Understanding the Barriers to Hiring and Promoting Women in Surgical Subspecialties

Nakul Valsangkar, MD, Alison M Fecher, MD, FACS, Grace S Rozycki, MD, MBA, FACS, Cassie Blanton, BS, Teresa M Bell, PhD, Julie Freischlag, MD, FACS, Nita Ahuja, MD, FACS, Teresa A Zimmers, PhD, Leonidas G Koniaris, MD, MBA, FACS

BACKGROUND: The objective of this study was to characterize potential disparities in academic output, NIH-funding, and academic rank between male and female surgical faculty and identify subspecialties in which these differences may be more pronounced.

STUDY DESIGN: Eighty metrics for 4,015 faculty members at the top-55 NIH-funded departments of surgery were collected. Demographic characteristics, NIH funding details, and scholarly output were analyzed. A new metric, academic velocity (V), reflecting recent citations is defined.

RESULTS: Overall, 21.5% of surgical faculty are women. The percentage of female faculty is highest in science/research (41%) and surgical oncology (34%), and lowest in cardiothoracic surgery (9%). Female faculty are less likely to be full professors (22.7% vs 41.2%) and division chiefs (6.2% vs 13.6%). The fraction of women who are full professors is lowest in cardiothoracic surgery. Overall median numbers of publications/citations are lower for female faculty compared with male surgical faculty (21 of 364 vs 43 of 723, $p < 0.001$), and these differences are more pronounced for assistant professors. Current/previous NIH funding (21.3% vs 24%, p = NS) rates are similar between women and men, and surgical departments with more female full professors have higher NIH funding ranking ($R^2 = 0.14$, $p < 0.05$). In certain subspecialties, female associate and full professors outperform male counterparts. Overall, female authors have higher numbers of more recent citations.

CONCLUSIONS: Subspecialty involvement and academic performance differences by sex vary greatly by subspecialty type and are most pronounced at the assistant professor level. Identification of potential barriers for entry of women into certain subspecialties, causes for the observed lower number of publications/citations among female assistant professors, and obstacles for attaining leadership roles need to be determined. We propose a new metric for assessment of publications/citations that can offset the effects of seniority differences between male and female faculty members. (J Am Coll Surg 2016;223:387−398. © 2016 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Women currently constitute almost one-half of medical school graduates; however, they account for only 17% of full professors and 12% of department heads and deans.[1]

Drs Valsangkar and Fecher contributed equally to this manuscript.

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From the Departments of Surgery, Indiana University School of Medicine, Indianapolis, IN (Valsangkar, Fecher, Rozycki, Blanton, Bell, Zimmers, Koniaris); University of California Davis School of Medicine, Sacramento, CA (Freischlag); and Johns Hopkins University School of Medicine, Baltimore, MD (Ahuja).

Correspondence address: Leonidas G Koniaris, MD, MBA, FACS, Department of Surgery, Indiana University School of Medicine, 550 N University Blvd, UH 1295, Indianapolis, IN 46202. email: Lkoniari@iu.edu

This problem is more pronounced in the surgical fields, where there is a lack of academic female faculty[2] and where, even among full-time academic faculty members, there are differences in the proportions of women promoted to senior academic levels and leadership positions.[3]

Metrics of publications and citations are routinely used to evaluate academic faculty and make decisions regarding tenure and promotion.[4-7] Although publications authored by women have increased many-fold over the past several decades, there are considerable differences in scholarly output across different medical specialties.[8] These differences in publications and citations also extend to extramural research funding by agencies such as the National Institutes of Health (NIH) in that women in certain specialties are less likely to have had current or previous NIH

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funding.[9-11] Given that grants awarded by the NIH positively affect scholarly output,[11-15] this negative cycle of lower output and funding among female faculty members may deeply undermine both sex parity and the academic missions of departments of surgery.

The extent of this deficiency in scholarly output by female surgical faculty so far remains poorly understood. This study sought to quantify the differences in numbers of publications/citations and the impact on men and women surgical faculty members, and to identify surgical subspecialties in which these differences may be more conspicuous. This article also proposes a potentially more objective metric to nullify any sex-based differences that may exist in promotion criteria by scholarly output to support the academic success and growth of female surgical faculty.

METHODS

Surgical faculty demographics and scholarly output

The Blue Ridge Institute for Medical Research (http://www.brimr.org/) was used to identify the top 50 university-based and 5 hospital-based departments of surgery based on NIH funding, as previously described.[16] From each of these institutions, 4,015 surgical faculty were identified and entered into a faculty database. Using multiple data sources, 80 academic parameters for all 4,015 faculty members were collected. Departmental websites were used to collect demographic data, including the individual faculty member's sex, academic rank, division, any leadership title, career track, and degrees. Next, the faculty member's number of publications/citations was determined from the Scopus online database (http://www.scopus.com/), including total publications, total citations, 3-year citations, and h-index. An overview of the academic metrics of surgical faculty in different surgical subspecialties has previously been published by this group,[16] and a copy of the dataset can be found in the supplementary digital content with this article (Appendix A, online only).

