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Editorial

Recent advances in statistics

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Almost all clinical researchers have had at least one experience of receiving a request for statistical correction after submitting a manuscript to a scientific journal. Some of these requests may have been about matters that were not previously considered problematic, such as the application of unfamiliar statistical techniques, consideration of study details, or presentation of newer, better alternatives beyond *P* values. Many researchers may be embarrassed by these unexpected requests. Statistical science is changing rapidly with advances in computer technology and statistical software. In many cases, statistical methods accepted 20 years ago are now considered outdated or unacceptable.

One good example is the tendency to implement the concept of a random-effect model or a mixed model for correlated data as a treatment of violations of independence more strictly than before. If we place 2 implants in a person's oral cavity and observe the change of marginal bone after 4 years, the resulting differences in bone change would be correlated because the 2 implants would have shared the same environment in the oral cavity. Similarly, when we use a randomized block design, where 4 different types of implants are inserted into a bovine scapular bone, we obtain correlated data. Such data with multiple outcome values from the same patient were typically modeled as fixed effects until statistical software became available in the early 1990s; however, we are now able to model them more correctly as random effects by using various statistical software platforms. The application of random-effect models in accordance with the study design is strongly encouraged by most high-impact journals.

In addition to independence, basic assumptions of classical statistical models include normality and equal variance. The previous approach to handling violations of these assumptions was to transform dependent variables to apply analysis of variance (ANOVA) or regression models. In the last decade, generalized linear mixed models have become available in statistical software, enabling more accurate modeling of data with such violations. Therefore, it has become easier to apply statistical methods correctly and strictly in accordance with the basic principles of statistics.

We previously interpreted quantitative studies based mainly on *P* values from significance testing, such as the standard threshold of a *P* value <0.05 indicating statistical significance. Significance testing relies on test statistics of the sample size, such as $t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}}$. Consequently, any effect, no matter how tiny, can produce a small *P* value if the sample size is large enough, and vice versa. Determining the appropriate sample size prior to any experiments is critical in

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this regard. In recent years, to address prevalent misuses of and misconceptions concerning *P* values, statisticians have suggested supplementing or even replacing *P* values with other approaches [1]. Supplementarily providing various measures of the clinical or practical effect size, such as Cohen's d, the odds ratio, or correlation coefficients, is a good remedy [2].

Furthermore, statistical reviewers tend to request more comprehensive descriptions of the design of the study, the appropriateness of the chosen analysis methods, correct interpretations, and detailed descriptive statistics than before. Researchers need to describe their sampling process in more detail than ever, including the number of units (i.e., the size of samples), the number of replications in a design, and the nature of randomization (if applicable). Transparent accounts of statistical analyses and the provision of tables of results and interpretations that match the experimental design are also critically important. Some clinical researchers have argued that 1-way ANOVA could be applied instead of 2-way ANOVA for data from studies with a 2-factorial design because previous studies did so. Furthermore, they frequently misused *post hoc* comparison methods (e.g., least significant differences) which do not compensate for an elevated overall experiment-wise type I error rate. These errors are expected to be corrected quickly by reflecting rapid changes in statistics in the review process.

Modern research is inherently multidisciplinary, and the relevant disciplines are rapidly developing simultaneously. Although it is unrealistic for clinical researchers to be fully familiar with all advances in statistics, clinical researchers need to improve the accuracy of their use of statistical science concomitantly with the evolution of statistics as a field. In addition to studying the statistical input process as a regular subject, it is desirable for clinical researchers to engage in continuing education and collaborate with statisticians.

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