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An Assessment of Fundamental Statistical Knowledge among Health Science Faculty Teaching Statistics at Accredited Institutions

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ORIGINAL RESEARCH REPORTS

An Assessment of Fundamental Statistical Knowledge Among Health Science Faculty Teaching Statistics at Accredited Institutions

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Abstract

Purpose: **The purpose of this study was to compare statistical knowledge of faculty who teach statistics (versus those who do not) in accredited health science schools (dentistry, medicine, nursing, pharmacy and public health).**

Methods: **A stratified probability sample of accredited schools was selected, and all faculty at each selected school were invited to participate in an online survey assessment of fundamental statistical topics.**

Results: **A total of 708 faculty from 102 schools participated. The overall response rate was 6.5%. Seventeen percent of faculty who reported teaching statistics had taken two or less statistics/biostatistics courses. Among the faculty who reported teaching statistics, the average score on the eight-question, multiple-choice assessment was 84.7%, with 37.2% unable to score higher than a ‘C’ grade. Among faculty not teaching statistics, the average assessment score was 62.1%, with 77.7% unable to score higher than a ‘C’ grade.**

Discussion: **Statistical knowledge is critical for researchers/scientists to function knowledgeably and ethically in the current evidence-based Information Age. These study results reveal limited statistical training of health educators and concerns regarding the knowledge of those same health educators responsible for instructing the next generation of health science professionals. Recommendations for addressing these issues are provided.**

Keywords: Health sciences, Biostatistics, Medical education, Statistics education, Statistical concepts

1. Introduction

We are living in the Information Age, experiencing exponential growth in the creation, collection, storage, use and disseminations of information. The field of statistics, generally agreed to have started developing in the 18th century, has traditionally been the umbrella that covered all things related to data collection and analysis. In recent years, entirely new fields, such as data science, have blossomed in an attempt to keep pace with the type and quantity of information that is being produced. As such, there has never been a greater need or demand for people educated in all things pertaining to data. Subsequently, proper education is imperative for those dealing with information on appropriate data-related methodology.

In the past few decades, statistics courses have evolved from theoretical abstract attended to by only the most mathematically-oriented to being ubiquitously included in curricula ranging from

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elementary school to college. In fact, the American Statistical Association holds an annual data visualization competition for students as young as kindergarten [1]. In our experience, the vast majority of college degree programs, even liberal arts programs, strongly encourage, if not require, a statistics course to graduate (from this point forward in the paper, the terms 'statistics' and 'biostatistics' will be utilized interchangeably, unless specifically stated otherwise). A wide range of graduate programs require more than one such course. With more and more data being generated and collected – the amount of data currently being collected was unimaginable just a decade or two ago – the available evidence requires improved methods to distinguish signals from the noise and a dramatically larger cohort of trained individuals to interpret it. This increased emphasis on statistics education, including study design and the handling of information in addition to data analysis, is deeply interconnected with the increased focus on evidence-based science. Arguably nowhere are statistics courses more important than in the health sciences.

Our author group has published a series of recent papers describing a study that included assessment of statistics knowledge of health science faculty in the disciplines of dentistry, nursing, medicine, pharmacy and public health. To date, the survey results collected from dentistry, nursing and pharmacy programs have been individually analyzed and published in separate manuscripts [2–4]. In addition, we recently published a multidisciplinary paper based on the same survey data that looked comparatively across all five health disciplines [5]. We sought to investigate the statistical knowledge of faculty in graduate health science programs by providing the opportunity to complete an eight question, multiple-choice assessment focused on fundamental statistical concepts. While the respondents included both those that teach statistics in their department as well as those who do not, 95.8% of the faculty across all five health science disciplines rated the importance of statistics in their role as a researcher as either somewhat or very important. Among those who responded to the survey self-identifying as teaching statistics, we had hypothesized the assessment results to be higher than for those not teaching a statistics course, as those teaching a subject would be expected to demonstrate content mastery. In our previous publications based on the collected survey data, those who identified as teaching statistics and those who identified as not teaching statistics were not analyzed separately; rather, the focus in that work was on the evaluation and comparison of the health science disciplines. The objective of this paper is to report the assessment results of the statistics-teaching faculty versus their non-statistics teaching counterparts.