For each of the 50 university-based departments of surgery, the NIH funding rank was identified and the institutions were grouped into quintiles. The resultant rank groups created were rank 1 to 10, 11 to 20, 21 to 30, 31 to 40, and 41 to 50. Subset analyses were performed within each of these NIH funding deciles, as indicated in the following sections.

NIH funding

Details regarding current or former NIH funding at the level of the principal investigator were collected from 2 independent sources: the NIH Research Portfolio Online Reporting Tools (RePORT) database and the Grantome online database (http://www.grantome.com/). All current or previous NIH grants, including the funding amount, years funded, and type of NIH award were collected. The NIH awards were categorized into 3 broad categories: NIH P01/R01/U01 awards; nonmajor NIH funding (eg F32, K08, R00, R21, R43); and no history of current/former NIH funding. In all cases, the funding data were corroborated between both sources of collection.

Data quality and statistical analyses

After the database was generated, a check was performed to identify faculty members with missing data resulting from common names, alternate name spellings, and lack of available data on websites. A re-check of all data sources was performed for these faculty members with missing data ($n = 408$), and data were updated as available. Furthermore, in order to correct inadvertent data collection errors due to the large volume, a random data quality assurance was performed for 30% of the data, and all errors were corrected. Small updates in funding were not counted as errors, and an error rate of <1% was found in individual faculty data collection.

Demographic details, including academic levels and leadership positions, were compared between sexes using chi-square tests and *t*-tests. Multiple group comparisons were performed using ANOVA. Multivariate logistic regressions were used to predict faculty publications, citations, and NIH funding. Alpha was set at 0.05. All data warehousing and analyses were performed using SPSS version 16 (IBM). This study was exempt from review by the institutional review board (IRB) of Indiana University School of Medicine.

Final results were reported as median publications ± standard deviation (P) and median citations ± standard deviation (C). These were compared in order to account for variations in mean values introduced by extremes in data points, and the non-normal distribution of these data points.

In order to take into account the academic impact and the relative recentness of the publications authored by women, we defined a new measure for individual faculty members, the "academic velocity," or V, which represents the median number of 3-year citations per total publications. This factor is calculated as below.

$$V = ([\text{publications}/\text{total citations}] \times [3 - \text{year citations}/\text{total citations}])$$

The advantage of using this calculation is that it allows us to quickly do a "bedside" calculation of the impact of an individual faculty member's body of work and to derive the recentness of this work.

RESULTS

Sex-based differences in publication/citation numbers, academic rank, leadership positions, and NIH funding

Overall, 4,015 surgical faculty members from 55 departments of surgery were included in this study (Table 1). Male surgical faculty comprised 76.9% (3,087) of the surgical faculty; 23.1% (928) were female surgical faculty. The scholarly output for male surgical faculty was higher than that for female surgical faculty concerning both total publications (43 ± 97.5 vs 19 ± 58, $p < 0.05$) and total citations (723 ± 3,322 vs 317 ± 1,774, $p < 0.05$).

Sex-based differences in academic rank

Female surgical faculty members were far more likely to be represented at lower academic levels. Overall, 49.7% of the female surgical faculty were at the assistant professor level as compared with 31.8% of the male faculty. An equal proportion of male and female surgical faculty were at the associate professor level (27%); however, only 22.7% of female surgical faculty were at full professor level, as compared with 41.2% of male surgical faculty. At higher academic ranks, the publications and citations for women were similar to those for their equivalently ranked male counterparts. Numbers of publications and citations among assistant professors were 17 ± 46 and 213 ± 1,144 for male faculty, respectively, and 12 ± 27 and 161 ± 661 for female faculty, respectively ($p < 0.001$). Similar values among associate professors were 44 ± 44 and 675 ± 1,824, respectively, for male faculty and 38 ± 33 and 638 ± 1,356 for female faculty (not significant), respectively. For full professors, however, only a small difference in number of publications, but no difference in citations, were observed (Table 1).

Sex-based differences in leadership positions and academic degrees

Female surgical faculty were half as likely as male surgical faculty to be in divisional leadership positions (division chiefs or department heads), at 6.2% vs 13.6%,

