problematic and yield slightly differing quartile values.

It is important to note that for extremely large data sets, the results derived from these different calculation methodologies tend to converge, rendering the minor numerical differences negligible for practical purposes. However, researchers must nonetheless exercise methodological caution, especially when comparing quartile results generated by disparate software environments (e.g., comparing results from Microsoft Excel's various QUARTILE functions versus results from a package in Python or R). Best practice dictates that academic reports should always cite the specific statistical environment and, ideally, the percentile algorithm used (e.g., specifying R type 7 or R type 8 interpolation) to ensure maximum transparency and reproducibility. This methodological nuance underscores that while the conceptual meaning of a quartile is constant, its precise numerical realization can be context- and convention-dependent.

Further Reading

[Quartile \(Wikipedia\)](#)

[Quantile \(Wikipedia\)](#)

[Interquartile Range \(Wikipedia\)](#)

[NIST/SEMATECH e-Handbook of Statistical Methods: Quartiles](#)

[Descriptive Statistics and Measures of Spread](#)