Chapter

2 Statistical Essentials

Learning Objectives

The principal goal of this chapter is to provide you with an understanding of the basic statistical concepts essential for interpreting and performing statistical analyses. This chapter will prepare you to:

- Explain the general concepts of statistics and understand related terminology
- Distinguish sample from population
- Distinguish descriptive from inferential statistics
- Discuss random and nonrandom sampling procedures and explain the strengths and limitations of each procedure
- Discuss the application of sampling to inferential statistics, and how this relates to evidence-based practice

Key Terms

Central tendency
Confidence level
Descriptive statistics
Hypothesis testing
Inferential statistics
Nonrandom sampling
Parameter
Population
Power analysis
Random sampling
Sample
Sampling
Sampling distribution
Sampling error
Variability

STATISTICS

What is statistics? Statistics is an empirical method for collecting, organizing, summarizing, and presenting data, and to make inferences about the population from which the data are drawn. Statistics is used extensively in many fields of study and it is important to ensure that statistics are appropriately applied to research and other quantitative forms of inquiry. One of the first steps in understanding and applying research to practice is learning the basic premises of statistics.

Most of us do not understand why we need to study statistics. In fact, you may dislike statistics or think that you will never use statistics. You may not know it, but you are living in a world full of statistics:

- Despite the current easing of the nursing shortage due to the recession, the U.S. nursing shortage is projected to grow to 260,000 registered nurses by 2025 (Buerhaus et al., 2009).
- Around 30% of people aged 65 years or older living in the community, and more than 50% of those living in residential care facilities or nursing homes, fall every year, and about 50% of those fall repeatedly (Baranzini et al., 2009).

These example statistics are not a matter of opinion or conjecture. Unlike everyday observation, researchers use the power of statistics to ensure that a study was designed carefully and statistical findings are trustworthy.

Let us look at another example. Suppose you are shopping at a local grocery store and are used to paying $3.27 for a gallon of milk. One day, you find that a gallon of milk is priced at $20.00. You would be shocked and very likely would put the milk back on the shelf. You may not know it, but you just made a rational decision. A rational decision is based on the probability of whether an event is likely to occur; we do not take an action if the probability of an event is not likely. This differs from making an irrational decision, which may occur when we do not pay adequate attention or base our decision on incomplete information. The probability of an event occurring is a statistical concept.

There are many important essential concepts in statistics. In this text, you will learn how to comfortably understand and use statistical findings. In this chapter, we discuss some of the most important statistical essentials so that you can smoothly progress towards more complex topics and eventually use these tools as advanced practice nurses.

Population versus Sample

A **population** is an entire group of individuals that a researcher wants to study. A **sample** is a subset of a population from which a researcher draws conclusions that are used to understand the population. For example, we are very interested in the prevention and treatment of diabetes, but it would be impossible to study every single diabetic person. Instead, we study a small group, perhaps 100 children aged 10–16 in order to speculate in a scientific way about all children aged 10–16 living with diabetes in the United States.

Occasionally, research is conducted on a population. One example of population-based research is the U.S. Census. In the census, all people residing in the United States are asked to complete the survey. However, in most health-related studies researchers collect data from a sample that represents the population.

Numerical measurements taken from a population are **parameters** and they are usually unknown. For instance, average job satisfaction of all nurses in the United States is a parameter when all nurses in the United States are defined as the population. On the other hand, those taken from a sample are statistics. For instance, job satisfaction of a selected group, or sample, of nurses in the United States is a statistic.

Descriptive and Inferential Statistics

Descriptive Statistics

Descriptive statistics are used to describe or convey an understanding of data. Consider a nursing college that wants to know more about the admission records of incoming nursing students. The college typically collects data on average age, entering grade point average, standardized test scores, and family income. The college will have to organize and summarize the data in order to understand the essential nature of the data, which would allow the college to know what characterizes the average student profile, especially when the number of data units is large. Descriptive statistics allow data to be organized, summarized, and described in a format that is more easily understood. Through descriptive statistics, administrators at the college will better understand the characteristics of students admitted to the college in a given year. For instance, the average student admitted to the college this year is 19 years old with a GPA of 3.89, a score of 24 on the ACT, and from families making $65,000 per year. Summarizing the data with descriptive statistics is a more efficient way to understand the student characteristics than having to examine every individual student record. With descriptive statistics, we can present the data with the use of graphs, charts, tables, and/or numerical measures such as **central tendency** and **variability**. We discuss descriptive statistics in more detail in Chapters 4 and 5.