Table 1. Demographics and Scholarly Metrics of Male and Female Surgical Faculty

		Male (n = 3,087)			Female (n = 928)			
Parameter	n	% of dataset	Total publications, median ± SD*	Total citations, median± SD†	% of dataset	Total publications, median ± SD‡	Total citations, median ± SD§	p Value*
Overall	4,015	76.9	43 ± 97	723 ± 3,322	21.5	19 ± 58	317 ± 1,774	<0.001
Academic rank								
Assistant professor	1,151	31.8	17 ± 46	213 ± 1,144	49.7	12 ± 27	161 ± 661	<0.001
Associate professor	877	27	40 ± 44	675 ± 1,824	27.6	38 ± 33	638 ± 1,356	NS
Professor	1,212	41.2	99 ± 126	2,290 ± 4,384	22.7	85 ± 114	2,278 ± 4,064	<0.05
Division chief								
Division chief/director	437	13.6	84 ± 138	1,870 ± 3,838	6.2	38 ± 156	976 ± 4,806	<0.001
No title	3,193	86.4	38 ± 97	672 ± 3,244	93.8	21 ± 54	368 ± 1,957	<0.001
Academic credentials								
MD	3,262	89	40 ± 94	404 ± 654	84.4	19 ± 63	294 ± 1,913	<0.001
MD, PhD	224	4.9	74 ± 123	1,416 ± 3,916	11.3	34 ± 61	960 ± 1,995	<0.001
PhD	178	6.1	53 ± 89	1,570 ± 2,675	4.4	37 ± 130	988 ± 4,814	<0.001
Current/former NIH funding								
NIH R01/U01/P01 grants	333	9.9	111 ± 173	3,227 ± 5,372	7.1	79 ±111	2,349 ± 3,531	<0.05
Non−R01 grants	496	13.8	63 ± 110	1,392 ± 3,826	14.2	33 ± 92	802 ± 3,486	NS
No NIH funding	2,733	76	32 ± 69	472 ± 2,360	79	16 ± 47	266 ± 1,467	NS
10 most cited faculty	530	13.8	177 ± 168	5,038 ± 5,908	6.9	112 ± 148	4,244 ± 5,129	<0.001

Values of p were calculated between relevant male and female comparisons (* vs ‡ and † vs §).
NS, not significant.

Table 2. Scholarly Metrics of Male and Female Surgical Faculty by Academic Divisions

		Male (n = 3,087)			Female (n = 928)			Disparity measures		
Parameter	**n**	**% of dataset**	**Total publications, median ± SD***	**Total citations, median ± SD[†]**	**% of dataset**	**Total publications, median ± SD[‡]**	**Total citations, median ± SD[§]**	**Publications[‖]**	**Citations[‖]**	**p Value**
Surgeons, n, %	4,015	76.9			21.5					
Scholarly output	4,015		43 ± 97[¶]	723 ± 3,322[#]		19 ± 58[**]	317 ± 1,774[††]	77.41	78.07	<0.001
Division										
Cardiothoracic surgery	408	91	55 ± 91	981 ± 9,217	9	27 ± 36	401 ± 1,260	68.29	83.94	<0.001
Cardiac surgery	148	90	59 ± 97	1,003 ± 3,700	10	9 ± 39	389 ± 1,177	88.22	147.06	<0.001
Thoracic surgery	260	92	51 ± 88	981 ± 2,985	8	29 ± 35	763 ± 1,311	25.00	55.00	<0.001
General surgery	1538	74	39 ± 89	708 ± 3,444	26	21 ± 55	353 ± 2,032	60.00	66.92	<0.001
Acute care surgery	76	76	24 ± 54	457 ± 1,436	24	7 ± 40	96 ± 1,376	125.85	109.68	<0.05[‡‡]
General and minimally invasive	828	76	36 ± 90	685 ± 3,268	24	24 ± 57	416 ± 2,089	44.64	40.00	<0.001
Surgical oncology	371	66	52 ± 96	1,246 ± 4,370	34	24 ± 59	357 ± 2,142	111.69	73.68	<0.001
Trauma/critical care	263	77	31 ± 101	412 ± 2,993	23	14 ± 43	205 ± 1,322	67.10	75.56	<0.05
Pediatric surgery	311	81	37 ± 72	629 ± 2,075	19	18 ± 86	307 ± 2,741	69.09	68.80	NS[§§]
Plastic surgery	317	78	30 ± 56	261 ± 1,247	22	11 ± 87	216 ± 1,751	92.68	18.87	NS
Science/research	96	59	75 ± 72	1,856 ± 2,441	41	53 ± 43	960 ± 1,336	34.38	63.64	<0.05
Transplant	303	82	59 ± 167	1378 ± 4,300	18	36 ± 125	629 ± 4,419	48.42	74.64	NS
Vascular surgery	222	83	43 ± 71	743 ± 2,183	17	14 ± 59	374 ± 1,420	101.75	66.07	<0.05

Values of p were calculated between relevant male and female comparisons (* vs [‡] and [†] vs [§]).
NS, not significant ($p > 0.05$).
[‖]Columns expressed as percent difference.
[¶]Range 1 to 1,938.
[#]Range 1 to 55,118.
[**]Range 1 to 488.
[††]Range 1 to 19,113.
[‡‡]$p < 0.05$ for publications only. No difference was noted for citations in acute care surgery division.
[§§]$p > 0.05$.

