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Trends in female surgeon authorship – The role of the middle author

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A B S T R A C T

Background: The objective of this study was to compare middle authorships between male and female general surgeons in the United States.

Methods: A stratified random sample of American College of Surgeons general surgery fellows was identified. Relevant author demographic, affiliation, and publication metrics were collected and compared across cohorts to determine which demographics were prognostic for each outcome variable. The primary endpoint was the number of middle author papers between genders.

Results: Males were more likely to enter into practice earlier ($p<0.001$), be fellowship-trained ($p<0.001$), obtain higher academic rank ($p<0.001$), and practice at more highly ranked academic institutions ($p=0.019$). Females had fewer middle author publications ($p=0.044$) and higher annual rates of first author publications ($p=0.020$) despite similar rates of total publications.

Conclusions: Female surgeons hold the middle author position less frequently than males despite similar total publication numbers. Reasons for this finding should be the target of future study.

Introduction

In 2018–2019, 52% of United States medical school matriculants were women. The same year, equal numbers of men and women applied for residency in general surgery.[1] Despite these trends, gender gaps in salary, research funding, academic rank, time to promotion, and leadership roles persist.[2–5] Meanwhile, academic productivity remains a central indicator of career success and is a widely-used quantitative measure for promotion at academic institutions.[6–8] Studies examining gender differences in academic productivity in both surgical and non-surgical specialties have yielded conflicting results.[9–12] While some studies demonstrate disparities in publication metrics, others suggest these disparities merely reflect differences in academic rank.[13–15] In academic general surgery, the most recent meta-analysis showed a gender gap in academic productivity only at the assistant professor level.[16] Other studies have shown an increase in female first, last, and overall authors over time.[9,17–19]

The number of middle authors in American scientific literature has increased significantly in the past decade.[20] Authors who are not first, second, or last often do not have defined roles and may contribute minimally.[21,22] Thus, it can be inferred that middle authorships are distributed more freely than other authorship positions and may be influenced by such factors as social and gender dynamics in the workplace. However, many institutions utilize total publication numbers to determine promotion, without weighing first and last authorship more heavily. We hypothesize that a difference in middle authorship exists between female and male surgeons.

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Materials and methods

Study design and population

This study was observational, analytical, retrospective, and cross-sectional. Members of the American College of Surgeons (ACS) online "Find a Surgeon" registry who had a "fellow" designation in the "general surgeon" specialty category and whose practicing address was within United States of America were included. This accessible population was used to represent the target population, as the majority of practicing general surgeons subscribe to ACS membership. Following sampling, surgeons who belonged to another specialty or for whom publications could not be identified were excluded. The study cohorts were dichotomous by gender - male and female. The data was collected over a 4-week period to maintain the cross-sectional nature of the study. Three investigators collected the data after training to ensure reliability. Inter-observer reliability was confirmed by reassigning a small, random subset of the study population for data collection amongst all investigators and comparing the results. Intra-observer reliability was confirmed by comparing a small, random subset of the study population for data collection from the beginning of the collection time period to one at the end.

Study procedures

A 30-subject prototype of the study group examining only the primary objective - number and proportion of middle author texts, was first conducted in order to perform reflective sample size estimation. To achieve a power of 80% with a 95% confidence interval, 195 authors from each gender cohort were required. The effect size was chosen to be 10%. A sample size of 478 surgeons was then chosen to allow for exclusion of physicians with common names that could not be distinguished from colleagues as well as those physicians for whom publications could not be identified.

