Advances in Radiation Oncology (2023) 8, 101135

advances in radiation oncology

www.advancesradonc.org

Scientific Article

Gender Differences in the Research Productivity of Radiation Oncology Resident Graduates in the United States: 2015 to 2019

Brianna M. Jones, MD,[a,*] Jared P. Rowley, MD,[b] Kunal K. Sindhu, MD,[a] Eric J. Lehrer, MD,[a] Kristin Hsieh, MD,[a] Anthony D. Nehlsen, MD,[a] Sheryl Green, MBBCh,[a] and Karyn A. Goodman, MD[a]

[a]*Department of Radiation Oncology, Icahn School of Medicine at Mount Sinai, New York, New York; and* [b]*Department of Radiation Oncology, Maimonides Medical Center, Brooklyn, New York*

Received 1 November 2022; accepted 18 November 2022

Abstract

Purpose: It is well-documented that gender disparities exist in academic radiation oncology departments. The purpose of this study was to analyze gender differences in research productivity during residency among recent graduates of radiation oncology training programs in the United States (US).

Methods and Materials: We used several publicly available sources to create a database of US radiation oncology residents who graduated between 2015 and 2019. We systematically collected gender information from the National Plan and Provider Enumeration System National Provider Identifier Registry and Medicare claims registry. Postresidency employment information was collected using several publicly available sources. PubMed was queried to identify first-author publications of residents. A secondary analysis of metadata including impact factor, number of citations, modified Hirsch index (*h* index), and type of publication was performed. A multivariable linear regression was performed to evaluate the effect of gender on research productivity during residency.

Results: There were 910 total graduates identified during this period and who were entered into this database, of whom all had available gender information. Female trainees comprised 29.0% (n = 264) of RO residents and had fewer first-author publications and citations, had lower mean modified *h* index, and were published in journals with lower impact factors. On multivariable linear regression analysis, female gender was independently associated with decreased total number of publications ($P = .005$), mean number of citations ($P < .001$), and modified *h* index ($P = .001$) when controlling for residency size and advanced (PhD or master's) degrees.

Conclusions: In the US, female RO trainees had lower research productivity, which was not explained by advanced degrees or residency size. A significant gender gap in trainee research productivity persists, which has known implications in terms of academic achievement, promotions, and career trajectory. Future interventions to improve resident research productivity and mentorship are warranted.

Introduction

Female applicants now represent more than half (55.6%) of all medical matriculates.[1] Despite this significant increase, there has not been a proportionate increase in representation of women in the field of radiation

Sources of support: This work had no specific funding.

Disclosures: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Research data are stored in an institutional repository and will be shared upon request to the corresponding author.

*Corresponding author: Brianna M. Jones, MD; E-mail: brianna.jones@mountsinai.org

https://doi.org/10.1016/j.adro.2022.101135

oncology (RO); in fact, as of 2021, women constituted only 30.3% of residents, and only 17.4% held leadership positions.[2,3] Previous studies have shown that underrepresentation of women in the field, particularly in leadership positions, also can lead to disparities in research funding, philanthropic donations, salary, research productivity, and appointment to leadership positions.[3−8] This can affect the retention of women in academic RO, perpetuating the dearth of women role models in senior faculty positions.

Scholastic activity is an important component of residency training, and the Accreditation Council for Graduate Medical Education requires the completion of a scholarly project suitable for peer-reviewed publication or presentation at a scientific meeting under faculty member supervision by the end of RO residency training. Research productivity among RO residents in the United States (US) has been steadily increasing, with the mean first-author publications of graduates increasing from 1.01 between 2002 and 2007 to 2.90 between 2015 and 2019.[9,10] Despite these promising trends, continued gender differences in productivity, as measured by number of publications and *h* index, have been demonstrated.[8,11]

Previous work has demonstrated male gender was predictive of an increased number of first-author publications during residency.[10] This discrepancy in research productivity has implications for future promotion, salary, and career trajectory.[4,7] Therefore, it is paramount that, as a field, we continue to evaluate progress in closing this well-established gender gap. This study can serve as a contemporary benchmark of gender disparities in US RO resident research productivity.