Table 3. Comparison of Scholarly Output by Specialty, Rank, and Sex

Specialty/category	Assistant professor	Associate professor	Professor
Science/research (n = 96)			
% within sex			
Male	30.4	42.9	26.8
Female	26.4	33.3	30.3
Publications			
Male	23 ± 39	81 ± 50	113 ± 86
Female	23 ± 14	66 ± 23	87 ± 50
Citations			
Male	547 ± 1,573	1,980 ± 2,979	3,192 ± 1,727
Female	511 ± 335	1,747 ± 902	2,454 ± 1,559
Cardiac surgery (n = 148)			
% within sex			
Male	29.1	28.2	42.7
Female	60	40	
Publications			
Male	28 ± 57	54 ± 46	
Female	5	60 ± 72	
Citations			
Male	468 ± 1,587	892 ± 4,804	
Female	389	1,781 ± 2,184	
Thoracic surgery (n = 260)			
% within sex			
Male	28.6	23.8	47.6
Female	38.9	38.9	22.2
Publications			
Male	18 ± 22	63 ± 76	103 ± 103
Female	13 ± 14	44 ± 40	82 ± 30
Citations			
Male	244 ± 479	1,201 ± 3,024	1,833 ± 3,514
Female	255 ± 412	1,026 ± 2,017	1,177 ± 454
Vascular surgery (n = 222)			
% within sex			
Male	35.2	19.8	45.1
Female	53.8	23.1	23.1
Publications			
Male	16 ± 77	42 ± 21	92 ± 63
Female	12 ± 16	20 ± 16	127 ± 93
Citations			
Male	163 ± 682	462 ± 754	2,561 ± 2,616
Female	183 ± 387	442 ± 296	3,988 ± 1,764
Surgical oncology (n = 371)			
% within sex			
Male	30	22.7	47.3
Female	46	38	16
Publications*			
Male	20 ± 28	50 ± 52	117 ± 111

(Continued)

Table 3. Continued

Specialty/category	Assistant professor	Associate professor	Professor
Female	12 ± 15	43 ± 37	115 ± 116
Citations*			
Male	362 ± 834	974 ± 2,180	4,152 ± 5,336
Female	168 ± 403	901 ± 1,586	2,436 ± 4,573
General surgery (n = 1,238)			
% within sex			
Male	35.3	28.3	36.5
Female	51.3	30.1	18.6
Publications			
Male	13 ± 28	37 ± 38	98 ± 107
Female	12 ± 21	36 ± 32	91 ± 91
Citations			
Male	166 ± 691	634 ± 1,241	2,451 ± 4,563
Female	139 ± 829	559 ± 1,278	2,411 ± 3,551

Publications and citations numbers are expressed as median ± SD.
*Differences are statistically and numerically significant.

$p < 0.05$. Furthermore, the scholarly output for women in these leadership positions (P: 38 ± 156, C: 976 ± 4,806) was also lower than that of the male surgical faculty (P: 84 ± 138, C: 1,870 ± 3,838), $p < 0.05$.

In this dataset, female surgical faculty were twice as likely to have MD/PhDs (11.3%) compared with male faculty (4.9%). Women surgical faculty had fewer publications and citations within each academic degree group (MD, MD/PhD, PhD), Table 1.

Differences in NIH funding

Although, there was no difference in the history of NIH funding, either current or historical, between sexes, subset analysis revealed a higher percentage of large NIH grant (R01/P01/U01)-funded male faculty (9.9%) compared with that of their female colleagues (7.1%), $p < 0.001$. Furthermore, among all faculty funded with NIH R01/P01/U01 grants, male surgical faculty had higher numbers of publications and citations. Among female surgical faculty, 6.9% were likely to be included in the list of 10 most-cited faculty for any department compared with 13.8% of the male faculty members, $p < 0.001$ (Table 1).

Sex-specific differences in academic output vary considerably across surgical subspecialties

Different surgical subspecialties had varying sex representation and sex-based differences in scholarly output (Table 2). For example, within the specialty of acute care surgery, women constitute 24% of the surgical faculty, and the largest difference in publications/citations (P/C) between sexes was faculty in acute care surgery (24/457 for males vs 7/109 for females). The subspecialty of cardiothoracic surgery had the lowest representation of women. Within cardiothoracic surgery, women comprised 10% of cardiothoracic surgeons and 8% of thoracic surgeons. The median P/C for cardiothoracic surgical faculty men was 55/981 compared with 27/401 for women, $p < 0.001$.

On the other hand, the 3 divisions with the best representation of women included the divisions of science/research (41%), surgical oncology (34%), and general surgery as an aggregate (26%). Among these divisions, sex-based disparities for publications were lowest in the science/research divisions. Women in this specialty also had the most publications and citations among all subspecialties, with median P/C of 53 ± 43/960 ± 1,336 (Table 2).

Surgical specialties and individual departments of surgery have varying fractions of female full professors

Among science/research divisions, 36.8% of the male surgical faculty were associate professors and 26.3% were full professors; 28.2% of female faculty were associate professors and 25.6% were full professors. Furthermore, at all academic ranks in science/research divisions, the numbers of publications and citations among female surgical faculty were lower than among male faculty. This difference was more pronounced at senior academic ranks.