2. Methods

A cross-sectional survey was developed to assess the fundamental statistical concept knowledge of health science faculty in accredited health science schools from the disciplines of dentistry, medicine, nursing, pharmacy and public health. One question on each of the following topics was included: randomization, observational studies, statistical power, confidence intervals, multiple comparisons, standard error, regression response variables, and odds ratios. The topics were chosen based on the ascertainment of the most commonly used statistical methods in the research literature [6]. Each multiple-choice knowledge item had four answer choices: one correct answer, two incorrect answers, and an opt-out option to allow participants to avoid guessing. At the authors' request, a review of the survey was undertaken by colleagues actively involved in health sciences research to establish the validity of the survey. Their feedback was incorporated into the final survey. Limited demographic information was collected to ensure respondent anonymity. Institutions in each discipline were randomly selected and all faculty at selected institutions were emailed the survey. This process was repeated until the predetermined sample size was achieved. The survey was emailed out between April and August 2017. The methodological specifications surrounding the survey design, sampling procedures and power/sample size for this project have been detailed previously [5].

Qualtrics was used to construct the online survey and all analyses were conducted utilizing the SAS Software System (SAS Institute, Cary, NC). The survey questions used in the assessment of statistics knowledge can be found in the appendix of Hayat et al. (2021), with correct answers bolded. The frequencies and percentages of survey participants in each health science discipline and overall, stratified by whether or not they taught statistics, were tabulated.

Descriptive statistics (means/standard deviations and frequencies/percentages, as appropriate) were used to report faculty characteristics for those who taught statistics and separately for those who did not. The primary outcomes were the frequency (percentage) answering each statistical knowledge question correctly, the average overall percent correct of the total number of correct responses out of the eight questions that comprised the statistics knowledge portion of the survey and the distribution of correct responses (in tabular and boxplot form), all by teaching status and, where appropriate, overall.

3. Results

A total of 10,931 faculty from 102 different accredited academic health science programs were invited to participate. Among these invitations, 708 responded. Just under 20% of respondents (n = 129) reported that they do teach statistics (Table 1). Public health programs demonstrated the highest percentage of their faculty teaching statistics (30.2%), with the other four disciplines reporting considerably lower percentages of their faculty teaching statistics courses (11.0%–16.5%).

Table 2 summarizes faculty characteristics by teaching status and overall. Most of the faculty characteristics are comparable for those teaching statistics and those not teaching statistics, with a few exceptions worth noting. Among statistics-teaching faculty, 51.9% are male, while among those that reported not teaching statistics 39.0% are male. More of the statistics-teaching faculty have research doctorates compared to those who reported not teaching statistics (74.4% vs. 49.2%, respectively), further indicating that fully one out four of those teaching statistics in health science graduate programs (25.6%) are doing so with clinical/practical doctorates, master's or 'other' degrees. Just over six percent of statistics-teaching faculty (6.2%) are doing so with only zero or one statistics courses completed. Across all faculty respondents, just under half (49.7%) had completed two or less statistics courses. The proportion of those reading peer-reviewed health-related journal articles among those teaching statistics and those not teaching statistics were similar (96.9% vs. 93.6%, respectively).

The frequency and percentage of respondents correctly answering each of the eight statistical knowledge questions on the survey by teaching status and overall can be found in Table 3. A higher percentage of those teaching statistics (as compared to those not teaching statistics) answered each of the eight questions question correctly, but the good news largely ends there. Among faculty teaching statistics in accredited health science programs, 23.2% were unable to answer a three-option multiple-choice question on power correctly (with 34.4% of those not teaching statistics unable to do so). Just less than 25% of statistics-teaching faculty were unable to answer a three-option multiple-choice question on the rationale for randomization correctly (with 53.5% of those not teaching statistics unable to do so). Just less than 28% of statistics-teaching faculty were unable to answer a three-option multiple-choice question on interpreting an odds ratio correctly (with 57.7% of those not teaching statistics unable to do so). Approximately 30% of statistics-teaching faculty were unable to answer a three-option multiple-choice question on interpreting a confidence interval correctly (with 54.7% of those not teaching statistics unable to do so). While the questions on describing an observational study, understanding the issue with multiple testing and the relationship between sample size and power yielded somewhat higher percentages, the overall percentage correct across the eight statistics knowledge questions asked was 84.7% for the statistics-teaching faculty and 62.1% for those who reported not teaching statistics. Across all respondents, health science faculty in accredited graduate programs achieved an average score of 66.2% on this assessment of fundamental statistics concepts.

