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SAMPLING TECHNIQUES & DETERMINATION OF SAMPLE SIZE IN APPLIED STATISTICS RESEARCH: AN OVERVIEW

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Abstract

Applied statistics research plays pivotal role in diverse problems of social sciences, agricultural sciences, health sciences, and business research. Many investigations are conducted by survey research. The technique of sampling and determination of sample size have crucial role in survey-based research problems in applied statistics. Specific sampling techniques are used for specific research problems because one technique may not be appropriate for all problems. Similarly, if the sample size is inappropriate it may lead to erroneous conclusions. The present paper gives an overview of some commonly used terms and techniques such as sample, random sampling, stratified random sampling, power of the test, confidence interval that need to be specified for a sample size calculation and some techniques for determination of sample size, and also describes some sampling methods such as purposive random sampling, random sampling, stratified random sampling, systematic random sampling and quota sampling for specific research purposes.

Keywords: Sampling, Sample Size, Power of the Test, Confidence Interval, Level of Significance

INTRODUCTION

Statistics are used to summarize the data collected through survey or investigation. The basic role of statistics in research is to make conclusions about a population of interest when data is only available from a sample. Research data usually measure observations of an occurrence of an event as well as indicate exposure. Also, the role of statistician is to determine whether any association that is observed in the sample is actually a real one. In most cases, there will be some association even though very small. The statistician also have important role in determining if the association is different than what would occur by chance.

The most common and basic statistical method used in applied research is frequency measure, which is simply a measure of counting and comparing their characteristics. These frequency measures are rates, ratios and proportions. The sampling techniques, on the other hand, are commonly used for research investigations to better estimate at low cost and less time with greater precision. The selection of sampling methods and determination of sample size are extremely important in applied statistics research problems to draw correct conclusions. If the sample size is too small, even a well conducted study may fail to detect important effects or associations, or may estimate those impacts or associations too imprecisely. Similarly, if the sample size is too large, the study would be more complex and may even lead to inaccuracy in results. Moreover, taking a too large sample size would also escalate the cost of study. Therefore, the sample size is an essential factor of any scientific research. Sathian (2010) has pointed out that sample size determination is a difficult process to handle and requires the collaboration of a specialist who has good scientific knowledge in the art and practice of medical statistics. Techniques for estimating sample size and performing power analysis depend mainly on the design of the study and the main measure of the study. There are distinct methods for calculating sample size for different study designs and different outcome measures. Additionally, there are also some different procedures for calculating the sample size for two approaches of drawing statistical inference from the study results on the basis of confidence interval approach and test of significance approach. With mushroom growth of journals in recent years the number of publications in survey-based investigations has gone considerably high. Many of the studies, however, lack in selection of the appropriate sampling methodology. It was therefore considered pertinent to give single source information about the sampling and sample size determination to the readers. The present paper, thus, gives an overview of some commonly used terms and techniques that need to be specified for a sample size calculation and some techniques for determination of sample size, and also describes some sampling methods for specific research purposes.

SAMPLING

Sampling is an old concept, mentioned several times in the Bible. In 1786, Pierre Simon Laplace estimated the population of France by using a sample technique, along with ratio estimator. He also computed probabilistic estimates of the error. Alexander Ivanovich Chuprov introduced sample surveys to Imperial Russia in the 1870s (Cochran 1963 and Robert et al. 2004).

Sampling is related with the selection of a subset of individuals from within a population to estimate the characteristics of whole population. The two main advantages of sampling are the faster data collection and lower cost. (Kish 1965, Robert 2004)Each observation measures one or more properties of observable subjects distinguished as independent individuals. In business research, medical research, agriculture research, sampling is widely used for gathering information about a population.

Sampling Techniques

The method for the selection of individuals on which information are to be made has been described in literature (Kish 1965, Gupta and Kapoor 1970). The following points need to be considered in selection of individuals.

a. Investigations may be carried out on an entire group or a representative taken out from the group.
b. Whenever a sample is selected it should be a random sample.
c. While selecting the samples the heterogeneity within the group should be kept in mind and proper sampling technique should be applied.

Some common sample designs described in the literature include purposive sampling, random sampling, and quota sampling (Cochran 1963, Rao 1985, Sudman 1976). The random sampling can also be of different types.

Purposive Sampling

In this technique, sampling units are selected according to the purpose. Purposive sampling provides biased estimate and it is not statistically recognized. This technique can be used only for some specific purposes.

Random Sampling

In this method of sampling, each unit included in the sample will have certain pre assigned chance of inclusion in the sample. This sampling provides the better estimate of parameters in the studies in comparison to purposive sampling.

