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Exploring Gender Disparities in Scholarly Communication Metrics within Digital Library Research

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ABSTRACT

This study investigates gender disparities in scholarly communication in digital library research over 30 years from 1993-2022, focusing on authorship roles, citation metrics, external funding, and open-access publishing. A bibliometric approach was adopted, analysing 831 publications extracted from the Core Collection database of Web of Science. The gender of the first, last, and sole authors was identified using the Gender API and supplementary online searches. Statistical tests, including the Wilcoxon Signed-Ranks test, Independent Samples t-test, and Chi-Square test, were employed to examine gender differences in citation metrics, access to research funding, and open-access publishing across different authorship positions. The findings reveal persistent gender disparities, with male authors dominating senior authorship positions and high-impact publications. However, female first authors demonstrated competitive citation metrics and a slight advantage in open-access publishing. Geographical analysis showed varying levels of gender parity across countries, with the USA, Spain, and England exhibiting a balanced gender distribution, where female authors' contributions are nearly equal to those of male authors. Despite progress toward gender equity, challenges remain in access to funding and leadership roles. The findings highlight the need for institutional policies that promote equitable access to research funding and address the barriers that hinder women from securing financial support for their research endeavors.

Keywords: Gender disparity; Scholarly communication metrics; Digital library research; Citation metrics; External funding; Open access publishing

1. INTRODUCTION

Scholarly communication is a process of creating, transforming, disseminating, and preserving knowledge related to teaching, research, and scholarly endeavors[1]. Research metrics are quantitative measures used to assess various aspects of scholarly output, impact, and productivity[2]. These metrics help researchers, institutions, and policymakers evaluate the influence and significance of research contributions, providing critical insights into academic impact and decision-making processes[3]. Examples of research metrics include journal-level metrics (e.g., impact factor), article-level metrics (e.g., citation counts), and author-level metrics (e.g., h-index). The digital age has transformed the scholarly communication landscape, significantly altering how academic research is disseminated, shared, and evaluated.

One critical aspect of research metrics that demands attention is the persistent gender disparity observed across scholarly communication. Previous research indicates that female researchers face challenges such as lower research productivity, lower citation rates, limited access to funding, and restricted participation in collaborative networks[4-5]. These disparities are also reflected in the underrepresentation of women in senior academic roles, where decision-making power influences not only career advancement but also the allocation of research funding[6]. Furthermore, women often face challenges in securing research grants and leadership positions within academia, as evidenced by the lower success rates of female researchers in obtaining competitive funding than their male counterparts[7]. These disparities reflect significant biases within academia and undermine the objectivity and fairness of research evaluation systems[8]. Recognising and addressing gender disparity as an essential dimension of research metrics is crucial for fostering inclusivity and equity in academic environments, ensuring that diverse contributions are accurately represented and valued.

The intersection of gender and scholarly communication metrics has received limited attention in academic research despite the growing reliance on metrics-driven approaches for evaluating research impact, especially in recruitment, career advancement, and resource allocation. As more academic institutions and research organisations adopt these evaluation metrics, such as citation counts, h-index, and publication visibility, their role in shaping academic

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assessments becomes increasingly critical[9]. However, these metrics can inadvertently perpetuate gender imbalances, with citation patterns favoring male-authored papers and women's work receiving fewer citations, even when their research is of equal quality[10-11]. The h-index, often used to measure academic productivity, similarly rewards researchers with more publications and citations, which tends to benefit male scholars due to historical gender imbalances in academia[12]. The lack of attention to gender disparities within these scholarly communication metrics raises significant concerns about the fairness and inclusivity of these systems, particularly when they are used to inform decisions such as tenure, research funding, and institutional rankings. Addressing these disparities is essential not only for achieving gender equity in academia but also for ensuring that future scholarly communication metrics are inclusive and representative of all scholars, regardless of gender[13-15].

The existing research on gender disparities primarily focuses on traditional academic publishing, with little attention given to scholarly communication metrics such as citations, research funding, and the visibility of research through open-access publishing. The field of Library and Information Science (LIS) has long had a higher number of women than men, especially among library employees. However, men remain the primary authors of library literature[16]. Equitable representation in scholarly communication is as crucial as in any other domain. Despite over 80 % of professional roles in librarianship being held by women, the representation of female authors remains significantly lower, ranging from 20 % to 40 %)[17]. This disparity between professionals and scholarly researchers has been a longstanding issue concerning equity within LIS. Some studies have examined gendered authorship trends and disparities in citation metrics in the LIS domain. A recent study shows that, although, on average, males and females are nearly equally productive in the field of LIS at the global level, male-authored manuscripts receive more citations, resulting in greater research impact compared to those authored by females[18]. However, a study focusing on male and female contributions in a specific journal reveals a disparity in research productivity, with only slight differences in research impact.[19] Additionally, another study highlights significant differences between male and female scholars in their choice of research methods, regardless of topic or journal[20]. Despite existing research on gender disparities in the LIS domain, a notable gap remains in studies examining gender differences in scholarly communication metrics within the field of digital library research. Digital Libraries (DLs) have become essential tools for curating, preserving, and accessing scholarly content. Research on digital libraries is an emerging area within the LIS domain. Therefore, this study aims to explore gender disparities in scholarly communication metrics within the digital library research domain, focusing on gender differences in research productivity, impact, funding, and visibility of male and female authors in this field.

