Matching Research Designs and Analyses

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Research can be defined as a planned and systematic course of action taken to understand a phenomenon, find answers to questions, establish facts, and reach new conclusions.[1] Although researchers use a variety of research methods to contribute to new knowledge, the process often begins with observing the world and what is already known, asking a question, and developing a hypothesis. To answer a question and test a hypothesis, the researcher devises a research plan and collects and analyzes data to provide objective conclusions.[2] The best research is objective and free of bias so that the study's conclusion is not affected. Research does not always lead to the expected outcome; thus, the researcher must remain open to what the data do or do not reveal. This article describes research design and methodology, including different techniques for developing a hypothesis and collecting and analyzing data.

Research Question

The first step in a research project is formulating a clear and specific research question. Relevant research questions incorporate variables of interest and query the nature of a variable or concept or the relationship between 2 or more variables.[2] Typically, questions begin with terms such as *who, what, when, where,* and *how.*[3,4] Examples of research questions for clinical, educational, or administrative settings are:

- clinical – Which method of positioning the lateral knee results in the most consistent superimposition of the condyles?
- educational – What preadmission data are the best predictors for the successful completion of a radiography program?
- administrative – How can a department be staffed to reduce overtime hours while maintaining adequate coverage of all shifts?

Research Design

After devising a research question, the researcher determines the data collection methods that will ensure the question is answered. Selecting the best design for a research project is critical because the design determines how the data are collected and analyzed.[1,5] A well-planned research design ensures the results and conclusions are valid and trustworthy; therefore, data analysis, including statistical analysis, should be included in the research design.[1,2] Research plans vary depending on whether the research is quantitative, qualitative, or mixed-methods. The entire research process must be considered to ensure the most appropriate data collection and analysis methods are used to answer the research question.[6]

Research is categorized as descriptive or experimental.[1] Descriptive studies collect data without changing or manipulating the environment. Their findings describe situations and demonstrate relationships, but they do not make predictions. Observational studies, case studies, and surveys are types of descriptive research. Descriptive studies ask open-ended questions such as those starting with *what is* and *what was.*[1] In

addition, descriptive studies can be cross-sectional, involving a single interaction with participants, or longitudinal, following participants during a specific period. To collect data, the researcher can interact with participants through interviews or surveys. Alternatively, a descriptive study might be purely observational or use existing records to collect data.[1] Descriptive studies are exploratory and not designed to test a hypothesis. However, these studies can generate new information that can contribute to formulating hypotheses.[7]

In experimental studies, a program, treatment, or procedure is introduced, and the effect of the manipulation is observed and analyzed.[1] Clinical trials are experimental studies involving humans. After a research question is formed, the researcher reviews the relevant literature to construct a hypothesis—a concise, informed explanation or answer to a research question—that will guide the experimental study.[1] Hypotheses can use the if-then or null format.[3,8] The if-then format is a statement predicting the cause-and-effect relationship between the research variables. With the null format, the researcher seeks to reject the hypothesis. The null hypothesis states that there is no relationship present between the research variables.

For example, the research question regarding the lateral knee could be addressed by using a positioning phantom to obtain images using different positioning techniques for the lateral knee and having a group of experts compare the images. Research hypotheses for this example might be:

- if-then format – If the cross-table lateral projection of the knee is used, then a more consistent superimposition of the condyles will be achieved compared with that obtained using a traditional mediolateral projection.
- null format – There will be no statistically significant difference in the superimposition of the condyles obtained when using a cross-table lateral projection of the knee vs a traditional mediolateral projection of the knee.

Data Collection

Data can be defined as collections of information such as numbers, words, or observations. Data are classified as primary or secondary. Primary data are being collected for the first time, secondary data were collected previously by someone else.[9] Data collection is a systematic process of gathering information during research.