Inferential Statistics

An inference is a conclusion based on logical reasoning in the absence of evidence or when only incomplete evidence is available. **Inferential statistics** allows a researcher to generalize the results from a sample to a population through a **hypothesis testing**. Suppose you are hired by United States Department of Health and Human Services to examine how Americans feel about healthcare reform. You could survey every American on their opinion about the reform; however, this would be a costly and lengthy study with a likelihood that someone would be left out. Therefore, you take a sample of Americans, following a strategy to ensure that this sample accurately represents all Americans, ask their opinion about healthcare reform, draw conclusions from those data, and then infer those findings to the population. If the researcher has been careful about sampling, we will have a good idea of what all Americans think about healthcare reform. We should note here that this inference process often relies on the representativeness of the sample for a given population. We discuss different sampling procedures in more detail in a later section of this text.

Inferential statistics help the practicing nurse make clinical treatment decisions or recommendations. What nurses often need to know is the strength or quality of the research evidence in support of a particular treatment or how various treatments compare with regard to effectiveness. Inferential statistics are tools to determine the strength of research evidence. For example, Seidel and colleagues (2008) conducted a meta-analysis (reviewing all randomized controlled trials and re-analyzing the combined data) on the effectiveness of antipsychotics for pain management. Across 770 participants in 11 studies, Seidel et al. found that antipsychotics were effective for pain management, but that extrapyramidal and sedation effects are a major consideration in prescribing. The advanced practice nurse may find this information important for treatment decisions, but must be able to weigh the strengths and limitations of such work, including the applicability or generalizability of the study.

It may seem that descriptive statistics and inferential statistics are two separate functions. However, descriptive statistics allow you to examine the collected data and to explain it better. Therefore, researchers use descriptive statistics as a prerequisite step to the use of inferential statistics.

Sampling

So, why do we select a sample from a population? The answer is simple. In many cases, a population is too large and too costly to access as a whole. Therefore, we take a sample out of the population and try to infer what we find from sample to population.

The researcher must take care in their approach to sampling. Because inferences are made from sample to population, it is important that the sample is the best representation of the population, in that it resembles the population as much as possible. Without careful sampling, inferences may be flawed (see **Figure 2-1**). In the world of evidence-based practice, it is important that the nurse evaluates how representative the sample is and, equally important, if the sample reflects the target population. For example, if the nurse is treating a child, it will be important to examine evidence from studies with children with similar characteristics. Clinically and statistically, it is problematic to apply evidence from studies of adults to children.

Random Sampling

There are two types of **sampling** procedures: random sampling and nonrandom sampling. **Random sampling** is a method of selecting subjects based on "chance" alone and is the strongest approach to sampling. All random sampling procedures select subjects for a sample based on an equal chance of selection for each person. If a researcher wishes to draw a random sample of 10 from a population of 100, we would say that each person in the population has 10 chances in 100 of selection; each person has an equal chance of selection. Random sampling does require that the entire population is known and can be accessed for sampling, such as all patients over the age of 65 with suspected myocardial infarction admitted through the emergency room

Figure 2-1

How to use a random number table.

in fiscal year 2012. However, random sampling becomes more challenging if the population includes unknown elements. For example, it would be difficult to conduct a true random sample of all undocumented immigrants using primary care services in the Chicago metropolitan area. How would the researcher find these subjects and give them a number? While many statistical tests assume random sampling and random sampling is the most likely to produce a representative sample, it is not always feasible. Researchers employ four main types of random sampling.

Simple Random Sampling

A simple random sample is taken so that all subjects in a population have an equal probability of being selected (i.e., without any pattern). One way to obtain a simple random sample is to identify all subjects

Figure 2-2

How to use a random number table.