Table 4 summarizes the frequency distribution of correct responses by teaching status. Approximately 37% of statistics teaching faculty failed to score better than 75% (i.e., a grade of 'C'), while nearly 80% of faculty who responded that they do not teach statistics failed to score better than this 'C' grade. Fig. 1 includes boxplots stratified by teaching status showing the outcome distribution for number of correct responses out of 8 questions.

4. Discussion

We discussed in our prior work [2–5] the low response rate generated by this survey. While only 6.5% of faculty invited to participate also responded, this is in line with other national online surveys of health professionals [7–9]. Despite this limitation and the bias that likely resulted, we believe that any such

Table 1. Frequency distribution of statistics educators by discipline.

	Dentistry	Medicine	Nursing	Pharmacy	Public Health	Total
Teaches statistics/biostatistics	12 (11.0)	17 (14.5)	27 (16.5)	19 (13.7)	54 (30.2)	129 (18.2)
Does not teach statistics/biostatistics	97 (89.0)	100 (85.5)	137 (83.5)	120 (86.3)	125 (69.8)	579 (81.8)
All participants	109	117	164	139	179	708

Table 2. Distribution of faculty characteristic by teaching status.

	Teaches statistics/ biostatistics (n = 129)	Does not teach statistics/ biostatistics (n = 579)	Total (n = 708)
Faculty Characteristic	**Mean (Standard Deviation)**		
Years of professional experience	23.0 (12.4)	22.7 (13.4)	22.8 (13.2)
Years as a faculty member[a]	17.5 (11.8)	13.1 (11.3)	13.9 (11.5)
	Frequency (%)		
Sex			
Male	67 (51.9)	226 (39.0)	293 (41.4)
Female	62 (48.1)	353 (61.0)	415 (58.6)
Highest Degree			
Clinical/Practice doctorate	25 (19.4)	230 (39.7)	255 (36.0)
Research doctorate	96 (74.4)	285 (49.2)	381 (53.8)
Master's prepared	2 (1.6)	43 (7.4)	45 (6.4)
Other	6 (4.7)	21 (3.6)	27 (3.8)
Number of statistics/biostatistics courses completed			
0	4 (3.1)	41 (7.1)	45 (6.4)
1	4 (3.1)	153 (26.4)	157 (22.2)
2	14 (10.9)	135 (23.3)	149 (21.1)
3+	107 (83.0)	250 (43.2)	357 (50.4)
Number of epidemiology courses completed			
0	53 (41.1)	291 (50.3)	344 (48.6)
1	19 (14.7)	161 (27.8)	180 (25.4)
2	24 (18.6)	52 (9.0)	76 (10.7)
3+	33 (25.6)	75 (13.0)	108 (15.3)
Rating of importance of statistics in role as a researcher			
Very important	125 (96.9)	386 (66.7)	511 (72.2)
Somewhat important	4 (3.1)	163 (28.2)	167 (23.6)
Not important	0 (0.0)	30 (5.2)	30 (4.2)
Reads peer-reviewed health-related scientific journal articles			
Yes	125 (96.9)	542 (93.6)	667 (94.2)
No	4 (3.1)	37 (6.4)	41 (5.8)
Attitude about fundamental statistical concepts			
Understands all expressions	127 (98.5)	373 (64.4)	500 (70.6)
Understands some expressions	2 (1.6)	183 (31.6)	185 (26.1)
Understands little/no expressions	0 (0.0)	23 (4.0)	23 (3.3)

[a] There are 8 missing values for years of experience as a faculty member.

bias would be favorable to generating higher scores. That is, those who took the time and made the effort to respond to a brief survey on statistical fundamentals are probably those more comfortable with the topic and therefore likely to have performed better than if the entire sample to whom the survey was sent had responded. It appears likely the actual statistical knowledge of health science faculty, both statistical educators as well as those who do not teach statistics, is worse than reported here. While this cannot be known

Table 3. Statistics knowledge assessment individual question scores by teaching status.

