frontiers | Frontiers for Young Minds

MATHEMATICS
Published: 11 January 2023
doi: 10.3389/frym.2022.926624

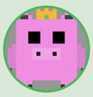
UNDERSTANDING THE ODDS: STATISTICS IN PUBLIC HEALTH

Gabriella Goodwin and So Young Ryu*

School of Public Health, University of Nevada, Reno, NV, United States

YOUNG REVIEWERS:

SHANMUKH
AGE: 14



TOTORO
AGE: 13

In the world of public health and medicine, researchers are often trying to discover new ways of understanding and preventing diseases and other negative health outcomes. When public health researchers want to examine the relationship between some sort of exposure, like smoking, and a disease, such as lung cancer, they will often start by calculating what is called an odds ratio. An odds ratio is a comparison of odds between people who were exposed and people who were not exposed. However, odds ratios can be tricky to understand, even for experienced researchers. In this article, we will break down the odds ratio by reviewing the concepts and calculations of probability and odds. We will also discuss how to interpret an odds ratio, and how these ratios can be useful in real-world applications.

WHAT ARE THE ODDS?

Imagine it is the middle of winter and you and your friends are camping by a lake. You turn to your friend and ask, "What are the odds you jump in the lake?" Immediately your friend protests and says, "Zero!" You understand this to mean that there is no way your friend will be jumping in the freezing lake—but have you ever considered what "odds" really means? Many times, the term "odds" is actually used incorrectly. However, odds are a vitally important concept in **biostatistics** [1]. More specifically, odds can be used to calculate odds ratios, which explain the relationship between measurable characteristics that scientists are interested in, such as the relationship between smoking and lung cancer. As such, odds ratios can be used in important areas of research that have real-world implications, making this a critical concept for young scientists who are looking to enter the world of public health.

BIOSTATISTICS

The discipline concerned with the treatment and analysis of numerical data derived from biological, biomedical, and health related studies.

PROBABILITY AND ODDS

To understand the odds ratio, we first need to understand probability and odds. **Probability** refers to the likelihood that an event will occur. Probability is a number between 0 and 1, where 1 is a 100% chance that the event will occur. Let us think about a deck of cards. In a deck of 52 cards, there are 13 cards of the heart suit. If you shuffled the deck of cards and picked the first card off the top of the deck, the probability of getting a heart suit would be:

PROBABILITY

The proportion of times an even is expected to occur in the long run, which are always a number between 0 and 1.

$$\frac{13\ (\#\ of\ hearts)}{52\ (\#\ of\ cards\ in\ the\ deck)} = \frac{1}{4} = 0.25 \qquad (1)$$

This would give you a probability of 0.25, or a 25% chance of drawing a heart. Understanding probability is the basis for understanding odds and the odds ratio.

Odds are simply the ratio of two probabilities: the probability that the event *will* occur divided by the probability that the event *will not* occur [2]. Recall that a probability of 1 is a 100% chance of occurring. Therefore, if you subtract the probability of a specific event occurring from 1, you are left with the probability of the event *not* occurring (Figure 1).

ODDS

The odds of an event is the proportion of successes divided by the proportion of failures.

Using the previous example of a deck of cards, the odds of drawing a heart would be:

$$\frac{Probability\ of\ drawing\ a\ heart}{Probability\ of\ NOT\ drawing\ a\ heart} = \frac{0.25}{1-0.25} = \frac{0.25}{0.75} \qquad (2)$$

Figure 1

The total probability is the combination of the probability that the event *will* occur and the probability that the event *will not* occur. Total probability always equals 1.

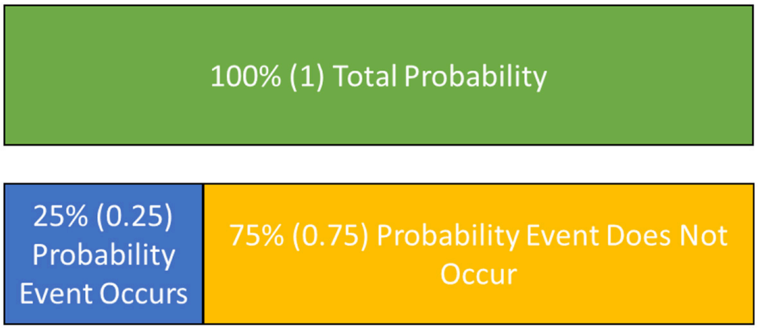


Figure 1

ODDS RATIO

A measure of association which measures the odds of an event happening in one group compared to the odds of the same event happening in another group.

