

## Chapter 210

# Non-Inferiority Tests for the Difference Between Two Proportions

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### Introduction

This module provides power analysis and sample size calculation for non-inferiority tests of the difference in two-sample designs in which the outcome is binary. Users may choose from among eight popular test statistics commonly used for running the hypothesis test.

The power calculations assume that independent, random samples are drawn from two populations.

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### Example

A non-inferiority test example will set the stage for the discussion of the terminology that follows. Suppose that the current treatment for a disease works 70% of the time. Unfortunately, this treatment is expensive and occasionally exhibits serious side-effects. A promising new treatment has been developed to the point where it can be tested. One of the first questions that must be answered is whether the new treatment is as good as the current treatment. In other words, do at least 70% of treated subjects respond to the new treatment?

Because of the many benefits of the new treatment, clinicians are willing to adopt the new treatment even if it is slightly less effective than the current treatment. They must determine, however, how much less effective the new treatment can be and still be adopted. Should it be adopted if 69% respond? 68%? 65%? 60%? There is a percentage below 70% at which the difference between the two treatments is no longer considered ignorable. After thoughtful discussion with several clinicians, it was decided that if a response of at least 63% were achieved, the new treatment would be adopted. The difference between these two percentages is called the *margin of non-inferiority*. The margin of non-inferiority in this example is 7%.

The developers must design an experiment to test the hypothesis that the response rate of the new treatment is at least 0.63. The statistical hypothesis to be tested is

$$H_0: p_1 - p_2 \leq -0.07 \text{ versus } H_1: p_1 - p_2 > -0.07$$

Notice that when the null hypothesis is rejected, the conclusion is that the response rate is at least 0.63. Note that even though the response rate of the current treatment is 0.70, the hypothesis test is about a response rate of 0.63. Also notice that a rejection of the null hypothesis results in the conclusion of interest.

## Non-Inferiority Tests for the Difference Between Two Proportions

### Technical Details

The details of sample size calculation for the two-sample design for binary outcomes are presented in the chapter “Tests for Two Proportions,” and they will not be duplicated here. Instead, this chapter only discusses those changes necessary for non-inferiority tests.

Approximate sample size formulas for non-inferiority tests of the difference between two proportions are presented in Chow et al. (2008), page 90. Only large sample (normal approximation) results are given there. It is also possible to calculate power based on the enumeration of all possible values in the binomial distribution. Both options are available in this procedure.

Suppose you have two populations from which dichotomous (binary) responses will be recorded. Assume without loss of generality that the higher proportions are better. The probability (or risk) of cure in population 1 (the treatment group) is  $p_1$  and in population 2 (the reference group) is  $p_2$ . Random samples of  $n_1$  and  $n_2$  individuals are obtained from these two populations. The data from these samples can be displayed in a 2-by-2 contingency table as follows

Group	Success	Failure	Total
Treatment	$x_{11}$	$x_{12}$	$n_1$
Control	$x_{21}$	$x_{22}$	$n_2$
Totals	$m_1$	$m_2$	$N$

The binomial proportions,  $p_1$  and  $p_2$ , are estimated from these data using the formulae

$$\hat{p}_1 = \frac{a}{m} = \frac{x_{11}}{n_1} \quad \text{and} \quad \hat{p}_2 = \frac{b}{n} = \frac{x_{21}}{n_2}$$

Let  $p_{1.0}$  represent the group 1 proportion tested by the null hypothesis,  $H_0$ . The power of a test is computed at a specific value of the proportion which we will call  $p_{1.1}$ . Let  $\delta$  represent the smallest difference (margin of non-inferiority) between the two proportions that still results in the conclusion that the new treatment is not inferior to the current treatment. For a non-inferiority test,  $\delta < 0$ . The set of statistical hypotheses that are tested is

$$H_0: p_{1.0} - p_2 \leq \delta \quad \text{versus} \quad H_1: p_{1.0} - p_2 > \delta$$

which can be rearranged to give

$$H_0: p_{1.0} \leq p_2 + \delta \quad \text{versus} \quad H_1: p_{1.0} > p_2 + \delta$$

There are three common methods of specifying the margin of non-inferiority. The most direct is to simply give values for  $p_2$  and  $p_{1.0}$ . However, it is often more meaningful to give  $p_2$  and then specify  $p_{1.0}$  implicitly by specifying the difference, ratio, or odds ratio. Mathematically, the definitions of these parameterizations are

<u>Parameter</u>	<u>Computation</u>	<u>Hypotheses</u>
Difference	$\delta = p_{1.0} - p_2$	$H_0: p_{1.0} - p_2 \leq \delta_0$ vs. $H_1: p_{1.0} - p_2 > \delta_0$ , $\delta_0 < 0$
Ratio	$\phi = p_{1.0} / p_2$	$H_0: p_1 / p_2 \leq \phi_0$ vs. $H_1: p_1 / p_2 > \phi_0$ , $\phi_0 < 1$
Odds Ratio	$\psi = Odds_{1.0} / Odds_2$	$H_0: o_{1.0} / o_2 \leq \psi_0$ versus $H_1: o_{1.0} / o_2 > \psi_0$ , $\psi_0 < 1$

## Non-Inferiority Tests for the Difference Between Two Proportions

### Difference

The difference is perhaps the most direct method of comparison between two proportions. It is easy to interpret and communicate. It gives the absolute impact of the treatment. However, there are subtle difficulties that can arise with its interpretation.

One difficulty arises when the event of interest is rare. If a difference of 0.001 occurs when the baseline probability is 0.40, it would be dismissed as being trivial. However, if the baseline probability of a disease is 0.002, a 0.001 decrease would represent a reduction of 50%. Thus interpretation of the difference depends on the baseline probability of the event.

Note that if  $\delta < 0$ , the procedure is called a *non-inferiority test* while if  $\delta > 0$  the procedure is called a *superiority test*.

### Non-Inferiority using a Difference

The following example might help you understand the concept of a *non-inferiority test*. Suppose 60% of patients respond to the current treatment method ( $p_2 = 0.60$ ). If the response rate of the new treatment is no less than 5 percentage points worse ( $\delta = -0.05$ ) than the existing treatment, it will be considered to be noninferior. Substituting these figures into the statistical hypotheses gives

$$H_0: \delta \leq -0.05 \text{ versus } H_1: \delta > -0.05$$

Using the relationship

$$p_{1.0} = p_2 + \delta$$

gives

$$H_0: p_{1.0} \leq 0.55 \text{ versus } H_1: p_{1.0} > 0.55$$

In this example, when the null hypothesis is rejected, the concluded alternative is that the response rate is at least 55%, which means that the new treatment is not inferior to the current treatment.

### Superiority using a Difference

The following example is intended to help you understand the concept of a *superiority test*. Suppose 60% of patients respond to the current treatment method ( $p_2 = 0.60$ ). If the response rate of the new treatment is at least 10 percentage points better ( $\delta = 0.10$ ), it will be considered to be superior to the existing treatment. Substituting these figures into the statistical hypotheses gives

$$H_0: \delta \leq 0.10 \text{ versus } H_1: \delta > 0.10$$

Using the relationship

$$p_{1.0} = p_2 + \delta$$

gives

$$H_0: p_{1.0} \leq 0.70 \text{ versus } H_1: p_{1.0} > 0.70$$

In this example, when the null hypothesis is rejected, the concluded alternative is that the response rate is at least 0.70. That is, the conclusion of superiority is that the new treatment's response rate is at least 0.10 more than that of the existing treatment.

## A Note on Setting the Significance Level, Alpha

Setting the significance level has always been somewhat arbitrary. For planning purposes, the standard has become to set alpha to 0.05 for two-sided tests. Almost universally, when someone states that a result is statistically significant, they mean statistically significant at the 0.05 level.

Although 0.05 may be the standard for two-sided tests, it is not always the standard for one-sided tests, such as non-inferiority tests. Statisticians often recommend that the alpha level for one-sided tests be set at 0.025 since this is the amount put in each tail of a two-sided test.

## Power Calculation

The power for a test statistic that is based on the normal approximation can be computed exactly using two binomial distributions. The following steps are taken to compute the power of these tests.

