

How to Easily Understand Odds Ratio vs. Relative Risk

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The fields of statistics and epidemiology frequently utilize metrics designed to quantify the association between an exposure (or treatment) and an outcome (or event). Among the most commonly encountered, yet frequently confused, are the concepts of the **Odds ratio** and the **Relative risk**. While both measures assess the strength of an association, they rely on fundamentally different mathematical constructs--odds versus probability--leading to distinct interpretations in research findings.

Understanding the precise distinction between these two metrics is vital for accurate data interpretation, particularly in clinical trials, observational studies, and risk assessment. The Odds ratio (OR) provides a ratio of the odds of an event occurring in an exposed group compared to a non-exposed group. Conversely, the Relative risk (RR), also known as the risk ratio, calculates the ratio of the actual probability of the event occurring across these same two groups. Although their numerical results can be similar, especially when the event is rare, their fundamental definitions diverge significantly.

This comprehensive guide aims to clearly delineate the mathematical basis, calculation methods, and appropriate usage scenarios for both the OR and the RR, ensuring clarity for students and researchers alike. We will begin by establishing the necessary framework used for their calculation: the 2x2 contingency table.

The Foundation: Understanding 2x2 Contingency Tables

Both the **Odds ratio** and the **Relative risk** derive their calculations from data organized within a simple yet powerful structure known as the 2x2 contingency table. This table format is essential because it stratifies observations based on the presence or absence of two primary binary variables: the exposure (or treatment) and the outcome (or event).

A standard 2x2 table organizes the counts into four cells, typically labeled A, B, C, and D, representing all possible combinations of exposure and outcome. Understanding what each cell represents is crucial before proceeding to the calculation of association measures. Cell **A** represents subjects who were exposed and experienced the outcome; Cell **B**, those exposed who did not experience the outcome; Cell **C**, those not exposed who experienced the outcome; and Cell **D**, those not exposed who did not experience the outcome. The structure provides the raw counts necessary to calculate various measures of effect size.

We often use these two metrics when performing an analysis on a 2-by-2 table, which takes on the following standardized format, providing the variables required for the subsequent formulas:

	Event	No Event
Treatment	A	B
Control	C	D

The totals for the exposed group (Treatment Group) are A + B, and the totals for the non-exposed group (Control Group) are C + D. These totals form the denominators needed when calculating the event probability for each respective group, which is central to the computation of the **Relative risk**.

Exploring the Odds Ratio (OR)

The **Odds ratio** is fundamentally a ratio of two odds. Specifically, it compares the odds of the outcome occurring in the treatment or exposed group (Odds 1) to the odds of the outcome occurring in the control or unexposed group (Odds 2). The concept of odds differs mathematically from probability; odds are defined as the ratio of the probability that an event will occur to the probability that it will not occur ($P / (1-P)$).

In the context of the 2x2 table, the odds of the event in the exposed group is A/B (successes divided by failures in the exposed group), and the odds of the event in the unexposed group is C/D (successes divided by failures in the unexposed group). The ratio of these two values simplifies elegantly through algebraic manipulation, leading to a simple cross-product formula that is often cited:

The **Odds ratio** tells us the ratio of the odds of an event occurring in a treatment group to the odds of an event occurring in a control group. It is calculated as:

Odds ratio = (Odds in Exposed Group) / (Odds in Control Group)

Odds ratio = (A/B) / (C/D)

Odds ratio = (A * D) / (B * C)

The primary advantage of the **Odds ratio** is its applicability in statistics and epidemiology, particularly in case-control studies. Since case-control studies sample based on the outcome status rather than exposure status, calculating the true incidence or risk is impossible. However, the OR provides a valid estimate of the association, even when the true risks cannot be determined directly.

Exploring the Relative Risk (RR)

In contrast to the OR, the **Relative risk**, or risk ratio, is a direct measure of effect size, providing the ratio of two probabilities. It quantifies how many times more likely an event is to occur in the exposed group compared to the unexposed group. Because it uses true probabilities (or risks), the RR is the preferred measure in prospective study designs, such as cohort studies and randomized controlled trials (RCTs), where the incidence rates can be accurately calculated.