Qualitative, Quantitative, and Mixed-Methods Research

There are 3 methodological approaches used for collecting research data: quantitative, qualitative, and mixed-methods.[10] Quantitative methods include numerical data collection processes, research designs, and statistical procedures (see **Table**). If the goal of the research is to test a hypothesis, identify patterns, or make predictions, then quantitative data are collected. Quantitative research designs include experimental, quasi-experimental, descriptive, and correlational methods.

Conversely, qualitative methods gather nonnumerical data to explore and analyze subjective experiences, often through observation and surveys. Qualitative data typically are descriptive, more difficult to analyze, and collected if the research goal is to explore ideas or understand experiences. Qualitative research designs are defined less strictly than are quantitative designs and include case studies, observations, questionnaires, and interviews.[11-13]

A mixed-methods approach incorporates qualitative and quantitative methods to provide a more complete answer to a research question. Observations and questionnaires are data collection methods that can provide the researcher with a mix of quantitative and qualitative data.[11,12]

Data collection methods should be considered carefully. The method the researcher chooses depends on the research question, the type of data required to address that question, and the study's hypothesis. Data collection methods include[12]:

- experiments
- observations
- physiological assessments (eg, blood pressure readings, laboratory blood tests)
- record reviews
- surveys

Experimental Research

Experimental studies introduce a treatment, procedure, or program to test a hypothesis and measure

Table
Comparison of Qualitative and Quantitative Research Methods[10-13]

Research aspect	Qualitative	Quantitative
Keywords	Complexity, contextual, inductive logic, discovery, exploration	Experiment, random assignment, independent or dependent variable, causal or correlational, validity, deductive logic
Purpose	To understand a phenomenon	To discover causal relationships or describe a phenomenon
Sample	Purposive sample, small	Random sample, large
Data	Focus groups, interviews, field observation	Tests, surveys, questionnaires
Methods and design	Phenomenological, grounded theory, ethnographic, case study, historical or narrative research, participatory research, clinical research	Experimental, quasi-experimental, descriptive, methodological, exploratory, comparative, correlational, developmental (eg, cross-sectional; longitudinal, prospective, or cohort; retrospective, ex post facto, or case control)

a result.[1] They are used to study causal relationships where 1 or more independent variables are manipulated and effects on dependent variables are measured.[13] True experimental research consists of 4 elements: manipulation, control, random assignment, and random selection.

Manipulation is the purposeful introduction or change of a variable. Control is when factors outside the study are kept from affecting or influencing the study, ensuring that changes measured in the study are due to the manipulation element of the study instead of other factors.[1] The purpose of a control group is to determine what happens under the same study circumstances in the absence of the treatment. Without a control group, separating the effects of other factors from the effects of the variable being studied is impossible.[13]

Random selection, or random sampling, is the process of selecting a sample from a known population using a randomization process. For example, a researcher numbers their population from 1 to 1000 and has a computer program randomly select 200 numbers between 1 and 1000 or every tenth number. The numbers correspond to the randomly selected participants drawn from the study population.

Random assignment distributes an established population into control and treatment groups. Study subjects or participants have the same chance of being assigned to the control or treatment group. Randomization is critical for assessing the effects of a treatment and ensures the study will produce meaningful data that can be used for evaluation.[1]

Experimental Research Variables

Experimental research examines cause-and-effect questions. Causation is when a change in 1 variable causes a change in another variable. A variable is a characteristic that can have different values (eg, height, temperature, age). An independent variable is the stimulus or treatment the researcher manipulates to cause a response. The dependent variable is the response or effect caused by the stimulus; it is the variable that is measured during an experiment.[1,13]

A classic example of a cause-and-effect experiment is the conditioning behavior study conducted by Pavlov. In his study conducted on dogs, Pavlov would ring a bell then feed a selection of dogs. The dogs salivated when presented with the food. After a time, the dogs began associating the sound of the bell ringing with food and thus salivated at the sound of the bell regardless of whether food was presented. In Pavlov's study, the dependent variable was salivation (effect), and the bell ringing was the independent variable (cause).[14]