1. Find the critical value using the standard normal distribution. The critical value,  $z_{critical}$ , is that value of  $z$  that leaves exactly the target value of alpha in the appropriate tail of the normal distribution.
2. Compute the value of the test statistic,  $z_t$ , for every combination of  $x_{11}$  and  $x_{21}$ . Note that  $x_{11}$  ranges from 0 to  $n_1$ , and  $x_{21}$  ranges from 0 to  $n_2$ . A small value (around 0.0001) can be added to the zero-cell counts to avoid numerical problems that occur when the cell value is zero.
3. If  $z_t > z_{critical}$ , the combination is in the rejection region. Call all combinations of  $x_{11}$  and  $x_{21}$  that lead to a rejection the set  $A$ .
4. Compute the power for given values of  $p_{1,1}$  and  $p_2$  as

$$1 - \beta = \sum_A \binom{n_1}{x_{11}} p_{1,1}^{x_{11}} q_{1,1}^{n_1 - x_{11}} \binom{n_2}{x_{21}} p_2^{x_{21}} q_2^{n_2 - x_{21}}$$

5. Compute the actual value of alpha achieved by the design by substituting  $p_2$  for  $p_{1,1}$  to obtain

$$\alpha^* = \sum_A \binom{n_1}{x_{11}} \binom{n_2}{x_{21}} p_2^{x_{11} + x_{21}} q_2^{n_1 + n_2 - x_{11} - x_{21}}$$

## Asymptotic Approximations

When the values of  $n_1$  and  $n_2$  are large (say over 200), these formulas often take a long time to evaluate. In this case, a large sample approximation can be used. The large sample approximation is made by replacing the values of  $\hat{p}_1$  and  $\hat{p}_2$  in the  $z$  statistic with the corresponding values of  $p_{1,1}$  and  $p_2$ , and then computing the results based on the normal distribution. Note that in large samples, the Farrington and Manning statistic is substituted for the Gart and Nam statistic.

## Non-Inferiority Tests for the Difference Between Two Proportions

### Test Statistics

Several test statistics have been proposed for testing whether the difference is different from a specified value. The main difference among the several test statistics is in the formula used to compute the standard error used in the denominator. These tests are based on the following  $z$ -test

$$z_t = \frac{\hat{p}_1 - \hat{p}_2 - \delta_0 - c}{\hat{\sigma}}$$

The constant,  $c$ , represents a continuity correction that is applied in some cases. When the continuity correction is not used,  $c$  is zero. In power calculations, the values of  $\hat{p}_1$  and  $\hat{p}_2$  are not known. The corresponding values of  $p_{1.1}$  and  $p_2$  may be reasonable substitutes.

Following is a list of the test statistics available in **PASS**. The availability of several test statistics begs the question of which test statistic one should use. The answer is simple: one should use the test statistic that will be used to analyze the data. You may choose a method because it is a standard in your industry, because it seems to have better statistical properties, or because your statistical package calculates it. Whatever your reasons for selecting a certain test statistic, you should use the same test statistic when doing the analysis after the data have been collected.

### Z Test (Pooled)

This test was first proposed by Karl Pearson in 1900. Although this test is usually expressed directly as a chi-square statistic, it is expressed here as a  $z$  statistic so that it can be more easily used for one-sided hypothesis testing. The proportions are pooled (averaged) in computing the standard error. The formula for the test statistic is

$$z_t = \frac{\hat{p}_1 - \hat{p}_2 - \delta_0}{\hat{\sigma}_1}$$

where

$$\hat{\sigma}_1 = \sqrt{\bar{p}(1-\bar{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

$$\bar{p} = \frac{n_1\hat{p}_1 + n_2\hat{p}_2}{n_1 + n_2}$$

### Z Test (Unpooled)

This test statistic does not pool the two proportions in computing the standard error.

$$z_t = \frac{\hat{p}_1 - \hat{p}_2 - \delta_0}{\hat{\sigma}_2}$$

where

$$\hat{\sigma}_2 = \sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{n_2}}$$

## Non-Inferiority Tests for the Difference Between Two Proportions

### Z Test with Continuity Correction (Pooled)

This test is the same as Z Test (Pooled), except that a continuity correction is used. Remember that in the null case, the continuity correction makes the results closer to those of Fisher's Exact test.

$$z_t = \frac{\hat{p}_1 - \hat{p}_2 - \delta_0 + \frac{F}{2} \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}{\hat{\sigma}_1}$$

$$\hat{\sigma}_1 = \sqrt{\bar{p}(1-\bar{p}) \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}$$

$$\bar{p} = \frac{n_1 \hat{p}_1 + n_2 \hat{p}_2}{n_1 + n_2}$$

where  $F$  is -1 for lower-tailed hypotheses and 1 for upper-tailed hypotheses.

### Z Test with Continuity Correction (Unpooled)

This test is the same as the Z Test (Unpooled), except that a continuity correction is used. Remember that in the null case, the continuity correction makes the results closer to those of Fisher's Exact test.

$$z_t = \frac{\hat{p}_1 - \hat{p}_2 - \delta_0 - \frac{F}{2} \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}{\hat{\sigma}_2}$$

$$\hat{\sigma}_2 = \sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{n_2}}$$

where  $F$  is -1 for lower-tailed hypotheses and 1 for upper-tailed hypotheses.

### T-Test

Because of a detailed, comparative study of the behavior of several tests, D'Agostino (1988) and Upton (1982) proposed using the usual two-sample t-test for testing whether the two proportions are equal. One substitutes a '1' for a success and a '0' for a failure in the usual, two-sample  $t$ -test formula.

### Miettinen and Nurminen's Likelihood Score Test

Miettinen and Nurminen (1985) proposed a test statistic for testing whether the difference is equal to a specified, non-zero, value,  $\delta_0$ . The regular MLE's,  $\hat{p}_1$  and  $\hat{p}_2$ , are used in the numerator of the score statistic while MLE's  $\tilde{p}_1$  and  $\tilde{p}_2$ , constrained so that  $\tilde{p}_1 - \tilde{p}_2 = \delta_0$ , are used in the denominator. A correction factor of  $N/(N-1)$  is applied to make the variance estimate less biased. The significance level of the test statistic is based on the asymptotic normality of the score statistic. The formula for computing this test statistic is

$$z_{MND} = \frac{\hat{p}_1 - \hat{p}_2 - \delta_0}{\hat{\sigma}_{MND}}$$

where

$$\hat{\sigma}_{MND} = \sqrt{\left( \frac{\tilde{p}_1 \tilde{q}_1}{n_1} + \frac{\tilde{p}_2 \tilde{q}_2}{n_2} \right) \left( \frac{N}{N-1} \right)}$$

## Non-Inferiority Tests for the Difference Between Two Proportions

$$\tilde{p}_1 = \tilde{p}_2 + \delta_0$$

$$\tilde{p}_1 = 2B \cos(A) - \frac{L_2}{3L_3}$$

$$A = \frac{1}{3} \left[ \pi + \cos^{-1} \left( \frac{C}{B^3} \right) \right]$$

$$B = \text{sign}(C) \sqrt{\frac{L_2^2}{9L_3^2} - \frac{L_1}{3L_3}}$$

$$C = \frac{L_2^3}{27L_3^3} - \frac{L_1 L_2}{6L_3^2} + \frac{L_0}{2L_3}$$

$$L_0 = x_{21} \delta_0 (1 - \delta_0)$$

$$L_1 = [n_2 \delta_0 - N - 2x_{21}] \delta_0 + m_1$$

$$L_2 = (N + n_2) \delta_0 - N - m_1$$

$$L_3 = N$$

**Farrington and Manning's Likelihood Score Test**

Farrington and Manning (1990) proposed a test statistic for testing whether the difference is equal to a specified value  $\delta_0$ . The regular MLE's,  $\hat{p}_1$  and  $\hat{p}_2$ , are used in the numerator of the score statistic while MLE's  $\tilde{p}_1$  and  $\tilde{p}_2$ , constrained so that  $\tilde{p}_1 - \tilde{p}_2 = \delta_0$ , are used in the denominator. The significance level of the test statistic is based on the asymptotic normality of the score statistic.

