How to Easily Understand Percentiles, Quartiles, and Quantiles

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December 5, 2025

In the field of statistics, understanding how to divide a dataset into meaningful segments is crucial for data analysis. The terms percentile, quartile, and quantile all refer to specific points that partition a probability distribution or sample data into continuous intervals with equal probabilities or fractions.

While often used interchangeably by beginners, these terms represent a hierarchy of data division. The fundamental difference lies in the unit of division: a percentile divides the data into 100 parts, a quartile divides it into 4 parts, and the quantile acts as the overarching term for any division into equal fractions.

Mastering these definitions is essential for accurately interpreting statistical measures of relative standing and variability, providing deep insights into the distribution of observations within any given population or sample. This guide provides a comprehensive breakdown of each concept, emphasizing their relationships and appropriate usage.

Navigating these related but distinct concepts--percentiles, quartiles, and quantiles--is a common hurdle for students learning statistical methodology. Although they all serve the purpose of partitioning data, their scale and application differ significantly, making precise definitions necessary for accurate analysis.

The core concept uniting these measures is their function as division points in a dataset. They indicate the value below which a specified fraction of observations fall. Understanding this hierarchical relationship--where percentiles and quartiles are merely specialized forms of quantiles--is the first step toward clarifying their usage.

The Fundamental Distinction: Quantiles as the Umbrella Term

The term quantile is the most general and encompassing term among the three. A quantile is a cut point that divides the range of a probability distribution into continuous intervals with equal probabilities. If a dataset is divided into N equal portions, the cut points are called the N-quantiles. This framework allows for immense flexibility in data segmentation, depending on the analytical requirements.

A quantile is formally defined as a measure q_p such that $p times 100%$ of the data values fall below or are equal to q_p. Here, p is a fraction ranging between 0 and 1, representing the proportion of data to be separated. For instance, if $p=0.5$, the quantile is the value below which 50% of the data lies, which is famously known as the median.

Because the definition of a quantile is so broad--allowing the data to be split into any number of equal groups--it serves as the theoretical basis for all other related division metrics. If we specify the number of partitions (N), we generate the specific names we use in practical statistics, such as quartiles ($N=4$) or percentiles ($N=100$).

The Specificity of Percentiles: Measuring Relative Standing

A percentile is a specific type of quantile where the data is divided into 100 equal parts. The k-th percentile (P_k) is the score below which k percent (or $k/100$ fraction) of the scores in a distribution may be found. For example, if a student's score is at the 90th percentile, it means that 90% of the scores in the comparison group are less than or equal to their score, and only 10% are higher.

Percentiles are perhaps the most common and intuitive way to describe relative standing, especially in educational testing, health metrics (like growth charts), and financial modeling. They range from the 0th percentile (the minimum value) up to the 100th percentile (the maximum value). Since they provide a fine-grained division of data, they are ideal for detailed comparisons and identifying outliers or extreme performance levels.

The formulaic relationship is straightforward: the k-th percentile corresponds to the quantile where $p = k/100$. This level of detail makes percentiles invaluable when the analysis requires precise segmentation, such as identifying the top 5% of performers or the bottom 10% of values in a quality control process.

Quartiles: Dividing Data into Four Equal Parts

Quartiles are another specific form of quantile, used when the dataset is divided into four equal parts. This division yields three specific cutoff points, known as the first quartile (Q_1), the second quartile (Q_2), and the third quartile (Q_3). Each quartile separates 25% of the data.

Quartiles are essential components of the five-number summary (minimum, Q_1, median, Q_3, maximum) used to construct box plots. They provide a robust measure of central tendency and variability, particularly useful when dealing with skewed distributions or data containing outliers, as they are less sensitive to extreme values than measures like the mean.

Q_1 (First Quartile): Separates the lowest 25% of data from the highest 75%.
Q_2 (Second Quartile): This is the median, separating the lower 50% from the upper 50%.
Q_3 (Third Quartile): Separates the lowest 75% of data from the highest 25%.

The range between the first and third quartiles is known as the Interquartile Range (IQR), a powerful descriptive statistic for measuring data spread.

A Family of Quantiles: Deciles, Quintiles, and More

As established, percentiles and quartiles are just specialized members of the broader quantile family. Depending on the level of granularity required for analysis, statisticians utilize various N-quantiles, each with its own specific name:

When studying distributions, recognizing these specific divisions simplifies communication and standardizes analytical reporting. Here is a summary of commonly named quantiles based on their division factor:

4-quantiles are called **quartiles** (divides data into 4 parts).
5-quantiles are called **quintiles** (divides data into 5 parts).
8-quantiles are called **octiles** (divides data into 8 parts).
10-quantiles are called **deciles** (divides data into 10 parts).
100-quantiles are called **percentiles** (divides data into 100 parts).

For example, using deciles, the 7th decile represents the value below which 70% of the observations fall, which is equivalent to the 70th percentile. These divisions are often used in economic analyses, such as dividing populations into income quintiles or deciles for fairness comparisons.

