REVISTA CIE

Revista de Investigación Educativa | Vol. 1, No. 1
ISSN: 3061-8657 | Enero-Junio 2025

ESTADÍSTICA

A brief historical overview of statistics
From its origins to the modern era

Dr. Gerardo García Maldonado
Full-time Professor and Researcher
Universidad Autónoma de Tamaulipas
Facultad de Medicina de Tampico "Dr. Alberto Romo Caballero"
gmaldonado@docentes.uat.edu.mx

Dr. Wilberto Sánchez Márquez
Full-time Professor and Researcher
Universidad Autónoma de Tamaulipas
Facultad de Medicina de Tampico "Dr. Alberto Romo Caballero"

MPSS Brenda Daniela Gaytán Mendoza
Universidad Autónoma de Tamaulipas
Facultad de Medicina de Tampico "Dr. Alberto Romo Caballero"

INTRODUCTION

The perception of statistics among students at the Faculty of Medicine of Tampico "Dr. Alberto Romo Caballero" varies considerably, but some common aspects stand out. For example, many of them recognize the importance of this discipline in medicine in general, and in scientific research in particular, considering the wide range of medical information that is now available on electronic platforms, much of which is expressed in mathematical terms, probabilities, estimates, or statistical significance. Of course, I am referring to scientific information. Today, a significant theoretical and practical foundation in this field is required for adequate critical reading of scientific literature. It is recognized, therefore, that it is also a fundamental tool for evidence-based clinical decision-making.

Secondly, although students are aware of its importance, most find it difficult to understand, which generates anxiety when facing this subject, as it is part of the academic curriculum in medical school. Without a doubt, the terminology used and abstract concepts, as well as the equations, calculations, formulas, and algorithms this implies can be intimidating.

There are, of course, other contributing factors. On one hand, the teaching of this subject by professionals who are not physicians, which, while it might presuppose that as experts they would be better suited, in reality does not work as the approach, whether intended or not, is different. The experience of being a physician makes a difference. But on the other hand, and perhaps most significantly, is the lack of interested medical faculty with competencies and experience in this field.

We must say then that, in most cases, the teaching of statistics is not always aligned with practical applications in medicine, but rather tends to focus on mathematical theory. Without a doubt, the latter is important, but we must not forget, from my point of view, that students should ideally learn and understand what statistical data analysis implies, as well as their interpretation.

Therefore, what should prevail is offering a more applied approach contextualized to the medical field. It is not uncommon to hear students express their disenchantment with teaching in this overwhelming and boring discipline, which inevitably generates a negative attitude, lacking motivation and tending toward absenteeism in classrooms when it is time to take the course. It is discouraging that a high proportion of medical students finish their university career with a great deficiency in this area.

What is significant and transcendent is that when students face questions with statistical topics in the General Examination for Medical Degree (EGEL PLUS MEDI), endorsed by the National Center for Higher Education Assessment (CENEVAL), the thematic deficiencies are obvious, leading to responses that are not analytical, reflective, or based on knowledge. In the December 2023 exam administration, various items with statistical topics of practical application were presented in very concrete clinical examples. Of course, this exam also included content related to scientific research methodology, another area where there is also a lack of solid knowledge.

The difference between passing or failing this exam can, by probability, be defined by the responses to these items. For some students, this reality is confrontational and frustrating. Unfortunately, if the exam is passed, and contrary to what one might think, these deficiencies will not be addressed with any type of subsequent training by the student. They surely imagine that they will no longer need this knowledge. Similarly, although with a random approach (not included for all applicants), the National Examination for Medical Residency Aspirants (ENARM) also incorporates items with these topics. It is a reality that deficiencies cross boundaries in academic training levels, that is, it is observed that the majority of graduates who enter medical residencies also show broad gaps in knowledge in these topics. It is not uncommon that some residents show even limited competencies for searching scientific information on specific platforms, or frank ignorance of their existence.