The every single individual in the sampling frame has known and non-zero chance of being selected into the sample. It is the ideal and recognized single stage random sampling.

Lottery Method of Sampling

There are several different ways to draw a simple random sample. The most common way is the lottery method. Here, each member or item of the population at hand is assigned a unique number. The numbers are then thoroughly mixed, like if you put them in a bowl or jar and shook it. Then, without looking, the researcher selects *n* numbers. The population members or items that are assigned that number are then included in the sample.

By Using Random Number Table

Most statistics books and many research methods books contain a table of random numbers as a part of the appendices. A random number table typically contains 10,000 random digits between 0 and 9 that are arranged in groups of 5 and given in rows. In the table, all digits are equally probable and the probability of any given digit is unaffected by the digits that precede it.

Simple Random Sampling

In the Simple random sampling method, each unit included in the sample has equal chance of inclusion in the sample. This technique provides the unbiased and better estimate of the parameters if the population is homogeneous.

Stratified Random Sampling

Stratified random sampling is useful method for data collection if the population is heterogeneous. In this method, the entire heterogeneous population is divided in to a number of homogeneous groups, usually known as Strata, each of these groups is homogeneous within itself, and then units are sampled at random from each of these stratums. The sample size in each stratum varies according to the relative importance of the stratum in the population. The technique of the drawing this stratified sample is known as Stratified Sampling. In other words, stratification is the technique by which the population is divided into subgroup/strata. Sampling will then be conducted separately in each stratum. Strata or Subgroup are chosen because evidence is available that they are related to outcome. The selection of strata will vary by area and local conditions.

After stratification, sampling is conducted separately in each stratum. In stratified sample, the sampling error depends on the population variance within stratum but not between the strata. Stratified random sampling also defined as where the population embraces a number

of distinct categories, the frame can be organized by these categories into separate "strata." Each stratum is then sampled as an independent sub-population, out of which individual elements can be randomly selected.

Cluster Sampling

Cluster sampling is a sampling method where the entire population is divided into groups, or clusters, and a random sample of these clusters are selected. All observations in the selected clusters are included in the sample. Cluster sampling is a sampling technique used when "natural" but relatively homogeneous groupings are evident in a statistical population.

Cluster sampling is generally used when the researcher cannot get a complete list of the units of a population they wish to study but can get a complete list of groups or 'clusters' of the population. This sampling method may well be more practical and economical than simple random sampling or stratified sampling.

Compared to simple random sampling and stratified sampling, cluster sampling has advantages and disadvantages. For example, given equal sample sizes, cluster sampling usually provides less precision than either simple random sampling or stratified sampling. On the other hand, if contact costs between clusters are high, cluster sampling may be more cost-effective than the other methods.

Systematic Random Sampling

In this method of sampling, the first unit of the sample selected at random and the subsequent units are selected in a systematic way. If there are N units in the population and n units are to be selected, then R = N/n (the R is known as the sampling interval). The first number is selected at random out of the remainder of this R (Sampling Interval) to the previous selected number.

Multistage Random Sampling

In Multistage random sampling, units are selected at various stages. The sampling designs may be either same or different at each stage. Multistage sampling technique is also referred to as cluster sampling, it involves the use of samples that are to some extent of clustered. The principle advantage of this sampling technique is that it permits the available resources to be concentrated on a limited number of units of the frame, but in this sampling technique the sampling error will be increased.

Quota sampling

In quota sampling, the population is first segmented into mutually exclusive sub-groups, just as in stratified sampling. Then judgment is used to select the subjects or units from each segment based on a specified proportion.

It is this second step which makes the technique one of non-probability sampling. In quota sampling, the selection of the sample is non-random. For example interviewers might be tempted to interview those who look most helpful. The problem is that these samples may be biased because not everyone gets a chance of selection. This random element is its greatest

Spatial Sampling

Spatial sampling is an area of survey sampling associated with sampling in two or more dimensions.

Independent Sampling

Independent samples are those samples selected from the same population, or different populations, which have no effect on one another. That is, no correlation exists between the samples.

SAMPLE SIZE FOR RESEARCH PURPOSES

The sample size should be carefully fixed so that it will be adequate to draw valid and generalized conclusions. The fixation of the adequate sample size requires specific information about the problems under investigation in the population under study. And also, the sub classifications of sample require for analysis, variation, precision, availability and cost of investigations. The information collected during investigation from samples is to be recorded on pre-designed schedule or on questionnaire. The design of questionnaire depends on the objectives and facilities for analysis.

