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Gender Disparity in Authorship Among Orthopaedic Surgery Residents

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Background: Gender disparity remains pervasive in orthopaedic surgery, which affects the research pursuits of orthopaedic surgeons. The purpose of this study was to characterize gender-related authorship trends of orthopaedic surgery residents, including evaluation of gender-concordant publication rates.

Methods: An observational cross-sectional analysis of US orthopaedic surgery residency programs was performed. Information on residency programs and demographics of each cohort was collected. Publication metrics consisting of number of first and non-first author publications and H-indices were manually obtained for PGY-3 to PGY-5 residents attending the 25 programs ranked the highest for research output by Doximity. Gender of each resident and senior author was determined from institutional websites using photos, biographies, and preferred pronouns when available.

Results: A total of 532 residents, 169 (31.8%) female and 363 (68.2%) male, were included for authorship analysis. Of them, 415 (78%) had at least one first author publication, which did not vary significantly by gender. Female residents had disproportionately fewer first author publications compared with their representation (22% vs. 31.8%, $p < 0.00001$). Female residents averaged fewer first and non-first author publications compared with male residents (2.8 vs. 4.6, $p = 0.0003$; 6.4 vs. 10, $p = 0.0001$ respectively). Despite fewer publications overall, a greater subset of publications by female residents were written in collaboration with a female senior author compared with publications by male residents ($p < 0.0001$). Male residents had a higher average H-index of 5.4 vs. 3.9 among female residents ($p = 0.00007$).

Conclusion: Despite similar rates of first author publication among male and female residents, female residents had fewer publications overall, lower H-indices, and disproportionately fewer first author publications than would be expected given their representation. Findings from this study suggest that gender disparity in orthopaedic surgery extends to differences in research productivity as early as in residency. This may have negative implications on the career advancement of female orthopaedic surgeons. Additional work is needed to identify and understand biases in research productivity and career advancement, to promote more equitable strategies for academic achievement.

Level of Evidence: IV.

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Introduction

Despite significant efforts to improve gender diversity in surgical subspecialties, as well as increases in the proportion of women matriculating into medical school, orthopaedic surgery continues to harbor a substantial gender gap. The Association of American Medical Colleges (AAMC) 2022 Report on Residents notes that women made up only 18.3% of orthopaedic surgery residents, the lowest proportion among all surgical specialties[1]. Gender discrepancy is even more apparent within academic orthopaedic surgery, with one study finding that in 2014, only 12.9% of assistant professors, 11.3% of associate professors, and 6.4% of full professors were female[2]. Similar findings have been noted for academic leadership within orthopaedic surgery, with women comprising only 9% of program directors and 4.1% of department chairpersons in 2019[3].

Gender disparity has also been found to extend into research pursuits, with studies finding that female orthopaedic surgeons have lower H-indices and publish in lower-impact journals[2,4]. Similar findings have been reported in subspecialty-specific investigations, with female authors publishing fewer articles than their male counterparts and with female authors being less likely to continue publishing 5 years after initial publication in both foot and ankle and spine literature[5,6]. In 2023, Johnson et al. found that female first authors only accounted for 12% of abstracts presented at the 2016 and 2017 American Academy of Orthopaedic Surgeons (AAOS) Annual Meetings and that female-authored abstracts were less likely to lead to publication, despite no observable differences in study quality[7]. As research productivity has a significant impact on academic recruitment and career advancement, gender disparity in research pursuits may continue to limit opportunities for female orthopaedic surgeons[8].

The purpose of this study was to characterize gender-related authorship trends of orthopaedic surgery residents and to evaluate what role gender-concordant publications may have on authorship trends of female vs. male residents.

Methods

An observational cross-sectional analysis of US orthopaedic surgery residency programs was performed. Baseline information on geographic location and total number of orthopaedic surgery residents was collected through AAMC's Residency Explorer tool (accessed August 2023)[9]. Residency program regions were categorized in accordance with those defined by the US Census Bureau (West, Midwest, Northeast, South)[10]. All other data on resident demographics, including gender and current postgraduate year (PGY), were collected through institutional websites (accessed September 2023). Gender of each resident was categorized in a binary manner (male or female) and was determined using photographs, biographies, and preferred pronouns when available. Programs without a publicly accessible list of residents were excluded from resident gender-related analysis.

