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Review Article

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Errors in Medical Research: Statistical Thinking

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Abstract

The role of statistical methods in medical studies is indisputable. Using incorrect statistical methods in medical publications will result in inaccurate reporting of publication results to health readers and patients. This situation is not only unethical, it causes patients not to get better and hinders our progress in the field of medicine. For this reason, this study will focus on statistical mistakes made especially in medical research, and then on statistical thinking.

The foundations of statistical thinking come primarily from methods related to the discipline of statistics. It also comes from the study fields of medical informatics and computer science. Evidence-based Statistical thinking allows us to accurately identify problems. In fact, all statistical methods are evidence-based. Especially when human intuition often uses statistical thinking, it reaches more accurate results.

Statistical thinking provides us with important tools to accurately understand events and determine whether human intuition is right or wrong.

The solution to incorrect statistical reporting will be prevented by researchers better learning the methods and terminology of Biostatistics science. Unfortunately, although the importance of statistical tests is emphasized, statistical errors continue to appear in serious scientific journal articles.

Keywords: Errors, Medical Research, Statistical Thinking

Errors in Medical Research

The role of statistical methods in medical studies is undisputed. Using incorrect statistical methods in medical publications will convey the results of the publication incorrectly to healthcare readers and patients. This situation is not only unethical but also causes patients not to recover and prevents us from progressing in the medical field. Therefore, in this study, we will focus on how statistical distributions should be used and their assumptions, which are especially important in the first step in medical research. Having a good understanding of these will ensure that the statistical methods to be used are used correctly.

Statistical distributions also play an important role in the validity and reliability of the research. Care must be taken to avoid the spread of Type I and Type II errors in research. Having a good understanding of statistical terms is the first step in avoiding mistakes. For this reason, it is necessary to teach Biostatistics courses to enough students in medical education.

Doctors, who are required to read scientific articles, and all scientists interested in science have a responsibility to understand the research methods.

In the study conducted by Costantino G et all. errors were investigated in articles published in the three most reliable clinical journals. Two reviewers reviewed 200 consecutive original articles containing at least two tables, published between October 2010 and April 2011. Of the 125 articles included in the study (1);

102 (82%, 95% CI 74-88%) contained some type of error, even more than one.

Nine articles (7%, 95% CI 3-13%) contained a slip,

92 articles (74%, 95% CI 65-81%) contained at least one numerical error, and

22 articles (18%, 95% CI 11) -25 %) contained a methodological error.

Five articles (4%, 95% CI 1-9%) contained one serious error.

AbdulRaheem Y. with the titled "Statistics in medical research: Common mistakes", has identified and reported the mistakes made under the following headings, respectively (2);

- Sampling bias.
- Inappropriate sample size calculation.
- Effect of confounding variables.
- Errors in the application of statistical tests.
- Type I and Type II errors.
- Failure to adjust for multiple comparisons.

- Inappropriate use of p-values.
- Data dredging or "fishing".
- Publication bias.

In a study, the errors found in residency theses were identified and classified under the following headings (3,4);

Errors relating to the p-value;

• p-values given in closed form ($p<0.01$, $p<0.05$, $p>0.05$,etc.),

• Non-reported p-values,

• Incorrect p-values,

• Incorrect demonstration of p-values ($p=0.000$, $p<0.0005$, etc.).

Errors relating to the statistical tests;

• Statistical technique defined but not used,

• Incorrect name for the statistical test,

• Undefined statistical test,

• Use of incorrect test,

• Statistical analysis required but not performed.

Other errors;

• Mathematical demonstration errors,

• Statistical symbol errors,

• Incomprehensible statistical terms,

• Inappropriate interpretation,

• Errors in (statistical) terminology,

• Errors in summarizing data,

• Presentation of statistical method analysis and results in the incorrect section of the manuscript.

In the study of Yabacı TA et al.; by examining 321 medical residency theses, it was reported that the most common mistake was "mistakes made in summarizing the data" with a rate of 70.1% (n = 225). The errors made are listed as follows (5).

- Errors relating to the p-value:
- p-values given in closed form 149 (46.4%)
- Non-reported p-values 92 (28.7%)

- Incorrect p-values 111 (34.6%)
- Incorrect demonstration of p-values 152 (47.4%)
- Errors relating to the statistical tests:
- Undefined statistical test 142 (44.2%)
- Incorrect name for the statistical test 81 (25.2%)
- Statistical technique defined but not used 60 (18.7%)
- Use of incorrect test 91 (28.3%)
- Statistical analysis required but not performed 70 (21.8%)
- Errors in summarizing data 225 (70.1%)
- Mathematical demonstration errors 165 (51.4%)
- Statistical symbol errors 63 (19.6%)
- Incomprehensible statistical terms 46 (14.3%)
- Inappropriate interpretation 74 (23.1%)
- Errors in (statistical) terminology 92 (28.7%)
- Presentation of statistical method-analysis and
- Results in the incorrect section of the manuscript 135 (42.1%)

In the study of Glenn T. Clark and Roseann Mulligan, 15 different errors are listed as follows (6):

- Failure to carefully examine the literature for similar, prior research
- Failure to critically assess the prior literature
- Failure to specify the inclusion and exclusion criteria for your subjects
- Failure to determine and report the error of your measurement methods
- Failure to specify the exact statistical assumptions made in the analysis
- Failure to perform sample size analysis before the study begins
- Failure to implement adequate bias control measures
- Failure to write and stick to a detailed timeline
- Failure to vigorously recruit and retain subjects
- Failure to have a detailed, written, and vetted protocol
- Failure to examine for normality of the data