1765	4379	2763	205	162
9921	989	1908	7680	7554
3279	6589	442	5224	560
7995	8954	2603	8891	9452
5091	5276	1409	7835	9585
4904	2311	1572	2153	5850
8130	2667	9918	2402	6099
3916	2949	3512	4319	4669
7047	9501	8191	4008	8912
7643	3828	3091	541	2185
9027	7937	6953	6551	6476
2904	672	9849	7608	9079
1656	2693	2508	8439	5606
625	6222	3046	5476	2734
2127	6640	3880	2888	8009
3649	1356	3387	5712	8717
1843	8312	431	6023	9265
1170	6461	9818	6282	7340
799	578	3314	1014	6165
2718	4534	8512	2106	5639
9986	5254	8025	5435	1772
6853	3764	6210	1771	5364
5634	8882	2983	3709	8887
6272	1370	6786	6241	5413
9811	9361	4397	6349	3278
1810	6232	3288	749	6066
7109	4601	9517	9616	8715
6256	7868	7195	6087	1340
1625	8504	374	9999	7212
2240	9727	9955	1502	1748
7770	2716	549	6350	2521
7753	3475	5945	1812	6111

1. Pick **any** number as a starting point.

2. Assume that we are to take a sample of 10 from a population of 80. This means that we only need two digits to choose our sample. You can go anyway you want from here, but I will go down to explain.

3. The first two digits, 89, is out of my range since I have only 80 people. The next two digits, 54, is in my range, so the 54th person is my first subject for the sample.

4. The next random number in the table is 5276, so we have 52 and 76. Both of them are in range, so they will be selected for my sample. The steps continue until a sample size of 10 is obtained.

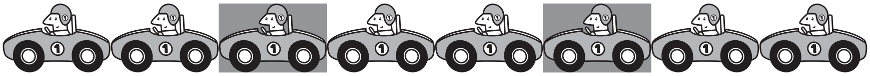
in the population by a number, then write each number on a piece of paper, place these in a hat, and randomly select the pieces of paper until the desired number of subjects for a sample is reached. A random number table or random number generator is also a useful tool for selecting a sample. **Figure 2-2** is an example of a random number table and shows a list of randomly generated numbers.

Systematic Random Sampling

A systematic random sample (**Figure 2-3**) begins with assigning a number to each subject in the population and then selecting every k-th

Figure 2-3

Examples of systematic sampling where every third subject is being selected.



person (where *k* is the population size divided by the desired sample size). For example, if a researcher wanted to select a sample of 40 out of 800 subjects in the population, the researcher would select every 20th subject from the population since $800 \div 40 = 20$. One thing to note here, however, is that the first subject will have to be randomly selected between 1 and 20. Systematic random sampling is a straightforward sampling procedure as long as the order of subjects is random. If the researcher is not careful about the order of subjects, it can create a nonrandom sample. For example, suppose that subjects were numbered in the repeating order of Caucasian, Hispanic, African American, and Asian. If a researcher begins with Hispanic as the first subject and selects every fourth subject, the sample would only contain Caucasian subjects except for the first person.

Stratified Random Sampling

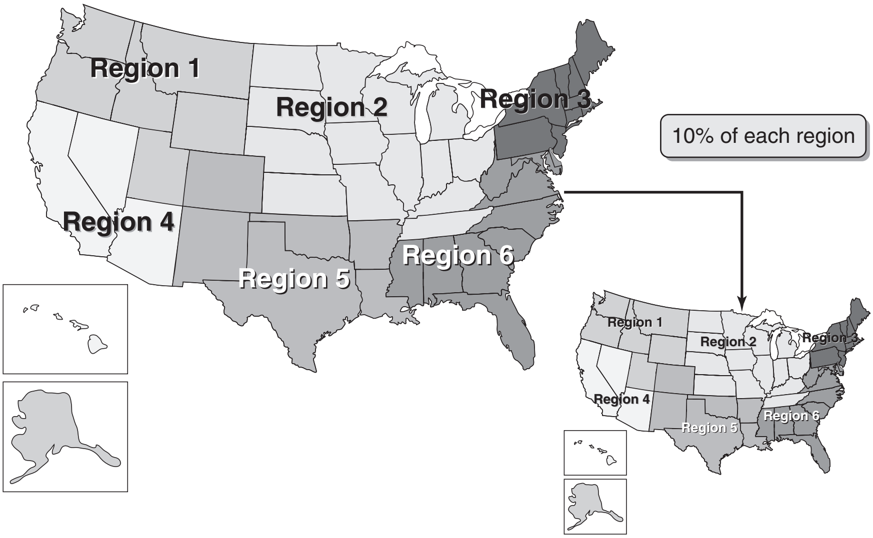
To conduct a stratified random sample, divide the population into groups, called strata, based on important variables in the study and then randomly selecting subjects from each group. For example, suppose a clinical researcher is interested in learning how much stress men and women have about an upcoming surgery. The researcher will divide patients into two gender groups, men and women, and randomly select patients from each gender group.

