

Chapter 392

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Introduction

This module calculates the power for simultaneously testing the differences among the slopes of two or more groups of continuous, correlated data that are analyzed using the GEE method. Such data can occur in both clustered and longitudinal designs. The slopes are measured across repeated measurements of a specific subject.

GEE is different from mixed models in that it does not require the full specification of the joint distribution of the repeated measurements, as long as the marginal mean model is correctly specified. Estimation consistency is achieved even if the correlation matrix is incorrect. Also, the correlation matrix of the responses is specified directly, rather than using an intermediate, random effects model as is the case in MM. For clustered designs, GEE often uses a *compound symmetric* (CS) correlation structure. For longitudinal data, an *autoregressive* (AR(1)) correlation structure is often used.

Missing Values

This procedure allows you to specify various patterns of incomplete (or missing) data. Subjects may miss some appointments but attend others. This phenomenon of incomplete data can be accounted for in the sample size calculation which can greatly reduce the overall sample size from that calculated by just omitting subjects with incomplete observations.

Technical Details

Theory and Notation

Technical details are given in Ahn, Heo, and Zhang (2015), chapter 4, section 4.3.5, pages 100-105 and in Jung and Ahn (2004).

Suppose we have n_k ($k = 1, \dots, G$) subjects in each of G groups for a total of N subjects, each measured on M occasions at times t_j ($j = 1, \dots, M$). For convenience, we normalize these time points to the proportion of total time so that $t_1 = 0$ and $t_M = 1$.

For each group k , the time-specific mean of y_{kij} is fit using GEE by

$$y_{kij} = \mu_{kij} + \epsilon_{kij} \text{ and } \mu_{kij} = \theta_k + \beta_k t_j$$

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where

y_{kij} is the j^{th} response from subject i in group k at time t_j , with variance given by σ^2 ,

r_k is the proportion of subjects in group k ,

μ_{kij} is group-specific treatment effect ($k = 1, \dots, G$) given by $\theta_k + \beta_k t_j$,

ϵ_{kij} is a zero-mean, random-effect error term with covariance $\sigma^2 \rho_{jj'}$,

θ_k is the intercept of group k ,

β_k is the slope of group k ,

t_j is j^{th} measurement time, scaled to go from 0 to 1.

Note that at the first scheduled time

$$\mu_{kij} = \theta_k$$

And at the last scheduled time

$$\mu_{kij} = \theta_k + \beta_k.$$

Also, since subjects are assigned randomly to the groups, it is reasonable to assume that the responses will all have the same mean at t_1 . Thus, it is likely that all intercepts will be equal.

The main focus of this design is to compare the average response of each group at the final time point, t_M . The difference between any two-group means will thus reduce to the difference between the corresponding group slopes. That is why this test is popular.

In this procedure, the primary interest is to test $H_0: \beta_1 = \dots = \beta_G$ against the alternative that at least one slope is different.

GEE is used to estimate and test hypotheses about these group slopes. H_0 is rejected with a type I error α if $\mathbf{B}'\mathbf{V}^{-1}\mathbf{B} > \chi_{G-1,1-\alpha}^2$ where $\chi_{G-1,1-\alpha}^2$ is the 100(1 - α)th percentile of a chi-square distribution with $G-1$ degrees of freedom. The slope deviation vector \mathbf{B} is given by

$$\mathbf{B} = \sqrt{N}(\hat{\beta}_1 - \hat{\beta}, \dots, \hat{\beta}_{G-1} - \hat{\beta})'$$

and \mathbf{V} is a consistent estimate of the variance matrix based on the residuals.

Correlation Patterns

In a longitudinal design with N subjects, each measured M times, observations from a single subject are correlated, and a pattern of those correlations through time needs to be specified. Several choices are available.

Compound Symmetry

A compound symmetry correlation model assumes that all correlations are equal. That is

$$[\rho_{jj'}] = \begin{bmatrix} 1 & \rho & \rho & \rho & \cdots & \rho \\ \rho & 1 & \rho & \rho & \cdots & \rho \\ \rho & \rho & 1 & \rho & \cdots & \rho \\ \rho & \rho & \rho & 1 & \cdots & \rho \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho & \rho & \rho & \rho & \cdots & 1 \end{bmatrix}_{M \times M}$$

where ρ is the baseline correlation.

Banded(1)

A Banded(1) (banded order 1) correlation model assumes that correlations for observations one time period apart are equal to ρ , and correlations for measurements greater than one time period apart are equal to zero. That is

$$[\rho_{jj'}] = \begin{bmatrix} 1 & \rho & 0 & 0 & \cdots & 0 \\ \rho & 1 & \rho & 0 & \cdots & 0 \\ 0 & \rho & 1 & \rho & \cdots & 0 \\ 0 & 0 & \rho & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 1 \end{bmatrix}_{M \times M}$$

where ρ is the baseline correlation.

Banded(2)

A Banded(2) (banded order 2) correlation model assumes that correlations for observations one time period or two periods apart are equal to ρ , and correlations for measurements greater than one time period apart are equal to zero. That is

$$[\rho_{jj'}] = \begin{bmatrix} 1 & \rho & \rho & 0 & \cdots & 0 \\ \rho & 1 & \rho & \rho & \cdots & 0 \\ \rho & \rho & 1 & \rho & \cdots & 0 \\ 0 & \rho & \rho & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 1 \end{bmatrix}_{M \times M}$$

where ρ is the baseline correlation.

AR1 (Traditional)

This version of AR1 (autoregressive order 1) correlation model assumes that correlations t time periods apart are equal to ρ^t . That is

$$[\rho_{jj'}] = \begin{bmatrix} 1 & \rho & \rho^2 & \rho^3 & \dots & \rho^{M-1} \\ \rho & 1 & \rho & \rho^2 & \dots & \rho^{M-2} \\ \rho^2 & \rho & 1 & \rho & \dots & \rho^{M-3} \\ \rho^3 & \rho^2 & \rho & 1 & \dots & \rho^{M-4} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho^{M-1} & \rho^{M-2} & \rho^{M-3} & \rho^{M-4} & \dots & 1 \end{bmatrix}_{M \times M}$$

where ρ is the baseline correlation.

AR1 (Proportional)

This version of AR1 (autoregressive order 1) correlation model is described in the book by Ahn et al. (2015). It assumes that correlations $|t_j - t_k|$ time periods apart are equal to $\rho^{|t_j - t_k|}$. That is

$$[\rho_{jk}] = [\rho^{|t_j - t_k|}]_{M \times M}$$

where ρ is the baseline correlation. Note that in this pattern, the value of ρ is shown in the final column since in this case $t_j = 0$ and $t_k = 1$, so $|t_j - t_k| = 1$.

Damped Exponential

A damped exponential is an extension of the AR(1) correlation model in which the exponents are raised to the power $Dexp$ ($\theta = Dexp$ in the diagram below). This causes the resulting correlations to be reduced (dampened). Here is an example

$$[\rho_{jj'}] = \begin{bmatrix} 1 & \rho & \rho^{2\theta} & \rho^{3\theta} & \dots & \rho^{(M-1)\theta} \\ \rho & 1 & \rho & \rho^{2\theta} & \dots & \rho^{(M-2)\theta} \\ \rho^{2\theta} & \rho & 1 & \rho & \dots & \rho^{(M-3)\theta} \\ \rho^{3\theta} & \rho^{2\theta} & \rho & 1 & \dots & \rho^{(M-4)\theta} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho^{(M-1)\theta} & \rho^{(M-2)\theta} & \rho^{(M-3)\theta} & \rho^{(M-4)\theta} & \dots & 1 \end{bmatrix}_{M \times M}$$

where ρ is the baseline correlation.

Damped Exponential (Proportional)

This version of the damped exponential correlation model is described in the book by Ahn et al. (2015). It assumes that all variances on the diagonal are equal and that correlations $|t_j - t_k|$ time periods apart are equal to $\rho^{|t_j - t_k|^\theta}$. That is

$$[\rho_{jk}] = \left[\rho^{|t_j - t_k|^\theta} \right]_{M \times M}$$

where ρ is the baseline correlation. Note that in this pattern, the value of $\rho^{|t_j - t_k|^\theta}$ turns up in the final column since in this case $t_j = 0$ and $t_k = 1$, so $|t_j - t_k| = 1$.

Linear Exponential Decay

A linear exponential decay correlation model is one in which the exponent of the correlation decays according to a linear equation from 1 at the *Base Time Proportion* to a final value, *Emax*. The resulting pattern looks similar to the damped exponential. Note that the exponents are applied to the absolute difference between the Measurement Time Proportions. This method allows you to easily construct comparable correlation matrices of different dimensions. Otherwise, differences in the resulting power would be more strongly due to differences in the correlation matrices.

Here is an example. Suppose M is 6, $\rho = 0.5$, $Emax = 3$, the *Base Time Proportion* is 0.20, and the Measurement Time Proportions are (0, 0.2, 0.4, 0.6, 0.8, 1). The following correlation matrix would be obtained

$$[\rho_{jj'}] = \begin{bmatrix} 1 & 0.5 & 0.3536 & 0.25 & 0.1768 & 0.125 \\ 0.5 & 1 & 0.5 & 0.3536 & 0.25 & 0.1768 \\ 0.3536 & 0.5 & 1 & 0.5 & 0.3536 & 0.25 \\ 0.25 & 0.3536 & 0.5 & 1 & 0.5 & 0.3536 \\ 0.1768 & 0.25 & 0.3536 & 0.5 & 0.3536 & 0.5 \\ 0.125 & 0.1768 & 0.25 & 0.3536 & 0.5 & 1 \end{bmatrix}_{M \times M}$$

Note that in the top row, the correlation is 0.5 for the second (0.2 - 0) time point and 0.125 (0.5^3) at the last (1 - 0) time points. The correlations are obtained by raising 0.5 to the appropriate exponent. The linear equation from 1 to 3 results in the exponents 1, 1.5, 2, 2.5, 3 correspondent to the time proportions 0, 0.2, 0.4, 0.6, 0.8, and 1.

As a further example, note that the correlation for the 0.4 time point is, $0.5^{1.5} = 0.35355339 \approx 0.3536$.

This method allows you to compare various values of M while keeping the correlation matrix similar. To see what we mean, consider what the correlation matrix looks like when M is reduced to 4 and the measurement time proportions are set to (0, 0.2, 0.6, 1). It becomes

$$[\rho_{jj'}] = \begin{bmatrix} 1 & 0.5 & 0.25 & 0.125 \\ 0.5 & 1 & 0.5 & 0.25 \\ 0.25 & 0.5 & 1 & 0.5 \\ 0.125 & 0.25 & 0.5 & 1 \end{bmatrix}_{M \times M}$$

Note that the correlation at a measurement time difference of 0.6 is equal to 0.25 in both matrices.

Missing Data Patterns

The problem of missing data occurs for several reasons. In longitudinal studies in which a subject is measured multiple times, missing data becomes more complicated to model because it is possible that a subject is measured only some of the time. In fact, it is probably more common for data to be incomplete than complete. The approach of omitting subjects with incomplete data during the planning phase is very inaccurate. Certainly, subjects with partial measurements are included in the analysis. This procedure provides several missing data patterns to choose from so that your sample size calculations are more realistic.

In the presentation to following, we denote the percent of subjects with a missing response at time point t_j as κ_j . The proportion non-missing at a particular time point is $\phi_j = 1 - \kappa_j$. We will refer to ϕ_j as the *marginal observant probability* at time t_j and $\phi_{jj'}$ as a *joint observant probability* at times t_j and $t_{j'}$.

Pairwise Missing Pattern

The program provides three options for how the pairwise (joint) observant probabilities $\phi_{jj'}$ are calculated. These are

Independent (Ind): $\phi_{jj'} = \phi_j \phi_{j'}, \phi_{jj} = \phi_j$

Monotonic (Mon): $\phi_{jj'} = \phi_k$ where $k = \max(j, j')$

Mixture: $\phi_{jj'} = W(\text{Ind}) + (1 - W)(\text{Mon})$ for weighting factor W .

Missing Input Type

There are several ways in which the missing value pattern can be specified. Each missing value pattern is a list of missing proportions at each of the M time points. Each value in the list must be non-negative and less than 1. Possible input choices are

- **Constant = 0**
All missing proportions are set to 0. That is, there are no missing values.
- **Constant**
All missing proportions are set to constant value.
- **Piecewise Constant on Spreadsheet**
A set of missing proportions are defined for several time intervals using the spreadsheet. One column contains the missing proportions for the interval, going down the rows. Another column defines the corresponding upper limit of time proportion of the interval. The lower limit is implied by the limit given immediately above. The program assumes that the first-time interval starts at 0 percent.
- **Linear (Steady Change)**
The missing proportions fall along a straight-line between 0 and 1 elapsed time. Only the first and last proportions are entered.
- **Piecewise Linear on Spreadsheet**
The missing proportions fall along a set of connected straight-lines that are defined by two columns on the spreadsheet.

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- **List**

Enter a list of M missing proportions, one for each time point.

- **Multiple Lists on Spreadsheet**

Select multiple columns containing vertical lists of missing proportions. Each column contains a set of missing proportions in rows, one for each time point.

- **Pairwise Observed Proportions on Spreadsheet**

Enter an $M \times M$ matrix of observant probabilities by selecting M columns. These observant probabilities are the proportion of the responses for both the row and column time points that are observed.

Sample Size Calculations

The details of the calculation of sample size and power is given in Ahn, Heo, and Zhang (2015), Chapter 4 and Jung and Ahn (2004). These are summarized here.

As explained above, GEE is used to estimate the regression coefficients. Under the alternative hypothesis, as N approaches infinity, the test statistic $B'\hat{V}^{-1}B$ is approximately distributed as a noncentral chi-square random variable with $G - 1$ degrees of freedom and noncentrality parameter $U = N\boldsymbol{\eta}'\mathbf{V}^{-1}\boldsymbol{\eta}$

where

$$\boldsymbol{\eta}' = (\beta_1 - \bar{\beta}, \dots, \beta_{G-1} - \bar{\beta})$$

$$\bar{\beta} = \sum_{k=1}^G r_k \beta_k$$

$$\boldsymbol{\eta}'\mathbf{V}^{-1}\boldsymbol{\eta} = \frac{\bar{m}^2 \sigma_t^4}{\sigma^2 s_t^2} \left[\sum_{k=1}^{G-1} r_k \eta_k^2 + \frac{1}{r_G} \left(\sum_{k=1}^{G-1} r_k \eta_k \right)^2 \right]$$

$$\bar{m} = \sum_{j=1}^m \phi_j$$

$$\sigma_t^2 = \frac{1}{\bar{m}} \sum_{j=1}^m \phi_j (t_j - \bar{t})^2$$

$$\bar{t} = \frac{1}{\bar{m}} \sum_{j=1}^m \phi_j t_j$$

$$s_t^2 = \sum_{j=1}^m \sum_{j'=1}^m \phi_{jj'} \rho_{jj'} (t_j - \bar{t})(t_{j'} - \bar{t})$$

$\phi_j = 1 - \kappa_j$, where $\kappa_j =$ proportion missing at the j^{th} time point

$\rho_{jj'}$ is the corresponding element from within-subject correlation matrix

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$\phi_{jj'}$ is the joint observant probability of observing both y_{ij} and $y_{ij'}$ for every subject i

Three possible choices are available to calculate $\phi_{jj'}$. These are

Independent: $\phi_{jj'} = \phi_j \phi_{j'}$, $\phi_{jj} = \phi_j$

Monotonic: $\phi_{jj'} = \phi_k$ where $k = \max(j, j')$

Mixture: $\phi_{jj'} = w(\text{Independent}) + (1 - w)(\text{Monotonic})$ for weighting factor w .

This noncentral distribution can be used to calculate the power using the following

$$\text{Power} = Pr(\chi_{G-1}^{\prime 2}(U) > \chi_{G-1, 1-\alpha}^2)$$

Using this power function, the sample size can be determined using a simple binary search.

Example 1 – Determining Sample Size for a Three-Arm Trial

Researchers are planning a study comparing three heart-rate medications: a standard drug and two experimental drugs. The experimental drugs appear to have about the same impact on heart rate. Each subject will receive four applications of one drug, two days apart. The researchers want a sample size large enough to detect a slope difference of 5 between the highest and lowest slopes. They will use the slopes of 65, 60, and 60 to represent this difference.

Similar studies have had a standard deviation of the residuals within a subject across time of between 5 and 7. These studies also showed an autocorrelation between adjacent measurements on the same individual of 0.7, so they want to try values of 0.6, 0.7, and 0.8. The researchers assume that first-order autocorrelation adequately represents the autocorrelation pattern. The test will be conducted at the 0.05 significance level and powered at 90%. The subjects will be randomly assigned equally among the three groups.

The researchers anticipate that the missing pattern across time will begin at 0% missing and increase steadily to 40% at the fourth measurement. They assume that the pairwise missing is *independent*.

What are the sample size requirements for this study?

Setup

If the procedure window is not already open, use the PASS Home window to open it. The parameters for this example are listed below and are stored in the **Example 1** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Design Tab

Solve For	Sample Size
Power.....	0.90
Alpha.....	0.05
G (Number of Groups)	3
Group Allocation Input Type	Equal (n1 = n2 = ... = nG = n)
Measurement Time Input Type	Equally Spaced Measurement Times
M (Number of Measurement Times)	4
β 's Input Type	$\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means)
$\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means)	65 60 60
σ (Standard Deviation).....	5 6 7
Pattern of ρ 's Across Time.....	AR1 (Traditional)
ρ (Base Correlation).....	0.6 0.7 0.8
Missing Input Type.....	Linear (Steady Change)
Pairwise Missing Pattern.....	Independent (Ind)
First Missing Proportion (Ind).....	0
Last Missing Proportion (Ind)	0.4

Output

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

Numeric Reports

Numeric Results for a Multi-Group Slope Comparison Test using GEE

Solve For: Sample Size
 Measurement Times: Equally spaced
 Correlation: AR1: $\rho(j,k) = \rho^{|j-k|}$
 Missing Pattern: Range of missing proportions
 Observant Proportions: Assume independence
 Number of Groups: 3

Power	Total Sample Size N	Group Allocation Proportions ri	Number of Measurement Times M	Group Slopes β_i	Standard Deviation		Base Correlation ρ	First Row of Correlation Matrix	Missing Data Proportions	Measurement Times	Alpha
					Group Slopes σ_m	Responses σ					
0.9072	123	ri(1)	4	$\beta_i(1)$	0.75	5	0.6	$\rho_1(1)$	Ms1(1)	T(1)	0.05
0.9078	108	ri(1)	4	$\beta_i(1)$	0.75	5	0.7	$\rho_2(1)$	Ms1(1)	T(1)	0.05
0.9062	87	ri(1)	4	$\beta_i(1)$	0.75	5	0.8	$\rho_3(1)$	Ms1(1)	T(1)	0.05
0.9019	174	ri(1)	4	$\beta_i(1)$	0.75	6	0.6	$\rho_1(1)$	Ms1(1)	T(1)	0.05
0.9030	153	ri(1)	4	$\beta_i(1)$	0.75	6	0.7	$\rho_2(1)$	Ms1(1)	T(1)	0.05
0.9007	123	ri(1)	4	$\beta_i(1)$	0.75	6	0.8	$\rho_3(1)$	Ms1(1)	T(1)	0.05
0.9021	237	ri(1)	4	$\beta_i(1)$	0.75	7	0.6	$\rho_1(1)$	Ms1(1)	T(1)	0.05
0.9012	207	ri(1)	4	$\beta_i(1)$	0.75	7	0.7	$\rho_2(1)$	Ms1(1)	T(1)	0.05
0.9017	168	ri(1)	4	$\beta_i(1)$	0.75	7	0.8	$\rho_3(1)$	Ms1(1)	T(1)	0.05

Item	Values
ri(1)	0.333, 0.333, 0.333
$\beta_i(1)$	65, 60, 60
$\rho_1(1)$	1, 0.6, 0.36, 0.216
$\rho_2(1)$	1, 0.7, 0.49, 0.343
$\rho_3(1)$	1, 0.8, 0.64, 0.512
Ms1(1)	0, 0.13, 0.27, 0.4
T(1)	0, 0.33, 0.67, 1

- Power: The probability of rejecting a false null hypothesis when the alternative hypothesis is true.
- N: The total number of subjects in the study.
- ri: The Group Allocation Proportions gives the name of the set containing group allocation proportions.
- M: The number of time points at which each subject is scheduled to be measured.
- β_i : Gives the name of the set containing the slopes for each group.
- σ_m : Gives the standard deviation of group slopes.
- σ : The standard deviation of a response.
- ρ : The base correlation between two responses on the same subject. It may be transformed based on the correlation pattern.
- First Row of Correlation Matrix: Presents the top row of the correlation matrix.
- Missing Data Proportions: Gives the name of the set containing the individual missing value proportions for each time period.
- Measurement Times: The Measurement Times gives the name of the set containing the time proportions. The values represent the proportion of the total study time that has elapsed just before the measurement.
- Alpha: The probability of rejecting a true null hypothesis.

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Summary Statements

A 3-group repeated measures design (with a continuous response and with 4 measurements for each subject) will be used to test whether there is a difference in slopes among any of the 3 groups. The test will be performed by collectively comparing the GEE estimates of the slopes using a Chi-square test with 2 degrees of freedom, with a Type I error rate (α) of 0.05. The (repeated) measurements of each subject will be made at the following 4 times, expressed as proportions of the total study time: 0, 0.33, 0.67, 1. Missing values are assumed to occur completely at random (MCAR). The missing value proportions will be combined to form the pairwise observant probabilities using an independent pairwise missing pattern. The anticipated proportions missing at each measurement time are 0, 0.13, 0.27, 0.4. The first row of the autocorrelation matrix of the responses within a subject is assumed to be 1, 0.6, 0.36, 0.216, with subsequent rows following the same pattern (AR1: $\rho(j,k) = \rho^{|j-k|}$). The residual (zero-mean) standard deviation for all 3 groups is assumed to be 5. To detect slopes of 65, 60, 60 with 90% power, the total number of needed subjects is 123 (divided into the 3 groups according to the proportions: 0.333, 0.333, 0.333).

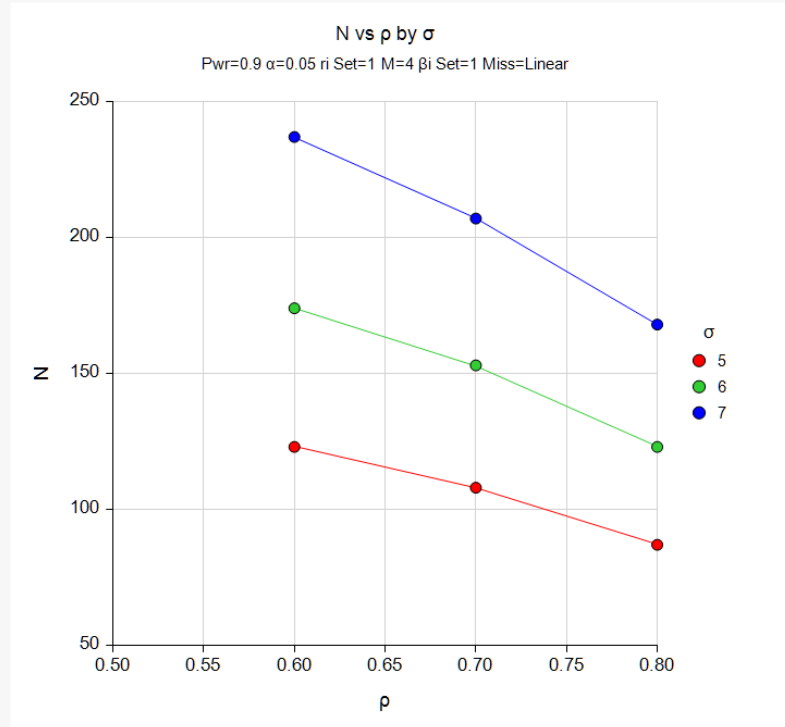
References

Ahn, C., Heo, M., and Zhang, S. 2015. Sample Size Calculations for Clustered and Longitudinal Outcomes in Clinical Research. CRC Press. New York.
 Jung, S.H. and Ahn, C. 2004. K-Sample Test and Sample Size Calculation for Comparing Slopes in Data with Repeated Measurements. Biometrical Journal. Vol 46(5). Pages 554-564.

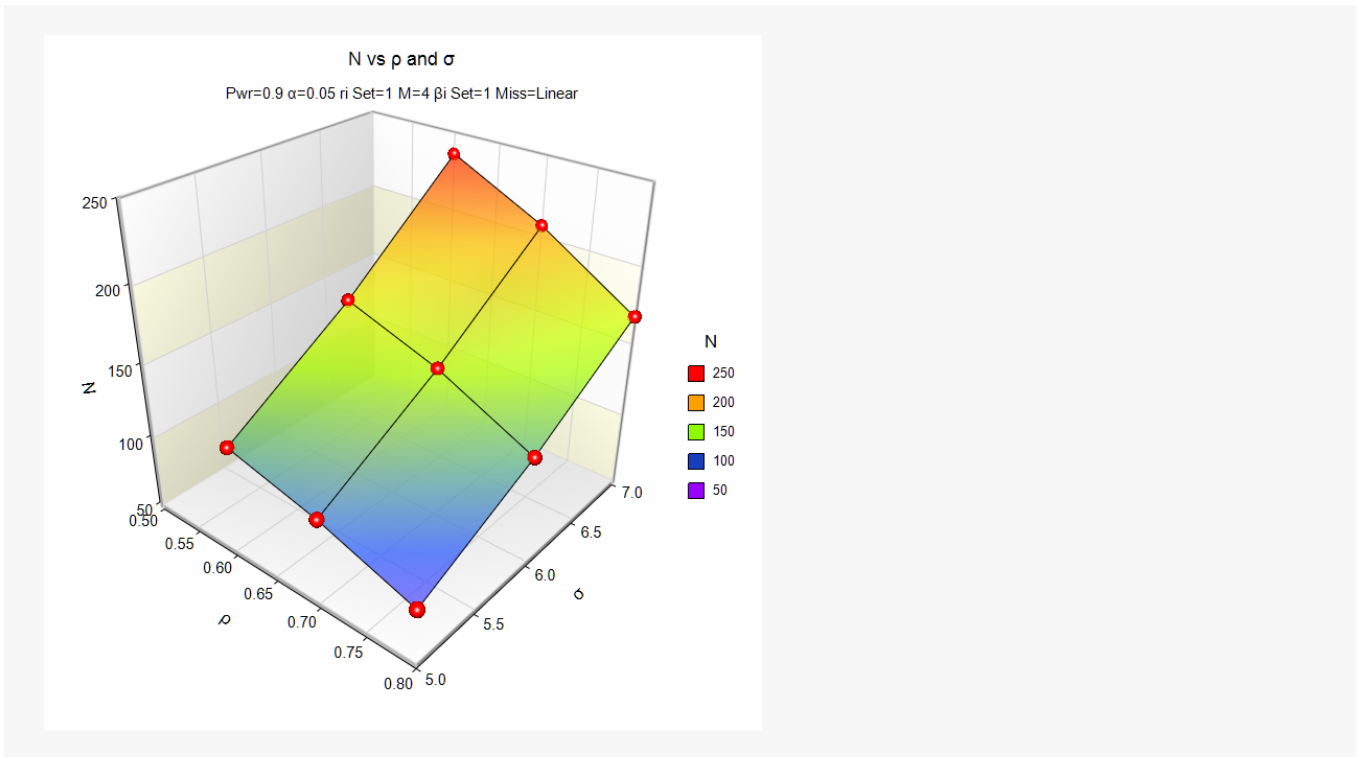
This report gives the sample size for each value of the other parameters.

Plots Section

Plots



GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)



These charts show the relationship among the design parameters.

Autocorrelation Matrices

Autocorrelation Matrix for Report Row 1

Time	T(0)	T(0.33)	T(0.67)	T(1)
T(0)	1.000	0.60	0.36	0.216
T(0.33)	0.600	1.00	0.60	0.360
T(0.67)	0.360	0.60	1.00	0.600
T(1)	0.216	0.36	0.60	1.000

Autocorrelation Matrix for Report Row 2

Time	T(0)	T(0.33)	T(0.67)	T(1)
T(0)	1.000	0.70	0.49	0.343
T(0.33)	0.700	1.00	0.70	0.490
T(0.67)	0.490	0.70	1.00	0.700
T(1)	0.343	0.49	0.70	1.000

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(More Reports Follow)

These reports show the autocorrelation matrix for the indicated row of the report.

Example 2 – Finding the Power

Continuing with Example 1, the researchers want to determine the power corresponding to group sample sizes ranging from 20 to 80 for the middle values of the other parameters.

Setup

If the procedure window is not already open, use the PASS Home window to open it. The parameters for this example are listed below and are stored in the **Example 2** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Design Tab

Solve For	Power
Alpha.....	0.05
G (Number of Groups)	3
Group Allocation Input Type	Equal (n1 = n2 = ... = nG = n)
n (Sample Size Per Group).....	20 to 80 by 10
Measurement Time Input Type	Equally Spaced Measurement Times
M (Number of Measurement Times)	4
β 's Input Type	$\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means)
$\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means).....	65 60 60
σ (Standard Deviation).....	6
Pattern of ρ 's Across Time.....	AR1 (Traditional)
ρ (Base Correlation).....	0.7
Missing Input Type.....	Linear (Steady Change)
Pairwise Missing Pattern.....	Independent (Ind)
First Missing Proportion (Ind).....	0
Last Missing Proportion (Ind).....	0.4

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Output

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

Numeric Results for a Multi-Group Slope Comparison Test using GEE

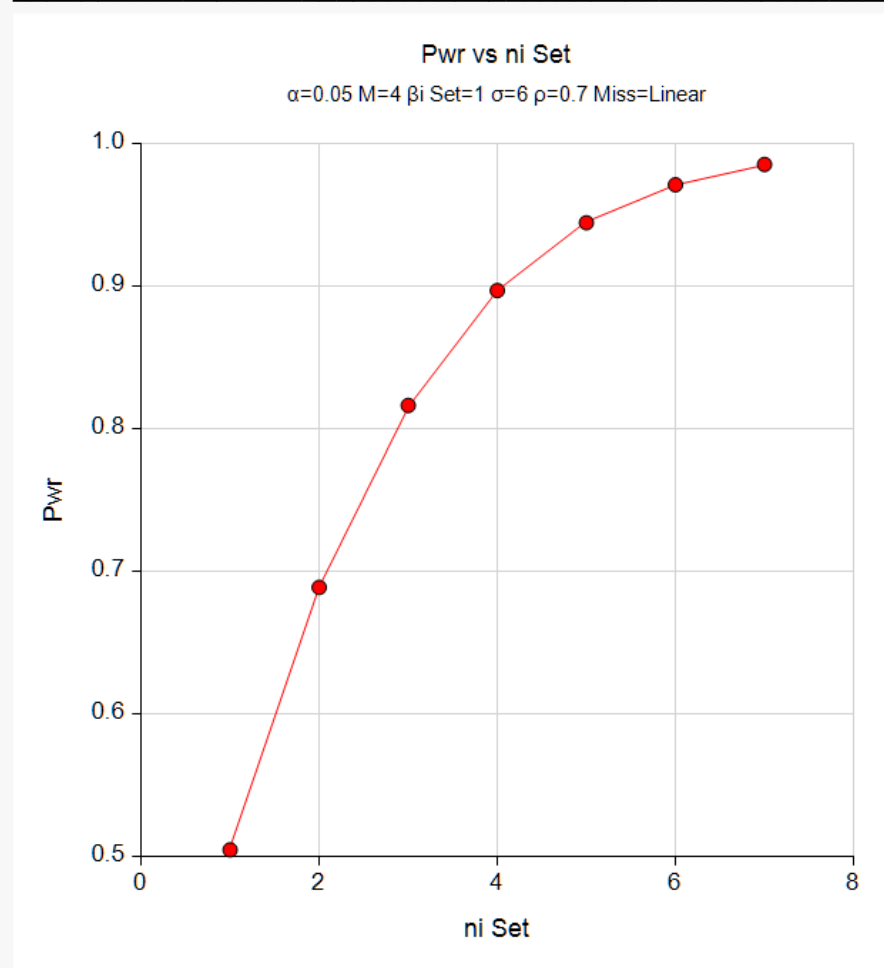
Solve For: [Power](#)
 Measurement Times: Equally spaced
 Correlation: AR1: $\rho(j,k) = \rho^{|j-k|}$
 Missing Pattern: Range of missing proportions
 Observant Proportions: Assume independence
 Number of Groups: 3

Power	Total Sample Size N	Group Sample Sizes ni	Number of Measurement Times M	Standard Deviation		Group Responses σ	Base Correlation ρ	First Row of Correlation Matrix	Missing Data Proportions	Measurement Times	Alpha
				Group Slopes β_i	Group Slopes σ_m						
0.5047	60	ni(1)	4	$\beta_i(1)$	0.75	6	0.7	$\rho_1(1)$	Ms1(1)	T(1)	0.05
0.6888	90	ni(2)	4	$\beta_i(1)$	0.75	6	0.7	$\rho_1(1)$	Ms1(1)	T(1)	0.05
0.8164	120	ni(3)	4	$\beta_i(1)$	0.75	6	0.7	$\rho_1(1)$	Ms1(1)	T(1)	0.05
0.8970	150	ni(4)	4	$\beta_i(1)$	0.75	6	0.7	$\rho_1(1)$	Ms1(1)	T(1)	0.05
0.9445	180	ni(5)	4	$\beta_i(1)$	0.75	6	0.7	$\rho_1(1)$	Ms1(1)	T(1)	0.05
0.9711	210	ni(6)	4	$\beta_i(1)$	0.75	6	0.7	$\rho_1(1)$	Ms1(1)	T(1)	0.05
0.9854	240	ni(7)	4	$\beta_i(1)$	0.75	6	0.7	$\rho_1(1)$	Ms1(1)	T(1)	0.05

Item	Values
ni(1)	20, 20, 20
ni(2)	30, 30, 30
ni(3)	40, 40, 40
ni(4)	50, 50, 50
ni(5)	60, 60, 60
ni(6)	70, 70, 70
ni(7)	80, 80, 80
$\beta_i(1)$	65, 60, 60
$\rho_1(1)$	1, 0.7, 0.49, 0.343
Ms1(1)	0, 0.13, 0.27, 0.4
T(1)	0, 0.33, 0.67, 1

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Plots



Note that the horizontal axis is scaled according to the ni footnote index. Hence, 1 is for $ni1$, 2 is for $ni2$, and so on. The same is true for the β_i 's and the *Linear Miss* in the subtitle.

Example 3 – Comparing Various Effect Sizes

Continuing with Examples 1 and 2, the researchers want to compare the impact of various sets of slopes on sample size. To do this, they will compare the four sets of slopes shown in the following table. The first row is the standard medication. The second and third rows give the anticipated response to the experimental medications.

The values in this table must be loaded into the spreadsheet.

Table of Four Sets of Time-Averaged Responses

C1	C2	C3	C4
65	65	65	65
60	61	62	63
60	61	62	63

Setup

If the procedure window is not already open, use the PASS Home window to open it. The parameters for this example are listed below and are stored in the **Example 3** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Design Tab

- Solve For **Power**
- Alpha..... **0.05**
- G (Number of Groups) **3**
- Group Allocation Input Type **Equal (n1 = n2 = ... = nG = n)**
- n (Sample Size Per Group)..... **20 to 80 by 10**
- Measurement Time Input Type **Equally Spaced Measurement Times**
- M (Number of Measurement Times) **4**
- βi's Input Type **Columns containing sets of βi's**
- Columns Containing Sets of βi's **C1-C4**
- σ (Standard Deviation)..... **6**
- Pattern of ρ's Across Time..... **AR1 (Traditional)**
- ρ (Base Correlation)..... **0.7**
- Missing Input Type..... **Linear (Steady Change)**
- Pairwise Missing Pattern..... **Independent (Ind)**
- First Missing Proportion (Ind)..... **0**
- Last Missing Proportion (Ind) **0.4**

Input Spreadsheet Data

Row	C1	C2	C3	C4
1	65	65	65	65
2	60	61	62	63
3	60	61	62	63
4	60	61	62	63

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Output

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

Numeric Results for a Multi-Group Slope Comparison Test using GEE

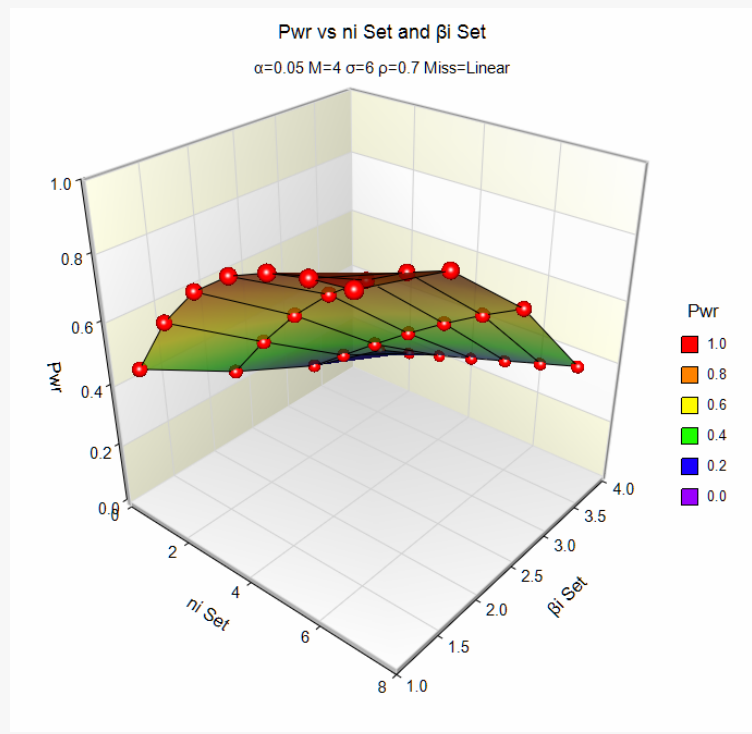
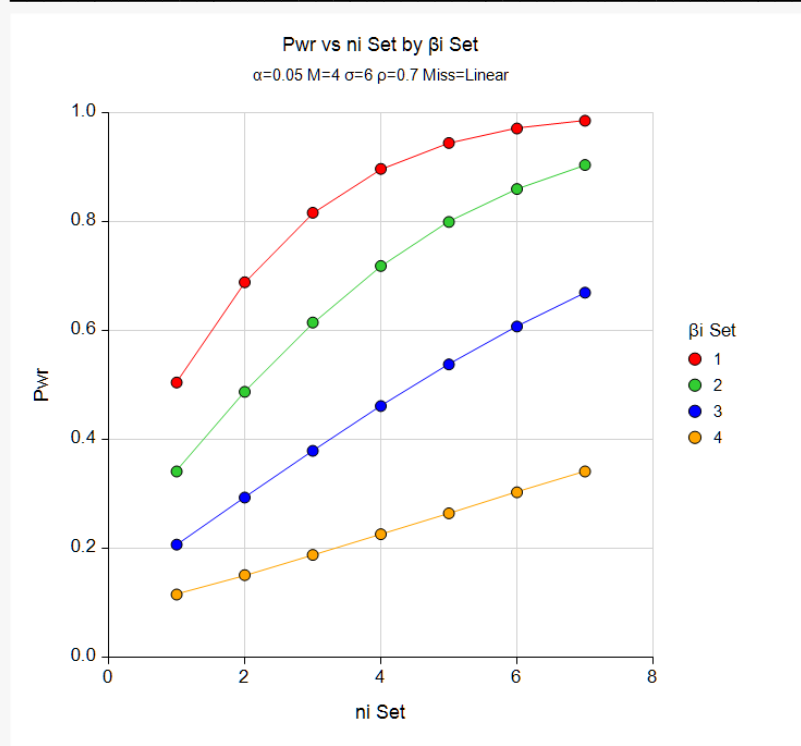
Solve For: **Power**
 Measurement Times: Equally spaced
 Correlation: AR1: $\rho(j,k) = \rho^{|j-k|}$
 Missing Pattern: Range of missing proportions
 Observant Proportions: Assume independence
 Number of Groups: 3

Power	Total Sample Size N	Group Sample Sizes ni	Number of Measurement Times M	Group Slopes β_i	Standard Deviation		Base Correlation ρ	First Row of Correlation Matrix	Missing Data Proportions	Measurement Times	Alpha
					Group Slopes σ_m	Responses σ					
0.5047	60	ni(1)	4	C1(1)	0.75	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.3413	60	ni(1)	4	C2(2)	0.67	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.2069	60	ni(1)	4	C3(3)	0.58	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.1153	60	ni(1)	4	C4(4)	0.47	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.6888	90	ni(2)	4	C1(1)	0.75	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.4876	90	ni(2)	4	C2(2)	0.67	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.2934	90	ni(2)	4	C3(3)	0.58	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.1510	90	ni(2)	4	C4(4)	0.47	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.8164	120	ni(3)	4	C1(1)	0.75	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.6148	120	ni(3)	4	C2(2)	0.67	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.3792	120	ni(3)	4	C3(3)	0.58	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.1880	120	ni(3)	4	C4(4)	0.47	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.8970	150	ni(4)	4	C1(1)	0.75	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.7187	150	ni(4)	4	C2(2)	0.67	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.4614	150	ni(4)	4	C3(3)	0.58	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.2260	150	ni(4)	4	C4(4)	0.47	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.9445	180	ni(5)	4	C1(1)	0.75	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.7995	180	ni(5)	4	C2(2)	0.67	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.5379	180	ni(5)	4	C3(3)	0.58	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.2644	180	ni(5)	4	C4(4)	0.47	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.9711	210	ni(6)	4	C1(1)	0.75	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.8601	210	ni(6)	4	C2(2)	0.67	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.6075	210	ni(6)	4	C3(3)	0.58	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.3030	210	ni(6)	4	C4(4)	0.47	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.9854	240	ni(7)	4	C1(1)	0.75	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.9042	240	ni(7)	4	C2(2)	0.67	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.6697	240	ni(7)	4	C3(3)	0.58	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05
0.3413	240	ni(7)	4	C4(4)	0.47	6	0.7	$\rho1(1)$	Ms1(1)	T(1)	0.05

Item	Values
ni(1)	20, 20, 20
ni(2)	30, 30, 30
ni(3)	40, 40, 40
ni(4)	50, 50, 50
ni(5)	60, 60, 60
ni(6)	70, 70, 70
ni(7)	80, 80, 80
C1(1)	65, 60, 60
C2(2)	65, 61, 61
C3(3)	65, 62, 62
C4(4)	65, 63, 63
$\rho1(1)$	1, 0.7, 0.49, 0.343
Ms1(1)	0, 0.13, 0.27, 0.4
T(1)	0, 0.33, 0.67, 1

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Plots



Note that the horizontal axis gives the index of the slopes' footnotes. Thus, '1.0' is column C1, '2.0' is column C2, and so on. Obviously, as the slopes get closer together, the required sample size gets larger.

Example 4 – Validation of Sample Size Calculation using Ahn, Heo, and Zhang (2015)

Ahn, Heo, and Zhang (2015) page 110 present sample size results for several scenarios. We will validate this procedure using a few results from the table found there. In this example, the standard deviation is 28.56, the slope difference is 28.6, the significance level is 0.05, the power is 0.90, group sizes are equal, and the number of repeated measurements per subject is 6. We will use the compound symmetry option for the correlation matrices with $\rho = 0.1, 0.25, 0.4$. The proportion missing at each time point is equal to 0, 0.1, 0.22, 0.33, 0.46, 0.59. The pairwise observant probabilities assume independence. Using these settings, the sample sizes were reported as 86, 76, and 67

Setup

If the procedure window is not already open, use the PASS Home window to open it. The parameters for this example are listed below and are stored in the **Example 4** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Design Tab

Solve For	Sample Size
Power.....	0.90
Alpha.....	0.05
G (Number of Groups)	2
Group Allocation Input Type	Equal (n1 = n2 = ... = nG = n)
Measurement Time Input Type	Equally Spaced Measurement Times
M (Number of Measurement Times)	6
β 's Input Type	$\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means)
$\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means).....	0 28.6
σ (Standard Deviation).....	28.56
Pattern of ρ 's Across Time	Compound Symmetry (All ρ's Equal)
ρ (Base Correlation).....	0.1 0.25 0.4
Missing Input Type.....	List
Pairwise Missing Pattern.....	Independent (Ind)
List of Missing Proportions (Ind)	0 0.1 0.22 0.33 0.46 0.59

Output

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

Numeric Results for a Multi-Group Slope Comparison Test using GEE

Solve For: [Sample Size](#)
 Measurement Times: Equally spaced
 Correlation: Compound symmetry (all ρ 's equal)
 Missing Pattern: List of missing proportions
 Observant Proportions: Assume independence
 Number of Groups: 2

Power	Total Sample Size N	Group Allocation Proportions r_i	Number of Measurement Times M	Group Slopes β_i	Standard Deviation			Base Correlation ρ	First Row of Correlation Matrix	Missing Data Proportions	Measurement Times	Alpha
					Group Slopes σ_m	Responses σ						
0.9022	86	ri(1)	6	$\beta_i(1)$	2.67	28.56	0.10	$\rho_1(1)$	Ms(1)	T(1)	0.05	
0.9011	76	ri(1)	6	$\beta_i(1)$	2.67	28.56	0.25	$\rho_2(1)$	Ms(1)	T(1)	0.05	
0.9079	68	ri(1)	6	$\beta_i(1)$	2.67	28.56	0.40	$\rho_3(1)$	Ms(1)	T(1)	0.05	

Item	Values
ri(1)	0.5, 0.5
$\beta_i(1)$	0, 28.6
$\rho_1(1)$	1, 0.1, 0.1, 0.1, 0.1, 0.1
$\rho_2(1)$	1, 0.25, 0.25, 0.25, 0.25, 0.25
$\rho_3(1)$	1, 0.4, 0.4, 0.4, 0.4, 0.4
Ms(1)	0, 0.1, 0.22, 0.33, 0.46, 0.59
T(1)	0, 0.2, 0.4, 0.6, 0.8, 1

The sample sizes of 86 and 76 match Ahn, Heo, and Zhang (2015). The sample size of the third scenario was calculated as 68, which is one more than the reported 67. This difference occurred because **PASS** searches among only balanced designs. These require an even sample size, so **PASS** selected 68, the next balanced design above the reported 67.

Example 5 – Impact of Measurement Time Distribution

This example will investigate the impact of measurement time distribution on power. It will compare the power of studies in which the measurements are evenly spaced with those that take more measurements at the beginning of the study, near the middle of the study, or at the end of the study.

This example uses $G = 4$, $m = 6$, $\sigma = 14.3$, $\alpha = 0.05$, and power = 0.9. The correlation pattern is Linear Exponential Decay with a base correlation of 0.8, Base Time Proportion of 0.20, and Emax set to 4. The missing input type is set to Linear from 0 to 30% and the pairwise missing assumption is independent. Group slopes are 5, 5, 7, 10. The per group sample size is 200.

The measurement times for five scenarios are given in the following table.

Table of Measurement Times in Proportion of Total Study Time

Tm1	Tm2	Tm3	Tm4	Tm5
0	0	0	0	0
0.20	0.60	0.10	0.10	0.45
0.40	0.70	0.20	0.20	0.50
0.60	0.80	0.30	0.80	0.55
0.80	0.90	0.40	0.90	0.60
1.00	1.00	1.00	1.00	1.00

Note that the measurements in Tm1 are evenly spaced, those in Tm2 are loaded near the end, those of Tm3 occur at the beginning, those of Tm4 occur only at the beginning and the end, and those of Tm5 occur mostly near the middle.

Setup

If the procedure window is not already open, use the PASS Home window to open it. The parameters for this example are listed below and are stored in the **Example 5** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Design Tab

Solve For **Power**
 Alpha..... **0.05**
 G (Number of Groups) **4**
 Group Allocation Input Type **Equal (n1 = n2 = ... = nG = n)**
 n (Sample Size Per Group)..... **200**
 Measurement Time Input Type **Columns of Measurement Time Proportions**
 Columns of Time Proportions **TM1-TM5**
 β 's Input Type **$\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means)**
 $\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means)..... **5 5 7 10**
 σ (Standard Deviation)..... **14.3**
 Pattern of ρ 's Across Time **Linear Exponential Decay**
 ρ (Base Correlation)..... **0.8**
 Base Time Proportion **0.2**

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Emax (Max Decay Exponent) **4**
 Missing Input Type..... **Linear (Steady Change)**
 Pairwise Missing Pattern..... **Independent (Ind)**
 First Missing Proportion (Ind)..... **0**
 Last Missing Proportion (Ind)..... **0.30**

Input Spreadsheet Data

Row	Tm1	Tm2	Tm3	Tm4	Tm5
1	0.0	0.0	0.0	0.0	0.00
2	0.2	0.6	0.1	0.1	0.45
3	0.4	0.7	0.2	0.2	0.50
4	0.6	0.8	0.3	0.8	0.55
5	0.8	0.9	0.4	0.9	0.60
6	1.0	1.0	1.0	1.0	1.00

Output

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

Numeric Results for a Multi-Group Slope Comparison Test using GEE

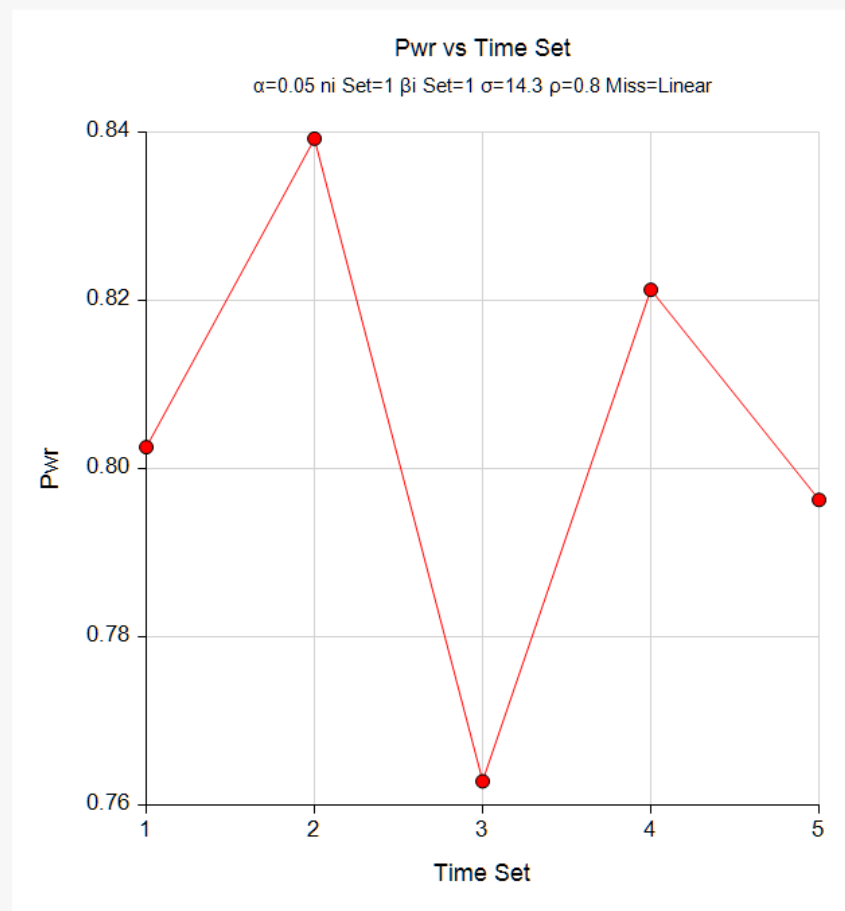
Solve For: [Power](#)
 Measurement Times: Lists in spreadsheet columns: {TM1-TM5}
 Correlation: Linear exponential decay, with Emax = 4 and Base Time Prop = 0.2
 Missing Pattern: Range of missing proportions
 Observant Proportions: Assume independence
 Number of Groups: 4

Power	Total Sample Size N	Group Sample Sizes ni	Number of Measurement Times M	Standard Deviation		Responses σ	Base Correlation ρ	First Row of Correlation Matrix	Missing Data Proportions	Measurement Times	Alpha
				Group Slopes β_i	Group Slopes σ_m						
0.8026	800	ni(1)	6	$\beta_i(1)$	0.9	14.3	0.8	$\rho_1(Tm1)$	Ms1(Tm1)	Tm1(1)	0.05
0.8392	800	ni(1)	6	$\beta_i(1)$	0.9	14.3	0.8	$\rho_1(Tm2)$	Ms1(Tm2)	Tm2(2)	0.05
0.7628	800	ni(1)	6	$\beta_i(1)$	0.9	14.3	0.8	$\rho_1(Tm3)$	Ms1(Tm3)	Tm3(3)	0.05
0.8213	800	ni(1)	6	$\beta_i(1)$	0.9	14.3	0.8	$\rho_1(Tm4)$	Ms1(Tm4)	Tm4(4)	0.05
0.7963	800	ni(1)	6	$\beta_i(1)$	0.9	14.3	0.8	$\rho_1(Tm5)$	Ms1(Tm5)	Tm5(5)	0.05

Item	Values
ni(1)	200, 200, 200, 200
$\beta_i(1)$	5, 5, 7, 10
$\rho_1(Tm1)$	1, 0.8, 0.6767, 0.5724, 0.4842, 0.4096
$\rho_1(Tm2)$	1, 0.5724, 0.5265, 0.4842, 0.4453, 0.4096
$\rho_1(Tm3)$	1, 0.8698, 0.8, 0.7358, 0.6767, 0.4096
$\rho_1(Tm4)$	1, 0.8698, 0.8, 0.4842, 0.4453, 0.4096
$\rho_1(Tm5)$	1, 0.649, 0.6224, 0.5969, 0.5724, 0.4096
Ms1(Tm1)	0, 0.06, 0.12, 0.18, 0.24, 0.3
Ms1(Tm2)	0, 0.18, 0.21, 0.24, 0.27, 0.3
Ms1(Tm3)	0, 0.03, 0.06, 0.09, 0.12, 0.3
Ms1(Tm4)	0, 0.03, 0.06, 0.24, 0.27, 0.3
Ms1(Tm5)	0, 0.14, 0.15, 0.17, 0.18, 0.3
Tm1(1)	0, 0.2, 0.4, 0.6, 0.8, 1
Tm2(2)	0, 0.6, 0.7, 0.8, 0.9, 1
Tm3(3)	0, 0.1, 0.2, 0.3, 0.4, 1
Tm4(4)	0, 0.1, 0.2, 0.8, 0.9, 1
Tm5(5)	0, 0.45, 0.5, 0.55, 0.6, 1

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Plots



The horizontal axis, *Time Column Id*, gives the sequence number of the measurement columns. Thus, 1 is Tm1, 2 is Tm2, and so on.

The pattern Tm2 produces the highest power. Remember that Tm2 put the measurements at the end.

Patterns Tm1, Tm4, and Tm5 are nearly tied for achieving the medium powers. Tm1, the equally spaced measurement scenario, is near the middle.

Example 6 – Entering a Correlation Matrix

This example will show how a correlation matrix can be loaded directly.

This example uses $G = 4$, $M = 4$, $\sigma = 14.3$, $\alpha = 0.05$, and power = 0.9. The missing input type will be set to Linear from 0 to 30% and the pairwise missing assumption is independent. Group means are 5, 5, 7, 10. The per group sample sizes range from 150 to 300. A correlation matrix (shown below) is available from a previous study.

Table of Correlations

C1	C2	C3	C4
1.0000	0.7000	0.4900	0.3430
0.7000	1.0000	0.7000	0.4900
0.4900	0.7000	1.0000	0.7000
0.3430	0.4900	0.7000	1.0000

Setup

If the procedure window is not already open, use the PASS Home window to open it. The parameters for this example are listed below and are stored in the **Example 6** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Design Tab

Solve For **Power**
 Alpha..... **0.05**
 G (Number of Groups) **4**
 Group Allocation Input Type **Equal (n1 = n2 = ... = nG = n)**
 n (Sample Size Per Group)..... **150 200 250 300**
 Measurement Time Input Type **Equally Spaced Measurement Times**
 M (Number of Measurement Times) **4**
 β 's Input Type **$\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means)**
 $\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means) **5 5 7 10**
 σ (Standard Deviation)..... **14.3**
 Pattern of ρ 's Across Time..... **Matrix on Spreadsheet**
 Columns Containing the ρ 's **C1-C4**
 Missing Input Type..... **Linear (Steady Change)**
 Pairwise Missing Pattern..... **Independent (Ind)**
 First Missing Proportion (Ind)..... **0**
 Last Missing Proportion (Ind) **0.30**

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Input Spreadsheet Data

Row	C1	C2	C3	C4
1	1.000	0.70	0.49	0.343
2	0.700	1.00	0.70	0.490
3	0.490	0.70	1.00	0.700
4	0.343	0.49	0.70	1.000

Output

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

Numeric Results for a Multi-Group Slope Comparison Test using GEE

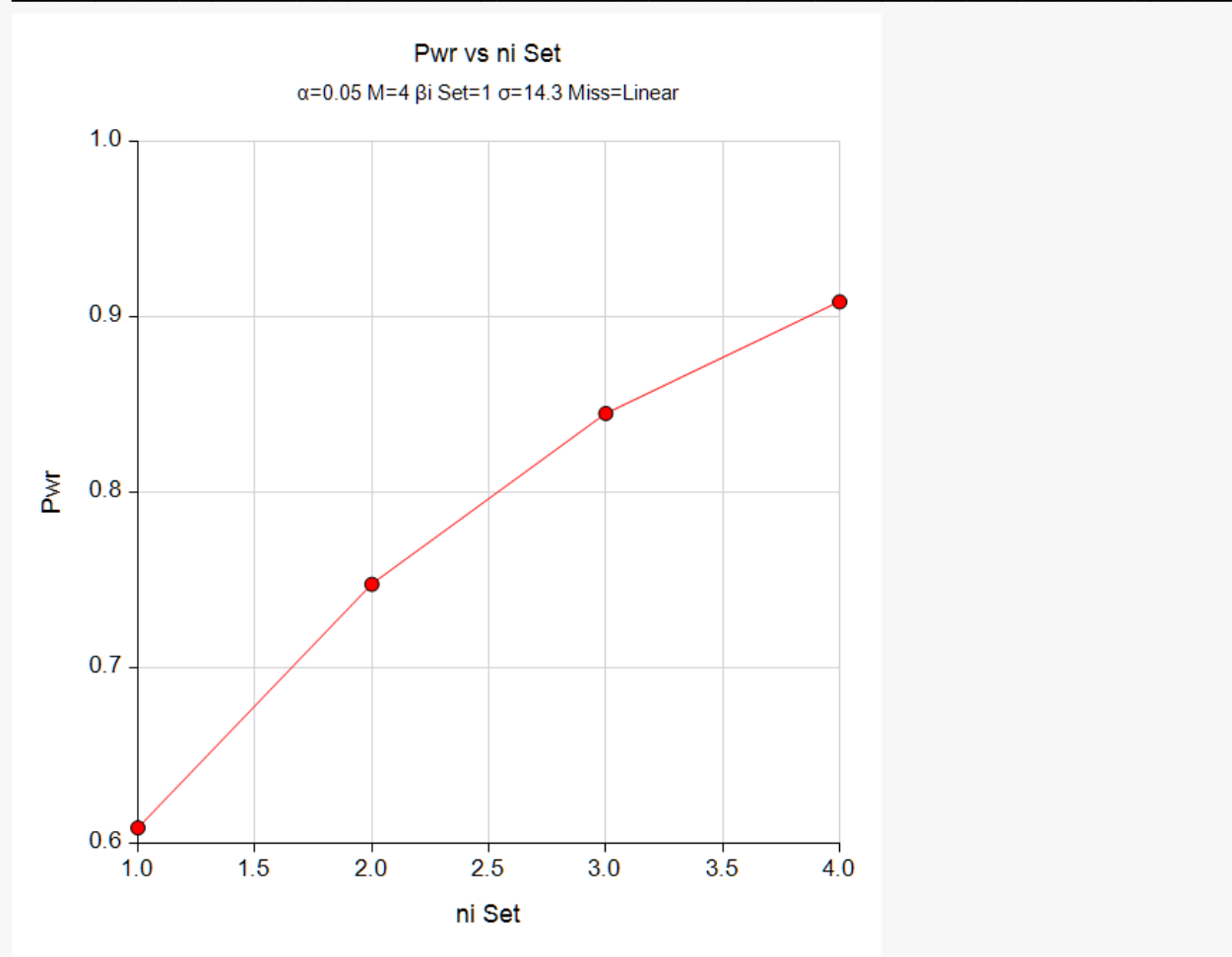
Solve For: [Power](#)
 Measurement Times: Equally spaced
 Correlation: Matrix stored on spreadsheet in columns C1-C4
 Missing Pattern: Range of missing proportions
 Observant Proportions: Assume independence
 Number of Groups: 4

Power	Total Sample Size N	Group Sample Sizes ni	Number of Measurement Times M	Group Slopes β_i	Standard Deviation			Base Correlation ρ	First Row of Correlation Matrix	Missing Data Proportions	Measurement Times	Alpha
					Group Slopes σ_m	Responses σ						
0.6088	600	ni(1)	4	$\beta_i(1)$	0.9	14.3	N/A	$\rho_1(1)$	Ms1(1)	T(1)	0.05	
0.7476	800	ni(2)	4	$\beta_i(1)$	0.9	14.3	N/A	$\rho_1(1)$	Ms1(1)	T(1)	0.05	
0.8450	1000	ni(3)	4	$\beta_i(1)$	0.9	14.3	N/A	$\rho_1(1)$	Ms1(1)	T(1)	0.05	
0.9086	1200	ni(4)	4	$\beta_i(1)$	0.9	14.3	N/A	$\rho_1(1)$	Ms1(1)	T(1)	0.05	

Item	Values
ni(1)	150, 150, 150, 150
ni(2)	200, 200, 200, 200
ni(3)	250, 250, 250, 250
ni(4)	300, 300, 300, 300
$\beta_i(1)$	5, 5, 7, 10
$\rho_1(1)$	1, 0.7, 0.49, 0.343
Ms1(1)	0, 0.1, 0.2, 0.3
T(1)	0, 0.33, 0.67, 1

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Plots



Autocorrelation Matrix for Report Row 1

Time	T(0)	T(0.33)	T(0.67)	T(1)
T(0)	1.000	0.70	0.49	0.343
T(0.33)	0.700	1.00	0.70	0.490
T(0.67)	0.490	0.70	1.00	0.700
T(1)	0.343	0.49	0.70	1.000

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·
·

(More Reports Follow)

Note that the horizontal axis corresponds to the sequence number of the ni's. Hence, 1 is ni1, 2 is ni2, and so on.

Example 7 – Entering an Observant Probabilities Matrix

This example will show how an observant probabilities matrix can be loaded directly.

This example uses $G = 4$, $M = 4$, $\sigma = 14.3$, and $\alpha = 0.05$. The per group sample sizes range from 150 to 300. Group means are 5, 5, 7, 10. The correlation pattern will be Linear Exponential Decay with a base correlation of 0.8, Base Time Proportion of 0.1, and Emax set to 4.

The missing input type will be set to Matrix of Pairwise Missing.

Table of Observant Probabilities

Row	C1	C2	C3	C4
1	1.00	0.90	0.80	0.70
2	0.90	0.90	0.72	0.63
3	0.80	0.72	0.80	0.56
4	0.70	0.63	0.56	0.70

This table gives the pairwise observant probabilities. That is, each entry gives the probability of obtaining a response for both the row and column time points. For example, 0.63 is the probability of observing both the second response and the fourth response.

Setup

If the procedure window is not already open, use the PASS Home window to open it. The parameters for this example are listed below and are stored in the **Example 7** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Design Tab

Solve For **Power**
 Alpha..... **0.05**
 G (Number of Groups) **4**
 Group Allocation Input Type **Equal (n1 = n2 = ... = nG = n)**
 n (Sample Size Per Group)..... **150 200 250 300**
 Measurement Time Input Type **Equally Spaced Measurement Times**
 M (Number of Measurement Times) **4**
 β 's Input Type **$\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means)**
 $\beta_1, \beta_2, \dots, \beta_G$ (Slopes, i.e., Means)..... **5 5 7 10**
 σ (Standard Deviation)..... **14.3**
 Pattern of ρ 's Across Time **Linear Exponential Decay**
 ρ (Base Correlation)..... **0.8**
 Base Time Proportion **0.1**
 Emax (Max Decay Exponent) **4**
 Missing Input Type..... **Pairwise Observed Proportions on Spreadsheet**
 Columns of Pairwise Observed..... **C1-C4**

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Input Spreadsheet Data

Row	C1	C2	C3	C4
1	1.0	0.90	0.80	0.70
2	0.9	0.90	0.72	0.63
3	0.8	0.72	0.80	0.56
4	0.7	0.63	0.56	0.70

Output

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

Numeric Results for a Multi-Group Slope Comparison Test using GEE

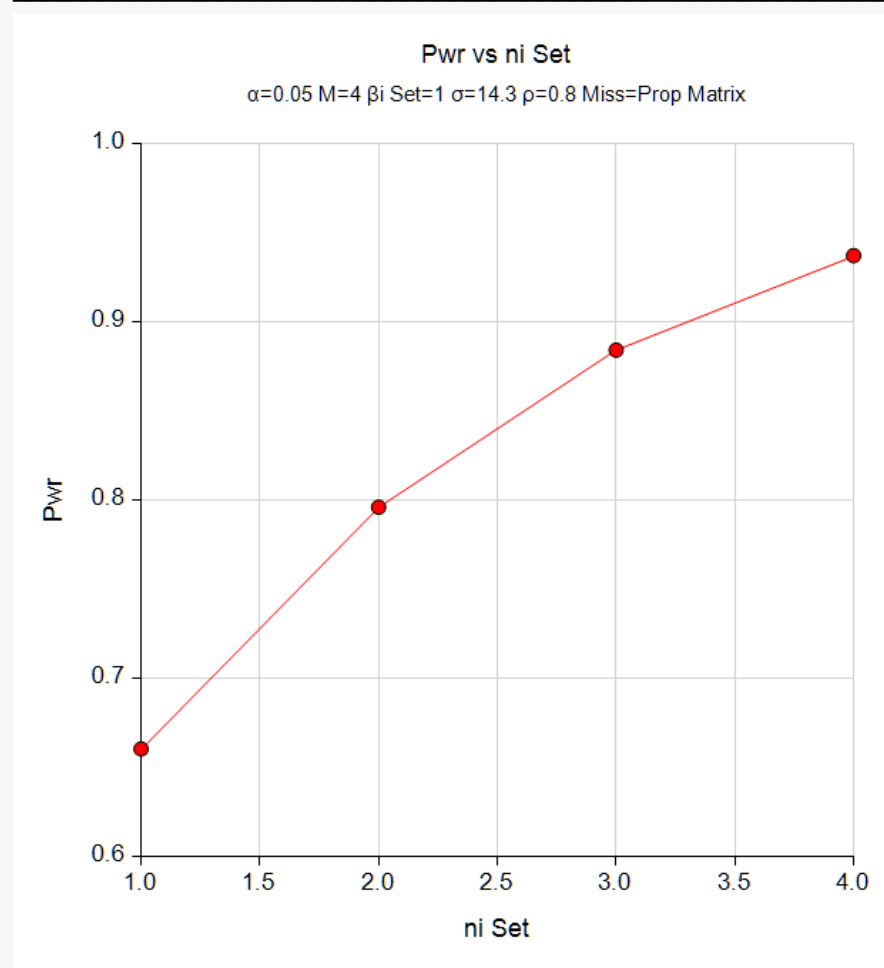
Solve For: [Power](#)
 Measurement Times: Equally spaced
 Correlation: Linear exponential decay, with Emax = 4 and Base Time Prop = 0.1
 Missing Pattern: N/A. Matrix of observant probabilities entered in columns C1-C4.
 Number of Groups: 4

Power	Total Sample Size N	Group Sample Sizes ni	Number of Measurement Times M	Group Slopes β_i	Standard Deviation			Base Correlation ρ	First Row of Correlation Matrix	Missing Data Proportions	Measurement Times	Alpha
					Group Slopes σ_m	Responses σ						
0.6604	600	ni(1)	4	$\beta_i(1)$	0.9	14.3	0.8	$\rho_1(1)$	N/A	T(1)	0.05	
0.7960	800	ni(2)	4	$\beta_i(1)$	0.9	14.3	0.8	$\rho_1(1)$	N/A	T(1)	0.05	
0.8842	1000	ni(3)	4	$\beta_i(1)$	0.9	14.3	0.8	$\rho_1(1)$	N/A	T(1)	0.05	
0.9372	1200	ni(4)	4	$\beta_i(1)$	0.9	14.3	0.8	$\rho_1(1)$	N/A	T(1)	0.05	

Item	Values
ni(1)	150, 150, 150, 150
ni(2)	200, 200, 200, 200
ni(3)	250, 250, 250, 250
ni(4)	300, 300, 300, 300
$\beta_i(1)$	5, 5, 7, 10
$\rho_1(1)$	1, 0.6725, 0.5249, 0.4096
T(1)	0, 0.33, 0.67, 1

GEE Tests for the Slope of Multiple Groups in a Repeated Measures Design (Continuous Outcome)

Plots



The standard reports are displayed.