Sample size determination is the technique of electing the number of observations to include in a sample. The sample size is an important feature of any study or investigation in which the aim is to make inferences about the population from a sample. In general, the sample size used in a study is determined based on the cost of data collection, and based on sufficient statistical power. In advanced studies there may be several different sample sizes involved in the study: for example, in a survey sampling if population is heterogeneous involving stratified sampling there would be different sample sizes for each population. In a census, data are collected through complete enumeration, hence the sample size is equal to the population size. In experimental study, where a study may be divided into different experimental groups, there

may be different sample sizes for each experimental group. Larger sample sizes generally lead to increased precision when estimating unknown parameters. Several fundamental facts of mathematical statistics describe this phenomenon, including the law of large numbers and the central limit theorem. Generally sample sizes may be chosen in three different ways as follows.

Cost base - Include those items readily available or convenient to collect. A choice of small sample sizes, though sometimes necessary, can result in wide confidence intervals or risks of errors in statistical hypothesis testing.

Variance base - Using a target variance for an estimate to be derived from the sample eventually obtained

Statistical power base - Using a target for the power of a statistical test to be applied once the sample is collected. Sample sizes are judged based on the quality of the resulting estimates, sample size may be assessed based on the power of a hypothesis test.

Significance of the Sample Size

In a comparative study, the means or proportions of some characteristic in two or more comparison groups are observed. A statistical test is then applied to determine the significant difference between the means or proportions observed in the different groups.

Sample size is important principally due to its effect on statistical power. Statistical power is the chance that a statistical test will indicate a significant difference when there truly is one. Statistical power is analogous to the sensitivity of a diagnostic test (Browner and Newman 1978), and one could mentally substitute the word “sensitivity” for the word “power” during statistical conclusions.

In a comparative study of two groups of individuals, the power of a statistical test must be sufficient to detection of a statistically significant difference between the two groups if a difference is truly present. This issue becomes important if the study results were to demonstrate no statistically significant difference. If such a negative result were to occur, there would be two possible interpretations. The first interpretation is that the results of the statistical test are correct and that there truly is no statistically significant difference (a true-negative result). The second interpretation is that the results of the statistical test are erroneous and that there is actually an underlying difference, but the study was not powerful enough (sensitive enough) to find the difference, yielding a false-negative result. In statistical terminology, a false-negative result is known as a type II error. An adequate sample size gives a statistical test enough power so that the first interpretation is much more plausible than the second interpretation (that a type II error occurred) in the event no statistically significant difference is found in the study.

It is well known that many published clinical research studies possess low statistical power owing to inadequate sample size or other design issues (Moher et al. 1994 and Freiman et al. 1978).

Determination of the sample size for parameters

A sample size generally depends on five study design parameters: minimum expected difference or also known as the effect size, estimated measurement variability, desired statistical power, significance criterion, and whether a one- or two-tailed statistical analysis is planned.

Basis of Minimum Expected Difference or size effects

The minimum expected difference is made smaller, the sample size needed to detect statistical significance increases. The setting of this parameter is subjective and is based on clinical judgment or experience with the problem being investigated. For example, suppose a study is designed to compare a standard diagnostic procedure of 85% accuracy with a new procedure of unknown but potentially higher accuracy. Suppose the investigator believes that it would be a clinically important improvement if the new procedure were 95% accurate. Therefore, the investigator would choose a minimum expected difference of 10% (0.10).

Estimated Measurement Variability

This parameter is represented by the expected standard deviation in the measurements decide within each comparison group. As statistical variability increases, the sample size needed to detect the minimum difference increases. Ideally, the estimated measurement variability should be determined on the basis of preliminary data collected from a similar study population. A review of the literature can also provide estimates of this parameter. If preliminary data are not available, this parameter may have to be estimated on the basis of subjective experience, or a range of values may be assumed. A separate estimate of measurement variability is not required when the measurement being compared is a proportion (in contrast to a mean), because the standard deviation is mathematically derived from the proportion.

Based on Statistical Power

This parameter is the power that is need from the study. As power is increased, sample size increases. While high power is always desirable, there is an obvious trade-off with the number of individuals that can feasibly be investigated, given the usually fixed amount of time and resources available to conduct a research or investigational study. In randomized controlled

trials, statistical power is customarily set to a number greater than or equal to 0.80, with many clinical trial experts now advocating a power of 0.90. (Wood and Lombert 1999, Writes 2002)

Significance Criterion (P – Value)

This parameter is the maximum P value for which a difference is to be considered statistically significant. As the significance criterion is decreased, the sample size needed to detect the minimum difference increases. The statistical significance criterion is customarily set to 5 percent.