The problem at this level is that this insufficiency will affect not only the acquisition of necessary information for their training as residents but also the development of the thesis protocol, the sole tool with which they must graduate as medical specialists. This is, of course, regardless of their interest or not in dedicating themselves to scientific research. The contradiction is that the residents themselves, like undergraduate students, recognize that mastery of the subject could make a difference in their training and medical practice. The negative perception and rejection, like everything else, has assumptions as diverse as there are residents being questioned, that is, from complicated teaching to a frank lack of subjects related to statistics and methodology in the medical curriculum at their universities of origin. A separate point is the very particular comment that there was no one to teach these subjects. Whether true or not, the deficiencies are obvious from day one.

By virtue of all this, a teaching method is proposed, with concrete medical examples, practical application, accessible, friendly, and support with continuous guidance, all of which can make the difference. Likewise, this alternative proposes that the information above all preserves clarity, relevant content, and applicability from the first topics.

The objective is to offer students material with various topics in this discipline, but with the focus on statistical data analysis, with the ability to interpret them and with the vision that statistics is fundamental in medicine, in other words "knowing how to do," but in the medical context. Although the tools available in this field are multiple and very varied, those that I estimate are of greatest practical application will be addressed. For those interested in developing research projects, other statistical instruments may eventually be reviewed.

It would be a great achievement if the students themselves were capable of implementing and working with the statistical tools necessary for the development of their projects, and not just looking for someone to do the "statistical work," which most of the time, whoever does it, does not provide elements for understanding an effective statistical-clinical correlation. This material does not intend to replace textbooks on the subject; on the contrary, the intention is to provide information that adds to the knowledge of relevant content in this field. With this in mind and with the purpose of achieving the objective, I have considered presenting monthly installments with different topics. The content of this first installment is related to the history of statistics, an approach through time.

The journey will be brief, so to speak, since this is not an exhaustive review, simply to know the contributions of great men and impressive ancient cultures. It will be interesting to read the names of some authors that students have surely heard in their classes, as it is common for some statistical tests to bear the names of their creators.

HISTORICAL DEVELOPMENT

ORIGINS

Statistics is a scientific discipline, a branch of mathematics. Initially, the meaning was restricted to information about states. This consideration was extended to later include information of any type, and finally to include the organization, collection, and analysis and interpretation of data. Its applicability in health sciences has given rise to the use of the term biostatistics. The historical evolution in this field has been vertiginous, with great progress through the centuries, and always with the purpose of providing methods and tools to make informed decisions and make inferences from data. Its applicability in health sciences has given rise to the use of the term biostatistics. The historical evolution in this field has been vertiginous, with great progress through the centuries, and always with the purpose of providing methods and tools to make informed decisions and make inferences from data.

Over time, methods were developed and matured, giving rise to the emergence of key concepts and techniques that today constitute the basis of modern statistical analysis. As we delve into the history of statistics, we acquire a valuable perspective of the methods and thought processes that have shaped our current understanding of data and its importance in various fields. The evolution of this discipline is a testimony to the continuous search to better understand the world around us. Without attempting to make an exhaustive summary, it is advisable to learn about some representative background and know some of the most famous exponents in this field of knowledge.

For some experts, its origins date back to ancient civilizations such as the Babylonian and Egyptian, which collected and analyzed data for commercial, tax, and astronomical purposes, among others. These early methods laid the foundations in the field of statistics. For example, the Babylonians used these strategies for agricultural production, which allowed for the implementation of tax payment and efficient resource allocation. Similarly, the Egyptians used data to plan and manage public infrastructure projects, such as irrigation systems, pyramid and temple construction projects, as well as population censuses. The first known writings on statistical methods are found in the works of ancient Persian and Arab scholars such as Al-Kindi, Al-Karayi, and Al-Jwarizmi, who made important contributions to the understanding of data analysis and interpretation through algebraic calculations and mathematical equations.

In Greece, Greek philosophers and mathematicians such as Pythagoras, Plato, and Aristotle carried out systematic studies of data and developed fundamental concepts, such as information gathering, trend analysis, and theory formulation. Pythagoras, through his famous theorem, explained how to measure and study distance and height that are of great help today for geographical analysis and map making; moreover, his contributions initiated the development of trigonometry. Archimedes and Euclid also contributed advances in mathematics and geometry. The latter demonstrated with his theorem the existence of infinite prime numbers.

