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MATHEMATICAL STATISTICS IN BIOLOGY AND MEDICINE



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Abstract: It is devoted to the main issues of conducting statistical analysis in medical and biological research. Statistical processing of data from experience is a complex multi-stage process, the quality of the collected statistical data, the results of their processing and understanding have a decisive influence on the level of scientific organization.

Key words: medicine and statistics, random sampling and sampling based on experimental characteristics.

Annotatsiya: Ushbu maqola tibbiy va biologik tadqiqotlarda statistik tahlilni amalga oshirishdagi asosiy masalalarga bag'ishlangan. Tajribaga asoslangan ma'lumotlarni statistik qayta ishlash murakkab va ko'p bosqichli jarayon bo'lib, yig'ilgan statistik ma'lumotlar sifati, ularni qayta ishlash natijalari va tahlil qilinishi ilmiy tashkil etish darajasiga hal qiluvchi ta'sir ko'rsatadi.

Kalit so'zlar: tibbiyot va statistika, tasodifiy tanlash, tajriba xususiyatlariga asoslangan tanlanma.

Аннотация: Основным вопросам проведения статистического анализа в медико-биологические исследований. Статистическая обработка представляет собой сложный многоступенчатый процесс, от уровня научной организации которого решающим образом зависит качество накапливаемых статистических данных, результаты их обработки и осмысления.

Ключевые слова: медицина и статистика, случайная выборка и моделирование выборки по свойствам генеральной совокупности.

INTRODUCTION

Mathematical statistics plays a fundamental role in advancing research in biology and medicine by providing the analytical tools necessary for interpreting complex experimental data. In modern biomedical studies, the ability to collect, process, and draw valid conclusions from data is essential for developing accurate diagnoses, effective treatments, and evidence-based public health strategies. The increasing complexity of biological systems and medical interventions requires rigorous statistical approaches to ensure scientific reliability and reproducibility.

Statistical methods help researchers address uncertainty, identify significant patterns, and test hypotheses within clinical trials, epidemiological studies, genetic research, and experimental biology. Techniques such as random sampling, estimation, hypothesis testing, regression analysis, and variance analysis allow scientists to extract meaningful insights from noisy and variable datasets. Moreover, the choice of appropriate sampling strategies whether based on purely random models or experimental design features directly influences the validity of conclusions and the generalizability of research findings.



This paper explores the methodological foundations and practical applications of mathematical statistics in biology and medicine. It emphasizes how proper statistical planning, data collection, and interpretation contribute to the quality of scientific outcomes and highlights the importance of integrating statistical thinking into the design and execution of biomedical research projects.

REVIEW OF LITERATURE ON THE SUBJECT

The integration of mathematical statistics into biological and medical research has long been recognized as a vital component of scientific methodology. One of the foundational contributions in this domain came from R.A. Fisher, whose work on the design of experiments laid the groundwork for statistical rigor in biological studies. His concept of randomization and analysis of variance (ANOVA) is now central to evaluating biological variability and treatment effects in clinical trials.

In the realm of medical statistics, D.G. Altman's extensive work emphasized the misuse of statistical methods in biomedical literature and advocated for the correct application of statistical principles. Altman argued that many published studies suffer from poor statistical interpretation, which undermines reproducibility and clinical validity. His contributions helped establish ethical and methodological standards for statistical reporting in medical journals.

Recent developments in biostatistics have highlighted the growing importance of computational methods. For instance, Bradley Efron introduced the bootstrap method, which has proven crucial in handling complex biological data where traditional parametric assumptions may fail. This method is especially relevant in genomic studies, where sample sizes are often limited, but the number of variables is enormous.

Meanwhile, in epidemiological and public health research, the work of Geoffrey Rose on population-based strategies for disease prevention showed how statistical models could influence health policies. His insights emphasized the need to move beyond individual-level risk assessment and consider broader statistical patterns in populations.