One- or Two-tailed Statistical Analysis

In a some cases, it may be known before the investigation that any difference between comparison or experimental groups is possible in only one direction. In such cases, use of a one-tailed statistical analysis, which would require a smaller sample size for detection of the minimum difference than would a two-tailed analysis, may be considered. The sample size of a one-tailed study design with a given statistical significance criterion—for example, α—is equal to the sample size of a two-tailed design with a significance criterion of 2α, all other parameters being equal.

Criteria for good Sample Size (Glenn 1992, Cochran 1963, Gupta and Kapoor 1970)

In addition to the purpose of the study and population size, three criteria usually will need to be specified to determine the appropriate sample size: the level of precision, the level of confidence or risk, and the degree of variability in the attributes being measured (Miaoulis and Michener, 1976). Each of these is reviewed below:

The Level of Precision

The level of precision, sometimes called sampling error, is the range in which the true value of the population is estimated to be. This range is often expressed in percentage points (e.g., ±5 percent) in the same way that results for political campaign polls are reported by the media. Thus, if a researcher finds that 60% of farmers in the sample have adopted a recommended practice with a precision rate of ±5%, then he or she can conclude that between 55% and 65% of farmers in the population have adopted the practice.

The Confidence Level

The risk level of confidence level is based on ideas of Central Limit Theorem. The key idea in the Central Limit Theorem is that when a population is repeatedly sampled, the average value of

the attribute obtained by those samples is equal to the true population value. Further, the values obtained by these samples are normally distributed about the true value, with some samples having a higher value and some obtaining a lower value than the true population value. In a normal distribution, approximately 95% of the sample values are within two standard deviations of the true population value. This confidence interval is also known as risk of error in the statistical hypothesis testing.

In other words, this means that if a 95% confidence level is selected, 95 out of 100 samples will have the true population value within the range of precision specified. There is always a probability that the sample obtain by the researcher or investigator does not represent the true population value. Such samples with extreme values are represented. This risk is reduced for 99% confidence levels and increased for 90% or lower levels of confidence (Gupta and Kapoor 1970 and Singh and Masuku 2012).

Degree of Variability

The third criterion, the degree of variability in the attributes being investigated, refers to the distribution of attributes in the population. The variables with more homogeneous population, the smaller the sample size required. If the more heterogeneous population, the larger the sample size required to obtain a given level of precision. For example, a proportion of 50% indicates a greater level of variability than either 80% or 20%. This is because 80% and 20% indicate that a large majority do or do not, respectively, have the attribute of interest. Because a proportion of .5 indicates the maximum variability in a population, it is often used in determining a more conservative sample size, that is, the sample size may be larger than if the true variability of the population attribute were used.

Strategies for Determining Sample Size
(Glenn 1992, Rao 1985 and Sudman 1976, Singh and Masuku 2013)

There are many approaches to determining the sample size. These include using a census for small populations, imitating a sample size of similar studies, using published tables, and also applying formulas to calculate a sample size.

Using a Census for Small Populations

One approach is to use the entire population as the sample. Although cost considerations make this impossible for large populations, a census is more attractive for small populations (e.g., 200 or less). A census eliminates sampling error and provides data on all the individuals in the population. In addition, some costs such as questionnaire design and developing the sampling

frame are "fixed," that is, they will be the same for samples of 50 or 200. Therefore, entire population will have to be sampled in small populations to achieve a desirable level of precision.

Using a Sample Size of a Similar Study

Another approach is to use the same sample size as those of studies similar to the plan. Without reviewing the methods used in these studies may run the risk of repeating errors that were made in determining the sample size for another study. However, a review of the literature in this discipline can provide supervision about typical sample sizes that are used (Glenn1992).

Using Published Tables

A third way to determine sample size is to rely on published tables, which provide the sample size for a given set of criteria. Sample sizes that would be necessary for given combinations of precision, confidence level and variability. Glenn (1992), presented two tables for the selection of sample size (Table-1 and Table-2). Please note two things. First, these sample sizes reflect the number of obtained responses and not necessarily the number of surveys mailed or interviews planned. Second, the sample sizes in Table 2 presume that the attributes being measured are distributed normally or nearly so. If this assumption cannot be met, then the entire population may need to be surveyed.

Table 1. Sample Size for ±5% and ±10% Precision Levels where Confidence Level is 95% and P=0.5.