2. OBJECTIVES OF THE STUDY

The primary aim of this study is to examine gender disparities in authorship, citation metrics, external funding, and open-access publishing within digital library research over 30 years. The specific objectives of the study are as follows:

- To investigate temporal trends in gender disparities in authorship within digital library research, focusing on first and last authorship positions.
- To examine gender disparities in authorship roles, including first, last, and sole authors.
- To analyse gender disparities in scholarly publications across the top publishing countries.
- To assess gender disparities in citation metrics across different authorship positions.
- To analyse gender disparities in securing external funding and participation in open-access publishing, with a focus on whether these factors influence gender-based authorship patterns.

3. LITERATURE REVIEW

3.1 Gender Disparities in Research Productivity and Career Progression

Gender disparities in research productivity and career progression are widely documented across academic fields. Several studies highlight the underrepresentation of women in leadership roles, research productivity, citation rates, and challenges such as limited mentorship opportunities and unequal resource distribution. Eloy[21], *et al*. examined gender disparities in research productivity among 9,952 academic physicians, particularly in otolaryngology, revealing significant gaps in scholarly output, leadership representation, and higher academic ranks for women. Despite similar qualifications, these disparities were attributed to institutional biases, unequal resource distribution, and societal roles traditionally assigned to women, resulting in fewer publications and citations for female physicians than their male counterparts. Similarly, Waljee[22], *et al*. and Paik[23], *et al*. highlighted barriers in surgical specialties, such as limited mentorship and sponsorship, which hindered women's career advancement and research visibility. Mueller[24], *et al*. analysed gender disparities among U.S. academic surgeons, finding that women produced fewer publications, had lower h-indices, and faced slower career progression compared to men. These gaps were linked to limited mentorship, reduced access to resources, challenges balancing clinical and research duties, fewer leadership opportunities, and restricted participation in collaborative research networks. Liu[25], *et al*. explored gender disparities in economics, revealing that female economists were underrepresented in high-impact journals, had lower citation counts, and often pursued less-cited subfields.

3.2 Representation in High-Impact Publications and Citation Patterns

Several studies have explored gender disparities in scientific authorship, publication, and citation patterns,

revealing inequities across disciplines. Bendels[10], *et al*. highlighted the underrepresentation of women in Nature Index journals, particularly in first and last author positions. This underrepresentation was consistent across fields, with the most significant disparities observed in physical sciences and engineering. The authors attributed these gaps to biases in access to resources, mentorship, funding, societal expectations, and peer review practices. Nygaard[11], *et al*. further analysed gender disparities in research performance by comparing researchers with similar academic backgrounds and career stages. Their findings revealed that traditional metrics underestimated women's contributions due to biases in citation practices and publication opportunities. They emphasised the importance of equitable evaluation criteria that account for structural barriers. Similarly, Larivière[12], *et al*. identified a global underrepresentation of women in scientific authorship, leadership roles, and international collaborations, with male-authored papers receiving more citations. The study recommended gender-sensitive policies and mentorship programs to address these inequities. Benjamens[26], *et al*. analysed gender disparities in transplantation research, finding that women were underrepresented as first and senior authors in high-impact journals and received fewer citations.