The specialty of cardiothoracic surgery had the lowest fraction of female full professors. Among faculty identified as pure cardiothoracic surgeons, to the best of our knowledge, there was 1 female full professor, and among thoracic surgeons, 22% of the female faculty were full

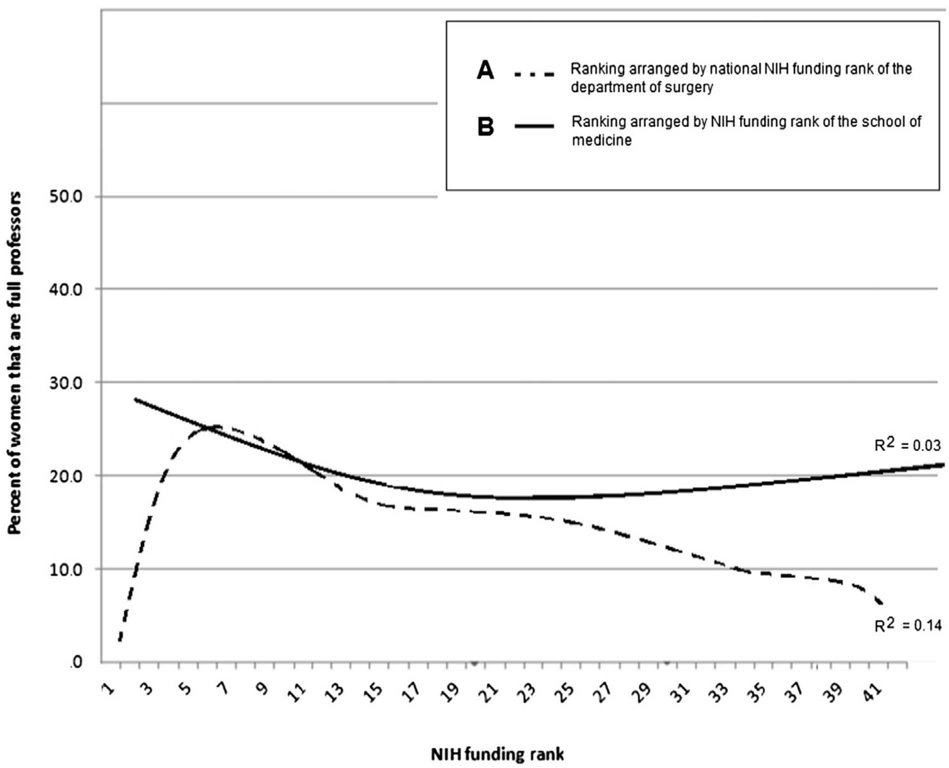

Figure 1. Correlation analysis between percentage of female surgical faculty who are full professors and the NIH funding rank. The departments of surgery were ranked either by NIH funding to the department of surgery (A) or by NIH funding to the school of medicine (B). Correlation coefficient analysis revealed that the percentage of women who were full professors decreased with progressively lower NIH funding rank of the respective departments of surgery, $R^2 = 0.14$, $p < 0.05$ (A, dashed line). This trend of fewer women at full professor rank was not seen, however, when the same departments were arranged by NIH funding to the concerned school of medicine (B, $R^2 = 0.03$, p = NS).

professors compared with 48% of the male surgical faculty. Similar findings of lower percentages of women at the rank of full professor were observed for other surgical specialties, including vascular surgery and surgical oncology. Within surgical oncology, female full professors were as academically productive as male faculty when comparing publications, but not citations. Although only 18.6% of the women were full professors compared with 36.5% of the male surgical faculty in general surgery, no sex-based difference in scholarly output was observed; both sexes were numerically equivalent concerning publications and citations (Table 3, Fig. 1).

Percentile cut points for different academic ranks indicate well-published female junior faculty but no differences in promotion criteria between sexes

Analysis of scholarly output by academic rank indicated that the publications and citations for assistant and associate professors among general surgery faculty were similar. Median P/C were: male assistant professors, 13 ± 28/166 ± 691, male associate professors, 37 ± 38/634 ± 1,241; female assistant professors, 12 ± 21/139 ± 829, and female associate professors, 36 ± 32/559 ± 1,278 (Table 4). Therefore, in order to evaluate whether female assistant and associate professors were being promoted less than their male counterparts, the scholarly output for each academic rank was broken down into deciles (Table 4). Comparisons of these deciles between sexes for each corresponding rank did not indicate an increased concentration of women at lower ranks with higher publication/citation numbers. For example, 22 publications for an individual general surgery faculty member who is an assistant professor would place that person below the 70^{th} percentile among men and above the 70^{th} percentile among women.

Better NIH-funded departments of surgery had a higher fraction of female full professors

Analyses were then undertaken to identify the fraction of women who were full professors at individual

