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RESEARCH ARTICLE

IFST2BR: AN INTERPRETIVE FRAMEWORK FOR STATISTICAL TESTS AIMED AT BUDDING BIOLOGICAL RESEARCHERS

Shahad Dakhil Khalaf*

College of Pharmacy, University of Kerbala, Karbala, Iraq.
****Corresponding author Email: Shahad.d@uokerbala.edu.iq***

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ABSTRACT

Emerging biological researchers frequently encounter challenges in appropriately selecting and interpreting statistical tests, often due to a lack of structured guidelines tailored to their discipline. Misapplication of statistical methods risks generating misleading conclusions, compromising research validity, and perpetuating errors in scientific practice. To address this gap, this paper proposes the Interpretive Framework for Statistical Tests for Emerging Biological Researchers (IFST2BR), a structured decision-making tool designed to guide novice scholars in aligning their research questions with appropriate statistical tests and interpreting results within biological contexts. The framework was rigorously validated through expert reviews and focus group discussions, which assessed its relevancy to common biological research scenarios and its accessibility for users with limited statistical training. Validation results confirmed that IFST2BR effectively bridges theoretical knowledge and practical application, offering clear pathways for test selection and interpretation. Participants reported enhanced confidence in navigating statistical decisions, underscoring the framework's usability as both an educational and analytical aid. By reducing the risk of methodological errors and fostering reproducibility, IFST2BR contributes to more rigorous and ethically sound research practices in the biological sciences. This work highlights the importance of domain-specific interpretive frameworks in statistical education and calls for broader adoption of such tools to empower emerging researchers in an era of increasingly data-driven science. Future efforts could expand IFST2BR's adaptability to advanced methodologies and interdisciplinary applications.

KEYWORDS

Interpretive Framework, Budding Biological Researchers, Statistical Tests, Biostatistician, Biostatistics Test types, Expert Review, Focus group discussion.

1. Introduction

Statistics is a field that involves the collection and organization of data to address research problems. Data serves as the fundamental building block for gaining knowledge. Using the right data along with appropriate statistical tests is crucial for producing accurate insights. However, selecting the correct statistical test can be challenging, particularly for emerging researchers. When a researcher chooses the wrong statistical test, it can lead to various issues during the interpretation process. Additionally, using an inappropriate test may result in incorrect conclusions (Trajkovski, 2016; Ajee et al., 2024).

Thanks to modern technology, we now have a variety of statistical software and applications, such as R, SPSS, SEM-PLS SAS, and so on, all of which simplify the process of statistical testing. However, choosing the right test can still be a challenge for biological researchers. While these applications help manage the statistical process, they do not offer guidance on which statistical test is most appropriate for a given situation (Mishra et al., 2019). Choosing the appropriate test depends on the nature of the collected data and the main purpose of the research. If the researcher succeeds in selecting the right test, the results will be significant, and vice versa (Upadhyay, 2017).

The primary purpose of this paper is to propose a systematic framework that is utilized as a guide for junior researchers in the field of biology to first understand the data and then choose the appropriate statistical test. In this research, in the beginning, the proposed framework has presented all its components, relying on an extensive study of all research related to the topic and reliable websites specializing in the above research topic. Next, we will provide a brief explanation of its components. After that, we will validate the framework using two scientific methods: focus group discussions and expert reviews. Finally, we will present the results of the validation and draw our conclusions. Figure 1 illustrates the proposed framework.

As indicated in Figure 1, the proposed framework IFST2BR consists of three main sides, and each side has its components; consequently, an explanation of each side with its components have outlined in the following paragraphs.

2. Basic Statistical Concepts

Based on relevant studies, statistics divided into two key kind: the first type is descriptive statistics: Statistical methods used to describe collected data. The second type is Inferential statistics: Statistical methods used to predict, forecast, and help decision makers make appropriate decisions based on the selected sample (Murga et al., 2023). To obtain the correct statistical analysis, the main objective of the analysis must be determined. The beginning biological researcher must ensure that the statistical test used is appropriate for the type of data collected and the method of research design. Therefore, the beginning researcher must ask the following question: What are we looking for? The answer to this question is the plan for choosing the appropriate statistical test. Clinical research is conducted using biostatistics. Including choosing the patients, creating a protocol, and their measurements, organizing the design of a clinical trial, and efficacy and comparative efficacy of certain treatment. Gene frequency is determined with the aid of biostatistics.

