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Artículo de Revisión

Use of Statistical Methods in Medical Research: Bibliographic Review and Procedure Proposal

Uso de métodos estadísticos en la investigación médica. Revisión bibliográfica y procedimiento propuesto

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ABSTRACT

Introduction: The appropriate use of statistical methods is essential in medical research to ensure validity, reliability and reproducibility. This study examines the application of statistical techniques in medical publications from 2015 to 2025, identifying trends, gaps and opportunities to develop a standardized methodological framework.

Objectives: To analyze the use of statistical methods in medical research between 2015 and 2025, and to design a systematic procedure for selecting appropriate statistical techniques based on study design, variable types, and analytical objectives.

Methods: A systematic literature review was performed following PRISMA guidelines. Searches in PubMed, SciELO, Cochrane Library and Google Scholar identified peer-reviewed studies published between 2015 and 2025. Statistical methods were classified into four levels of complexity: descriptive, univariate, multivariate and advanced (e.g. machine learning, survival modeling).

Results: Of 3,340 initially identified records, 127 studies met inclusion criteria. Descriptive statistics were most prevalent (82.7%, 95% CI: 75.8-88.9%), followed by univariate techniques (70.1%, 95% CI: 62.0-77.9%). Multivariate methods were used in 37.8% of studies, while advanced techniques remained uncommon (15.0%, 95% CI: 9.8-22.2%). A stepwise decision algorithm for statistical method selection was developed, addressing common errors in test selection, repeated-measures analysis, and multiplicity adjustment.

Conclusions: The continued reliance on basic statistical methods and recurrent methodological errors underscore the need for enhanced statistical training and prospective planning in medical research. The proposed selection algorithm provides a practical tool for improving methodological rigor and reproducibility.

RESUMEN

Introducción: El uso adecuado de métodos estadísticos es fundamental en la investigación médica, para garantizar validez, fiabilidad y replicabilidad. Este estudio analiza la aplicación de estas técnicas en publicaciones médicas entre 2015 y 2025, identificando tendencias, limitaciones y oportunidades desarrollar un marco metodológico estandarizado.

Objetivos: Analizar el uso de métodos estadísticos en la investigación médica entre 2015 y 2025, y diseñar un procedimiento sistematizado para seleccionar métodos estadísticos apropiados según diseño de investigación, tipos de variables y objetivos analíticos.

Métodos: Se realizó una revisión sistemática de la literatura, siguiendo la guía PRISMA. Búsquedas en las bases de datos PubMed, SciELO, Cochrane Library, Google Académico identificaron estudios con revisión por pares publicados entre 2015 y 2025. Los métodos estadísticos se clasificaron en cuatro niveles de complejidad: descriptivo, univariado, multivariado y avanzado.

Resultados: De 3.340 registros identificados inicialmente, 127 estudios cumplieron los criterios de inclusión. Predominaron las estadísticas descriptivas (82,7%, IC 95%: 75,8-88,9%), seguidas de técnicas univariadas (70,1%, IC 95%: 62,0-77,9%). Los métodos multivariados aparecieron en el 37,8% de los estudios, mientras que las técnicas avanzadas permanecieron limitadas (15,0%, IC 95%: 9,8-22,2%). Se desarrolló un procedimiento sistemático para la selección de métodos estadísticos, abordando errores comunes en la selección de pruebas, manejo de medidas repetidas y control de multiplicidad.

Conclusiones: El predominio persistente de métodos básicos y los errores metodológicos frecuentes destacan la necesidad de mejorar la formación estadística y la planificación. El procedimiento sistemático de selección propuesto proporciona un marco práctico para mejorar el rigor metodológico y la replicabilidad.

INTRODUCTION

The scientific credibility of contemporary medical research relies on the rigorous application of statistical methods that transform clinical data into reliable evidence for healthcare decision-making.[1-3] Biostatistics, defined as the discipline that applies statistical reasoning problems in the life sciences, provides an objective mathematical framework for testing medical hypotheses.[4-6]

Statistical literacy empowers medical professionals to move beyond passive consumption of information and generate high-quality evidence that advances clinical knowledge.[1-3] However, challenges persist in the appropriate application of these methods, often due to limited understanding of their relevance to population health questions.[6]

Over the last decade (2015-2025), biostatistics in medical research has evolved significantly because of technological advances, widespread availability of specialized software, and increased editorial demands for methodological rigor.[7,8] Longitudinal analyses demonstrate that both the proportion of publications employing statistical methods and the average number of techniques per article have increased substantially over recent decades.[9]

This systematic review examines the use of statistical methods in medical research from 2015 to 2025, identifies predominant trends, evaluates methodological limitations, and proposes a standardized procedure for selecting appropriate statistical techniques based on research design and analytical objectives.

