Chapter 556

Kruskal-Wallis Tests (Simulation)

Introduction

This procedure analyzes the power and significance level of the Kruskal-Wallis Test which is used to test statistical hypotheses in a one-way experimental design. For each scenario that is set up, two simulation studies are run. One simulation estimates the significance level and the other estimates the power.

Technical Details

Computer simulation allows us to estimate the power and significance level that is actually achieved by a test procedure in situations that are not mathematically tractable. Computer simulation was once limited to mainframe computers. But, in recent years, as computer speeds have increased, simulation studies can be completed on desktop and laptop computers in a reasonable period of time.

The steps to a simulation study are

1. Specify how the test is carried out. This includes indicating how the test statistic is calculated and how the significance level is specified.

2. Generate random samples from the distributions specified by the <u>alternative</u> hypothesis. Calculate the test statistics from the simulated data and determine if the null hypothesis is accepted or rejected. Tabulate the number of rejections and use this to calculate the test's power.

3. Generate random samples from the distributions specified by the <u>null</u> hypothesis. Calculate each test statistic from the simulated data and determine if the null hypothesis is accepted or rejected. Tabulate the number of rejections and use this to calculate the test's significance level.

4. Repeat steps 2 and 3 several thousand times, tabulating the number of times the simulated data leads to a rejection of the null hypothesis. The power is the proportion of simulated samples in step 2 that lead to rejection. The significance level is the proportion of simulated samples in step 3 that lead to rejection.

Generating Random Distributions

Two methods are available in PASS to simulate random samples. The first method generates the random variates directly, one value at a time. The second method generates a large pool (over 10,000) of random values and then draws the random numbers from this pool. This second method can cut the running time of the simulation by 70%.

The second method begins by generating a large pool of random numbers from the specified distributions. Each of these pools is evaluated to determine if its mean is within a small relative tolerance (0.0001) of the target mean. If the actual mean is not within the tolerance of the target mean, individual members of the population are replaced with new random numbers if the new random number moves the mean towards its target. Only a few hundred such swaps are required to bring the actual mean to within tolerance of the target mean. This population is then sampled

with replacement using the uniform distribution. We have found that this method works well as long as the size of the pool is at least the maximum of twice the number of simulated samples desired and 10,000.

Kruskal-Wallis One-Way ANOVA on Ranks

This section summarizes the Kruskal-Wallis rank-sum test. See Conover (1999) and Gibbons and Chakraborti (2011) for more details.

Assumptions

1. A simple random sample is available from each group. This implies that the individual subjects with the sample are independent.

2. There is mutual independence between samples.

3. The measurement scale is at least ordinal (the data can be ranked).

4. The g distributions are identical, or, some groups tend to produce larger values than others.

Test Statistic

Suppose that X_{kj} represents the (at least ordinal) data value of the jth subject in the kth group. Let r_{kj} represent the rank of X_{kj} when the N values are ranked without regard to their group. Let n_1, n_2, ..., n_g denote the number of subjects in each group and let N denote the total sample size of all groups.

The formula for the Kruskal-Wallis test is

$$T = \frac{\frac{12}{N^2 + N}\Sigma_{k=1}^{g}\frac{R_k^2}{n_k} - 3(N+1)}{\left[1 - \frac{\Sigma_{i=1}^{G}\left(t_i^3 - t_i\right)}{N^3 - N}\right]}$$

where R_k is the sum of the ranks of the data k^{th} group ($R_k = \Sigma_{j=1}^{n_k} r_{kj}$), G is the number sets of tied ranks, and t_i is the number of tied values within set i.

Distribution of *T*

If these assumptions are met, the distribution of T follows the *Chi-square* distribution with g-1 degrees of freedom. These results can be used to form an approximate statistical test of the null hypothesis that the distributions of all groups are equal versus the alternative hypothesis that at least one group tends to produce larger values than the others.

Procedure Options

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

Design Tab

The Design tab contains the parameters and options needed to described the experimental design, the data distributions, the error rates, and sample sizes.

