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A retrospective analysis of gender parity in scientific authorship in a biomedical research centre

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ABSTRACT

Objective: Scientific authorship is a vital marker of success in academic careers and gender equity is a key performance metric in research. However, there is little understanding of gender equity in publications in biomedical research centres funded by the National Institute for Health Research (NIHR). This study assesses the gender parity in scientific authorship of biomedical research.

Design: A retrospective descriptive study.

Setting: NIHR Oxford Biomedical Research Centre.

Data: 2409 publications accepted or published from 1 April 2012 to 31 March 2017.

Main outcome measures: Gender of authors, defined as a binary variable comprising either male or female categories, in six authorship categories: first author, joint first authors, first corresponding author, joint corresponding authors, last author and joint last authors.

Results: Publications comprised clinical research (39%, n=939), basic research (27%, n=643), and other types of research (34%, n=827). The proportion of female authors as first author (41%), first corresponding authors (34%) and last author (23%) was statistically significantly lower than male authors in these authorship categories. Of total joint first authors (n=458), joint corresponding authors (n=169), and joint last authors (n=229), female only authors comprised statistically significant smaller proportions i.e. 15% (n=69), 29% (n=49) and 10% (n=23) respectively, compared to male only authors in these joint authorship categories. There was a statistically significant association between gender of the last author(s) with gender of the first author(s) (χ^2 33.742, $P < 0.001$), corresponding author(s) (χ^2 540.774, $P < 0.001$) and joint last author(s) (χ^2 91.291, $P < 0.001$).

Conclusions: Although there are increasing trends of female authors as first authors (41%) and last authors (23%), female authors are underrepresented compared to male authors in all six categories of scientific authorship in biomedical research. Further research is needed to encourage gender parity in different categories of scientific authorship.

Strengths and limitations of this study

- This is the first study to investigate gender parity in six categories of scientific authorship: first authors, first corresponding authors, last authors and three joint authorship categories i.e. joint first authors, joint corresponding authors and joint last authors in biomedical research.
- This study provides an important benchmark on gender equity in scientific authorship for other NIHR funded centres and organisations in England.
- The generalisability of the findings of this study may be limited due to differences in medical specialities, research areas, institutional cultures, and levels of support to individual researchers.
- Using secondary sources for determining the gender of authors may have limitations, which could be avoided by seeking relevant information from original authors and institution affiliation at the time of submission.

Keywords: Responsible Research and Innovation, Gender Equity, Scientific Authorship, National Institution for Health Research, Biomedical Research Centres, Evaluation, Translational Research Organisations, Translational Research, Basic Science Research.

INTRODUCTION

Promoting Responsible Research and Innovation (RRI) is a major strategy of the "Science with and for Society" work programme of the European Union's (EU) Horizon 2020 Framework Programme for Research and Innovation[1]. RRI aims to build capacity and develop innovative ways to connect science to society[2]. The RRI approach enables all societal members (such as researchers, citizens, policymakers, businesses and third sector organisations) to work together during the research and innovation process in order to better align research and innovation with the values, needs and expectations of the society[1,2]. The RRI strategy includes the "keys" of public engagement, open access, gender, ethics and science education, and two further "keys": sustainability and social justice, which have been added recently [3]. The idea is that by prioritising these key components of RRI, it would help make science more attractive to young people and society, and raise awareness of the meaning of responsible science[2].

We have focussed on the 'gender' element of the RRI because it is imperative to advance gender equality within research institutions, as well as within the design and content of research and innovation[1]. The issue of enhancing female participation in economic decision-making has become prominent in the national, European and international spheres, with a particular focus on the economic dimension of gender diversity[4]. In order to achieve a fair female participation within positions of power, it is recommended that women should hold half of the total seats in board rooms[5], however, a ratio between 40% and 60%, also known as a "gender balance zone"[6], is considered acceptable – a threshold that is set by the European Commission[4].

From the perspective of gender equality in academia and scientific research, gender parity in scientific authorship is an important measure of achievement. The term gender parity refers to "the equal contribution of women and men to different dimensions of life" and it is operationalised as a "relative equality in terms of numbers and proportions of women and men" for a particular indicator"[7]. Gender (dis)parity in scientific authorship has important implications for gender equity in academic advancement[8] because scientific authorship is commonly used as a measure of academic productivity that is used for performance management, reward, and recognition[9,10]. The acceleration of women's advancement and leadership in research is one of the stated objectives of the National Institute of Health Research (NIHR) in the United Kingdom (UK) and it is imperative for the RRI in the wider European research area. Yet, there is limited research concerning gender equity in scientific authorship of translational research funded through NIHR biomedical research centres (BRCs).