	Teaches statistics/ biostatistics (n = 129)	Does not teach statistics/ biostatistics (n = 579)	Total (n = 708)
	Frequency (%) Responding Correctly		
Understanding the rationale for randomization.	97 (75.2)	269 (46.5)	366 (51.7)
Describing an observational study.	121 (93.8)	463 (80.0)	584 (82.5)
Defining statistical power.	99 (76.8)	380 (65.6)	479 (67.7)
Interpreting a confidence interval.	90 (69.8)	262 (45.3)	352 (49.7)
Understanding the issue with multiple testing.	127 (98.5)	446 (77.0)	573 (80.9)
Relationship between sample size and standard error.	125 (96.9)	453 (78.2)	578 (81.6)
Understanding the difference between linear and logistic regression.	122 (94.6)	358 (61.8)	480 (67.8)
Interpreting an odds ratio.	93 (72.1)	245 (42.3)	338 (47.7)
Overall percentage correct	84.7	62.1	66.2

Table 4. Frequency distribution of correct responses by teaching status.

Number (%) correct out of 8 questions	Teaches statistics/biostatistics		Does not teach statistics/biostatistics	
	Count (%)	Cumulative Count (%)	Count (%)	Cumulative Count (%)
0 (0.0%)	0 (0)	0 (0)	11 (1.9)	11 (1.9)
1 (12.5%)	0 (0)	0 (0)	19 (3.3)	30 (5.2)
2 (25.0%)	2 (1.6)	2 (1.6)	28 (4.8)	58 (10.0)
3 (37.5%)	1 (0.8)	3 (2.4)	63 (10.9)	121 (20.9)
4 (50.0%)	3 (2.3)	6 (4.7)	97 (16.8)	218 (37.7)
5 (62.5%)	12 (9.3)	18 (14.0)	111 (19.2)	329 (56.8)
6 (75.0%)	30 (23.2)	48 (37.3)	121 (20.9)	450 (77.7)
7 (87.5%)	33 (25.6)	81 (62.9)	89 (15.4)	539 (93.1)
8 (100.0%)	48 (37.2)	129 (100.0)	40 (6.9)	579 (100.0)

in practice for certain from the results of this study, it is worth pointing out that the *a priori* specified target sample size of respondents was met.

As expected, the statistical educators performed better overall, on average, than those that reported they did not teach statistics (84.7% vs 62.1% respectively) as well as on each individual question, but we note the percentage responding correctly in many instances was well below what would be expected from those assumed to be subject area experts. Here in particular, the scores from the questions on the rationale for randomization, power, interpreting a confidence interval and interpreting an odds ratio are low. These topics are some of the most commonly utilized and reported in the literature, but less than three out of four health science faculty teaching statistics were able to answer a three option multiple choice question on each topic correctly [6]. Fewer than 50% of non-statistics teaching health science faculty were able to answer the questions on these topics correctly. Below, we attempt to identify some root causes of, as well as provide suggestions to ameliorate, the problem.

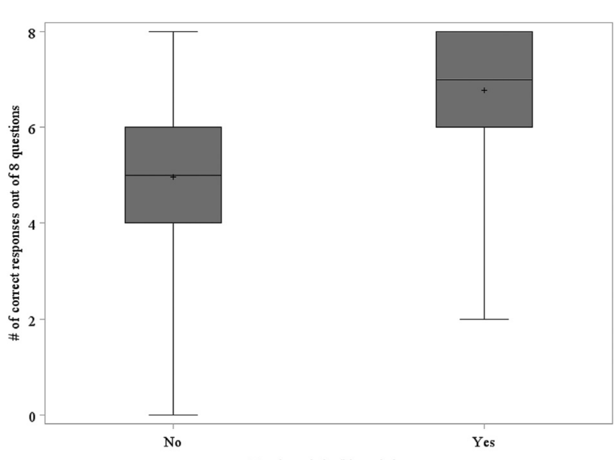

Fig. 1. Distribution of number of correct responses by teaching status.