Solve For

This option specifies the parameter to be calculated using the values of the other parameters.

Select *Power* when you want to determine the power based on the values of the other parameters.

Select *Sample Size* when you want to determine the sample size needed to achieve a given power and alpha error level. This option is very computationally intensive, so it may take a long time (several hours) to complete.

Power, Alpha, and Simulations

Power (Only shown when *Solve For* is set to *Sample Size*)

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. In this procedure, a type-II error occurs when you fail to reject the null hypothesis of equal means when in fact the means are different.

Power values must be between zero and one. Historically, 0.80 was used for power. Now, 0.90 is also commonly used.

You may enter a single value or a range of values such as *0.8 to 0.95 by 0.05*.

Alpha

This option specifies one or more values for the probability of a type-I error, alpha. A type-I error occurs when a true null hypothesis is rejected. In this procedure, a type-I error occurs when you reject the null hypothesis of equal means when in fact the means are equal.

Alpha values must be between zero and one. Historically, 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.

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

Simulations

This option specifies the number of simulations, *M*. The larger the number of simulations, the longer the running time and the more accurate the results.

The precision of the simulated power estimates are calculated from the binomial distribution. Thus, confidence intervals may be constructed for various power values using the binomial distribution. The following table gives an estimate of the precision that is achieved for various simulation sizes when the power is either 0.50 or 0.95. The table values are interpreted as follows: a 95% confidence interval of the true power is given by the power reported by the simulation plus and minus the 'Precision' amount given in the table.

Simulation Size M	Precision when Power = 0.50	Precision when Power = 0.95
100	0.100	0.044
500	0.045	0.019
1000	0.032	0.014
2000	0.022	0.010
5000	0.014	0.006
10000	0.010	0.004
50000	0.004	0.002
100000	0.003	0.001

Notice that a simulation size of 1000 gives a precision of plus or minus 0.01 when the true power is 0.95. Also note that as the simulation size is increased beyond 5000, there is only a small amount of additional accuracy achieved.

Number of Groups and Sample Size Allocation

Number of Groups

Enter the number of groups in the design. The program can handle between 2 and 20 groups.

Group Allocation (If *Solve For* is set to *Power*)

Select the method used to allocate subjects to groups. The choices are

- **Equal (n = n1 = n2 = ...)**

  All group sample sizes are the same. The value(s) of n are entered in the *n (Group Size)* box that will appear immediately below this box. See also *n (Group Size)* below.

- **Enter base group size and group multipliers**

  The group sample sizes are found by multiplying the corresponding *Multiplier* value (found in the Power Simulation section) times the *Base Group Size* that will appear immediately below this box. See also *Base Group Size* and *Multiplier* below.

- **Enter total sample size and group percentages**

  The group sample sizes are found by taking the corresponding percentage (found in the Power Simulation section) of the *N (Total Size)* value that will appear immediately below this box. See also *N (Total Size)* and *Percent of N* below.

  Note that the *Percent of N* values are adjusted so they sum to 100%.

- **Enter individual group sample sizes**

  Enter each group's sample size directly in the corresponding *Sample Size* box in the Power Simulation section. See also *Sample Size* below.

Group Allocation (If *Solve For* is set to *Sample Size*)

Select the method used to allocate subjects to groups. The choices are

- **Equal (n1 = n2 = ...)**

  All group sample sizes are the same. This sample size itself will be searched for.

- **Enter group multipliers**

  The group sample sizes are found by multiplying the corresponding *Multiplier* value (found in the Power Simulation section) times the *Base Group Size* that is being searched for.

n (Group Size)

This is the group sample size of all groups. One or more values, separated by blanks or commas, may be entered. A separate analysis is performed for each value listed here.

Base Group Size

This is the base sample size per group. One or more values, separated by blanks or commas, may be entered. A separate analysis is performed for each value listed here.

The individual group samples sizes are determined by multiplying this value times the corresponding *Multiplier* value entered in the Power Simulation section.