In the UK, women currently outnumber men in medical schools[11], however, a persistent gender disparity in scientific publications remains[10,12–23]. While the proportion of women as first and senior authors of original medical research has increased over the past few decades[24], women are still significantly underrepresented as authors of research articles in medical journals, especially as first and senior authors[14,22,23,25]. For example, in radiology the proportion of women as first author increased from 8% in 1978 to 32% in 2013 and senior author increased from 7% in 1978 to 22% in 2013[23]. Similarly, in gastroenterology the proportion of women as first author increased from 9% in 1992 to 29% in 2012, and senior author increased from 5% in 1992 to 15% in 2012[14].

The profile of gender equity in higher education and research has been raised by the introduction of Athena SWAN-linked funding incentives by the NIHR[26–28]. While Athena SWAN awards are useful markers of achievement for higher education institutions and research institutes, they alone are insufficient to assess and monitor the progress of NIHR BRCs towards gender equity[29]. Currently, the proportion of women and the rate of their achievements are not tracked routinely by the NIHR BRCs and little is known about how much women contribute to scientific research and innovation in the BRCs. It is important to inform the acceleration of women's advancement and leadership in translational research in line with the stated objectives of the NIHR within the UK and RRI within the wider European research area through the collection of gender-disaggregated bibliometric data and analysis of scientific authorship by gender.

For addressing the paucity of empirical research on women's advancement and leadership in translational research in the UK and Europe, a recent study on gender equity in Neurology suggests the need for institutions to take a systematic approach to addressing gender disparities that involve customised, defined metrics and transparent reporting to stakeholders[30].

The aim of this study was to assess the gender parity in six types of scientific authorship in biomedical research.

METHODS

Study design

A retrospective descriptive study.

Setting

This study was conducted at the NIHR Oxford BRC, which is research collaboration between the Oxford University Hospitals NHS Foundation Trust and the University of Oxford[31]. The aim of NIHR BRCs is to support translational research and innovation to improve healthcare for patients[32]. During the study period (April 2012-March 2017), the NIHR Oxford BRC was awarded £96m to support research across nine research themes, five cross-cutting themes, and a range of underpinning platforms. The research themes included Blood, Cancer, Cardiovascular, Dementia and Cerebrovascular Disease, Diabetes, Functional Neuroscience and Imaging, Infection, Translational Physiology, and Vaccines. The crosscutting themes included Genomic Medicine, Immunity and Inflammation, Surgical Innovation and Evaluation, Biomedical Informatics and Technology, and Prevention and Population Care. The major underpinning platforms included a Biorepository, Education and Training, Public Engagement, and Research Governance. It is a contractual requirement to report the number of BRC supported publications published by researchers funded or supported by the NIHR research funds on an annual basis. Additionally, the NIHR uses bibliometric analyses to inform eligibility for NIHR funding[33,34]. This study was carried out as part of a wider programme of research on the markers of achievement for assessing and monitoring gender equity in translational research organisations[29].

Data

Data comprised translational research publications published by researchers funded or supported by the NIHR Oxford BRC. The eligibility criteria for inclusion of a publication were funding or support by the NIHR Oxford BRC and publication between April 2012 and March 2017. Based on these criteria, 2409 publications were identified. These publications were classified as: basic science studies, clinical studies (both trial and non-trial studies), and other studies (comments, editorials, systematic reviews, reviews, opinions, meeting reports, guidelines and protocols).

Main outcome measures

The main outcome measures were: (1) Gender of authors, defined as a binary variable comprising, either male or female categories, (2) Six categories of scientific authorship: first author, joint first authors, first corresponding author, joint corresponding authors, last author and joint last authors (Figure 1). These categories are conventionally associated with the highest amount of contribution, credit and prestige[10,17].

First author was defined as the first-named author of the publication. Publications that consisted of single authors were categorised as first authors. We considered the first author to be the main intellectual contributor in the publication, in terms of study design, data collection and analysis, and manuscript writing. Joint first authors were defined as two or more authors who were named as equal contributors and mentioned as joint first authors of the publication. The first corresponding author was defined as the only author who was reported as a corresponding author in the publication and his/her contact details such as an institutional address and/or an email address were provided for correspondence in the publication. Joint corresponding authors were defined as two or more authors who were listed or marked as corresponding authors and their contact details were provided for correspondence in the publication. Last author was defined as the last-named author of a publication. The last author was considered to be a group leader or principal investigator who may have provided significant intellectual contribution or supervision of the research work as well as acquisition of research funding[17,35]. Joint last authors were defined as two or more authors who were named as equal contributors in the publication and their names were mentioned as joint last authors in the publication. A major confounding factor, for which we could not control, was the informal nature of the conventions for the sequence and role of authors[35]. Although conventions for scientific authorship are well established in biomedical sciences[36,37], they may vary between different research areas and even between different research groups within the same area.