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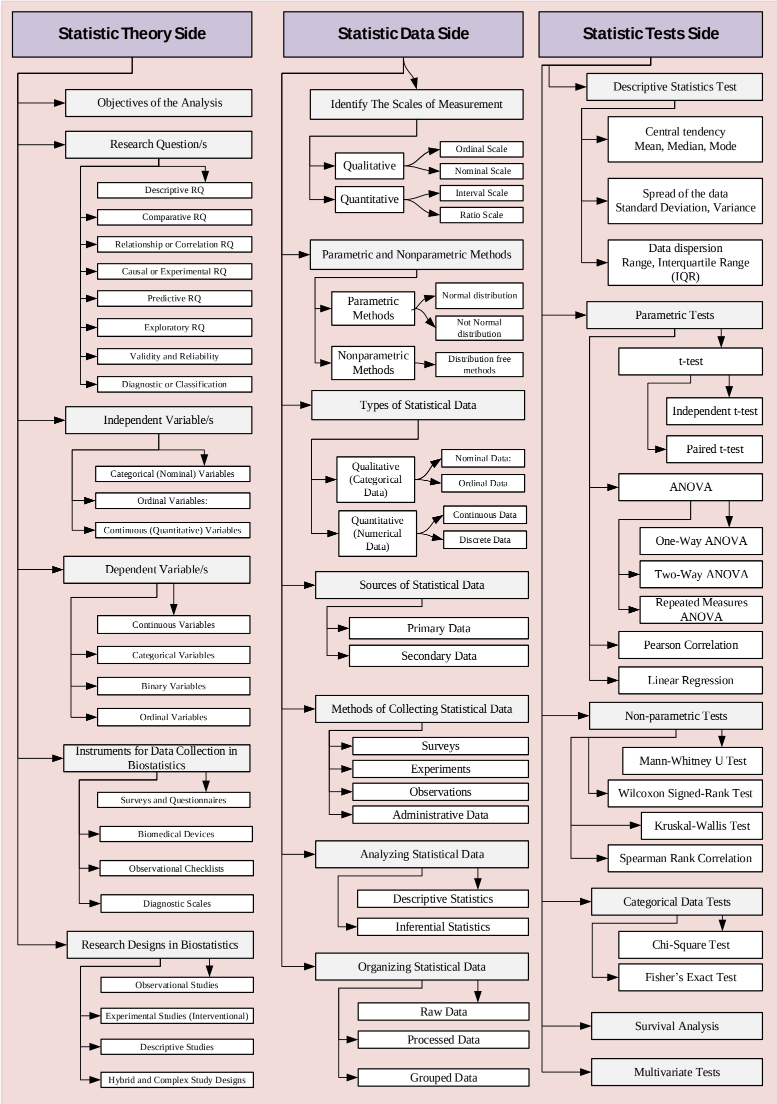


Figure 1: The Proposed Framework IFST2BR with Its Phases and Components.

3. Statistical Theory Side

This aspect includes four important and necessary concepts in determining and selecting the appropriate statistical test, which is determining the objectives of the analysis, forming research questions, and deducing the dependent and independent variables. In the following paragraphs, each concept is explained in some detail.

3.1 Objectives of the Analysis

Determining the purpose of the statistical analysis is very important because the process of choosing the appropriate statistical test depends fundamentally on determining the purpose of the analysis. Accordingly, the researcher must ask the following question: What knowledge are we looking for? The answer to this question determines the basic purpose of the analysis.

3.2 Research Question/s

Research questions are often derived from the primary objective of the study and there is a close relationship between them. Accordingly, and based on previous relevant studies, there are several different types of research questions, including diagnostic or classification, exploratory, validity and reliability, predictive, causal or experimental, relationship or correlation, comparative, and descriptive research questions. Well-formulated research questions have a positive impact on the selection of appropriate statistical tests as well as analysis methods that ensure that results are meaningful and consistent with the purpose of the study.

3.3 The Independent Variables

In the context of biostatistics, independent variables play a prominent role in the selection of the appropriate statistical test because they provide the possibility of determining the type and structure of the analysis and are also called predictors. Three types of independent variables include Categorical (Nominal), Ordinal, and Continuous (Quantitative) (Hazra and Gogtay, 2017). Choosing the suitable statistical test based on independent variables has tabulated in Table 1

Table 1: Statistical Test Based On Independent Variables

Independent Variable	Group No.	Statistical Test Used	Outcome Type
Categorical Independent Variable	2 groups	t-test	Continuous
Categorical Independent Variable	more than 2 groups	ANOVA	Continuous
Continuous	N/A	Correlation, Linear Regression	Continuous
Categorical	2 groups	Chi-square or Fisher's exact test	Categorical (binary)
Continuous	N/A	Logistic Regression	Categorical (binary)
Repeated Measures	N/A	Repeated Measures ANOVA, Mixed-effects frameworks	Continuous

3.4 The Dependent Variable

In the context of biostatistics, a dependent variable, also known as a response variable in biostatistics is the crucial variable in any statistical study that the researcher must explain or forecast based on how much the independent variables react to it (Muth, 2009). Choosing the suitable statistical test based on dependent variables is tabulated in Table 2. Five types of dependent variables include continuous, categorical, binary, ordinal, and count dependent variables.