The data reported in this paper were from a survey that was sent out to faculty at accredited health science programs in dentistry, medicine, nursing, pharmacy and public health. Standards and guidelines for all such programs are established and updated by the associated accrediting bodies. In the most recent guideline/competency updates for these health science programs (dentistry published by the American Dental Education Association in 2011, medicine published by the Liaison Committee on Medical Education in 2021, nursing published by the American Association of Colleges of Nursing in 2021, pharmacy published by the Accreditation Council for Pharmacy Education in 2015, and public health published by the Council on Education for Public Health in 2016) [10–14] an increased curricular focus on research and evidence-based science is apparent as increasing amounts of research continue to be conducted in each field.

Statistical knowledge is a crucial component of not only analyzing any data collected, but designing and sizing the studies to ensure valid, representative results. However, statistical competencies in the latest guideline revisions do not appear to be commensurate with the increased focus on research across these programs. As we noted previously, "… there are no known biostatistics-specific competency guidelines in dentistry, nursing, pharmacy or medicine" [5]. To emphasize this point, the mere appearance of the term 'statistics' (or 'biostatistics') in these disciplines' guidelines is essentially non-existent: in the dentistry guidelines, the 23 page document for general dentistry/dental hygiene mentions statistics once, while the 31 page medicine guidelines contains zero mentions, the 88 page nursing guidelines offers zero mentions and the 39 page pharmacy document includes just a single reference to statistical testing.

Public health, the best performing discipline in our survey, as outlined in the multidisciplinary paper [5], has placed the most emphasis on statistics in their curricula guidelines. The guidance provided by the Association of Schools and Programs of Public Health (briefly) specifies statistical analysis and programming skills recommended for graduate programs as part of public heath's evidence-based approach (Association of Schools of Public Health Education Committee, 2006) [15]. This (relative) emphasis on statistical knowledge is likely due in part to many such schools offering concentrations/degrees in biostatistics and epidemiology. Further, while causality cannot be claimed based on the results of our survey, we believe the statistical specifications in the public health guidelines may explain a large portion of the performance by the public health faculty respondents. We also believe that more detailed and specific (bio)statistical competencies need to be laid out in the standards and guideline documents for each discipline. The benefits of the increased research focus that has occurred in the most recent versions of each guideline document will only come to fruition if a commensurate focus on (bio)statistics appears. Creating guidelines which imply we need future instructors and scientists better educated in research methods without providing formal recommendations for the associated statistical knowledge would not appear to be a strategy that would, going forward, ameliorate the issues identified in this study.

Statistics plays a central role in the Information Age in which we live: a critical skill-set for health science degree programs. One approach to incentivizing these programs to implement such changes would be for competency/licensing exams to include a section on statistics and research methodology-based questions.

More frequently, complex statistical methods are implemented in the health science literature. However, health science students may not receive formal training in methods beyond, for example, basic regression, odds ratios and introductory survival analysis. While such topics provide a solid underpinning of commonly used statistical methods, they are insufficient for the increasingly sophisticated studies being conducted and the methodology required to analyze the information collected therein. We recommend that careful consideration be given to not only how much, but also what, statistical methodology should be included in graduate health science programs with the next iteration of each discipline's curricular guidelines.

Finally, graduate programs that require statistics courses have received relatively little research focus or funding. We recommend that a better understanding of the needs of and challenges faced by health science programs is needed to be able to adequately educate future generations of health science researchers to enable them to stay current as the Information Age continues to progress.

Ethical approval

This study was reviewed and classified as exempt by the Georgia State University (#H17341) and University of North Carolina at Chapel Hill (# 17–0230) Institutional Review Boards.

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Other disclosure

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Conflict of interest

The authors declare no conflict of interest in the development or submission of this work.

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