Another critical dimension is the role of Bayesian statistics, which has found increasing application in both experimental biology and medical diagnostics. Andrew Gelman's work has significantly advanced hierarchical modeling and the use of prior information, making statistical inference more robust in situations with sparse or uncertain data.

In recent years, the development of statistical software and data visualization tools has allowed for more accessible and reproducible data analysis. The R language and its specialized packages for biostatistics, such as *Bioconductor*, have enabled researchers to analyze high-throughput biological data efficiently, as noted by Robert Gentleman and his collaborators.

These developments collectively underscore that the application of mathematical statistics in medicine and biology is not just a technical tool, but a central pillar of scientific reasoning, with direct implications for patient care, public health, and policy-making.

RESEARCH METHODOLOGY

In medicine, statistical analysis and comparison of medico-biological data, comparative analysis and other methods were used. Statistical processing of data from experience in determining a medical diagnosis is a complex multi-stage process, the quality of the collected statistical data, the results of their processing and understanding have a decisive influence on the level of scientific organization.

ANALYSIS AND RESULTS

Errors, which are of fundamental importance as material analysis, are very difficult to detect. This type of error involves misidentifying the reliability of individual indicators listed in Table, graph, reliability value intervals, etc.

The informative composition of the results of experimental studies is largely determined by the depth of statistical processing and the quality of their presentation. Only sample parts are used to reliably predict the phenomenon under study, since it is almost impossible to verify the entire experiment (thousands, hundreds of thousands, millions of subjects).

The sample should reflect all the characteristics of the experiment so that any researcher can understand the results of your research.

The main ways to achieve this condition are: 1) Random Selection; 2) sample modeling by the characteristics of the experiment.



The issue of the necessary and sufficient number of subjects is important in the organization of the experiment. A small number of subjects ($n < 10$) does not ensure the accuracy of experimental results. A large amount ($n > 30$), on the other hand, increases labor, time and costs in the conduct of the study.

The statistical reliability or statistical significance of the research results is determined using methods of statistical inference that impose certain requirements on the size of the choice or sample.

General recommendations on the number of samples:

1. When developing diagnostic techniques, the largest sample size is required - from 200 to 1000-2500.
2. If a comparison of 2 samples is necessary, the total number must be at least 50 people; the number of samples compared must be approximately the same.
3. If the relationship between any characteristics is studied, then the sample size should be at least 30-35 people.
4. The greater the variability of the property under study, the larger the sample size should be. Variability can therefore be reduced by increasing sampling uniformity, such as gender, age, etc.

The need for statistical processing and the provision of experimental data appeared as soon as biologists switched from the descriptive method to the analysis of experimental results. In fact, a researcher involved in measurements and data processing must constantly turn to the basic foundations of Mathematical Statistics in order to obtain the most useful information from the measurement results. The first experiments using mathematical knowledge to analyze biological phenomena were attributed to Francis Galton (1889), who used statistical analysis to evaluate the relationship between individual characteristics in humans and the degree of similarity between relatives on the basis of such complex signs of human growth. F. Galton first introduced the concept of biometry into the scientific literature.

F. Galton's research was continued by his follower, pupil, admirer and promoter Carl Pearson. Pearson made significant contributions to the development of the theory and practice of using statistical indicators in the description of biological phenomena.

F. Galton and K. While Pearson was unable to distinguish the genetic components that control human growth, these authors, with their work, turned the attention of biologists to statistics as one of the ways to analyze various characteristics. Later, Robert Fisher (1918) made a significant contribution to the assessment of individual factors that contribute to the formation and development of signs.

Since the 60s of the 20th century, mathematical statistics have become a prerequisite for the analysis of experimental data in the field of biology, medicine and agriculture. One of the factors that influenced the need to use statistical calculations of experimental data is that all biological objects have opposite properties.

The wide amplitude of the variability of properties on different objects forces experimenters to average data and evaluate the limits of variability and the strength of the bond between properties.