Methods and Materials

We created a comprehensive database of US RO residents who graduated from Accreditation Council for Graduate Medical Education−accredited residency training programs between 2015 and 2019. Data were collected from publicly available sources, including the Association of Residents in Radiation Oncology directory, National Plan and Provider Enumeration System National Provider Identifier Registry (NPI), Medicare Provider Utilization and Payment Data, residency training program websites, and hospital websites.

To collect publication data, we systematically queried PubMed to determine the number of first-author publications during residency. As previously defined, publications had to be published between the start of residency and up to 3 months after graduation to be included in our analysis. Inclusion criteria also required that the author's institutional affiliation listed on a manuscript match their residency program.[9,10,12,13] For each publication, the publication date, journal name, type of publication, impact factor (IF) of the journal, and the number of citations were abstracted and then used to calculate a modified *h* index. The Hirsch index is defined as the number of publications with citations ≥*h*.[14] In using this formula, however, we restricted our search to a specific time frame and only counted first-author publications; therefore, we report a modified *h* index in this study. Each publication was categorized as either original research, review, commentary, or case report. Original research was further classified into subcategories including retrospective analysis, basic science, secondary analysis, physics/dosimetry, clinical trials, and other work.[15] The number of citations for each publication was determined using Scopus or PubMed, and the Journal Citation Reports was used to determine the IF of each journal. To avoid missing any publications due to alterations in surname, additional searches were performed, as described in the following.

We collected gender information from a combination of Medicare claims and NPI. Gender was classified in a binary manner within these publicly available sources. If the resident's gender was indeterminate or information was discordant (n = 3), an Internet search was performed using the Google search engine. The gender of residents was determined for our entire cohort. Common surnames (eg, Smith, Jones) prompted additional searches to ensure that names matched institutional websites. Surname changes were identified by comparing available data and, when discordant, an extensive search of existing professional profiles (ie, institutional websites, Doximity, LinkedIn) was performed to corroborate research publications and educational backgrounds/institutional affiliations.

Postresidency employment information was collected for female trainees using publicly available sources, including hospital/institutional websites, Doximity, LinkedIn, and NPI. The employment information gathered included first and current job, job title, and address. In addition, each job was then classified as academic (either as a main site or satellite job) or nonacademic. The classification of an academic job was defined as a full-time faculty position at an academic medical center affiliated with a medical school or RO residency training program, as previously described.[15] For the purposes of this analysis, academic main site and academic satellite jobs were both considered "academic," and all other jobs were defined as "nonacademic."

Descriptive statistics were used to calculate the mean, median, and standard deviation for PhD status, residency size, total number of PubMed-indexed first-author publications, IF of journal, modified *h* index, and number of citations in both male and female RO graduates. A normal distribution of all variables was verified. χ^2 analysis, Fisher exact test, or Student *t* test was performed to compare male and female RO residents. A multivariable linear regression analysis was performed to determine whether gender was a significant independent predictor of first-author publications, number of citations, IF, and *h* index, which was controlled for by residency program size (as a continuous variable) or any advanced degree. A correlative analysis of practice type and research productivity was performed. A 2-sided $P < .05$ was considered statistically significant, and statistical analyses were conducted in R Studio (version 1.1.383).

This study was determined to be exempt by the institutional review board due to use of publicly available data (IR-02888).

Results

We identified 910 RO graduates between 2015 and 2019, and all graduates had available gender information. There were 264 female RO graduates (29.0%) and 646 male RO graduates (71.0%) in our cohort. The incidence of surname alteration in our sample size was 16.3% (n = 43). Female trainees had significantly fewer first-author publications and citations, as well as lower mean IF and modified *h* index. There was no significant difference in the proportion of these trainees with a PhD, any advanced degree, or residency size.

Of the available publications, there did not seem to be a significant difference in the type of publications by gender. The majority of publications were classified as original research, followed by review, commentary, and case report (Table 1, Fig. 1). On multivariable linear regression analysis, we found female gender was an independent predictor of decreased total number of publications, number of citations, and mean modified *h* index when controlling for residency size and any advanced degree (PhD or master's). Female gender was associated with a 0.75 decrease in total number of publications, 19.64 decrease in mean citations, and 0.48 decrease modified *h* index compared with male gender. Overall, gender was associated with various research productivity metrics despite similar residency size and attainment of advanced degrees between male and female graduates.

