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Article

Distribution of Female and Male First and Last Authorship across Drug Delivery Related Journals with Respect to Year and Journal Impact Factor

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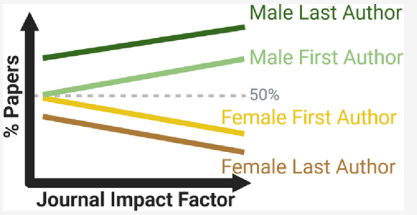
ABSTRACT: First and last authorship are important metrics of productivity and scholarly success for trainees and professors. For 11 drug delivery-related journals in 2021, the percentage of female first (39.5%) and last (25.7%) authorship was reported. A strong negative correlation, with female first (r_p = −0.73) and female last authorship (r_p = −0.66), was observed with respect to journal impact factor. In contrast, there was a strong positive correlation with male first and last authorship (r_p = 0.71). Papers were ∼1.5 times more likely to have a male first author, and ∼3 times more likely to have a male last author, than females. A female was 22% more likely to have first authorship if the last author was female, although there is an ∼1% increase per year in female authorship with male last authorship, which equates to equality in first authorship by 2044. Considering that drug delivery is composed of engineering, chemistry, and pharmaceutical science disciplines, the observed 25.7% female last authorship does not represent the approximately 35.5% to 50% of professors that are female in these disciplines, internationally. Overall, female authorship in drug delivery-related journals should improve to better represent the work of female senior authors.



KEYWORDS: *women, pharmaceutics, gender, publications, biomedical engineering, peer review*

INTRODUCTION

An important metric of success for any researcher is publishing their research in peer-reviewed journals. Trainees are most often evaluated on the number of first author publications they have produced during their training. This is underscored by the fact that many programs in the United States require at least one first author paper for completion of a PhD. For tenure track investigators, last authorship is indicative of independent work and the number of last or corresponding author publications is a significant metric for promotion and tenure at most research universities. Publication of one's research is therefore an important proxy for researchers' achievements throughout their career. For this reason, it is important to understand the extent that women have been successful in obtaining first and last authorship on publications and in particular in the drug delivery space as it is an interdisciplinary area composed of engineers, chemists, and pharmaceutical scientists.

To understand this extent, we have looked at the number of publications of female authors in drug delivery as well as the impact factor of journals in which these researchers publish. Journal impact factor (JIF) is a metric of how many times the average article in a journal is cited. It is calculated each year for a journal and is determined as the number of times articles were cited during the previous 2 years the journal was published divided by the total number of articles that could be cited during those 2 years. This value is calculated by the analytics company Clarivate. By definition, journals of a higher JIF are cited more and therefore are more often discussed in the media and research community that can lead to increased invitations to present at conferences and universities as well as invitations to submit reviews or other published works.

When considering the steps of peer review, there are both internal and external decisions relative to the author(s) which affects where the publication is finally published. The first step in peer review relies on the author(s), typically the last and sometimes first or other authors, selecting an appropriate journal. Once the manuscript is prepared, it is then submitted to the journal and routed to an editor. The editor can then decide to send the manuscript out for peer review or reject it. Sometimes, the editor will reject the manuscript and suggest routing to a "sister" journal that is often a lower JIF or an open access journal in the same publishing group. If the manuscript is sent out for review, then it can be sent to any number of reviewers who ideally read the manuscript, comment on it, and either accept or reject it. Then, these comments are sent to the editor who decides to reject or accept (likely with revisions) the manuscript. Often, these processes can be elongated with

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Table 1. Journal Impact Factors (JIF) for Journals Where Drug Delivery Research Is Published

publisher	journal title	JIF (2021)
American Chemical Society (ACS)	ACS Nano	16.24
Wiley	Advanced Materials (AdvMat)	32.09
Elsevier	Biomaterials (Biomat)[a]	15.30
Elsevier	International Journal of Pharmaceutics (IJP)[a]	6.27
Elsevier	Journal of Controlled Release (JCR)[a]	11.47
ACS	Molecular Pharmaceutics (MolPharm)	5.36
ACS	Nano Letters (NL)	11.38
Nature	Nature Nanotechnology (NN)[a]	40.52
Wiley	Small[a]	15.15
American Association for the Advancement of Science (AAAS)	Science Translational Medicine (STM)[a]	19.32
Springer	The AAPS Journal (AAPS)	3.60
mean ± SD		16.06 ± 11.29

[a]Indicating the subset of journals evaluated over a 5 year period (2017−2021).

higher JIF journals. Routing to a "sister" journal can also occur after the peer review is received. The outcomes of female authors at each of these various steps are not well reported, but the number of manuscripts as well as JIF of the manuscript journals is freely available information.