Another important case that influenced the process of introducing statistical methods for the analysis of biological phenomena is that almost all biological phenomena and properties are subject to statistical laws inherent in the entire set of objects, and not to individual objects.

It turns out that if we Group the data obtained by measuring the uniform summation of any biological properties, then this will have the form of a pure statistical summation. Therefore, the word Mathematical Statistics began to be called biological statistics or biometry in biology.

Thus, biological statistics or biometry is an area of scientific knowledge that involves the classification, systematization and processing of experimental data in biology, medicine and agriculture by methods of Mathematical Statistics.

The purpose of many studies is to collect information that helps to obtain information in a specific area, in order to then apply flour in an area. Usually the data is obtained by researchers from a sample of individuals. The purpose of any research work is to group these data and obtain reliable data from them. Any identifiable set of objects that differ slightly from each other by a particular property, but maintain similarity over certain important properties, is called a set-sum. The totality includes these animals, plant areas, diversity of animal breeds or cultural plants, bacteria, virus strains, etc. The totality is represented by individual members or units.

A set of members or units is called a cumulative volume. The measured value of each unit of concentration is itself called the cumulative variant. Differences between jam variants are called variations or dispersions.

If you define the summation of any sample by Σ and each variant of the summation by x , then in this case a number of variants in the summation are n , can be written as $\Sigma = nx$. As an example, if in animals the effect of any substance on the activity of the heart is checked, then, to say $n=20$, it can be taken as the number of animals. In it, the effect of the substance on the activity of each animal is a variant of the summation.

If the measured material is only a fraction of the total large material, then such a choice is called the sample selection aggregate, and all giant materials from the sample selection are called the total selection aggregate. For example, if any wheat variety has a sample aggregate with a measured volume of 100 grains of V , then the weight of the grain of the whole wheat variety can be thought of as a total aggregate with a volume of V .



The processing of data and the interpretation of the calculations obtained depends on what signs were measured in the experiment. The signs of biological objects are mainly expressed in three categories.

1. Cumulative signs that differ in a certain quality. Such signs are called high-quality or alternative. For example, the cumulative . It is represented by red and white pea flowers, as in Mendel experiments.

2. Signs with a quantitative measure, but the differences between the individual variants of the sum are expressed in integers. For example, the number of eggs laid in birds. Such quantitative variability and such quantitative signs are called discrete

3. There are no well-defined (discrete) boundaries between signs with quantitative measurement, but between individual variants of the summation. For example, the live weight of animals is expressed in kilograms, but not in grams. Such variability and such signs are called quantitative signs with constant variability (measurement signs, constant).

If measurements of any character are made on the biological object under study, they are recorded in magazines in the order of measuring objects, that is, the material is often a set of numbers in an irregular (chaotic) order. When considering these numerical values, it is impossible to determine any order. There are some simple rules for arranging the material.

You can rewrite the resulting data in order to increase their value or reduce the amounts. This method of data regulation is called ordered. The rating of the data provides some information about the nature of the experimental material.

Thus, the minimum and maximum values of the variant are strictly defined, which are called volatility limits. The smallest value of the variants is called the minimum value (min), and the largest is called the maximum value (max). In the center of such an ordered series of numbers, the main number of the option with the "average value" of the character is summed up.

Example. In a physical education class at the university, research was carried out to study the functioning of cardiac activity among freshmen. The heart rate of 30 students was studied. The following information was obtained: 65, 64, 63, 62, 68, 77, 68, 64, 73, 78, 65, 68, 62, 78, 62, 67, 69, 65, 71, 72, 68, 62, 63, 71, 68, 73, 67, 69, 68, 65. We rank the cumulative options in order of heart rate increase in freshmen; 62, 62, 62, 62, 63, 63, 64, 64, 65, 65, 65, 65, 67, 67, 68, 68, 68, 68, 68, 68, 69, 69, 71, 71, 72, 73, 73, 77, 78, 78.