Table 2: Statistical Test Based On Dependent Variables

Type of Dependent Variable	Example	Type of Analysis	Statistical Test(s) Used
Continuous Dependent Variable	Measuring a Blood pressure	Comparing 2 groups	Using t-test
Continuous Dependent Variable	Measuring a Heart rate	Comparing more than 2 groups	Using ANOVA Test
Continuous Dependent Variable	Measuring a Weight gain	Association dependent Variable with another variable	Using Pearson or Spearman correlation test
Categorical (Nominal) Dependent Variable	(Yes/No) Disease status	Comparing proportions among groups	Using the Chi-square test, Fisher's exact test
Binary Dependent Variable	Survival status	Association dependent variable with predictors	Using a Logistic regression test
Ordinal Dependent Variable	Measuring a Pain severity	Comparing ordered categories variable	Using Ordinal regression, the Wilcoxon rank-sum test
Count Dependent Variable	Measuring a No. infections	Frameworking count outcomes	Using Poisson regression test

4. Statistic Data Side

This aspect includes four important and necessary concepts in determining and selecting the appropriate statistical test, which are identifying and interpreting the collected data of the analysis. Includes all the procedures and processes for managing data (Mishra et al., 2019). Therefore, the following essential elements should understood by researchers to manage statistical data:

4.1 Identify the Scales of Measurement

These involve classifying the variables that comprise the data and determining what type of statistical analysis is used. There are typically two key categories of these scales: Quantitative (interval, ratio) and Qualitative (ordinal m nominal) (Mishra et al., 2018).

4.1.1 Nominal Scale

Group data into distinct categories mutually exclusive and exhaustive; order or ranking is unnecessary. The researcher can calculate counts and modes. In test analysis, usually use frequencies and proportions (Roberts, 2008).

4.1.2 Ordinal scale

The principle of operation of the ordinal scale is to classify the selected categories into ordered categories, which means that the order of the categories is significant in this scale. Arithmetic operations are not significant in this scale and should be replaced by calculating the mean and mode as well as using non-parametric tests (Merbitz et al., 1989).

4.1.3 Interval Scale

Unlike an ordinal scale, it has ordered categories but does not have a true zero point. The variance between values on this scale is significant and comparable. Researchers can use the standard deviation, median, mean, and mode as well as arithmetic operations (Wu and Leung, 2017).

4.1.4 Ratio Scale

The principle of this scale is the same as the principle of the interval scale with the only difference being that it has a true zero point in addition to its security. It uses all the test scales that the interval scale uses with the addition of a coefficient of variation (Saaty, 1993).

4.2 Parametric and Nonparametric Methods

4.2.1 Parametric Methods

The parametric approach is widely used to interpret and manage biological data in the field of biostatistics. These approaches rely on interpreting assumptions about the normal distribution of the data and drawing inferences and predictions from selected samples (Kraska-Miller, 2013). Figures 2 and 3: illustrate the normal distribution and not normal distribution respectively.

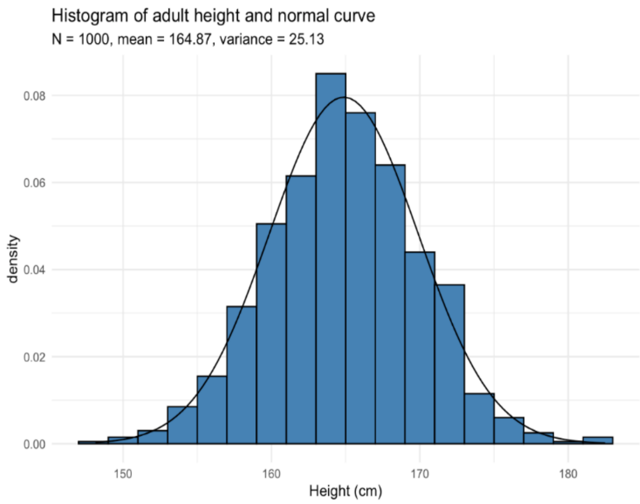


Figure 2: Normal Distribution Example.