The formula for computing the test statistic is

$$z_{FMD} = \frac{\hat{p}_1 - \hat{p}_2 - \delta_0}{\sqrt{\left( \frac{\tilde{p}_1 \tilde{q}_1}{n_1} + \frac{\tilde{p}_2 \tilde{q}_2}{n_2} \right)}}$$

where the estimates  $\tilde{p}_1$  and  $\tilde{p}_2$  are computed as in the corresponding test of Miettinen and Nurminen (1985) given above.

**Gart and Nam's Likelihood Score Test**

Gart and Nam (1990), page 638, proposed a modification to the Farrington and Manning (1988) difference test that corrects for skewness. Let  $z_{FMD}(\delta)$  stand for the Farrington and Manning difference test statistic described above. The skewness corrected test statistic,  $z_{GND}$ , is the appropriate solution to the quadratic equation

$$(-\tilde{\gamma})z_{GND}^2 + (-1)z_{GND} + (z_{FMD}(\delta) + \tilde{\gamma}) = 0$$

where

$$\tilde{\gamma} = \frac{\tilde{V}^{3/2}(\delta)}{6} \left( \frac{\tilde{p}_1 \tilde{q}_1 (\tilde{q}_1 - \tilde{p}_1)}{n_1^2} - \frac{\tilde{p}_2 \tilde{q}_2 (\tilde{q}_2 - \tilde{p}_2)}{n_2^2} \right)$$

## Non-Inferiority Tests for the Difference Between Two Proportions

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### Procedure Options

This section describes the options that are specific to this procedure. These are located on the Design tab. For more information about the options of other tabs, go to the Procedure Window chapter.

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### Design Tab

The Design tab contains the parameters associated with this test such as the proportions, non-inferiority and actual differences, sample sizes, alpha, and power.

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#### Solve For

##### Solve For

This option specifies the parameter to be solved for using the other parameters. The parameters that may be selected are *Power*, *Sample Size*, and *Effect Size*.

Select *Power* when you want to calculate the power of an experiment.

Select *Sample Size* when you want to calculate the sample size needed to achieve a given power and alpha level.

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#### Power Calculation

##### Power Calculation Method

Select the method to be used to calculate power. When the sample sizes are reasonably large (i.e. greater than 50) and the proportions are between 0.2 and 0.8 the two methods will give similar results. For smaller sample sizes and more extreme proportions (less than 0.2 or greater than 0.8), the normal approximation is not as accurate so the binomial calculations may be more appropriate.

The choices are

- **Binomial Enumeration**

Power for each test is computed using binomial enumeration of all possible outcomes when  $N_1$  and  $N_2 \leq$  Maximum  $N_1$  or  $N_2$  for Binomial Enumeration (otherwise, the normal approximation is used). Binomial enumeration of all outcomes is possible because of the discrete nature of the data.

- **Normal Approximation**

Approximate power for each test is computed using the normal approximation to the binomial distribution.

Actual alpha values are only computed when “Binomial Enumeration” is selected.

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#### Power Calculation – Binomial Enumeration Options

*Only shown when Power Calculation Method = “Binomial Enumeration”*

##### Maximum $N_1$ or $N_2$ for Binomial Enumeration

When both  $N_1$  and  $N_2$  are less than or equal to this amount, power calculations using the binomial distribution are made. The value of the “Actual Alpha” is only calculated when binomial power calculations are made.

When either  $N_1$  or  $N_2$  is larger than this amount, the normal approximation to the binomial is used for power calculations.



## Non-Inferiority Tests for the Difference Between Two Proportions

### Zero Count Adjustment Method

Zero cell counts cause many calculation problems when enumerating binomial probabilities. To compensate for this, a small value (called the “Zero Count Adjustment Value”) may be added either to all cells or to all cells with zero counts. This option specifies which type of adjustment you want to use.

Adding a small value is controversial, but may be necessary. Some statisticians recommend adding 0.5 while others recommend 0.25. We have found that adding values as small as 0.0001 seems to work well.

### Zero Count Adjustment Value

Zero cell counts cause many calculation problems when enumerating binomial probabilities. To compensate for this, a small value may be added either to all cells or to all zero cells. This is the amount that is added. We have found that 0.0001 works well.

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## Test

### Higher Proportions Are

This option specifies whether proportions represent successes (better) or failures (worse).

- **Better (Successes)**

When proportions represent successes, higher proportions are better. A non-inferior treatment is one whose proportion is at least almost as high as that of the reference group.

For testing non-inferiority, D0 is negative. For testing superiority, D0 is positive.

- **Worse (Failures)**

When proportions represent failures, lower proportions are better. A non-inferior treatment is one whose proportion is at most almost as low as that of the reference group.

For testing non-inferiority, D0 is positive. For testing superiority, D0 is negative.

### Test Type

Specify which test statistic is used in searching and reporting. Although the pooled  $z$ -test is commonly shown in elementary statistics books, the likelihood score test is arguably the best choice.

Note that *C.C.* is an abbreviation for *Continuity Correction*. This refers to the adding or subtracting  $1/(2n)$  to (or from) the numerator of the  $z$ -value to bring the normal approximation closer to the binomial distribution.

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## Power and Alpha

### Power

This option specifies one or more values for power. Power is the probability of rejecting a false null hypothesis, and is equal to one minus Beta. Beta is the probability of a type-II error, which occurs when a false null hypothesis is not rejected.

Values must be between zero and one. Historically, the value of 0.80 (Beta = 0.20) was used for power. Now, 0.90 (Beta = 0.10) is also commonly used.

A single value may be entered here or a range of values such as *0.8 to 0.95 by 0.05* may be entered.

### Alpha

This option specifies one or more values for the probability of a type-I error. A type-I error occurs when a true null hypothesis is rejected.

Values must be between zero and one. Historically, the value of 0.05 has been used for alpha. This means that about one test in twenty will falsely reject the null hypothesis. You should pick a value for alpha that represents the risk of a type-I error you are willing to take in your experimental situation.

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You may enter a range of values such as  $0.01$   $0.05$   $0.10$  or  $0.01$  to  $0.10$  by  $0.01$ .

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### Sample Size (When Solving for Sample Size)

#### Group Allocation

Select the option that describes the constraints on  $N1$  or  $N2$  or both.

The options are

- **Equal ( $N1 = N2$ )**  
This selection is used when you wish to have equal sample sizes in each group. Since you are solving for both sample sizes at once, no additional sample size parameters need to be entered.
- **Enter  $N1$ , solve for  $N2$**   
Select this option when you wish to fix  $N1$  at some value (or values), and then solve only for  $N2$ . Please note that for some values of  $N1$ , there may not be a value of  $N2$  that is large enough to obtain the desired power.
- **Enter  $N2$ , solve for  $N1$**   
Select this option when you wish to fix  $N2$  at some value (or values), and then solve only for  $N1$ . Please note that for some values of  $N2$ , there may not be a value of  $N1$  that is large enough to obtain the desired power.
- **Enter  $R = N2/N1$ , solve for  $N1$  and  $N2$**   
For this choice, you set a value for the ratio of  $N2$  to  $N1$ , and then PASS determines the needed  $N1$  and  $N2$ , with this ratio, to obtain the desired power. An equivalent representation of the ratio,  $R$ , is
 
$$N2 = R * N1.$$
- **Enter percentage in Group 1, solve for  $N1$  and  $N2$**   
For this choice, you set a value for the percentage of the total sample size that is in Group 1, and then PASS determines the needed  $N1$  and  $N2$  with this percentage to obtain the desired power.

#### **$N1$ (Sample Size, Group 1)**

*This option is displayed if Group Allocation = "Enter  $N1$ , solve for  $N2$ "*

$N1$  is the number of items or individuals sampled from the Group 1 population.

$N1$  must be  $\geq 2$ . You can enter a single value or a series of values.

#### **$N2$ (Sample Size, Group 2)**

*This option is displayed if Group Allocation = "Enter  $N2$ , solve for  $N1$ "*

$N2$  is the number of items or individuals sampled from the Group 2 population.

$N2$  must be  $\geq 2$ . You can enter a single value or a series of values.