The stratified random sample of general surgery fellow members of the ACS was generated from the online registry via random number assignment. Various online sources were utilized to obtain information. Gender was self-assigned and determined as listed in the ACS "Find a Surgeon" registry. Degree type, second degree, medical school, residency, residency reputation and research ranking, year of completion of highest level of training, fellowship, and current affiliation were obtained from the Doximity website (www.doximity.com). These findings were confirmed through the author's affiliation website, which in case of authors employed at an academic institution also yielded the author rank. Medical school rankings were determined from the U.S. News and World Report (www.usnews.com) section on Medical School Research ranking. For surgeons employed at an academic institution, the Academic Ranking of World Universities (ARWU) website (www.shanghairanking.com) was used to determine the affiliation rank. The National Institute of Health (NIH) Research Portfolio Online Reporting Tools (RePORT) (www.report.nih.gov) database was utilized to determine NIH research funding status. Elsevier's Scopus database (www.scopus.com) was utilized to extract total number of publications listed in the database including book chapters as well as grouped h-index of a given author. The Hirsch or h-index is a widely used metric to assess an author's scholarly influence. This metric is defined as the highest number of publications (*h*) that have been cited at least *h* times.[23] The use of the h-index has been validated in general surgery.[24] For each author's publication record, the year of publication, journal, and authorship position, coded as first, middle, or last, were recorded. Sole authors were coded as last authors. The Scopus database was then utilized to determine the journal ranking or impact factor, according to Scientific Journal Rankings (SJR) published in the most recent year available, for each publication.

Study endpoints

The primary endpoint of the study was the number of middle author papers between genders. Secondary endpoints included the number and proportion of total, first author, and last author publications, the h-index and average journal rank, the publication rate (number of total, middle author, first author, and last author papers per years in practice), and the productivity curve for the number of total, first, middle, and last author publications as a function of years in practice across gender cohorts.

Statistical analyses

Baseline and demographic characteristics were summarized by standard descriptive summaries and compared across gender cohorts utilizing a student's t-test for continuous variables and Chi Square test for categorical variables with post-hoc analysis among statistically significant subgroups. For author demographic variables with multiple levels (e.g. years in practice cohorts, affiliation type, academic rank), a two-way analysis of variance (ANOVA) test was conducted.

The primary and secondary endpoints stated above were compared across gender cohorts utilizing a student's t-test for continuous variables and a Chi square test for categorical variables. Univariate analysis followed by multivariate analysis with significant variables were conducted to determine which author demographic variables were prognostic for each of the outcome publication metrics. A univariate linear regression model was then utilized to examine the effect of significant author demographic variables from univariate analysis on each publication metric.

For each gender cohort, a natural logarithmic regression was constructed for the productivity curve (cumulative number of total, first, middle, and last author publications) as a function of years in practice (at 1, 5, 10, and 20-year intervals). Tests were two-tailed, and results were considered significant for values of $p < 0.05$.

Results

One hundred ninety-five (40.8%) female and 195 (40.8%) male surgeon authors with publications were successfully identified from the 478 authors sampled. Compared to excluded authors, authors included in the study were more like to be affiliated with an academic or community center ($p < 0.001$), have completed training more recently ($p = 0.030$), be fellowship trained ($p < 0.001$), hold a higher academic or university rank ($p = 0.008$, $p < 0.001$, respectively), and be NIH funded ($p = 0.035$). The median years in practice was 17.

Compared to females, males were more likely to enter into practice earlier ($p < 0.001$), be in practice longer ($p < 0.001$), and be fellowship trained ($p < 0.001$). Although a greater proportion of females had an academic affiliation ($p = 0.005$), males obtained higher academic rank ($p < 0.001$) and practiced at more highly ranked academic institutions ($p = 0.019$). The type of fellowship pursued was also different between males and females ($p < 0.001$), with females more likely to pursue breast, critical care, endocrine, or plastic surgery fellowships, and males more likely to pursue thoracic surgery fellowships. There was no difference between males and females in type of degree, number of degrees, region in practice, hospital affiliation type, and acquisition of NIH funding (Table 1).

The average number of total, first, middle, and last author publications across surgeons was 24.6, 3.4, 16.4, and 4.9,

Table 1
Descriptive characteristics of authors, subdivided by gender (n = 390).