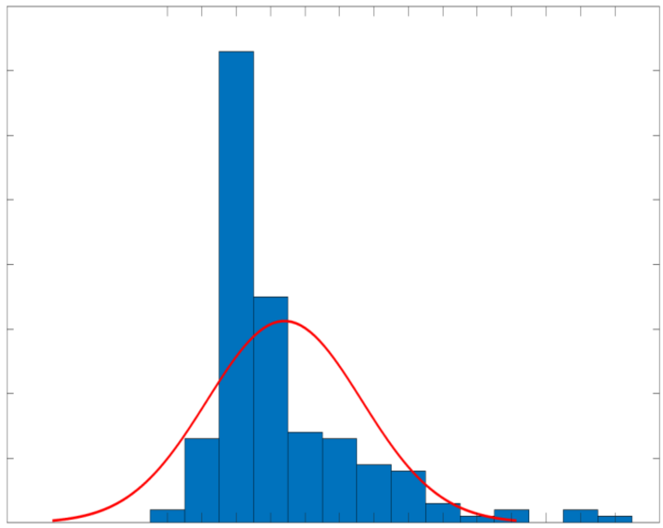


Figure 3: Non-Normal Distribution Example.

Table 3 lists a few popular methods that biostatisticians frequently employ.

Table 3: Parametric Method with Examples

Method/ test selection used	Description	Examples
t-Tests	Compares means between groups	Impact of treatment
ANOVA	differences groups	Comparing drug dosages, diet studies
Linear Regression	Frameworks linear relationships	Predicting continuous output
Logistic Regression	Frameworks binary	Disease prediction
Mixed-Effects Frameworks	Analyzes hierarchical	Longitudinal case studies
Bayesian Inference	beliefs using the normal distribution	Estimating infection rates

4.2.2 Non-parametric approaches

Are methods that do not rely on normal distribution and do not require the required assumptions to be met as in the case of normal distribution (Siegel, 1956; Awang et al., 2015).

4.3 Sources of Statistical Data

There are two types of data sources used by biological researchers in statistical tests. The data sources chosen to depend on the field of study, the nature of the required case study, and the objectives of the analysis. Accordingly, the data are either primary or secondary data sources.

4.3.1 Primary Data Source

Primary sources are those used by the researcher to collect original data and collect data directly. Data collection from primary sources depends on the research questions**.**

4.3.2 Secondary data Sources

Data sets collected for different purposes by individuals or organizations that the researcher uses to analyze the data for his study.

4.4 Methods of Collecting Statistical Data

It includes four commonly used approaches in the field of biological statistics, which are questionnaires, experiments, administrative data, and observations.

4.4.1 Questionnaires

It is an approach to collect data through questionnaires from users related to the field of study or real users or the selected sample and is usually about certain behaviors, points of view, or characteristics.

4.4.2 Experiments

It is an approach to collecting data through certain experiments under the control of the researcher and is usually useful in studying and analyzing causal relationships.

4.4.3 Observations

An approach to collect data based on observing the selected sample for a certain behavior or phenomenon and deducing the data and the relationships that link them together.

4.4.4 Administrative data

It is an approach to collect data found in institutions related to the field of research such as patient records in hospitals and historical data for patients such as analysis data and others.

4.5 Analyzing Statistical Data

Raw Data: The basic data collected that not analyzed and usually not processed yet and needs to be organized.

Processed Data: Data that has cleansed, classified, and organized to make it appropriate for the analysis process.

Grouped Data: Data has classified based on age, gender, yearly income as well as blood groups.

5. Statistical Tests Side

Statistical tests in biology, like other statistical disciplines, are mechanisms and tools that researchers use to analyze and interpret data to make appropriate decisions and indicate whether the inferences obtained are statistically significant or whether they occurred by chance or randomly.

5.1 Descriptive Statistics

Descriptive statistics tests are concerned with summarizing and interpreting sample data descriptively, for example, calculating the mean, median, mode, variance, range, and standard deviation, as well as providing the ability to interpret most charts and graphs. It composite of three key types a) central tendency, b) Spread of the data, and c) Data dispersion (Yellapu, 2018; George and Mallery, 2018).

5.2 Parametric Tests

Parametric tests are typically used to assess differences or find relationships in population parameters and are a very powerful tool because they conclude the interpretation of underlying sample information. Parametric tests consist of four types of statistical tests. Table 4 lists parametric test types and their purpose with assumptions (Harwell, 1988; Luengo et al., 2009; Vimal et al., 2022).