Table 1 Comparison of female and male radiation oncology graduates

	Total	Female	Male	*P* value
Total, n (%)	910	264 (29.0%)	646 (71.0%)	
PhD, n (%)	199 (21.9%)	51 (19.3%)	148 (22.9%)	.23
Any advanced degree, n (%)	347 (38.1%)	88 (33.3%)	259 (40.1%)	.05
Residency size, n (%)				.58
≤6	248	68 (27.4%)	180 (72.5%)	
>6	662	196 (29.6%)	466 (70.4%)	
Mean number of publications, n (SD)	2.9 (3.8)	2.5 (2.7)	3.1 (4.1)	.02*
Mean number of citations, n (SD)	13.6	11.4 (17.0)	14.4 (25.6)	.0007*
Mean IF, n (SD)	4.8	4.3 (4.9)	4.9 (6.5)	.006*
Modified *h* index, n (SD)	2.0 (2.1)	1.7 (1.7)	2.1 (2.2)	.02*
Type of publication, n (%)				.53
Original research	1868 (70.8%)	482 (72.6%)	1386 (70.2%)	
Review	360 (13.6%)	84 (12.7%)	276 (14.0%)	
Case report	172 (6.5%)	43 (6.5%)	129 (6.5%)	
Commentary	238 (9.0%)	55 (8.3%)	183 (9.3%)	
Original research, n (%)				.95
Basic science	69 (3.7%)	15 (3.1%)	54 (3.9%)	
Health economics	46 (2.5%)	9 (1.9%)	37 (2.7%)	
Physics/dosimetry	122 (6.5%)	27 (5.6%)	95 (6.9%)	
Retrospective	1375 (73.6%)	354 (73.4%)	1021 (73.7%)	
Secondary analysis	61 (3.3%)	9 (1.9%)	52 (3.8%)	
Surveys	66 (3.5%)	26 (5.4%)	40 (2.9%)	
Trials	87 (4.7%)	33 (6.8%)	54 (3.9%)	
Other	42 (2.2%)	9 (1.9%)	33 (2.4%)	

Abbreviations: IF = impact factor; SD = standard deviation.
* $P < .05$ was considered statistically significant.

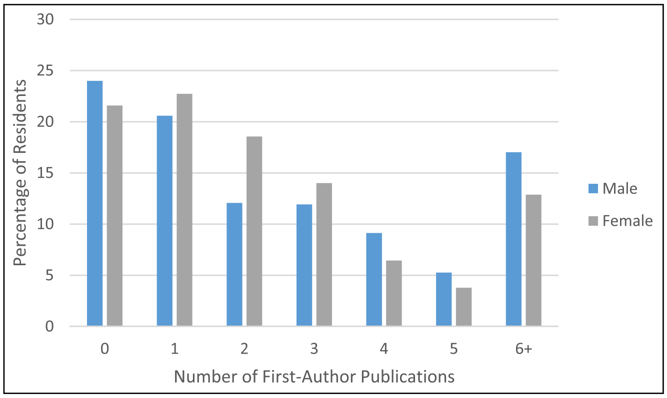

Figure 1 The distribution of the number of first-author publications during residency by gender.

Further, for each unit increase in residency size, there was a 0.14 increase in total number of publications, 3.47 increase in mean number of citations, 0.19 increase in mean IF, and 0.11% increase in modified *h* index. If the trainee had an advanced degree (master's or PhD), there was a 0.61 decrease in the total number of publications and 0.28 decrease in the modified *h* index during residency compared with trainees without an advanced degree (Table 2).

We found that 54.5% of female graduates were working for an academic center. Women working in academia had significantly more first-author publications during their residency, with 3.1 ± 3.0 publications compared with 1.8 ± 2.2 publications for female graduates in a nonacademic position ($P = .0002$).

Discussion

Women are underrepresented in RO. Female trainees comprised 29.0% of RO residents during our study period, in line with trends from 1980 to 2010[16] and recent cross-sectional analyses of RO resident graduates in 2019.[17,18] Moreover, there have been several studies indicating discrepancies in academic and professional achievements for female radiation oncologists.[3−8,19] Our study sought to determine whether these gender differences can be identified in female RO trainees.