Table 4. Details of Scholarly Output by Sex and Academic Level

	Male			Female		
Parameter	Assistant professor	Associate professor	Professor	Assistant professor	Associate professor	Professor
Scholarly output, n						
P ± SD	17 ± 46	41 ± 44	99 ± 128	12 ± 27	38 ± 33	83 ± 114
C ± SD	213 ± 1,132	684 ± 1,820	2,271 ± 4,371	160 ± 653	650 ± 1,340	2,257 ± 4,044
Academic divisions for comparison, n, median						
General surgery						
P ± SD	13 ± 28	37 ± 38	98 ± 107	12 ± 21	36 ± 32	91 ± 91
C ± SD	166 ± 691	634 ± 1,241	2,451 ± 4563	139 ± 829	559 ± 1,278	2,411 ± 3,551
Other surgical specialties, n, median						
P ± SD	19 ± 57	46 ± 48	98 ± 138	13 ± 36	37 ± 32	76 ± 149
C ± SD	231 ± 1,386	792 ± 2,228	2,197 ± 4,085	183 ± 420	687 ± 1,613	1,414 ± 4,675
Publications/Citations cut-points for percentile groups (P/C)						
General surgery (P/C)						
10th percentile	3/15	10/84	24/311	3/12	7/79	24/392
20th percentile	5/30	16/200	44/845	4/29	13/223	37/532
30th percentile	7/59	22/388	64/1,405	6/56	21/353	41/1,065
40th percentile	10/109	30/498	82/1,864	8/84	29/421	58/2,029
50th percentile	13/166	37/634	98/2,451	12/139	36/559	91/2,411
60th percentile	16/274	47/881	117/3,221	14/187	40/815	105/2,966
70th percentile	23/283	53/1,090	147/4,097	18/298	45/961	134/3,452
80th percentile	32/497	66/1,645	198/5,274	24/401	56/1,452	157/4,179
90th percentile	49/1,006	103/2,507	290/9,268	36/726	79/1,873	173/7,784

C, citations; P, publications; SD, standard deviation.

departments of surgery regardless of surgical subspecialty. A positive correlation was observed between the fraction of women who were full professors and increasing (better) NIH funding rank of the individual department of surgery (Fig. 1), ($R^2 = 0.14$, $p < 0.05$). There was, however, no correlation between the percentages of female full professors when cross-tabulated against the NIH funding rank of the medical school (Fig. 1).

Publications authored or coauthored by female surgical faculty have greater impact

As described in the Methods section of this article, academic velocity, or V, represents the median number of 3-year citations per total publications. Figure 2 indicates normal distributions of V for both male and female surgical faculty. The median ± SD academic velocity for male surgical faculty was 4.8 ± 14.2 compared with 5.56 ± 6.37 for the female surgical faculty, $p < 0.05$. This larger V indicates that publications authored by women are cited more frequently and more recently than those authored by their male faculty colleagues.

Multivariable analysis

Finally, multivariable analyses (Supplementary Tables 1 to 3, online only) were performed using the covariates of individual factors (sex, publications, citations, h-index, academic level, degree), division/subspecialty, and departmental NIH funding rank in order to predict higher numbers of publications, citations, and successful NIH R01/P01/U01 funding. Sex was a small negative predictor in multivariable analysis for total numbers of publications, but for not citations or for successful NIH funding (odds ratio 0.94, 95% CI 0.93 to 0.96, $p < 0.05$).

DISCUSSION

There are likely multiple incompletely understood and unidentified barriers to the successful entry and advancement of women in general surgery and surgical specialties. Sex-based differences in scholarly output appear to be present across most surgical subspecialties and are most pronounced in cardiothoracic surgery and surgical oncology. These results suggest that barriers to advancement include lower numbers of publications and citations among female surgical faculty, especially at the assistant

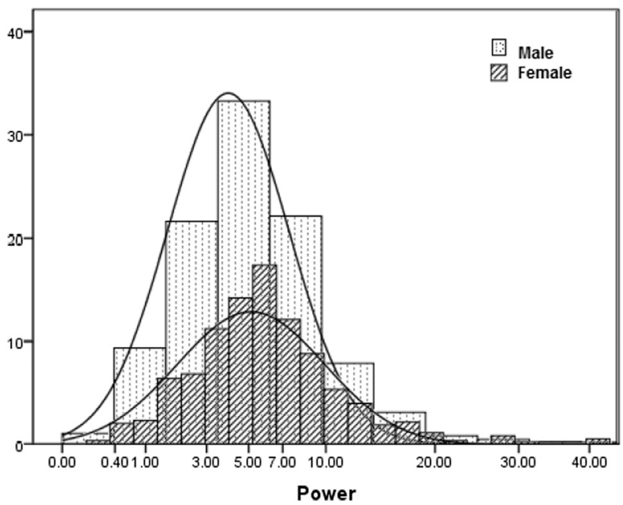

Figure 2. Diagrammatic representation of normal distribution curves for academic velocity (defined as [publications/total citations] × [3-year citations/total − citations]) comparing male and female surgical faculty. The median ± SD Velocity for males was 4.8 ± 14.2 and for females was 5.56 ± 6.37.

professor level, and a paucity of female surgical faculty among divisional leadership positions at senior academic levels.

The lower representation of female surgical faculty among full professors and leadership positions is similar to that observed among medical school faculty in specialties other than surgery.[1] Presently, women constitute a little more than 50% of medical school graduates, and a step-wise reduction in representation is observed with increasing academic rank and leadership positions.[2,17-21] The percentage of women in senior positions is disproportionately small, even after accounting for fewer female medical school graduates at their time of entry.[1,3] A lower representation of women among senior academic ranks is also associated with lower numbers of publications and citations.[8,18,22] These data demonstrate, however, that the lower numbers of publications and citations do not necessarily translate to diminished funding from the NIH, and although male surgical faculty are slightly more likely to have larger NIH grants, there is no sex-based difference concerning overall history of NIH funding.