If the Multiplier numbers are represented by

m1, m2, m3, ...

and this value is represented by n, the group sample sizes are calculated as follows:

n1 = [n(m1)]

n2 = [n(m2)]

n3 = [n(m3)]

where the operator, [X] means the next integer after X, e.g. [3.1]=4.

For example, suppose there are three groups and the multipliers are set to 1, 2, and 3. If *n* is 5, the resulting group sample sizes will be 5, 10, and 15.

N (Total Size)

This is the total sample size. One or more values, separated by blanks or commas, may be entered. A separate analysis is performed for each value listed here.

The individual group samples sizes are determined by multiplying this value times the corresponding *Percent of N* value entered in the Power Simulation section.

If the Percent values are represented by

p1, p2, p3, ...

and this value is represented by N, the group sample sizes are calculated as follows:

n1 = [N(p1)]

n2 = [N(p2)]

n3 = [N(p3)]

where the operator, [X] means the next integer after X, e.g. [3.1]=4.

For example, suppose there are three groups and the percentages are set to 25, 25, and 50. If N is 36, the resulting group sample sizes will be 9, 9, and 18.

Power Simulation

These options specify the distributions to be used in the power simulation, one row per group. The first option specifies distribution. The second option, if visible, specifies the sample size of that group.

Distribution

Specify the distribution of each group under the alternative hypothesis, H1. This distribution is used in the simulation that determines the power.

A fundamental quantity in a power analysis is the amount of variation among the group means. In fact, in classical power analysis formulas, this variation is summarized as the standard deviation of the means. You must pay particular attention to the values you give to the means of these distributions because they are fundamental to the interpretation of the simulation.

For convenience in specifying a range of values, the parameters of the distribution can be specified using numbers or letters. If letters are used, their values are specified in the *Parameter Values* boxes below.

Following is a list of the distributions that are available and the syntax used to specify them. Each of the parameters should be replaced with a number or parameter name.

Distributions with Common Parameters

Beta(Shape1, Shape2, Min, Max)

Binomial(P,N)

Cauchy(Mean,Scale)

Constant(Value)

Exponential(Mean)

Gamma(Shape,Scale)

Gumbel(Location,Scale)

Laplace(Location,Scale)

Logistic(Location,Scale)

Lognormal(Mu,Sigma)

Multinomial(P1,P2,P3,...,Pk)

Normal(Mean,Sigma)

Poisson(Mean)

TukeyGH(Mu,S,G,H)

Uniform(Min, Max)

Weibull(Shape,Scale)

Distributions with Mean and SD Parameters

BetaMS(Mean,SD,Min,Max)

BinomialMS(Mean,N)

GammaMS(Mean,SD)

GumbelMS(Mean,SD)

LaplaceMS(Mean,SD)

LogisticMS(Mean,SD)

LognormalMS(Mean,SD)

UniformMS(Mean,SD)

WeibullMS(Mean,SD)

Details of writing mixture distributions, combined distributions, and compound distributions are found in the chapter on *Data Simulation* and will not be repeated here.

Finding the Value of the Mean of a Specified Distribution

The mean of a distribution created as a linear combination of other distributions is found by applying the linear combination to the individual means. However, the mean of a distribution created by multiplying or dividing other distributions is not necessarily equal to applying the same function to the individual means. For example, the mean of 4 Normal(4, 5) + 2 Normal(5, 6) is 4*4 + 2*5 = 26, but the mean of 4 Normal(4, 5) * 2 Normal(5, 6) is not exactly 4*4*2*5 = 160 (although it is close).

Multiplier

The group allocation *Multiplier* for this group is entered here. Typical values of this parameter are 0.5, 1, and 2.

- **Solve For = Power**

  The group sample size is found by multiplying this value times the *Base Group Size* value and rounding up to the next whole number.

- **Solve For = Sample Size**

  The group sample size is found by multiplying this value times the *base group size* that is being searched for and rounding up to the next whole number.

Percent of N

This is the percentage of the total sample size that is allocated to this group. The individual group samples sizes are determined by multiplying this value times the *N (Total Size)* value entered above.