In this study of recent resident graduates, we found gender differences in research productivity during residency that were not associated with an advanced degree or residency size. This study found significant discrepancies in several metrics of research productivity, including the total number of first-author PubMed-indexed publications, number of citations, IF, and modified *h* index. Despite similarities in the proportion of female trainees in large (>6) residencies and with advanced degrees, we found that female trainees had lower research productivity. Female gender was significantly associated with a decreased number of total publications, modified *h* index, and number of citations. In particular, it appears that male and female residents have a similar likelihood of producing 0 to 3 first-author publications, but male residents are more likely to produce 4+ first-author publications compared with female residents (Fig. 1). Our data suggest that the greatest barriers for female RO trainees are in "large"-volume publishing (ie, 4+) rather than "average"-volume publishing. The types of articles RO trainees published did not differ by gender, with a majority publishing original research.

In terms of the types of jobs female RO graduates obtained, we found that the number of female RO trainees entering academia was 54.5% for graduates between 2015 and 2019. These graduates in academia had significantly more total first-author publications compared with graduates in nonacademic positions. To date, there has not

Table 2 Multivariable linear regression analysis of bibliometric indices

	Residency size			Master's or PhD			Female gender		
	Intercept	Standard error	*P* value	Intercept	Standard error	*P* value	Intercept	Standard error	*P* value
Total publications	0.14	0.02	<.001*	−0.61	0.26	.02*	−0.75	0.27	.005*
Mean citations	3.47	0.44	<.001*	−4.83	5.44	.38	−19.64	5.73	<.001*
Mean IF	0.19	0.02	<.001*	0.49	0.28	.08	−0.25	0.30	.40
Modified *h* index	0.11	0.01	<.001*	−0.28	0.14	.04*	−0.48	0.15	.001*

Abbreviation: IF = impact factor.
* $P < .05$ was considered statistically significant.

been an evaluation of gender differences in practice setting. In 2019, there was a survey of recent RO residency graduates regarding workforce placement, which found 51% of respondents worked in an academic setting and 49% worked in private practice.[20] In 2021, Sindhu et al demonstrated female residents were significantly more likely to accept an academic position compared with male residents.[21] Another workforce study performed by the American Society for Radiation Oncology found a shift from predominantly private practice to a more equivalent balance with academic settings.[19] Our data are reflective of these previous practice entry surveys, but we could not determine whether there was a significant different in practice setting based on gender.

These findings suggest that disparities occur early in a physician's career and likely persist on completion of residency. The substantial gender differences in research productivity found in this study indicate a need to reduce barriers to resident research engagement while residents are in training. Holliday et al suggest early mentorship and career development may narrow gender disparities in research productivity.[22] As research productivity is used as a performance metric for promotion and tenure-track assessment in many academic institutions, an intervention to close the gender gap on research productivity could contribute to greater female representation in academic and leadership positions. Future interventions designed to improve resident research engagement and expand mentorship opportunities will be important.[11] Although early-career mentorship is likely to be helpful, the identification of barriers to participation in research will fully inform future interventions. A study investigating perceived barriers of female residents also could help facilitate targeted interventions.

The reason for gender differences in research productivity is undoubtedly multifactorial. It is well established that there is a disproportionate burden of child care and domestic duties on women[23] but similar career aspirations and desire for research productivity compared with men.[24] A recent survey study demonstrated disparate child care responsibilities, with male residents and recent graduates reporting performing 25% of child care duties and a majority having nonemployed partners, whereas female residents and recent graduates reported performing the majority of child care duties.[24] In addition, female residents and recent graduates took more leave than their male counterparts, but Holliday et al[24] did not find a significant difference in academic career aspirations between women and men. Previous research has demonstrated that female residents performed approximately 8.5 more hours in domestic activities weekly than male residents.[23] Female physicians face unique challenges, including pregnancy, postpartum recovery, and child care duties. These challenges are exacerbated by a lack of maternity and paternity leave, affordable child care, and flexible schedules in the US.[25,26] The unequal division of child care duties has implications on academic achievement. Inflexible timing of the American Board of Radiology Radiation Oncology Initial Certification examinations and punitive payment models are some additional barriers to academic achievement and compensation. Dover et al[27] shed light on the effect of rigid board examination scheduling on RO trainees. In this study, an Internet-based survey of early-career female radiation oncologists graduating residency between 2016 and 2021 found 58% delayed timing of pregnancy or adoption to schedule American Board of Radiology Radiation Oncology Initial Certification examinations, 88% reported inadequate accommodations for lactation during an examination, and >50% of respondents reported board certification had a significant effect on promotion, partnership, and salary.[27] Taken together, the unequal distribution of child care duties, expensive child care, the lack of mandatory parental leave, and inflexible work and board examination schedules reinforce gender inequities, particularly in academic RO. The decreased research productivity among female RO residents suggests that gender disparities begin early in a female physician's career. Although interventions to improve research engagement and mentorship would be helpful, there are also deep-seated systemic issues that will need to be addressed.