A stratified random sample is *proportionate* if the subject size of each stratum in the sample is in proportion to that in population (**Figure 2-4**). In the above example, the sample is a proportionate stratified random sample if there are 60 men and 40 women in a selected sample taken from a population with 600 men and 400 women. Each stratum in the sample represents 10% of that in the population.

A stratified sample can also be *nonproportionate* if the subject size of each stratum in the sample is not proportionate to that of the population. For example, suppose that there are 600 men and 20 women

Figure 2-4

Example of proportionate stratified random sampling.



in a population. A proportionate stratified sampling will provide 60 men and only 2 women for a sample if a researcher were to select 10% in each stratum. However, this strategy would result in the group of women having too few subjects, causing the comparison between men and women to be meaningless. In this case, the researcher can select all 20 women and select 42 men, creating greater balance between groups.

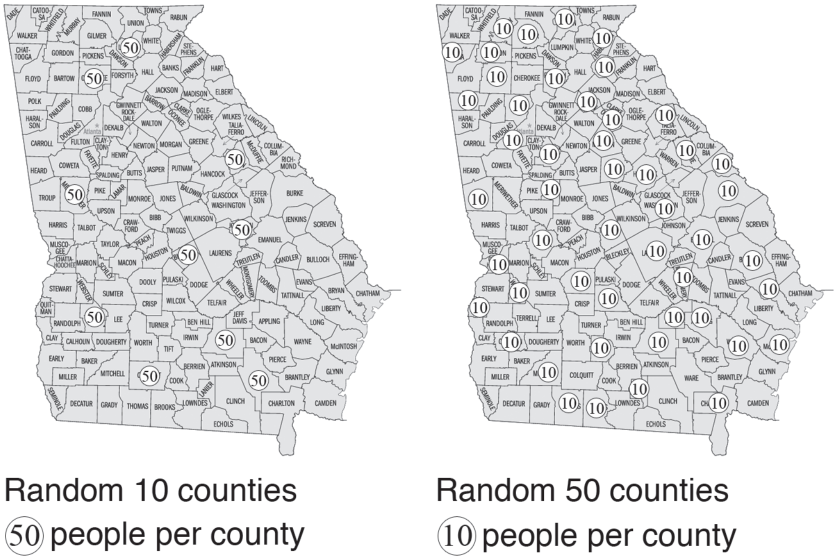
In general, stratified random sampling is a more precise sampling procedure than simple random sampling. The accuracy of the sampling is maximized when subjects within a stratum are *homogenous*—when the subjects in the stratum are very alike. However, it can be a weaker sampling procedure when stratification is designed poorly and can be more complicated than the previous two sampling procedures.

Cluster Sampling

Cluster sampling is similar to stratified sampling. A cluster sample begins with dividing a population into different groups, called *clusters*. However, cluster sampling works better when subjects within a cluster are *heterogeneous* as much as possible (as opposed to stratified

Figure 2-5

Examples of cluster random sampling.



sampling, which favors homogeneous subjects). Cluster sampling is particularly useful when a population is large or when a study covers a large geographic area. For example, suppose that a researcher wants to do a study on health needs in counties in Texas. It would be more efficient to randomly select counties and then randomly select subjects from those counties to study than to select subjects using simple random sampling (see **Figure 2-5**).

In general, cluster sampling provides less precision than simple random sampling or stratified sampling, but it is more cost-effective.