Characteristic	Female, N (%)	Male, N (%)	p-value
Degree			0.653
MD	193 (99.0)	192 (98.5)	
DO	2 (1.0)	3 (1.5)	
Second Degree			0.829
None	178 (91.3)	176 (90.3)	
One	16 (8.2)	17 (8.7)	
Multiple	1 (0.5)	2 (1.0)	
Second Degree Type			0.730
PhD	5 (2.6)	6 (3.1)	
MPH	5 (2.6)	5 (2.6)	
MS	3 (1.5)	3 (1.5)	
MBA	3 (1.5)	1 (0.5)	
MHPE	0 (0.0)	1 (0.5)	
MS, MPH	1 (0.5)	0 (0.0)	
PhD, MBA	0 (0.0)	1 (0.5)	
PhD, MHCM	0 (0.0)	1 (0.5)	
RVT	0 (0.0)	1 (0.5)	
Region			0.088
Midwest	33 (16.9)	41 (21.0)	
Northeast	57 (29.2)	38 (19.5)	
South	59 (30.3)	74 (37.9)	
West	46 (23.6)	42 (21.5)	
Missing	0 (0.0)	0 (0.0)	
Affiliation Type			0.089
Academic	63 (32.2)	45 (23.1)	
Community	74 (37.9)	87 (44.6)	
Private	42 (21.5)	53 (27.2)	
Military	3 (1.5)	5 (1.3)	
Academic Association	13 (6.7)	5 (2.6)	
Missing	0 (0.0)	0 (0.0)	
Academic Affiliation			***0.005***
Yes	76 (39.0)	50 (25.6)	
Year of Training Completion			***<0.001***
Median/Range	2006/1972–2016	1996/1964–2016	
1960s	0 (0.0)	4 (2.1)	
1970s	5 (2.6)	27 (13.8)	
1980s	15 (7.7)	39 (20.0)	
1990s	32 (16.4)	46 (23.6)	
2000s	67 (34.4)	49 (25.1)	
2010s	76 (39.0)	30 (15.4)	
Years in Practice			***<0.001***
Median/Range	12.7 (3 – 47)	22.6 (3 – 55)	
Fellowship			***<0.001***
None	73 (37.4)	117 (60.0)	
One	118 (60.5)	73 (37.4)	
Multiple	4 (2.1)	5 (2.6)	
Fellowship Type			***< 0.001***
Breast	16 (8.2)	0 (0.0)	
Colorectal	7 (3.6)	2 (1.0)	
Critical Care	38 (19.5)	19 (9.7)	
Endocrine	4 (2.1)	0 (0.0)	
Minimally Invasive/Bariatric	14 (7.2)	13 (6.7)	
Pediatric	2 (1.0)	2 (1.0)	
Plastics	4 (2.1)	0 (0.0)	
Surgical Oncology	20 (10.3)	12 (6.2)	
Thoracic	0 (0.0)	6 (3.1)	
Transplant	4 (2.1)	9 (4.6)	
Vascular	1 (0.5)	5 (2.6)	
Hepatopancreaticobiliary	0 (0.0)	3 (1.5)	
Head & Neck	2 (1.0)	0 (0.0)	
Hand	2 (1.0)	0 (0.0)	
Vascular, Critical Care	0 (0.0)	1 (0.5)	
Vascular, Thoracic	0 (0.0)	1 (0.5)	
HPB, Surgical Oncology	0 (0.0)	1 (0.5)	
GI Pathology	0 (0.0)	1 (0.5)	
MIS, Surgical Oncology	1 (0.5)	0 (0.0)	
MIS, Breast	1 (0.5)	0 (0.0)	
MIS, Transplant	1 (0.5)	0 (0.0)	
Transplant, Surgical Oncology	0 (0.0)	1 (0.5)	
MIS, Surgical Infectious Disease	0 (0.0)	1 (0.5)	
Critical Care, Breast, Plastics	1 (0.5)	0 (0.0)	
Missing	4 (2.1)	1 (0.5)	
Academic Rank			***<0.001***

(*continued on next page*)

Table 1 (*continued*)