#### **$R$ (Group Sample Size Ratio)**

*This option is displayed only if Group Allocation = "Enter  $R = N2/N1$ , solve for  $N1$  and  $N2$ ."*

$R$  is the ratio of  $N2$  to  $N1$ . That is,

$$R = N2 / N1.$$

Use this value to fix the ratio of  $N2$  to  $N1$  while solving for  $N1$  and  $N2$ . Only sample size combinations with this ratio are considered.

$N2$  is related to  $N1$  by the formula:

$$N2 = [R \times N1],$$

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where the value  $[Y]$  is the next integer  $\geq Y$ .

For example, setting  $R = 2.0$  results in a Group 2 sample size that is double the sample size in Group 1 (e.g.,  $N1 = 10$  and  $N2 = 20$ , or  $N1 = 50$  and  $N2 = 100$ ).

$R$  must be greater than 0. If  $R < 1$ , then  $N2$  will be less than  $N1$ ; if  $R > 1$ , then  $N2$  will be greater than  $N1$ . You can enter a single or a series of values.

### Percent in Group 1

*This option is displayed only if Group Allocation = "Enter percentage in Group 1, solve for N1 and N2."*

Use this value to fix the percentage of the total sample size allocated to Group 1 while solving for  $N1$  and  $N2$ . Only sample size combinations with this Group 1 percentage are considered. Small variations from the specified percentage may occur due to the discrete nature of sample sizes.

The Percent in Group 1 must be greater than 0 and less than 100. You can enter a single or a series of values.

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## Sample Size (When Not Solving for Sample Size)

### Group Allocation

Select the option that describes how individuals in the study will be allocated to Group 1 and to Group 2.

The options are

- **Equal ( $N1 = N2$ )**  
This selection is used when you wish to have equal sample sizes in each group. A single per group sample size will be entered.
- **Enter N1 and N2 individually**  
This choice permits you to enter different values for  $N1$  and  $N2$ .
- **Enter N1 and R, where  $N2 = R * N1$**   
Choose this option to specify a value (or values) for  $N1$ , and obtain  $N2$  as a ratio (multiple) of  $N1$ .
- **Enter total sample size and percentage in Group 1**  
Choose this option to specify a value (or values) for the total sample size ( $N$ ), obtain  $N1$  as a percentage of  $N$ , and then  $N2$  as  $N - N1$ .

### Sample Size Per Group

*This option is displayed only if Group Allocation = "Equal ( $N1 = N2$ )."*

The Sample Size Per Group is the number of items or individuals sampled from each of the Group 1 and Group 2 populations. Since the sample sizes are the same in each group, this value is the value for  $N1$ , and also the value for  $N2$ .

The Sample Size Per Group must be  $\geq 2$ . You can enter a single value or a series of values.

### N1 (Sample Size, Group 1)

*This option is displayed if Group Allocation = "Enter N1 and N2 individually" or "Enter N1 and R, where  $N2 = R * N1$ ."*

$N1$  is the number of items or individuals sampled from the Group 1 population.

$N1$  must be  $\geq 2$ . You can enter a single value or a series of values.

### N2 (Sample Size, Group 2)

*This option is displayed only if Group Allocation = "Enter N1 and N2 individually."*

## Non-Inferiority Tests for the Difference Between Two Proportions

$N_2$  is the number of items or individuals sampled from the Group 2 population.

$N_2$  must be  $\geq 2$ . You can enter a single value or a series of values.

### R (Group Sample Size Ratio)

*This option is displayed only if Group Allocation = "Enter  $N_1$  and  $R$ , where  $N_2 = R * N_1$ ."*

$R$  is the ratio of  $N_2$  to  $N_1$ . That is,

$$R = N_2/N_1$$

Use this value to obtain  $N_2$  as a multiple (or proportion) of  $N_1$ .

$N_2$  is calculated from  $N_1$  using the formula:

$$N_2 = \lceil R \times N_1 \rceil,$$

where the value  $\lceil Y \rceil$  is the next integer  $\geq Y$ .

For example, setting  $R = 2.0$  results in a Group 2 sample size that is double the sample size in Group 1.

$R$  must be greater than 0. If  $R < 1$ , then  $N_2$  will be less than  $N_1$ ; if  $R > 1$ , then  $N_2$  will be greater than  $N_1$ . You can enter a single value or a series of values.

### Total Sample Size (N)

*This option is displayed only if Group Allocation = "Enter total sample size and percentage in Group 1."*

This is the total sample size, or the sum of the two group sample sizes. This value, along with the percentage of the total sample size in Group 1, implicitly defines  $N_1$  and  $N_2$ .

The total sample size must be greater than one, but practically, must be greater than 3, since each group sample size needs to be at least 2.

You can enter a single value or a series of values.

### Percent in Group 1

*This option is displayed only if Group Allocation = "Enter total sample size and percentage in Group 1."*

This value fixes the percentage of the total sample size allocated to Group 1. Small variations from the specified percentage may occur due to the discrete nature of sample sizes.

The Percent in Group 1 must be greater than 0 and less than 100. You can enter a single value or a series of values.

## Effect Size

### Input Type

Indicate what type of values to enter to specify the non-inferiority and actual differences. Regardless of the entry type chosen, the calculations are the same. This option is simply given for convenience in specifying the differences.

### Effect Size – Differences (P1 – P2)

*These options are displayed only if Input Type = "Differences"*

#### D0 (Non-Inferiority Difference)

This option specifies the trivial difference (often called the *margin of error*) between  $P_{1.0}$  (the value of  $P_1$  under  $H_0$ ) and  $P_2$ . This difference is used with  $P_2$  to calculate the value of  $P_{1.0}$  using the formula:  $P_{1.0} = P_2 + D_0$ .

## Non-Inferiority Tests for the Difference Between Two Proportions

When *Higher Proportions Are* is set to *Better*, the trivial difference is that amount by which P1 can be less than P2 and still have the treatment group declared non-inferior to the reference group. In this case, D0 should be negative for non-inferiority tests and positive for superiority tests.

The reverse is the case when *Higher Proportions Are* is set to *worse*.

You may enter a range of values such as *-.03 -.05 -.10* or *-.05 to -.01 by .01*. Differences must be between -1 and 1. D0 cannot take on the values -1, 0, or 1.

### D1 (Actual Difference)

This option specifies the actual difference between P1.1 (the actual value of P1) and P2. This is the value of the difference at which the power is calculated. In non-inferiority trials, this difference is often set to 0.

The power calculations assume that P1.1 is the actual value of the proportion in group 1 (experimental or treatment group). This difference is used with P2 to calculate the value of P1 using the formula:  $P1.1 = D1 + P2$ .

You may enter a range of values such as *-.05 0 .5* or *-.05 to .05 by .02*. Actual differences must be between -1 and 1. They cannot take on the values -1 or 1.

---

## Effect Size – Group 1 (Treatment)

*These options are displayed only if Input Type = "Proportions"*

### P1.0 (Non-Inferiority Proportion)

This option allows you to specify the value P1.0 directly. This is that value of treatment group's proportion above which the treatment group is considered non-inferior to the reference group.

When *Higher Proportions Are* is set to *Better*, the trivial proportion is the smallest value of P1 for which the treatment group is declared non-inferior to the reference group. In this case, P1.0 should be less than P2 for non-inferiority tests and greater than P2 for superiority tests. The reverse is the case when *Higher Proportions Are* is set to *Worse*.

Proportions must be between 0 and 1. They cannot take on the values 0 or 1. This value should not be set to exactly the value of P2.

You may enter a range of values such as *0.03 0.05 0.10* or *0.01 to 0.05 by 0.01*.

### P1.1 (Actual Proportion)

This option specifies the value of P1.1 which is the value of the treatment proportion at which the power is to be calculated. Proportions must be between 0 and 1. They cannot take on the values 0 or 1.

You may enter a range of values such as *0.03 0.05 0.10* or *0.01 to 0.05 by 0.01*.

---

## Effect Size – Group 2 (Reference)

### P2 (Group 2 Proportion)

Specify the value of  $p_2$ , the reference, baseline, or control group's proportion. The null hypothesis is that the two proportions differ by no more than a specified amount. Since P2 is a proportion, these values must be between 0 and 1.