Determination of gender of authors

The gender of the authors was defined as a binary variable comprising either male or female categories, which were determined based on the first name of authors in all six categories of authorship included in the analysis. When the first names of authors were initialled in the publication or were difficult to associate with either male or female gender, further information was sought through searching their institutional webpages and online social network sites such as the LinkedIn and ResearchGate. We also used the Gender API (gender-api.com) when it was not possible to ascertain the gender of the authors by the above-mentioned sources. In addition, we contacted five authors directly via email to ascertain their gender. After completing data coding by two researchers (MJM and RD), to ensure the accuracy of data coding, 10% of the data were checked independently (CH). Consensus was achieved through discussion between the researchers on data fields that did not match the assigning of the gender of authors and types of authorship (Figure 1).

Statistical analysis

Data were analysed using frequencies including counts and percentages. Chi-square tests were used for identifying statistically significant differences and associations between male and female authors in various categories of authorship. The level of significance was set at $p < 0.05$. Data were analysed using the IBM SPSS Statistics for Windows, Version 25.0 (Armonk, NY: IBM Corp.).

Patient and public involvement statement

There was no patient or public involvement in the study design.

RESULTS

Type of research study

Table 1 presents an overview of the types of research studies by year. Clinical research studies (both trial and non-trial studies) comprised 39% (n=939), basic science research 27% (n=643) and a third of publications (34%, n=827) included other types of research, such as systematic reviews, reviews, research protocols, editorials, guidelines, opinions, comments, and meeting reports.

Table 1 Number of publications by year of acceptance and types of research studies

	Types of research studies Count (%)				
Year (Accepted)	**Basic science**	**Clinical trial**	**Clinical study - Not a trial**	**Other***	**Total Count (%)**
2012†	75 (27.6)	18 (6.6)	90 (33.1)	89 (32.7)	272 (100)
2013◊	151 (28.2)	27 (5.0)	183 (34.2)	174 (32.5)	535 (100)
2014◊	122 (22.2)	29 (5.3)	204 (37.2)	194 (35.3)	549 (100)
2015◊	137 (24.7)	48 (8.7)	158 (28.5)	211 (38.1)	554 (100)
2016◊	137 (31.8)	31 (7.2)	120 (27.8)	143 (33.2)	431 (100)
2017‡	21 (30.9)	5 (7.4)	26 (38.2)	16 (23.5)	68 (100)
Total	**643 (26.7)**	**158 (6.6)**	**781 (32.4)**	**827 (34.3)**	**2409 (100)**

†April-December, ◊January-December ‡January-March, *systematic reviews, reviews, research protocols, editorials, guidelines, opinions, comments, and meeting reports

Authorship type and Gender

Table 2 presents an overview of gender of authors by types of authorship. This highlights that male authors were statistically significant more likely to be first authors (59%, $\chi 2$ 972.938, P <0.001), first corresponding authors (66%, $\chi 2$ 242.970, P <0.001) and last authors (77%, $\chi 2$ 702.411, P <0.001)) (Table 2). Furthermore, analyses of joint authorship categories revealed that the proportion of 'female only' authors was statistically significantly lower than 'male only' authors in the joint corresponding authors (29%, $\chi 2$ 79.858, P<0.001) and joint last authors categories (10%, $\chi 2$ 56.550, P<0.001) (Table 2). However, in the joint first authors category, the proportion of 'male and female' as joint first authors (57%, χ2 128.467, P <0.001) was statistically significantly higher than male only and female only first authors (Table 2).

Table 2. Authorship categories and gender of authors

Authorship type Number of publications in the category	**Gender of authors** Count (%)			**Chi-Square Test** χ^2 (p)
	Male only	Female only	Male and female	
First author (n=2407)	1413 (58.7)	994 (41.3)	N/A*	72.938 (<0.001)
First corresponding author (n=2371)	1565 (66)	806 (34)	N/A	242.970 (<0.001)
Last author (n=2406)	1853 (77)	553 (23)	N/A	702.411 (<0.001)
Joint first authors (n=458)	127 (27.7)	69 (15.1)	262 (57.2)	128.467 (<0.001)
Joint corresponding authors (n=169)	107 (63.3)	49 (29)	13 (7.7)	79.858 (<0.001)
Joint last authors (n=229)	108 (47.2)	23 (10)	98 (42.8)	56.550 (<0.001)

*N/A= not applicable.