Therefore, across years and journals, we evaluated female and male authorship in the first or last author position. This was evaluated as a function of JIF for 11 journals that publish drug delivery research. We also evaluated the likelihood of a women having first authorship if a woman or a man is the last author, presumably as an indicator as to if a woman is better mentored by a woman or a man. Further, we evaluated authorship over a 5 year span for six journals that publish drug delivery research. Since editors have such a significant role in a manuscript's fate, we also evaluated these metrics with respect to the percentage of women on the editorial board and if the editor-in-chief is a woman or man. This work is meant to characterize and generate discourse about authorship in drug delivery journals for female and male authors at both the trainee and principal investigator level.

METHODS

Data Collection. Articles were collected at the indicated year via the journal's International Standard Serial Number (ISSN) using Publish or Perish software (https://harzing.com/resources/publish-or-perish; London UK). Although gender is not binary, for our analysis, gender was assumed to be either male or female based on the individual's first name. A database of male and female names was developed from an online list (https://adoption.com/baby-names/browse) and enriched for ambiguous or undetermined names via picture identification through a web search (Table S1). Initials were identified through Scopus links to the author, a web search that included the individual's affiliation or the individual's middle name. Names that could not be grouped due to the lack of information (i.e., names could not be identified and initials could not be determined) were excluded from analysis (n = 85; Table S2).

Data was collected for papers from 11 journals in which drug delivery research was published in 2021: International Journal of Pharmaceutics (IJP), Journal of Controlled Release (JCR), Biomaterials (BioMat), Advanced Materials (AdvMat), Science Translational Medicine (STM), Nanoletters (NL), Nature Nanotechnology (NN), Small, Molecular Pharmaceutics (Mol Pharm), Nanoletters, ACS Nano, and the AAPS Journal (AAPS). A subset of six of those journals was also used to collect data for the years 2017−2021 (IJP, JCR, AdvMat, STM, and NN). Data was organized in Excel (see the Supporting Information). The 2021 Clarivate journal impact factor (JIF) used for comparisons is given in Table 1.

Statistical Analysis. All papers with at least two authors were included in the analyses (n = 6712 for 2021 articles; n = 16,822 for 2017−2021 articles). Chi-square was used to determine differences in the authorship position by gender as indicated by the male first and last author (MM), female first and male last author (FM), male first author and female last author (MF), and female first and last author (FF). Also, analysis was performed on the female first author with either the male or female last author (FX) and the female last author with either the male or female first author (XF). This data is also reported for males (MX and XM). Pearson (r_p) correlations were used to examine the strength of the relationships between JIF, gender position, and editorial composition. Spearman's correlation (r_s) was also determined, although r_p is an appropriate test given the distribution of the data. An independent t-test was used to determine differences in continuous variables for editor-in-chief (EIC) gender. All analyses were conducted in SPSS version 25 (IBM Corp., Armonk, NY). The minimum significance level for all significance tests in this study was $p < 0.05$.

Regression Analysis of Authorship Controlling for JIF in 2021. Logistic multilevel modeling (MLM) was used to examine the relationship of last author gender (level 1) and JIF (level 2) with first author gender. MLM is an appropriate method for analyzing nested data structures (e.g., papers within journals). When papers are handled by the same journal, their outcomes are likely to be similar in important ways, violating the assumption of independent observations in traditional regression analysis. Other analytic approaches that do not account for nested data can produce misestimated standard errors, incorrect statistical inferences, and biased coefficients. Therefore, the MLM developed in this study statistically controlled for papers nested within journals.

To build the full MLM, an unconditional model (also called the null model) containing no independent variables was used to determine MLM appropriateness. Journal-level variance (i.e., random effect variance) indicated whether the intercept variance varied between papers, which confirmed the appropriateness of MLM for this dataset. A full model was built that included paper- and journal-level characteristics. All variables were entered into the models as fixed effects. Model

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coefficients were calculated as odd ratio (OR), 95% confidence interval (CI).

In general, the intercept for each model represents the likelihood of female first or last authorship when controlling for all variables in the model. For female first authorship, since the standard deviation of the intercept (or random effect intercept) between journals was statistically significant (P-value = 0.047), we can assume that the intercept variance varied significantly between journals, which indicates significant variation between journals regarding first authorship gender and provides justification for the use of MLM for this data set. When controlling for JIF and last authorship gender in the full MLM, the model correctly classified 61.5% of cases. For female last authorship, since the standard deviation of the intercept (or random effect intercept) between journals was statistically significant (P-value = 0.048), we can assume that the intercept variance varied significantly between journals, which indicates significant variation between journals regarding last authorship gender and provides justification for the use of MLM for this data set. When controlling for JIF and first authorship gender in the full MLM, the model correctly classified 74.3% of cases.

