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# Diversity Drives Representation: An Internal Audit of Gender Representation in Citation Practices of a Single Surgical Laboratory

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**Background:** Large-scale retrospective studies have identified implicit gender bias in citation behaviors across multiple medical fields. There are minimal resources to directly assess one's own citation behavior before publication at a laboratory level. In this study, we performed an internal audit of our own citation practices and behavior, looking at the representation of authors by gender in our own bibliographies.

**Methods:** Bibliographies were collated from our laboratory's publications between 2015 and 2022 with a single senior author, who was excluded from participating in this study. Bibliographies were run through a simulation originally constructed and used by authors from the University of Pennsylvania that categorized authors of each article by gender: man or woman, according to external database records.

**Results:** Of the 1697 citations, the first and last authorship sequences displayed to be 60.8% male/male, 10.1% male/female, 16.3% female/male and 12.8% female/female. Men-led articles within our laboratory cited 67.4% male/male articles in their bibliographies compared with women-led articles citing 53.9%. All laboratory bibliographies consisted of 77.1% male senior authors compared with 22.9% female senior authors.

**Conclusions:** Our data confirm that a gender bias in citation practices exists at the laboratory level. Promisingly, these data also indicate that diversity within an individual laboratory group leads to diversity in representation; therefore, diversifying a team of researchers is prone to improve the overall work and success of the laboratory. We encourage laboratory groups to challenge their own biases by replicating their own results and discovering how these biases might be impacting their publications. *(Plast Reconstr Surg Glob Open 2024; 12:e5823; doi: 10.1097/GOX.0000000000005823; Published online 14 June 2024.)*

## INTRODUCTION

"The leaky pipeline" describes the loss in women's leadership, moving up the academic ladder. There has been a slight narrowing of the gender gap in medical graduates from 1965 to 2016,[1] but when examining senior positions in academia, gender role incongruence is apparent.[2–8] There is an underrepresentation of women speakers at scientific conferences[9–11] and less funding for women-led medical research.[12–15] Women were less likely to receive research awards in subspecialties of hematology, oncology, and physiatry[16–18] and were outnumbered in winning Nobel prizes in any medical field.[19] Women-led articles are cited less often than men-led articles.[20–30] This discrepancy serves as a prime example of implicit gender bias in citation behaviors.

Homophily, defined as "contact between similar people occurring at a higher rate than among dissimilar people," elicits disproportionate coauthorship across all collaboration types.[31] The following concepts provide theories for the overrepresentation of men in scientific publications. The "Matilda effect" suggests that women's accomplishments are less frequently recognized and often disregarded compared with male counterparts.[16,18] The "Matthew effect" suggests that the status and reputation

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of the author define the quality of an article.[32] Historically, women have been afforded lower social status than men,[33] which translates into less credibility assigned to women's work. These stereotypes disproportionately impact women's capacity for success due to pro-male bias.[34–37] Both theories find gender disparity as a consequence of unintentional bias when looking at citation behaviors. A study of 1.5 million research articles showed that men cited their male colleagues 56% more often than women scholars.[37] Data also revealed that same-sex collaboration was three times more apparent with male authors. Both genders tended to co-author with men, despite claims of women having stronger gender homophily in research.[38] Literature from mixed-gender collaborations indicates higher quality research compared with same-gender collaborations.[39–41] Although there have been efforts to recruit more female medical professionals, the visibility of women-led articles remains scarce in medical research, such as neuroscience.[20,21,42–47] The field of plastic surgery is an exception when it comes to more equitable representation of women.[41,48–50]

Surveys showed that female medical students felt discouraged from pursuing a surgical career due to lifestyle/family commitments (99%) and that there is a shortage of women role models and mentors (57%).[49] Furthermore, women residents stated that lack of access to same-sex collaborations and academic support serve as limitations when considering advancing their careers in surgery.[51] Women should have the opportunity to find mentors from a similar sociocultural perspective that can relate to unique challenges by providing role modeling, work–life guidance, and networking opportunities.[52,53] Specific interventions identified as necessary for their career continuation included a flexible work–life balance schedule and increased women-led mentorship.[54,55] Subspecialties of medical and radiation oncology showed that higher percentages of women faculty were led by women physicians.[56] Gender diversity within high-position faculty remains a driving influence to attract more women students and residents to medical disciplines.[49]

Recent studies reviewing medical publishing practices suggest reviewing gender equity within citation lists before publication.[57] Previous studies have compared the gender of authorship to quantitative citation trends.[58–60] However, there are limited resources for laboratories to directly self-assess their publication behavior. In response, we used a validated method designed to quantify author gender.[20] We hypothesized (1) an overrepresentation of men-led publications compared with women-led publications overall, and (2) less undercitation of women in women-led articles. We aimed to encourage other teams to address their citation practices to increase equity among their members and create a more diverse research environment.