Table 4: Paramedical Tests Overview

	Test	**Test Purpose**	**Assumptions**
1	Parametric Test Type		
1.1	**t-Test**		
1.1.1	One-Sample t-Test	Tests whether there is a difference between the mean of a selected sample and the mean of a known or hypothesized population.	Normally distributed data, interval or ratio scale, sample size generally >30.
1.1.2	Independent (Two-Sample) t-Test	Make a comparison between the means of two independent groups to justify there is a big different.	Normally distributed data in each group, equal variances (or use of Welch's correction if variances are unequal), independent samples.
1.1.3	Paired Sample t-Test (Dependent t-Test)	Make a comparison between the means of two related groups (e.g., the same group measured at two different times).	Normally distributed differences, interval or ratio data, paired samples
1.2	**ANOVA**	It is an important statistical approach used to compare the means of data for three or more groups with the aim of determining whether these differences have a statistical explanation	Try to compares the means of more than two groups
1.2.1	One-Way ANOVA		
1.2.2	Two-Way ANOVA		
1.2.3	Repeated Measures ANOVA		
1.3	Pearson Correlation	The Pearson correlation coefficient is widely used to measure the strength and direction of a linear relationship between two continuous variables and is therefore useful for biological researchers to evaluate all associations.	Linearity, Continuous Data, Normality, Homogeneity of Variances

Table 4 (cont): Paramedical Tests Overview			
1.4	Linear Regression	It is a statistical approach that is considered one of the fundamental and widely used methods in biostatistics and is considered a very important method in analyzing and frameworking the relationship between the dependent and independent variables	Linearity, Independence, Normality of Residuals, Homoscedasticity
1.4.1	Simple	One independent variable with one depended variable	
1.4.2	Multiple	One depended variable with more than one independent variables	

5.3 Non-parametric Tests

This type of test is used if there is no specific distribution of the data selected for the sample. It is often utilized in biostatistics to test medical data that does not follow the standardization. In biostatistics, there are common Non-Parametric Tests types (Gerald and Patson, 2021; Sedgwick, 2012). Table 5 visualize these types with the relevant purpose for each.

Table 5: Non-Parametric Overview

Test	Purpose	Biomedical Example
Wilcoxon Signed-Rank Test	Compare median differences in paired data	Testing whether blood sugar levels before and after treatment differ significantly
Mann-Whitney U Test	Compare medians between two independent groups	Comparing blood pressure between males and females.
Kruskal-Wallis Test	Compare medians across more than two independent groups	Comparing recovery times among three drug treatments.
Friedman Test	Compare medians in repeated measures from the same group	Effect of diet on cholesterol levels over time.
Chi-Square Test	Test independence or goodness-of-fit in categorical data	Association between smoking and lung cancer.
Spearman's Rank Correlation	Measure correlation between two ordinal or non-normally distributed variables	Association between stress level and heart rate.
Kolmogorov-Smirnov Test	Test if a sample differs from a reference distribution	Comparing sample distribution to a normal distribution.
Sign Test	Test for median differences in paired data	Effectiveness of a new drug on paired patient outcomes.

6. The Proposed Framework Ifst2br Evaluation

In the context of this study, the proposed framework was evaluated for its understandability and relevance using a well-known and accepted academic evaluation method, focus groups in expert review (Morgan, 1996). Accordingly, this paper uses the expert review technique through focus groups to evaluate the proposed framework.

6.1 Expert Review

Experts engaged in this evaluation process were lectures and instructors in biostatistics. The criteria for the experts are as follows:

- Have a PhD in Biostatistics, Data Science (DS), Bioinformatics or related areas.
- Have fifteen years or more of teaching background in biostatistics or DS or related areas.

Twenty experts participated in this review session (focus group), and Table 4444 details the demographics of the experts. Twenty experts are more than adequate for this study, as endorsed by (Fattah et al., 2022; Freeman and Nelson, 2004).

Table 6: Demographic Details Of Experts Review (Focus Group)

Gender	Age (Year)	Education	Field of Expertise	Experience (Year)
FeMale	47	PhD in Statistics	Biostatistics	16
Male	50	PhD in Data Science	Data Analysis	17
Female	49	PhD in Statistics	Biostatistics	20
Male	52	PhD in Data Science	Data Analysis	19
Female	49	PhD in Statistics	Biostatistics	20
Female	50	PhD in Statistics	Biostatistics	21
Female	48	PhD in Statistics	Data Analysis	23
Female	55	PhD in Statistics	Biostatistics	24
Female	50	PhD in Bioinformatics	Bioinformatics	18
Male	51	PhD in Statistics	Data Analysis	20
Female	57	PhD in Statistics	Biostatistics	19
Female	53	PhD in Bioinformatics	Bioinformatics	17
Male	50	PhD in Bioinformatics	Bioinformatics	21
Female	57	PhD in Data Science	Biostatistics	19
Female	53	PhD in Data Science	Biostatistics	17
Male	50	PhD in Bioinformatics	Bioinformatics	21
Female	57	PhD in Bioinformatics	Bioinformatics	19
Female	59	PhD in Statistics	Biostatistics	24
Female	53	PhD in Data Science	Biostatistics	17
Male	50	PhD in Statistics	Biostatistics	21

As illustrated in Table 6, the experts' backgrounds represent various fields of expertise: 10 participants in biostatistics, 6 in data analysis, and 6 in bioinformatics.