In ancient Rome, statistics became an indispensable tool for maintaining control and efficiency in such an extensive and diverse empire; population censuses and mechanisms stand out, like those of other cultures, for controlling the empire's finances. These early techniques reflect the fundamental human need to understand and use data for practical purposes, laying the foundations for sophisticated statistical principles that exist today.

STATISTICS IN THE MIDDLE AGES

During the medieval period, European scholars such as the Italian Leonardo of Pisa nicknamed "Fibonacci," promoted the development of statistical methods in fields such as economics and demographics, popularized the Hindu-Arabic numerical system in Europe, and introduced in his fourth book the so-called "Square Numbers," which have found applications in probability distribution.

Other figures such as the English Franciscan friar Robert Grosseteste, who was even bishop in Lincoln, England, and the French Nicole Oresme, also bishop in Lisieux now region of Normandy and advisor to King Charles V of France, began to explore primitive statistical concepts, such as dispersion measurement and graphical representation of data.

The first made contributions to the study of light, heat, and movement, and made speculations about the creation of the universe, while the second postulated among other topics, Merton's theorem to explain the so-called average velocity, which was in favor of the earth moving and not celestial bodies. He was also the discoverer of light curvature and atmospheric refraction, although this was attributed to the English scientist Robert Hooke. Nicole Oresme is considered to have been clearer and more explicit in heliocentric considerations of the universe than Copernicus himself, an astronomer and Polish physician who was born and lived two centuries later.

ADVANCES IN THE RENAISSANCE AND THE SCIENTIFIC REVOLUTION

During the Renaissance until the epoch of the Scientific Revolution that followed it, contributions to mathematics and science in general were conducted by outstanding figures such as the Italian Galileo Galilei, who due to his interest in astronomy and using the telescope empirically confirmed the heliocentric model of the universe, which indicated that the earth and planets were the ones that orbited around the sun. He is also attributed with the formulation of the first laws about movement and dynamics, which would be culminated a century later by the Englishman Isaac Newton.

The brief reference to this great figure would not be complete if it were not noted that for criticizing Ptolemy's postulates and the geocentric vision of the universe (the opposite of heliocentric) prevailing at that time, he was found guilty of heresy in 1633, for which he was forced to live under house arrest in his villa in Tuscany, Italy, despite having abjured his heliocentric conception of the universe.

He is attributed with the hypothetical phrase "and yet it moves," which would refer to the fact that despite what was said and what he had abjured, it was the earth that moved around the sun. As an interesting added fact, it is worth saying that in 1992, Pope John Paul II vindicated Galileo Galilei and reconciled faith with science. This historical fact was 359 years after the unjust condemnation of this great man.

For his part, the French mathematician and scientist René Descartes, father of modern rationalism and creator of the work "Metaphysical Meditations" and the "Discourse on Method," among others, made notable contributions to mathematics, medicine, analytic geometry, equation theory, mechanics, and geology. He established that one can only say that the existence of everything that exists is through everything that can be proven, hence his famous phrase "I think, therefore I am." Precisely this is the basis of methodological skepticism or Cartesian method, proposed by him. In other words, for Descartes the act of doubting is undoubtable.

In the publication at that time of the work "Liber de Ludo Aleae" (Book on Games of Chance), by the Italian Gerolamo Cardano, a detailed description of the sample spaces corresponding to the throwing of 1, 2, or 3 dice is proposed, and a first approximation to the concept of probability in terms of proportions is presented. This same author was also the first to publish complete solutions for third and fourth-degree equations. The first writings with topics related to probability calculation were proposed to solve problems posed by card and dice players. Luca Pacioli, an Italian Franciscan friar, in his work Summa Arithmetica, Geometria, Proportioni et Proportionalita, made reference to the so-called problem of points, through which it was intended to find the best solution for distributing money wagered by several players when the game was interrupted before finishing. It is also recognized that his contributions are the basis of modern accounting.

However, time later, the solution to the betting issue came from two French mathematicians, Blaise Pascal and Pierre de Fermat, who did not intend to reflect on the concept of chance, but only sought to apply numerical methods to analyze the alternatives posed by games of chance. In any case, in the history of science, it is considered that the Theory of Probability appeared in the second half of the 17th century, with Luca Pacioli and his writing on the "Problem of Points."