Characteristic	Female, N (%)	Male, N (%)	p-value
Instructor	2 (2.6)	0 (0.0)	
Adjunct	1 (1.3)	1 (2.0)	
Assistant	44 (57.9)	10 (20.0)	
Associate	22 (28.9)	18 (36.0)	
Full	6 (7.6)	21 (42.0)	
Medical School Ranking			0.706
Top 10	15 (7.7)	18 (9.2)	
Top 25	20 (10.3)	18 (9.2)	
Top 50	44 (22.6)	36 (18.5)	
Top 75	48 (24.6)	30 (15.4)	
Top 100	18 (9.2)	12 (6.2)	
Top 125	11 (5.6)	10 (5.1)	
Missing	39 (20.0)	71 (36.4)	
Residency Reputation Ranking			0.507
Top 10	13 (6.7)	23 (11.8)	
Top 50	45 (23.1)	43 (22.1)	
Top 100	30 (15.4)	24 (12.3)	
Top 150	22 (11.3)	20 (10.3)	
Top 200	7 (3.6)	9 (4.6)	
Top 250	3 (1.5)	7 (3.6)	
Top 300	1 (0.5)	1 (0.5)	
Missing	74 (37.9)	68 (34.9)	
Residency Research Ranking			0.066
Top 10	13 (6.7)	20 (10.3)	
Top 50	45 (23.1)	50 (25.6)	
Top 100	45 (23.1)	37 (19.0)	
Top 150	22 (11.3)	29 (14.9)	
Top 200	18 (9.2)	10 (5.1)	
Top 250	1 (0.5)	4 (2.1)	
Top 300	14 (7.2)	5 (2.6)	
Missing	37 (19.0)	40 (20.5)	
University Ranking			***0.019***
Top 10	6 (7.6)	2 (4.0)	
Top 50	21 (27.6)	13 (26.0)	
Top 100	9 (11.8)	4 (8.0)	
Top 150	5 (6.7)	5 (10.0)	
Top 200	7 (9.2)	2 (4.0)	
Top 300	7 (9.2)	2 (4.0)	
Top 400	8 (10.5)	2 (4.0)	
Top 500	5 (6.7)	11 (22.0)	
Missing	8 (10.5)	9 (18.0)	
NIH Funding			0.240
Yes	7 (3.6)	12 (6.2)	

respectively. The mean h-index for authors was 7.8 and the mean journal impact factor was 1.7. Male and female surgeons had similar total publications, first author publications, last author publications, mean h-index, and mean impact factor. Compared to males, females had significantly fewer middle author publications (mean 12.4 ± 2.6 vs. 20.4 ± 2.9, $p = 0.044$). Although annual publication rate was similar for males and females, females had a significantly higher annual rate of first author publications (0.4 ± 0.1 vs. 0.2 ± 0.1, respectively, $p = 0.020$). Author publication metrics are shown in Table 2.

Significant factors found on multivariate regression for each of the publication metrics are shown in Table 3. Variables that were significant on univariate analysis for number of middle author publications, namely gender, second degree, affiliation type, years in practice, fellowship training, academic rank, residency research ranking, university ranking, and NIH funding were included.

Table 2
Surgeon publication metrics grouped by sex.

Publication Metric, Mean ± Std. Error	Total	Female	Male	p-value
h-index	7.8 ± 0.6	6.8 ± 0.7	8.8 ± 0.8	0.084
Total Number of Publications	24.6 ± 2.8	20.6 ± 3.9	28.7 ± 3.9	0.146
Annual Publication Rate	1.6 ± 0.2	1.6 ± 0.2	1.6 ± 0.2	0.954
Average Impact Factor	1.7 ± 0.1	1.8 ± 0.1	1.6 ± 0.1	0.094
Total Number of First Author Publications	3.4 ± 0.3	3.65 ± 0.4	3.1 ± 0.5	0.367
Percentage of First Author Publications	25.7 ± 1.6	26.9 ± 2.1	24.5 ± 2.3	0.450
First Author Publication Rate	0.3 ± 0.1	0.4 ± 0.1	0.2 ± 0.1	***0.020***
Total Number of Middle Author Publications	16.4 ± 2.0	12.4 ± 2.6	20.4 ± 2.9	***0.044***
Percentage of Middle Author Publications	59.1 ± 1.7	56.5 ± 2.3	61.8 ± 2.6	0.126
Middle Author Publication Rate	1.0 ± 0.1	0.9 ± 0.1	1.2 ± 0.2	0.257
Total Number of Last Author Publications	4.9 ± 0.8	4.5 ± 1.1	5.2 ± 1.2	0.664
Percentage of Last Author Publications	15.2 ± 1.2	16.6 ± 1.7	13.7 ± 1.6	0.208
Last Author Publication Rate	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.655

Table 3
Multivariable regression analysis of factors that were significantly associated with publication metrics on univariate analysis.