**Takeaways**

**Question:** Does gender bias in citation practices exist at the laboratory level?

**Findings:** Bibliographies were collated from our laboratory's publications between 2015 and 2022 with a single senior author, who was excluded from participating in this study, and run through a simulation that categorized authors by binary gender. Articles written by men in our laboratory were more likely to cite articles with male first and last authors, than women in our laboratory (67.4% versus 53.9%, respectively).

**Meaning:** Our data confirm that a gender bias in citation practices exists at the laboratory level and that diversity within an individual laboratory group leads to diversity in representation.

## METHODS

We performed an audit focusing on bibliographies within publications from a single male senior author in our microsurgical laboratory in the Department of Plastic Surgery at the University of Wisconsin-Madison. The internal audit reported the gender of the first and last authors within the reference lists of each article published since the laboratory's establishment from January 2015 to December 2022.

Diversity benchmarks in this study were two genders or sexes: woman and man. The social category of "gender" and the biological category of "sex" are used interchangeably as we analyzed names assigned according to their biological sex. The label "female" or "male" was assigned by the Gender API database to authors whose name had a 70% probability (or more) of being given to someone assigned female or male sex at birth or who identifies with female or male sex on social media.[20] PubMed was used to search all publications approved and peer-reviewed by a single senior author. This methodology is presented as a step-by-step guide for direct replication and summarized in Figure 1.

### Zotero

Zotero (by Corporation for Digital Scholarship, version 5.0.96.3) was used to sort each original article (OA) by its bibliography. Different collections were created for each year studied, and subcollections were created for each OA. The OA bibliographies (OAB) were uploaded on each assigned subcollection.

For each OAB, we removed middle authors, as well as middle names or initials. For OABs that did not include the author's full first name, different databases were searched. (eg, if Zotero exported an author named "Smith, J.," we searched to find that "J" was for "James"). If no full name was found, the article was excluded. Additionally, OABs that had the same first/last author as OA (self-citations) were removed to decrease potential bias.

After repeating the process for each OAB, we selected the subfile of each A, right-clicked, and selected "export collection" and "BibTeX" format.

### CleanBib Simulation

Accessed through GitHub (https://github.com/dalejn/cleanBib#instructions) to run data. To launch the coding environment, the user scrolled down to the