Size of Population	**Sample Size (n) for precision (e)**	
	±5%	**±10%**
500	222	83
1,000	286	91
2,000	333	95
3,000	353	97
4,000	364	98
5,000	370	98
7,000	378	99
9,000	383	99
10,000	385	99
15,000	390	99
20,000	392	100
25,000	394	100
50,000	397	100
100,000	398	100
>100,000	400	100

Table 2. Sample Size for ±5% and ±10% Precision Levels where Confidence Level is 95% and p=0.5.

Size of Population	Sample Size (n) for Precision (e) of:	
	±5%	±10%
100	81	51
125	96	56
150	110	61
200	134	67
250	154	72
300	172	76
350	187	78
400	201	81
450	212	82

Using Formulas to Calculate a Sample Size

Glenn 1992 tables can provide a useful guide for determining the sample size, you may need to calculate the necessary sample size for a different combination of levels of precision, confidence, and variability. The fourth approach to determining sample size is the application of one of several formulas was used to calculate the sample sizes in Table 1 and Table 2.

Some techniques for Calculation of sample size (Kish 1965)

1. Required Sample sizes for hypothesis tests by Cohen's d and Power

Calculating the sample size required to yield a certain power for a test, given a predetermined Type I error rate α. As follows, this can be estimated by pre-determined tables for certain values, by Mead's resource equation, or, more generally, by the cumulative distribution function:

- The desired statistical power of the trial, shown in column to the left.
- Cohen's d (=effect size), which is the expected difference between the means of the target values between the experimental group and the control group, divided by the expected standard deviation.

Table 3. Sample sizes for hypothesis tests by Cohen's d and Power

Cohen's d	POWER							
	0.25	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**	**0.95**	**0.99**
0.20	84	193	246	310	393	526	651	920
0.50	14	32	40	50	64	85	105	148
0.80	06	13	16	20	26	34	42	58

2. Determination of sample size for laboratory animal study based on Mead's resource equation (Kish 1965)

Mead's resource equation is often used for estimating sample sizes of laboratory animals, as well as in many other laboratory experiments. It may not be as accurate as using other methods in estimating sample size, but gives a hint of what is the appropriate sample size where parameters such as expected standard deviations or expected differences in values between groups are unknown or very hard to estimate(Kirkwood and Robert 2010).

All the parameters in the equation are in fact the degrees of freedom of the number of their concepts, and hence, their numbers are subtracted by 1 before insertion into the equation. The equation is:

$E = N – B - T$

where:

N is the total number of individuals or units in the study (minus 1)

B is the blocking component, representing environmental effects allowed for in the design (minus 1)

T is the treatment component, corresponding to the number of experimental groups (including control group) being used, or the number of questions being asked (minus 1)

E is the degrees of freedom of error component, and shall be somewhere between 10 and 20.

For Example, if a study using laboratory animals is planned with four treatment groups (T=3), with eight animals per group, making 32 animals total (N=31), without any further stratification (B=0), then E would equal 28, which is above the cutoff of 20, indicating that sample size may be a bit too large, and six animals per group might be more appropriate.

3. Determination of sample size by cumulative distribution function

Let X_i, i = 1, 2, ...,n be independent observations taken from a normal distribution with unknown mean μ and known variance σ^2. Let us consider two hypotheses, a null hypothesis:

$H_0 : \mu = 0$

and an alternative hypothesis:

$H_1 : \mu = \mu^*$

For some 'smallest significant difference $\mu^*>0$. This is the smallest value for which we care about observing a difference. Now, if we wish to reject H_0 with a probability of at least 1-β when H_1 is true (i.e. a power of 1-β), and second reject H_0 with probability α when H_0 is true, then we need the following:

If Z_α is the upper α percentage point of the standard normal distribution, then

$$\mathbf{P}\ \mathbf{x > Z_\alpha \sigma / \sqrt{n}}\ \ H_0] = \boldsymbol{\alpha}$$

And hence, 'Reject H_0 if our sample average sample mean is more than $\mathbf{Z_\alpha \sigma / \sqrt{n}}$
is a decision rule for 1-tailed test.

Now we wish for this to happen with a probability at least 1-β when H_1 is true. In this case, our sample average will come from a Normal distribution with mean μ^*. Therefore we require

$\mathbf{P [x > Z_\alpha \sigma / \sqrt{n} \quad H_1] = 1 - \beta}$ **where x = sample mean**

Through careful manipulation, this can be shown to happen when

$$\mathbf{n \geq [\{\Phi^{-1} (1-\beta) + Z_\alpha\} / (\mu^* / \sigma)]^2}$$

Where **Φ** is the normal cumulative distribution function.