18TH CENTURY

Later in the 18th century, Jacob Bernoulli of Swiss origin made contributions to the theory of infinite series and differential equations, and like other authors contributed to probability theory, which for many authors began in that century. He stands out for his proposal to apply mathematical theory to physiological processes such as blood circulation and respiration, and conceptualized what is called binomial distribution.

Abraham de Moivre, a French mathematician, stands out for his work related to extended binomial coefficients, as well as his book "The Doctrine of Chances," which addresses topics related to normal distribution and probability. In addition, this author made contributions to the so-called irrational or golden number, which represents an algebraic number with infinite decimal representation, that is, the calculation never reaches a final digit, although the authorship of this contribution was finally awarded to Jacques Philippe Marie Binet, also of French origin, a century later.

Thomas Bayes, British mathematician and Presbyterian minister, proposed a revolutionary approach to statistical inference, arguing that probabilities are updated as new information is obtained. His theorem, known as Bayes' Theorem, became the fundamental basis of this field. Bayesian statistics is distinguished by its ability to incorporate prior knowledge and observed evidence to make predictions and decisions. Unlike classical approaches, the Bayesian approach allows researchers to update their beliefs as new data is collected. Also in the mid-18th century began the rise of descriptive statistics in social and economic matters; however, there was opposition to the use of numerical procedures for the analysis of clinical data, as medicine was considered a discipline based on the physiology of each patient, so there could not be generalizable conclusions.

19TH CENTURY

The organization and tabulation of data was first produced in sociology, around 1927, taking into account variables and their categories. With the consolidation of probability theory in 1933, the current foundations of probabilities were established and the modern era of statistics began with inferential statistics. Similarly, in this century emerged techniques that allow the study of relationships between two variables, such as correlation and linear regression for quantitative variables and the X^2 test for qualitative variables.

In that era of continuous advances, important developments in statistics occurred with the contributions of key figures such as the German Carl Friedrich Gauss and the British Sir Francis Galton, Charles Darwin's cousin. The works of both introduced concepts such as probability distributions, regression analysis, and hypothesis testing, which are still widely used in statistical analysis today.

Carl Friedrich Gauss's contributions to statistics are significant; in 1809 he published work on the method of least squares, which is fundamental in data analysis and parameter estimation. In 1823, he introduced the famous normal distribution law to analyze astronomical data and, additionally, made important contributions in mathematics, physics, and geometry. His understanding of normal distribution and its association with the Central Limit Theorem have had a significant impact on probability theory and the modeling of natural and social phenomena. The famous normal distribution bell curve for random variables bears his name thanks to his contributions and the extensive use this author gave it in his works; however, it should be said that the normal distribution as such was initially described by mathematician Abraham de Moivre since 1733.

Sir Francis Galton's contribution to the development of linear regression was significant. His initial work on the inherited characteristics of sweet peas led to the initial conceptualization of linear regression. Through his observations, he recognized the relationship between paired variables and also developed the concept of regression to the mean. Furthermore, he generalized his work on regression to a variety of inheritance problems, which laid the foundations for the later development of multiple regression. His focus on genetics and inheritance provided the initial inspiration that led to the development of regression and the product moment correlation coefficient. This work had a significant influence on his famous proposal about correlation and regression.

Karl Pearson of English origin, who worked in Galton's laboratory, continued developing his mentor's ideas regarding rigorous mathematical treatment in multiple regression procedures. Pearson also introduced standardized methods of statistical data management, challenged the tyrannical acceptance of the normal curve as the only distribution on which to base the interpretation of statistical data, and provided mathematical statistical tools to examine the shape of empirical distribution.

He organized the first statistics course in Great Britain in 1917, and his work also included the development of goodness of fit tests. This test provided scientists with an objective tool to determine if an observed empirical distribution fit an expected theoretical distribution. Before this test, scientists had no underlying theoretical basis for their goodness of fit formulas.

Pearson's chi-square test allowed statisticians to use methods that did not depend on normal distribution, which represented a significant advance in statistical methodology. This author is recognized for creating laboratories and academic departments at the University of London, England. His prolific career and interest also led him to make significant contributions in collaboration with Raphael Weldon, also of English origin, on one hand applying statistical methods to the study of psychological differences and hereditary intelligence, and on the other hand founding the journal BIOMETRIKA in 1901 (a term used for Galton's biometric approach to inheritance topics).