The objectives of this article are: To analyze the use of statistical methods in medical research during the last 10 years (2015-2025), and to design a systematized procedure for selecting appropriate statistical methods according to research design, variable types, and analytical aims.

METHODS

This systematic review followed an adapted PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework.[9,10] Given the narrative nature of this bibliographic review and the absence of meta-analysis, a focused subset of PRISMA elements was applied:

Protocol development: A predefined definition of search strategy, eligibility criteria, and analytical plan.

Search strategy: Comprehensive electronic searches with documented search terms and timeframes.

Study selection: Dual independent screening using explicit criteria.

Data extraction: Standardized collection of publication and methodological details.

Synthesis approach: Narrative synthesis supplemented by quantitative summaries.

Search Strategy and Study Selection

Electronic searches were conducted in PubMed, SciELO, Cochrane Library, and Google Scholar from January 2015 to December 2025 using the Boolean string: ("statistical methods" OR "biostatistics" OR "medical research") AND ("descriptive statistics" OR "inferential statistics" OR "logistic regression" OR "survival analysis" OR "multivariate analysis").

The selection process (figure 1) included: (1) Identification of records; (2) screening of titles and abstracts after duplicate removal; (3) full-text eligibility assessment; and (4) final Inclusion of studies meeting all criteria.

Inclusion criteria:

- Original research published in peer-reviewed medical journals.
- Methodological papers on statistical application in medicine.
- Systematic reviews addressing statistical methods in medical research.
- Epidemiological studies employing statistical analysis.
- Articles published between 2015 and 2025 in Spanish, English, or Portuguese.

Exclusion criteria:

- Brief communications, letters, editorials without original data.
- Case reports or case series lacking statistical analysis.
- Opinion pieces without a methodological framework.
- Basic science studies without clinical applicability.
- Purely qualitative studies without quantitative components.

Classification of Statistical Methods

Methods were grouped into four levels of analytical complexity:[6,11]

Level 1: Descriptive statistics—frequency distributions, measures of central tendency and dispersion, and graphical summaries.

Level 2: Basic inferential techniques—univariate parametric tests (t-tests, ANOVA) and non-parametric alternatives (Mann–Whitney U, Kruskal–Wallis, Wilcoxon signed rank).

Level 3: Multivariate techniques—regression models (linear, logistic), survival analysis (Cox proportional hazards, Kaplan-Meier), and correlation methods (Pearson, Spearman).

Level 4: Advanced analytical methods—mixed-effects models, Bayesian inference, machine learning algorithms and structural equation modeling.

Note: Although certain non-parametric methods (e.g., PERMANOVA) can be extended to multivariate contexts, they were seldom observed in the reviewed medical literature.

Data Extraction and Analysis

A standardized form captured: publication year, journal, medical specialty, study design, statistical methods, software used, and quality indicators.

Descriptive statistics (frequencies and percentages with 95% confidence intervals calculated using the Wilson score method) were computed. Temporal trends were assessed visually and through non-parametric tests where appropriate. Analyses were performed using R version 4.3.1.

RESULTS

Figure 1 presents the PRISMA flow diagram of the study selection process. Of 3,340 initially identified records (3,215 from database searches and 125 from manual searches), 493 duplicates were removed. After screening 2,847 titles and abstracts, 2,482 were excluded for not meeting inclusion criteria. Full-text assessment of 365 articles resulted in 127 studies that met all eligibility criteria.