You may enter a range of values such as *0.1 0.2 0.3* or *0.1 to 0.9 by 0.1*.

## Non-Inferiority Tests for the Difference Between Two Proportions

### Example 1 – Finding Power

A study is being designed to establish the non-inferiority of a new treatment compared to the current treatment. Historically, the current treatment has enjoyed a 60% cure rate. The new treatment reduces the seriousness of certain side effects that occur with the current treatment. Thus, the new treatment will be adopted even if it is slightly less effective than the current treatment. The researchers will recommend adoption of the new treatment if it has a cure rate of at least 55%.

The researchers plan to use the Farrington and Manning likelihood score test statistic to analyze the data that will be (or has been) obtained. They want to study the power of the Farrington and Manning test at group sample sizes ranging from 50 to 500 for detecting a difference of -0.05 when the actual cure rate of the new treatment ranges from 57% to 70%. The significance level will be 0.025.

### Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Non-Inferiority Tests for the Difference Between Two Proportions** procedure window by expanding **Proportions**, then **Two Independent Proportions**, then clicking on **Non-Inferiority**, and then clicking on **Non-Inferiority Tests for the Difference Between Two Proportions**. You may then make the appropriate entries as listed below, or open **Example 1** by going to the **File** menu and choosing **Open Example Template**.

<u>Option</u>	<u>Value</u>
<b>Design Tab</b>	
Solve For .....	<b>Power</b>
Power Calculation Method.....	<b>Normal Approximation</b>
Higher Proportions Are .....	<b>Better</b>
Test Type.....	<b>Likelihood Score (Farr. &amp; Mann.)</b>
Alpha.....	<b>0.025</b>
Group Allocation .....	<b>Equal (N1 = N2)</b>
Sample Size Per Group .....	<b>50 to 500 by 50</b>
Input Type.....	<b>Differences</b>
D0 (Non-Inferiority Difference).....	<b>-0.05</b>
D1 (Actual Difference) .....	<b>-0.03 0.00 0.05 0.10</b>
P2 (Group 2 Proportion) .....	<b>0.6</b>

## Non-Inferiority Tests for the Difference Between Two Proportions

## Output

Click the Calculate button to perform the calculations and generate the following output.

## Numeric Results

## Numeric Results for Non-Inferiority Tests for the Difference Between Two Proportions

Test Statistic: Farrington & Manning Likelihood Score Test

H0:  $P_1 - P_2 \leq D_0$  vs. H1:  $P_1 - P_2 = D_1 > D_0$ .

Power*	N1	N2	N	Ref. P2	P1 H0 P1.0	P1 H1 P1.1	NI Diff D0	Diff D1	Alpha
0.03959	50	50	100	0.6000	0.5500	0.5700	-0.0500	-0.0300	0.0250
0.04733	100	100	200	0.6000	0.5500	0.5700	-0.0500	-0.0300	0.0250
0.05405	150	150	300	0.6000	0.5500	0.5700	-0.0500	-0.0300	0.0250
0.06029	200	200	400	0.6000	0.5500	0.5700	-0.0500	-0.0300	0.0250
0.06623	250	250	500	0.6000	0.5500	0.5700	-0.0500	-0.0300	0.0250
0.07199	300	300	600	0.6000	0.5500	0.5700	-0.0500	-0.0300	0.0250
0.07762	350	350	700	0.6000	0.5500	0.5700	-0.0500	-0.0300	0.0250

(report continues)

\* Power was computed using the normal approximation method.

## References

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- Farrington, C. P. and Manning, G. 1990. 'Test Statistics and Sample Size Formulae for Comparative Binomial Trials with Null Hypothesis of Non-Zero Risk Difference or Non-Unity Relative Risk.' Statistics in Medicine, Vol. 9, pages 1447-1454.
- Fleiss, J. L., Levin, B., Paik, M.C. 2003. Statistical Methods for Rates and Proportions. Third Edition. John Wiley & Sons. New York.
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- Lachin, John M. 2000. Biostatistical Methods. John Wiley & Sons. New York.
- Machin, D., Campbell, M., Fayers, P., and Pinol, A. 1997. Sample Size Tables for Clinical Studies, 2nd Edition. Blackwell Science. Malden, Mass.
- Miettinen, O.S. and Nurminen, M. 1985. 'Comparative analysis of two rates.' Statistics in Medicine 4: 213-226.

## Report Definitions

Power is the probability of rejecting a false null hypothesis.

N1 and N2 are the number of items sampled from each population.

N is the total sample size,  $N_1 + N_2$ .

P2 is the proportion for Group 2. This is the standard, reference, or control group.

P1 is the treatment or experimental group proportion. P1.0 is the smallest treatment-group response rate that still yields a non-inferiority conclusion. P1.1 is the proportion for Group 1 at which power and sample size calculations are made.

D0 is the non-inferiority margin. It is the difference  $P_1 - P_2$ , assuming H0. D1 is the difference  $P_1 - P_2$  assumed for power and sample size calculations.

Alpha is the probability of rejecting a true null hypothesis.

## Summary Statements

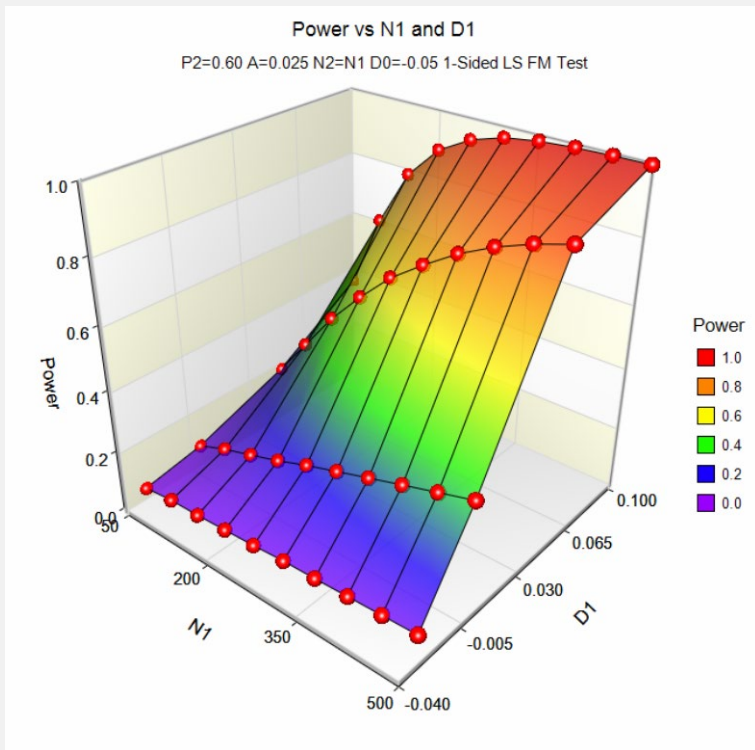
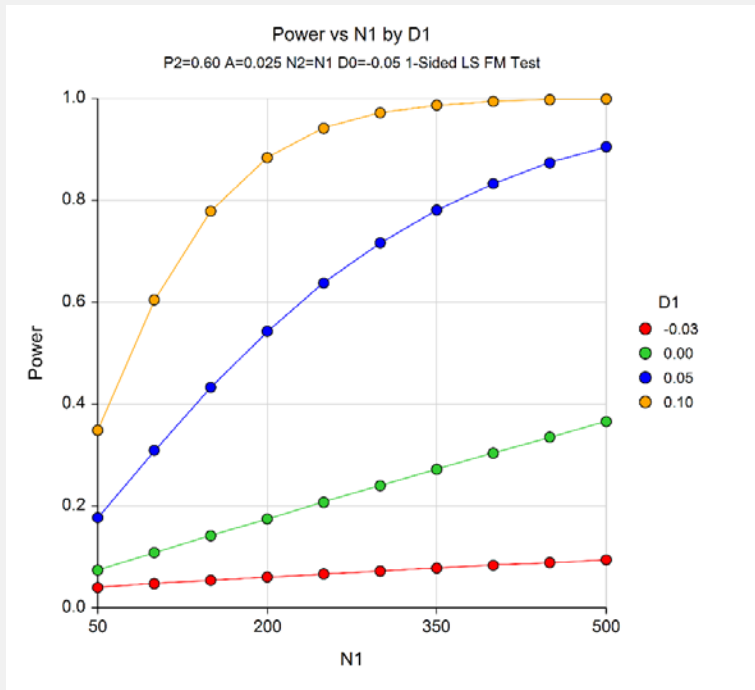
Sample sizes of 50 in Group 1 and 50 in Group 2 achieve 3.959% power to detect a non-inferiority margin difference between the group proportions of -0.0500. The reference group proportion is 0.6000. The treatment group proportion is assumed to be 0.5500 under the null hypothesis of inferiority. The power was computed for the case when the actual treatment group proportion is 0.5700. The test statistic used is the one-sided Score test (Farrington & Manning). The significance level of the test is 0.0250.