Formula for Calculating A Sample for Proportions

Cochran (1963, 1975) developed the equation to yield a representative sample for proportions of large sample.

$$\mathbf{n_0 = Z^2 p q / e^2}$$

Which is valid where n_0 is the sample size, Z^2 is the abscissa of the normal curve that cuts off an area α at the tails (1 - α equals the desired confidence level is 95%), **e** is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q is 1-p. The value for Z is found in statistical tables which contain the area under the normal curve.

To illustrate, suppose we wish to evaluate a state-wide Extension program in which farmers were encouraged to adopt a new practice. Assume there is a large population but that we do not know the variability in the proportion that will adopt the practice; therefore, assume p=.5 (maximum variability). Furthermore, suppose we desire a 95% confidence level and ±5% precision. The resulting sample size is

$$\mathbf{n_0 = Z^2 p q / e^2}$$

Finite Population Correction for Proportions (If small population)

If the population is small then the sample size can be reduced slightly. This is because a given sample size provides proportionately more information for a small population than for a large population. The sample size (n_0) can be adjusted as

$$\mathbf{n = n_0 / [1 + \{(n_0 - 1) / N\}]}$$

Where n is the sample size and N is the population size.

Suppose our evaluation of farmers' adoption of the new practice only affected 2,000 farmers. The sample size that would now be necessary is given as

$$\mathbf{n = n_0 / [1 + \{(n_0 - 1) / N\}]}$$

This adjustment can substantially reduce the necessary sample size for small populations and also called the population correction.

A Simplified Formula for Proportions

Yamane (1967) provides a simplified formula to calculate sample sizes. This formula was used to calculate the sample sizes in Tables 2 and 3 and is shown below. A 95% confidence level and P = .5 are assumed.

$$n = N / [1 + N (e)^2]$$

Where n is the sample size, N is the population size, and e is the level of precision. When this formula is applied to the above sample, we get.

$$n = N / [1 + N (e)^2]$$

Rao (1985) presented some another calculation for sample size under different circumstances in simple manner. These determinations are also more useful for medical or clinical research investigations.

a. When it is a field survey to estimate the prevalence rate of specific event or cases or disease the sample size is calculated by the formula

$$n = 4 p q / L^2$$

where n is the required sample size, p is the approximate prevalence rate for which the survey is to be conducted. The knowledge of this is to be obtained from previous surveys or from pilot survey. q = 1 – p and L is the permissible error in the estimate. Similarly, calculated sample size for different levels are presented in the Table-4

Table 4. Calculated sample size for different levels

Prevalence		**Permissible error in the estimate**	
		5%	**10%**
p (%)	**1-p = q (%)**	**Required Sample**	**Required Sample**
0.5	99.5	318400	79600
01	99.0	158400	39600
05	95.0	30400	7600
10	90.0	14400	3600
25	75.0	4800	1200
50	50.0	1600	400

b. When conducting research investigation on quantitative data, the sample size is calculated by the given formula

$$n = t_\alpha^2 s^2 / \varepsilon^2$$

Where n is the desired sample size, s is the standard deviation of observations, ε is the permissible in the estimate of mean and t_α is the value of at 5%level of significance.

For illustration

If from pilot it is known the mean is 12gm.% with 1.5 gm.% standard deviation and permissible error 0.5 gm.%. So $t_{0.05} = 2.0$

Therefore required sample size

$n = [(2.0)^2 \times (1.5)^2] / (0.5)^2 = 36$

(c) In a clinical trials usually there will be two groups one experimental and the other control group. In order to estimate the size of sample for each group, the difference in the response rates of the two groups is to be taken in to consideration and the sample size is estimated from the following formula

$$n = 2\, t_\alpha^2 s^2 / d^2$$

where n is the required sample size for each group, s is the pooled standard deviation of the two groups and d is anticipated smallest difference in the estimates for the two groups and t_α is usually taken as 5 % level of significance.

For illustration

If d is the smallest anticipated difference in the rise of mean between two groups is 2%, pooled standard deviation s = 3.0 gm.% and $t_{0.05}= 2$

Therefore, required sample size

$n = [2 \times (2)^2 \times (3.0)^2] / (2)^2 = 18$

The appropriate sample size for a population-based survey is determined largely by three factors:

(i) the estimated prevalence of the variable of interest – chronic malnutrition in this instance

(ii) the desired level of confidence

(iii) the acceptable margin of error.

In the similar manner sample size can be calculated based on margin of error in confidence interval especially for estimation of population mean.