The Interrelationship: Mapping Percentiles to Quartiles

Since quartiles are simply four specific cut-points within the 100 divisions defined by percentiles, a clear mapping exists between the two measures. This relationship is foundational for converting between detailed percentage-based views and the simpler, four-part summary view.

The relationship confirms that the structure of the data remains consistent regardless of whether we choose to express the division using a 4-part or 100-part scale. This standardization is critical for comparing results obtained using different descriptive statistics.

0th percentile is equivalent to the **0th quartile** (the minimum value).
25th percentile is equivalent to the **1st quartile** (Q_1).
50th percentile is equivalent to the **2nd quartile** (Q_2), which is also the dataset's median.
75th percentile is equivalent to the **3rd quartile** (Q_3).
100th percentile is equivalent to the **4th quartile** (the maximum value).

This direct correspondence allows analysts to translate between the precise detail of percentiles and the summary power of quartiles, ensuring consistency when reporting various statistical findings.

Practical Application Example: Calculating Quantiles in a Dataset

To solidify the theoretical distinctions, let us examine how percentiles and quartiles are calculated and interpreted using a sample dataset. Suppose we are analyzing a small sample of 20 observations, such as test scores or measurement readings, which have been sorted in ascending order.

We begin with the raw data. Note that quantile calculations rely heavily on the position of the observation within the ordered data rather than the exact value itself, although various computational methods (like interpolation) exist, which may slightly alter the resulting quantile value based on the statistical software used.

Consider the following dataset with 20 values:

Data
3
4
4
6
7
9
12
13
14
16
17
19
22
23
23
25
28
29
34
37

Using robust statistical software (such as R, Python's Pandas library, or Microsoft Excel's dedicated functions), we can determine the specific values corresponding to the key percentiles and quartiles for this distribution. The software handles the complex interpolation required to find the exact cut-points, even when they fall between two observed data points.

The calculated results for the critical quantiles are as follows:

Data
3
4
4
6
7
9
12
13
14
16
17
19
22
23
23
25
28
29
34
37

Percentile	Quartile	Value
0	0	3
25	1	8.5
50	2	16.5
75	3	23.5
100	4	37

Interpreting the Calculated Quantile Values

The calculated values derived from the statistical software provide concrete boundaries that partition the dataset. Interpreting these values correctly is crucial for drawing valid conclusions about the data distribution. Each value represents the score or observation magnitude that separates the specified proportion of the data.

Here is how to interpret the resulting calculated values for our sample dataset:

The 0th percentile and 0th quartile is **3**. This confirms that 3 is the absolute minimum value in the dataset.
The 25th percentile and 1st quartile (Q_1) is **8.5**. This means that 25% of the observations in the dataset have a value of 8.5 or less.
The 50th percentile and 2nd quartile (Q_2) is **16.5**. This is the median of the dataset, indicating that half of the scores are above 16.5 and half are below.
The 75th percentile and 3rd quartile (Q_3) is **23.5**. This value signifies that 75% of the

observations are 23.5 or lower, meaning only the top 25% of scores exceed this value.
The 100th percentile and 4th quartile is **37**. This is the absolute maximum value recorded in the dataset.

These findings not only provide the central tendency (the median) but also define the spread of the data, especially the middle 50% contained between 8.5 and 23.5.

Strategic Usage: When to Choose Percentiles vs. Quartiles

The choice between using percentiles or quartiles depends entirely on the analytical goal and the required level of detail. Percentiles offer granularity for precise boundary definition, whereas quartiles provide a quick, robust summary of data spread.

Percentiles are typically deployed when the analysis requires high precision regarding relative standing or specific cutoff points:

Identifying Top or Bottom $X\%$ of Scores: Analysts use percentiles to answer detailed questions such as: **What score does a student need to earn on a particular test to be in the top 10% of scores?** To address this, one would calculate the 90th percentile, which is the exact value separating the bottom 90% of scores from the critical top 10%.

Defining Central Intervals: They are useful for establishing precise ranges that encompass the middle portion of a distribution, such as: **What heights encompass the middle 40% of heights for students at a particular school?** This requires finding the 30th percentile (the lower bound) and the 70th percentile (the upper bound), defining the exact two values that determine the desired central interval.

Quartiles are best suited when the focus is on summarizing the data's overall spread, detecting variability, or identifying potential outliers through the Interquartile Range (IQR):

Analyzing Major Data Segments: Quartiles answer questions related to 25% segments of the data, such as: **What score does a student need to earn on a test to be in the top quarter of scores?** The answer lies with the 3rd quartile (Q_3), which is the critical value separating the bottom 75% of scores from the top 25%.

Measuring Robust Spread: The primary use of quartiles is calculating the Interquartile Range (IQR), which is the most common measure of spread for non-normal or skewed data: **What is the interquartile range of a given dataset?** The IQR is calculated simply as the difference between the 3rd quartile and the 1st quartile ($Q_3 - Q_1$), representing the range of the middle 50% of the data values.

In summary, while the quantile provides the theoretical framework for data segmentation, percentiles offer high precision (100 divisions), and quartiles offer robust, quick summaries (4 divisions) essential for descriptive statistics.