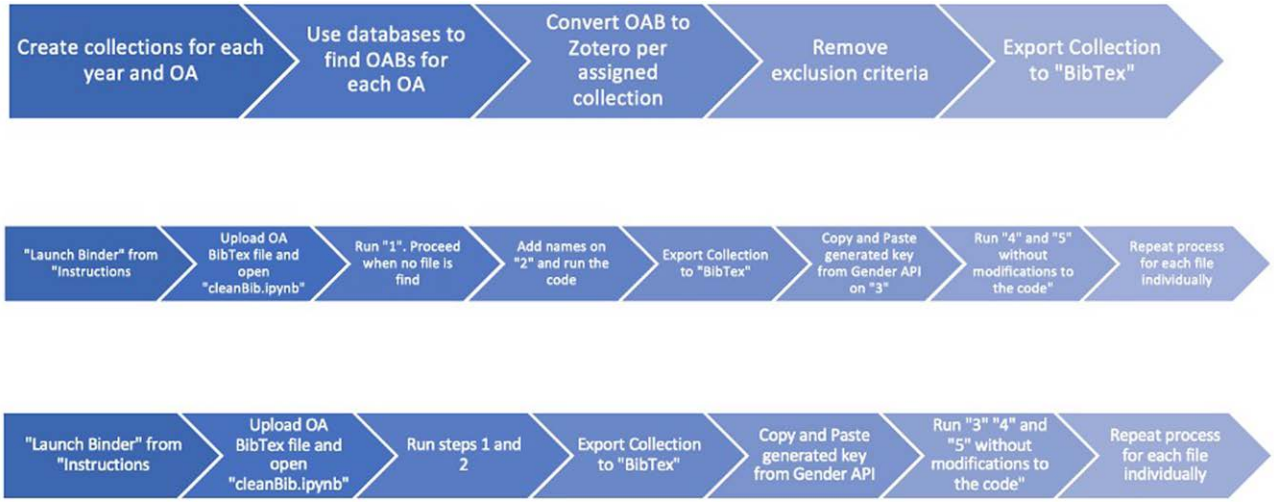


**Fig. 1.** Flowchart presenting step-by-step guide of methodology, including Zotero, CleanBib Simulation, and Microsoft Excel.

"instructions" section and selected "launch binder" from Step 2. "Upload" was selected from the upper-right corner, and the OA's BibTeX file was uploaded from Zotero. Once uploaded, the "cleanBib.ipynb" file (easy-bibb R-mgcv package in R – and Python – ethicolr package) was launched.

1. "Import functions"
   - Clicked on the box under Step 1 and pressed "run" on the upper tab.
   - Proceeded to the next step once the message "no optional.tex file found" appeared.
2. "Define the *first* and *last* author of your article"
   - Added the last and first names of the authors from the selected OA and reran the code.
     i. E.g,: yourFirstAuthor = "Smith, James"; yourLastAuthor= "Cohen, Grace."
   - Once a list with the author's first and last names appeared, we proceeded.
3. "Estimate gender and race of authors from cleaned bibliography"
   - Created a free account on the Gender API database (https://gender-api.com), and generated a Gender API key.
   - Key copied and pasted into CleanBib, and code was executed.
     i. E.g.: genderAPI_key = "&key=12345abc"
   - No messages appeared following this code.
4. Describe the proportions of genders in your reference list and compare it with published base rates in neuroscience.
   - This step did not require further modifications; code was executed.
   - Once the red box showed 100%, the next steps were followed.
5. "Print the diversity statement and visualize your results"
   - No required modifications; code was executed.
   - Generated a citation diversity statement within the "plain text template" This process was repeated for each OA.

## RESULTS

### Data Description

Fifty-four OAs attributed to a single senior author were identified between 2015 and 2022. Self-citations, published abstracts, and publications of equal contribution were excluded. OABs yielded a total of 1697 publications, with the exclusion of articles that had unidentifiable authors.

### Gender Representation in Our Laboratory

Apart from 2016, laboratory publications increased from 2015 to 2022, with a notable rise in women first authors from 2018 to 2022 (Fig. 2). Although the male-to-female ratio of laboratory participants has fluctuated over the years (Table 1), it should be noted that most publications included in this study were published a year or more after the research was completed, indicating that the laboratory participants listed for a given year were not necessarily representative of the authors who were published in that same year (Fig. 2). Overall, the laboratory has consisted of more male than female members, dominated by undergraduate and medical students (Table 1).

### Gender Representation in Bibliographies

For each OAB, the simulation broke down subcategories of the first and last author by gender as listed: male and male (MM), male and female (MF), female and male (FM), and female and female (FF).