3.3 Barriers to International Collaboration and Visibility

Gender disparities in international collaboration and academic visibility remain significant barriers to achieving equity in research. Kwiek & Roszka[15] analysed data from 25,000 university professors, finding that male academics were more likely to engage in international collaborations, significantly enhancing their research impact. In contrast, female academics faced challenges such as limited access to collaborative networks and disproportionate domestic responsibilities, which restricted their participation in global projects. Institutional policies, including inadequate support for work-life balance and insufficient funding for women-led initiatives, further exacerbated these inequities. Similarly, Dijksterhuis[27], *et al*. examined gender disparities in oncological research, particularly in the transition from conference presentations to journal publications. Female researchers were less likely to convert conference abstracts into full publications due to unequal access to funding, mentorship, and collaborative opportunities. These barriers adversely affected their academic visibility and career progression. The authors advocated for systemic changes to address these challenges, including mentorship programs, academic writing workshops, and equity-focused funding policies. Sugimoto[6], *et al*. linked gender disparities in scholarly communication to global development indicators, showing that women were less likely to be first or last authors and received fewer citations, especially in less economically developed countries. Women face substantial challenges in achieving academic visibility due to gender biases in publication metrics and collaborative opportunities. Halevi[28] reviewed bibliometric studies and found that women were underrepresented in high-impact journals and international collaborations, limiting their academic influence. The study also highlighted biases in peer review and grants allocation processes and recommended diversity-focused editorial boards, blind peer review, and increased support for women-led projects.

3.4 Gender Bias in Academic Evaluation Systems

Studies have also explored gender disparities in academic evaluation systems, research publishing, recognition, and career progression. Thelwall[9], *et al*. analysed gender disparities across disciplines in the UK, revealing that women were less likely to publish in high-impact journals and were underrepresented in fields such as physical sciences and engineering. Systemic biases contributed to these inequities, including unequal resource access, limited representation in collaborative networks, and gendered academic expectations. Additionally, papers authored by women received fewer citations, underscoring the presence of citation bias. Santos[8], *et al*. investigated the influence of gendered research priorities on academic outcomes. Their findings indicated that women were more likely to focus on socially impactful fields like education and public health, while men dominated prestigious areas like engineering and economics. This divergence often resulted in disparities in funding, publication opportunities, and recognition, with systemic biases undervaluing traditionally female-associated fields. Kent[29] *et al.* expanded on this perspective, examining gender disparities in healthcare access, outcomes, and leadership. They identified structural inequities and cultural biases as key barriers and advocated for gender-sensitive policies and increased representation of women in leadership roles.

3.5 Research Funding and Research Resource Allocation

Gender disparities in research funding and resource allocation continue to impede the advancement of female researchers across various academic disciplines. Hall[30] *et al*. found that women in neurology were less likely to receive large grants or lead major research initiatives than their male counterparts. This inequity was primarily attributed to implicit bias, a lack of mentorship, and the disproportionate caregiving responsibilities women often face. Similarly, Nguyen[31], *et al*. identified significant disparities in NIH funding for surgeon-scientists, with women receiving fewer and smaller grants. The study highlighted biases in the grant review process and unequal access to mentorship, advocating for greater transparency to ensure equitable funding distribution.

Mirin[32] focused on the gender funding gap in healthcare research, noting that diseases primarily affecting women received less funding than those impacting men despite similar disease burdens. This discrepancy limits women's health research advancements and exacerbates broader healthcare disparities. Both Piccini[33], *et al*. & Day[34] *et al*. examined funding challenges in pediatrics and the chemical sciences, respectively, and found that women

in these fields face systemic barriers that hinder their ability to secure funding and leadership roles.

Safdar[35], *et al*. also found significant gender disparities in grant allocation at the NIH, with women not only less likely to apply for or receive grants but also awarded smaller amounts when funded. The authors noted biases in the grant evaluation process and recommended changes, including revised evaluation criteria, reviewer bias training, and targeted funding initiatives. Van der Lee & Ellemers[7] further explored how gender influences research funding success, revealing that female researchers, despite having similar qualifications and publication records, were less likely to receive funding due to stereotypical biases regarding their competence and leadership abilities.

3.6 Gender Disparities in LIS Research

Gender disparities in Library and Information Science (LIS) research have become a significant study area, highlighting imbalances in authorship, research topics, methodology, and leadership roles. Shah[18], *et al.* explored gender differences in LIS research and found that female authors were consistently underrepresented in high-impact journals. Despite their active contributions, women face barriers to equitable representation, particularly in prestigious publications, and often occupy secondary roles in co-authorship networks. Similarly, Gul[19], *et al*. identified male dominance in collaborative authorship patterns in research papers published in The Electronic Library, underscoring cultural and institutional biases that hinder women's career progression in LIS.

Parabhoi, *et al*.[36] analysed gender disparities among Indian LIS professionals from 1999 to 2018 and found a significant gap between male and female authors in publishing research in high-impact journals, with male authors being significantly more prevalent than female authors. Female researchers were more likely to publish in regional or less-cited journals, indicating unequal access to resources and networking opportunities. Zhang, *et al*[20]. further investigated gender differences in research topics and methods, finding that male authors preferred quantitative and technical methods. In contrast, female authors leaned towards qualitative methods and user-centered themes.