If these values are represented by *p1, p2, p3, ...* the group sample sizes are calculated as follows:

$n1 = [N(p1)]$

$n2 = [N(p2)]$

$n3 = [N(p3)]$

where the operator, $[X]$ means the next integer after X, e.g. $[3.1]=4$.

For example, suppose there are three groups and these percentages are set to 25, 25, and 50. If N is 36, the resulting group sample sizes will be 9, 9, and 18.

Sample Size

This option allows you to enter the sample size of this group directly.

Power Simulation – Parameter Values for Group Distributions

These options specify the names and values for the parameters used in the distributions.

Name

Up to six sets of named parameter values may be used in the simulation distributions. This option lets you select an appropriate name for each set of values. Possible names are

- **M1 to M5**

  You might use M1 to M5 for means.

- **SD**

  You might use SD for standard deviations.

- **A to T**

  You might use these letters for location, shape, and scale parameters.

Value(s)

These values are substituted for the *Parameter Name* (M1, M2, SD, A, B, C, etc.) in the simulation distributions. If more than one value is entered, a separate calculation is made for each value.

You can enter a single value such as "2" or a series of values such as "0 2 3" or "0 to 3 by 1".

Alpha Simulation

These options specify the distributions to be used in the alpha simulation, one row per group. The alpha simulation generates an estimate of the actual alpha value that will be achieved by the test procedure. The magnitude of the differences of the means of these distributions, which is often summarized as the standard deviation of the means, represents the magnitude of the mean differences specified under H0. Usually, the means are assumed to be equal under H0, so their standard deviation should be zero except for rounding.

Specify Alpha Distributions

This option lets you choose how you will specify the alpha distributions. Possible choices are

- **All equal to the group 1 distribution of the power simulation**

  Often, the first group will represent a neutral group such as the control group. This option indicates that the first group of the power distributions should be used for all of the alpha simulation groups. Typically, this is what you want since the null hypothesis assumes that all distributions are the same.

- **All equal to a custom distribution**

  Set all group distributions in the alpha simulation equal to the custom alpha distribution specified below.

- **Enter each distribution separately**

  Each group's simulation distribution is entered individually below.

Custom Alpha Distribution

Specify the alpha distribution to be used for all groups. The syntax is the same as that for the Power Simulation Distribution (see above) and will not be repeated here.

Individual Alpha Distributions

Specify a separate distribution for each group. The syntax is the same as that for the Power Simulation Distribution (see above) and will not be repeated here.

Keep in mind that the null hypothesis assumes that all distributions are the same.

Simulations Tab

The option on this tab controls the generation of the random numbers. For complicated distributions, a large pool of random numbers from the specified distributions is generated. Each of these pools is evaluated to determine if its mean is within a small relative tolerance (0.0001) of the target mean. If the actual mean is not within the tolerance of the target mean, individual members of the population are replaced with new random numbers if the new random number moves the mean towards its target. Only a few hundred such swaps are required to bring the actual mean to within tolerance of the target mean. This population is then sampled with replacement using the uniform distribution. We have found that this method works well as long as the size of the pool is at least the maximum of twice the number of simulated samples desired and 10,000.

Random Number Pool Size

This is the size of the pool of values from which the random samples will be drawn. Pools should be at least the minimum of 10,000 and twice the number of simulations. You can enter *Automatic* and an appropriate value will be calculated.

If you do not want to draw numbers from a pool, enter 0 here.

Example 1 – Power at Various Sample Sizes

For this first example we repeat Example 1 of the regular One-Way ANOVA procedure. This will allow you to compare the values obtained by simulation with the actual values obtained from the theoretical results.

An experiment is being designed to compare the means of four groups using an *F* test with a significance level of 0.05. Previous studies have shown that the standard deviation within a group is 18. Treatment means of 40, 10, 10, and 10 represent clinically important treatment differences. To better understand the relationship between power and sample size, the researcher wants to compute the power for group sample sizes of 4, 8, and 12. The group sample sizes are equal.

Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Kruskal-Wallis Tests (Simulation)** procedure window by expanding **Means**, then **One-Way Designs (ANOVA)**, then clicking on **Nonparametric**, and then clicking on the **Kruskal-Wallis Tests (Simulation)**. 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**.

Option	Value
Design Tab	
Solve For	**Power**
Simulations	**5000**
Alpha..	**0.05**
Number of Groups	**4**
Group Allocation	**Equal**
n (Group Size)	**4 8 12**
Group 1 Distribution..............................	**Normal(M1 SD)**
Group 2 Distribution..............................	**Normal(M2 SD)**
Group 3 Distribution..............................	**Normal(M2 SD)**
Group 4 Distribution..............................	**Normal(M2 SD)**
M1	**40**
M2	**10**
SD	**18**
Specify Alpha Distributions....................	**All equal to the group 1 distribution of the power simulation**

Annotated Output

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

Numeric Results Report

Simulation Summary

Group	Power Distribution	Alpha Distribution
1	Normal(M1 SD)	Normal(M1 SD)
2	Normal(M2 SD)	Normal(M1 SD)
3	Normal(M2 SD)	Normal(M1 SD)
4	Normal(M2 SD)	Normal(M1 SD)

Number of Groups	4
Random Number Pool Size	10000
Number of Simulations Per Run	5000

Numeric Results

Row	Power	Mean Group Sample Size n	Total Sample Size N	Target Alpha	Actual Alpha	Std Dev of H1 μ's	Mean of H1 σ's	M1	M2	SD
1	0.383	4.0	16	0.050	0.034	13.0	17.9	40.0	10.0	18.0
2	0.863	8.0	32	0.050	0.042	13.0	18.0	40.0	10.0	18.0
3	0.982	12.0	48	0.050	0.038	13.0	18.1	40.0	10.0	18.0

Run Time: 2.12 seconds.

Definitions of the Numeric Results Report
Row identifies this line of the report. It will be used cross-reference this line in other reports.
μ is the mean of a group.
σ is the within-group standard deviation.
H0 is the null hypothesis that all μ's are equal.
H1 is the alternative hypothesis that at least one μ is different from the others.
Power is the probability of rejecting H0 when it is false. This is the actual value calculated by the power
    simulation.
Mean Group Sample Size, n, is the average of the individual group sample sizes.
Total Sample Size, N, is the total sample size found by summing all group sample sizes.
Target Alpha is the planned probability of rejecting a true H0. This is the planned Type-1 error rate.
Actual Alpha is the alpha achieved by the test as calculated by the alpha simulation. Note that the alpha
    simulation is separate from the power simulation.
Std Dev of H1 μ's is the standard deviation of the group μ's used in the power simulation. This measures the
    magnitude of the difference among the μ's.
Mean of H1 σ's is the mean of the group σ's used in the power simulation. This measures the magnitude of the
    σ's.

Summary Statements
A one-way design with 4 groups has sample sizes of 4, 4, 4, and 4. The null hypothesis is that
the standard deviation of the group means is 0.0 and the alternative standard deviation of the
group means is 13.0. The total sample of 16 subjects achieves a power of 0.383 using the
Kruskal Wallis Test with a target significance level of 0.050 and an actual significance level
of 0.034. The average within group standard deviation assuming the alternative distribution is
17.9. These results are based on 5000 Monte Carlo samples from the null distributions:
Normal(M1 SD); Normal(M1 SD); Normal(M1 SD); and Normal(M1 SD) and the alternative
distributions: Normal(M1 SD); Normal(M2 SD); Normal(M2 SD); and Normal(M2 SD). Other parameters
used in the simulation were: M1 = 40.0, M2 = 10.0, and SD = 18.0.

These reports show the output for this run. We will annotate the Numeric Results report.

Power

This is the probability of rejecting a false null hypothesis. This value is estimated by the power simulation. The
Power and Alpha Confidence Interval report displayed next will provide estimates of the precision of these power
values.

Kruskal-Wallis Tests (Simulation)

Mean Group Size n

This is the average of the group sample sizes.

Total Sample Size N

This is the total sample size of the study.

Target Alpha

The target value of alpha: the probability of rejecting a true null hypothesis. This is often called the significance level.

Actual Alpha

This is the value of alpha estimated by the alpha simulation. It should be compared with the Target Alpha. The Power and Alpha Confidence Interval report displayed next will provide estimates of the precision of these Actual Alpha values.

Std Dev of H1 µ's

This is the standard deviation of the hypothesized means of the power (H1) simulation distributions, $\sigma_m|H1$. Under H0, this value is zero. So this value represents the magnitude of the difference among the means that is being tested.

Note that a popular definition of effect size is the ratio of $\sigma_m|H1$ and $\sigma|H1$.

Mean of H1 σ's

This is the mean of the group standard deviations calculated from the power simulation distributions, $\sigma|H1$.

M1

These are the values entered for M1, the group 1 mean in the power simulation.

M2

These are the values entered for M2, the groups 2, 3, and 4 means in the power simulation.

SD

These are the values entered for SD, the standard deviation.

Power and Alpha Confidence Intervals from Simulations

Row	Total Sample Size N	Power	Lower Limit of 95% C.I. of Power	Upper Limit of 95% C.I. of Power	Target Alpha	Actual Alpha	Lower Limit of 95% C.I. of Alpha	Upper Limit of 95% C.I. of Alpha	M1	M2	SD
1	16	0.383	0.370	0.397	0.050	0.034	0.029	0.039	40.0	10.0	18.0
2	32	0.863	0.853	0.873	0.050	0.042	0.037	0.048	40.0	10.0	18.0
3	48	0.982	0.979	0.986	0.050	0.038	0.033	0.043	40.0	10.0	18.0

Definitions of the Power and Alpha Confidence Intervals Report
Total Sample Size, N, is the total sample size found by summing all group sample sizes.
Power is the probability of rejecting H0 when it is false. This is the actual value calculated by the power simulation.
Lower and Upper Limits of a 95% C.I. for Power are the limits of an exact, 95% confidence interval for power based on the binomial distribution. They are calculated from the power simulation.
Target Alpha is the desired probability of rejecting a true null hypothesis at which the tests were run.
Actual Alpha is the alpha achieved by the test as calculated by the alpha simulation.
Lower and Upper Limits of a 95% C.I. for Alpha are the limits of an exact, 95% confidence interval for alpha based on the binomial distribution. They are calculated from the alpha simulation

Total Sample Size N

This is the total sample size of the study.

Lower/Upper Limit of 95% C.I. for Power

These are the limits of an exact, 95% confidence interval for power using the power simulation. The confidence interval is based on the binomial distribution. The width of this confidence interval is directly related to the number of simulations that were used.

Lower/Upper Limit of 95% C.I. for Alpha

These are the limits of an exact, 95% confidence interval for alpha using the alpha simulation. The confidence interval is based on the binomial distribution. The width of this confidence interval is directly related to the number of simulations that were used. Since the target alpha is 0.05, 0.05 should be within these limits.

Detailed Results Reports

Details for Row 1 of the Numeric Results Report

Group	ni	Pct of N	H0 μ	H1 μ	H0 σ	H1 σ
1	4	25.0	40.0	40.0	17.9	18.0
2	4	25.0	40.0	10.0	18.0	17.7
3	4	25.0	40.0	10.0	18.2	18.0
4	4	25.0	40.0	10.0	18.0	17.8
			Std Dev	**Std Dev**	**Mean**	**Mean**
Group	**N**		**of H0 μ's**	**of H1 μ's**	**of H0 σ's**	**of H1 σ's**
All	16	100.0	0.0	13.0	18.0	17.9