RESULTS AND DISCUSSION

Of the 11 chosen journals for 2021, the percentage of female authorship for both the first and last author was determined (Figure 1 and Table S3). Our results indicated that a higher

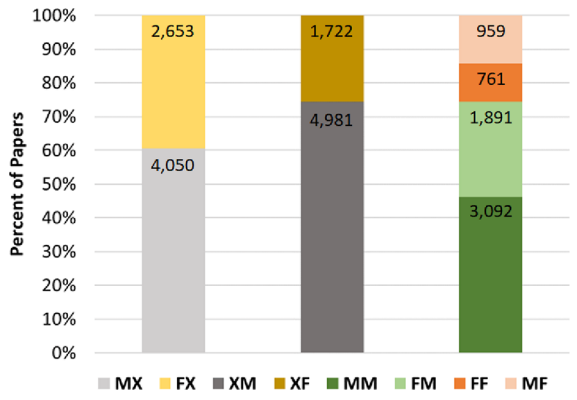

Figure 1. Data collected from 11 journals that published research related to drug delivery in 2021. Percentage of paper authorship for a given group. The total number of publications for that group is indicated in the bar. Average % of papers with MX = male first author and either a male or female last author; FX = female first author and either a male or female last author; XM = male last author and either a male or female first author; XF = female last author and either a male or female first author; MM = male first and last author; FM = female first and male last author; FF = female first and last author; MF = male first author and female last author.

percentage of female authors was published as first authors (FX; 39.5%) over last authors (XF; 25.7%) across the 6712 articles evaluated for 2021. When averaged across all 11 journals, this trend is illustrated again, with the average ± standard deviation percentages of female first authorship at 40.80 ± 8.31% and female last authorship at 27.41 ± 8.31%.

The lower percentage of female authors could be attributed to the lower number of female PhD graduates in drug delivery, compared to males. To evaluate this, one can look at the graduation percentages of female PhD students in the primary fields that make up drug delivery research: pharmaceutical sciences, chemical engineering, biomedical engineering, and chemistry. Data from the last 20 years or earlier has indicated that the percentage of females is reported to be 45.7% for pharmaceutical sciences for the 2000s and 2010s,[1] 31.2 ± 1.2% for chemical engineering between 2010 and 2019,[2] 38.1 ± 0.8% for biomedical engineering in 2009, 2010, and 2014−2017,[3] and 37.6 ± 1.6% for chemistry for 2009−2015, in the United States.[2] This data indicated that approximately 38% of graduates in fields that include drug delivery are female, which is within the range of what is observed here with the average first authorship (40.80 ± 8.31%); however, this does not consider international data when the journals selected include international authors. Recent surveys of international pharmaceutical science (Asia, North America, Europe, Africa, and Australia) and engineering (European Union (EU)) graduate students indicated that female graduate students represent about 50% of the students across the locations surveyed.[4,5] Although additional data is needed to draw significant conclusions, female first author publication rates in drug delivery are within the range or slightly lower than female PhD graduate students graduating in related fields.

However, the average last authorship (27.41 ± 8.31) is well below what is observed for women professors at most levels across these fields in the United States (Table 2). Further, with

Table 2. Percentage of Women Professors across Fields of Drug Delivery in the United States[6]

women professors	assistant professors	associate professors	full professors
all	49%	42%	29%
pharmacy	59%	45%	24%
chemistry	27%	30%	15%
engineering	29%	29%	NA

the inclusion of international data, female professors in pharmaceutical sciences are reported to be approximately 50% across Asia, North America, Europe, Africa, and Australia.[4] This is slightly higher than for general science and engineering (STEM), which is reported to be approximately 40% across the EU for women.[7] Even if it is assumed that most last authored manuscripts are produced when a professor is an associate or full professor, the average percentage of these two positions is 35.5% in the United States and greater than that internationally, which equates to a greater than 8.5% gap in gender for the last author percentage.

Some of this difference in last authorship could be accounted for in the roles of female faculty as women are often overrepresented in non-tenure track academic positions.[8] Faculty who have primarily teaching or clinical appointments may have less of a requirement for publishing than research centric faculty. The American Association of University Professors surveyed 996 universities and reported the roles of male and females in various appointments (Table 3A). Women have a higher percentage of appointments in non-tenure track positions, regardless of the rank, and reduced percentage in tenured positions. The largest differences between males and females in a given rank in non-tenure track positions are assistant professors (7.2%) followed by associates (3.1%) and professors (2.5%), and the remaining differences are less than 1%. Although these differences are significant, they cannot alone account for the difference in male and female last authorship.[9] Further, the reduced last authorship of females we observed (27.41 ± 8.31%) is not

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Table 3. (A, B) Role of Women in Faculty with Respect to Teaching or Clinical Appointments[9,10]