Gender disparities in LIS also extend to leadership roles and education. In a study, Owoicho & Awomuse[37] found that male professionals occupied senior positions in Nigerian polytechnics. In contrast, female professionals remain underrepresented in decision-making roles due to societal expectations, workplace discrimination, and limited mentorship. Harris[38], *et al.* highlighted gender gaps in library education, particularly in recruitment, curriculum design, and career progression, reinforcing gender stereotypes within the profession.

Longitudinal studies, such as those by Monroe-Gulick, Weaver & Morris[16] and Lund & Shamsi[39], provide valuable insights into the evolving gender representation in LIS. While gradual progress has been observed, significant disparities persist in leadership roles and high-impact publications. These studies emphasize the importance of sustained efforts to support female scholars through mentorship programs, funding opportunities, and equitable evaluation criteria. Addressing gender inequities is essential for enhancing the discipline's intellectual diversity and innovation. However, gaps remain in understanding qualitative aspects, such as discrimination and mentorship, and the intersectionality of gender with race, ethnicity, and socioeconomic status, which warrants further research.

4. METHODOLOGY

The issue of gender disparities has long been recognised in various areas of society and has also been identified in scholarly communication[18,40]. The present study adopts a bibliometric approach to investigate gender disparities in scholarly communication within the field of digital library research. Since gender disparities in research can be examined using publication and citation data, bibliometric analysis is deemed the most suitable method for this study.

4.1 Data Extraction Process

Data for this study were extracted from the Core Collection database of Web of Science (WoS). The WoS database was selected due to its extensive coverage of peer-reviewed, high-quality journals and its detailed citation data, which facilitate the analysis of academic impact[41].

Initially, a topic search using the keyword "Digital Librar"* was conducted on WoS via the document search option on December 16, 2024. The search was limited to the period from January 1, 1993, to December 31, 2022, using the date range option. This timeframe (1993–2022) was selected for two main reasons:

- The year 1993 was chosen as the starting point because research on digital libraries began that year.
- The year 2022 was chosen as the endpoint to provide an extended citation window, enabling a more accurate assessment of citation impact.

This search yielded a total of 6,811 results. The results were refined by applying specific filters, including document type and subject categories.

- The document type filter was used to include only journal and review articles (n = 3,196), excluding other document types (n = 3,615).
- The subject category filter was then applied to select documents covering the "Information Science & Library Science" discipline to ensure alignment with the study's objectives, resulting in 836 publications.

Five publications that lacked complete author details were excluded from the study. Consequently, 831 publications were selected for analysis. Fig. 1 presents a flowchart illustrating the inclusion and exclusion criteria for publications

4.2 Gender Identification

The gender of the authors was identified using the Gender API (https://www.genderapi.io/), a tool developed by Ozan Soft in 2016. For cases where the Gender API could not determine an author's gender or where author

details were missing from the bibliographic information, the DOI of each article was searched in Google Scholar, Google, and ScienceDirect to download the PDF file. The biographical sketches provided at the end of each article were then carefully reviewed.

If biographical sketches were unavailable in the full paper, additional searches were conducted in Google Scholar, social media platforms (LinkedIn, Facebook, and Academia.edu), and the websites of affiliated institutions to confirm the author's gender. Each article was thoroughly examined, and all available biographical notes were reviewed to determine the authors' gender.

The authorship pattern of publications was classified based on the gender of the first author, last author, and sole author (in the case of single-authored publications).

- If the first author was male, the publication was categorised as male authorship; if the first author was female, it was categorised as female authorship.
- The same classification was applied when considering the last author.
- For single-authored publications, the categorisation was based on the gender of the sole author.

The identification of the first and last authors was conducted using MS Excel software by utilising data filtering and cell-splitting functions. The first and last authors were then manually extracted from the processed Excel file.

4.3 Study Variables and Use of Statistical Analysis

The following independent variables were considered to investigate gender disparities in scholarly communication:

- Number of publications
- Funded and non-funded publications
- Open-access and closed-access publications

The number of citations was considered the dependent variable for measuring gender-wise disparities in scholarly impact.

Statistical tests, including the Wilcoxon Signed-Ranks Test, the Independent Samples t-test, and the Chi-Square Test, were applied to measure gender disparities across different scholarly communication metrics.

5. RESULTS

5.1 Temporal Trends in Gender Disparity in The First Authorship

Figure 2 shows the percentage of publications by male and female first authors over 30 years, divided into six-time intervals from 1993 to 2022. Overall, male authors consistently contributed a higher proportion of first-author publications compared to female authors throughout the observed periods. In the initial period (1993–1997), however, female authors accounted for the majority of publications (60.47 %) compared to male authors (39.53 %).