Publication metrics were manually obtained for PGY-3 to PGY-5 residents at the 25 orthopaedic surgery residency programs ranked the highest for research output by Doximity. Measurement of research output ranking by Doximity is based on a combination of the H-index and publications of program alumni within the past 10 years, the ratio of current residents and recent graduates publishing, research grants awarded, and participation in clinical trials[11]. A list of the top 25 programs per this ranking system can be found in Table I. For each resident listed, PubMed search was used to identify all orthopaedic-related publications. Single author publications were excluded from analysis, as were any publications pertaining to non-orthopaedic topics. Publications were not excluded if they were pursued at an institution outside of the author's residency program. Publications were then manually subdivided into first or non-first author publications, in accordance with previous bibliometric studies[4,12-14]. Gender of the senior author on each publication was recorded; similarly, senior author gender was determined from the author's first name and Internet photographs, biographies, and preferred pronouns when available. The H-index, which is commonly used as an objective measure in academia, was obtained for each resident using the Scopus database[15,16]. In instances where residents had multiple Scopus records (because of affiliation with multiple institutions, as may be the case in medical school-to-residency transitions), the record correlating to the higher H-index was used. All publication metrics were collected between September and December 2023.

Descriptive statistics were employed for program and resident demographics. Pearson χ^2 test of independence and Student *t*-test were used to compare all categorical variables (distribution of residents by gender and residency programs by geographic region, proportion of residents by gender, publication metrics of residents by gender). Statistical significance was set to $p < 0.05$. Statistical analyses were conducted using Microsoft Excel and RStudio (version 2023.12.0).

Results

A total of 207 US orthopaedic surgery residency programs were identified. Geographic distribution of the top 25 Research Residency Programs was not significantly different from that of the remaining residency programs ($p = 0.46$) (Table II). Of 207 programs, 29 (14%) lacked a publicly accessible resident roster and/or information on residency demographics and hence were excluded from further analyses. Ultimately, 178 residency programs were included in the evaluation of resident demographics for gender-related analyses, yielding a total of 4,101 residents, 912 (22.2%) female and 3,183 (77.8%) male. Nine (5%) programs had no female residents, whereas one program had a majority of female residents (52%; Table I).

The distribution of female vs. male residents within the 25 selected orthopaedic surgery residency programs was significantly different from that of the remaining programs, with 283 (30.8%) female residents compared with 629 (19.8%) of 912 total female residents ($p < 0.001$) (Table II). The geographic distribution of female vs. male residents across all 178 orthopaedic surgery residency programs was also significantly different, with a higher proportion of female residents in the

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TABLE I Orthopaedic Residency Programs, Ranked by Research Output

Ranking*	Residency Program (2022)	State	Total Residents†	Female Residents, N (%)
1	Rush University Medical Center Program	IL	25	8 (32.0)
2	Hospital for Special Surgery/Cornell Medical Center Program	NY	47	15 (31.9)
3	University of Michigan Health System Program	MI	39	11 (28.2)
4	NYU Grossman School of Medicine/NYU Langone Orthopedic Hospital Program	NY	70	23 (32.9)
5	Mayo Clinic College of Medicine and Science (Rochester) Program	MN	62	16 (25.8)
6	Massachusetts General Hospital/Brigham and Women's Hospital/ Harvard Medical School Program	MA	56	21 (37.5)
7	UPMC Medical Education Program	PA	41	13 (31.7)
8	New York Presbyterian Hospital (Columbia Campus) Program	NY	30	12 (40.0)
9	Sidney Kimmel Medical College at Thomas Jefferson University/ TJUH Program	PA	32	5 (15.6)
10	University of California (San Francisco) Program	CA	34	15 (44.1)
11	Washington University/B-JH/SLCH Consortium Program	MO	39	20 (51.3)
12	University of Pennsylvania Health System Program	PA	42	15 (35.7)
13	UCLA David Geffen School of Medicine/UCLA Medical Center Program	CA	32	10 (31.3)
14	University of Utah Health Program	UT	29	10 (34.5)
15	Cleveland Clinic Foundation Program	OH	30	8 (26.7)
16	University of Virginia Medical Center Program	VA	26	7 (26.9)
17	Vanderbilt University Medical Center Program	TN	25	9 (36.0)
18	Johns Hopkins University Program	MD	31	8 (25.8)
19	University of Maryland Program	MD	31	9 (29.0)
20	Icahn School of Medicine at Mount Sinai Program	NY	34	12 (35.3)
21	Stanford Health Care-Sponsored Stanford University Program	CA	34	15 (44.1)
22	University of Iowa Hospitals and Clinics Program	IA	29	6 (20.7)
23	Duke University Hospital Program	NC	40	16 (40.0)
24	Ohio State University Hospital Program	OH	30	6 (20.0)
25	Brown University Program	RI	30	7 (23.3)