Such an ordered series provides insight that the volatility limits of a feature such as heart rate are within the limits of min=62, max=78. The average heart rate can be estimated at about 70.

Another visual way to organize is a variant of the summation. All types of options found together must be written in a column. Numbers can be written in ascending order from a smaller value to a larger one, i.e. from 1 to 8, or in descending order, i.e. from 8 to 1. We write the numbers in ascending order and determine how many times each number appears in the distribution. The different variants encountered in the distribution are then known as classes and denoted by and denoted by numbers or frequencies corresponding to each class and denoted by the letter (Table 1).

Table 1. Value in the f distribution occur.

Heart rate ()	62	63	64	65	67	68	69	71	72	73	77	78	Total
how many times does the value in the distribution occur	4	2	2	4	2	6	2	2	1	2	1	2	30

Such a series of numbers, consisting of numbers and frequencies, is called a variational series. The variation series gives a more accurate representation of the distribution representation with respect to the simple order.

To make a choice, you can use the following methods:

Simple random selection:

Simple re Choice. The use of such a choice is based on the assumption that each respondent can enter the sample with equal probability. On the basis of the list of the general population, Cards are drawn up with the numbers of respondents.

They are laid out in series, shuffled, and a random card is drawn from them, the number is written, then repeated again.

The procedure is repeated the more samples we need, the more times. Until the repetition of the units of choice is over.



The procedure for creating a simple random selection includes the following steps:

1. It is necessary to take a complete list of members of the population and number this list. Recall that such a list is called the basis of choice;
2. Determine the approximate selection size, that is, the expected number of respondents;
3. Extract the numbers that require selected units from the table of random numbers. If the selection requires 100 people, 100 random numbers are taken from the table. These random numbers can be generated by a computer program.
4. Select random numbers from the list that correspond to random numbers with selected numbers written on them.

A simple random choice has obvious advantages. This method is very easy to understand. The results of the study can spread to the experience under study. Most approaches to obtaining statistical inference involve gathering information through simple random sampling. However, the method of obtaining a simple random choice has at least four significant limitations:

1. It is often difficult to create a tracking basis that allows you to get a simple random choice.
2. The result of using a simple random selection can be either a large experiment or an experiment distributed over a large geographical area, which significantly increases the time and cost of data collection.
3. The results of obtaining a simple random choice are often characterized by lower accuracy and greater standard error than the results of using other methods of consolation.

A simple unrepeatable choice. The procedure for obtaining a selection is the same, only cards with the numbers of the respondents are not re-entered.

Systematic probability selection. This simple probability is a simplified version of the choice. On the basis of the general population list, respondents are selected in a certain range. The value of is determined by chance. The most reliable result is achieved in a homogeneous general experiment, otherwise the step size and some internal repetition laws of the sample (mixing the selection) may coincide. Disadvantages: the simple probability is the same as the choice.

Get a choice in a row. Selection units are statistical series (Family, School, Brigade, etc. Selection elements are subject to constant inspection. The selection of statistical units can be organized by random or systematic type of selection.

Often referred to simply as the "mean", the arithmetic mean is defined by adding all the X variables to the values and dividing this sum by the number of N values in the choice. This can be written using the algebraic formula as:

$$x = \frac{x_1 + x_2 + x_3 + \dots x_n}{n}$$

The arithmetic mean has a number of properties:

If the same amount is added or removed or multiplied to each value of the choice and divided by the same amount, the arithmetic mean increases or decreases by the same amount.

1. From the arithmetic mean of this experiment, the algebraic sum of the deviations of the individual variant experiment is zero.
2. The sum of the deviation squares is less than the sum of the deviation squares from the arithmetic mean of the experimental variant x from any other value.