The calculation of the RR necessitates determining the actual probability (or risk) of the outcome occurring within each group. For the exposed group, the probability is the number of subjects who experienced the event (A) divided by the total number of exposed subjects (A + B). Similarly, for the unexposed group, the probability is C divided by the total number of unexposed subjects (C + D).

The **Relative risk** tells us the ratio of the probability of an event occurring in a treatment group to the probability of an event occurring in a control group. It is calculated as:

Relative risk = (Probability of event in Exposed Group) / (Probability of event in Control Group)

Relative risk = /

The interpretation of the RR is straightforward: an RR of 2.0 means the risk of the outcome is twice as high in the exposed group compared to the unexposed group. An RR of 1.0 indicates no association, and an RR less than 1.0 indicates a protective effect of the exposure.

Core Conceptual Difference: Odds vs. Probability

The fundamental mathematical distinction between these two key measures lies in their denominators. The **Relative risk** is based on probability, where the denominator is the total number of individuals in that specific group (e.g., A+B or C+D). Probability is the count of successful outcomes divided by the total number of trials.

The **Odds ratio**, however, is based on odds. In odds calculation, the denominator is the number of individuals who did **not** experience the outcome in that group (e.g., B or D). Odds represents the ratio of success to failure. This subtle but critical difference is why the OR is not a direct measure of risk like the RR.

In summary, the key difference is:

An **Odds ratio** is a ratio of two **odds** (Success/Failure) / (Success/Failure).

Relative risk is a ratio of two **probabilities** (Success/Total) / (Success/Total).

While the numerical values of OR and RR are often quite close when the event or disease prevalence is low (typically below 10%), they diverge significantly when the outcome is common. For common outcomes, the OR will typically be further from 1.0 than the RR, potentially overstating the apparent effect size relative to the true risk ratio. Researchers must exercise caution and choose the appropriate metric based on the study design and outcome prevalence.

Practical Application: A Basketball Training Example

To illustrate the calculation and interpretation of these two measures in a realistic setting, consider a study evaluating the effectiveness of a new basketball training program compared to an old, established program. Suppose 200 players were randomly allocated: 100 players utilized the new training program (Exposed/Treatment Group) and 100 players utilized the old training program (Unexposed/Control Group). At the conclusion of the program, all players attempt a standardized skills test, resulting in a pass/fail outcome.

The following 2x2 contingency table summarizes the observed results, showing the distribution of players who passed (Outcome) and failed (No Outcome) based on the training program used:

	Passed	Failed
New Program	61	39
Old Program	52	48

From this table, we derive the cell counts: A=61, B=39, C=52, and D=48. The total number of players in the New Program group is 100 (A+B), and the total in the Old Program group is 100 (C+D). These values allow for the direct computation of both the association metrics.

It is important to notice that the outcome (passing the test) is relatively common in this specific example (over 50% in both groups). This high prevalence suggests that the resulting **Odds ratio** and **Relative risk** values may show a noticeable difference, highlighting the importance of using the correct measure.

Calculating the Odds Ratio (OR)

We calculate the **Odds ratio** by first determining the odds of passing the skills test for each training program. The odds calculation is based on the ratio of passers to failures within each group.

Odds of passing using New Program (Odds 1) = $A / B = 61 / 39 = 1.564$

Odds of passing using Old Program (Odds 2) = $C / D = 52 / 48 = 1.083$

The **Odds ratio** is calculated using the cross-product formula derived earlier:

$$\text{Odds ratio} = (A * D) / (B * C)$$

$$\text{Odds ratio} = (61 * 48) / (39 * 52)$$

$$\text{Odds ratio} = 2,928 / 2,028$$

$$\text{Odds ratio} = 1.44$$

We interpret this result to mean that the odds that a player passes the skills test by utilizing the new program are **1.44 times the odds** that a player passes the test by utilizing the old program. Since 1.44 is greater than 1.0, the association is positive, suggesting the new program is associated with increased odds of success compared to the old one.