There are some limitations to this study. Research productivity is one metric of academic achievement and does not give a complete record of achievement in female trainees. It is also possible that publications were undercounted due to surname alteration even with additional steps taken to confirm trainee identity. Further contributing to an underestimation of research productivity, the predefined criteria of publications within 3 months of graduating may have excluded publications that were delayed and therefore missed by this analysis. The reasons for decreased publication could not be explicitly determined and can only be postulated without a prospective survey study. Because all data were collected from publicly available sources without the ability to verify individual-level data, our study is susceptible to sampling bias and missing information. There are also several limitations in regard to the variables we collected. It is suggested that h index is a good metric of research productivity, as it reflects the importance of an individual's publications rather than quantity alone. The h index is directly associated with career duration. The m index is a better measure of productivity because it corrects for longer career duration; however, our modified h index accounts for time because we only included publications during a prespecified time frame. In this study, we were only able to calculate a modified h index due to the restricted time frame and inclusion of only first-author PubMed-indexed publications. Despite collecting gender information for our entire cohort, gender was only classified in a binary manner. Thus, the database did not capture individuals who are gender nonbinary. However, this study serves as one of the most comprehensive studies of US RO residents, with a near-complete census of all US RO residents between 2015 and 2019.

Conclusion

In the US, female RO trainees had lower research productivity that was not explained by having an advanced degree or by residency size. Gender appears to be associated with various bibliometrics including IF, *h* index, first-author publications, and the average number of citations. A significant gender gap in trainee research productivity persists, which has known implications in terms of academic achievement, promotions, and career trajectory. Future interventions are warranted to identify and alleviate barriers to resident research engagement. Moreover, future studies should evaluate the effect of the number of women in senior RO faculty positions and formal mentorship pathways for female trainees.