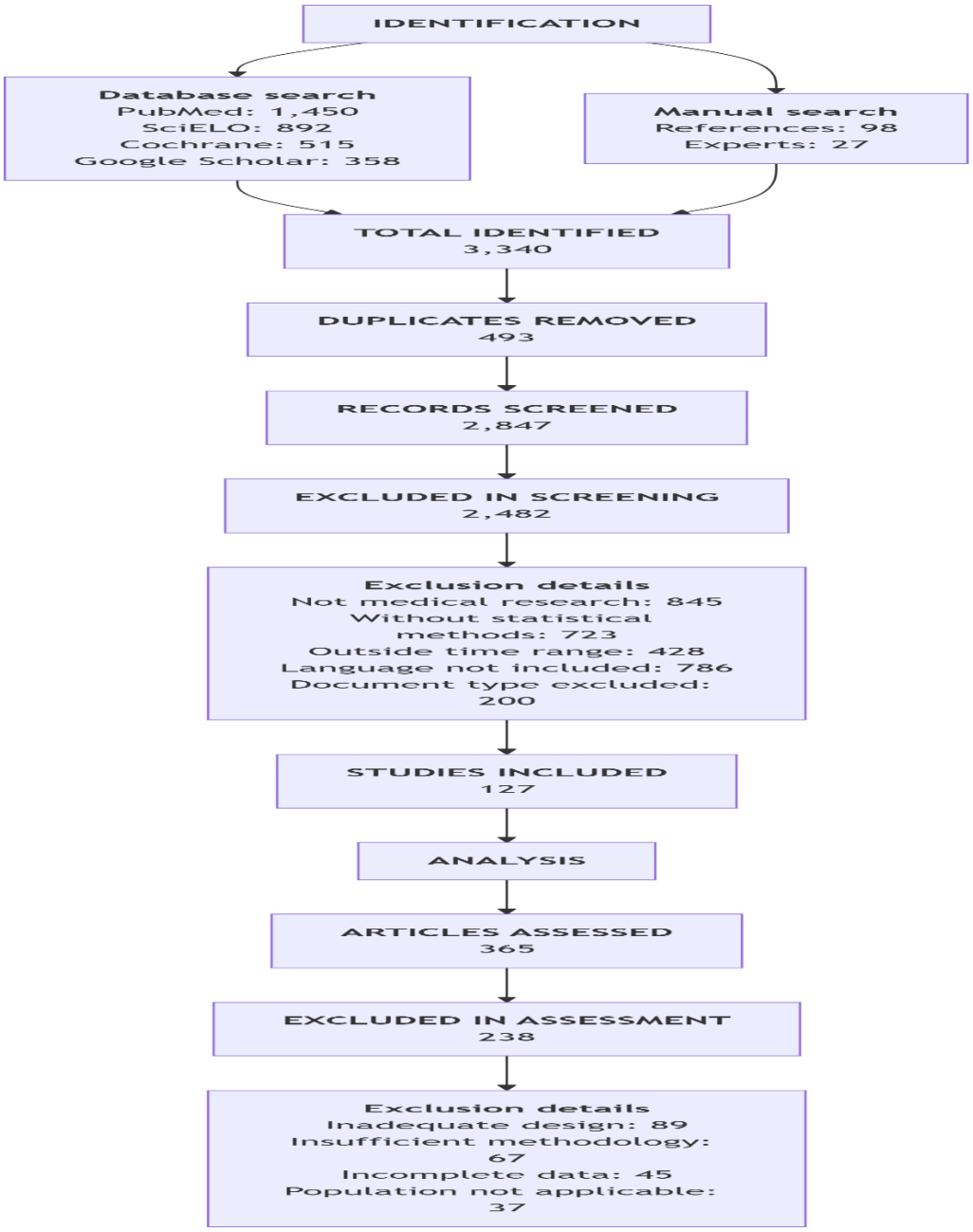

Fig. 1. PRISMA flow diagram of the study selection process.

Characteristics of Included Studies

The 127 included studies covered multiple medical specialties: internal medicine (28.3%, 36/127), epidemiology (22.0%, 28/127), surgery (14.9%, 19/127), pediatrics (11.8%, 15/127), psychiatry (9.4%, 12/127), and others (13.4%,

17/127). Publication frequency increased progressively over time, peaking in 2022-2023 (32.3%, 41/127).