*Ranking provided by Doximity based on research output. †Total number of residents obtained from AAMC's Residency Explorer Tool.

West and South and a lower proportion in the Midwest and Northeast (Table III).

Across the 25 selected residency programs, 921 total residents, 624 (67.8%) male and 297 (32.2%) female, were identified. After excluding PGY-1, PGY-2, and research year residents, a total of 542 PGY-3 to PGY-5 residents remained. Ten male residents were further excluded given difficulty identifying publications specific to that resident because of common names. Ultimately, 532 residents, 169 (31.8%) female and 363 (68.2%) male, were included for authorship analysis.

Among 532 residents, 415 (78%) had at least one first author publication, which did not vary significantly by resident gender, and 486 (91.4%) had non-first author publications, with 5.5% more male residents having at least one non-first author publication compared with female residents (93.1% vs. 87.6%; Table IV). Female residents had disproportionately fewer first author publications compared with their representation in the cohort (22% vs. 31.8%, $p < 0.00001$) (Table V). Female residents averaged fewer first and non-first author publications than male residents (2.8 vs. 4.6 first author publications, $p = 0.0003$; 6.4 vs. 10 non-first author publications, $p = 0.0001$). In evaluating the gender of the senior author, 182 (8.4%) of all first author and 353 (7.5%) of all non-first author publications had a female senior author. For both publication subtypes, female residents had a greater proportion of publications in collaboration with a female senior author compared with male residents (15.3% vs. 6.5% first author publications, $p < 0.0001$; 10.9% vs. 6.5% non-first author publications, $p < 0.0001$) (Figures 1 and 2). Male residents had a higher average H-index of 5.4 vs. 3.9 among female residents ($p = 0.00007$). Publication metrics between female and male orthopaedic surgery residents are summarized in Table IV.

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TABLE II Comparison of Highest Research Output Residency Programs With All Other Residency Programs, by Geographic Distribution and Resident Demographics

	All Programs (N = 207)	Highest Research Output Programs (N = 25)	All Other Programs (N = 182)	p-value
Region, N (%)				
West	31 (15.0)	4 (16)	27 (14.8)	0.46
Midwest	56 (27.1)	7 (28)	49 (26.9)	
Northeast	53 (25.6)	9 (36)	44 (24.2)	
South	67 (32.4)	5 (20)	62 (34.1)	
Total residents*	4,101	918	3,183	—
Total female residents, N (%)*	912 (22.2)	283 (30.8)	629 (19.8)	<0.001
Average No. of residents per program*	23.1	36.7	20.9	<0.001

*Out of programs with publicly available residency rosters (N = 178 total programs, N = 25 Top 25 residency programs, N = 153 all other residency programs).

Discussion

The purpose of this study was to characterize gender-related authorship trends of orthopaedic surgery residents and to evaluate what role gender-concordant publications may have on authorship trends of female vs. male residents. Despite similar rates of first author publication among male and female residents, this study found that female residents had fewer publications overall and accounted for disproportionately fewer first author publications than their representation within the resident cohort by 10%. Female residents also had lower mean H-index scores compared with their male counterparts. Despite fewer publications by female residents overall, a greater subset of publications by female residents were written in collaboration with a female senior author compared with publications by male residents.