	R2	Gender	Degree	Second Degree	Region	Affiliation Type	Years in Practice	Fellowship	Academic Rank	Med School Rank	Residency Reputation Rank	Residency Research Rank	University Rank	NIH Fund
h-index	0.275			0.313		0.651		0.965	**<0.001**			0.107	**0.002**	**<0.001**
Total Pubs	0.287			0.729		0.588		0.370	**<0.001**			0.167	**0.003**	**<0.001**
Annual Pub Rate	0.350			0.001		0.591	0.011	0.497	**<0.001**			0.398	**0.008**	**<0.001**
Avg Impact Factor	0.094							0.139			0.165	0.939		**0.001**
First Author Pubs	0.210			0.129		0.479		0.493	**0.002**			0.871	**0.045**	**<0.001**
% First Author Pubs	0.043						0.003		**0.002**					
First Author Pub Rate	0.203	0.633		0.009	0.637	0.358	<0001	0.164	**0.092**				0.314	**<0.001**
Middle Author Pubs[a]	0.378	0.003		0.710		0.488	0.173	0.906	**<0.001**			0.210	**0.014**	**0.006**
% Middle Author Pubs														
Middle Author Pub Rate	0.317			**0.002**		0.691	**0.027**	0.762	**<0.001**			0.291	**0.012**	**<0.001**
Last Author Pubs	0.235			0.916		0.735	0.029	0.815	**<0.001**			0.540	**0.023**	**<0.001**
% Last Author Pubs	0.075		0.441				<0001	0.011		0.410				
Last Author Pub Rate	0.250			0.057		0.575		0.752	**0.002**			0.602	**0.044**	**<0.001**

[a] A significant regression equation was found ($F(1,311) = 12.873$, $p < 0.001$) with an R^2 of 0.378. The predicted total number of middle author publications was equal to 7793.839 (gender) + 183.172 (second degree) + 6388.134 (affiliation type) + 18.383 (fellowship) + 48063.280 (academic rank) + 2084.497 (residency research ranking) + 7997.725 (university ranking) + 10323.978 (NIH funding).

Gender ($p = 0.003$), academic rank ($p < 0.001$), university ranking ($p = 0.014$), and NIH funding ($p = 0.006$) were associated with a significant difference in the number of middle author publications.

Years in practice predicted first, middle, last, and total publications for male, female, and all surgeons. These regression curves are depicted in Fig. 1. For cumulative middle author publications, a significant regression equation was found for all authors ($R^2 = 0.917$, $p = 0.010$, 95%CI 3–4.2), female authors ($R^2 = 0.913$, $p = 0.011$, 95%CI 2.3–3.3), and male authors ($R^2 = 0.938$, $p = 0.007$, 95%CI 3.9–5.2). When comparing cumulative middle author publications across gender cohorts, these regressions approached statistical significance ($p = 0.085$), indicating that males appear to publish more middle author texts, especially earlier in their careers.

Discussion

In 2017, the number of women enrolling in United States medical schools exceeded the number of men for the first time in history.[25] At the same time, only 24% of full professors and 14% of department chairs are women.[26] Although total number of publications was similar between genders in this study, others have shown that compared to male surgeons, female surgeons publish fewer scientific articles and are less likely to be promoted.[3,9–11,14,27–29]

This study demonstrates persistent gender disparities in academic general surgery, with male surgeons achieving higher academic rank and gaining employment at more highly ranked academic institutions compared to their female colleagues. Despite having similar overall numbers of publications and annual publication rates, female surgeons have fewer middle author publications and higher first author publication rates.

