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EDITORIAL

Inappropriate Statistical Analysis and Reporting in Medical Research: Perverse Incentives and Institutional Solutions

Wang and colleagues (1) present a sobering report of a national survey of nearly 400 consulting statisticians about requests from investigators to engage in inappropriate statistical practices. Framed as an exploration of bioethical issues, the report implicitly adopts Doug Altman's mantra: "Misuse of statistics is unethical" (2). Although the survey did not ask statisticians whether they fulfilled these requests, the inappropriate methods described in this report are still used in the published literature, and thus contribute to the problem of nonreproducible research.

Practices like these are extraordinarily difficult to detect in published work; identification takes either unusual transparency or a time-consuming re-examination of the original research methods and data. We cannot determine whether these requests arise largely from researchers' inexperience or their response to academic and professional incentives that reward impressive-looking results in higher-profile publications.

Educational and structural changes in biostatistics cannot counteract these incentives completely, but they can reduce the role of inexperience. In responses to *Nature*'s online survey of 1576 researchers about ways to "boost research reproducibility," the top choice was "better understanding of statistics," followed by "better mentoring/supervision," "more robust designs," and "better teaching" (3). Attaining these goals requires an altered structure for biostatistics education and collaboration.

Introductory courses and textbooks in biostatistics for clinician-investigators often focus on formulae and software. However, even more powerful, informal curricula of discipline-specific statistical practices are available (not all correct), gleaned from published literature, journal clubs, research presentations, and grant proposals. Collectively, these sources can foster an unfortunate illusion that reading published analyses imparts the technical skills and experience to analyze real-world, messy data and may lead some investigators to design studies and undertake analyses without expert help. Preferable would be formal and informal education, in both statistical and team science, on how to work with methodology experts to frame research questions, design studies that can answer those questions, and collect data and conduct and interpret analyses properly. Principles of reproducible research should permeate all phases of education and research.

In practice, the potential value and role of a consulting statistician often are poorly appreciated, and statisticians enter the picture after the study is designed, the data are gathered, and the analysis is under way—or worse, when complications arise during sponsor or journal review. At any of these points, statistician–investigator interactions may be rushed and possibly contentious, with the investigator wanting a late-stage fix and the statistician recognizing problems or even fatal flaws in the data, analysis, or study design. This difference in perspectives may set the stage for inappropriate requests to the statistician to fix problems that earlier involvement might have prevented.

Given that statisticians' most valuable expertise lies in design, the preferred alternative starts with an investigator and statistician collaboratively crafting the research questions and a design to answer them. As Donald Rubin posited, "For objective causal inference, design trumps analysis" (4). Optimal designs not only improve statistical power and precision, they minimize bias and often simplify the analysis (5). Consulting a statistician only for the analysis or to bless the sample size (or make an inadequate sample size appear legitimate) represents too little statistical science, far too late.

Written designs and statistical analysis plans, in advance of any look at outcome data (6), may serve as a research plan to govern not only the analysis but also the entire collaboration. This framework allows the statistician to contribute expertise on data exploration, sensitivity analyses, missing data, and the proper interpretation of the reported numbers, and the clinician to supply disease-specific knowledge of measurement processes, outcomes, and clinical reality—what is known and unknown. Both contributions unite to guide a rigorous and meaningful analysis that represents the strength of evidence on a question of interest. These written plans also may help minimize the impact of power differentials, such as when a junior statistician feels pressure to accede to a clinician. The investigative team can implement the prespecified plan, avoiding the temptations of inappropriate analysis after seeing the outcomes. For randomized controlled trials, this statistical design and analysis plan can generate text for both a submission to the institutional review board and a registration with ClinicalTrials.gov.

Support for this research paradigm must begin with research institutions, because as employers and funding recipients, they ultimately are responsible for "detrimental research practices" (7). A frequent complaint, as well as a problem, for clinical investigators is that statisticians often are not available, which sometimes is a direct result of institutional policies that keep their supply lower than demonstrated demand.

Sponsors of biomedical research can support the paradigm of collaborative research and team science. The report from the Methodology Committee of the Patient-Centered Outcomes Research Institute contains guidelines, checklists, extensive documentation, and ample references, essentially mandating design-focused, collaborative arrangements (8). The National Institutes of Health and U.S. Food and Drug Administration published

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an annotated template that seeks to accomplish the same function (9). For an institution to be designated a comprehensive cancer center, the National Cancer Institute requires it to have a fully staffed quantitative division with capacity that aligns with institutional research needs.

Changing the criteria for professional advancement at research institutions, including moving away from counts of published papers and impact factors, also might align incentives with appropriate statistical methods and results reporting. These malincentives have attracted much attention, along with a variety of scientific–social movements for research transparency and less attention to bibliometric indices (10).

As editors, we can diminish the perceived need to exaggerate findings by welcoming submission and publication of well-designed, well-analyzed studies regardless of whether the results are statistically significant. We cannot demand that all research studies include collaborating statisticians, but we can insist on the highest standards of research design, conduct, analysis, interpretation, and transparency, along with levels of statistical and methodological expertise appropriate for the scientific question. This goal will be challenging to achieve without properly educated, configured, and functional research teams, to include investigators who we hope will be less likely to request the inappropriate practices that Katz and colleagues found in their survey.

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