Title: Gender differences in the research productivity of Radiation Oncology Resident Graduates in the United States: 2015 to 2019

Short Running Title: Gender disparities in research productivity

Authors: Brianna M. Jones MD¹, Jared P. Rowley MD², Kunal K. Sindhu MD¹, Eric J. Lehrer MD, MS¹, Kristin Hsieh MD¹, Anthony D. Nehlsen MD¹, Sheryl Green MBBCh¹, Karyn A. Goodman MD¹

¹Department of Radiation Oncology, Icahn School of Medicine at Mount Sinai, New York, New York, United States
²Department of Radiation Oncology, Maimonides Medical Center, Brooklyn, New York, United States

Corresponding Author: Brianna M. Jones MD
Department of Radiation Oncology
Icahn School of Medicine at Mount Sinai
New York, NY 10029
E: brianna.jones@mountsinai.org

Author Responsible for Statistical Analysis: Eric J. Lehrer, MD
Department of Radiation Oncology
Icahn School of Medicine at Mount Sinai
New York, NY 10029
E: eric.lehrer@mountsinai.org
Disclosures: the authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Funding: None

Data Availability Statement: Research data area stored in an institutional repository and will be shared upon request to the corresponding author.

Journal: Advances in Radiation Oncology

Text word count: 2,559

Abstract word count: 290

Tables: 2

Figure: 1

References: 26

Acknowledgements: None.

Funding sources: None

Conflicts of Interest: None
Abstract

Purpose: It is well-documented that gender disparities exist in academic radiation oncology departments. The purpose of this study is 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 (NPI) and Medicare claims registry. Post-residency 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 (IF), number of citations, modified Hirsch index (h index), and type of publication was performed. A multivariable linear regression was performed to evaluate the impact of gender on research productivity during residency.

Results: There were 910 total graduates identified during this period and were entered into this database, all of whom had available gender information. Female trainees comprised 29.0% (n=264) of RO residents. Females had fewer first-author publications and citations, lower mean modified h index, and were published in journals with lower IFs. On multivariable linear regression analysis, female gender was independently associated with decreased total number of publications (p=0.005), mean number of citations (p<0.001), and modified h index (p=0.001) when controlling for residency size and advanced (PhD or Masters) degree.
Conclusions: In the US, female RO trainees had lower research productivity, which was not explained by advanced degree, 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.

Key words: gender disparities, medical education, radiation oncology, residents, research, publications

1. Introduction

Females now represent more than half (55.6%) of all medical matriculates (AAMC 2022). Despite this significant rise, there has not been a proportionate increase in representation of women in the field of radiation oncology; in fact, as of 2021, women constituted only 30.3% of residents and 17.4% of leadership positions. Previous studies have shown that underrepresentation of women in the field, particularly in leadership positions, can also lead to disparities in research funding, philanthropic donations, salary, research productivity, and appointment to leadership positions. This can impact the retention of women in academic radiation oncology, 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 (ACGME) 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 radiation oncology residency training. Research productivity among US radiation oncology residents has been steadily increasing, with mean first-author publications of graduates rising from 1.01 between 2002 and 2007 to 2.90 between 2015 and 2019. Despite these promising trends, continued gender
differences in productivity, as measured by number of publications and $h$ index, have been demonstrated.\textsuperscript{8,11}

Previous work has demonstrated male sex was predictive of increased number of first-author publications during residency.\textsuperscript{10} This discrepancy in research productivity has implications for future promotion, salary, and career trajectory.\textsuperscript{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 radiation oncology resident research productivity.

2. Methods and Materials

We created a comprehensive database of US Radiation Oncology residents who graduated from ACGME-accredited residency training programs between 2015 and 2019. Data was collected from publicly available sources, including the Association of Residents in Radiation Oncology (ARRO) directory, National Plan and Provider Enumeration System National Provider Identifier Registry, 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 his or her residency program.\textsuperscript{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. Hirsch index is defined as the number of publications with citations $\geq h$.\textsuperscript{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, reviews, commentaries, or case reports. Original research was further classified into subcategories including retrospective analysis, basic science, secondary analysis, physics/dosimetry, clinical trials, and other work. The number of citations for each publication was determined using SCOPUS or PubMed and the Journal of Citation Reports was used to determine the impact factor of each journal. In order to avoid missing any publications due to alterations in surname, additional searches were performed, as described below.

We collected gender information from a combination of Medicare claims and the NPI registry. 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 (e.g., 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 (i.e., institutional websites, Doximity, LinkedIn) was performed to corroborate research publications and educational backgrounds/institutional affiliations.