Both the reason for these differences and its meaning are unclear. Although guidelines regarding authorship allocation in health sciences research are increasingly being utilized,[30,31] the role of middle authors is less defined and more variable. Studies have demonstrated that in academic science, processes that are less structured and less transparent are more likely to introduce unconscious bias.[32] Therefore, one possible explanation is that middle authorship is more likely to be affected by "softer" factors, such as gender dynamics, interpersonal interactions, mentorship, available resources, and perhaps even unconscious bias.

In a study examining the effect of departmental climate on research productivity in female and male academic medical faculty, Sheridan et al. found that both women and men produce more publications with more positive collegial interactions (eg being treated with respect by colleagues, feeling valued) in departments with higher proportions of their own gender. Men and women had similar numbers of total publications with a good collegial environment only in departments with a higher percentage of women. Even with a positive perception of collegiality, in departments with relatively few females, women's publication numbers actually decreased. Meanwhile, men saw large increases in productivity with improved collegial interactions in departments with few women.[33] Another study found that when women were senior authors in cardiology scientific publications, they published more manuscripts with female first authors and more female authors overall.[34] Mentorship and professional interactions between female academicians appear to foster academic productivity.

Unfortunately, although the number of women entering surgical fields has increased dramatically, women surgeons continue to face bias and discrimination across a variety of outcomes in addition to publication success, including promotion, compensation, and leadership opportunities. Traditional gender roles, sexism in the medical environment, and lack of effective mentors are thought to contribute to this discrepancy.[3] In a survey of 190 male surgeons, only 78% considered female surgeons to be as capable as their male colleagues. Although 43% agreed that gender discrimination exists in surgery, 57% of male surgeons did not consider the rate of women entering into surgery as a problem to address and only 24% believed there are "too few" women in surgery.[35] A recent study demonstrated that regardless of gender, surgeons more strongly associate men with surgery and women with family medicine.[36] Another study showed that among surgical faculty with children,