A				B				
2017–2018	non-tenure track (M%:F%)	tenure track (M%:F%)	tenured (M%:F%)	%women	1990–1991	2002–2003	2012–2013	2012–2013
professor	4.2:6.7	1.3:1.3	94.6:92.0	pharmacy practice	36%	53%	61%	66%
associate	7.1:10.2	6.3:6.7	86.6:83.2					
assistant	18.3:25.5	77.5:70.5	4.1:4.0	social sciences/ outcomes	21%	31%	44%	47%
instructor	96.1:96.5	1.5:1.6	2.4:1.9					
lecturer	94.6:95.1	4.5:4.1	1.0:0.8	pharmaceutical sciences[a]	19.5	28.5%	33.5%	36.2%
no rank	86.9:87.4	3.7:4.1	9.4:8.5					

[a]Data is averaged across several pharmaceutical science disciplines (e.g., pharmaceutics, medicinal chemistry, and pharmacokinetics).

accounted by female faculty in clinical positions, which may have less of an emphasis on publishing (Table 3B). Both social sciences and pharmaceutical sciences researchers in pharmacy programs would require publications for promotion, and women account for 47 and 36.2% of the faculty in these areas, respectively.[10] These figures align similarly with engineering, where 2019 statistics indicated that women constitute 36.7% of teaching faculty in that discipline, with 35.5% as research faculty, as collected by the National Science Foundation.[11] Overall, this data indicates that there are small increases in women in positions that may have a reduced requirement for publishing, but these small differences likely do not account for the reduction in the overall last author publications.

Across 11 journals and their articles published in 2021, we evaluated male and female authorship as it relates to JIF. Very strong relationships were seen between JIF and female or male authorship (Table 2 and Figure 2) that were observed.

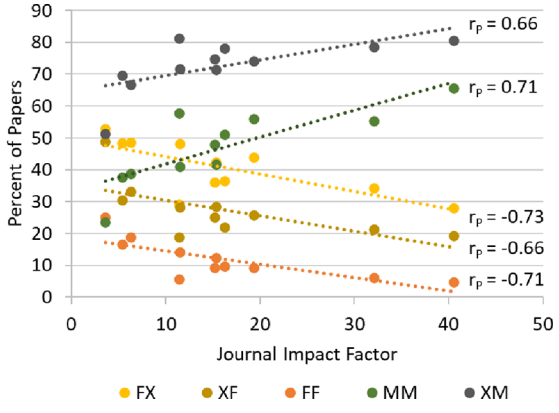

Figure 2. Data collected from 11 journals that published research related to drug delivery in 2021. Authorship for a given group across journal impact factor (r_p = −0.73 to 0.71). FX = average % of papers with female first author; XF = average % of papers with female last author; FF = average % of papers with female first and last author; MM = average % of papers with male first and last author; XM = average % of papers with male last author.

Specifically, JIF demonstrated strong negative correlations with % first female (r_p = −0.73, *P*-value = 0.010), % last female (r_p = −0.66, *P*-value = 0.028), and % first and last female (r_p = −0.71, *P*-value = 0.013) and a strong positive correlation with % first and last male (r_p = 0.71, *P*-value = 0.014). Chi-square also revealed differences in the authorship position by gender (*P*-value <0.001) (Table S3). A similar observance was reported by Shen et al. for several high impact journals across neuroscience.[12] In their analysis of female first and last authorship from 2005 to 2017 for JIFs in the same range we report, they report Spearman's coefficient of −0.75 for female first authors and −0.56 for last authors. Our data yields more negative Spearman's coefficients of −0.85 and −0.87 for female first and last authorship, respectively (Table S3). This would indicate that in comparison to the data from the general and neuroscience-focused journals studied by Shen et al., journals in which drug delivery research is published have a reduced incidence of female first and last authors as it correlates to JIF. Although neuroscience has a significantly higher percentage of female PhD graduates (53%) than drug delivery disciplines reported domestically above (38%), the percentage of women in tenure track faculty is less in neuroscience with the percentage of females reported for 2017−2018 being only 30.8% with 13.8% of tenured professors at the rank of full professor.[13] In addition to Shen et al.'s work, the percentages of women first authors and last authors for 40 infectious disease journals were evaluated and there was no observed correlation between gender and JIF, but the range of JIFs (4.46 ± 4.13) evaluated was lower than we evaluated in this study (16.06 ± 11.29).[14] Overall, this data would indicate that females in drug delivery have a decreased frequency of publication in high impact journals over other scientific fields, including those like neuroscience that have fewer female professors.