Calculating the Relative Risk (RR)

Next, we calculate the **Relative risk** by determining the actual probability (risk) of passing the skills test for each program. This calculation uses the total number of participants in the denominator for each group.

$$\text{Probability of passing using New Program (Risk 1)} = A / (A + B) = 61 / 100 = 0.61 \text{ (or 61\%)}$$

$$\text{Probability of passing using Old Program (Risk 2)} = C / (C + D) = 52 / 100 = 0.52 \text{ (or 52\%)}$$

The **Relative risk** is then the ratio of these probabilities:

$$\text{Relative risk} = /$$

$$\text{Relative risk} = /$$

$$\text{Relative risk} = 0.61 / 0.52$$

$$\text{Relative risk} = 1.17$$

We interpret this result to mean that the ratio of the probability (risk) of a player passing the test using the new program compared to the old program is **1.17**. Put simply, players using the new program are 1.17 times more likely to pass the test than those using the old program. This calculation provides a direct measure of increased likelihood, which is often easier for non-specialists to grasp than the concept of odds.

Interpretation and Contextual Differences

In the basketball example, we obtained two different values: an **Odds ratio** of 1.44 and a **Relative risk** of 1.17. Both values are greater than 1.0, confirming that the new program is superior to the old program. However, the 1.44 OR value suggests a seemingly larger effect size than the 1.17 RR value. This divergence is expected because the outcome (passing the test) is a common event (61% and 52% risks).

The choice between these two metrics depends heavily on the study design and the necessity for accurate risk communication. In the scenario of a randomized trial like this training example, where we can accurately calculate the incidence, the **Relative risk** of 1.17 is the most accurate representation of the treatment effect. It directly tells us the extent to which the probability of success changes between the two groups.

The following shows the direct probability comparison that yields the RR:

Probability of passing under new program = $61 / 100 = 61\%$

Probability of passing under old program = $52 / 100 = 52\%$

Taking the ratio of these probabilities, we calculate the relative risk as $61\% / 52\% = 1.17$.

Conversely, the **Odds ratio** is commonly employed in case-control studies or logistic regression models. When the event is rare (low prevalence), the OR approximates the RR closely, making it a reliable substitute. If the risk of passing the test had only been 5% versus 3%, for example, the OR and RR would have been much closer numerically. When communicating high-prevalence results to the public, using the **Relative risk** prevents the overestimation of effect size that the OR often introduces.

In particular, the interpretation focuses on the mathematical basis:

The **Odds ratio** tells us that the odds of passing the skills test is higher under the new program (1.44 times the odds).

The **Relative risk** tells us that the probability of passing the skills test is higher under the new program (1.17 times the probability).

When to Use Which Metric

The selection of the appropriate metric--OR or RR--is dictated by the study design, not by preference. Both measures are greater than 1, indicating that the chances of experiencing the event are greater in the treatment group compared to the control group.

The **Relative risk** should be used whenever possible, as it is a direct measure of risk incidence. It is the gold standard for studies where the population at risk is clearly defined and followed forward in time, such as in prospective **cohort studies** and **randomized controlled trials**. In these designs, researchers can calculate the true incidence rate or probability of the event occurring in both the exposed and unexposed groups.

The **Odds ratio** is necessary and appropriate in situations where the true incidence cannot be calculated. This applies primarily to **case-control studies**, where researchers sample subjects

based on their outcome status (cases vs. controls) and then retrospectively assess exposure history. In this setting, the OR serves as a powerful and mathematically sound estimate of the Relative risk, provided the disease or outcome is rare. Furthermore, the OR is the natural output of logistic regression, a highly versatile modeling technique used across many disciplines in [statistics](#).

Summary of Key Differences

To conclude, both measures are critical tools for quantifying association, but they address different mathematical dimensions of the data. The **Odds ratio** focuses on the ratio of successes to failures, while the **Relative risk** focuses on the ratio of successes to total trials. This distinction drives their appropriateness across different study designs.

A concise summary of the critical differentiators is often helpful for reference:

Mathematical Basis: The RR compares two probabilities; the OR compares two odds.

Denominator: RR uses the total group size (A+B or C+D) as the denominator; OR uses the non-event count (B or D) as the denominator.

Study Design Preference: RR is preferred in prospective studies (RCTs, Cohort studies); OR is required in retrospective studies (Case-Control studies).

Effect of Prevalence: When the outcome is common, OR significantly overestimates the effect relative to RR. When the outcome is rare, OR approximates RR.

The following tutorials offer additional information on odds ratios and relative risk: