BIOSTATISTICS
TOPIC 11: ESTIMATION OF SAMPLE SIZE

The design of an experiment is essentially a plan for collecting information, which, like any other commodity, may be acquired at varying prices, depending on the manner in which the data are obtained. Some measurements contain a large amount of information concerning the parameter of interest; others may contain little or none. Since the product of research is information, we want to make its "purchase" at minimum cost.

The sampling procedure, or experimental design as it is usually called, affects the quantity of information per measurement. This, along with the sample size *n*, controls the total amount of relevant information in a sample. With few exceptions, we shall be concerned with the simplest sampling situation, random sampling from a relatively large population, and will devote our attention to the selection of sample size, *n*.

The investigator makes little progress in planning an experiment before encountering the problem of selecting the sample size. Indeed, perhaps one of the most frequency questions asked of the statistician is: "how many measurements should be included in the sample?". Unfortunately, the statistician can not answer this question without knowing how much information the experimenter wishes to collect. Certainly, the total amount of information in the sample will affect the measure of goodness of the method of inference and must be specified by the investigator. Referring specifically to estimation, we would like to know how accurate the investigator wishes the estimate to be. This may be stated by specifying a bound on the error of estimation.

THE LOGIC OF STATISTICAL SIGNIFICANCE

In previous topics, we have learned several statistical procedures used to test the numerical "significance" of an observed difference between groups. The calculations used for the procedures depend on the kind of basic data in which the results were expressed. For dimensional data, the results would be cited as mean and the usual statistical procedure would be the t-test. For nominal data, the results are expressed as frequency counts or proportions, percentages or rates; and the usual statistical procedure would be a Chi square test. If the data are expressed in rank ordinal values, the usual statistical procedure would be the Wilcoxon rank sum test or the Mann-Whitney U test.

Although each of these tests is chosen according to the type of data under examination, the underlying logic is identical. It follows the same principle that was used to prove theorems in school geometry. We assume that a particular conjecture is true. We then determine the consequences of that conjecture. If the consequences produce an obvious absurdity or implausibility, we conclude that the original conjecture can not be true, and we reject it as false.

When this reasoning is used for the statistical strategy that is called "**hypothesis testing**", the argument proceeds as follows. We have observed a difference, called δ, between groups A and B. To test its "statistical significance", we assume, as a conjecture, that groups A and B are actually not different. This conjecture is called **null hypothesis** and is usually denoted by H_O. With this assumption, we then determine how often a difference as large as δ, or even larger, would arise by chance from data for two groups having the same number of subjects as A and B. The result of this determination is the **P value** that emerges from the statistical test procedure.

To draw statistical conclusions, we must establish a concept that was not necessarily for the inferential reasoning of school geometry. This concept is called an **α level of significance.** It is used to demarcate the **rejection zone**. If the P value that emerges from the statistical test is equal to or smaller than α, we decide that we shall reject the null hypothesis. In doing so, we demarcate α as the risk of being wrong in this conclusion - but it is a risk we must take in order to have a statistical mechanism for drawing conclusions. In geometrical inference, α is always 0. In statistical inference, α is usually chosen to be 0.05 (or 5%) or 1 in 20, although some investigators may select other bounderies such as 0.1 or 0.01.

The α level is analogous to the risk of getting a **false positive** result in a diagnostic test. Suppose that we make a diagnosis of lung cancer after finding a positive result in the Pap smear of a patient. If the patient does in fact have lung cancer, the diagnostic decision is correct - a true positive. If the patient does not have a lung cancer, the diagnosis is wrong - a false positive conclusion. The α level indicates the statistical risk that this decision may be wrong and that there is actually no difference between the groups. Statisticians refer to this error as **type I error**. The value $1-\alpha$ can therefore be viewed as the **specificity** of a diagnostic test, which the likelihood that the test will have a negative result when the disease us absent. The value of $1-\alpha$ denotes the likelihood of being correct when we do not reject the null hypothesis and thereby conclude that the observed difference is not "statistically significance".

All of the strategies described constitute a long-standing, well established statistical procedure that is still used by many investigators as the natural way to calculate test statistic. In 192, Jerzy Neyman and Egon S. Pearson pointed out that the reasoning was incomplete. According to Neyman-Pearson argument, a statistical test of significance, like a medical test of diagnosis, has another side to it. In diagnosis, when thinking about the situation where the disease is absent, we recognise that a diagnostic test will yield either a false positive diagnosis or a true positive, but what about the situation where the disease is actually present? We thus have far ignored this side of diagnostic reasoning. What about the **false negative** or **true positive** diagnoses that will occur if the disease actually exists? In statistical reasoning, the counterpart to a false negative diagnosis is the error we make if we conceded the null hypothesis and concluded that the observed difference was not statistically significant when, in fact, an important difference exists. If the true difference is important and if we fail to draw that conclusion, we would make an erroneous decision. This type of false negative is what statistician call a **type II error**. Thus, if 1-α corresponds to **specificity** of a diagnostic test, 1-β corresponds to its **sensitivity** - the likelihood of making a positive conclusion when it is true.

ANALOGY OF CONCLUSIONS IN DIAGNOSTIC AND STATISTICAL REASONING

(a) Diagnostic reasoning

Test result	Disease is really: Present	Absent
Positive	True positive	False positive
Negative	False negative	True negative

(b) Statistical reasoning

Statistical test result	Significant difference is: Present (H_o not true)	Absent (H_o true)
Reject H_o	No error; $1 - \beta$	Type I error; α
Accept H_o	Type II error;	No error;

	β	$1-\alpha$

Although an investigator is free to set any boundary of error that makes sense, the usual values for type I and type II errors are 0.05 and 0.20, respectively. The reason is that in science, it is seen as less desirable to mistakenly reject a true H_o (which leads to false positive claims) than to mistakenly fail to reject H_o (which leads only to failure to find something and no claim at all).

In calculation of sample size, the investigator must specify the following information:

(a) the parameter of major interest;
(b) the bound of on the error of estimation (type I and type II error);
(c) the difference of interest and its standard deviation.

We will illustrate the procedure of calculation by considering several examples as follows:

I. SAMPLE SIZE FOR ESTIMATING A POPULATION PARAMETER

1.1 Determination of sample size for estimating mean of a population

Suppose it is desired to estimate, with a confidence interval, the mean of a population (μ). One of the first question arise is how large the sample should be? This question must be given serious consideration, because it is a waste of time and resources to take a larger sample than is needed to achieve the desired results. Similarly, a sample that is too small may lead to results that are of no practical value. The key questions are:

First, how close do we want our estimate to be to the true value? In other words, how wide would we like to make the confidence interval that we want to construct?

Second, how much confidence do we want to place in our interval? That is, what confidence coefficient do we wish to employ?

These questions bring to mind the nature of the confidence interval that will eventually be constructed. This interval will be of the form:

$$\bar{y} \pm z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$$

where $z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$ is equal to one half the confidence interval. If question 1 can be answered, then the following equation can be set up:

$$d = z_{\alpha/2} \frac{\sigma}{\sqrt{n}} \qquad [1]$$

where *d* indicates how close the true mean we want our estimate to be. That is, *d* is equal to one half the desired interval width. Equation 1 can be written another way which yields the required sample size:

$$\boxed{N = \frac{(z_{\alpha/2})^2 \sigma^2}{d^2}} \qquad [2]$$

The value of z_γ for various a levels is tabulated in Table 1. For example, for α = 0.05, z_α = 1.96 and $z_{\alpha/2} = z_{0.025}$ = 1.96.

Table 1: Table of Normal deviates

α	Z_α	$Z_{\alpha/2}$
0.20	0.84	1.28
0.10	1.28	1.64
0.05	1.64	1.96
0.01	2.33	2.81

Example 1: Suppose that we wish to estimate the average height (denoted by μ) in a population, and we wish the error of estimation to be less than 2 cm with a probability of 0.95. Since approximately 95% of the sample means will lie within 1.96(SE) of μ in repeated sampling, we are asking that 1.96(SE) equal 2 cm See Figure 1). Then,

$$1.96(\text{SE}) = 2$$

or $$\frac{1.96\sigma}{\sqrt{n}} = 2 \qquad (\text{since } SE = \frac{\sigma}{\sqrt{n}})$$

=> $n = \left(\frac{1.96}{2}\right)^2 \sigma^2$

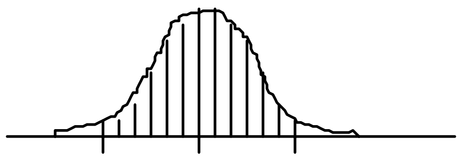

Figure 1. Approximate sampling distribution of $\bar{y}$ for large samples

You should now note that we can not obtain a sample size *n* unless the population standard deviation is specified. This is certainly what we would expect, because the variability of $\bar{y}$, the sample mean, depends upon the variability of the population from which the sample was drawn.

In the above example, if the standard deviation of the population (σ) is unknown, we may use the sample standard deviation (*s*). Suppose that from previous study, the sample standard deviation was 10 cm, then the required sample size would be:

$$n = \left(\frac{1.96}{2}\right)^2 \sigma^2 = \left(\frac{1.96}{2}\right)^2 \left(10^2\right) \approx 100 .$$

1.2 Determination of sample size for estimating proportions

When a population proportion is to be estimated, the sample size is determined in essentially the same way as described above for estimating a population mean. Half the desired interval *d* is set to equal to the product of the reliability coefficient and the standard error. The assumption of random sampling and conditions warranting approximate normality of the distribution of $\bar{p}$ (the sample proportion) lead to the following formula:

[3]

As can be seen, this formula requires a knowledge of *p*, the proportion of population with the characteristic of interest.

Example 2: We want to estimate the proportion of population whose VDR genotype is *tt*. We would like to estimate *p* to within 0.05 with 95% confidence interval. The proportion of population with *tt* in a normal population is 13%. Using these information, we obtain:

$$n = \frac{(1.96)^2(0.13)(0.87)}{(0.05)^2} = 174 \text{ subjects.}$$

1.3 Determination of sample size for estimating correlation coefficients

In observational studies which involve estimate a correlation (ρ) between two variables of interest, say, X and Y, a typical hypothesis is of the form:

$$H_o: \rho = 0$$

versus $H_1: \rho \neq 0$

That is, we are interested in testing a hypothesis of no relationship the two variables against an unspecified, but significant, relationship.

The test statistic is of the Fisher's z transformation, which can be written as:

$$t = \frac{1}{2}\log_e\left[\frac{1+r}{1-r}\right]\sqrt{n-3}$$

where n is the sample size and r is the observed correlation coefficient. It can be shown that t is normally distributed with mean 0 and unit variance, and the sample size to detect a statistical significance of t can be derived as:

$$N = \frac{(z_\alpha + z_b)^2}{\frac{1}{4}\left[\log_e\left(\frac{1+\rho}{1-\rho}\right)\right]^2} + 3 \qquad [4]$$

For instance, the sample size required to detect a correlation coefficient of 0.5 at the significance level of 5% (α = 0.05) and power 80% (β = 0.2) is:

$$N = \frac{(1.64 + 0.84)^2}{\frac{1}{4}\left[\log_e\left(\frac{1+0.5}{1-0.5}\right)\right]^2} + 3 \cong 23 \qquad //$$

II. TWO PARALLEL GROUPS

2.1 Determination of sample size for testing differences between means

Consider the one-sided significance test for comparing the means μ_1 and μ_2 of X_1 and X_2, respectively, where X_1 and X_2 are two random variables representing the endpoint in the two groups. To test:

$$H_o: \mu_1 = \mu_2$$

$$H_1: \mu_1 = \mu_2 + \Delta$$

Let n_1 and n_2 be the sample sizes for groups 1 and 2, respectively; $N = n_1 + n_2$ be the total sample size, and $r = \frac{n_1}{n_2}$ be the ratio of sample sizes in first and second groups. Also, let σ be the common standard deviation of X_1 and X_2, and z_γ be the value from tables of cumulative normal distributions, i.e. $P(Z < z_\gamma) = 1 - \gamma$ for a standard normal, Z

α = P(type I error)
   = P(reject H_o | H_o is true)
   = size of test

β = P(type II error)
   = 1 - P(reject H_o | H_1 is true)
   = 1 - (Power of test)

Assuming that X_1 and X_2 are normally distributed, then the required total sample size is given by:

$$N = \frac{(r+1)^2 (z_\alpha + z_\beta)^2 \sigma^2}{r\Delta^2}$$

Note that the difference Δ can also be expressed in terms of the standard deviation σ (as a *Z* score) by:

$$Z = \frac{\Delta}{\sigma}$$

then, the above formula becomes:

$$N = \frac{(r+1)^2 (z_\alpha + z_\beta)^2}{rZ^2} \qquad [5]$$

Tabulation of this formula is given in Table 1 in the appendix section. Note that in this table, **N1:N2** is equivalent to *r* of equation [5].

This is the formula used in many introductory texts. It rejects H_O whenever the difference between means is large in *either* direction.

Evaluation of power

These basic formulae can be used to estimate the smallest difference which can be detected (Δ) or the power of a study which has been performed. For example, using [5], we can also write:

$$\Delta = \frac{(r+1)(z_\alpha + z_\beta)\sigma}{\sqrt{rN}}$$

or

$$z_\beta = \frac{\Delta\sqrt{rN}}{\sigma(r+1)} - z_\alpha \qquad [6]$$

2.2 Determination of sample size for testing differences between two proportions

Let π_1 and π_2 be the proportions with the endpoint of interest in the two population. The usual null and alternative hypothesis could be stated as:

$$H_o: \pi_1 = \pi_2$$

$$H_1: \pi_1 = \pi_2 + \Delta \qquad \text{or} \qquad H_1: \frac{\pi_1}{\pi_2} = R$$

In practice, we do not know π_1 and π_2, but have to estimate them from sample data. Let p_1 and p_2 be the two respective estimates from two samples of populations, then the test of whether π_1 and π_2 are difference is given by the well-known statistic:

$$T = \frac{p_1 - p_2}{K}$$

which, in this case, arising from a normal approximation to a binomial.

where $K = \sqrt{p(1-p)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$

and $p = \frac{n_1 p_1 + n_2 p_2}{n_1 + n_2}$ is the average proportion of the two samples.

For a one-sided test of size α and power 1-β, reject H_o if $T > z_\alpha$ such that $P(T > z_\alpha \mid H_1 true) = 1 - \beta$.

Now, when H_1 is true $\frac{p_1 - p_2 - (R-1)\pi}{\sqrt{\frac{R\pi(1-R\pi)}{n_1} + \frac{\pi(1-\pi)}{n_2}}}$ is normally distributed with mean 0 and variance of 1.

Let $K_1 = \sqrt{\frac{R\pi(1-R\pi)}{n_1} + \frac{\pi(1-\pi)}{n_2}}$,

then:

$$P(T > z_\alpha \mid H_1 true) = P\left\{\frac{p_1 - p_2 - (R-1)\pi}{K_1} > z_\alpha \frac{K}{K_1} - \frac{(R-1)\pi}{K_1} \middle| H_1 true\right\}$$

$$= P\left(Z > \frac{z_a K - (R-1)\pi}{K_1}\right)$$

$$= 1 - \beta$$

=> $z_\alpha K - (R-1)\pi = z_{1-\beta} K_1 = -z_\beta K_1$

=> $z_\alpha K + z_\beta K_1 = (R-1)\pi$

Substituting for K and K_1 and rearranging gives:

$$\boxed{N = \frac{r+1}{r(R-1)^2 \pi^2}\left[z_\alpha \sqrt{(r+1)p(1-p)} + z_\beta \sqrt{R\pi(1-R\pi) + r\pi(1-\pi)}\right]^2} \quad [7]$$

Now p is unknown in advance, but a reasonable approximation may be obtained by assuming that p_1 and p_2 take their population values under H_1, i.e. $R\pi$ and π, respectively. Thus:

$$p \approx \frac{n_1 R\pi + n_2\pi}{n_1 + n_2} = \frac{\pi(rR+1)}{r+1}$$

Tabulation of this formula is given in Table 2 in the appendix section. Note that in this table, **RR** (the relative risk) is equivalent to *R* of equation [7], **P** is equivalent to π of equation [7] and **N1:N2** is equivalent to *r* in the equation.

Evaluation of power

For a given value of *R*, *r* and π, we can evaluate the power of a study by using the following formula:

$$z_\beta = \frac{\pi(|R-1|)\sqrt{rN} - z_\alpha(r+1)\sqrt{p(1-p)}}{\sqrt{(r+1)[R\pi(1-R\pi)+r\pi(1-\pi)]}} \qquad [8]$$

2.3 Determination of sample size for case-control studies

In a case control study, data are often summarised by an odds ratio or relative risk, rather than a difference between proportions. If p_1 is the proportion of cases exposed to a risk factor and p_2 is the proportion of controls exposed to the same risk factor, then the odds ratio of being a case given the risk factor is odds ratio (OR)

$$\text{OR} = \frac{p_1(1-p_2)}{p_2(1-p_1)}$$

An approximate sample size formula for this design is:

$$N = \frac{(1+r)^2(z_{\alpha/2}+z_\beta)^2}{r(\ln OR)^2\,\overline{p}(1-\overline{p})} \qquad [9]$$

Tabulation of this formula is given in Table 3 in the appendix section. Note that in this table, **P** is equivalent to $\overline{p}$ of equation [9] and **N1:N2** is equivalent to *r* in the equation.

2.4 Determination of sample size for testing differences between two correlation coefficients

In detecting a relevant difference between two correlation coefficients r_1 and r_2 obtained from two independent samples of sizes n_1 and n_2, respectively, we need to firstly transform these coefficients into z value as follows:

$$z_1 = \frac{1}{2}\log_e\left[\frac{1+r_1}{1-r_1}\right]$$

and

$$z_2 = \frac{1}{2}\log_e\left[\frac{1+r_2}{1-r_2}\right]$$

These two statistics have variances equal to $\frac{1}{n_1-3}$ and $\frac{1}{n_2-3}$, respectively.

To test the hypothesis of

$$H_o: \rho_1 = \rho_2$$

against

$$H_1: \rho_1 \neq \rho_2$$

we use the statistic:

$$t = \frac{z_1 - z_2}{\sqrt{\frac{n_1+n_2-6}{(n_1-3)(n_2-3)}}}$$

which is normally distributed with mean 0 and unit variance.

With a specification of power 1-β, the above equation can be solved for total sample size N as follows:

$$N = \frac{4(z_\alpha + z_\beta)^2}{(z_1 - z_2)^2} \qquad [10]$$

For instance the sample size required to detect a difference between two correlation coefficients of 0.4 and 0.8 at the significance level of 5% (two-tailed) test and 90% power can be calculated as follows:

$$z(0.4) = \frac{1}{2}\ln\left(\frac{1+0.4}{1-0.4}\right) = 0.424$$

$$z(0.8) = \frac{1}{2}\ln\left(\frac{1+0.8}{1-0.8}\right) = 1.098$$

and $$N = \frac{4(1.96+1.28)^2}{(0.424-1.098)^2} = 92$$ subjects or 46 in each group.

Full tabulation of sample size (N) for various correlation coefficients based on formula [10] is given in Table 4. Note that in this table the ratio of sample size for group 1 to that of group 2 is assumed to be 1.

III. MORE THAN TWO PARALLEL GROUPS

The determination of sample sizes required in the comparison of g groups when $g > 2$ is far more complicated than the determination of sample sizes for the case $g = 2$. Consider first the comparison of g parallel groups with n subjects studied in each. Let $\mu_1, \mu_2, \ldots, \mu_g$ denote the g underlying means, let σ^2 denote the assumed common underlying variance, and assume that the measurements in each group are independently and normally distributed. Under the statistical hypothesis that

$$H_o: \mu_1 = \mu_2 = \ldots = \mu_g,$$

the ratio of mean squares from the analysis of variance table

$$F = \frac{BMS}{WMS}$$

has the so-called central F distribution. This distribution has two parameters, the number of degrees of freedom in the mean square between groups (BMS), say $v = g - 1$, and the number of degrees of freedom in the mean square within groups (WMS), say, $u = g(n - 1)$.

When the hypothesis is not true, meaning that at least two of the underlying means are unequal, the test statistic has a distribution, the non-central F distribution, which depends on a third quantity termed the non-centrality parameter:

$$\delta = \frac{\sqrt{n\sum(\mu_i - \bar{\mu})^2}}{\sigma}$$

where $\bar{\mu} = \frac{1}{g}\sum \mu_i$.

Let $F_{v,u,\delta}$ denote a random variable having the non-central F distribution with df *v, u* and parameter δ. A statistical statement of the problem of sample size determination is as follows. Let the significance level be α as well as the value of the underlying variance σ^2 and the values of the mean $\mu_1, \mu_2 \ldots, \mu_g$ which, if they indeed characterised the *g* groups, would be considered clinically significant that the chances should be 1 - β of finding statistical significance. Significance would be declared if the ratio of MS exceeded the tabulated value of $F_{v,u,\alpha}$ and the probability statement defining the power is:

$$P(F_{v,u,\delta} > F_{v,u,\alpha}) = 1 - \beta$$

Let F* = $F_{v,u,\alpha}$ and define:

$$\lambda = \frac{\sum(\mu_i - \bar{\mu})^2}{(g-1)\sigma^2}$$

a parameter whose value does not depend on *n*. The non-central parameter is obviously related to λ by means of the expression:

$$\delta^2 = n(g-1)\lambda$$

With the values of *g,* λ*,* α and β specified, the required sample size per group, *n*, is such that the equation:

$$Z_\beta = \frac{1}{\sqrt{(g-1)(1+n\lambda)F^* + g(n-1)(1+2n\lambda)}}$$

$$\times\left(\sqrt{g(n-1)\left[2(g-1)(1+n\lambda)^2 - (1+2n\lambda)\right]} - \sqrt{F^*(g-1)(1+n\lambda)(2g(n-1)-1)}\right)$$

is approximately satisfied.

For *g* = 4 groups, using α = 0.05 and assume that the value of the standard deviation within each group is σ = 3, and that the four means $\mu_1 = 9.775$, $\mu_2 = \mu_3 = 12$ and $\mu_4 = 14.225$, represent such clinically significant that the power 1- β = 0.8 when those are the underlying means, the value of $\lambda = \frac{9.901}{3 \times 9} = 0.367$

You are required to verify that for n = 10, $F^* = F_{3,36,0.05} = 2.85$ and $z_\beta = 0.712$. For n = 11, $F^* = F_{3,40,0.05} = 2.83$, $z_\beta = 0.873$. Thus n = 11 is the required sample size.

IV. SOME COMMENTS

Some basic formulae for calculating sample sizes have been presented. It would be appropriate to summarise a few points here:

(a) In designing a study, an investigator must consider the issue of sample size. With respect to this, the investigator must specify four values: (i) the level of significance α (type I error); (ii) the power (1-β) of type II error; (iii) the difference of clinical significance to be detected and (iv) the (estimated) standard deviation for the significance test.

All of these values are interlinked:

(b) As have been implicitly assumed from these formulae, the larger the sample size, the larger the power.

(c) The larger the difference to be detected, the larger the power required. Large sample sizes will be needed in order to have a high power to detect a small difference.

(d) The larger the variability as represented by the standard deviation, the weaker the power.

(e) If α is increased, power is increased (β is decreased). An increase in α results in a smaller Z.

V. EXERCISES

1. Refer to the Melhus et al study - ask to calculate power.

2. Refer to the Looney et al study - power ?

3. R Prince's study

4. Abstract in Wayne State University

4. How many subjects would you need to estimate a proportion of within ±5% (95% confidence interval) if the expected proportion is 10% in the general population?

5. Two diets are to be compared with regard to weight gain of weaning rats. If the weight gains due to the diets differ by 10 g or more, we would like to be 80% sure that we obtain a significant results. How many rats should be in each group if the standard deviation is estimated to be 5 g and the test will be performed at 5% significance level.

6. An investigator hypothesises that the improvement rate associated with a placebo is 0.45 and that the improvement rate associated with an active drug is 0.65. He plans to perform a one-tailed test.
(a) If the desired significance level is 0.01 and a power of $1 - \beta = 0.95$, how large a sample per treatment must he study?
(b) How large must this sample sizes if he relaxes his significance level to 0.05 and power 0.80?

Table 1:
SAMPLE SIZE FOR VARIOUS STANDARDISED DIFFERENCES
POWER = 0.90 AND ALPHA = 0.025

	N1:N2								
	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3
Z									
0.10	4203	4256	4378	4541	4728	4933	5149	5373	5604
0.15	1868	1891	1946	2018	2101	2192	2288	2388	2491
0.20	1051	1064	1095	1135	1182	1233	1287	1343	1401
0.25	672	681	700	727	757	789	824	860	897
0.30	467	473	486	505	525	548	572	597	623
0.35	343	347	357	371	386	403	420	439	457
0.40	263	266	274	284	296	308	322	336	350
0.45	208	210	216	224	233	244	254	265	277
0.50	168	170	175	182	189	197	206	215	224
0.55	139	141	145	150	156	163	170	178	185
0.60	117	118	122	126	131	137	143	149	156
0.65	99	101	104	107	112	117	122	127	133
0.70	86	87	89	93	96	101	105	110	114
0.75	75	76	78	81	84	88	92	96	100
0.80	66	66	68	71	74	77	80	84	88
0.85	58	59	61	63	65	68	71	74	78
0.90	52	53	54	56	58	61	64	66	69
0.95	47	47	49	50	52	55	57	60	62
1.00	42	43	44	45	47	49	51	54	56
1.05	38	39	40	41	43	45	47	49	51
1.10	35	35	36	38	39	41	43	44	46
1.15	32	32	33	34	36	37	39	41	42
1.20	29	30	30	32	33	34	36	37	39
1.25	27	27	28	29	30	32	33	34	36
1.30	25	25	26	27	28	29	30	32	33
1.35	23	23	24	25	26	27	28	29	31
1.40	21	22	22	23	24	25	26	27	29
1.45	20	20	21	22	22	23	24	26	27
1.50	19	19	19	20	21	22	23	24	25
1.55	17	18	18	19	20	21	21	22	23
1.60	16	17	17	18	18	19	20	21	22
1.65	15	16	16	17	17	18	19	20	21
1.70	15	15	15	16	16	17	18	19	19
1.75	14	14	14	15	15	16	17	18	18
1.80	13	13	14	14	15	15	16	17	17
1.85	12	12	13	13	14	14	15	16	16
1.90	12	12	12	13	13	14	14	15	16
1.95	11	11	12	12	12	13	14	14	15
2.00	11	11	11	11	12	12	13	13	14
2.05	10	10	10	11	11	12	12	13	13
2.10	10	10	10	10	11	11	12	12	13
2.15	9	9	9	10	10	11	11	12	12
2.20	9	9	9	9	10	10	11	11	12
2.25	8	8	9	9	9	10	10	11	11
2.30	8	8	8	9	9	9	10	10	11
2.35	8	8	8	8	9	9	9	10	10
2.40	7	7	8	8	8	9	9	9	10
2.45	7	7	7	8	8	8	9	9	9

(CONTINUED)

Table 1 (Cont)
SAMPLE SIZE FOR VARIOUS STANDARDISED DIFFERENCES
POWER = 0.90 AND ALPHA = 0.025

	N1:N2								
	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3
Z									
2.50	7	7	7	7	8	8	8	9	9
2.55	6	7	7	7	7	8	8	8	9
2.60	6	6	6	7	7	7	8	8	8
2.65	6	6	6	6	7	7	7	8	8
2.70	6	6	6	6	6	7	7	7	8
2.75	6	6	6	6	6	7	7	7	7
2.80	5	5	6	6	6	6	7	7	7
2.85	5	5	5	6	6	6	6	7	7
2.90	5	5	5	5	6	6	6	6	7
2.95	5	5	5	5	5	6	6	6	6
3.00	5	5	5	5	5	5	6	6	6

Table 2:
SAMPLE SIZE FOR VARIOUS RELATIVE RISK (RR)
POWER = 0.90 AND ALPHA = 0.025

		N1:N2								
		1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
P	RR									
0.1	0.50	1162	1168	1194	1231	1276	1325	1377	1432	1489
	0.75	5365	5416	5557	5751	5978	6226	6490	6765	7048
	1.25	6710	6809	7017	7288	7597	7933	8287	8653	9030
	1.50	1835	1865	1924	2000	2086	2179	2278	2379	2484
	1.75	882	897	927	964	1006	1051	1099	1148	1198
	2.00	532	542	559	582	607	635	664	693	724
	2.25	362	369	381	397	414	433	452	472	493
	2.50	266	271	280	291	304	317	332	347	362
	2.75	205	209	216	225	234	245	256	267	279
	3.00	164	167	173	180	188	196	205	214	223
	3.25	135	137	142	148	154	161	168	175	183
	3.50	113	115	119	124	129	135	141	147	153
	3.75	96	98	102	106	110	115	120	125	130
	4.00	83	85	88	91	95	99	103	108	112
0.2	0.50	532	535	547	564	585	608	632	657	683
	0.75	2423	2447	2512	2600	2703	2816	2935	3060	3188
	1.25	2927	2969	3059	3176	3310	3456	3609	3768	3932
	1.50	784	796	821	852	889	928	969	1012	1056
	1.75	368	374	386	401	418	436	456	476	497
	2.00	216	220	227	236	246	256	268	279	291
	2.25	143	146	150	156	162	169	177	184	192
	2.50	102	104	107	111	115	120	125	131	136
	2.75	76	77	80	83	86	89	93	97	101
	3.00	59	60	61	63	66	69	71	74	77
	3.25	46	47	48	50	52	54	56	58	61
	3.50	37	38	39	40	41	43	45	46	48
	3.75	30	31	31	32	33	35	36	37	39
	4.00	25	25	26	26	27	28	29	30	31
0.3	0.50	322	324	331	342	355	368	383	399	415
	0.75	1442	1457	1496	1549	1611	1679	1750	1825	1902
	1.25	1667	1689	1740	1805	1881	1963	2050	2140	2232
	1.50	434	440	453	470	490	511	533	557	581
	1.75	197	200	206	213	222	232	242	252	263
	2.00	111	113	116	120	125	130	136	141	147
	2.25	70	71	73	76	79	82	85	88	92
	2.50	47	48	49	51	52	54	57	59	61
	2.75	33	33	34	35	36	38	39	40	42
	3.00	24	24	24	25	25	26	27	28	29
	3.25	17	17	17	17	18	18	19	19	20
	3.50	12	12	12	12	12	12	12	13	13
	3.75	7	8	8	8	8	8	8	8	8
	4.00	.	4	5	5	5	4	4	4	3
0.4	0.50	216	218	223	231	239	249	259	269	280
	0.75	952	962	989	1024	1065	1110	1158	1207	1258
	1.25	1036	1049	1080	1120	1166	1217	1270	1325	1382
	1.50	259	262	269	279	290	302	315	329	343
	1.75	111	113	115	119	124	129	134	140	145
	2.00	59	59	61	62	65	67	70	72	75
	2.25	34	34	35	36	37	38	39	40	42
	2.50	20	20	20	21	21	21	22	22	23
	2.75	11	11	11	11	11	11	11	11	11
	3.00	.	5	5	5	5	5	4	3	2

P: Prevalent proportion
RR: Relative risk

(CONTINUED)

Table 2:
SAMPLE SIZE FOR VARIOUS RELATIVE RISK (RR)
POWER = 0.90 AND ALPHA = 0.025

		N1:N2								
		1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
P	RR									
0.5	0.50	153	155	159	164	170	177	184	192	199
	0.75	658	665	684	709	738	769	802	837	872
	1.25	658	665	684	709	738	769	802	837	872
	1.50	153	155	159	164	170	177	184	192	199
	1.75	60	60	61	63	65	67	70	72	75
	2.00	27	27	27	28	28	29	30	30	31
	2.25	12	12	12	11	11	11	11	10	10
	2.50	.	2	3	2	1	.	.	.	.
0.6	0.50	111	113	115	119	124	129	134	140	145
	0.75	462	468	481	499	519	541	565	589	614
	1.25	406	409	420	435	452	470	490	510	532
	1.50	83	84	85	87	90	93	96	100	103
	1.75	26	25	25	25	26	26	26	26	26
	2.00	4	5	5	4	2	.	.	.	.
0.7	0.50	81	82	85	88	91	95	99	103	107
	0.75	322	326	336	348	363	379	395	412	430
	1.00	.	.	.	.	.	.	.	.	.
	1.25	225	227	232	239	247	256	266	277	288
	1.50	33	33	32	32	32	32	32	32	32
0.8	0.50	59	60	61	63	66	69	71	74	77
	0.75	216	220	227	236	246	256	268	279	291
	1.25	90	89	90	91	93	95	97	99	101
0.9	0.50	41	42	43	45	46	48	50	52	54
	0.75	135	137	142	148	154	161	168	175	183

P: Prevalent proportion
RR: Relative risk

Table 3:
SAMPLE SIZE FOR VARIOUS ODDS RATIOS AND PREVALANCE - CASE CONTROL STUDY
POWER = 0.90 AND ALPHA = 0.05

		N1:N2								
		1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
P	OR									
0.10	0.25	243	246	253	263	273	285	298	311	324
	0.50	972	984	1012	1050	1093	1141	1191	1243	1296
	0.75	5643	5713	5878	6096	6348	6622	6912	7214	7524
	1.25	9379	9496	9770	10132	10551	11007	11489	11990	12505
	1.50	2841	2876	2959	3069	3196	3334	3480	3631	3787
	1.75	1491	1510	1553	1611	1678	1750	1827	1906	1988
	2.00	972	984	1012	1050	1093	1141	1191	1243	1296
	2.25	710	719	740	767	799	833	870	908	947
	2.50	556	563	579	601	626	653	681	711	742
	2.75	456	462	475	493	513	536	559	583	608
	3.00	387	392	403	418	435	454	474	495	516
	3.25	336	340	350	363	378	395	412	430	448
	3.50	298	301	310	321	335	349	365	380	397
	3.75	267	271	278	289	301	314	327	342	356
	4.00	243	246	253	263	273	285	298	311	324
0.15	0.25	172	174	179	185	193	201	210	219	229
	0.50	686	695	715	741	772	805	840	877	915
	0.75	3983	4033	4149	4303	4481	4675	4879	5092	5311
	1.25	6620	6703	6896	7152	7448	7770	8110	8463	8827
	1.50	2005	2030	2089	2166	2256	2353	2456	2563	2673
	1.75	1053	1066	1096	1137	1184	1235	1289	1346	1403
	2.00	686	695	715	741	772	805	840	877	915
	2.25	501	508	522	542	564	588	614	641	668
	2.50	393	398	409	424	442	461	481	502	524
	2.75	322	326	336	348	362	378	395	412	430
	3.00	273	277	285	295	307	321	335	349	364
	3.25	237	240	247	256	267	278	291	303	316
	3.50	210	213	219	227	236	247	257	269	280
	3.75	189	191	197	204	212	221	231	241	252
	4.00	172	174	179	185	193	201	210	219	229
0.20	0.25	137	138	142	148	154	160	167	175	182
	0.50	547	554	570	591	615	642	670	699	729
	0.75	3174	3214	3306	3429	3571	3725	3888	4058	4232
	1.25	5276	5341	5495	5699	5935	6191	6463	6744	7034
	1.50	1598	1618	1664	1726	1798	1875	1957	2043	2130
	1.75	839	849	874	906	944	984	1028	1072	1118
	2.00	547	554	570	591	615	642	670	699	729
	2.25	399	404	416	432	449	469	489	511	533
	2.50	313	317	326	338	352	367	383	400	417
	2.75	257	260	267	277	289	301	314	328	342
	3.00	218	220	227	235	245	255	267	278	290
	3.25	189	191	197	204	213	222	232	242	252
	3.50	167	169	174	181	188	196	205	214	223
	3.75	150	152	157	162	169	176	184	192	200
	4.00	137	138	142	148	154	160	167	175	182
0.25	0.25	117	118	121	126	131	137	143	149	156
	0.50	467	472	486	504	525	548	572	596	622
	0.75	2709	2742	2821	2926	3047	3179	3318	3463	3611

P: Average proportion for group 1 and group 2;
OR: Odds ratio;
N1:N2 : Ratio of sample size N1 over N2.

(CONTINUED)

Table 3:
SAMPLE SIZE FOR VARIOUS ODDS RATIOS AND PREVALANCE - CASE CONTROL STUDY
POWER = 0.90 AND ALPHA = 0.05

		N1:N2								
		1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
P	OR									
0.25	1.25	4502	4558	4689	4864	5065	5283	5515	5755	6002
	1.50	1363	1381	1420	1473	1534	1600	1670	1743	1818
	1.75	716	725	746	773	805	840	877	915	954
	2.00	467	472	486	504	525	548	572	596	622
	2.25	341	345	355	368	383	400	418	436	454
	2.50	267	270	278	288	300	313	327	341	356
	2.75	219	222	228	237	246	257	268	280	292
	3.00	186	188	193	201	209	218	228	237	248
	3.25	161	163	168	174	182	189	198	206	215
	3.50	143	145	149	154	161	168	175	183	190
	3.75	128	130	134	139	144	151	157	164	171
	4.00	117	118	121	126	131	137	143	149	156
0.30	0.25	104	105	108	113	117	122	128	133	139
	0.50	417	422	434	450	469	489	510	533	555
	0.75	2418	2449	2519	2613	2721	2838	2962	3092	3224
	1.25	4019	4070	4187	4342	4522	4717	4924	5139	5359
	1.50	1217	1233	1268	1315	1370	1429	1491	1556	1623
	1.75	639	647	666	690	719	750	783	817	852
	2.00	417	422	434	450	469	489	510	533	555
	2.25	304	308	317	329	342	357	373	389	406
	2.50	238	241	248	258	268	280	292	305	318
	2.75	196	198	204	211	220	230	240	250	261
	3.00	166	168	173	179	187	195	203	212	221
	3.25	144	146	150	156	162	169	176	184	192
	3.50	128	129	133	138	143	150	156	163	170
	3.75	115	116	119	124	129	134	140	146	153
	4.00	104	105	108	113	117	122	128	133	139
0.35	0.25	96	97	100	104	108	113	118	123	128
	0.50	385	389	401	415	433	451	471	492	513
	0.75	2232	2260	2325	2412	2511	2620	2735	2854	2976
	1.25	3710	3757	3865	4008	4174	4354	4545	4743	4947
	1.50	1124	1138	1171	1214	1264	1319	1377	1437	1498
	1.75	590	597	615	637	664	692	723	754	787
	2.00	385	389	401	415	433	451	471	492	513
	2.25	281	284	293	304	316	330	344	359	375
	2.50	220	223	229	238	248	258	270	281	293
	2.75	181	183	188	195	203	212	221	231	241
	3.00	153	155	159	165	172	180	188	196	204
	3.25	133	135	139	144	150	156	163	170	177
	3.50	118	119	123	127	132	138	144	150	157
	3.75	106	107	110	114	119	124	130	135	141
	4.00	96	97	100	104	108	113	118	123	128
0.40	0.25	91	92	95	98	103	107	112	116	121
	0.50	364	369	380	394	410	428	447	466	486
	0.75	2116	2142	2204	2286	2381	2483	2592	2705	2821
	1.25	3517	3561	3664	3800	3957	4128	4308	4496	4689
	1.50	1065	1079	1110	1151	1198	1250	1305	1362	1420
	1.75	559	566	582	604	629	656	685	715	746

P: Average proportion for group 1 and group 2;
OR: Odds ratio;
N1:N2 : Ratio of sample size N1 over N2.

(CONTINUED)

Table 3:
SAMPLE SIZE FOR VARIOUS ODDS RATIOS AND PREVALANCE - CASE CONTROL STUDY
POWER = 0.90 AND ALPHA = 0.05

		N1:N2								
		1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
P	OR									
0.40	2.00	364	369	380	394	410	428	447	466	486
	2.25	266	270	277	288	300	313	326	340	355
	2.50	209	211	217	225	235	245	256	267	278
	2.75	171	173	178	185	193	201	210	219	228
	3.00	145	147	151	157	163	170	178	185	193
	3.25	126	128	131	136	142	148	154	161	168
	3.50	112	113	116	121	126	131	137	143	149
	3.75	100	101	104	108	113	118	123	128	134
	4.00	91	92	95	98	103	107	112	116	121
0.45	0.25	88	89	92	95	99	104	108	113	118
	0.50	353	358	368	382	398	415	433	452	471
	0.75	2052	2078	2137	2217	2308	2408	2514	2623	2736
	1.25	3410	3453	3553	3685	3837	4003	4178	4360	4547
	1.50	1033	1046	1076	1116	1162	1212	1265	1321	1377
	1.75	542	549	565	586	610	636	664	693	723
	2.00	353	358	368	382	398	415	433	452	471
	2.25	258	261	269	279	291	303	316	330	344
	2.50	202	205	211	219	228	237	248	259	270
	2.75	166	168	173	179	187	195	203	212	221
	3.00	141	142	147	152	158	165	172	180	188
	3.25	122	124	127	132	138	143	150	156	163
	3.50	108	110	113	117	122	127	133	138	144
	3.75	97	98	101	105	109	114	119	124	130
	4.00	88	89	92	95	99	104	108	113	118
0.50	0.25	87	89	91	95	98	103	107	112	117
	0.50	350	354	364	378	394	411	429	447	467
	0.75	2031	2057	2116	2195	2285	2384	2488	2597	2709
	1.25	3376	3419	3517	3648	3798	3963	4136	4316	4502
	1.50	1023	1035	1065	1105	1150	1200	1253	1307	1363
	1.75	537	544	559	580	604	630	658	686	716
	2.00	350	354	364	378	394	411	429	447	467
	2.25	256	259	266	276	288	300	313	327	341
	2.50	200	203	209	216	225	235	245	256	267
	2.75	164	166	171	177	185	193	201	210	219
	3.00	139	141	145	150	157	163	171	178	186
	3.25	121	123	126	131	136	142	148	155	161
	3.50	107	108	112	116	121	126	131	137	143
	3.75	96	97	100	104	108	113	118	123	128
	4.00	87	89	91	95	98	103	107	112	117
0.55	0.25	88	89	92	95	99	104	108	113	118
	0.50	353	358	368	382	398	415	433	452	471
	0.75	2052	2078	2137	2217	2308	2408	2514	2623	2736
	1.25	3410	3453	3553	3685	3837	4003	4178	4360	4547
	1.50	1033	1046	1076	1116	1162	1212	1265	1321	1377
	1.75	542	549	565	586	610	636	664	693	723
	2.00	353	358	368	382	398	415	433	452	471
	2.25	258	261	269	279	291	303	316	330	344
	2.50	202	205	211	219	228	237	248	259	270

P: Average proportion for group 1 and group 2;
OR: Odds ratio;
N1:N2 : Ratio of sample size N1 over N2.

(CONTINUED)

Table 3:
SAMPLE SIZE FOR VARIOUS ODDS RATIOS AND PREVALANCE - CASE CONTROL STUDY
POWER = 0.90 AND ALPHA = 0.05

		N1:N2								
		1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
P	OR									
0.55	2.75	166	168	173	179	187	195	203	212	221
	3.00	141	142	147	152	158	165	172	180	188
	3.25	122	124	127	132	138	143	150	156	163
	3.50	108	110	113	117	122	127	133	138	144
	3.75	97	98	101	105	109	114	119	124	130
	4.00	88	89	92	95	99	104	108	113	118
0.60	0.25	91	92	95	98	103	107	112	116	121
	0.50	364	369	380	394	410	428	447	466	486
	0.75	2116	2142	2204	2286	2381	2483	2592	2705	2821
	1.25	3517	3561	3664	3800	3957	4128	4308	4496	4689
	1.50	1065	1079	1110	1151	1198	1250	1305	1362	1420
	1.75	559	566	582	604	629	656	685	715	746
	2.00	364	369	380	394	410	428	447	466	486
	2.25	266	270	277	288	300	313	326	340	355
	2.50	209	211	217	225	235	245	256	267	278
	2.75	171	173	178	185	193	201	210	219	228
	3.00	145	147	151	157	163	170	178	185	193
	3.25	126	128	131	136	142	148	154	161	168
	3.50	112	113	116	121	126	131	137	143	149
	3.75	100	101	104	108	113	118	123	128	134
	4.00	91	92	95	98	103	107	112	116	121
0.65	0.25	96	97	100	104	108	113	118	123	128
	0.50	385	389	401	415	433	451	471	492	513
	0.75	2232	2260	2325	2412	2511	2620	2735	2854	2976
	1.25	3710	3757	3865	4008	4174	4354	4545	4743	4947
	1.50	1124	1138	1171	1214	1264	1319	1377	1437	1498
	1.75	590	597	615	637	664	692	723	754	787
	2.00	385	389	401	415	433	451	471	492	513
	2.25	281	284	293	304	316	330	344	359	375
	2.50	220	223	229	238	248	258	270	281	293
	2.75	181	183	188	195	203	212	221	231	241
	3.00	153	155	159	165	172	180	188	196	204
	3.25	133	135	139	144	150	156	163	170	177
	3.50	118	119	123	127	132	138	144	150	157
	3.75	106	107	110	114	119	124	130	135	141
	4.00	96	97	100	104	108	113	118	123	128
0.70	0.25	104	105	108	113	117	122	128	133	139
	0.50	417	422	434	450	469	489	510	533	555
	0.75	2418	2449	2519	2613	2721	2838	2962	3092	3224
	1.25	4019	4070	4187	4342	4522	4717	4924	5139	5359
	1.50	1217	1233	1268	1315	1370	1429	1491	1556	1623
	1.75	639	647	666	690	719	750	783	817	852
	2.00	417	422	434	450	469	489	510	533	555
	2.25	304	308	317	329	342	357	373	389	406
	2.50	238	241	248	258	268	280	292	305	318
	2.75	196	198	204	211	220	230	240	250	261
	3.00	166	168	173	179	187	195	203	212	221
	3.25	144	146	150	156	162	169	176	184	192

P: Average proportion for group 1 and group 2;
OR: Odds ratio;
N1:N2 : Ratio of sample size N1 over N2.

(CONTINUED)

Table 3:
SAMPLE SIZE FOR VARIOUS ODDS RATIOS AND PREVALANCE - CASE CONTROL STUDY
POWER = 0.90 AND ALPHA = 0.05

		N1:N2								
P	OR	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
0.70	3.50	128	129	133	138	143	150	156	163	170
	3.75	115	116	119	124	129	134	140	146	153
	4.00	104	105	108	113	117	122	128	133	139
0.75	0.25	117	118	121	126	131	137	143	149	156
	0.50	467	472	486	504	525	548	572	596	622
	0.75	2709	2742	2821	2926	3047	3179	3318	3463	3611
	1.25	4502	4558	4689	4864	5065	5283	5515	5755	6002
	1.50	1363	1381	1420	1473	1534	1600	1670	1743	1818
	1.75	716	725	746	773	805	840	877	915	954
	2.00	467	472	486	504	525	548	572	596	622
	2.25	341	345	355	368	383	400	418	436	454
	2.50	267	270	278	288	300	313	327	341	356
	2.75	219	222	228	237	246	257	268	280	292
	3.00	186	188	193	201	209	218	228	237	248
	3.25	161	163	168	174	182	189	198	206	215
	3.50	143	145	149	154	161	168	175	183	190
	3.75	128	130	134	139	144	151	157	164	171
	4.00	117	118	121	126	131	137	143	149	156
0.80	0.25	137	138	142	148	154	160	167	175	182
	0.50	547	554	570	591	615	642	670	699	729
	0.75	3174	3214	3306	3429	3571	3725	3888	4058	4232
	1.25	5276	5341	5495	5699	5935	6191	6463	6744	7034
	1.50	1598	1618	1664	1726	1798	1875	1957	2043	2130
	1.75	839	849	874	906	944	984	1028	1072	1118
	2.00	547	554	570	591	615	642	670	699	729
	2.25	399	404	416	432	449	469	489	511	533
	2.50	313	317	326	338	352	367	383	400	417
	2.75	257	260	267	277	289	301	314	328	342
	3.00	218	220	227	235	245	255	267	278	290
	3.25	189	191	197	204	213	222	232	242	252
	3.50	167	169	174	181	188	196	205	214	223
	3.75	150	152	157	162	169	176	184	192	200
	4.00	137	138	142	148	154	160	167	175	182
0.85	0.25	172	174	179	185	193	201	210	219	229
	0.50	686	695	715	741	772	805	840	877	915
	0.75	3983	4033	4149	4303	4481	4675	4879	5092	5311
	1.25	6620	6703	6896	7152	7448	7770	8110	8463	8827
	1.50	2005	2030	2089	2166	2256	2353	2456	2563	2673
	1.75	1053	1066	1096	1137	1184	1235	1289	1346	1403
	2.00	686	695	715	741	772	805	840	877	915
	2.25	501	508	522	542	564	588	614	641	668
	2.50	393	398	409	424	442	461	481	502	524
	2.75	322	326	336	348	362	378	395	412	430
	3.00	273	277	285	295	307	321	335	349	364
	3.25	237	240	247	256	267	278	291	303	316
	3.50	210	213	219	227	236	247	257	269	280
	3.75	189	191	197	204	212	221	231	241	252
	4.00	172	174	179	185	193	201	210	219	229

P: Average proportion for group 1 and group 2;
OR: Odds ratio;
N1:N2 : Ratio of sample size N1 over N2.

(CONTINUED)

Table 3:
SAMPLE SIZE FOR VARIOUS ODDS RATIOS AND PREVALANCE - CASE CONTROL STUDY
POWER = 0.90 AND ALPHA = 0.05

		N1:N2								
		1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
P	OR									
0.90	0.25	243	246	253	263	273	285	298	311	324
	0.50	972	984	1012	1050	1093	1141	1191	1243	1296
	0.75	5643	5713	5878	6096	6348	6622	6912	7214	7524
	1.25	9379	9496	9770	10132	10551	11007	11489	11990	12505
	1.50	2841	2876	2959	3069	3196	3334	3480	3631	3787
	1.75	1491	1510	1553	1611	1678	1750	1827	1906	1988
	2.00	972	984	1012	1050	1093	1141	1191	1243	1296
	2.25	710	719	740	767	799	833	870	908	947
	2.50	556	563	579	601	626	653	681	711	742
	2.75	456	462	475	493	513	536	559	583	608
	3.00	387	392	403	418	435	454	474	495	516
	3.25	336	340	350	363	378	395	412	430	448
	3.50	298	301	310	321	335	349	365	380	397
	3.75	267	271	278	289	301	314	327	342	356
	4.00	243	246	253	263	273	285	298	311	324

P: Average proportion for group 1 and group 2;
OR: Odds ratio;
N1:N2 : Ratio of sample size N1 over N2.

Table 4:
TOTAL SAMPLE SIZE REQUIRED TO TEST FOR A DIFFERENCE
BETWEEN TWO CORRELATION COEFFICIENTS

	R2										
	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55
R1											
0.00	16784	4175	1840	1023	644	439	315	234	179	139	110
0.02	46578	6513	2444	1259	758	501	352	258	195	150	117
0.04	419E3	11554	3404	1588	906	579	397	286	213	162	126
0.06	418E3	25926	5068	2065	1101	675	451	318	233	176	135
0.08	46299	103E3	8345	2798	1369	799	516	356	257	191	145
0.10	16616	.	16283	4008	1748	961	598	402	284	209	157
0.12	8447	103E3	45006	6228	2312	1177	701	458	317	229	170
0.14	5088	25510	403E3	11002	3207	1479	834	526	356	252	184
0.16	3390	11276	4E5	24586	4754	1915	1009	611	402	279	201
0.18	2414	6305	44184	97617	7795	2584	1249	720	459	312	221
0.20	1803	4008	15790	.	15145	3686	1588	861	529	350	243
0.22	1394	2764	7993	96003	41676	5701	2091	1051	617	396	270
0.24	1108	2015	4794	23779	371E3	10026	2886	1314	730	453	301
0.26	900	1529	3180	10464	367E3	22302	4259	1693	880	524	339
0.28	744	1197	2254	5824	40363	88135	6951	2273	1083	614	384
0.30	624	961	1676	3686	14357	.	13439	3227	1370	731	441
0.32	530	786	1290	2529	7232	85840	36797	4966	1794	887	511
0.34	455	653	1020	1835	4316	21155	326E3	8687	2464	1103	602
0.36	393	550	825	1386	2848	9261	321E3	19220	3616	1414	721
0.38	343	468	678	1079	2009	5127	35076	75531	5867	1887	882
0.40	301	402	566	861	1485	3227	12406	85E31	11276	2662	1108
0.42	266	348	478	700	1137	2201	6213	72707	30687	4071	1443
0.44	236	304	408	579	894	1588	3686	17808	27E4	7075	1968
0.46	210	267	351	484	718	1192	2417	7746	264E3	15547	2867
0.48	188	235	304	410	587	922	1693	4259	28676	60663	4618
0.50	169	209	265	350	487	731	1243	2662	10070	85E31	8809
0.52	152	185	232	301	408	590	945	1803	5005	57511	23779
0.54	137	166	205	261	346	484	738	1290	2945	13970	208E3
0.56	124	148	181	227	295	402	588	961	1915	6024	201E3
0.58	112	133	161	199	254	337	476	737	1330	3282	21629
0.60	102	120	143	175	219	286	391	579	967	2031	7519
0.62	92	108	128	154	191	243	325	463	728	1362	3697
0.64	84	97	114	136	166	209	273	376	562	963	2151
0.66	76	88	102	121	146	180	230	308	443	709	1381
0.68	69	79	91	107	128	156	195	256	354	537	946
0.70	63	71	82	95	112	135	167	214	287	416	678
0.72	57	64	73	85	99	117	143	179	235	327	502
0.74	52	58	66	75	87	102	123	151	194	261	381
0.76	47	52	59	67	77	89	106	128	161	210	294
0.78	42	47	53	59	67	78	91	109	134	171	231
0.80	38	42	47	52	59	67	78	92	112	139	182
0.82	34	38	42	46	52	59	67	78	93	114	145
0.84	31	33	37	41	45	51	57	66	77	93	116
0.86	27	30	32	35	39	43	49	56	64	76	92
0.88	24	26	28	31	33	37	41	46	53	62	73
0.90	21	22	24	26	28	31	34	38	43	49	58
0.92	18	19	20	22	24	26	28	31	34	39	45
0.94	15	16	17	18	19	21	22	24	27	30	34
0.96	12	12	13	14	15	16	17	18	20	22	24
0.98	8	9	9	10	10	11	11	12	13	14	15
1.00	.	.	.	.	.	.	.	.	.	.	.

(CONTINUED)

Table 4:
TOTAL SAMPLE SIZE REQUIRED TO TEST FOR A DIFFERENCE
BETWEEN TWO CORRELATION COEFFICIENTS

	R2							
R1	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
0.00	87	70	56	44	35	27	19	13
0.02	93	74	59	46	36	28	20	13
0.04	99	78	61	48	38	28	20	13
0.06	105	82	65	50	39	29	21	13
0.08	112	87	68	53	41	30	22	14
0.10	120	92	71	55	42	31	22	14
0.12	128	98	75	58	44	33	23	14
0.14	138	104	80	61	46	34	24	15
0.16	149	112	84	64	48	35	24	15
0.18	161	119	89	67	50	36	25	15
0.20	175	128	95	71	52	38	26	16
0.22	191	138	101	75	55	39	27	16
0.24	209	149	108	79	58	41	28	17
0.26	230	162	116	84	61	43	29	17
0.28	256	177	125	90	64	45	30	18
0.30	286	194	135	95	67	47	31	18
0.32	322	214	146	102	71	49	32	19
0.34	366	237	160	110	76	52	34	19
0.36	420	265	175	118	81	54	35	20
0.38	489	298	193	128	86	57	37	21
0.40	579	340	214	139	92	61	38	21
0.42	698	392	239	152	99	64	40	22
0.44	861	458	269	168	107	68	42	23
0.46	1096	544	307	186	116	73	44	24
0.48	1452	660	355	208	127	78	47	25
0.50	2031	823	416	234	139	84	49	26
0.52	3080	1062	496	267	154	91	52	27
0.54	5307	1435	607	309	172	99	56	28
0.56	11554	2071	765	363	194	108	60	29
0.58	44639	3301	1002	436	221	119	64	31
0.60	85E31	6228	1386	537	256	133	69	32
0.62	41412	16616	2076	684	301	149	75	34
0.64	9940	143E3	3529	911	363	169	82	36
0.66	4231	137E3	7575	1295	449	196	91	39
0.68	2273	14513	28823	2031	579	230	102	42
0.70	1386	4966	85E31	3765	786	278	115	45
0.72	914	2400	25822	9854	1152	346	132	49
0.74	635	1370	6075	83201	1915	450	154	54
0.76	458	861	2529	77685	4008	622	185	60
0.78	339	576	1325	8015	14827	946	231	68
0.80	256	402	786	2662	21E31	1693	301	78
0.82	195	289	501	1243	12406	4259	423	92
0.84	151	211	336	682	2798	34351	667	113
0.86	117	157	232	409	1108	30385	1314	145
0.88	90	117	163	259	547	2938	4518	202
0.90	69	87	115	169	301	900	34E30	325
0.92	52	63	81	111	175	379	3080	713
0.94	38	45	55	72	103	181	595	4784
0.96	27	31	36	44	59	88	187	3227
0.98	16	18	21	24	29	39	62	194

Appendix 2:

1. Program to solve *n* two-group design: Continuous data

```
/* program: ssize1.sas
   purpose: calculate sample size based on (mean1-mean2)/sd
        standardised difference
   Method:
        t = (R+1)/R
        nml = (zalpha+zbeta)**2
        z = 1/z**2
        n = t*z*nml
   where R=n1/n2 the ratio of sample1 to sample2
  author : TN
 */

options ps=60 ls=80 nodate;
data t;
 alpha = 0.025;
 beta  = 0.90;
 zalpha = probit(alpha);
 zalpha = abs(zalpha);
 zbeta  = probit(beta);
 zbeta  = abs(zbeta);
 put zalpha zbeta;
do R = 1 to 3 by 0.25;
 do z = 0.1 to 3 by 0.05;
   z2 = 1/z**2;
   ** sample size per group ;
      m = z2*2*(zalpha+zbeta)**2;
   ** sample size for group 1;
      n1 = (R+1)*m/(2*R);
      n2 = r*n1;
   ** total sample sizes ;
      n = n1+n2;
   output;
 end;
end;
run;

proc tabulate noseps;
  class r z;
  var n;
  table
  z,
  r='N1:N2'*n=' '*mean=' '*f=5. / rts=10;
  format z 5.2;
  title1 'SAMPLE SIZE FOR VARIOUS STANDARDISED DIFFERENCES';
  TITLE2 "POWER = 0.90 AND ALPHA = 0.025";
run;



/****** NOW CALCULATE POWER OF A STUDY:
        This program requires users to input the following data:
        * Z = Diff / SD (standardised difference)
        * Total sample size
        * Ratio of SS N1:N2
*******/


 DATA POWER;
   Alpha = 0.05;
   Zalpha = probit(alpha);
   Zalpha = Abs(Zalpha);
   N = 100;     /* this is TOTAL sample size */
   DO Z = 0.1 to 2 by 0.01;
     DO R = 1 to 3 by 0.5;
       T = (Z*sqrt(N*R)) / (R+1);
       Zbeta = T-Zalpha;
```

```
       Power = Probnorm(Zbeta);
       output;
     END;
   END;
 RUN;

 proc tabulate noseps;
   class Z R;
   var   Zbeta Power;
   table
    Z,
    (R='N1:N2')*power=' '*mean=' '*f=5.3 / rts=10;
   format z r 5.2;
   title 'POWER FOR VARIOUS STUDY DESIGNS';
  run;
```

2. Program to solve *n* two-group design: Binary data

```
options ps=60 ls=80 nodate;
/* program: ssize2.sas
   purpose: calculate sample size based on proportions
        standardised difference
   Method:
       equation 5 of text
   where r=n1/n2 the ratio of sample1 to sample2
  author : TN

 */

data t;
 alpha = 0.025;
 beta  = 0.90;
 zalpha = probit(alpha);
 zalpha = abs(zalpha);
 zbeta  = probit(beta);
 zbeta  = abs(zbeta);

do R = 1 to 3 by 0.25; /* this is the N1/N2 ratio */
 do P = 0.1 to 0.9 by 0.1; /* equival PI in text : prop of ref pop */
   do RR = 0.5 to 4 by 0.25; /* this is Rel Risk P1 / P2  */
     PC = (P*(R*RR + 1)) / (R+1);
     t1 = (R+1) / ( R*P*P*(RR-1)*(RR-1) );
     t2 = zalpha * sqrt((R+1)*PC*(1-PC));
     t3 = zbeta *  sqrt( (RR*P*(1-RR*P)) + (R*P*(1-P)) );
     n  = t1*((t2+t3)**2);
   output;
  end;
 end;
end;
run;

proc tabulate noseps;
  class R RR P;
  var n ;
  table
  P='P'*RR,
  R='N1:N2'*N=' '*mean=' '*f=5. / rts=15;
  format rr r 4.2 ;
  title1 'SAMPLE SIZE FOR VARIOUS RELATIVE RISK AND RATIOS';
  TITLE2 "POWER = 0.90 AND ALPHA = 0.025";
run;


/****** NOW CALCULATE POWER OF A STUDY:
        This program requires users to input the following data:
        * P the proportion in reference group
        * RR the relative risk RR = P1 / P
```

```
        * Total sample size
        * Ratio of SS N1:N2
*******/

 DATA POWER;
   Alpha = 0.05;
   Zalpha = probit(alpha);
   Zalpha = Abs(Zalpha);
   N = 100;     /* this is TOTAL sample size */
  do R = 1 to 3 by 0.25; /* this is the N1/N2 ratio */
    do P = 0.1 to 0.9 by 0.1; /* equival PI in text : prop of ref pop */
      do RR = 0.5 to 4 by 0.25; /* this is Rel Risk P1 / P2  */
        PC = (P*(R*RR + 1)) / (R+1);
        t  = abs(RR-1);
        t1 = P*t*sqrt(N*R);
        t2 = Zalpha*(R+1)*sqrt(pc*(1-pc));
        t  = (RR*P*(1-RR*P)) + (R*P*(1-P));
        t3 = sqrt((R+1)*t);
        Zbeta = (t1 - t2) / t3;
        Power = probnorm(Zbeta);
        output;
      end;
     end;
    end;
  run;

 proc tabulate noseps;
   class P R RR;
   var   Zbeta Power;
   table
    P*RR,
    (R='N1:N2')*power=' '*mean=' '*f=5.2 / rts=20;
   format P RR 5.2;
   title 'POWER FOR VARIOUS STUDY DESIGNS';
  run;
```

3. Program to solve *n* for case-control design with OR

```
/* program: ssize3.sas
   purpose: calculate sample size based on odds ratio for case control study
   Method: Equation 7 in text
  author : TN
 */


data t;
 alpha = 0.025;
 beta  = 0.90;
 zalpha = probit(alpha);
 zalpha = abs(zalpha);
 zbeta  = probit(beta);
 zbeta  = abs(zbeta);

do R = 1 to 3 by 0.25;
 do P = 0.1 to 0.9 by 0.05;
   do OR = 0.25 to 4 by 0.25;
     t1 = 2*(zalpha+zbeta)**2;
     logOR = (log(OR))**2;
     m = t1 / (logOR*p*(1-p));
     n1 = (R+1)*m/(2*R);
     n2 = n1*R;
     N = N1+N2;
     if OR ne 1 then output;
  end;
 end;
end;
run;
```

```
proc tabulate noseps;
  class R P OR ;
  var n n1 n2;
  table
  P='P'*OR='OR',
  R='N1:N2'*(n=' '*mean=' '*f=5.) / rts=15;
  format OR R P 4.2 ;
  title1 'SAMPLE SIZE FOR VARIOUS ODDS RATIOS AND PREVALANCE - CASE CONTROL STUDY';
  TITLE2 "POWER = 0.90 AND ALPHA = 0.05";
run;
```

4. Program to solve *n* for design with multiple groups.

```
/* program: SSIZE4.SAS
   location: c:\works\biostat\ssize4.sas
   purpose: iteratively solve for n in multiple group study design
   method : Fleiss' book
   author : tn
   date   : 12/6/1995
 */


%macro sszie(alpha, group, mean1, mean2, mean3, mean4, sigma);
data ss;
 alpha = &alpha;
 alpha1 = 1-alpha;
 g = &group ; /* number of groups */
 m1 = &mean1;
 m2 = &mean2;
 m3 = &mean3;
 m4 = &mean4;
 sigma = &sigma;
 ss = css(m1,m2,m3,m4);
 lambda = ss/((g-1)*sigma**2);
do N=1 to 50;
  g1  = g-1;
  v2  = g*(N-1);
  F   = FINV(alpha1, g1, v2);

  t1  = g1*(1+N*lambda)*F;
  t2  = v2*(1+2*N*lambda);
  tt1 = 1 / sqrt(t1+t2);

  t1  = (2*g1*(1+N*lambda)**2) - (1+2*N*lambda);
  tt2 = sqrt(v2*t1);

  tt3 = F*g1*(1+N*Lambda)*(2*v2 - 1);
  tt3 = sqrt(tt3);

  Zbeta = tt1 * (tt2 - tt3);
  Beta  = probnorm(zbeta);
 output;
end;
run;


proc print label;
  var N F Zbeta Beta;
  label N='SAMPLE SIZE PER GROUP'
        F='NON-CENTRAL F'
        ZBETA='Z(beta)'
        Beta='POWER';
  title1 "EVALUATION OF SAMPLE SIZE FOR &G GROUPS";
run;
%mend;


%ssize(0.05, 4, 9.775, 12.0, 12.0, 14.225, 3);
```