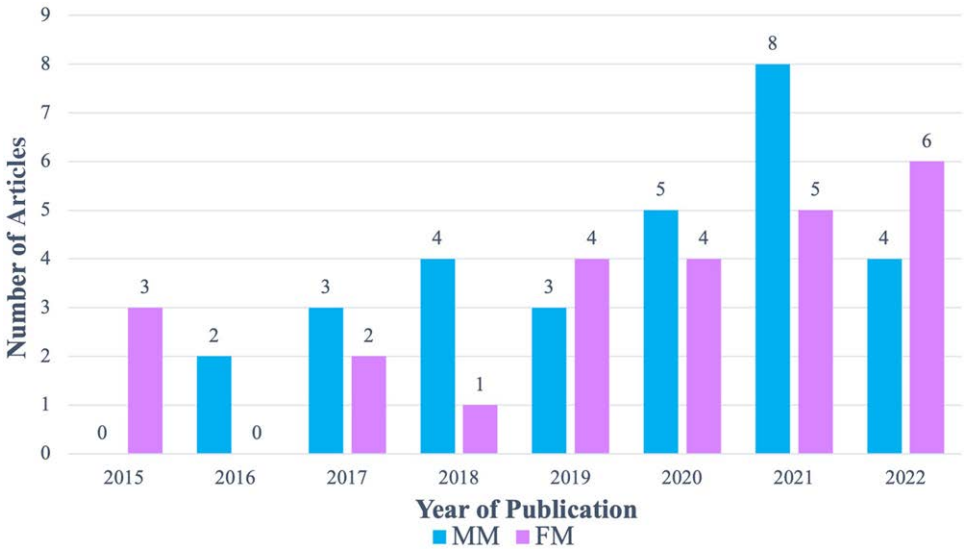


**Fig. 2.** Number of articles published by single male senior author with male or female first author. MM, male first author/male senior author; FM, female first author/male senior author.

**Table 1. Gender Representation of All Laboratory Members**

| | Undergraduate Students | | Medical Students | | Residents | | Laboratory Staff | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F | M | F |
| 2015 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 2016 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 2 |
| 2017 | 1 | 2 | 1 | 0 | 0 | 2 | 2 | 0 | 4 | 4 |
| 2018 | 3 | 2 | 1 | 0 | 1 | 1 | 2 | 0 | 7 | 3 |
| 2019 | 3 | 3 | 1 | 1 | 1 | 0 | 2 | 0 | 7 | 4 |
| 2020 | 3 | 2 | 1 | 4 | 1 | 0 | 2 | 0 | 7 | 6 |
| 2021 | 2 | 4 | 1 | 4 | 1 | 0 | 2 | 0 | 6 | 8 |
| 2022 | 4 | 5 | 3 | 2 | 1 | 1 | 2 | 0 | 10 | 8 |

M, male; F, female.

**Table 2. Gender Representation of Cited Authors from All Bibliographies Analyzed**

| Average % of All Data (2015-2022) | | | | |
|---|---|---|---|---|
| | MM | MF | FM | FF |
| 2015 | 25.0 | 10.0 | 10.0 | 55.0 |
| 2016 | 83.6 | 3.9 | 12.4 | 0.0 |
| 2017 | 56.3 | 16.4 | 24.7 | 2.5 |
| 2018 | 76.2 | 7.5 | 13.9 | 2.3 |
| 2019 | 60.4 | 12.9 | 20.2 | 8.6 |
| 2020 | 77.2 | 4.5 | 9.8 | 8.4 |
| 2021 | 57.8 | 7.4 | 19.5 | 14.5 |
| 2022 | 50.2 | 18.4 | 19.9 | 11.4 |
| Total | 60.8 | 10.1 | 16.3 | 12.8 |

Abbreviations: FF, female first author/ female senior author; FM, female first author/male senior author; MF, male first author/ female senior author; MM, male first author/male senior author.

Of the 1697 citations, 60.8% were MM, 10.1% were MF, 16.3% were FM, and 12.8% were FF (Table 2). If we consider two groups—MM and at least one female author in the authorship (F-U-F, which includes the FM, MF, and FF categories)—the percentage of male authors in citations (60.8%, Table 2) remains higher than the percentage of at least one woman in the authorship (39.2%, Table 2). Apart from 2015, there has been an increase in the percentage of FF citations over time (Table 2 and Figure 3) from 2016 (0%) to 2022 (11.4%). There is not a clear trend of increasing or decreasing percentages of either F-U-F or MM (Fig. 3); rather, the percentages vary from year to year in a nonlinear fashion.

In 2015, only three articles were analyzed, one of which had only two citations (FF), whereas the other two had 10 and 12 citations, respectively. In this study, authorship percentage of citations was weighted equally, regardless of the number of articles in their bibliography. As one out of the three articles had all citations (100%) that were FF, and therefore had the same weight as the other two articles, the average percentage of FF citations for 2015 was high compared with other articles analyzed. When analyzing trends of increasing or decreasing FF citations over the years, we did not consider the unscaled number of citations for 2015, as it is an outlier. This is a limitation of the size of our study compared with big-picture studies, as we were solely looking at the publications of a single senior author.