This report shows the values of each of the parameters, one scenario per row.



## Non-Inferiority Tests for the Difference Between Two Proportions

### Plots Section



The values from the table are displayed in the above chart. These charts give us a quick look at the sample size that will be required for various values of D1.



## Non-Inferiority Tests for the Difference Between Two Proportions

### Example 2 – Finding the Sample Size

Continuing with the scenario given in Example 1, the researchers want to determine the sample size necessary for each value of D1 to achieve a power of 0.80.

#### Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Non-Inferiority Tests for the Difference Between Two Proportions** procedure window by expanding **Proportions**, then **Two Independent Proportions**, then clicking on **Non-Inferiority**, and then clicking on **Non-Inferiority Tests for the Difference Between Two Proportions**. You may then make the appropriate entries as listed below, or open **Example 2** by going to the **File** menu and choosing **Open Example Template**.

<u>Option</u>	<u>Value</u>
<b>Design Tab</b>	
Solve For .....	<b>Sample Size</b>
Power Calculation Method.....	<b>Normal Approximation</b>
Higher Proportions Are .....	<b>Better</b>
Test Type.....	<b>Likelihood Score (Farr. &amp; Mann.)</b>
Power.....	<b>0.8</b>
Alpha.....	<b>0.025</b>
Group Allocation .....	<b>Equal (N1 = N2)</b>
Input Type.....	<b>Differences</b>
D0 (Non-Inferiority Difference).....	<b>-0.05</b>
D1 (Actual Difference) .....	<b>-0.03 0.00 0.05 0.10</b>
P2 (Group 2 Proportion) .....	<b>0.6</b>

#### Output

Click the Calculate button to perform the calculations and generate the following output.

#### Numeric Results

##### Numeric Results for Non-Inferiority Tests for the Difference Between Two Proportions

Test Statistic: Farrington & Manning Likelihood Score Test  
 H0:  $P_1 - P_2 \leq D_0$  vs. H1:  $P_1 - P_2 = D_1 > D_0$ .

Target Power	Actual Power*	N1	N2	N	Ref. P2	P1 H0 P1.0	P1 H1 P1.1	NI Diff D0	Diff D1	Alpha
0.80	0.80002	9509	9509	19018	0.6000	0.5500	0.5700	-0.0500	-0.0300	0.0250
0.80	0.80008	1505	1505	3010	0.6000	0.5500	0.6000	-0.0500	0.0000	0.0250
0.80	0.80075	368	368	736	0.6000	0.5500	0.6500	-0.0500	0.0500	0.0250
0.80	0.80187	159	159	318	0.6000	0.5500	0.7000	-0.0500	0.1000	0.0250

\* Power was computed using the normal approximation method.

The required sample size will depend a great deal on the value of D1. Any effort spent determining an accurate value for D1 will be worthwhile.

## Example 3 – Comparing the Power of Several Test Statistics

Continuing with Example 2, the researchers want to determine which of the eight possible test statistics to adopt by using the comparative reports and charts that **PASS** produces. They decide to compare the powers from binomial enumeration and actual alphas for various sample sizes between 50 and 200 when D1 is 0.1.

### Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Non-Inferiority Tests for the Difference Between Two Proportions** procedure window by expanding **Proportions**, then **Two Independent Proportions**, then clicking on **Non-Inferiority**, and then clicking on **Non-Inferiority Tests for the Difference Between Two Proportions**. You may then make the appropriate entries as listed below, or open **Example 3** by going to the **File** menu and choosing **Open Example Template**.

<u>Option</u>	<u>Value</u>
<b>Design Tab</b>	
Solve For .....	<b>Power</b>
Power Calculation Method.....	<b>Binomial Enumeration</b>
Max N1 or N2 for Binomial Enumeration	<b>5000</b>
Zero Count Adjustment Method.....	<b>Add to zero cells only</b>
Zero Count Adjustment Value .....	<b>0.0001</b>
Higher Proportions Are .....	<b>Better</b>
Test Type .....	<b>Likelihood Score (Farr. &amp; Mann.)</b>
Alpha .....	<b>0.025</b>
Group Allocation .....	<b>Equal (N1 = N2)</b>
Sample Size Per Group .....	<b>50 100 150 200</b>
Input Type .....	<b>Differences</b>
D0 (Non-Inferiority Difference).....	<b>-0.05</b>
D1 (Actual Difference) .....	<b>0.10</b>
P2 (Group 2 Proportion) .....	<b>0.6</b>
<b>Reports Tab</b>	
Show Comparative Reports.....	<b>Checked</b>
<b>Comparative Plots Tab</b>	
Show Comparative Plots .....	<b>Checked</b>

Non-Inferiority Tests for the Difference Between Two Proportions

Output

Click the Calculate button to perform the calculations and generate the following output.

Numeric Results and Plots

Power Comparison of Eight Different Non-Inferiority Tests for the Difference Between Two Proportions

H0:  $P_1 - P_2 \leq D_0$  vs. H1:  $P_1 - P_2 = D_1 > D_0$ .

N1/N2	P2	P1	Target Alpha	Z(P) Test Power	Z(UnP) Test Power	Z(P) CC Test Power	Z(UnP) CC Test Power	T Test Power	F.M. Score Power	M.N. Score Power	G.N. Score Power
50/50	0.6000	0.7000	0.0250	0.3581	0.3670	0.2782	0.2945	0.3464	0.3581	0.3464	0.3581
100/100	0.6000	0.7000	0.0250	0.6030	0.6088	0.5474	0.5475	0.5982	0.6030	0.6030	0.6030
150/150	0.6000	0.7000	0.0250	0.7821	0.7837	0.7453	0.7474	0.7821	0.7837	0.7821	0.7821
200/200	0.6000	0.7000	0.0250	0.8849	0.8857	0.8635	0.8638	0.8849	0.8857	0.8849	0.8849

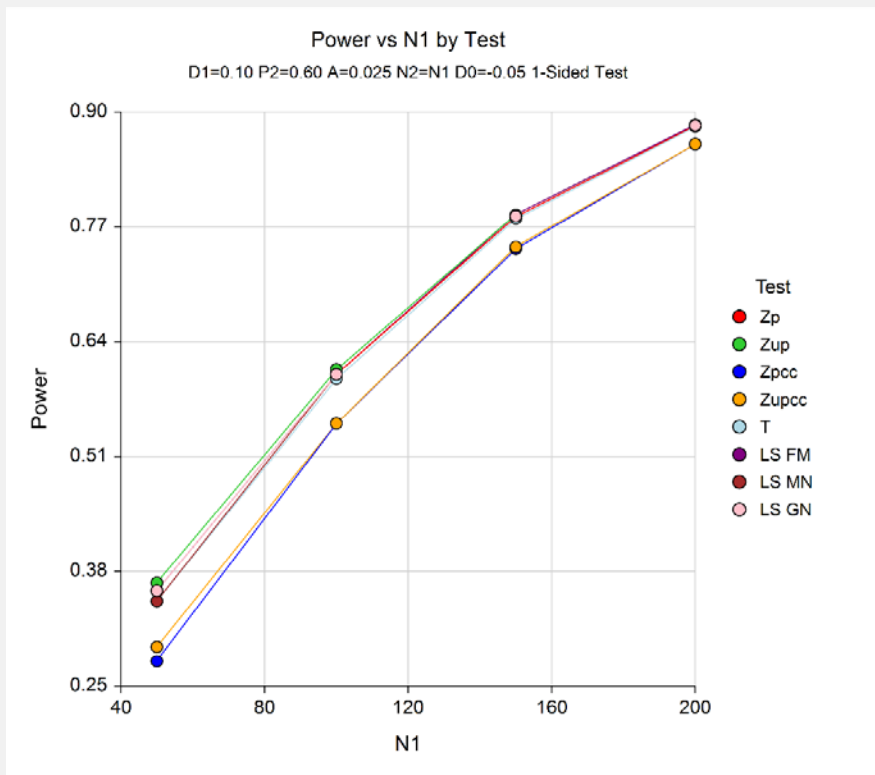
Note: Power was computed using binomial enumeration of all possible outcomes.