Experimental Research Design

An experiment should be designed to test a hypothesis. Keeping the research question in mind, the researcher should formulate a hypothesis in a testable format and include independent and dependent

variables. For example, if the researcher wants to know if a fertilizer increases plant growth, then fertilizer is the independent variable and plant growth is the dependent variable. A testable hypothesis for this research question would be: "Fertilizer A causes plants to grow taller." The null hypothesis would be: "Fertilizer A does not cause plants to grow taller." A hypothesis should be formulated as specifically as possible. In this case, the hypothesis should include the specific fertilizer and type of plant.

For a controlled experiment, the independent variable must be manipulated precisely for all groups, and the dependent variable must be measured precisely. Confounding variables, which are external variables that could affect the independent or dependent variable, must be considered and controlled. For the fertilizer example, confounding variables consist of the soil type or the amount of sunlight and water received; therefore, these variables must be kept consistent to ensure outcome effects are due to the independent variable. The degree to which the independent variable is varied also must be decided when designing an experiment. Subjects should randomly be assigned to treatment and control groups. Control groups do not receive the treatment (eg, fertilizer in the previous illustration).

After the experiment is performed, the dependent variable must be measured. The researcher must ensure that the method used to measure the dependent variable is reliable, valid, and minimizes bias or error. Certain measurements, such as plant height, are measured objectively with scientific instruments; however, other measurements must be operationalized to transform the data into a measurable observation. Social anxiety is an example of data that must be operationalized because this construct cannot be directly measured. To measure social anxiety, participants could use self-rating scores or list the number of times they experienced social anxiety in a specific period.[1,13]

Solomon 4-Group Design

The Solomon 4-group design is used to control for the effects of a pretest, a measurement, or an assessment conducted before the experimental treatment. The Solomon 4-group design is used if the researcher is concerned that the pretest might influence how participants respond to the test or treatment. The design includes 4 groups:

- group 1 – pretest, treatment, and posttest
- group 2 – pretest, no treatment, and posttest
- group 3 – no pretest, treatment, and posttest
- group 4 – only the posttest

The treatment is administered to participants who are given the pretest and to participants who are not. This is how pretest sensitization is analyzed. Pretest sensitization should be assessed because it can affect the study outcome and make a treatment appear more effective than it is.[15]

A 2×2, 2-way analysis of variance (ANOVA), which is a statistical test used to analyze the difference of the means between 2 or more groups, is used to analyze Solomon 4-group experimental results. A 2-way ANOVA analyzes the effects of 2 or more independent variables on the dependent variable. In the Solomon 4-group design, the pretest condition and the treatment condition are the 2 independent variables that are manipulated.[16]

Pretest sensitization is a risk whenever a research study uses a pretest or covariate. The pretest might make the purpose of the study seem obvious, or some research participants might be more perceptive than others. By taking the pretest, certain research participants might become aware of what the outcome of the experimental treatment is expected to be; therefore, these participants' subsequent responses to the treatment might not be valid, even if the responses are subconscious in nature.[17]

Quasi-Experimental Research

Quasi-experimental research tests a hypothesis and evaluates the cause-and-effect relationships between variables. Quasi-experimental research is similar to true experimental research except it lacks randomization. At times, randomization is not practical or ethical. To equalize the 2 groups, the researcher can compensate for a lack of randomization by using various strategies such as increasing the sample size or adding covariates.[18]

Typically, quasi-experimental research involves an experimental treatment and 2 groups of subjects observed before and after the treatment. To adjust for the lack of randomness, the study might involve

2 groups from different locations with equivalent environments such as patients in 2 different hospitals. The researcher obtains pretest information from both groups to demonstrate whether patients in the 2 hospitals are similar at baseline. If they are similar, the researcher can be reasonably confident inferring that any difference found in the posttest is the result of the applied intervention.[18]

The main advantage of quasi-experiments is they are conducted with the least amount of disruption to ongoing activities. In the strictest sense, although they are not considered as strong as true experiments, they are considered acceptable.[18] In certain situations, quasi-experimental designs are more appropriate to use than are true experimental designs, for example, when[18]:

- assigning people to conditions is impossible or unethical.
- logistics of true experimental research are too prohibitive.
- the research goal is to examine individual-level instead of group-level performance.
- true experimental research design would produce highly artificial situations.
- true experimental research would result in small subgroups or the inability to randomize subjects to groups.