Similar bibliometric analyses of the academic productivity of female faculty among other specialties have also yielded similar sex-based differences in numbers of publications and citations and NIH funding,[19,22-28] with certain subtle differences. In some specialties, these differences in academic output are simply more pronounced among junior faculty ranks.[24,25] But in others, female faculty consistently perform better than their male counterparts at senior faculty positions.[25] The phenomenon that women have potential for career peaks later in their careers has also been suggested by other investigators,[29] and our data suggest that this occurs in many instances within surgery. In contrast to the current data regarding general surgery and general surgical subspecialties, women at various faculty levels in radiation oncology[30] and neuroscience[23] are no different than similarly ranked male faculty in terms of scholarly output. This indicates that the barriers preventing women from experiencing greater professional success in surgery may be different, and possibly more deeply entrenched, than in other medical fields.

In this dataset, there were many variations in the pattern of academic achievement and productivity among women, depending on the subspecialty. Among all the subspecialties in this analysis, the divisions of science/research had the highest representation of women, both overall and as full professors. This was also the division in which women had relatively higher numbers of publications and citations. Women also had a larger representation in general surgery and surgical oncology; however, these specialties had lower percentages of female full professors. The data suggest that these subspecialties might be evolving concerning the contribution of women in the academic enterprise, and that follow-up studies to examine the academic course of female assistant professors in these subspecialties will be critical to evaluate whether improving representation of women is met with appropriate academic advancement.

These data also show that cardiothoracic surgery has the lowest representation of women within the field of surgery. This, along with the sex-based differences in publications and citations, mimics the lack of academic advancement and scholarly output among women in orthopaedic surgery.[24,26,31,32] Factors that might play similar roles in both these specialties without significant representation of women include negative biases toward women within the specialty, lack of mentors and exposure to the field, unpredictable scheduling, and the persistence of strong male stereotypes in these fields.[26] In the subspecialties of science/research and vascular surgery, in which women appear to thrive, a more controllable schedule, better-structured research development programs, and presence of female mentors might positively influence academic productivity among women faculty members. The presence of a higher number of residents who specialize earlier within integrated training programs in vascular surgery might result in an academic environment that is beneficial to women and should be the subject of future research studies.

The other pertinent finding from this analysis is that there is not a concentration of women with higher numbers of publications/citations among female assistant and associate professors compared with their male colleagues. This indicates that if there are any differences in standards that are used for promotion criteria between male and female surgical faculty, they are not captured by this large nationwide dataset of academic output. Indeed, the academic output of women at every decile of performance and at every academic level, as measured by the volume of publications and citations, is lower than that of their corresponding male surgical colleagues. This may be an important finding because it may assist departmental leadership in focusing resources on faculty developmental programs with an emphasis on divisions with poor sex-specific performance. Additionally, this problem of fewer publications and citations at the assistant professor level might also reflect the need for more effective mentorship, improved protected time for research, and increased pilot funds to lower barriers for conducting research. Another potential explanation for this observed delay in academic performance could be female faculty taking time to have children.

These data demonstrate that the best-ranked departments of surgery by NIH funding are also those that are more likely to promote women to higher academic levels. Furthermore, this correlation may not be unique to the field of surgery. The lack of parity in promotion and leadership positions, in spite of an adequate representation of women in any given field, has often been termed the "sticky-floor," or second-generation bias. There has been considerable interest in evaluating the effect of these barriers toward success of Fortune-500 companies.[19,33-35] In the financial realm, companies that are in the bottom quartile of women's representation on the board have poorer return on equity, sales, and invested capital.[33] This bias has also been reported to result in 1-dimensional thinking and a poorer decision-making environment.[34]

This study supports the idea that a diminished promotion of women to higher-ranking positions because of barriers outside of capability alone results in poorer overall success of the organization, regardless of the metric of success that is used. This is further supported by the finding that publications authored by women are cited more frequently, and therefore appear to have higher impact.[36,37] Reduction of sex bias in the corporate community has been identified as critical to overall organizational success. Eagly and Carli[35] suggested the immediate implementation of several measures that include making performance-evaluation criteria explicit, using open recruitment techniques, providing leadership training to women, establishing family-friendly human resource policies, and adjusting the promotion cycle for parental responsibilities. Examples from the corporate community may set a good example of the extent of restructuring that is required for general surgery administration to support the advancement of women.

Our data have shown that there are differences in the numbers of publications and citations, which are associated with female sex. The exact etiology of these differences is unclear and cannot be attributed to biases in the system or to choices made by individual faculty members. The lack of women in leadership positions and senior academic ranks, and the fact that they have fewer publications and citations in spite of equivalent NIH funding, suggest that there are may be some obstacles and challenges to the advancement of academic careers that are unique to female surgical faculty members. There are many avenues in which there may be increased time spent by women surgical faculty, and these include committee work, dedication to education, and other nonacademic service obligations. In order to create a more equitable work environment, these will need to be objectively measured and their impact taken into account in the promotion and tenure process.