The average citation of MM authors in men-led OABs (67.4%, Table 3A) is higher than that of MM authors in


**Fig. 3.** Gender representation of cited authors from all bibliographies analyzed. MM, male first author/male senior author; MF, male first author/female senior author; FM, female first author/male senior author; FF, female first author/female senior author.

women-led OABs (53.9%, Table 3B). The average citation for FF authors was 1.66 times higher in women-led OABs (13.5%, Table 3B) than in men-led OABs (8.1%, Table 3A). If we consider two groups—citation of MM and F-U-F in women-led OABs—the average percent citation of F-U-F is 46.1%, whereas in men-led OABs this number is 33.1% (Table 3). For this analysis, the data from 2015 were also not considered when averaging each citation gender category of men-led articles (Table 3) because the laboratory did not publish any MM articles in that particular year. Similarly, the data from 2016 were not considered when taking the average for women-led articles (Table 3).

From all the data collected, regardless of the OAB originating from a men- or women-led article, the OAB citations consist of 77.1% male senior authors (MM and FM) compared with 22.9% female senior authors (MF and FF) (Table 2, Figure 3). There are 3.4 times more male senior authors within the 1697 OABs cited. In OABs cited by female primary authors, 25.1% of citations consisted of a female senior author, and 74.9% had a male senior author (Table 3B). In OABs cited by male primary authors, 18.5% of citations consisted of a female senior author, and 82.0% had a male senior author (Table 3A). Women-led articles cited female senior authors nearly 1.36 times more than men-led articles (25.1% to 18.5%) did in their bibliographies.

## DISCUSSION

Structural sexism and inequitable recognition of accomplishment highlight ethical challenges that medicine struggles to overcome. Despite the increase in female professionals in medicine, women's career development is stalled at entry or junior-level positions, whereas men tend to dominate senior-level positions.[23,28–30,46,47,49,57,61] Although gender diversity has improved across plastic surgery, female senior author positions on research teams remain low.[9,48,49,57] To address this "leaky pipeline," it is essential to address any gender imbalances at the entry-level and assess equity practices.

It has been well-established that there exists an underrepresentation of women's work in citation practices.[20–30,42–49,61] To analyze whether this bias would extend to our laboratory, an internal audit of our publication reference lists was conducted. We hypothesized that there would be an underrepresentation of women-led articles, especially within the citation lists of men-led articles. We also hypothesized that publications led by women would cite more scholarship by women.

The overrepresentation of men in citations elicits less recognition of women's work in academia. Our results show an overrepresentation of men-led articles compared with women-led publications (Fig. 3), consistent with larger-scale studies.[20–30,42–49] Same-sex collaborations were higher for male than female authors (Fig. 3), serving as an example of gender homophily where men tend to collaborate more often with other men, despite studies indicating higher quality work through mixed-sex collaborations.[39–41] In parallel with this phenomenon, male/male coauthorship exceeded the prevalence of F-U-F authorship. This finding suggests that the Matilda effect is most apparent in men's citation behavior, because women recognize the work by same-gender scholars more often, and that the gender status of the author, related to the Matthew effect, appears to not be as critical in women-led articles.

While a gender gap persists, evidence from male-dominated fields demonstrates the *increasing* and *increasingly recognized* contributions of women, including research

**Table 3. Average Percentage of Gender Citation Behavior in Male or Female First Author Bibliographies**

| A. Average % for Male First Author | | | | |
|---|---|---|---|---|
| | MM | MF | FM | FF |
| 2015* | 0.0 | 0.0 | 0.0 | 0.0 |
| 2016 | 83.6 | 3.9 | 12.4 | 0.0 |
| 2017 | 66.1 | 14.9 | 15.6 | 3.4 |
| 2018 | 80.3 | 6.8 | 9.9 | 2.9 |
| 2019 | 60.9 | 12.1 | 24.2 | 7.9 |
| 2020 | 74.9 | 8.7 | 6.2 | 10.1 |
| 2021 | 58.7 | 7.0 | 16.7 | 16.3 |
| 2022 | 47.2 | 19.3 | 17.3 | 16.2 |
| Total | 67.4 | 10.4 | 14.6 | 8.1 |
| **B. Average % for Female First Author** | | | | |
| | MM | MF | FM | FF |
| 2015 | 25.0 | 10.0 | 10.0 | 55.0 |
| 2016* | 0.0 | 0.0 | 0.0 | 0.0 |
| 2017 | 41.6 | 18.7 | 38.5 | 1.0 |
| 2018 | 60.0 | 10.0 | 30.0 | 0.0 |
| 2019 | 60.0 | 13.6 | 17.2 | 9.2 |
| 2020 | 81.9 | 3.1 | 5.6 | 9.4 |
| 2021 | 56.3 | 8.2 | 24.0 | 11.5 |
| 2022 | 52.3 | 17.8 | 21.8 | 8.2 |
| Total | 53.9 | 11.6 | 21.0 | 13.5 |

FF, female first author/ female senior author; FM, female first author/male senior author; MF, male first author/ female senior author; MM, male first author/male senior author.