Survey Research

Survey research is a popular method for gathering information from a sample or population regarding attitudes, experiences, and knowledge. There are 2 main ways to gather data in survey research: interviews and questionnaires.

Interviews

An interview involves the researcher directly asking a small number of participants questions, which are presented in person, over the phone, or via video conferencing.[1] Interviews initially provide qualitative data, which are subsequently converted into quantitative data by recording each response as a category or rating and employing statistical analysis on the resulting data.[19] Interviews allow more flexibility than do questionnaires. The researcher can gain a more detailed perspective of participants' thoughts because participants can answer in their own words and elaborate as necessary to clarify their responses. Typically, responses are recorded and transcribed in preparation for future analysis.[19-21]

Interviews can be structured or unstructured. Structured interviews follow a rigid procedure and use predetermined, prepared questions, the responses to which are recorded in a standardized format. Unstructured interviews do not follow a rigid structure, and the questions are not all predetermined.[9]

Questionnaires

A questionnaire is defined as a list of predetermined questions distributed by mail, online, or in person.[19] Flexibility and broadness of scope are the greatest advantages of a questionnaire. In addition, the use of questionnaires allows researchers to access large samples and assert some control over who completes the questionnaire. A disadvantage of questionnaires is that the collected information tends to be more superficial and does not delve as deeply into human behavior as that collected via interviews. In addition, questionnaires often have a low response rate.

Several electronic, online survey and questionnaire tools, such as SurveyMonkey and Qualtrics, are popular among researchers because of their ease of use and affordability. Online questionnaires are faster to complete, and the data are processed easily.[19]

Mailed questionnaires can reach more participants in varied locations compared with interviews. In addition, a mailed questionnaire gives respondents a guarantee of confidentiality; thus, their responses might be more truthful compared with those obtained in a personal interview, which in turn reduces the level of bias.[9,19] One disadvantage of a mailed questionnaire is that respondents might misunderstand the questions and complete the survey incorrectly. Also, some potential respondents might not be able to read and respond to the questionnaire. Mailed questionnaires are likely to be set aside by recipients and not completed. Thus, most mailed questionnaires have a low return rate; these low response rates limit the generalizability of a questionnaire study's results.[19]

Questionnaires administered directly can be handed out to people assembled for various purposes. Typical

examples include students in a classroom, attendees of a meeting, or people at a convention. Distributing questionnaires in person is inexpensive, and having the researcher present to answer questions is an advantage. Electronic surveys and questionnaires are becoming more popular because they typically result in quicker returns, lower item nonresponse rates, and more complete answers to open-ended questions.[19]

The questionnaire distributed might be an established and previously validated instrument, such as the Myers-Briggs Type Indicator (The Myer-Briggs Company) or the Maslach Burnout Inventory, or it might be constructed by the researcher and validated using a subsample of the target population. In addition, the researcher can adapt a previously validated survey used for a different study to ensure that the survey measures the intended content of the current study.[22]

Survey Research Steps

The survey should be guided by a specific research question. Keeping the research question in mind as a guide, the researcher must decide on a target population (eg, all radiologic technologists in the United States) and sampling method.[19] The researcher should decide what type of survey—an interview or questionnaire—is best suited to answer the research question. After these decisions have been made, the survey questions are written, keeping in mind question types, phrasing, order, and content. Before distributing the survey, the researcher should create a clear plan for where, when, and how the survey will be conducted. After the survey data are collected, the results are analyzed.[19]