6.2 Procedures and Review IFST2BR

The objective of the expert review was to conduct a focus group review of the proposed IFST2BR in terms of relevance and understanding, seeking the expert view on each IFST2BR item.

6.3 Review Findings

Data collected fron focus group descussion (expert review) are listed in Table 7. The data were documented as in frequency of responses of the expert review to the questions asked in the instrument.

Table 7: Overall Findings

Rrelevancy of IFST2BR	**No. of partecipants (n=20)**			
	All are relevant	**Some may not relevant**	**Some are definitely not relevant**	
Statistical Theory Side	20	0	0	
Statistical Data Side	19	1	0	
Statistical Tests Side	18	2	0	
Overall relevancy	20	0	0	
Understanding of IFST2BR	**All are relevant**	**Some are definitely not relevant**	**Some may not relevant**	
Statistical Theory Side	20	0	0	
Statistical Data Side	20	0	0	
Statistical Tests Side	19	0	1	
Overall Understanding	20	0	0	
Questions	**Strongly Agree**	**Agree**	**DisAgree**	**Strongly DisAgree**
Q1: The connections and flows of all **IFST2BR** Framework components are logically appropriate.	9	11	0	0
Q2: I found that proposed **IFST2BR** Framework components as part of biostatistics can be used as Evaluation interpretive guide by Budding Biological Researchers.	8	12	0	0
A3: Overall, I found that the proposed **IFST2BR** Framework are readable and understanding	15	5	0	0

As is clearly evident from the results listed in Table 7, Figurs 4,5,and 6, the majority of experts agreed or strongly agreed that the proposed framework components are feasible in practical terms, which indicates that the proposed framework is feasible in helping emerging biostatistics researchers complete their tasks. The over all findings are illustratr in Figures 4,5, and 6.