Gender of authors by type of research studies

Analysis of gender of authors by types of research studies (i.e. basic science, clinical trials, non-trial clinical studies and other research) showed that the proportions of male only authors were statistically significantly higher than the proportions of female only authors in three authorship categories: first authors (χ2 8.606 (df 3), P = 0.035), first corresponding authors (χ2 36.955 (df 9), P < 0.001) and last authors (χ2 10.314 (df 3), P= 0.016). The analysis by type of research studies also revealed that there were no significant differences between the proportions of male only and female only authors in all three joint authorship categories: joint first authors (χ2 5.549 (df 6), P = 0.476), joint corresponding authors (χ2 9.021 (df 6), P = 0 .172) and joint last authors (χ2 8.433 (df 6), P = 0 .208).

Yearly trends in Authorship by gender

Figure 2 presents the yearly trends in scientific authorship by gender. In all authorship types and across all five years of publication, the proportion of male and female authors varied (Figure 2). The analysis showed women were significantly underrepresented across all years and authorship types. Interestingly, joint first authorship indicated a higher proportion of 'male and female' authors compared to 'male only' and 'female only' authors (Figure 2).

Association between same gender across authorship categories

There was a statistically significant association between the same gender in first authorship and corresponding authorship categories (χ^2 775.425 (df 3), P < 0.001) and the first author and joint first authors (χ^2 138.849 (df 2), P < 0.001).

Furthermore, there were statistically significant associations between the same gender in the last author category with the same gender of first author(s) (χ^2 33.742 (df 2), P < 0.001), corresponding author(s) (χ^2 540.774 (df 1), P < 0.001) and joint last authors (χ^2 91.291 (df 2), P < 0.001). However, there was no statistically significant association between the male and female last authors with the respective gender of joint first authors (χ^2 4.29 (df 2), P = 0.117).

DISCUSSION

We retrospectively analysed the gender parity of authors in six categories of authorship of scientific publications that were published over a five-year period. Our analysis shows that the number of female authors were underrepresented across all six categories of authorship [10,38,39].

In the first author category the proportions of female authors and male authors were within the 40%-60% “gender balance zone”[6]. The greatest gender imbalance was observed in the last author category where ‘female only’ authors comprised only 23%. Nonetheless, this proportion is higher than other studies reporting similar analyses[11,16,24].

To the best of our knowledge, this study presents the first analysis of joint authorship in three categories. Secondly, it demonstrates underrepresentation in female only authors in six categories of scientific authorship[40]. Thirdly, the analysis highlights gender inequity with female underrepresentation in prestigious authorship positions compared to male in biomedical research. This is consistent with other fields including: epilepsy, lung cancer, dermatology, eating disorders and in medicine in general[17,19,41–43].

This study extends understanding of gender-based trends in scientific authorship (Figure2) by showing encouraging incremental changes in gender parity in authorship in a biomedical research setting. Previous research examined the gender gap in authorship within the medical literature reporting an upward trend for female first authors from 6% in 1970 to 29% in 2004 and female last authors from 4% in 1970 to 19% 2004. However, it was limited to US based institutions[12]. A similar UK based study covering the same period (i.e. 1970-2004) also showed upward trends for female first authors increasing from 11% in 1970 to 37% in 2004 and female last authors from 12% in 1970 to 17% in 2004[24]. In addition, a recent study by Filardo et al.[16] examined the prevalence of female first authorship of original research published in six high impact general medical journals between February 1994 and June 2014 revealed that the adjusted probability of an article having a female first authorship increased significantly from 27% in 1994 to 37% in 2014[16]. However, despite the proportion of female first authors varied greatly by journal, men were generally more likely to be first authors than women[16]. Compared to previous studies mentioned above, our study provides evidence of higher and increasing gender equity in the first authors, last authors and other four categories of scientific authorship in biomedical research (Table 2).