EXPOSURE

Any factor, condition, or characteristic that may be associated with an outcome of interest.

OUTCOME

The outcome of a study is a broad term for any defined disease, state of health, health-related event, or death.

REFERENCE GROUP

A group to which an individual or another group is compared.

CONTINGENCY TABLE

A table that displays the number of subjects observed at combinations of possible outcomes for the two variables.

This would give you an odds of 0.33, or 1/3. This can be stated as a 1–3 odds of drawing a heart. We can understand this to mean that we expect to observe one success (heart) for every three failures (non-heart), or that a failure is three times as likely as a success [3].

ODDS RATIO

When working with **odds ratios**, researchers are interested in the relationship an **exposure** and an **outcome**. As in our earlier example, a researcher may be interested in the relationship between smoking (exposure) and lung cancer (outcome). However, exposures are not always negative events that cause a disease—sometimes they can be preventative. An example of a preventative exposure would be a vaccine, or the use of protective equipment such as gloves.

The odds ratio measures the relationship of an exposure and a disease through division. The group on the bottom of the fraction (the divisor) is the **reference group**, which is usually the unexposed group. Typically, the odds ratio compares the odds of the outcome they are interested in in the exposed group to the odds of the unexposed group. This can be hard to follow, so we often use a type of table called a **contingency table** to organize this information [2]. Let us use a hypothetical example of eating sugary candy as an exposure and getting a cavity as the outcome. The columns in the contingency table (Figure 2) represent the outcome status (yes or no), and the rows represent the exposure status (yes or no).

Based on Figure 2, let us calculate the odds ratio for those who eat sugary candy. The odds ratio for compares the odds that an outcome will occur for those who *have* had the exposure vs. the odds that the outcome will occur for those who have *not* had exposure. In this circumstance, the odds ratio would be the odds that a person has a cavity if they eat sugary candy vs. the odds a person has a cavity if they do not eat sugary candy.

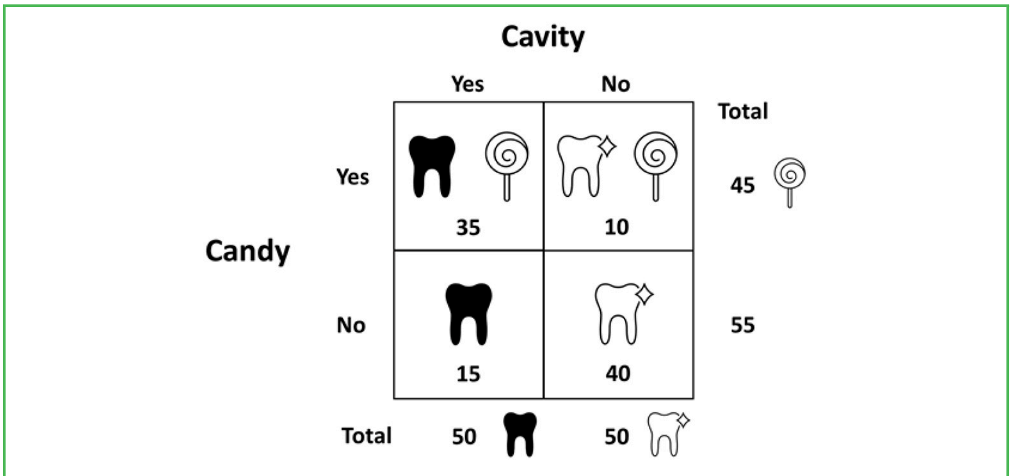


Figure 2

Figure 2

A 2 × 2 contingency table (two squares by two squares) for sugary candy (exposure) and cavities (outcome). This table shows the number of people in each combination of the two categories: Eats sugary candy (yes/no) and has a cavity (yes/no). This data is not real; it is meant for educational purposes only.