This observed difference in gender and authorship could be a function of many things, including bias by editors and reviewers during the peer review process or female authors (first or last) choosing lower JIF journals to submit their work. We evaluated the editorial board composition for the journals in Table 1 (Table S4) to understand the impact an editorial board may have on these observed gender differences. For the journals evaluated here, the relationship between journal JIF and percentage of females on the editorial board was not statistically significant (r_p = −0.33 to 0.38). Further, there was no difference in JIF based on editor-in-chief (EIC) gender (*P*-value = 0.25). Weak to negligible relationships were also found between XF and FX authorship and percentage of female editors (r_p = −0.32 to 0.23), number of editors (r_p = −0.34 to 0.31), and size of the editorial board (r_p = −0.29 to 0.34). This would indicate that having a female editor does not affect female authorship in the field of drug delivery. In the field of infectious diseases, the percentage of females on the editorial board had a significant effect on first and last authorship by women, but the gender of the EIC did not have an effect.[14] Similarly in urology, there was a positive correlation between total female authors and female editors.[15] In the journals evaluated here, 25.58% of the EICs were women and the editorial board averaged 42.93 ± 27.3% women. In comparison to the percentage of female last author publications, we

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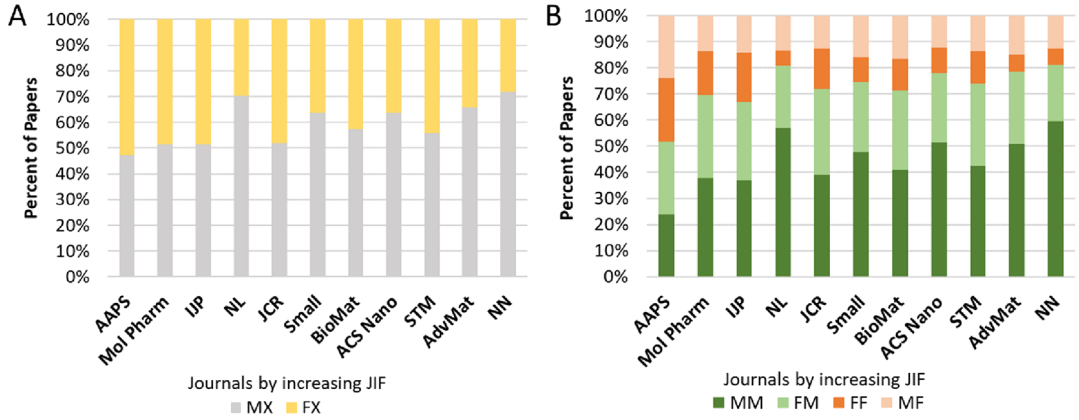

Figure 3. Percentage of first and last authorship for female and males across 11 journals for 2021. (A) Percentage based on first authorship. FX = average % of papers with female first author; MX = average % of papers with male first author. (B) Percentages for iteration of all four groups. MM = average % of papers with male first and last author; FM = average % of papers with female first and male last author; FF = average % of papers with female first and last author; MF = average % of papers with male first and female last author (Table S5).

observed (XF: 27.41 ± 8.31%) that these values are not significantly different, but women are on average represented at a higher percentage on editorial boards than the last authorship averaged over all the 11 journals reported here.

Female authors not submitting to higher impact journals could also result in the observed decrease in female authorship with increasing JIF. There is limited information regarding submission to journals; however, Squazzoni et al. evaluated submission in 2329 Elsevier journals (Biomat, IJP, and JCR are Elsevier's journals) from 2018 to 2020 and observed that women submit about 45% of the number of manuscripts as men.[16] They noted that across these journals, submission rates during the early stages of COVID mostly affected female authors, and similarly Bell and Fong concluded that women submitted less during COVID than men in the area of public health.[17] At the high impact journal Cell, data based on self-reported gender indicates that women made up 17.0% of all submissions, with men at 76.8%, non-binary individuals at 0.6%, and not reported at 5.6% for the years 2017−2021.[18] Despite these discrepancies in submission rates, the accepted rate is approximately the same (11−12%), but there was a smaller percentage invited to revise for women (31.7% invited to revise) than for men (36.7% invited to revise). Data that also supports that women authors receive increased adverse outcomes during reviews than males was shown in the field of ecology for >23,000 research manuscripts submitted to six journals in 2010−2015.[19] Their data showed that women first authors were as likely as male first authors to be sent for review, but female first authors received worse peer review scores and were rejected at a higher rate than males. When the data was self-reported, women and men reported the same level of rejection. Further, in sub-Saharan Africa, female STEM PhD students report 25% fewer manuscripts being accepted for publication in any given year, in comparison to men.[20] This data in conjunction with the editorial board data would indicate that one barrier to publication of articles by female authors is peer review. Peer review has also been reported as a barrier for historically excluded groups, including women. When peer review data was recently analyzed from 312,740 manuscripts in biological sciences, they reported that female authors had worse or similar outcomes at each step of the review than male authors.[21]