$Z \times (s / \sqrt{n})$ where **s** is the standard deviation. If fluctuations in the estimate of population mean is **ε**

$Z \times (s / \sqrt{n}) < \varepsilon$ Therefore**, $n = [Z^2 \times S^2] / \varepsilon^2$**

For calculation if standard deviation 0.4 gm and fluctuation in the estimated mean is 3 gm with 98% confidence interval

$n = [(2.326)^2 \times (3)^2] / (0.4)^2 = 304.3$ Therefore minimum sample size will be **n= 305**

Concepts to Minimize the Sample Size

Browner et al. (**2001**) presented a number of strategies for minimizing the sample size. These strategies are briefly discussed in the following paragraphs.

Use of Continuous Measurements Instead of Categories

The statistical tests that incorporate the use of continuous values are mathematically more powerful than those used for proportions, given the same sample size. In a radiological diagnosis is expressed in terms of a binary result, such as the presence or absence of a disease, it is natural to convert continuous measurements into categories. For example, the size of a lesion might be coded as “small” or “large.” For a sample of fixed size, the use of the actual measurement rather than the proportion in each category yields more power (Browner et al. 1992).

Use of More Precise Measurements

In the investigation any way to increase the precision or decrease the variability of the measurement process should be sought. For some types of research, precision can be increased by simply repeating the measurement. More complex equations are necessary for studies involving repeated measurements in the same individuals (**Frison 1992**), but the basic principles are similar.

Use of Paired Measurements

The paired t test are statistically more powerful for a given sample size than are unpaired tests because in paired tests, each measurement is matched with its own control. For example, instead of comparing the average lesion size in a group of treated patients with that in a control group, measuring the change in lesion size in each patient after treatment allows each patient to serve as his or her own control and yields more statistical power. The additional power and reduction in sample size are due to the standard deviation being smaller for changes within individuals than for overall differences between groups of individuals (Browner et al. 1992).

Use of Unequal Group Sizes

Sample size is statistically most efficient if the two groups are equal in size, benefit is still gained by studying more individuals, even if the additional individuals all belong to one of the groups. For example, it may be feasible to recruit additional individuals into the control group even if it is difficult to recruit more individuals into the noncontrol group. More complex equations are

necessary for calculating sample sizes when comparing means (Rosner 2000) and proportions (Fleiss 1981) of unequal group sizes.

Expansion of the Minimum Expected Difference

Perhaps the minimum expected difference that has been specified is unnecessarily small, and a larger expected difference could be justified, especially if the planned study is a preliminary one. The results of a preliminary study could be used to justify a more ambitious follow-up study of a larger number of individuals and a smaller minimum difference (Browner et al. 1992).

Some Recent Reports Emphasizing Sample Size

Some important studies which can be used to emphasize the significance of sample size include the determination of sample size for animal studies by Shah (2011), sample size calculations for cluster randomized controlled trials (CRCT) for fixed number of clusters (Karla, 2011), calculation of sample size for medical research (Sathian, 2010) and sample size and power analysis in medical research (Zodey, 2010). Macfarlane (2003) derived sample size determination for research projects for medical sciences whereas Wood (1999) studied the sample size calculations for trials in health services research.

Karla (2011) presented systematically the outline sample size formulae including required number of randomization units, detectable difference and power for cluster randomized control trials (CRCT) with a fixed number of clusters, to provide a concise summary for both binary and continuous outcomes and also extensions to the case of unequal cluster sizes were provided. This study concluded that CRCT with a fixed number of clusters might mean that the study would not be feasible and lead to the notion of a minimum detectable difference (or a maximum achievable power) irrespective of how many individuals were included within each cluster.

Macfarlane (2003) has described the sample size calculations for research projects as an essential part of a study protocol for submission to ethical committees, research funding bodies and some peer reviewed journals. In this study, it is conclude that sample size calculation is an important part of study design and a professional statistician is the best person to ask for help when planning a research project. However, researchers must be prepared to provide the necessary information in order that the sample size can be determined.

Wood (1999) presented the current orthodox way of estimating sample size for a trial is through a power calculation based on a significance test. This study carries the assumption that test should be the centerpiece of the statistical analysis. However, it is increasingly the case that confidence intervals are preferred to significance tests in summarizing the results of trials,

particularly in health services research. He believes that the way sample size is estimated should reflect this change and focus on the width of the confidence interval rather than on the outcome of a significance test. Such a method of estimation is described and shown to have additional advantages of simplicity and transparency, enabling a more informed debate about the proposed size of trials.

A very useful report by Zodey (2010) describes some commonly used terms, which need to be specified for a formal sample size calculation and are conventionally used for calculating sample size.