Details for Row 2 of the Numeric Results Report

Group	ni	Pct of N	H0 μ	H1 μ	H0 σ	H1 σ
1	8	25.0	40.0	40.0	18.4	17.9
2	8	25.0	40.0	10.0	17.8	18.2
3	8	25.0	40.0	10.0	17.8	18.0
4	8	25.0	40.0	10.0	18.0	18.1
			Std Dev	**Std Dev**	**Mean**	**Mean**
Group	**N**		**of H0 μ's**	**of H1 μ's**	**of H0 σ's**	**of H1 σ's**
All	32	100.0	0.0	13.0	18.0	18.0

Details for Row 3 of the Numeric Results Report

Group	ni	Pct of N	H0 μ	H1 μ	H0 σ	H1 σ
1	12	25.0	40.0	40.0	18.1	18.0
2	12	25.0	40.0	10.0	17.9	18.0
3	12	25.0	40.0	10.0	18.0	18.0
4	12	25.0	40.0	10.0	18.1	18.2
			Std Dev	**Std Dev**	**Mean**	**Mean**
Group	**N**		**of H0 μ's**	**of H1 μ's**	**of H0 σ's**	**of H1 σ's**
All	48	100.0	0.0	13.0	18.0	18.1

These reports show the details of each scenario.

Row (in Title)

This is the row number of the Numeric Results report about which this report gives the details.

Group

This is the number of the group shown on this line.

ni

This is the sample size of each group. This column is especially useful when the sample sizes are unequal.

Percent of N

This is the percentage of the total sample that is allocated to each group.

H0 μ and H1 μ

These are the means that were used in the alpha and power simulations, respectively.

H0 σ and H1 σ

These are the standard deviations that were obtained by the alpha and power simulations, respectively. Note that they often are not exactly equal to what was specified because of the error introduced by simulation.

Std Dev of H0 (and H1) μ's

These are the standard deviations of the means that were obtained by the alpha and power simulations, respectively. Under H0, this value should be near zero. The H0 value lets you determine if your alpha simulation was correctly specified. The H1 value represents the magnitude of the effect size (when divided by an appropriate measure of the standard deviation).

Mean of H0 (and H1) σ's

These are the average of the individual group standard deviations that were obtained by the alpha and power simulations, respectively.