Survey Question Design

Survey research should focus on 1 or more research questions. If the researcher is designing the survey instrument, the survey items should be formulated to address all or part of the research question. The research question establishes what the researcher wants to know and guides the formation of the survey questions. Survey design is an involved process. The researcher must devote sufficient time to question the design, number of questions asked, and overall layout of the survey to obtain high-quality, valid, and reliable data. Questions can be open-ended or closed-ended. Closed-ended questions can be binary (eg, yes-no), answered using a scale (eg, a Likert scale with 5 points ranging from strongly agree to strongly disagree), a list of options with only 1 possible answer choice, or a list of options with multiple possible answer choices.

When creating survey questions, questions must be worded carefully to consider the target population's level of knowledge so that respondents will clearly understand what is being asked. Questions should be precise and focused while providing enough context that respondents can answer them and provide useful information. Questions should be worded to minimize the risk of research or response bias. For close-ended questions, all possibilities should be included as answers, or a field labeled Other should be provided if the options are not exhaustive.[19]

Correlational Research

Correlational research uses statistical analysis to examine the relationship between 2 or more variables without the researcher controlling or manipulating them. This type of research does not generalize about the causal nature of correlations.[23] Examples of correlational research questions are:

- Is there a correlation between earning a master's degree in science and holding a professional leadership position?
- Is there a correlation between the outdoor air temperature during the winter months and the cost of heating bills?

In the first example, a high correlation level would indicate that more individuals who earn a master's degree in science hold a professional leadership position compared with those who do not. Similarly, a low correlation level would indicate that there is no predictable pattern between holding a master's degree in science and holding a professional leadership position. However, the results do not suggest that earning a master's degree in science results in one holding a professional leadership position.[23]

Another important factor to consider is whether the resulting coefficient of correlation is positive or negative. The sign (ie, + or −) of the coefficient indicates the direction of the relationship. A positive coefficient indicates that as 1 variable increases, the other also

increases. A negative coefficient indicates that as 1 variable increases, the other decreases. For example, the coefficient is negative for the research question regarding correlation between outdoor air temperature during the winter months and heating bills. This negative coefficient suggests that as outdoor temperature decreases, heating bills increase.[23]

Observational Research

Observational research is nonexperimental and often qualitative. The researcher observes and does not intervene actively or manipulate conditions. Observational research is used to study people and environments such as settings, surroundings, and societies. Direct observation is considered the gold standard of qualitative data collection because it avoids problems that are inherent in self-reported data and can reveal information that participants might be unaware of themselves.[24] Observational studies are low-cost, can aid in analyzing difficult topics, and are straightforward to conduct. However, observational studies are more prone to observer bias and confounding or omitted variables. The most common observation types include case studies, covert observations, naturalistic observations, and participant observations.[25]

Case studies incorporate multiple data sources and focus on a person or a group of people during an extended period.[24,25] They are based on in-depth explorations of complex issues in real-life settings. Dr Jane Goodall's years-long observation of chimpanzees in the wild is an example of a naturalistic observation study. She observed their food habits, social interactions, gestures, and way of life. In case studies, researchers observe participants in real-life settings but do not influence their behavior. Covert observations focus on participants who do not know they are being observed. In participant observations, the researcher observes participants in real-life situations and might immerse themself in the participant group to experience what participants are experiencing. Data gathered in this environment are usually valid and of rich quality. Case studies offer a depth of insight into behavior that is not possible with survey research. However, observational research requires a substantial investment in time, which means that it can be costly to conduct.[24]

The 3 main types of observational studies include cohort studies, case-control studies, and cross-sectional studies. Cohort studies follow a group of participants during an extended period, whereas cross-sectional studies observe a population at a specific point in time. Case-control studies analyze a case study group and a control group and compare them (eg, heart disease in people who smoke and people who do not smoke).[25]