First, we can calculate the numerator of this ratio (Figure 3A). The numerator is the odds of having a cavity if a person eats sugary candy. As previously discussed, odds are the probability that the event will occur, divided by the probability that the event will not occur. The probability that someone will have a cavity, given that they eat sugary candy, would be 35 (number of individuals who have a cavity and eat sugary candy) divided by 45 (total number of people who eat sugary candy). The probability that someone will not have a cavity, given that they eat sugary candy, would be 10 (number of individuals who do not have a cavity and eat sugary candy) divided by 45 (total number of people who eat sugary candy). This would give us 3.5.

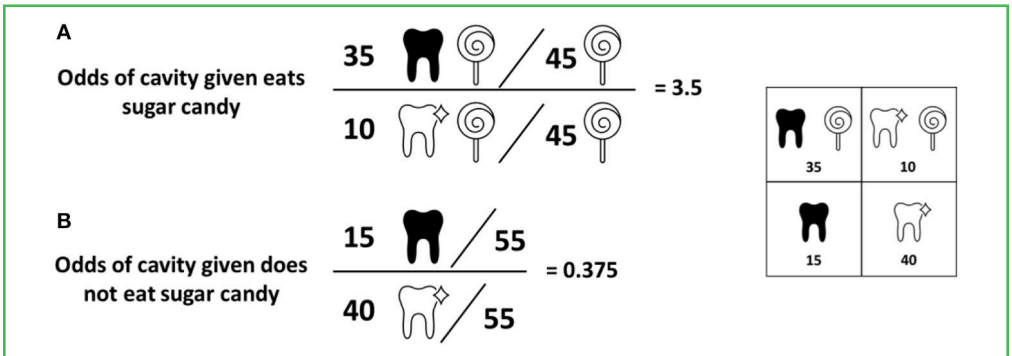


Figure 3

Figure 3

Calculations for **(A)** odds of a cavity for those who eat sugary candy and **(B)** odds of cavity for those who do not eat sugary candy.

Next, we can calculate the denominator of this ratio (Figure 3B). The denominator is the odds of having a cavity if a person does not eat sugary candy. The probability that someone will have a cavity, if they do not eat sugary candy, would be 15 (number of individuals who have a cavity and do not eat sugary candy) divided by 55 (total number of people who do not eat sugary candy). The probability that someone will not have a cavity if they do not eat sugary candy would be 40 (number of individuals who do not have a cavity and do not eat sugary candy) divided by 55 (total number of people who do not eat sugary candy). This would give us 0.375.

Finally, the odds ratio is the ratio of the two odds we just calculated. The calculation would be as follows:

$$\frac{\textit{Odds of cavity given eats sugary candy}}{\textit{Odds of cavity given does not eat sugary candy}} = \frac{3.5}{0.375} = 9.33 \quad (3)$$

The odds ratio of having a cavity for those who eat sugary candy compared to those who do not eat sugary candy is 3.5 divided by 0.375, which gives us 9.33. However, 9.33 may not intuitively mean anything to you, so let us discuss how you interpret odds ratios.

INTERPRETING ODDS RATIOS

There are three main interpretations for an odds ratio: no association, protective factor, and risk factor. If an odds ratio is equal to 1, this means that there is no association between the exposure and the odds of disease [4]. This is because, for an odds ratio to be equal to 1, the odds of disease given exposure and the odds of disease given no exposure are the same (any number divided by itself is 1). If the odds are the same, this would mean that the exposure does not affect the probability of disease. In the cavity example, you could think of the odds of eating name-brand sugary candy and getting a cavity, compared to the odds of eating generic sugary candy and getting a cavity. These two groups will likely have the same odds of getting a cavity, and thus their odds ratio will be equal to 1.

If the odds ratio is <1, this means that the exposure is a protective factor. What this means is that the exposure is associated with lower odds of disease [4]. As an example, an odds ratio of 0.5 means that there is a 50% decrease in the odds of disease if you have the exposure. An example of an exposure with a protective factor would be brushing your teeth twice a day. If you brush your teeth morning and night, you have smaller odds of getting a cavity compared to those who do not brush teeth morning and night.