Frequency of Statistical Methods by Complexity Level

Table 1 summarizes the use of statistical methods across complexity levels. Descriptive statistics (Level 1) were most prevalent, appearing in 82.7% of studies (105/127, 95% CI: 75.8-88.9%). Univariate inferential techniques (Level 2) followed at 70.1% (89/127, 95% CI: 62.0-77.9%), with t-tests (65.4%, 83/127) and chi-square tests (58.3%, 74/127) being the most common. Multivariate methods (Level 3) were employed in 37.8% of studies (48/127, 95% CI: 30.0-46.3%), primarily logistic regression (25.8%, 33/127) and linear regression (18.9%, 24/127). Survival analysis appeared in 9.4% of studies (12/127). Advanced techniques (Level 4) remained infrequent (15.0% (19/127, 95% CI: 9.8-22.2%), appearing mainly in specialized methodological journals.

Analysis of High-Impact Journals

Among 45 studies published in high-impact journals (Journal Impact Factor >10, JCR 2023):

- *New England Journal of Medicine* (n=18): 12% (2/18) used Level 4 methods.
- *The Lancet* (n=15): 13% (2/15) used Level 4 methods.
- *JAMA* (n=12): 17% (2/12) used Level 4 methods.

In contrast, specialized journals showed higher adoption:

- *American Journal of Epidemiology* (n=8): 38% (3/8) used Level 4 methods.
- *Statistics in Medicine* (n=5): 80% (4/5) used Level 4 methods.

Table 1. Frequency of Statistical Methods by Complexity Level (n=127)

Level	Method category	n (%)	95% CI
1	Descriptive statistics	105 (82.7%)	75.8-88.9%
2	Univariate tests	89 (70.1%)	62.0-77.9%
3	Multivariate techniques	48 (37.8%)	30.0-46.3%
4	Advanced methods	19 (15.0%)	9.8-22.2%

Note: Studies could employ multiple methods; percentages exceed 100%.

Temporal Trends (2015-2025)

A significant increase in multivariate method use was observed over the decade (χ^2 for trend=8.42, p=0.004). The proportion of studies using Level 3-4 methods rose from 28.6% (10/35) in 2015-2017 to 52.4% (22/42) in 2023-2025. However, descriptive and univariate methods remained dominant across the periods.

Statistical Software Utilization

SPSS was the most commonly cited software (68.5%, 87/127), followed by R (24.4%, 31/127) and SAS (18.1%, 23/127). Python and Stata appeared in less than 10% of studies. Although user-friendly interfaces facilitated access to advanced methods, inappropriate application remained common.

Proposed Systematic Procedure for Statistical Method Selection

As a primary result of this review, a five-phase decision algorithm for statistical method selection was developed. (Fig. 2)