In subsequent periods, the trend shifted, with male authors consistently surpassing female authors in first-author contributions. The most significant disparity was observed during 1998–2002, when male authors accounted for 64.77% of publications, compared to 35.23% of female authors.

Interestingly, the gender gap in first-author publications appears to narrow in the later periods (2013–2017 and 2018–2022). For instance, in 2018–2022, male authors

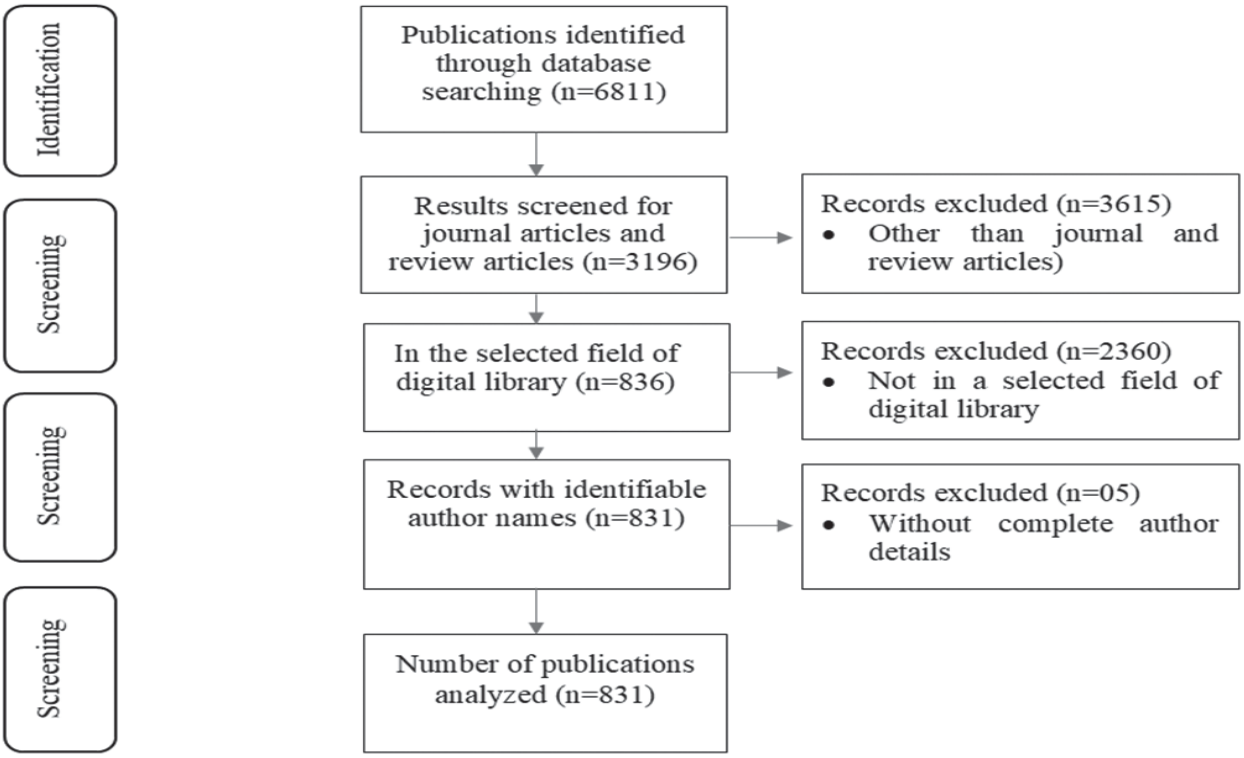

Figure 1. Four-phase PRISMA flowchart outlining the inclusion and exclusion criteria for publications.

contributed 53.89 % of publications, while female authors contributed 46.11 %, reflecting a reduced difference compared to earlier periods. This suggests a gradual shift toward gender balance in digital library research, although male authors still maintain a slight lead. The data indicate a positive trend in female participation, highlighting progress in addressing gender disparities in scholarly communication within this field.

5.2 Temporal Trends in Gender Disparity in The Last Authorship

Figure 3 shows the percentage of publications by male and female as last authors over 30 years. Throughout the observed periods, male authors consistently held a dominant position compared to female authors as last authors. In the earliest period (1993–1997), male authors accounted for 58.82 % of last-author publications, while female authors contributed 41.18%. The gender gap widened in the subsequent periods, peaking during 2003–2007 when male authors accounted for 63.51 % of last-author publications, compared to 36.49 % by female authors.

Although male dominance in last-author positions persisted across all time frames, a slight narrowing of the gender gap is observed in the later periods. For example, in the most recent period (2018–2022), male authors accounted for 58.02 % of last-author publications, while female authors contributed 41.98 %. This narrowing suggests gradual progress toward gender balance, though male authors continue to occupy most senior authorship roles, which often reflect leadership positions in research projects. The data imply that while female representation among last authors has improved, gender disparities in senior authorship roles remain evident in digital library research.