Observation is used in quantitative and qualitative research depending on how the study questions are worded—open-ended vs structured answers—and the reporting method used. Observational qualitative research usually occurs in a natural environment. This type of research studies human experience and evaluates all factors and influences present in a particular situation. These studies rely on unstructured or loosely structured methods of data collection.[25]

For specific research problems, observational research is used as an alternative to asking individuals for information. It is a particularly helpful alternative for certain situations in which study participants might be likely to distort their behaviors and answers.[24]

Observations in Clinical Settings

In clinical situations, observational research is used to gather information about individuals' characteristics and conditions, verbal and nonverbal communication, activities and behavior, skill attainment and performance, and environmental conditions. Observational research is helpful when people might have difficulty accurately describing their behaviors, particularly when they are unaware of their behaviors such as in a clinical situation where they might be fearful. Observational research might be more appropriate during embarrassing situations (eg, displays of hostility or aggression, times of emotional difficulty, or grieving) or when studying participants who might find it difficult to explain their actions such young children or individuals with a diagnosed mental illness.[24,25]

Levels of Measurement

The 4 levels of measurement used in research, also known as *scales of measurement*, ranked from lowest order (least sophisticated) to highest order (most sophisticated) based on the amount of information the

data collected provide are nominal, ordinal, interval, and ratio. The data's level of measurement limits the extent to which the researcher can analyze the data and the type of statistical analysis performed. Because variables are measured in numerous ways, deciding what level of measurement to use before collecting data is important.[26]

Nominal is a naming level of measurement used to classify or categorize a variable (eg, sex, ethnicity, religious affiliation). This measurement recognizes whether an object or individual belongs in a specific category. For example, with nominal data, the number 1 can be used to represent men and the number 2 to represent women to categorize participants by sex. A mathematical operation is not used. The assigned number allows the researcher to group data for statistical analysis.[26,27]

Ordinal is a ranking level of measurement and is used to order by degree or amount such as competition results, percentile rank, grade point average, or Likert scale. Objects or individuals are placed in order based on the degree to which they possess a particular attribute but without indicating the degree of difference or distance between them. Ordinal data numbers are assigned to each subject or participant such that the order of the numbers (eg, 1, 2, and 3) have meaning. This allows the researcher to group data by likeness for analysis.[26]

Interval is defined as a standard unit of measurement that separates different levels and has an arbitrary floating 0 (eg, most test scores, degrees of temperature). With interval data, the researcher can perform mathematical operations and obtain results that are meaningful to the study. With interval data, 0 does not suggest a lack of something. For example, 0 °F does not refer to a lack of temperature.[26]

Ratio is defined as an interval scale with an absolute 0. For example, at some point the measurement of the variable does not exist (eg, dollars, speed). The same mathematical operations performed on interval data also might be performed on ratio data. The difference is that with ratio data, 0 does indicate a complete lack of the data being measured.[26]

Data Analysis

Data analysis varies depending on if the data collected are quantitative or qualitative. Quantitative data are numerical and analyzed by simple math or more advanced statistical analysis to find patterns and determine if the data support a hypothesis. Qualitative data (eg, text, images, videos) are more difficult to analyze. Qualitative data analysis techniques include thematic analysis and qualitative content analysis.[28]

Statistical Analysis

After collecting quantitative data, statistical analysis is used to describe the data collected. Descriptive statistics are used to summarize quantitative data, including determining the distribution, measures of central tendency, and measures of variability.