Nonrandom Sampling

Nonrandom sampling procedures do not rely on chance and members of the population do not have an equal chance of selection. These procedures prioritize feasibility or access to the population of interest and approaches other than random sampling are used to establish the representativeness of the sample. For example, if a researcher is testing an experimental drug for the treatment of pancreatic cancer, it will be most important to find patients who have the disease, are willing to volunteer, and are candidates for an experimental treatment. The competent researcher takes care to collect data on the characteristics of each participant so that the representativeness of the sample may be ascertained at the end of the study. When employing nonrandom sampling approaches, the researcher trades statistical power for feasibility. Four commonly used nonrandom sampling procedures will be addressed here.

Convenience Sampling

Use of convenience sampling is based primarily on accessibility of subjects in the population. A popular example is using every student in a single course at a university, such as Psychology 101. In clinical research, convenience sampling is used extensively; nurses might be interested in sampling all pediatric patients hospitalized or all residents of a nursing home during a particular time. This sampling approach saves the researcher's time and effort more than any other methods discussed previously, but it will be less likely to represent the population.

Volunteer Sampling

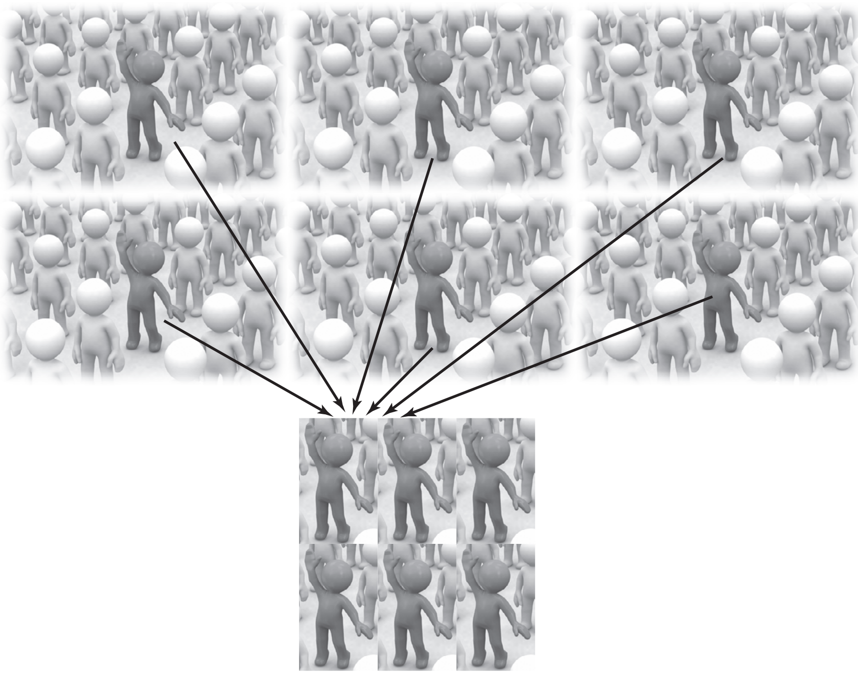
A volunteer sample is taken in a way that only those who offer themselves as participants in the study are included as a sample (**Figure 2-6**). This sampling method is a relatively inexpensive way of ensuring a sufficient number of subjects for a sample. However, it tends to obtain skewed opinions on the characteristics of interests for a study, as this group of individuals will have a narrower range of opinions compared to randomly selected group.

Quota Sampling

Quota sampling is done by dividing the population into mutually exclusive (not overlapping) groups and selecting subjects from each group, just like in stratified random sampling. However, in quota sampling subjects within each stratum or group are not selected randomly. Rather, a researcher may take a sample within each group using convenience sampling. Quota sampling may also be a proportionate sample, but using convenience measures to select participants.

Figure 2-6

Example of volunteer sampling.



Snowball Sampling

A snowball sample uses word-of-mouth, nomination, or referral to accrue subjects. The researcher must make at least one contact with a subject and then that first subject nominates or refers additional subjects based on personal contacts. Therefore, a sample will grow like a snowball rolling down a hill. This method is particularly useful for finding "hidden" subjects. For example, we might need to study teens who are injecting steroids. If we can find a few participants who are willing to ask others they know to participate, we are more likely to accrue a reasonably sized sample. The strength of this approach is in securing access to a sample of hard-to-find subjects. However, like all nonrandom samples, this method can produce a non-representative sample of population. In results, the statistics from this sample can be potentially misleading or biased if no other measures are used to improve the representativeness of the sample.