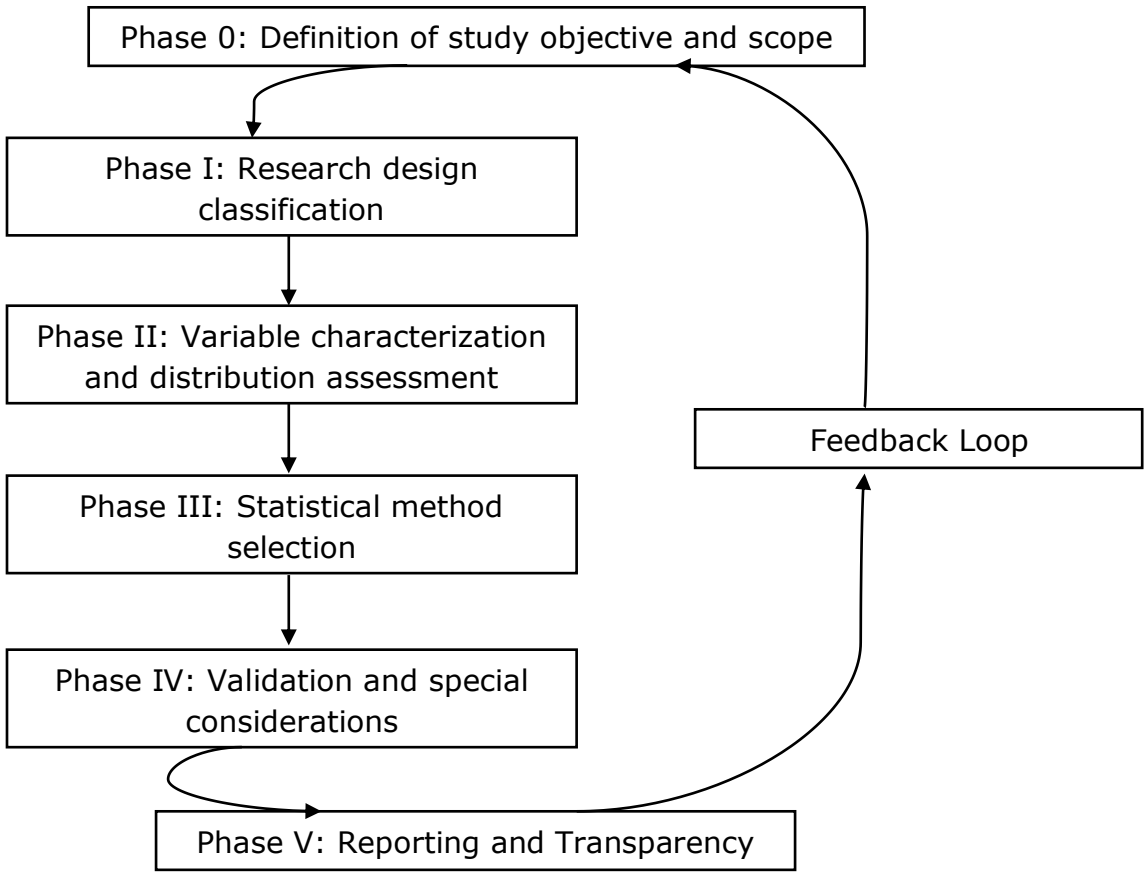

Fig. 2. Decision algorithm for statistical method selection

Phase 0: Definition of study objective and scope.

Define the research question using FINER criteria (Feasible, Interesting, Novel, Ethical, Relevant). Distinguish between:

- Exploratory/descriptive studies: Aim to describe or generate hypotheses (no formal statistical hypothesis).
- Confirmatory/analytical studies: Test a pre-specified hypothesis, defining α (Type I error and, where applicable, β (Type II error).

Phase I: Research design classification.

Classify as:

Descriptive: cross-sectional, case series.

Analytical:

- Observational (cohort, case-control, cross-sectional analytic)
- Experimental: (randomized controlled trials, quasi-experimental.

Also define temporal scope: cross-sectional vs. longitudinal.

Phase II: Variable characterization

Classify variables by type and measurement scale. Note: Analytical treatment may differ from nominal scale (e.g. Visual Analogue Scale (VAS) score, often treated as continuous if distribution permits.[12] Assess normality (Shapiro—Wilk if n<50; Kolmogorov—Smirnov if n≥50, variance homogeneity (Levene's test, and outliers (Tukey's fences).

Phase III: Statistical method selection.

Descriptive: mean ± SD (normal) or median [IQR] (non-normal); frequencies (%) for categorical variables.

Inferential:

- Two independent groups: t-test (normal) or Mann-Whitney U test (non-normal).
- Paired data: paired t-test or Wilcoxon signed-rank test; McNemar's test for binary outcomes.
- ≥3 groups: ANOVA or Kruskal-Wallis test; repeated-measures: RM-ANOVA or Friedman test.
- Association: Pearson (normal) or Spearman (non-normal).
- Multivariate: logistic (binary outcome), linear (continuous), Cox (time-to-event).

Phase IV: Validation and special considerations.

- Apply multiplicity corrections (e.g., Bonferroni, Holm, or Benjamini-Hochberg).[13,14]
- Conduct a priori power analysis for confirmatory studies.
- Address missing data (identify mechanisms: MCAR, MAR, MNAR); and use multiple imputation if MAR.
- Validate models via bootstrapping (≥1000 resamples) or train-test split.

Phase V: Reporting and transparency.

Clearly report of all methods, justify analytical choices, report confidence intervals, and detail missing data handling. Adhere to reporting guidelines (e.g. SAMPL, STROBE, CONSORT).[15,16]

DISCUSSION

This systematic review of 127 studies published between 2015 and 2025 reveals a persistent predominance of basic statistical methods in medical research, with descriptive and univariate techniques employed in over 80% of studies. While the increasing adoption of multivariate methods (particularly logistic regression [25.8%]) represents methodological progress, advanced analytical techniques remain limited to 15% of studies, mostly in specialized methodological journals.