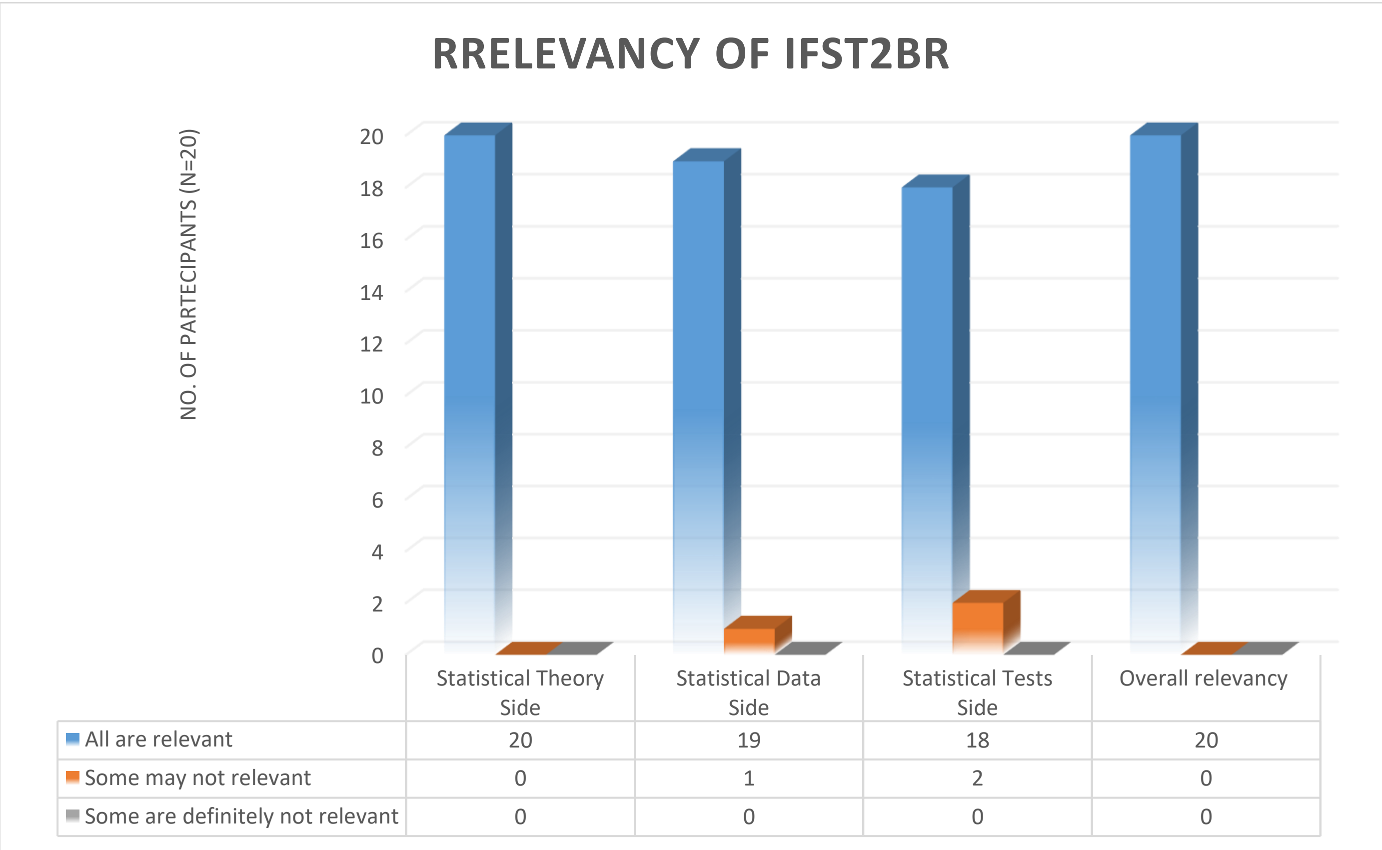
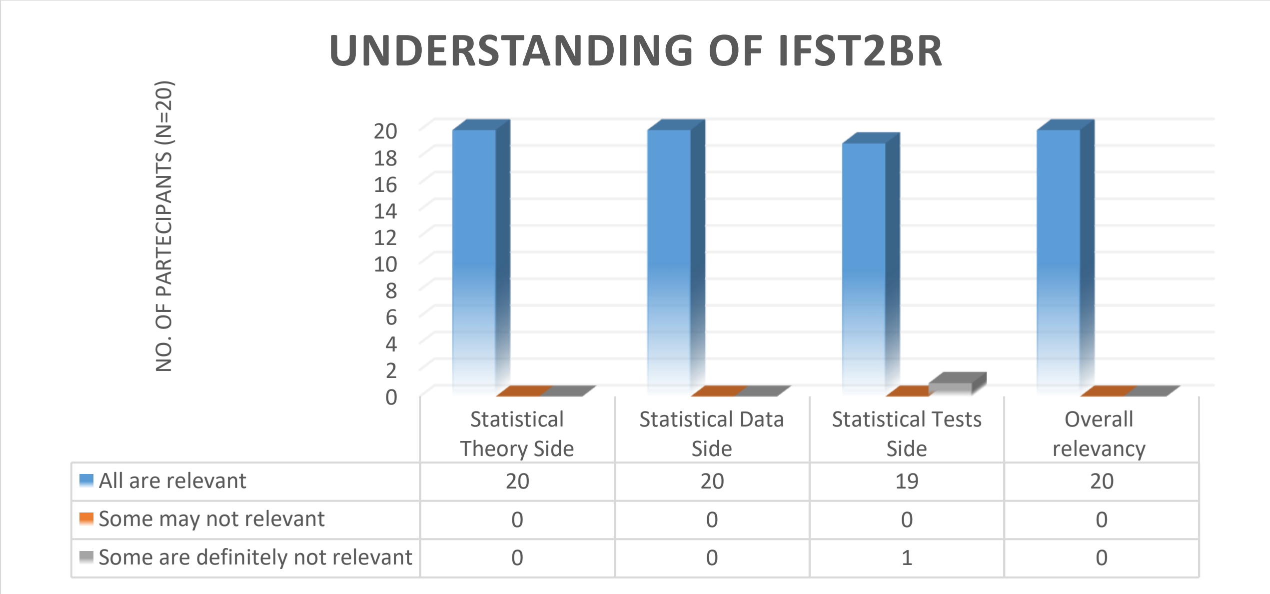
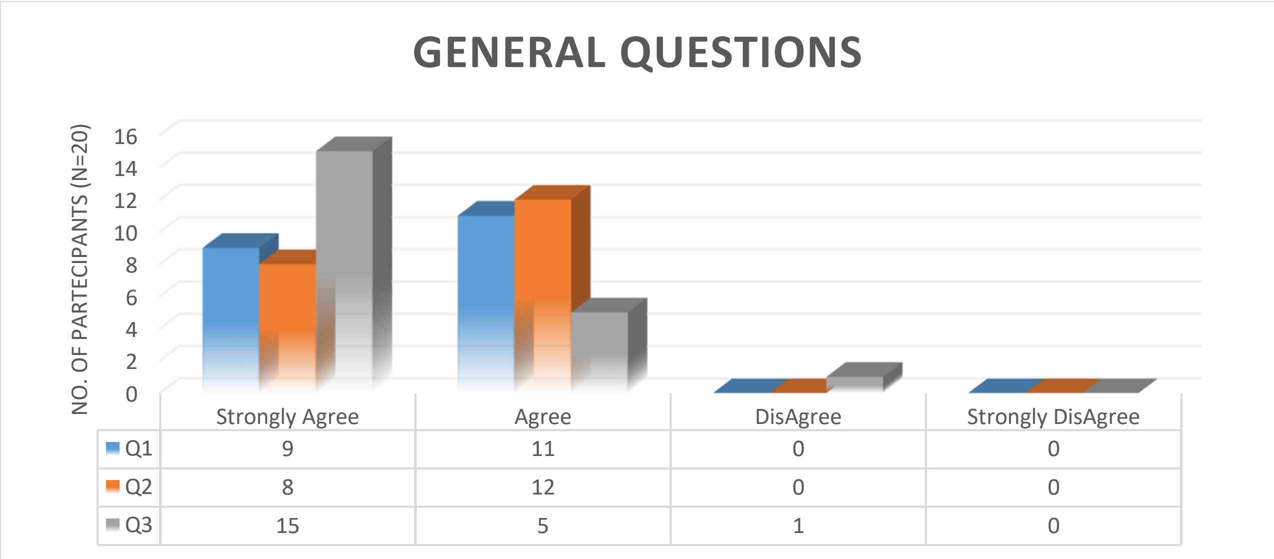