*As we aim to accurately compare citation behavior between male and female first authors, these values were excluded from the total average due to no male (2105) or female (2016) first authors in the laboratory of its respective year.

authorship.[17,23,34,49,52,57] Our data demonstrate that diversity in the first authorship resulted in gender-based fluctuations in citation behavior. After separating cited articles by author/gender, the imbalance within reference lists was primarily driven by citation practices of MM teams. Publications with primary male authors tended to undercite FF articles compared with primary female authors (8.1%–13.5%, respectively, Table 3). Male-led articles also demonstrated a strong over-citation of MM articles compared with women-led publications (67.4%–53.9%, Table 3). Women authors cited more women-led articles than male authors across all seven years of data, confirming our second hypothesis. This is possibly due to their greater awareness of gender inequity than men, leading to their increased effort to include women's work in their own.

Diversity within a laboratory group leads to diversity in representation. By diversifying a team of scientific researchers, the laboratory is prone to improve overall work and success. Our data show a drastic discrepancy between male versus female authors across all citations (Table 2 and Figure 3). Recruitment of women in academia allows opportunities for women-led research and recognition. Even in men-led research teams, primary female authors often highlighted a larger body of female work, thus increasing the recognition of women's contributions.

Based on our results, there is evidence of unequal citation practices between the binary sexes of male and female, which has been previously demonstrated in large-scale studies but not at the laboratory level.[12,13,25,26,29,30,38,46,47] To make the reading audience of scientific articles aware of this issue, we are advocating the placement of a "citation diversity statement" at the end of every publication as part of their ethical code of conduct in the same way that our field includes a statement recognizing the ethical use of human and animal subjects in research. Commitment to this practice brings citation practices to the audience's attention, spreading awareness of representation through the identification of bias.

## LIMITATIONS

Auditing our laboratory can be problematic because there might be bias in data analysis. To address this, the senior laboratory author from the publications analyzed did not participate in the study. Because we were looking specifically at a single male last author, the analysis was limited to the gender of the first author. This decreased diversity, as there was no possibility of FF or MF articles. Also, the number of articles analyzed is relatively small compared with larger-scale studies on citation imbalances. The sample size remains a limitation of the conclusions and any comparisons derived from larger data sets of other medical disciplines. Additionally, names alone do not inherently represent a specific gender, and using a gender binary of "male" and "female" may not accurately reflect an individual's gender identity. Significance between names and gender has only been grouped under the assumption that there is a positive statistical correlation of over 70%. This simulation fails to include any other gender. Future studies examining gender differences in citations should include the self-identification of an author, as this study could not provide that information.

## CONCLUSIONS

Our data confirm that a gender bias in citation practices exists at the laboratory level. These data also indicate that diversity within an individual laboratory group leads to diversity in representation; therefore, diversifying a team of researchers can improve the overall work and success of the laboratory. We structured this article so that this methodology could be replicated. We encourage laboratory groups to replicate their results and discover how these biases might be impacting their publications. Additionally, we hope that laboratory groups incorporate a citation diversity statement to identify and acknowledge citation bias toward creating equitable citation practices within laboratory levels, and the field of academic surgery as a whole. Overall, diverse perspectives create a broader network of colleagues that constitute a broader knowledge base, reducing citation imbalance and professional homophily.

### Citation Diversity Statement

We recognize that gender homophily in citation practices exists, where women's work tends to be under-cited compared with men's work in the field. The gender representation of citations within this article was quantified

using a simulation from GitHub (https://github.com/dalejn/cleanBib). Our reference authors are 40.38% female/female, 14.2% male/female, 22.35% female/male, and 23.07% male/male. A limitation is that the use of the gender binary "male" and "female" may not reflect an individual's gender identity. This statement is included as part of an outgoing commitment to improving equitable practices in scientific research.

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## DISCLOSURE

*The authors have no financial interest to declare in relation to the content of this article.*

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