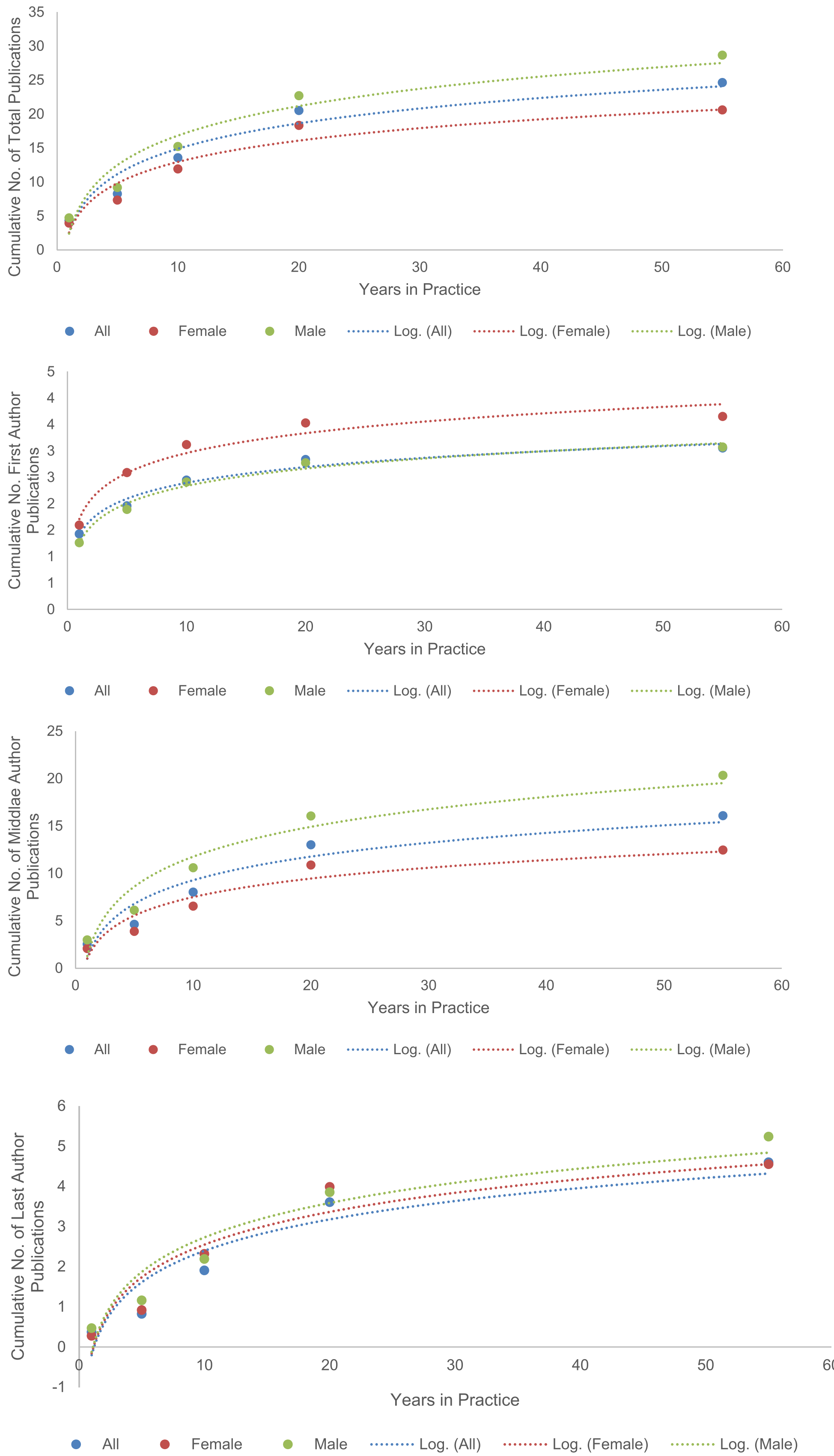

Fig. 1. Natural logarithmic regression analysis predicting the cumulative total, first, middle, and last author publications based on years in practice.

women receive less institutional research funding and secretarial support than men.[37] It has also been found that more female than male physician-scientists report inadequate access to grants administrators and statistical support.[38] These biases and disparities likely influence gender differences in authorship by creating fewer opportunities and fewer resources for women.

Our study demonstrated both a lower total number of middle author papers and a higher rate of first author publication in women compared to men. This difference appears to be greater earlier in surgical careers based on our regression curves, which corresponds with other studies showing similar publication rates after an initial "gap" in early careers.[33] Studies suggest that female academicians assume internal service or "institutional housekeeping" tasks such as faculty governance, student admissions, evaluation and promotion, more frequently than males.[39] Further, women shoulder greater proportions of clinical and educational responsibilities, roles traditionally less rewarded from an academic standpoint.[27,29] Moreover, women surgeons have younger children, more home responsibilities, and are more likely to be in a dual-career household.[40] Work-life balance has been shown to negatively affect publication productivity. Not surprisingly, this impact appears greater for senior women faculty.[33] These factors may help explain why women are not only less likely to be promoted, but also take longer to rise in academic rank.[29]

This study has several limitations that need to be discussed. First, we examined a subset of surgeons for whom we were able to find publications online. These surgeons were more likely to have a higher academic or university rank, NIH funding, and fellowship training amongst other differences and may therefore not be representative of American general surgeons as a whole. Additionally, some publications may not have been captured using our designated study procedures such as if authors changed their names during their careers. Further, unobserved covariates may have influenced publication productivity. Finally, our study was observational in nature and therefore findings are associations and do not imply causation, and our discussion largely contemplative.

Barriers to academic productivity exist for women surgeons. These should be taken into account when utilizing publication metrics to determine compensation, leadership positions, and promotion. Further, efforts should be made to provide women surgeons with strong mentorship and appropriate resources to foster successful academic careers.

Conclusions

To our knowledge, this is the first study in general surgery to demonstrate a gender difference in middle authorship, with female surgeons holding the middle author position less frequently than males despite similar total publication numbers. Variations in mentorship, professional interactions, resources, and work-life balance may contribute to this difference. Given the flexible allocation of middle authorship, our results provide a window into how social constructs and gender schemas may affect academic productivity.

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Declaration of competing interest

The authors have no potential conflicts of interests to disclose.

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