These findings corroborate previous reports of insufficient statistical training among medical researchers.[17,18] The most frequent errors identified—inappropriate test selection, mishandling of repeated measures, and unaddressed multiplicity—usually originate from inadequate *a priori* methodological planning rather than computational mistakes. This pattern aligns with broader concerns about reproducibility in biomedical science.[18-20]

The observed increase in multivariate methods use is encouraging and likely reflects both improved statistical training and greater accessibility to statistical software. However, the continued dominance of basic methods indicates that software availability alone is insufficient. Sustained improvements require targeted educational initiatives and editorial policies that enforce methodological rigor.

Methodological Limitations and Common Errors

The review identified four recurrent statistical errors:

Inappropriate test selection: frequent use of t-tests and ANOVA without verifying distributional assumptions or considering non-parametric alternatives.

Inadequate handling of correlated data: ignoring repeated measures or clustered structures, inflating Type I error rates.

Unaddressed multiplicity: Omitting correction for multiple comparisons in exploratory analyses.

Misapplication of inferential frameworks: Using hypothesis-testing paradigms in retrospective observational studies lacking probabilistic sampling.

These errors frequently reveal a misalignment between study objectives and analytical strategies, highlighting the need for structured methodological planning.[21,22]

The Proposed Selection Procedure: Addressing Identified Gaps.

The five-phase decision algorithm developed in this study (figure 2) directly aims these deficiencies by providing a structured framework. Its key strengths include:

1. A clear distinction between exploratory/descriptive and confirmatory/analytical studies, clarifying when α and β errors control is statistical meaningful.
2. Explicit inclusion of common observational designs (e.g., retrospective cohort, case-control studies).
3. Practical guidance for ambiguous variable classification (e.g. treating Visual Analogue Scale scores as continuous when justified by distribution).
4. Clear differentiation between independent and related samples to prevent analytical mismatches.
5. Integration of validation (e.g., bootstrapping) and transparent reporting practices.

Critically, this procedure positions statistical planning as essential component of study design, not a *post-hoc* step, preventing errors before data collection begins.

Implications for Research Practice and Education

To improve methodological quality, the authors recommend:

Curriculum reform: Statistical training should emphasize the logical linkage between research questions and analytical choices, not just computational procedures.

Editorial enforcement: Journals should mandate methodological justification and adherence to reporting guidelines (e.g., STROBE, CONSORT).

Tool development: Implementation of the proposed algorithm in digital decision support platforms

Early consultation: Routine involvement of biostatisticians from protocol development through analysis.

Limitations

This review has several limitations. The restriction to Spanish, English, and Portuguese publications may have excluded relevant studies in other languages. The focus on methodological reporting rather than re-analysis of original data limits assessment of analytical correctness. Finally, the narrative synthesis approach, while appropriate for a methodological review, precludes quantitative meta-analysis of methodological trends.

CONCLUSIONS

This bibliographic review of statistical methods in medical research from 2015 to 2025 reveals a field in transition, characterized by the persistent dominance of basic techniques alongside a gradual uptake of more sophisticated approaches. Descriptive and univariate analyses remain prevalent, appearing in over 80% of studies, while advanced techniques are confined to approximately 15% of publications, mostly in specialized methodological journals.

The high frequency of methodological errors—particularly in test selection, management of correlated data, and multiplicity adjustment—underscores an urgent need for enhanced statistical training and prospective planning in medical research. These deficiencies undermine the validity and reproducibility of scientific evidence, with direct consequences for clinical decision-making and public health.

To address these gaps, the authors developed a systematic, five-phase procedure for selecting appropriate statistical methods. This framework guides researchers through a structured evaluation of study objectives, design type, variable characteristics, and analytical options, embedding methodological rigor from protocol development through final reporting.

Future efforts should focus on implementing and validating this procedure in diverse research settings, creating accessible educational resources, and promoting editorial policies that require transparent methodological justification. Only through such integrated strategies can the medical research community fully leverage statistical science to generate reliable, reproducible, and clinically actionable evidence.

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Conflict of interest

The authors declare no conflict of interest.