Our study found that women made up approximately 22.2% of all US orthopaedic surgery residents, as of fall 2023. Previous investigation of gender diversity within US orthopaedic surgery residency programs has been thoroughly undertaken by Van Heest et al.[17-19] In their analysis of 15 years of residency data (2004-2019, analyzed in 5-year increments), the authors noted a statistically significant increase in the absolute number and percent of female orthopaedic surgery trainees, with 15.4% female representation in 2019[18]. Our data suggest that the number of female residents continues to increase, rising by almost 7% since 2019. There was also a significant difference in the proportion of female residents making up the 25 selected residency programs, with 11% more female representation (30.8% vs. 19.8%) at these programs compared with the remaining 153 programs. The exact reason for this finding is unclear. Residency program size has been demonstrated to be an independent predictor of general Doximity rankings, which appears to overlap with research output rankings[20,21]. However, regression modeling did not demonstrate any trends in female resident representation related to Doximity ranking of the top 25 programs or to residency size. One likely hypothesis is that female applicants may gravitate toward programs with higher female faculty representation—although not quantified in this study, female faculty representation has been shown to be associated with recruitment of female residents in multiple studies[22-24]. In addition to institutional differences, there may also be some effect attributable to geographic patterns, with prior geospatial investigation of orthopaedic surgeons finding gender diversity hotspots largely in the Northeast and West regions, as well as in areas considered urban and "white-collar" in demographic[25]. To fully understand why these programs had a greater make-up of female residents, further study is needed into factors related to recruitment of female residents to these programs, whether it be active diversity-related efforts (e.g., diversity scholarship opportunities for rotators), greater representation of female faculty, or other program-related and/or applicant-related influences.

TABLE III Geographic Distribution and Proportion of Male vs. Female Residents

	Programs with Resident Rosters (N = 178)	All Residents (N = 4,101)	Female Residents (N = 912)	Male Residents (N = 3,189)	p-value
Region, N (%)					
West	26	581 (14.2)	157 (17.2)	424 (13.3)	0.008
Midwest	48	1,106 (27.0)	228 (25.0)	878 (27.5)	
Northeast	47	1,181 (28.8)	242 (26.5)	939 (29.4)	
South	57	1,233 (30.1)	285 (31.3)	948 (29.7)	

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TABLE IV Publications by PGY-3 to PGY-5 Residents at Highest Research Output Residency Programs

All (N = 532)	Female (N = 169)	Male (N = 363)		p-value
All Publications				
Residents with publications, N (%)	500 (94.0)	152 (89.9)	348 (95.9)	0.007
Total publications	6,846	1,553	5,293	
Mean	12.9	9.2	14.6	0.0004
Range	0-166	0-74	0-166	
Total publications with female senior author	535 (7.8)	190 (12.2)	345 (6.5)	<0.0001
First author publications				
Residents with first author publications, N (%)	415 (78.0)	126 (74.6)	289 (79.6)	0.19
Total publications	2,163	476	1,687	
Mean	4.1	2.8	4.6	0.0003
Range	0-83	0-21	0-83	
Total publications with female senior author	182 (8.4)	73 (15.3)	109 (6.5)	<0.0001
Non-first author publications				
Residents with non-first author publications, N (%)	486 (91.4)	148 (87.6)	338 (93.1)	0.036
Total publications	4,683	1,077 (23.0)	3,606 (77.0)	
Mean	8.9	6.4	10	0.0001
Range	0-105	0-58	0-105	
Total publications with female senior author	353 (7.5)	117 (10.9)	236 (6.5)	<0.0001
H-index, mean (range)	4.9 (0-30)	3.9 (0-22)	5.4 (0-30)	<0.0001