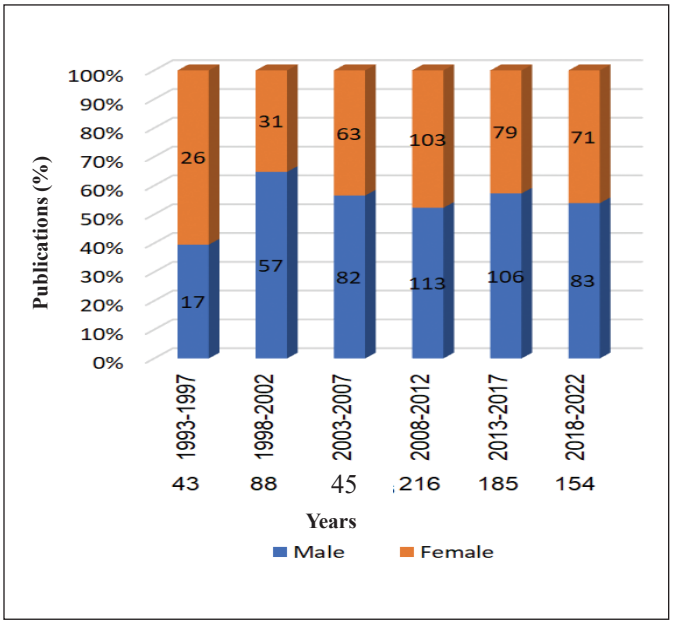

Figure 2. Percentage of first author publications by authors' gender.

5.3 Gender Disparity in Authorship Across Top Publishing Countries

Figure 4 presents the percentage of publications by male and female authors in the top ten publishing countries, revealing notable differences in gender distribution. In countries such as Germany, China, Taiwan, India, Iran and Brazil, male authors account for a larger share of publications than female authors.

The highest proportion of male authors is observed in Germany (80 % vs. 20 %), India (71 % vs. 29 %), China (67.9 % vs. 32.1 %), Iran (64.3 % vs. 35.7 %), Brazil (58.8 % vs. 41.2 %) and Taiwan (56.8 % vs. 43.2 %). In contrast, the lowest proportion is seen in Malaysia and South Korea, where female authors dominate with 85.7 % and 61.1 % of publications respectively.

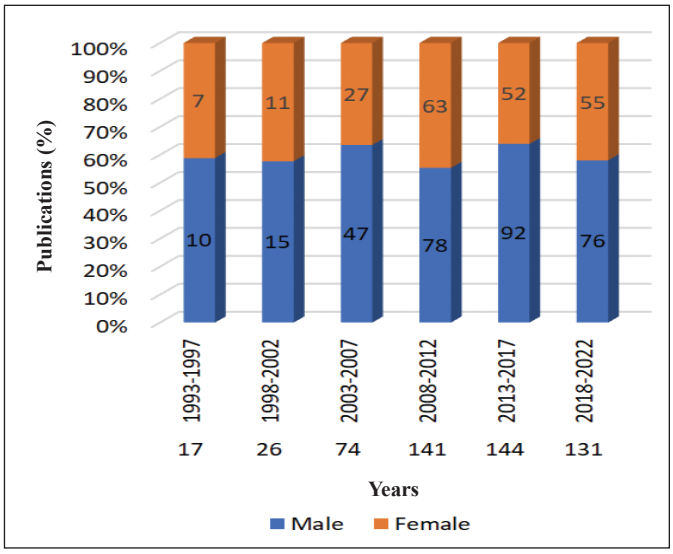

Figure 3. Percentage of last author publications by authors' gender.