References

1. Association of American Medical Colleges. 2022 FACTS: Applicants and matriculants data. Available at: https://www.aamc.org/data-reports/students-residents/interactive-data/2022-facts-applicants-and-matriculants-data. Accessed November 12, 2022.
2. Association of American Medical Colleges. Table B3. Number of active residents, by type of medical school, GME specialty, and sex. Available at: https://www.aamc.org/data-reports/students-residents/interactive-data/report-residents/2021/table-b3-number-active-residents-type-medical-school-gme-specialty-and-sex. Accessed July 20, 2022.
3. Chowdhary M, Chowdhary A, Jones GP, et al. Gender and racial/ethnicity dyad disparities in academic radiation oncology. *Int J Radiat Oncol Biol Phys*. 2020;108:e441.
4. Jagsi R, Griffith KA, Stewart A, Sambuco D, DeCastro R, Ubel PA. Gender differences in salary in a recent cohort of early-career physician−researchers. *Acad Med*. 2013;88:1689-1699.
5. Perni S, Bitterman D, Ryan J, et al. Gender, productivity, and philanthropic fundraising in academic oncology. *J Natl Compr Canc Netw*. 2021;19:1401-1406.
6. Guss ZD, Chen Q, Hu C, Guss LG, DeWeese TL, Terezakis SA. Differences in physician compensation between men and women at United States public academic radiation oncology departments. *Int J Radiat Oncol Biol Phys*. 2019;103:314-319.
7. Jagsi R. Sex differences in attainment of independent funding by career development awardees. *Ann Intern Med*. 2009;151:804.
8. Holliday EB, Jagsi R, Wilson LD, Choi M, Thomas CR, Fuller Clifton D. Gender differences in publication productivity, academic position, career duration and funding among U.S. academic radiation oncology faculty. *Acad Med*. 2014;89:767-773.
9. Morgan PB, Sopka DM, Kathpal M, Haynes JC, Lally BE, Li L. First author research productivity of United States radiation oncology residents: 2002-2007. *Int J Radiat Oncol Biol Phys*. 2009;74:1567-1572.
10. Rowley JP, Sindhu KK, Smith WH, et al. Radiation oncology resident research productivity in the United States: 2015 to 2019. *Int J Radiat Oncol Biol Phys*. 2021;109:1111-1118.
11. Rana S, Holliday EB, Jagsi R, et al. Scholastic activity among radiation oncology residents at US academic institutions: A benchmark analysis. *J Cancer Educ*. 2013;28:541-546.
12. Verma V, Burt L, Gimotty PA, Ojerholm E. Contemporary trends in radiation oncology resident research. *Int J Radiat Oncol Biol Phys*. 2016;96:915-918.
13. Sindhu KK, Rowley JP, Smith WH, et al. The rise of open access journals in radiation oncology: Influence on resident research, 2015-2019. *Adv Radiat Oncol*. 2023;8:101121.
14. Hirsch JE. An index to quantify an individual's scientific research output. *Proc Natl Acad Sci U S A*. 2005;102:16569-16572.
15. Sindhu KK, Rowley JP, Smith WH, et al. The Holman research pathway in radiation oncology: 2010 to 2019. *Int J Radiat Oncol Biol Phys*. 2021;111:627-637.
16. Ahmed AA, Hwang WT, Holliday EB, et al. Female representation in the academic oncology physician workforce: Radiation oncology losing ground to hematology oncology. *Int J Radiat Oncol Biol Phys*. 2017;98:31-33.
17. Rowley JP, Sindhu KK, Bakst RL, Buckstein M. In regard to Mattes et al. *Adv Radiat Oncol*. 2022;7:100892.
18. Thomas TVV, Kuruvilla TP, Bhanat E, et al. Gender disparities in radiation oncology residency programs in the United States�current status. *Int J Radiat Oncol Biol Phys*. 2019;105(suppl):S64-S65.
19. McClelland S, Huang CC, Griffith KA, et al. Composition of the current academic radiation oncology workforce in comprehensive cancer centers. *JCO Oncol Pract*. 2022;18:E740-E747.
20. Royce TJ, Doke K, Wall TJ. The employment experience of recent graduates from US radiation oncology training programs: The practice entry survey results from 2012 to 2017. *J Am Coll Radiol*. 2019;16:878-885.
21. Sindhu KK, Hsieh K, Sindhu TM, Rowley JP. Geographic employment outcomes for graduating residents in radiation oncology [e-pub ahead of print]. *Pract Radiat Oncol*. 2021. https://doi.org/10.1016/j.prro.2022.10.003. Accessed November 12, 2022.
22. Holliday EB, Siker M, Chapman CH, et al. Achieving gender equity in the radiation oncology physician workforce. *Adv Radiat Oncol*. 2018;3:478-483.
23. Jolly S, Griffith KA, DeCastro R, Stewart A, Ubel P, Jagsi R. Gender differences in time spent on parenting and domestic responsibilities by high-achieving young physician−researchers. *Ann Intern Med*. 2014;160:344-353.
24. Holliday EB, Ahmed AA, Jagsi R, et al. Pregnancy and Parenthood in Radiation Oncology, Views and Experiences Survey (PROVES): Results of a blinded prospective trainee parenting and career development assessment. *Int J Radiat Oncol Biol Phys*. 2015;92:516-524.
25. Lightfoote JB, Fielding JR, Deville C, et al. Improving diversity, inclusion, and representation in radiology and radiation oncology part 2: Challenges and recommendations. *J Am Coll Radiol*. 2014;11:764-770.
26. Foster CC, Hasan Y, Son CH, McCall AR. Linearly accelerating toward gender equity in radiation oncology. *Int J Radiat Oncol Biol Phys*. 2019;104:974-978.
27. Dover LL, Hentz C, Kahn JM, et al. Implications of medical board certification practices on family planning and professional trajectory for early career female radiation oncologists. *Pract Radiat Oncol*. 2022;12:95-102.