During this 19th century, statistics experienced notable development and consolidation as a scientific discipline. Other notable figures included the Belgian Adolphe Quetelet, who applied the first statistical techniques to the study of social and demographic phenomena, laying the foundations of social statistics. Likewise, Florence Nightingale of Italian origin and nursing profession used statistics to improve sanitary conditions in military hospitals, becoming a pioneer in statistics applied to public health. Meanwhile, the Englishman William Sealy Gosset, known as "Student," developed Student's t-distribution, fundamental for working with numerical variables and for statistical inference. The need to use a pseudonym was due to the policies of the company where he worked, which prohibited the publication of scientific research. His contribution was so important that the name is preserved, but from his pseudonym.

20TH CENTURY

The current era of statistics begins with decision theory and Bayesian methods, and is characterized by the establishment of multi-causal models, the search for more efficient estimation methods, the emergence of new non-parametric tests, and multivariate techniques. The advent of computers allowed this discipline to include large databases. In medicine, studies of risk factors and clinical trials begin to be conducted. The studies of this era aimed at causal relationships or probability-based predictions, within certain margins of error. The concepts of exposure, risk, association, confounding, and bias were developed with greater precision, and probability theory and numerous advanced statistical techniques were incorporated.

The British Ronald Fisher, considered one of the fathers of modern statistics, made fundamental contributions to the development of parameter estimation and statistical inference as we know it today. Fisher introduced key concepts such as the likelihood function, hypothesis testing, and analysis of variance, standing out for his line of research in genetics and for having been editor of the journal BIOMETRIKA.

As a curious and historical background in statistics and science, the rivalry with Karl Pearson stands out. The latter was known for using a more mathematical and formal approach, while Fisher had a more practical and empirical orientation focused on experimental design. The criticism between both became harsh and uncompromising; however, these controversies favored the evolution and diversification of statistical methods, given the continuous and incessant advent of scientific challenges.

Through his work, Fisher demonstrated how to use data to draw valid and generalizable conclusions about a population from a sample. His contributions in the field of statistics have been widely adopted and applied in various areas, from biology to economics and social sciences.

George Box, a prominent British statistician, made fundamental contributions to the field of experimental design. Box developed innovative techniques that allowed researchers to plan and analyze experiments more efficiently and effectively. His main contributions include factorial experimental design and the development of response surface methodology. This same author also proposed an approach known as the ARIMA (Autoregressive Integrated Moving Average) model, which allows identifying and adjusting statistical models capable of describing the behavior of complex time series. Finally, he contributed to the advancement of response surface methodology, which uses mathematical models to optimize processes and systems by identifying optimal conditions.

With the emergence of computational statistics, thanks to the appearance of the first computers, new possibilities opened up for the treatment and analysis of large data sets. Faced with these challenges, figures like John Wilder Tukey and David Cox, American and British respectively, led these developments. Tukey also focused on visualization and understanding of data through graphical and non-parametric methods, introduced innovative techniques such as the box plot and principal component analysis, which continue to be widely used today.

For his part, Cox is also recognized for his work called Cox regression analysis, a method used in survival analysis. Cox developed innovative techniques for modeling and analyzing complex data in a wide variety of fields, from medicine to economics and engineering. The Russian Andrey Kolmogorov, also in the 20th century, gained increasing importance in the field of probability theory and decision-making. Kolmogorov published in 1933 his work "Foundations of Probability Theory," where he proposed a set of axioms that define probability as a mathematical function. This collaboration marked a milestone in mathematics by providing probability theory with a solid theoretical foundation.

John Nash, the brilliant American mathematician, made fundamental contributions to the development of game theory, an interdisciplinary field that analyzes strategic interactions between rational agents. His innovative work revolutionized the way of thinking about decision-making in situations of conflict and competition. Nash developed the concept of "Nash equilibrium," a strategic solution in which each player chooses the best response to other players' strategies. This concept became a pillar of game theory and has been widely applied in fields such as economics, politics, biology, and computer science. Nash's contributions were recognized with the Nobel Prize in Economics in 1994, awarded for his work "Pioneering analysis of equilibrium processes in game theory." This work continues to be fundamental for understanding decision-making in competitive and cooperative environments.