One way to mitigate bias may be double-blinded peer review where the author and peer reviewers are blinded to each other's name and thereby gender. A majority of the journals that publish drug delivery research are only single-blinded, where the authors are blinded as to who performed the peer review. Smith et al. recently reported that for biological sciences, a higher percentage of female manuscripts was submitted for review when the manuscripts were double-blinded (authors and reviewers blinded) than when they were single-blinded.[21] A recent analysis of double-blinded peer review studies by Kern-Goldberger et al. concluded mixed results with this type of peer review. Of the eight double-blinded peer review studies examined, four concluded perceived gender bias with review and four concluded that there was no impact.[22] Other studies indicated that triple-blind review (blinded author, editor, and reviewers) could result in decreased gender bias.[23] However, blinded peer review is difficult to fully carry out as many authors will self-cite, particularly for methods. Further artificial intelligence has shown that women and men use different terms or vernacular in their writing, which may result in implicit bias in peer reivew.[24] Journals and publishing houses tracking reviewers for gender-based differences may lead to reduced gender bias if biased reviewers are then removed from the reviewing pool. Further, key word usage could be used to screen for bias during peer review.[25]

To understand differences in male and female authorship across the 11 journals evaluated, we used Chi-square analysis. Results showed significant differences between journals for FX, XF, FF, and MM (Figure 3 and Table S5). For female first or last authors, significant differences (P-value <0.001) across the journals were observed. Significant differences were also observed for FF and MM authorship (P-value <0.001). Also significant were FM and MF authorship (P-value <0.05). Of note, FF and MF authorship were the lowest percentages for all journals, except the AAPS Journal where authorship was most evenly distributed between rank and male or female (Figure 3B); however, it also has the lowest 2021 impact factor (JIF = 3.603) and the fewest articles (n = 121). Differences were also noted between publishing groups (Table S6).

To understand if the trends observed in 2021 were year-specific, six journals were evaluated over a 5 year period for male and female authorship. During this 5 year period, there

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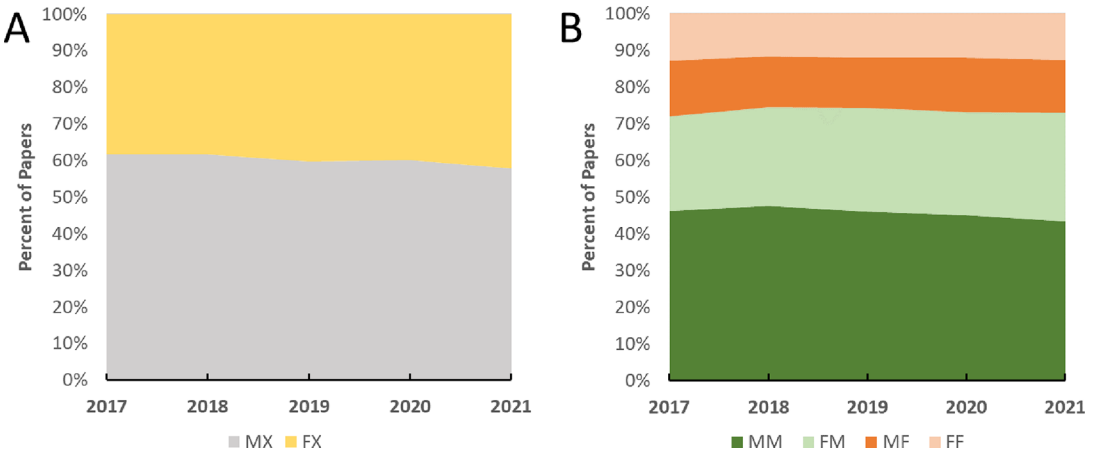

Figure 4. Average percentage of first and last authorship for female and males across six journals for 5 years. (A) Percent authorship for first author male and female publications. FX = average % of papers with female first author; MX = average % of papers with male first author. (B) Percent authorship for first and last authorship for male and female. FF = average % of papers with female first and last author; MM = average % of papers with male first and last author; FM = average % of papers with female first and male last author; MF = average % of papers with male first and female last author (Table S7).

were significant differences in the number of female first authors (P-value = 0.005), particularly with male last authors (Figure 4 and Table S7). A significant (P-value = 0.011) and general upward trend was observed for female first authors and male last authors across the 5 year period. This observed trend would indicate that female first authorship in drug delivery did not decrease due to COVID. If extrapolated, female first authors with male last authors are predicted to account for 50% of papers in the year 2044 (Figure S1). This is 14 years later (2030) than it is extrapolated for female first authors (regardless of male or female last authorship) to constitute 50% of first authorship (Figure S1). This data indicates that female first authorship is on the rise, while female last authorship is considered constant (P-value = 0.123), so it may be inferred that female trainees are increasing in the field, but female professors are remaining relatively constant. This lack of change in female last authorship could also be due to the particular time selected for analysis and that the COVID-19 pandemic began in 2019, significantly affecting professors with young children and particularly women.[26]