Measures of Central Tendency

Measures of central tendency describe how a number relates to the middle of a set of numbers. They include mean, median, and mode. Mean is the mathematical average of all values of a set; median is the middle value in a set of ascending or descending values; and mode is the most frequently occurring value (number or score).[29]

The mode generally is not used because sophisticated statistical tests with higher levels of analysis are available. Because it is insensitive to extreme scores, the median sometimes is used when the mean is not an appropriate option. The mean most often is used with interval and ratio data. The mean is drawn in the direction of extreme scores, which is a disadvantage; thus, the researcher should be cautious when they obtain data extremes. In a normal distribution, all measures have the same value: mode equals median equals mean. Nominal data only use the mode. Ordinal data use the mode or the median, depending on which is most appropriate for the data collected and nature of the research question. Interval and ratio data allow the use of mode, median, or mean.[29]

Measures of Variability

Measures of variability or dispersion describe how a number varies from the middle of a set of values. Measures of variability include range, variance, and standard deviation. Range is defined as the difference between the highest and lowest values in a set. Variance is defined as the variability of values in a distribution. To calculate the variance for a population, the sum of

the squared deviations is taken and divided by the total number (N) of cases or participants in the study. To calculate the variance for a sample, the sum of the squared deviations is calculated and divided by the number of cases minus 1 (ie, n − 1) or number of participants minus 1. Standard deviation is defined as the average deviation from the mean for a set of values. A large standard deviation indicates a high level of variability in the dataset, while a small standard deviation indicates a very homogenous dataset. Standard deviation is calculated as the square root of variance and is the most used measure of variability.[30]

Common Statistical Tests

Descriptive statistics are used to describe a numerical dataset, and inferential statistics are used to draw conclusions and make predictions based on the data. The researcher can use inferential statistics for hypothesis testing to compare populations and evaluate relationships between variables. Hypotheses are tested using statistical tests. Commonly used statistical tests and their corresponding levels of measurement are[31,32]:

- ANOVA – interval, ratio
- chi-square – nominal, ordinal
- Pearson correlation – interval, ratio
- *t* test – interval, ratio

t Test

A *t* test compares the means of 2 groups. The results determine how likely it is that the 2 groups differ by more than would be expected by chance, indicating whether the treatment affected the dependent variable. The obtained numerical answer is the *t* value. This value can be calculated by hand with a formula or statistical software (eg, R, SPSS). The degrees of freedom (ie, sample size) and α level (ie, predetermined threshold of statistical significance), which is usually $P = .01$ or $P = .05$, must be known. The calculated *t* value, the degrees of freedom, and the α level can then be compared against values in a Student's *t* table to determine if the calculated *t* value is greater than what is expected by chance. If it is greater, the null hypothesis is rejected, and the groups are reported as differing by more than what is expected by chance. When reporting *t* test results, a study also should report the *P* value and degrees of freedom to demonstrate whether the results are statistically significant (ie, the results are not due to chance).[31,33,34]

Analysis of Variance

ANOVA analyzes the differences between the means of 2 or more groups, differentiating this test from a *t* test, which is used to compare 2 groups. ANOVA addresses how likely it is that several groups differ by more than would be expected by chance. The numerical result of ANOVA is the *F* ratio. The ratio or interval data, the degrees of freedom, and the α level (usually $P = .01$ or $P = .05$) also must be known.

ANOVA examines the average difference between groups, like the *t* test, and the average amount of difference in each group. Although it is difficult to do so, ANOVA tests can be calculated manually. However, using statistical software to run such an analysis is more convenient. Significant ANOVA results require post-hoc analysis that enables researchers to further interpret the results by determining which groups differ significantly from each other with respect to the mean. When reporting ANOVA results, the *F* ratio, degrees of freedom, and *P* values for each independent variable should be included.[31,35]

Chi-Square Test

A chi-square (χ^2) test compares observations from a single group with an expected frequency (established through prior research or literature) or multiple groups with an expected outcome. A χ^2 test addresses how likely it is that a distribution of observations occurred by chance. The numerical result of this test is the χ^2 statistic. This test can be used on nominal or ordinal data. To conduct a χ^2 test, the frequency data are entered into a contingency table with the degrees of freedom and α level (usually $P = .01$ or $P = .05$).[31,36]

All uses of a χ^2 test have the same underlying premise: the observed frequencies are compared with the expected frequencies based on a null hypothesis. The vital element in using a χ^2 test is determining the expected frequency, which usually is based on theory or other research.[31,36]