Nonrandom sampling procedures are generally easier and more cost-effective to implement than random sampling procedures. However, one should keep in mind that there is a greater chance that these sampling procedures will not produce the best representative sample. When a sample is not randomly selected, it is less likely to represent the population, and potential bias is introduced into the results. This potential bias is *selection bias*. If selection bias is not taken into account, it will reduce the accuracy with which the researcher can generalize results to the population. It is possible to estimate selection bias as a function of sampling error.

Sampling Distribution and Sampling Error

A **sampling distribution** is defined as a distribution of a statistic that is computed from samples. In other words, the sampling distribution of a mean or arithmetic average will be a collection of all means that we would compute from an infinite number of samples from a given population (**Figure 2-7**). Understanding sampling distributions is important because it is the basis of making statistical inferences from a sample to a population and helps us to look at how the value of a mean is like other possible sample means. For example, suppose a researcher selects 200 samples of 10 nurses from a large population and computes the mean of salary for each of the 200 samples. This will generate 200 mean salary measurements, from each sample and the distribution of those 200 mean salary measurements will comprise a sampling distribution of the sample means.

These 200 mean salary measurements will not exactly match the population mean (a parameter), μ, when they are selected randomly because each sample of 10 will have somewhat different nurses (**Figure 2-8**). This difference is called **sampling error** because the sample means will be different as the sample, a subset of the population, will not be the same as population.

Sampling error can affect our statistical estimate. When sampling error is small, it means that there is small variability in a sampling distribution and we can be more confident with the sample estimate. When sampling error is large, however, it means that there is a lot of

Figure 2-7

Sampling distribution.

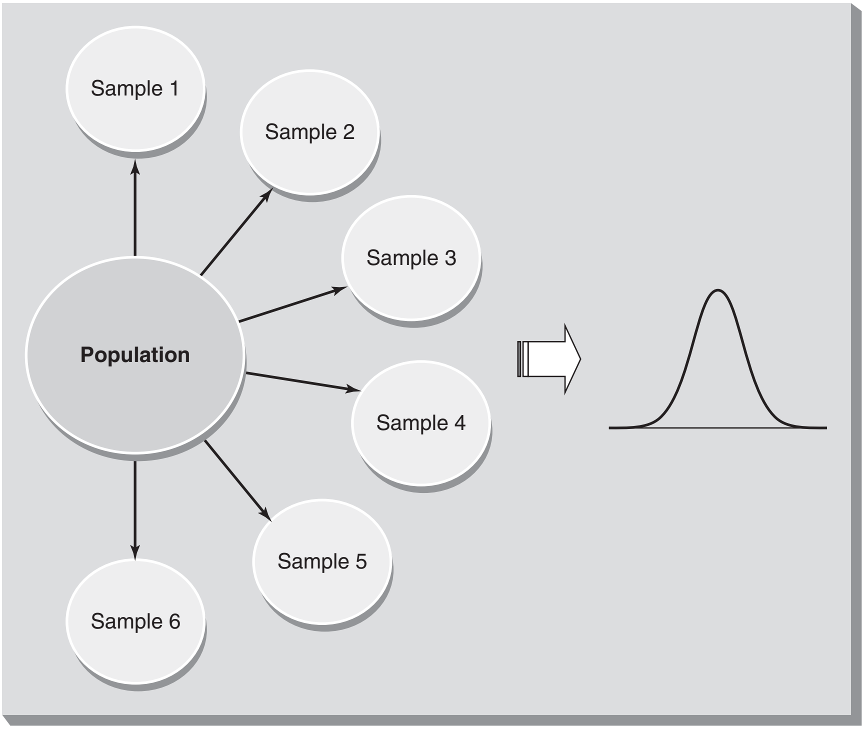
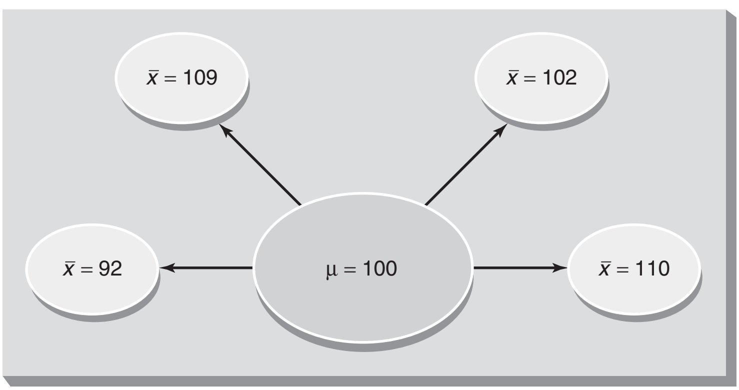