Plots Section
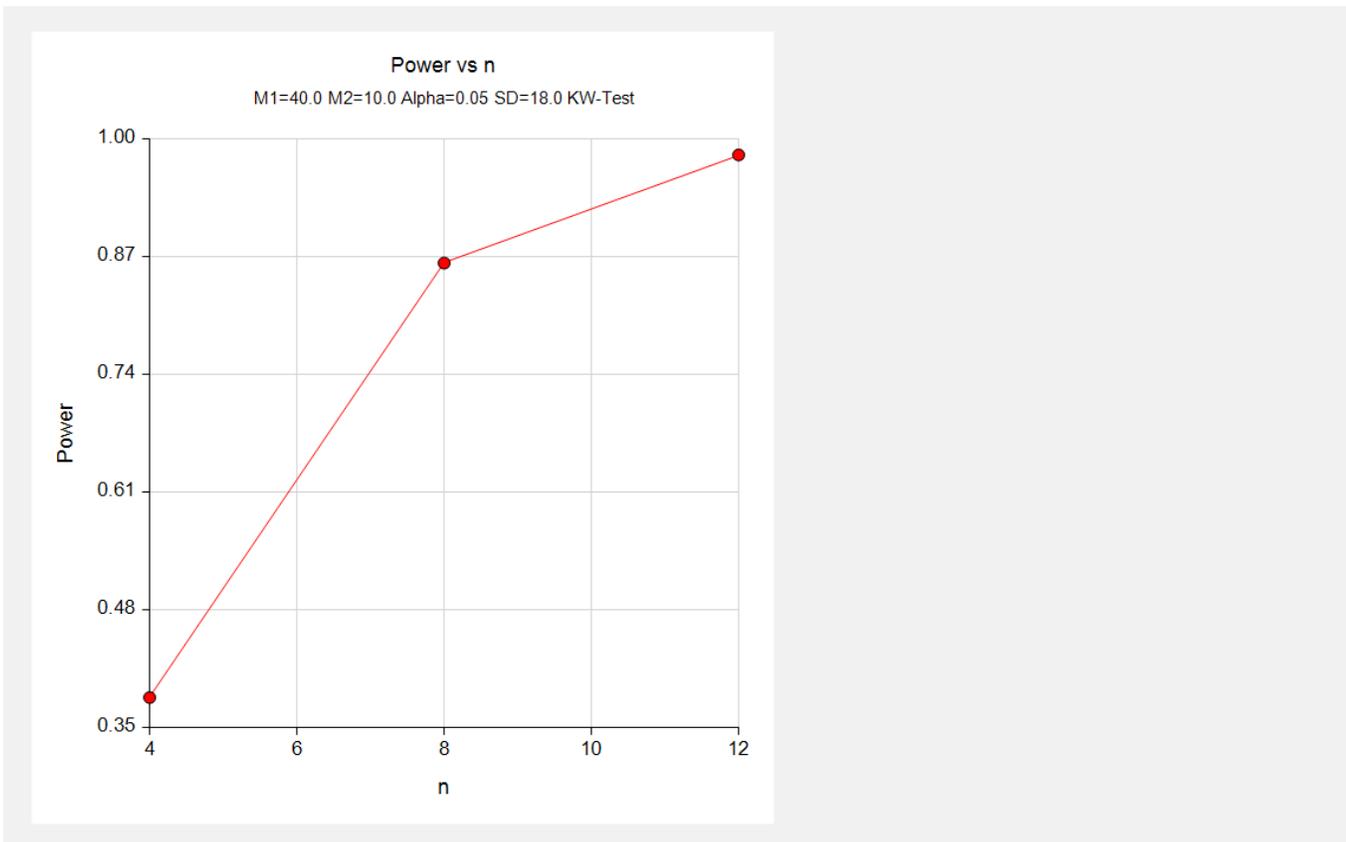
This plot gives a visual presentation to the results in the Numeric Report. We can quickly see the impact on the power of increasing the sample size.

Example 2 – Validation using Fleiss

Fleiss (1986) page 374 presents an example of determining an appropriate sample size when using an F-test in an experiment with 4 groups; means of 9.775, 12, 12, and 14.225; standard deviation of 3; alpha of 0.05, and beta of 0.20. He finds a sample size of 11 per group when using the F-Test. We anticipate that a slightly larger value will be needed for the Kruskal-Wallis 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 **Kruskal-Wallis Tests (Simulation)** procedure window by expanding **Means**, then **One-Way Designs (ANOVA)**, then clicking on **Nonparametric**, and then clicking on the **Kruskal-Wallis Tests (Simulation)**. 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**.

Option   **Value**

Design Tab
Solve For .... **Power**
Simulations **5000**
Alpha.. **0.05**
Number of Groups **4**
Group Allocation .... **Equal**
n (Group Size) **4 8 12**
Group 1 Distribution............................... **Normal(M1 SD)**
Group 2 Distribution............................... **Normal(M2 SD)**
Group 3 Distribution............................... **Normal(M3 SD)**
Group 4 Distribution............................... **Normal(M4 SD)**
M1 .... **9.775**
M2 .... **12**
M3 .... **12**
M4 .... **14.225**
SD **3**
Specify Alpha Distributions..................... **All equal to the group 1 distribution of the power simulation**

Reports Tab
Show Numeric Reports............................ **Checked**
Show Detail Reports................................ **Checked**
All other reports .... **Unchecked**

Plots Tab
All plots .... **Unchecked**

Output

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

Numeric Results

Row	Target Power	Actual Power	Mean Group Sample Size n	Total Sample Size, N	Target Alpha	Actual Alpha	Std Dev of H1 μ's	Mean of H1 σ's	M1	M2	M3	M4	SD
1	0.800	0.801	12.0	48	0.050	0.039	1.6	3.0	9.8	12.0	12.0	14.2	3.0

Note that PASS has also found the group sample size to be 12.