The American Harold Hotelling generalized Student's t-test to several dimensions, developed canonical correlation analysis and principal component analysis, previously outlined by Pearson. The Polish Jerzy Neyman began to develop sampling theory to scientifically overcome the possibility of saving resources by not studying the complete population, and formulated stratified and cluster sampling designs. He gave a new approach to significance tests, strengthened the theory of confidence intervals, and created what he called Neyman-Pearson law, which establishes an optimal criterion for deciding between two hypotheses based on a statistical test. He also introduced causal analysis through the concept of treatment effect.

The Englishman Charles Spearman developed exploratory factor analysis in the field of Psychometrics, which allowed measuring unobservable abstract variables (constructs), especially intelligence. He also developed factorial experimental design and the well-known Spearman correlation coefficient.

Maurice George Kendall, also of English origin, conducted time series studies and developed what bears his name and is called: Kendall's rank correlation coefficient. The Scotsman William Gemmell Cochran developed the test called Cochran's Q test for comparing paired samples, while the Romanian Abraham Wald introduced loss and risk functions, as well as admissible decision rules, a priori distributions, Bayesian decision theory, and minimax rules for decision-making.

The Englishman Frank Yates made contributions to the theory of analysis of variance, where he developed computational methods for analyzing experiments through least squares of so-called incomplete balanced blocks, while Frank Wilcoxon of Irish origin introduced non-parametric rank sum tests for two independent samples, and the sign test for two paired samples, alternatives to Student's parametric t-test.

The American Quinn Michael McNemar proposed a test to prove the homogeneity of proportions in two correlated samples, and the Israeli Jacob Yerushalmy introduced the terms sensitivity and specificity as indicators to evaluate the inherent effectiveness of a diagnostic test. Greater computational development achieved after the 1980s allowed the application of complex iterative algorithms that can only be carried out with computer aid, such as resampling classification techniques: Bootstrap, Monte Carlo simulation, and Markov chains.

Other techniques developed are fuzzy logic, self-sufficient estimation, Bayesian models, methods based on G-estimation, data mining techniques, association rules, classification trees, and neural networks, among others. Survival calculation techniques in medicine were also introduced, and other goodness-of-fit methods for logistic regression emerged such as the Hosmer and Lemeshow test, the Score test, and finally the Cox and Snell R^2 and the application of the Receiver Operating Characteristic (ROC) curve for the evaluation of medical diagnostic methods began.

21ST CENTURY AND FUTURE CHALLENGES

In this era of big data and machine learning, statistics constitutes the backbone of algorithms and models that drive innovations in artificial intelligence, predictive analysis, and data-based decision-making; without a doubt, all this will continue to drive statistics toward new frontiers. It will also be fundamental to develop interpretable and explainable models while maintaining precision and utility. Another major challenge will be to develop statistical methods to analyze unstructured data such as text, images, and videos and create new techniques to improve the complexity and dimensionality of current data. Without a doubt, the emphasis should be placed on ensuring the replicability of findings in different contexts, and above all, on training statisticians and data scientists.

In the field of health in general and medicine in particular, statistics will continue to play a decisive role in clinical trials, epidemiological studies, and scientific research, allowing evidence-based decision making and promoting advances in diagnoses and treatments. Through the use of statistical methods, researchers can identify patterns and correlations that help understand human behavior, social trends, and public opinion.

CONCLUSION

The enduring legacies that great men have left through time with their theoretical and methodological contributions have built the foundations of modern statistics. From its first applications in censuses and administrations in ancient civilizations, to its formalization as a scientific discipline from the 18th century, it has had a crucial role not only for knowledge but for decision making. Currently, it can be said that it is at the forefront of big data and artificial intelligence, providing indispensable tools for what is its fundamental task, data analysis. The challenges continue and without a doubt, its participation in different areas of knowledge will continue to be essential. Its history has not only maintained a rigorous approach but also an ethical one for understanding the world; these characteristics should continue to be in force.

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