Figure 2-8

Sampling error.



Box

EVALUATING THE REPRESENTATIVENESS OF THE SAMPLE

- Is the choice of sampling approach likely to ensure good representation of the population?
- Has the researcher described the sample characteristics in enough detail so that the reader may evaluate whether inferences to the population are reasonably accurate?
- Is the sample size adequate for detecting statistical significance?
- Has the author identified limitations of the sampling approach?

variability in a sampling distribution and we will not be confident with the sample estimate.

There are two characteristics of the sampling distribution of sample means.

1. The mean of all sample means from a population will be the same as the population mean.
2. The standard deviation of all sample means (i.e., standard error) will always be smaller than the standard deviation of the population mean. It is computed by dividing population standard deviation by the square root of the sample size.

In research and evidence-based practice, the nurse needs to understand how representative the sample is and what strategies increase the likelihood that the sample statistics are an accurate reflection of population parameters. A critical analysis of the strength of the sampling approach and the representativeness of the sample helps us determine how strong the inferences from sample to population are.

Sample Size

Once we determine the sampling procedure, the next legitimate question is "How large of a sample size do I need?" If a researcher selects too few subjects for a sample, there will not be enough coverage of the population to make inferences. At the same time, too large of a sample may be costly and time-consuming. So, how do we determine an adequate sample size? The answer to this question depends on many factors, such as the population size, the statistical procedure, and **confidence level** (this may be thought of as our tolerance for error). Most statistics books have a formula to calculate necessary sample size and it is easy to find sample size calculators or software programs through Internet search engines. A popular procedure to calculate the necessary sample size is **power analysis.** This should be performed before a researcher begins the study to ensure that there are enough subjects in a sample to make appropriate inferences to the population. Power analysis will be discussed in more detail in Chapter 6.

Case Study

Hawkins, S. Y. (2010). Improving glycemic control in older adults using a videophone motivational diabetes self-management intervention. *Research and Theory for Nursing Practice: An International Journal, 24*(4), 217–232.

Older adults experience the greatest burden of diabetes. Resources must be available and accessible to empower older adults to perform diabetes self-care. The purpose of this study was to evaluate a videophone motivational interviewing (MI) diabetes self-management education (DSME) intervention to improve glycemic control of rural older adults. Sixty-six participants (mean age = 64.9 years, range 60–81) with uncontrolled diabetes were enrolled in a 6-month videophone intervention. Experimental group participants (n = 34) received weekly, then monthly, videophone MI DSME calls, whereas control participants (n = 32) received monthly videophone healthy-lifestyle education calls. Although both groups experienced a decreased HbA1c, there was a statistically significant difference in experimental group mean values (p = .015), but not the control group (p = .086). The experimental group demonstrated statistically significant increases in diabetes knowledge (p = .023) and diabetes self-efficacy (p = .002). Experimental group participants with high self-efficacy in contrast to low self-efficacy had a statistically significant decrease in HbA1c (p = .043).

This abstract, published as part of a larger research report by Dr. Shelly Y. Hawkins, is a typical example of an experimental study on a topic of interest to nurses. Let us examine the abstract for key elements that help us understand the essential foundations of statistics and evidence-based practice.

Population: Rural older adults with diabetes

Sample: 66 adults between 60 and 81 years (note that the abstract does not indicate if this is a random or a nonrandom sample)

SUMMARY

There are many essential ideas to understand when learning statistics, and this chapter was intended to provide some of the most basic of these essentials. These include definitions and examples of descriptive and inferential statistics, the differences between population and sample, various sampling methods including random and nonrandom sampling approaches, and sampling distributions and sampling error.