Figure 4: Relevancy Measurement of IFST2BR.



	Statistical Theory Side	Statistical Data Side	Statistical Tests Side	Overall relevancy
All are relevant	20	20	19	20
Some may not relevant	0	0	0	0
Some are definitely not relevant	0	0	1	0

Figure 5: Understanding Measurement of IFST2BR.



	Strongly Agree	Agree	DisAgree	Strongly DisAgree
Q1	9	11	0	0
Q2	8	12	0	0
Q3	15	5	1	0

Figure 6: General Questions Findings.

7. Discussion

The development and validation of the Interpretive Framework for Statistical Tests for Emerging Biological Researchers (IFST2BR) address a critical gap in methodological guidance for novice researchers in the biological sciences. The challenges emerging scholars face—particularly in selecting appropriate statistical tests and interpreting their outcomes—are well documented, with missteps in this process risking invalid conclusions, wasted resources, and even ethical concerns if findings are misapplied. By integrating structured decision-making pathways with accessible interpretive guidelines, IFST2BR directly mitigates these risks, offering a scaffolded approach that aligns statistical rigor with practical usability.

The validation of IFST2BR through expert reviews and focus group discussions underscores its alignment with real-world needs. Experts emphasized the framework's *relevancy* in addressing common pitfalls, such as mismatched test assumptions (e.g., normality, variance homogeneity) and overreliance on default methods (e.g., misusing parametric tests for non-normal data). Focus group feedback further highlighted its *understandability*, particularly for researchers with limited statistical training. Participants reported increased confidence in test selection and interpretation, suggesting that the framework's visual aids, flowcharts, and contextual examples effectively demystify complex statistical concepts. This dual validation—methodological rigor and user-centric design—positions IFST2BR as both a cognitive and practical tool.

IFST2BR's strength lies in its systematic integration of theory and application. In contrast to generic statistical guidelines, which lack domain-specific nuance, the framework incorporates common scenarios such as small sample sizes, non-normal distributions, and categorical and continuous variables. There are, however, limitations to the framework's current validation. While expert reviews and focus groups provide robust preliminary evidence of its utility, longitudinal studies are needed to assess its long-term impact on researchers' statistical proficiency and the quality of published work. Additionally, the framework's effectiveness may vary across sub-disciplines of biology; for example, computational biologists working with high-dimensional data may require supplementary modules for advanced techniques (e.g., machine learning integration).

8. Conclusion

The findings of this study affirm that the research question has been effectively addressed, demonstrating the efficacy and applicability of the proposed evaluation framework within biostatistics. This framework not only serves as a valuable resource for emerging researchers in the field by offering structured guidance for interpreting and evaluating complex data but also establishes a methodological blueprint for developing and assessing similar models or frameworks in other domains. The systematic approach underpinning the interpretive framework and its evaluation underscores its potential to enhance rigor and reproducibility in research, empowering scholars to adopt or adapt such methodologies with confidence. Besides, by bridging theoretical innovation with practical utility, this work contributes meaningfully to advancing biostatistical research methodologies and fostering a culture of methodical inquiry. Future research could build on this foundation to explore adaptations of the framework across diverse contexts, further solidifying its impact on scientific practice and education.

Acknowledgment

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