Finally, if the odds ratio is >1, this means that the exposure is a risk factor. This means that the exposure is associated with higher odds of disease [4]. As an example, if the odds ratio is 1.5, the odds of disease after being exposed are 1.5 times greater than the odds of disease if you were not exposed another way to think of it is that there is a 50% increase in the odds of disease if you are exposed. For our sugary candy example, an odds ratio of 9.33 means that sugary candy is a risk factor for getting a cavity We could also state that if you eat sugary candy, your odds of getting a cavity are 9.33 times greater than the odds of getting cavity for those who do not eat sugary candy.

CONCLUSION

Researchers use odds ratios in many aspects of research. From the testing of new medical techniques, to vaccination trials testing the effectiveness of vaccines, to examining the impact of environmental factors like pollution or UV rays, odds ratios can help researchers understand how exposures effect the odds of disease. Naturally, odds ratios are often much more complex in real-life applications. However, these calculations are fundamental concepts for those working in public health. In light of the recent COVID-19 pandemic, it will be critical for upcoming young scientists to understand odds and odds ratios, so they can make a difference in the world of public health.

ACKNOWLEDGMENTS

This material was based upon work supported by the National Science Foundation under Grant No. 2046122. We would like to thank the members of the Ryu Computational Lab Group for their review and contribution to this article, including Riley Brenner, Kurtis Bertauche, Alexander Choi, and Korben DiArchangel.

AUTHOR DISCLAIMER

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

1. Gerstman, B. 2015. *Basic Biostatistics: Statistics for Public Health, 2nd Edn*. Burlington, NJ: Jones & Bartlett Learning.
2. Agretsi, A. 2018. *Statistical Methods for the Social Sciences, 5th Edn*. Boston, MA: Pearson.
3. Agresti, A. 2019. *Wiley Series in Probability and Statistics, 3rd Edn*. John Wiley & Sons. Available online at: http://www.wiley.com/go/wsps (accessed March 15, 2022).
4. Szumilas, M. 2010. Explaining odds ratios. *J Can Acad Child Adolesc Psychiatry.* 19:227–9.

SUBMITTED: 22 April 2022; **ACCEPTED:** 27 December 2022;
PUBLISHED ONLINE: 11 January 2023.

EDITOR: John S. Butler, Technological University Dublin, Ireland

SCIENCE MENTORS: Balasubrahmanyam Kottapalli and Malgorzata Lagisz

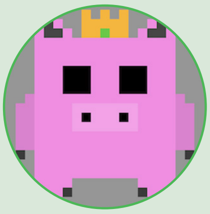
CITATION: Goodwin G and Ryu SY (2023) Understanding The Odds: Statistics in Public Health. Front. Young Minds 10:926624. doi: 10.3389/frym.2022.926624

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

SHANMUKH, AGE: 14

My name is Shanmukh, and I am a Young Minds Reviewer. I believe Frontiers for Young Minds is a great place for me to enhance my English, Math, and Science skills. In addition, reviewing for the journal gives me an opportunity to contribute to the scientific community around the world.



TOTORO, AGE: 13

Hi! I like to get creative and work on cool projects. Sometimes, I do a bit of experimentation or some DIY. When I do science, it makes me feel more creative, and I hope you do too. So, you could also get your brain working, enjoy, and be creative!

AUTHORS

GABRIELLA GOODWIN

Gabriella Goodwin is a biomedical researcher, who received her master's degree in Animal Science in 2019. Goodwin gained industry experience involving clinical trials, but an affinity for mathematics combined with a realization for the need for proper statistics in the research field led her back to school to pursue her second master's degree in biostatistics. Goodwin is now a graduate student in biostatistics and currently works as a biostatistics/bioinformatics research assistant at the School of Public Health, the University of Nevada, Reno. *gabriellagoodwin@unr.edu

SO YOUNG RYU

Dr. So young Ryu is an Associate Professor of Biostatistics at the School of Public Health, the University of Nevada, Reno. Prior to joining the University of Nevada, Reno, she received her Ph.D. in Statistics from the University of Washington and worked as a postdoctoral researcher at Stanford University and Massachusetts General Hospital. She has developed various statistical methods in biomedical research and public health for the past 18 years. Besides her biostatistics research, she has taught college students as a math tutor, an instructor, and a professor since 1996.