Descriptive statistics communicate important elements of the collected data, while inferential statistics are used to infer conclusions from the sample to the population.

Populations are often too large and costly to use in research, so usually we take a representative sample of the population to conduct a study. The sample should be the best representation of the population possible so that we can make accurate inferences, and each sampling procedure has strengths and limitations. Random sampling methods are usually the strongest approach, but may be more costly or not feasible, and include simple random sampling, systematic sampling, stratified sampling, and cluster sampling. Nonrandom sampling methods are less likely to produce representative samples, but are more expedient, less costly, and do not require the ability to access the whole population; they include convenience sampling, volunteer sampling, quota sampling, and snowball sampling. A researcher must consider the strengths and limitations of both random and nonrandom sampling approaches before designing a study.

Sample size is important as it can negatively affect our ability to make inferences if too few subjects are included or increase costs if too large a sample is used. The best sample size depends upon many factors, such as the population size, the statistical procedure, and confidence level.

The degree of sampling error helps us to understand how strong our inferences are from sample to population. The sampling distribution is one way of understanding sampling error.

The advanced practice nurse, nurse leader, and nurse administrator must be comfortable and skilled in the interpretation and application of the essential elements of descriptive and inferential statistics, sampling strategies, and evaluation of the representativeness of a sample in order to make sound practice decisions.

Critical Thinking Questions and Activities WWW

1. What are the differences between population parameters and sample statistics?
2. What does the term "representative sample" mean?
3. Is it reasonable to say that stratified random sampling tends to produce a representative sample? Explain your answer.
4. In your daily life, find an example of the followings:
   a. Descriptive statistics
   b. Inferential statistics
5. Why must the researcher begin with descriptive statistics when the goal to conduct inferential statistics?
6. Use a random number generator or a random-number table provided in this textbook to generate 5 samples of 10 integers between 1 and 100. Are there any numbers appearing in more than one sample? What happens if you increase the number of integers drawn for each sample? Why do you think this happened? Explain in relation to standard error.
7. You are to conduct a study on patient satisfaction in a nursing home. Which sampling procedure will you utilize? Explain your answer.
8. Case Study: From the following abstract, identify the population and probable sample type.

Box

Barkin, S. L., Gesell, S. B., Póe, E. K., & Ip, E. H. (2011). Changing overweight Latino preadolescent body mass index: The effect of the parent–child dyad. *Clinical Pediatrics*, *50*(1) 29–36.

Abstract

Background: Latino children are disproportionately burdened by obesity. *Objective:* To assess whether body mass index (BMI) change in preadolescents reflected that of their participating parent. *Methods:* A total of 72 Latino overweight/obese preadolescents (BMI ≥ 85%) and a parent participated in a randomized controlled trial. The intervention group received 5 monthly 60-minute sessions at a recreation center (group physical activity, goal setting). The control group received 2 standard-of-care clinic visits plus a group discussion. *Results:* Between baseline and 6-month follow-up, 47% of children (mean change = −0.37, SD = 2.48) and 63% of parents (mean change = −0.88, SD = 3.53) decreased their BMI. Parent–child dyad BMI change was significantly correlated ($r = .53$, $P = .001$). In linear modeling, those preadolescents in the control group were more likely to lose absolute BMI units (−0.96, $P = .03$); whereas those who had parents who gained BMI over the time interval were more likely to increase their BMI (0.17, $P = .008$). *Conclusions:* Obesity interventions should focus on the parent–child dyad.

Self-Quiz

1. True or false: Researchers take a sample from a population to infer the findings or results about a population.
2. True or false: Since descriptive statistics has a different objective from inferential statistics, they should not be performed together simultaneously.
3. What is the general process of organizing, summarizing, and describing the collected data in an easier format?
   a. Inferential statistics
   b. Random sampling
   c. Descriptive statistics
   d. Hypothesis testing
4. A researcher would like to study average sodium intake across various racial and ethnic groups. However, they are concerned

that sample sizes for some racial/ethnic groups might be too small to be useful in statistical analyses. What type of sampling procedure might be the most useful for their purpose?

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