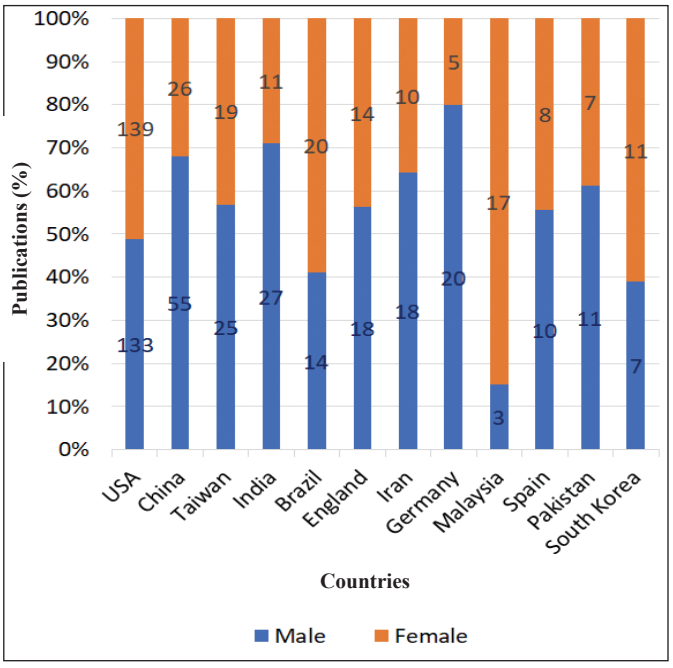

Figure 4. Percentage of publications by authors' gender in top 10 countries.

Table 1. Gender disparities in authorship, citations, funding, and open-access publishing

	Total citations	**Total publications**	**Female**	**Female %**	**Citations (Female)**	**Citations (Median)**	**Male**	**Male %**	**Citations (Male)**	**Citations (Median)**	***P***
First author											
Total	10026	831	373	44.88	4633	6(3,15)	458	55.11	5393	5(2,14)	0.000[a]
By citation groups											0.003[c]
Upto 10	-	552	249	45.1	-	-	303	54.89	-	-	
11-30	-	202	87	43.06	-	-	115	56.93	-	-	
30-50	-	45	21	46.67	-	-	24	53.33	-	-	
50-70	-	16	7	43.75	-	-	9	56.25	-	-	
70-100	-	8	5	62.5	-	-	3	37.5	-	-	
>100	-	8	4	50	-	-	4	50	-	-	
External Funding	-	93	38	40.86	-	-	55	59.14	-	-	0.097[b]
Open Access	-	147	75	51.02	-	-	72	48.98	-	-	0.001[b]
Last Author											
Total	6905	534	215	40.26	2613	6(2,15)	319	59.74	4292	7(3,17)	0.000[a]
By citation groups											0.000[c]
Up to 10	-	336	132	39.28	-	-	204	60.71	-	-	
11-30	-	146	61	41.78	-	-	85	58.21	-	-	
30-50	-	30	15	50	-	-	15	50	-	-	
50-70	-	11	5	45.45	-	-	6	54.54	-	-	
70-100	-	5	1	20	-	-	4	80	-	-	
>100	-	6	1	16.67	-	-	5	83.33	-	-	
External Funding	-	86	31	36.05	-	-	55	63.95	-	-	0.080[b]
Open Access	-	101	45	44.55	-	-	56	55.44	-	-	0.054[b]
Only One Author											
Total	3121	297	117	39.39	1283	4(2,10)	180	60.6	1838	5(2,12)	0.000[a]
By citation groups											
Up to 10	-	216	88	40.74	-	-	128	59.25	-	-	
11-30	-	56	18	32.14	-	-	38	67.86	-	-	
30-50	-	15	7	46.67	-	-	8	53.33	-	-	
50-70	-	5	2	40	-	-	3	60	-	-	
70-100	-	3	1	33.33	-	-	2	66.67	-	-	
>100	-	2	1	50	-	-	1	50	-	-	
External Funding	-	7	2	28.57	-	-	5	71.42	-	-	0.236[b]
Open Access	-	46	18	39.13	-	-	28	60.86	-	-	0.937[b]

aStatistical difference in number of citations by Wilcoxon Signed Ranks Test.

bStatistical difference number of male and female authors by Independent Sample t-test.

cStatistical differences for citation group by Chi-Square test. $P < 0.05$ is significant.

Meanwhile, the USA (48.9 % vs. 51.1 %), Spain (55.55 % vs. 44.45 %), Taiwan (56.8 % vs. 43.2 %) and England (56.25 % vs. 43.75 %) exhibit a more balanced gender distribution, with female authors' contributions nearly equal to those of male authors, indicating a more equitable environment for scholarly output in these countries.

Overall, the results highlight gender disparities in scholarly communication across different countries. However, the varying degrees of disparity suggest that some countries are progressing more toward gender parity than others.

5.4 Gender Disparities in Citation Metrics, External Funding, and Open Access Publishing

Table 1 presents data on the number of publications and citations by gender, categorised by authorship position (first author, last author, and sole author). It also includes subcategories such as citation groups, external funding, and open access status. Statistical tests were conducted to assess the gender disparity in authorship and citation metrics, gender disparity in securing external funding, and gender disparity in open-access publishing.