According to Shah (2011), researchers must calculate the sample size before starting of any animal study. It should be adequate enough to detect a small significant difference between the groups. In this study also reported that small sample size is not only responsible for the insignificant result but also for the less power of the study. Calculation of sample size involves complex statistics but it can be simplified to help the researchers who are not from statistical background.

Dell and coworkers have (2002) described the methodology of sample size determination for use in animal base experimental research. They calculated the sample size for single group experiment, continuous variable, sample size for repeated studies and for time to an event.

Sample size for single group experiment **(n) = log β / log p**

where β is the probability of Type II error (usually 0.10 or 0.05) and p represents the proportion of the animals are not infected.

Second case for continuous variable: In this case, a simple formula derived from the formula for the *t*-test can be used to compute sample size when power, significance level, size of difference in means (called the effect), and variability or standard deviation of the population means are specified.

Sample Size for Continuous Variable **(n) =1 + 2 C (S / d)^2**

Where *C* is dependent on values chosen for significance level (α) and power (1-β) and also defined the Constant C is Dependent on the Value of α and 1-β.

Third case for repeated studies: In this case n is derived from the paired *t*-test equation

Sample size **(n) = 2 + C (S/d)^2**

where $(S/d)^2$ is multiplied by C in paired studies, rather than 2C, indicating that a paired study is more powerful than a comparison of two independent means, as occurs in sample size calculations of continuous variables.

In this last case, the researchers could estimate the proportion of the control group that would exhibit the event and can state a difference that must be detected between the control group and the experimental group. The smaller this difference, the more animals will be needed. Thus, given estimates for proportion of the control group exhibiting the event ($\mathbf{p_c}$) and the desired proportion of the experimental group exhibiting the event ($\mathbf{p_e}$), then

Sample size $\mathbf{(n) = C [(p_c q_c + p_e q_e) / d^2] + (2 /d) + 2}$

Where $\mathbf{q_c} = 1 - \mathbf{p_c}$, $\mathbf{q}_e = 1 - \mathbf{p_e}$ and $d = |\mathbf{p_c} - \mathbf{p_e}|$. d is the difference between $\mathbf{p_c}$ and $\mathbf{p_e}$, expressed as a positive quantity.

Sampling theory, thus, is undoubtedly an important aspect of applied and scientific research investigations. Generally different sampling methodologies help to draw the good sample or better representative for estimation of parameters. Sample size is also more important to increase the precision of results, minimize the variability and for generalization of results with interpretation. In this paper for determination of the sample sizes for different types of research investigation are discussed. The above approaches to determining sample size have assumed that a simple random sample is the sampling design.

Another consideration with sample size is the number needed for the data analysis. If descriptive statistics are to be used, e.g., mean, frequencies, then nearly any sample size will suffice. In addition, an adjustment in the sample size may be needed to accommodate a comparative analysis of subgroups. Sudman (1976) suggested that a minimum of 100 elements were required for each major group or subgroup in the sample and for each minor subgroup, a sample of 20 to 50 elements was necessary. According to Kish (Kish, 1965) 30 to 200 elements are sufficient when the attribute is present 20 to 80 percent of the time if the distribution approaches normality. On the other hand, skewed distributions can result in serious departures from normality even for moderate size samples.

Finally, the sample size determination techniques provide the number of responses that need to be obtained. Many researchers commonly add 10% to the sample size to compensate for persons that the researcher is unable to contact. The sample size is also often increased by 30% to compensate for no-response. Thus, the number of mailed surveys or planned interviews can be substantially larger than the number required for a desired level of confidence and precision (Israel 1992).

SUMMARY & CONCLUSIVE REMARKS

Research investigation with the help of appropriate research designs provides the unbiased estimates of parameters through unbiased estimates the health status of community can be monitored. In the other hand research investigation is the part of a wider development of any

nation with regard to finance, education, public health, and agriculture, etc. that are indicators of better life of human beings. Modern applied research based on better living management is complex, requiring with a multiple set of skills such as medical, social, technological, mathematical, statistical etc. in the advance research with the help of suitable statistical tools and sampling research designs provide the unbiased estimates of the indicators, conclusions and their interpretations based on good samples with appropriate sample size. The present report emphasized the significance of sampling and determination of sample size in statistical research. The most common methods for sample size determination employed in recent statistical studies based on normal distribution, confidence interval (risk of error in the statistical hypothesis testing) and permissible error in the estimate. An investigator or researcher can calculate the appropriate sample size according to design of study mentioned above and measures the result. Attention to sample size will hopefully result in a more meaningful study whose results and interpretation will eventually receive a high priority for publication.

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