- Failure to report missing data, dropped subjects, and use of an intention to treat analysis
- Failure to perform and report power calculations
- Failure to point out the weaknesses of your own study
- Failure to understand and use correct scientific language

According to Good PI and Hardin JW, the sources of error in applying statistical procedures are as follows (7);

- Using the same set of data both to formulate hypotheses and to test them.
- Taking samples from the wrong population or failing to specify the population(s) about which inferences are to be made in advance.
- Failing to draw random, representative samples.
- Measuring the wrong variables or failing to measure what you'd hoped to measure.
- Using inappropriate or inefficient statistical methods.
- Failing to validate models.

The same authors offered a partial prescription for the error-free application of statistics as follows;

- Set forth your objectives and the use you plan to make of your research before you conduct a laboratory experiment, a clinical trial, or a survey and before you analyze an existing set of data.
- Define the population to which you will apply the results of your analysis.
- List all possible sources of variation. Control them or measure them to avoid their being confounded with relationships among those items that are of primary interest.
- Formulate your hypothesis and all of the associated alternatives. List possible experimental findings along with the conclusions you would draw and the actions you would take if this or another result should prove to be the case. Do all of these things before you complete a single data collection form and before you turn on your computer.
- Describe in detail how you intend to draw a representative sample from the population.
- Use estimators that are impartial, consistent, efficient, and robust and that involve minimum loss. To improve results, focus on sufficient statistics, pivotal statistics, and admissible statistics, and use interval estimates.

- Know the assumptions that underlie the tests you use. Use those tests that require the minimum of assumptions and are most powerful against the alternatives of interest.
- Incorporate in your reports the complete details of how the sample was drawn and describe the population from which it was drawn. If data are missing or the sampling plan was not followed, explain why and list all differences between data that were present in the sample and data that were missing or excluded.

Strasak AM et al. reported significant statistical inaccuracies in their publication as follows (8);

- No a priori sample size calculation/effect-size estimation (power calculation)
- No clear a priori statement or description of the Null-Hypothesis under investigation
- Method of randomization not clearly stated
- Use of an inappropriate control group
- Use of wrong statistical tests
- Unpaired tests for paired data or vice versa
- Inappropriate use of parametric methods
- Use of an inappropriate test for the hypothesis under investigation
- Inappropriate post-hoc Subgroup analysis
- Typical errors with Student's t-test
- Failure to prove test assumptions
- Unequal sample sizes for paired t-test
- No Yates-continuity correction reported if small numbers
- Use of chi-square when expected numbers in a cell are <5
- Failure to use multivariate techniques to adjust for confounding factors
- Wrong names for statistical tests
- Giving SE instead of SD to describe data
- Use of mean (SD) to describe non-normal data
- "p = NS", "p <0.05" or other arbitrary thresholds instead of reporting exact p-values

Medical journal editors should seriously examine whether incoming manuscripts comply with statistical rules. In this context, all articles should be carefully examined by a

Biostatistician before publication (9,10). Evaluating the models' assumptions and the effects resulting from their violation is crucial to reaching scientifically valid conclusions. Reviewers and editors of all academic journals should specifically request a detailed explanation of how these issues are managed in a manuscript. When we use a statistical test, we should give sufficient thought to whether it is appropriate to help us answer our research question. In fact, even if all assumptions (both primary and latent) are confirmed, statistics alone cannot provide solid evidence for or against its use for a particular scientific purpose (11).

Statistical Thinking

The foundations of statistical thinking come primarily from methods related to the discipline of statistics. Additionally, it also comes from the study fields of medical informatics and computer science.

Evidence-based Statistical thinking allows us to identify problems accurately. As a matter of fact, all statistical methods are evidence-based. Especially when human intuition often uses statistical thinking, it achieves more accurate results.

Statistical thinking gives us important tools to accurately understand events and determine whether human intuition is right or wrong.

Variation is at the core of statistics. It takes variation into account in all analyses. Unfortunately, there is no variation in mathematics. For example, if the student's passing grade is determined as 60 points, according to mathematics, the score of 59.5 is completed to 60 points and the student is considered successful. However, those who score 59.4 are considered unsuccessful. This situation is evaluated according to variation in the branch of statistics. Standard deviation, or variation, is nature's indispensable unit of measurement.

Statistical thinking teaches the correlation between events. It states that an event is affected by many variables, not just one. Statistical distributions allow us to predict the distribution of events.

The design of the research that needs to be done in the first step is of great importance in terms of interpreting the results. a) every design should be carefully designed to avoid observation and measurement errors, and b) it should be remembered that all designs are subject to limitations and uncertainties.

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It should not be forgotten that there is an important relationship between the hypothesis test to be performed and type I and type II errors. It is necessary to be careful about test assumptions. We need to be careful that confounding variables are controlled. It should not be forgotten that confounding variables that are not controlled will bias the results.

Clinical and basic medical research includes the most important factors that help doctors, patients, and health managers solve health-related problems. The solution to incorrect statistical reporting will be prevented by researchers better learning the methods and terminology of Biostatistics science. Unfortunately, even though the importance of statistical tests is emphasized, statistical errors continue to appear in serious scientific journal articles.

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