Publication analysis of residents within the 25 selected programs demonstrated that female residents had fewer publications overall than their male counterparts and that despite similar rates of first authorship, female residents accounted for disproportionately fewer first author publications than their representation within the resident cohort by 10%. This also translated to a lower H-index among female residents. Johnson et al. evaluated abstracts presented at the 2016 and 2017 AAOS meetings, finding that abstracts with first or last female author were significantly less likely to progress to publication relative to exclusively male-authored abstracts[7]. Previous study by the same author found that female-authored abstracts in the pediatric orthopaedic surgery subspecialty were also less likely to reach publication, despite pediatrics being one of the more gender diverse subspecialties within orthopaedic surgery[26]. Potential reasons for these discrepancies include editorial bias against female authors, disproportionate domestic obligations, and inadequate female mentorship[27]. Bias against female authors has been demonstrated in various studies, although not specifically in orthopaedic surgery. One investigation of high-impact cardiology journals found a negative correlation between the percentage of female first authors and the percentage of men on editorial boards[28]. In addition, previous research on the Matilda effect, which describes bias against acknowledging the achievements of female scientists and crediting work instead to male colleagues, have shown similar biases against female authors. This includes the work by Knobloch et al., which found that the same publications were graded for higher scientific quality when the author had a male name and when the topic was "male-typed" or seen as a field more often attributed to men (i.e., math, physics, politics)[29].

Other orthopaedic-specific studies have shown that practicing female orthopaedic surgeons publish less than would be expected based on their representation in practice[14]. Given that women have been shown to gravitate toward

TABLE V Proportion of Female Residents in Publication Analysis vs. Proportion of Female Author Publications

	Total Residents in Publication Analysis (N = 532)	First Author Publications, by Author Gender (N = 2,163)	p-value (First Author Publications)	All Publications, by Author Gender* (N = 6,846)	p-value (All Publications)
Female	169 (31.8)	476 (22.0)	<0.00001	1,553 (22.7)	<0.00001
Male	363 (68.2)	1,687 (78.0)		5,293 (77.3)	

*Publications may not account for multiple shared authors included in publication analysis and therefore are not considered unique publications.

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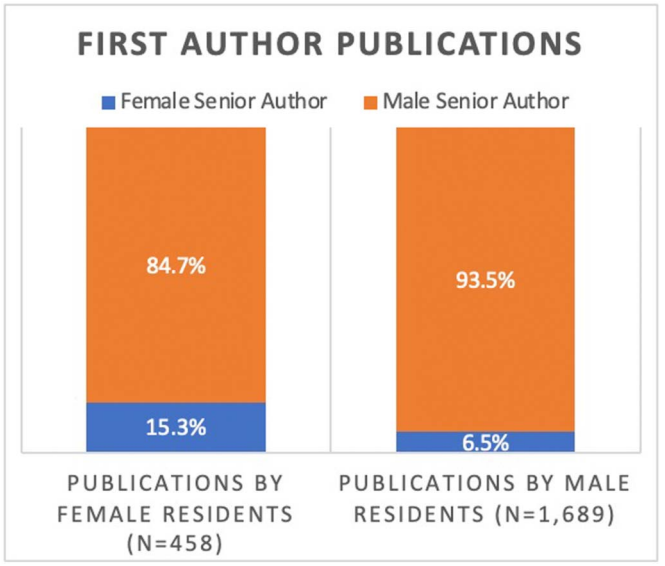

Fig. 1
Proportion of resident first author publications with female vs. male senior authors

careers in academic medicine, equal opportunity would suggest equivalent rates in authorship to the proportion of women in practice. Findings from our study raise the question as to what specific barriers female orthopaedic surgeons, including those in training, might be facing. Further efforts to achieve gender equality in the field of orthopaedic surgery may require reevaluation of career and academic advancement and implementation of flexible criteria for advancement understanding that biases affect professional opportunities offered