Post-residency employment information was collected for female trainees using publicly available sources, including hospital/institutional websites, Doximity, LinkedIn, and the NPI registry. The employment information gathered included first and current job, job title, and address. Additionally, 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. 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 mean, median, and standard deviation for PhD status, residency size, total number of PubMed-indexed first author publications, IF of journal, modified $h$ index, number of citations in both male and female radiation oncology graduates. A normal distribution of all variables were verified. Chi square analysis, Fischer exact, or student’s t-test was performed to compare male and female radiation oncology 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<0.05 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 publically available data (XX-XXXXX).

3. Results

We identified 910 radiation oncology (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, and 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 reviews, commentaries, and case reports. See Table 1 and Figure 1 for further details. 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 Masters). 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 males. Overall, gender was associated with various research productivity metrics despite similar residency size and attainment of advanced degrees between male and female graduates.

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 (Masters 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. See Table 2.

We found that 54.5% of female graduates were working for an academic center. Women working in academia had significantly more total number of first-author publications during their residency, with 3.1 ± 3.0 publications compared to 1.8 ± 2.2 publications for female graduates in a non-academic position (p=0.0002).

4. Discussion

Women are underrepresented in radiation oncology. Female trainees comprised 29.0% of RO residents during our study period, in line with trends from 1980 to 2010\textsuperscript{16} and recent cross-sectional analyses of RO resident graduates in 2019.\textsuperscript{17,18} Moreover, there have been several studies indicating discrepancies in academic and professional achievements for female radiation oncologists.\textsuperscript{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, impact factor, and modified $h$ index. Despite similarities in the proportion of female trainees in large (>6) residencies and with advanced degrees, we found that females 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 0-3 first author publications, but male residents are more likely to produce 4+ first author publications as compared to females (see Figure 1). Our data suggests that the greatest barriers for female RO trainees are in “large” volume publication (i.e., 4+) rather than “average” volume publishing. The types of papers 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 to graduates in non-academic positions. To date, there has not 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. In 2021, Sindhu et al demonstrated female residents were significantly more likely to accept an academic position compared to male residents. Another workforce study performed by ASTRO found a shift from predominantly private practice to a more equivalent balance with academic settings. Our data is reflective of these previous practice entry surveys, but it 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 upon 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 and colleagues suggest early mentorship and career development may narrow gender disparities in research productivity. 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 higher female representation in academic and leadership positions. Future interventions designed to improve resident research engagement and expand mentorship opportunities will be important. While 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 could also help facilitate targeted interventions.

The reason for gender differences in research productivity is undoubtedly multifactorial. It is well-established there is a disproportionate burden of childcare and domestic duties on females, but similar career aspirations and desire for research productivity as compared to males. A recent survey study demonstrated disparate child care responsibilities, with male residents and recent graduates reporting performing 25% of childcare duties and a majority having nonemployed partners, whereas females reported performing the majority of childcare duties. Additionally, females took more leave than their male counterparts, but Holliday and colleagues did not find a significant difference in academic career aspirations between women and men. Prior research has demonstrated that females performed approximately 8.5 more hours on domestic activities weekly than males. Female physicians face unique challenges including pregnancy, postpartum recovery, and childcare duties. These challenges are exacerbated by lack of maternity and paternity leave, affordable childcare, and flexible schedules in the United States. The unequal division of childcare duties have implications on academic achievement. Inflexible timing of the American Board of Radiology (ABR) radiation oncology initial certification (RO-IC) examinations and punitive payment models are some additional barriers to academic achievement and
compensation. Dover and colleagues shed light on the impact of rigid board exam schedule on radiation oncology 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 ABR RO-IC examinations, 88% reported inadequate accommodations for lactation during an examination, and over 50% of respondents reported board certification had a significant impact on promotion, partnership, and salary. Taken together, the unequal distribution of childcare duties, expensive childcare, the lack of mandatory parental leave, and inflexible work and board exam schedules reinforce gender inequities, particularly in academic radiation oncology. The decreased research productivity among female radiation oncology residents suggests that gender disparities begin early in a female physician’s career. While 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 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. Since all data was 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 regards 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; m-index is a better measure of productivity since it corrects for longer career duration, however our modified h index accounts for time since we only included publications during a pre-specified 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 radiation oncology residents with a near complete census of all US radiation oncology residents between 2015 and 2019.

5. Conclusions

In the US, female RO trainees had lower research productivity, which was not explained by having an advanced degree or 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 impact of the number of women in senior RO faculty positions and formal mentorship pathways for female trainees.

6. References


Figure legends.
Figure 1: The distribution of the number of first-author publications during residency by gender.
## Table 1. Comparison of female and male radiation oncology graduates.