Actual Alpha Comparison of Eight Different Non-Inferiority Tests for the Difference Between Two Proportions

H0:  $P_1 - P_2 \leq D_0$  vs. H1:  $P_1 - P_2 = D_1 > D_0$ .

N1/N2	P1	P2	Target Alpha	Z(P) Test Alpha	Z(UnP) Test Alpha	Z(P) CC Test Alpha	Z(UnP) CC Test Alpha	T Test Alpha	F.M. Score Alpha	M.N. Score Alpha	G.N. Score Alpha
50/50	0.6000	0.7000	0.0250	0.0236	0.0253	0.0140	0.0161	0.0225	0.0236	0.0225	0.0236
100/100	0.6000	0.7000	0.0250	0.0267	0.0267	0.0190	0.0190	0.0266	0.0267	0.0267	0.0267
150/150	0.6000	0.7000	0.0250	0.0239	0.0241	0.0181	0.0183	0.0239	0.0241	0.0239	0.0239
200/200	0.6000	0.7000	0.0250	0.0243	0.0244	0.0191	0.0191	0.0243	0.0244	0.0243	0.0243

Note: Actual alpha was computed using binomial enumeration of all possible outcomes.



It is interesting to note that the powers of the continuity-corrected test statistics are consistently lower than the other tests. This occurs because the actual alpha achieved by these tests is lower than for the other tests. An interesting finding of this example is that the regular *t*-test performed about as well as the *z*-test.

## Non-Inferiority Tests for the Difference Between Two Proportions

**Example 4 – Comparing Power Calculation Methods**

Continuing with Example 3, let's see how the results compare if we were to use approximate power calculations instead of power calculations based on binomial enumeration.

**Setup**

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Non-Inferiority Tests for the Difference Between Two Proportions** procedure window by expanding **Proportions**, then **Two Independent Proportions**, then clicking on **Non-Inferiority**, and then clicking on **Non-Inferiority Tests for the Difference Between Two Proportions**. You may then make the appropriate entries as listed below, or open **Example 4** by going to the **File** menu and choosing **Open Example Template**.

<u>Option</u>	<u>Value</u>
<b>Design Tab</b>	
Solve For .....	<b>Power</b>
Power Calculation Method.....	<b>Normal Approximation</b>
Higher Proportions Are .....	<b>Better</b>
Test Type.....	<b>Likelihood Score (Farr. &amp; Mann.)</b>
Alpha.....	<b>0.025</b>
Group Allocation .....	<b>Equal (N1 = N2)</b>
Sample Size Per Group .....	<b>50 100 150 200</b>
Input Type.....	<b>Differences</b>
D0 (Non-Inferiority Difference).....	<b>-0.05</b>
D1 (Actual Difference) .....	<b>0.10</b>
P2 (Group 2 Proportion) .....	<b>0.6</b>
<b>Reports Tab</b>	
Show Power Detail Report .....	<b>Checked</b>

**Output**

Click the Calculate button to perform the calculations and generate the following output.

**Numeric Results and Plots****Power Detail Report for Non-Inferiority Tests for the Difference Between Two Proportions**

Test Statistic: Farrington & Manning Likelihood Score Test

H0:  $P_1 - P_2 \leq D_0$  vs. H1:  $P_1 - P_2 = D_1 > D_0$ .

N1/N2	P2	D0	D1	Normal Approximation		Binomial Enumeration	
				Power	Alpha	Power	Alpha
50/50	0.6000	-0.0500	0.1000	0.34823	0.0250	0.35812	0.0236
100/100	0.6000	-0.0500	0.1000	0.60443	0.0250	0.60298	0.0267
150/150	0.6000	-0.0500	0.1000	0.77857	0.0250	0.78368	0.0241
200/200	0.6000	-0.0500	0.1000	0.88318	0.0250	0.88573	0.0244

Notice that the approximate power values are pretty close to the binomial enumeration values for all sample sizes.

## Non-Inferiority Tests for the Difference Between Two Proportions

### Example 5 – Finding the True Proportion Difference

Researchers have developed a new treatment with minimal side effects compared to the standard treatment. The researchers are limited by the number of subjects (140 per group) they can use to show the new treatment is non-inferior. The new treatment will be deemed non-inferior if it is at least 0.10 below the success rate of the standard treatment. The standard treatment has a success rate of about 0.75. The researchers want to know how much more successful the new treatment must be (in truth) to yield a test which has 90% power. The test statistic used will be the pooled Z test.

#### Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Non-Inferiority Tests for the Difference Between Two Proportions** procedure window by expanding **Proportions**, then **Two Independent Proportions**, then clicking on **Non-Inferiority**, and then clicking on **Non-Inferiority Tests for the Difference Between Two Proportions**. You may then make the appropriate entries as listed below, or open **Example 5** by going to the **File** menu and choosing **Open Example Template**.

Option	Value
<b>Design Tab</b>	
Solve For .....	<b>Effect Size (D1, P1.1)</b>
Power Calculation Method.....	<b>Binomial Enumeration</b>
Max N1 or N2 for Binomial Enumeration	<b>5000</b>
Zero Count Adjustment Method.....	<b>Add to zero cells only</b>
Zero Count Adjustment Value .....	<b>0.0001</b>
Higher Proportions Are .....	<b>Better</b>
Test Type.....	<b>Z-Test (Pooled)</b>
Power.....	<b>0.90</b>
Alpha.....	<b>0.05</b>
Group Allocation .....	<b>Equal (N1 = N2)</b>
Sample Size Per Group.....	<b>140</b>
Input Type.....	<b>Differences</b>
D0 (Non-Inferiority Difference).....	<b>-0.10</b>
P2 (Group 2 Proportion) .....	<b>0.75</b>

#### Output

Click the Calculate button to perform the calculations and generate the following output.

#### Numeric Results

##### Numeric Results for Non-Inferiority Tests for the Difference Between Two Proportions

Test Statistic: Z-Test with Pooled Variance

H0:  $P_1 - P_2 \leq D_0$  vs. H1:  $P_1 - P_2 = D_1 > D_0$ .

Power*	N1	N2	N	Ref. P2	P1 H0 P1.0	P1 H1 P1.1	NI Diff D0	Diff D1	Target Alpha	Actual Alpha*†
0.90000	140	140	280	0.7500	0.6500	0.7961	-0.1000	0.0461	0.0500	0.0505

\* Power and actual alpha were computed using binomial enumeration of all possible outcomes.

† Warning: When solving for effect size with power computed using binomial enumeration, the target alpha level is not guaranteed. Actual alpha may be greater than target alpha in some cases.

With 140 subjects in each group, the new treatment must have a success rate 0.0461 higher than the current treatment (or about 0.7961) to have 90% power in the test of non-inferiority.

## Non-Inferiority Tests for the Difference Between Two Proportions

## Example 6 – Validation of Sample Size Calculation for the Farrington and Manning Test using Machin et al. (1997)

Machin et al. (1997), page 106, present a sample size study in which  $P_2 = 0.5$ ,  $D_0 = -0.2$ ,  $D_1 = 0$ , one-sided  $\alpha = 0.1$ , and  $\beta = 0.2$ . Using the Farrington and Manning test statistic, they found the sample size to be 55 in each group.

### Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Non-Inferiority Tests for the Difference Between Two Proportions** procedure window by expanding **Proportions**, then **Two Independent Proportions**, then clicking on **Non-Inferiority**, and then clicking on **Non-Inferiority Tests for the Difference Between Two Proportions**. You may then make the appropriate entries as listed below, or open **Example 6** by going to the **File** menu and choosing **Open Example Template**.