5.4.1 Gender Disparities in Citation Metrics (First Author)

In the first-author publications and citations analysis, females accounted for 44.88 % (373 out of 831) of first authors, while males represented 55.11 % (458 out of 831). Females received 4,633 citations (median: 6; IQR: 3–15), compared to males, who received 5,393 citations (median: 5; IQR: 2–14). The Wilcoxon Signed Ranks Test revealed a statistically significant difference ($p = 0.000$), suggesting that female first authors tend to have slightly higher median citations than their male counterparts.

When examining citation groups, females and males were relatively evenly distributed. However, females were slightly overrepresented in the 70–100 citation group (62.5 % compared to 37.5 % for males). The Chi-Square test indicated a significant difference in citation group distribution by gender ($p = 0.003$).

5.4.2 Gender Disparities in Citation Metrics (Last Author)

In the last-author publications and citations analysis, females accounted for 40.26 % (215 out of 534), while males represented 59.74 % (319 out of 534). Females received 2,613 citations (median: 6; IQR: 2–15), compared to males, who received 4,292 citations (median: 7; IQR: 3–17). The Wilcoxon Signed Ranks Test showed a statistically significant difference ($p = 0.000$), indicating that male last authors tend to have slightly higher median citations.

Females were underrepresented in higher citation groups, such as the >100 citation group, where they accounted for only 16.67 %, compared to 83.33 % for males. The Chi-Square test indicated a significant difference in citation group distribution ($p = 0.000$).

5.4.3 Gender Disparities in Citation Metrics (Sole Author)

For single-author publications and citations, females accounted for 39.39 % (117 out of 297), while males represented 60.6 % (180 out of 297). Females received 1,283 citations (median: 4; IQR: 2–10), compared to males, who received 1,838 citations (median: 5; IQR: 2–12). The Wilcoxon Signed Ranks Test revealed a statistically significant difference ($p = 0.000$), indicating that male single authors tend to have slightly higher median citations. Citation groups were relatively evenly distributed between genders, with no significant differences observed.

5.4.4 Gender Disparities in Securing External Funding and Open-Access Publishing

The data in Table 1 reveals notable gender disparities in securing external funding and participation in open-access publishing. Among the first authors, male researchers secured a higher proportion of external funding (59.14 %) compared to their female counterparts (40.86 %), though the difference was not statistically significant ($p = 0.097$). A similar trend is observed in the last authorship, where men received 63.95 % of external funding, while women secured only 36.05 % ($p = 0.080$). The gap widens further for single-author publications, with male researchers receiving 71.42 % of external funding, while female authors received only 28.57 %, though this result was not statistically significant ($p = 0.236$). These findings suggest that women face challenges in securing research funding, likely due to implicit biases in grant allocation, restricted access to professional networks, and institutional barriers that limit their opportunities to lead funded projects.

In contrast, open-access publishing presents a more balanced gender representation, particularly in first authorship, where women slightly outnumber men (51.02 % vs. 48.98 %, $p = 0.001$). However, men still dominate open-access publications in last and single authorship positions, although the differences are not statistically significant ($p = 0.054$ and $p = 0.937$, respectively). The relatively higher participation of female researchers in open-access publishing could indicate an attempt to increase the visibility and accessibility of their work, compensating for disadvantages in traditional publishing and citation practices.

6. CONCLUSION

This study highlights persistent gender disparities in digital library research, though notable progress toward gender parity has been observed over the past three decades. Geographically, gender disparities varied significantly across the top publishing countries. While male authors dominated in Germany, India, and China, countries such as Malaysia and South Korea exhibited female-majority authorship. The USA, Spain, and England displayed near gender parity, suggesting more equitable environments for scholarly contributions.

The findings revealed significant gender disparities in authorship, citations, and access to external funding within the research landscape. Although female first authors demonstrate comparable citation metrics, their underrepresentation in senior roles and high-citation groups indicates a lack of parity with their male counterparts that must be addressed. Gender disparities were also evident in external funding, where female authors were underrepresented, particularly in single-author publications. However, females showed a slight advantage in open-access publishing.

Efforts to promote gender equity in research must address these gaps, particularly in securing funding, advancing to leadership positions, and achieving high-impact publications. Institutions and stakeholders must implement specific and actionable strategies to address gender disparities. These include equity-focused research funding policies, such as gender-blind review processes and funding schemes specifically designed for early-career female researchers. Structured mentorship programs should be established to support professional growth, leadership development, and enhance research visibility for women scholars. Additionally, academic writing and grant proposal workshops targeting female researchers, particularly in underrepresented regions, are essential. Institutional gender audits can also be conducted to identify and eliminate biases in recruitment, promotion, and resource allocation.

Further qualitative research is crucial to identifying the underlying causes of these disparities and developing evidence-based interventions to promote a more inclusive and equitable research environment. Addressing these gaps will support individual researchers and improve the quality and diversity of scientific contributions.

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