<table>
<thead>
<tr>
<th></th>
<th>Total No.</th>
<th>Female</th>
<th>Male</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (n, %)</td>
<td>910</td>
<td>264 (29.0%)</td>
<td>646 (71.0%)</td>
<td></td>
</tr>
<tr>
<td>PhD (n, %)</td>
<td>199 (21.9%)</td>
<td>51 (19.3%)</td>
<td>148 (22.9%)</td>
<td>0.23</td>
</tr>
<tr>
<td>Any advanced degree (n, %)</td>
<td>347 (38.1%)</td>
<td>88 (33.3%)</td>
<td>259 (40.1%)</td>
<td>0.05</td>
</tr>
<tr>
<td>Residency size (n, %)</td>
<td></td>
<td></td>
<td></td>
<td>0.58</td>
</tr>
<tr>
<td>≤6</td>
<td>248</td>
<td>68 (27.4%)</td>
<td>180 (72.5%)</td>
<td></td>
</tr>
<tr>
<td>&gt;6</td>
<td>662</td>
<td>196 (29.6%)</td>
<td>466 (70.4%)</td>
<td></td>
</tr>
<tr>
<td>Mean number of publications (n, std)</td>
<td>2.9 (3.8)</td>
<td>2.5 (2.7)</td>
<td>3.1 (4.1)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Mean number of citations (n, std)</td>
<td>13.6</td>
<td>11.4 (17.0)</td>
<td>14.4 (25.6)</td>
<td>0.0007*</td>
</tr>
<tr>
<td>Mean IF (n, std)</td>
<td>4.8</td>
<td>4.3 (4.9)</td>
<td>4.9 (6.5)</td>
<td>0.006*</td>
</tr>
<tr>
<td>Modified h index (n, std)</td>
<td>2.0 (2.1)</td>
<td>1.7 (1.7)</td>
<td>2.1 (2.2)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Type of publication (n, %)</td>
<td></td>
<td></td>
<td></td>
<td>0.53</td>
</tr>
<tr>
<td>Original research</td>
<td>1868 (70.8%)</td>
<td>482 (72.6%)</td>
<td>1386 (70.2%)</td>
<td></td>
</tr>
<tr>
<td>Reviews</td>
<td>360 (13.6%)</td>
<td>84 (12.7%)</td>
<td>276 (14.0%)</td>
<td></td>
</tr>
<tr>
<td>Case reports</td>
<td>172 (6.5%)</td>
<td>43 (6.5%)</td>
<td>129 (6.5%)</td>
<td></td>
</tr>
<tr>
<td>Commentaries</td>
<td>238 (9.0%)</td>
<td>55 (8.3%)</td>
<td>183 (9.3%)</td>
<td></td>
</tr>
<tr>
<td>Original research (n, %)</td>
<td></td>
<td></td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td>Basic Science</td>
<td>69 (3.7%)</td>
<td>15 (3.1%)</td>
<td>54 (3.9%)</td>
<td></td>
</tr>
<tr>
<td>Health Economics</td>
<td>46 (2.5%)</td>
<td>9 (1.9%)</td>
<td>37 (2.7%)</td>
<td></td>
</tr>
<tr>
<td>Physics/Dosimetry</td>
<td>122 (6.5%)</td>
<td>27 (5.6%)</td>
<td>95 (6.9%)</td>
<td></td>
</tr>
<tr>
<td>Retrospective</td>
<td>1375 (73.6%)</td>
<td>354 (73.4%)</td>
<td>1021 (73.7%)</td>
<td></td>
</tr>
<tr>
<td>Secondary Analysis</td>
<td>61 (3.3%)</td>
<td>9 (1.9%)</td>
<td>52 (3.8%)</td>
<td></td>
</tr>
<tr>
<td>Surveys</td>
<td>66 (3.5%)</td>
<td>26 (5.4%)</td>
<td>40 (2.9%)</td>
<td></td>
</tr>
<tr>
<td>Trials</td>
<td>87 (4.7%)</td>
<td>33 (6.8%)</td>
<td>54 (3.9%)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>42 (2.2%)</td>
<td>9 (1.9%)</td>
<td>33 (2.4%)</td>
<td></td>
</tr>
</tbody>
</table>

*p<0.05 was considered statistically significant*
Table 2. Multivariable linear regression analysis of bibliometric indices

<table>
<thead>
<tr>
<th></th>
<th>Residency size</th>
<th>Masters or PhD</th>
<th>Female gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept</td>
<td>Std error</td>
<td>p-value</td>
</tr>
<tr>
<td>Total publications</td>
<td>0.14</td>
<td>0.02</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Mean citations</td>
<td>3.47</td>
<td>0.44</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Mean IF</td>
<td>0.19</td>
<td>0.02</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Modified $h$ index</td>
<td>0.11</td>
<td>0.01</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

*p<0.05 was considered statistically significant