As the rate of female first authorship increased, the rate of male first authorship with male last authors decreased over the 5 year span (P-value = 0.011). This is in contrast to male first authors with female last authors, which remained relatively constant over the 5 year period (P-value = 0.301). Moreover, female first and last authorship are also stable over the period of time evaluated (P-value = 0.656). This would indicate that the overall female first authorship is increasing at the decrease in male first authorship with respect to male last authorship but not with respect to female last authorship. However, it should be noted that the increase in female first authorship (and decrease in male first authorship) is still relatively modest, at less than 1% a year (0.93%/year; Figure S1). Broderick and Casadevall reported a similar decrease in male first authorship broadly across scientific papers, which was observed to begin to decrease in 2007. In the same study, when male first authorship was compared between the United States, Europe, and other regions (e.g., Asia), there were no noticeable differences in the probability of male first authors, indicating that these gender differences were independent of the author's country.[27]

Our data indicated that there was a significant downward trend with respect to JIF if a female was the first (P-value = 0.004) or last author (P-value = 0.007), and a larger percentage of publications in most journals was observed when a male is the last author. We wanted then to explore the likelihood of a female being a first author, so we performed logistic multilevel modeling (MLM) at a fixed JIF. The intercept for the unconditional MLM was 0.64 (CI 0.55−0.75, P-value <0.001), which indicates that the odds for a paper to have a female first author were 0.64−1. This means that papers were about 1.5 times more likely to have a male first author than female (Table S8). For female last authors, the intercept was found to be 0.36 (CI 0.29−0.45, P-value <0.001), which indicates that the odds are 0.36−1 (Table S8). This means that males are approximately 3 times more likely to be the last author on a publication compared to females in the field of drug delivery. The odds of a female last author are approximately 2 times less than that of a female first author, which would indicate that a smaller percentage of females are transitioning from trainees to principal investigators.

There are multiple reasons why female trainees may not pursue academia, but it is indicated that this decision is made during PhD studies. One study noted that at the conclusion of their PhD, women are twice as likely to not want to pursue academia than their male counterpart, when the same study noted that an equal percentage of women and men wanted to pursue academia at the beginning of their PhD.[28] This change during their PhD could be because of a reported 147% increase in peer-sexual harassment experienced by female students.[29] Also, women during their PhD may be considering starting a family. This aligns with data that indicates that motherhood has been linked to 81% of women changing their desire to enter academia compared to the start of their PhD.[28] Likely, this turnaround is linked to the common, albeit fictitious,[30,31] discourse in the academic settings that women are less productive or that being faculty is too demanding for women with children. Further, the decision to have children has been shown to result in a less competitive tenure-track application since there is a documented bias against mothers being hired, especially as compared to fathers.[32]

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The ability of women to even compete for a tenure track position is another reason that women are not transitioning from a first to a senior author because they were not hired in academia. In addition to our data that indicates that female first authors are significantly less likely to publish in higher JIF journals, additional barriers have been reported like reduced credit for a female's work, leading to a reduced number of publications and patents. There are several studies that indicate that women are less likely to receive credit for their work than their male counterparts.[33−36] Indeed, Feldon et al. report that male PhD students are 15% more likely to be listed as an author than female PhD students in the area of biological sciences.[36] Additionally, Ross et al. conclude that women are 59% less likely to be named on patents than men.[33] This reduction in metrics can lead to fewer training opportunities to develop the ones researched into a publication, naivete related to intellectual property, and a less competitive application to a tenure track position. These differences in acknowledgement for publications and patents can translate into more female candidates being overlooked for tenure track positions. Indeed, Williams and Ceci noted that female candidates were preferred 2:1 in biology, engineering, economics, and psychology when candidates were identically qualified,[37] but in a study by the same team in the same year, they illustrated that this difference was not observed when women were slightly less qualified than the male candidate.[38] Taken together, these studies indicate that women's research work is more likely to be discounted or published in lower JIF papers that can directly impact their ability to acquire a tenure track position because women would be required to work harder to have the same research metrics as a man's whose work is less likely to be discounted.

Another barrier to female PhDs pursuing academia is the reported poor rate of promotion of female professors (Table 2). Poor promotion rates are likely because women faculty has been reported to receive fewer awards,[1] lower teaching scores,[39] reduced NIH dollars,[40] decreased invitations to give talks,[41] and fewer citations in publications[42] than their male counterparts. Further, as our data and others indicate, women have fewer publications[43,44] than their male colleagues, and these publications are in lower impact journals. Taken together, these metrics account for a majority of the metrics related to tenure and promotion. Additionally, women have been noted to have an increased service load compared to their male colleagues, usually at the detriment of their research.[45,46] Also, women are often burdened with higher teaching loads than their male counterparts.[47] In addition to reduced promotion, many female faculty members leave academia, further reducing representation. Notably, these departures are brought about due to underrepresentation and stereotypes, lack of social networks, and chilly academic climates.[47,48] With poor success rates and an adverse environment, it is therefore not surprising that fewer women pursue faculty.