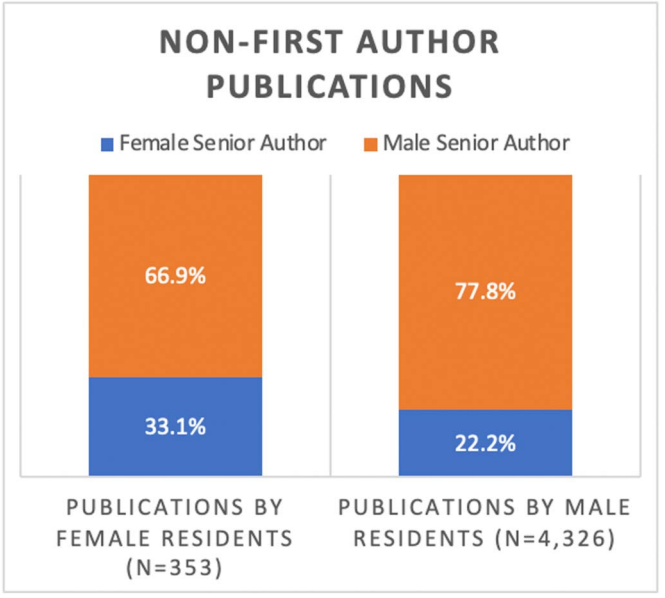

Fig. 2
Proportion of resident non-first author publications with female vs. male senior authors

to women[30]. Previous studies have demonstrated gender inequities at various academic ranks, with differences in research productivity acting as potential contributors to such disparity, although further investigation into modern-day promotion pathways are needed[31,32]. In 2016, Ence et al., investigated academic seniority, finding that m-index (defined as H-index divided by career duration) was equivalent for female and male surgeons, suggesting that gender parity may be more attributable to differences in career length than gender discrimination[2]. Although career length is certainly an important factor in determining academic seniority, our findings suggest that there may be discrepancies in H-index regardless of career duration and that gender disparity in research may be evident as early as in the formative years of residency. Nevertheless, it remains encouraging that our study, among others, demonstrates an upward trend in gender diversity among orthopaedic surgeons and in the orthopaedic literature, even if gains in research productivity may be disproportionate to that of overall female presence and slower when compared with other male-dominated medicine specialties[4,19,33-36].

Despite fewer publications overall, this study found that a greater subset of publications by female residents were written in collaboration with a female senior author compared with publications by male residents. These results are supported by other bibliometric studies which similarly found that female first authors were more likely to feature a female senior author[4,7]. This is likely attributable to female residents intentionally seeking mentorship and opportunities to work with female surgeons, especially when recognizing historically higher rates of gender discrepancy in older generations of surgeons. As female mentors have been shown to play an important role for female trainees entering orthopaedic surgery residency, increasing availability of female mentors may positively influence research productivity of female residents, although this relationship could not be explored in this study[22,37,38]. Although same-gender authorship serves an important role in furthering the academic pursuits of females in orthopaedic surgery, we also posit that our male colleagues, particularly those in senior leadership positions, can have an impact on advancing the academic profiles of female colleagues by serving as research mentors.

There are several limitations to this study. This was a cross-sectional study for which resident demographics and publication metrics were collected at a single point in time. Data inaccuracies are likely present given that many residency programs may not regularly update their online resident rosters and as all resident publications may not be searchable on PubMed (e.g., if published in a non-PubMed indexed journal or if the article were still in press). Owing to missing data, 29 residency programs were excluded from gender-related analyses, as well as 10 residents (notably all male) for whom we could not properly identify publications. In addition, because we chose to evaluate a select group of residents from a limited number of residency programs, findings from our study may not be generalizable to all orthopaedic surgery residents. We did not evaluate the effect of female faculty

representation among the selected residency programs or the effect of dedicated research time, which may have an impact on gender-related discrepancies in resident publication trends and could be future areas of study. Finally, for the purposes of this study, gender was assigned into binary categories, although the authors of this study recognize that this may be an oversimplification of the true gender spectrum and that misgendering may have occurred.

Conclusion

Despite similar rates of first author publication among male and female residents, female residents had fewer publications overall, lower H-indices, and disproportionately fewer first author publications than would be expected given their representation. Findings from this study suggest that gender disparity in orthopaedic surgery extends to differences in research productivity as early as in residency. This may have negative implications on the career advancement of female orthopaedic surgeons. Additional work is needed to identify and understand biases in research productivity and career advancement to promote more equitable strategies for academic achievement. ■

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