Pearson Correlation

The Pearson correlation coefficient measures linear correlations. It is defined as a number between −1 and

1 that measures the strength and direction of the relationship between 2 variables. The numerical result is the Pearson coefficient (r). The ratio or interval data, degrees of freedom, and α level (usually $P = .01$ or $P = .05$) must be known. A value of 0 indicates there is no correlation between the 2 analyzed variables, a value between 0 and 1 indicates a positive correlation between the variables, and a value between −1 and 0 indicates a negative correlation.[31,37]

Choosing the Appropriate Test

Statistical tests or interpretation techniques are designed for certain data types; thus, the chosen statistical test must lend itself to the type of data collected. The statistical test the researcher chooses depends on the nature of the study and the research question.[38]

Descriptive statistics (ie, measures of central tendency, measures of variability, or dispersion) are used when there is no question of statistical significance. Inferential statistics (ie, *t* test, ANOVA, Pearson correlation, and χ^2) are used when statistical significance should be calculated.[29,38] The choice of test depends on the type and level of data needed. If the study requires response or opinion percentages, then a descriptive statistical analysis or χ^2 test is sufficient. If the study question asks if there are statistically significant differences between scores or an instrument, then inferential statistical analysis is required.[29,38]

Researchers should consider consulting a statistician or psychometrician for assistance with research study design to ensure the correct choice of measures and tests. Most universities and medical facilities have staff statisticians who are available for consultations. Researchers who carefully plan which type of testing they will use before starting their research are more likely to collect the correct data for their study.

Considerations

A research study's purpose and goal should be clear and guide research design. The researcher should consider the research question, type of data collected, method of data collection, and statistical analyses in advance.

A common mistake made in research is a mismatch between the type or level of data and the statistical test used. For example, if the goal is to compare averages but the data collected did not generate a score, then averages cannot be determined. Another example of data mismatch is if the plan was to conduct a *t* test, which requires interval or ratio data, but the data collected for the study are nominal in nature.

Reliability, Validity, and Bias

Reliable and valid data are crucial for quality, well-designed research. Reliability refers to the consistency of a measure. The same result should be reproduced consistently if the same methods are used and the measurement is reliable. Validity refers to how accurate the results are and is particularly important in developing and evaluating measuring instruments. For example, when using a survey instrument, the extent to which the survey measures what it is expected to measure represents its validity level.[39]

Bias produces a distortion or error in the study results, which subsequently causes erroneous conclusions. Thus, accounting for known biases when interpreting the study findings is important. To eliminate bias, researchers should consider multiple factors when planning a study, including[40]:

- faulty methods of data collection
- flawed implementation
- inadequate study design
- participants' lack of candor
- researcher subjectivity
- sample imbalances

Study participants often modify their behaviors because they want to make a more positive impression on researchers. In addition, researchers might distort information when they record it or unintentionally communicate their expectations to participants. If the researcher decides to include members from certain groups in the study, the results might not be valid. Faulty methods of data collection can exaggerate or underestimate participant responses. If a study is poorly designed, receiving an unbiased answer to the research question might be impossible. Furthermore, a study can introduce bias if it is not carefully implemented. Although it is difficult to prevent bias completely, researchers should aim to reduce or eliminate bias to the best of their ability.[40]

Other Considerations

In addition to research design, other concerns must be considered in advance such as:

- Can the study be designed sufficiently to produce quality results without jeopardizing human rights?
- How will the study be funded?
- Is there enough time to complete the study?
- What study-related costs will be incurred?
- Will the methods used to address the research question yield accurate and valid results?
- Will the research goals conflict with clinical goals?
- Will there be enough study participants?

Conclusion

A well-designed plan is crucial for successful research. The first step to creating such a plan is developing a research question. After a research question and goal are established, the researcher determines the data type, data collection method, and data analysis that best suits the needs of the study. Research results and conclusions should be reliable, valid, and free from bias.

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