To understand the role of female representation in authorship, we evaluated the likelihood of a female first authorship with a female last authorship. The odds of a first author female paper were 1.22 (CI 1.09−1.36) times higher for papers with a female last author than a male last author (P-value = 0.001) (Table S8). This indicates that if a female is seeking out first authorship, then they are 22% more likely to achieve that with a female last author than a male last author, indicating potential bias in author selection by male senior authors. This thought aligns with a previous study that has reported that male-only pairings are most common with two author pairings,[27] shared first authorship is most common between three or more males, and that male scientists are most likely to share data with other male scientists.[49] However, with the general upward trend of female first author and male last author publications and no significant differences in female last author trends over the 5 years evaluated (Table S7), this ratio could improve overtime. The fact that there is no significant difference in female last author trends is interesting in the context that a study of French PhD students reported that mid-career female supervisors who have a national grant were most positively associated with student productivity (i.e., student's publication quantity, quality, and co-authorship network size).[50] Overall, our data support that female representation as last authors directly impacts female first authorship.

Our data indicates that the representation of females in academia and as mentors for female trainees can improve authorship outcomes; however, our noted discrepancy around gender differences and authorship is often amplified in other underrepresented groups. For instance, it is well observed that differences related to author ethnicity and affiliation affect representation across publications.[21] One way to mitigate this for gender, ethnicity, and LGBTQ+ status is to create a greater sense of inclusion.[51] NSF's program Targeting Equity in Access to Mentoring (TEAM) ADVANCE seeks to increase women in STEM tenure track positions by increasing networking and improving academic climate.[47] Inclusion of LGBTQ+ examples in case studies and other aspects of lectures has been shown to increase the feeling of acceptance for LGBTQ+ students, which is important because this group is 30% more likely to experience harassment than their peers.[52,53] Further, at the trainee level, underrepresented minority retention has been significantly increased by providing greater financial support, tutoring, and fostering teamwork, as exemplified by the University of Maryland Baltimore Campus' Meyerhoff Graduate Fellows Program as well as similar programs supported by Howard Hughes Medical Institute (HHMI) at the University of North Carolina at Chapel Hill and Penn State University.[54] These examples highlight that the creation of a more inclusive environment is needed to retain not only female faculty but also other underrepresented individuals.

CONCLUSIONS

For these journals evaluated in the field of drug delivery, female authorship is underrepresented, particularly for last author females. In contrast to the male first and last author, there is a significant negative correlation for the female first and female last author with respect to JIF. Significant differences between the 11 journals evaluated in the year 2021 were observed for the female first or last author and all authors groups (MM, FM, MF, and FF). Differences in first or last author gender were shown not to be dependent on percentage of female editor-in-chief or percentage of female editors. Literature would support that the primary barrier to increasing women authors is bias in the peer review process, although other factors might contribute. Male first authors were 1.5 times more likely than female first authors; however, in the journals evaluated, there is a general upward trend of <1% per year in the number of female first authors with male last authors with equality extrapolated to be achieved in 2030 for all female first authors. Despite the increase in female first authors, there is no notable yearly increase in female last authors, with male last authorship predicted to be observed 3

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times more than females. This indicates that females are less likely to transition to principal investigators, likely because of reduced credit for their scientific effort, difficulties in acquiring a tenure track position, and concerns around motherhood. Women last authors are 22% more likely to have female first authors than male last authors, which support literature that indicates that males are more likely to share data with other males. Overall, the differences reported for gender are also observed with other underrepresented groups and a greater sense of inclusion can help mitigate attrition of talented faculty and trainees in these groups.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.molpharmaceut.3c00328.

Link to the list of male and female names used for analysis as well as the number of authors omitted for each journal because their gender could not be identified; tables with number and percentages of total authorship, editorial board, differences in authorship by journal, publications by publishing house, and authorship across 2017−2021 with respect to gender; table of statistics for the relationship between JIF and authorship in 2021 providing the number, percentage, average, Pearson's coefficient, Spearman's correlation, and *P*-value for this relationship with respect to gender groupings; tables related to the multilevel modeling and projections to parity between male and female authorship; the number, percentage, and average for all relationships as well as the differences per year; the methods for analysis (PDF)

Excel file featuring the list of male and female names used for analysis (XLSX)

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J.E.M. contributed to the data analysis, manuscript writing, and editing. J.M.B. contributed to the data collection and analysis. K.M.A. contributed to the study design, data analysis, manuscript writing, and editing.

Notes

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