<u>Option</u>	<u>Value</u>
<b>Design Tab</b>	
Solve For .....	<b>Sample Size</b>
Power Calculation Method.....	<b>Normal Approximation</b>
Higher Proportions Are .....	<b>Better</b>
Test Type.....	<b>Likelihood Score (Farr. &amp; Mann.)</b>
Power.....	<b>0.8</b>
Alpha.....	<b>0.1</b>
Group Allocation .....	<b>Equal (N1 = N2)</b>
Input Type.....	<b>Differences</b>
D0 (Non-Inferiority Difference).....	<b>-0.2</b>
D1 (Actual Difference) .....	<b>0.0</b>
P2 (Group 2 Proportion) .....	<b>0.5</b>

### Output

Click the Calculate button to perform the calculations and generate the following output.

### Numeric Results

#### Numeric Results for Non-Inferiority Tests for the Difference Between Two Proportions

Test Statistic: Farrington & Manning Likelihood Score Test

H0:  $P_1 - P_2 \leq D_0$  vs. H1:  $P_1 - P_2 = D_1 > D_0$ .

Target Power	Actual Power*	N1	N2	N	Ref. P2	P1 H0 P1.0	P1 H1 P1.1	NI Diff D0	Diff D1	Alpha
0.80	0.80009	55	55	110	0.5000	0.3000	0.5000	-0.2000	0.0000	0.1000

\* Power was computed using the normal approximation method.

PASS found the required sample size to be 55 which corresponds to Machin.

## Non-Inferiority Tests for the Difference Between Two Proportions

## Example 7 – Validation of Sample Size Calculation for the Unpooled Z-Test using Chow, Shao, and Wang (2008)

Chow, Shao, and Wang (2008) page 92 gives the results of a sample size calculation for an unpooled Z-test for non-inferiority. When  $P_{1.0} = 0.55$  (from  $\delta = -0.1$ ),  $P_{1.1} = 0.85$ ,  $P_2 = 0.65$ , power = 0.8, and alpha = 0.05, Chow, Shao, and Wang (2008) reports a required sample size of 25.

### Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Non-Inferiority Tests for the Difference Between Two Proportions** procedure window by expanding **Proportions**, then **Two Independent Proportions**, then clicking on **Non-Inferiority**, and then clicking on **Non-Inferiority Tests for the Difference Between Two Proportions**. You may then make the appropriate entries as listed below, or open **Example 7** by going to the **File** menu and choosing **Open Example Template**.

<u>Option</u>	<u>Value</u>
<b>Design Tab</b>	
Solve For .....	<b>Sample Size</b>
Power Calculation Method.....	<b>Normal Approximation</b>
Higher Proportions Are .....	<b>Better</b>
Test Type.....	<b>Z-Test (Unpooled)</b>
Power.....	<b>0.80</b>
Alpha.....	<b>0.05</b>
Group Allocation .....	<b>Equal (N1 = N2)</b>
Input Type.....	<b>Proportions</b>
P1.0 (Non-Inferiority Proportion).....	<b>0.55</b>
P1.1 (Actual Proportion) .....	<b>0.85</b>
P2 (Group 2 Proportion) .....	<b>0.65</b>

### Output

Click the Calculate button to perform the calculations and generate the following output.

### Numeric Results

#### Numeric Results for Non-Inferiority Tests for the Difference Between Two Proportions

Test Statistic: Z-Test with Unpooled Variance

H0:  $P_1 - P_2 \leq D_0$  vs. H1:  $P_1 - P_2 = D_1 > D_0$ .

Target Power	Actual Power*	N1	N2	N	Ref. P2	P1 H0 P1.0	P1 H1 P1.1	NI Diff D0	Diff D1	Alpha
0.80	0.80858	25	25	50	0.6500	0.5500	0.8500	-0.1000	0.2000	0.0500

\* Power was computed using the normal approximation method.

PASS also found the required sample size to be 25.

## Example 8 – Validation of Sample Size Calculation for the Unpooled Z-Test using Julius and Campbell (2012)

Julius and Campbell (2012) presents Table XIII gives the results of sample size calculations for an unpooled Z-test for non-inferiority for P2 between 0.7 and 0.9,  $|D0|$  between 0.05 and 0.20 and D1 between -0.05 and 0.05. Sample sizes are calculated for 90% power and  $\alpha = 0.025$ . This example will replicate all values of D1 for P1 = 0.70 and  $|D0| = 0.20$  in the table.

The sample sizes reported in the table for D1 between -0.05 and 0.05 are 205, 179, 157, 139, 124, 111, 100, 90, 81, 74, and 67.

### Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Non-Inferiority Tests for the Difference Between Two Proportions** procedure window by expanding **Proportions**, then **Two Independent Proportions**, then clicking on **Non-Inferiority**, and then clicking on **Non-Inferiority Tests for the Difference Between Two Proportions**. You may then make the appropriate entries as listed below, or open **Example 8** by going to the **File** menu and choosing **Open Example Template**.

<u>Option</u>	<u>Value</u>
<b>Design Tab</b>	
Solve For .....	<b>Sample Size</b>
Power Calculation Method.....	<b>Normal Approximation</b>
Higher Proportions Are .....	<b>Better</b>
Test Type.....	<b>Z-Test (Unpooled)</b>
Power.....	<b>0.90</b>
Alpha.....	<b>0.025</b>
Group Allocation .....	<b>Equal (N1 = N2)</b>
Input Type.....	<b>Differences</b>
D0 (Non-Inferiority Difference).....	<b>-0.2</b>
D1 (Actual Difference) .....	<b>-0.05 to 0.05 by 0.01</b>
P2 (Group 2 Group Proportion) .....	<b>0.70</b>



## Non-Inferiority Tests for the Difference Between Two Proportions

## Output

Click the Calculate button to perform the calculations and generate the following output.

## Numeric Results

## Numeric Results for Non-Inferiority Tests for the Difference Between Two Proportions

Test Statistic: Z-Test with Unpooled Variance

H0:  $P_1 - P_2 \leq D_0$  vs. H1:  $P_1 - P_2 = D_1 > D_0$ .

Target Power	Actual Power*	N1	N2	N	Ref. P2	P1 H0 P1.0	P1 H1 P1.1	NI Diff D0	Diff D1	Alpha
0.90	0.90096	205	205	410	0.7000	0.5000	0.6500	-0.2000	-0.0500	0.0250
0.90	0.90111	179	179	358	0.7000	0.5000	0.6600	-0.2000	-0.0400	0.0250
0.90	0.90047	157	157	314	0.7000	0.5000	0.6700	-0.2000	-0.0300	0.0250
0.90	0.90067	139	139	278	0.7000	0.5000	0.6800	-0.2000	-0.0200	0.0250
0.90	0.90142	124	124	248	0.7000	0.5000	0.6900	-0.2000	-0.0100	0.0250
0.90	0.90172	111	111	222	0.7000	0.5000	0.7000	-0.2000	0.0000	0.0250
0.90	0.90257	100	100	200	0.7000	0.5000	0.7100	-0.2000	0.0100	0.0250
0.90	0.90203	90	90	180	0.7000	0.5000	0.7200	-0.2000	0.0200	0.0250
0.90	0.90049	81	81	162	0.7000	0.5000	0.7300	-0.2000	0.0300	0.0250
0.90	0.90228	74	74	148	0.7000	0.5000	0.7400	-0.2000	0.0400	0.0250
0.90	0.90073	67	67	134	0.7000	0.5000	0.7500	-0.2000	0.0500	0.0250

\* Power was computed using the normal approximation method.

The sample sizes from **PASS** match Table XIII of Julius and Campbell (2012) exactly.

We should point out that the values reported in Table XIII for  $P_1 - P_2 = -0.04$  where  $|D_0| = 0.05$  (45845, 41537, 36178, etc.) are incorrect for all  $P_1$  given. If you calculate the table values using formula (30) of Julius and Campbell (2012) or using **PASS**, you'll find that each sample size in the table is 200 more than the correct value. All other values in Table XIII are correct.