Lastly, our findings demonstrate that academic productivity measures that account for recentness of publications and citations, such as the V metric described in this study, may mitigate apparent differences in performance. By focusing on the recentness of achievements, departmental evaluations could offset the effects of seniority differences when assessing male and female faculty productivity. Furthermore, such a metric may diminish the impact of a period in a faculty member's history in which there was reduced academic productivity, such as in child-bearing years. The fact that women are associated with higher-impact articles is novel and important because it suggests that metrics such as the V metric, which give weight to the impact of the publications, should be taken into account rather than simply counting the numbers of publications.

This study has some limitations. This study was limited by the data that were available. Although, Scopus is a well validated tool to collect publication metrics, there may be technical limitations in the capture of name and institution changes. Although these are recognized by the Scopus website, some name changes, such as those for female faculty after marriage, may have been inadvertently missed. Furthermore, measuring bibliometrics captures only 1 dimension of the many criteria that affect promotion and tenure. Additional mission-critical responsibilities such as quality of clinical care, teaching, and service were not taken into account in these analyses. Therefore, differences by sex in these important components of career advancement might explain many of the potential differences observed. Nonetheless, these data do identify sex-specific differences in scholarly output and suggest ways that these may be addressed. The V metric gives importance to the impact and relative recentness of the publications, and should be taken into account rather than simply counting the numbers of publications. Follow-up studies on this existing dataset may be performed in a few years to identify factors that predict faster progression through academic ranks, prospectively evaluating individuals at 2 distinct time points.

CONCLUSIONS

There are significant differences in scholarly output concerning aggregate metrics among men and women in general surgery and surgical specialties. These sex-based differences in numbers of publications and citations vary considerably between surgical subspecialties. Cardiothoracic surgery has a relatively poor representation of women and a large gap in the academic performance of its female faculty. There is better representation of women in science/research and vascular surgery, and women in these subspecialties have higher scholarly output. The factors that may be responsible for these variations among subspecialties need to be identified and addressed.

Author Contributions

Study conception and design: Valsangkar, Koniaris
Acquisition of data: Valsangkar, Blanton
Analysis and interpretation of data: Valsangkar, Bell
Drafting of manuscript: Valsangkar, Fecher
Critical revision: Rozycki, Freischlag, Ahuja, Zimmers

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Supplementary Table 1. Factors Associated with Academic Success by NIH R01/P01/U01 Funding Using Multivariate Linear Regression Analyses

Factor	Regression coefficient (β)	Odds ratio	p Value
Individual-level factor			
Numbers of publications	0.108	1.11	0.01
H-index of individual	0.34	1.40	< 0.001
Academic rank	0.048	1.05	0.042
Degree, academic degrees include a PhD	0.145	1.16	<0.001
Sex	−0.009	0.99	0.641
Division-level factor			
Working in a higher performance division*	0.048	1.05	0.042
Cardiothoracic surgery	−0.016	0.98	0.434
Science/research	0.009	1.01	0.942
Surgical oncology	−0.039	0.96	0.907
Transplant	0.066	1.07	0.003
Departmental factor			
NIH funding rank group	−0.034	0.97	0.090

*High performance division included cardiothoracic, science/research, surgical oncology, or transplant.

Supplementary Table 2. Factors Associated with Academic Success by Numbers of Publications Using Multivariate Linear Regression Analyses

Factors	Regression coefficient (β)	Odds ratio	p Value
Individual-level factor			
H-index of individual	0.70	2.01	<0.001
Academic rank	0.273	1.31	<0.001
Division chief, directorial position	0.019	1.02	0.193
Degree, academic degrees include a PhD	0.17	1.19	0.097
Sex	−0.059	0.94	<0.001
NIH R01 funding	0.034	1.03	0.022
Division-level factor			
Working in a higher performance division*	0.028	1.03	0.935
Cardiothoracic surgery	0.048	1.05	<0.001
Science/research	0.048	1.05	<0.001
Surgical oncology	−0.029	0.97	0.204
Transplantation	0.075	1.08	0.197
Departmental factor			
Rank group	0.014	1.01	0.337

*High-performance division included cardiothoracic, science/research, surgical oncology, or transplantation.

Supplementary Table 3. Factors Associated with Academic Success by Numbers of Citations Using Multivariate Linear Regression Analyses

Factors	Regression coefficient (β)	Odds ratio	p Value
Individual-level factors			
Number of publications	0.861	2.37	<0.001
Academic rank	36.61	>10	0.407
Degree, academic degrees include a PhD	760.23	>10	0.033
Sex	16.67	>10	0.845
Division-level factors			
Working in a higher-performance division*			
Cardiothoracic surgery	−25.25	<0.001	0.804
Science/research	−1.9	0.15	0.993
Surgical oncology	609.3	>10	<0.001
Transplantation	31.52	>10	0.780
Departmental factors			
NIH-funding rank group	−76.68	<0.001	0.266

*High-performance division included cardiothoracic, science/research, surgical oncology, or transplantation.