The arithmetic mean is a very important parameter that characterizes the chosen experience. It is used to describe any aggregates in engineering, medicine and biology. The arithmetic mean is a generalized characteristic of the experiment. Often the value of the arithmetic mean does not really exist, for example, 4.5 sheep, etc. In this sense, the arithmetic mean is an abstract quantity, but at the same time it is a specific quantity that together characterizes the usual state of the sign. In biology, when presenting results, the arithmetic mean is defined as , it is especially important to know the arithmetic mean of samples with uncertain boundaries and large dispersion in values. Example. The physical education class measured the heart rate of 10 freshmen. The following information was obtained: 62, 65, 72, 68, 69, 71, 63, 67, 64, 62. The arithmetic mean in this case is calculated as follows. $62+65+72+68+69+71+63+67+64+62 / 10=66,3$ the average arithmetic value of the heart rate of 10 freshmen in a physical education class is 66.3. Accordingly .

The mean Square value is defined around the variational or scattering value of the mean arithmetic value. It is based on the consideration of deviations of the attribute values of the individual units of the experiment from the arithmetic mean. In this case, a method is used to calculate the deviations of options from the arithmetic mean, which allows you to bypass the difficulty due to the fact that their algebraic sum is zero. This method is reduced to calculate the deviation squares of the options from the average, their next average.



The mean square deviation (σ) is the root of the square dispersion:

$$\sigma = \sqrt{\sigma^2} = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2 f_i}{\sum f_i}} \quad (1)$$

The mean square deviation shows how much it varies in the average studied experiment and is expressed in the same units of measurement as the options.

Example. 62-66,3=-4,3, 65-66,3=-1,3, 72-66,3=5,7, 68-66,3=1,7, 69-66,3=2,7, 71-66,3=4,7, 63-66,3=-3,3, 67-66,3=0,7, 64-66,3=-2,3, 62-66,3=-4,3.

We square each deviation. $-4,3^2=18,49$, $-1,3^2=1,69$, $5,7^2=32,49$, $1,7^2=2,89$, $2,7^2=7,29$, $4,7^2=22,09$, $-3,3^2=10,89$, $0,7^2=0,49$, $-2,3^2=5,29$, $-4,3^2=18,49$.

We find the sum of each deviation square $18,49+1,69+32,49+2,89+7,29+22,09+10,89+0,49+5,29+18,49=120,1$.

We remove from the root of 120,1. Thus, we calculated $\sigma = 10.96$.

To provide the results of sampling options, the mean arithmetic (M) and mean error (m) are specified in the formula $M \pm m$, and the corresponding error in the graphs is set in the form $\perp \text{---}$. This error is calculated by the following formula:

$$m = \frac{\sigma}{\sqrt{n}} \quad (2), m = \frac{\sigma}{\sqrt{n-1}} \quad (3)$$

Where m is the mean arithmetic error, σ is the mean quadratic deviation of the selected experiment; n is the sample size (number of measurements or subjects). The formula shows that the larger the variety (size σ) of a character, the larger the error, and the larger the sample number, the smaller the error-if all objects are the same, i.e. the variety is zero, then the error is zero ($m = 0$). In this case, even one copy accurately describes the whole experience. For example: we calculated the value σ using the formula (1).

If the sample is less than 30, we will use the Formula (3) to calculate the arithmetic mean. If n is more than 30, the Formula (2) is used to calculate the mean arithmetic. Using the Formula (3) we find $m=10.96/3=3.65$.

CONCLUSION AND SUGGESTIONS

Thus, the processing and presentation of data obtained from random sampling and selective modeling based on the characteristics of clinical research involves several key stages: identifying the nature of the variable under analysis (quantitative or qualitative), determining whether the data come from related or independent groups, and assessing the distribution type, particularly whether it conforms to a normal distribution. Each of these stages is critical in guiding the selection of appropriate statistical methods.

The validity and reliability of the conclusions drawn from biomedical data depend heavily on the adequacy of these methodological decisions. Inaccurate or inappropriate analytical choices may lead to misinterpretation of results, potentially affecting clinical decision-making and research outcomes. Therefore, a rigorous statistical approach is not merely a technical necessity, but a fundamental prerequisite for high-quality evidence in biology and medicine.

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