Our study identified a strong association between same gender and authorship types showing if the first author of a publication was male, it was highly likely that the first corresponding author of the same publication would also be male. Similarly, the likelihood of the first author being female was higher, if the first corresponding author was also female[44]. Likewise, there appeared to be a significant association of male and female last authors with the respective gender of first authors. Previous research has highlighted males and females were more likely to be first authors on papers if the last authors were of the same gender; however, these were not conducted in a translational research setting[23,45–47]. There was also a strong association of male and female last authors with the respective gender of corresponding authors[44].

However, due to the differences in gender equity between different research areas and medical specialties, where a centre-specific mix of research themes is likely to influence gender equity in scientific authorship, it is difficult to make direct comparisons across the literature.

Overall, our results build an important evidence base in biomedical research settings concerning gender parity and support the findings from previous studies where analysis of scientific authorship by gender has been used as an important marker of gender equity[12,24,48–50].

Implications for policy and practice

While NIHR BRCs routinely collect bibliometric data on publications arising from the NIHR-funded research, and report to the NIHR (the funder), to the best of our knowledge, this data is not routinely analysed by gender. Our study supports the feasibility of using NIHR BRCs funded or supported research publications for analysing scientific authorship by gender. While retrospective analysis of the gender of authors in scientific publications is labour-intensive and has limitations, there is an opportunity to begin to track this prospectively. As more data becomes available, this would enable longitudinal analysis of scientific authorship by gender, which could be useful for tracking progress towards gender equity and related issues such as markers of achievement across all NIHR BRCs.

In addition, since the acceleration of women's advancement and leadership in translational research is one of the stated objectives of the NIHR, investigating the extent of gender equity in scientific authorship may usefully inform strategies to accelerate women's advancement and leadership in NIHR-funded research. Moreover, bibliometric analyses used by the NIHR to inform competition for NIHR funding may incorporate the gender dimension into the analysis, which could provide additional information on the competitiveness for NIHR funding[51,52].

CONCLUSION

Our results show that while first authorship is within the 40%-60% gender balance zone, a greater gender disparity is prevalent in other types of scientific authorship in biomedical research. The proportion of female authors is significantly lower than the proportion of male authors in all six categories of authorship included in our analysis. This study also demonstrates the feasibility of analysing scientific authorship by gender, which could provide useful insight about gender equity in scientific publications, which may be a useful marker of achievement. Overall, our study demonstrates that it is feasible to analyse the available bibliometric data on publications arising from NIHR funding by gender and consider establishing processes for analysing gender equity in scientific authorship over time.

Contributors

LDE conceived the study. RD and MJM coded the data. SGSS analysed the data. RD and SGSS drafted the manuscript. PVO contributed to the conception of the study and co-wrote parts of the manuscript. CRH and OC participated in data collection. VK, LRH, and AMB contributed to the conception of the study, facilitated access to the publications and coordinated the study. All authors read, contributed to and approved the final manuscript.

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Competing interests

VK is Chief Operating Officer and LRH is Clinical Research Manager at the National Institute for Health Research (NIHR) Biomedical Research Centre, Oxford. AMB is a senior medical science advisor and co-founder of Brainomix, a company that develops electronic ASPECTS (e-ASPECTS), an automated method to evaluate ASPECTS in stroke patients. MJM, LDE and PVO were funded by STARBIOS2 and the National Institute for Health Research (NIHR) Oxford Biomedical Research Centre (BRC). PVO is a member of the NIHR Advisory Group on Equality, Diversity, and Inclusion, a member of the European Association of Science Editors Gender Policy Committee, and a member of the Athena SWAN Self-Assessment Team of the Radcliffe Department of Medicine, University of Oxford. The other authors declare no competing interests.

Ethics

The University of Oxford Clinical Trials and Research Governance Team reviewed the study and deemed it exempt from full ethics review on the grounds that it falls outside of the Governance Arrangements for Research Ethics Committees (GAfREC), which stipulate which research studies are required to have ethics review. A wider programme of research on the activities of the NIHR Oxford Biomedical Research Centre from 2017 to 2022 received ethics clearance through the University of Oxford Central University Research Ethics Committee (R51801/ RE001), the Health Research Authority (IRAS ID 228049) and the Oxford University Hospitals NHS Foundation Trust Management (PID 12779).

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Data sharing statement

No additional data available.

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Additional files list

Figure 1 Publication analysis workflow. The workflow shows the process of extracting data according to gender from six types of authorship.

Figure 2 Yearly trends in scientific authorship by gender (male and female), April 2012 - March 2017. This plot represents the yearly variation of the proportion of male and female authors according to six types of authorship between the years of publication/acceptance from 2012 to 2017.

Supplementary File 1

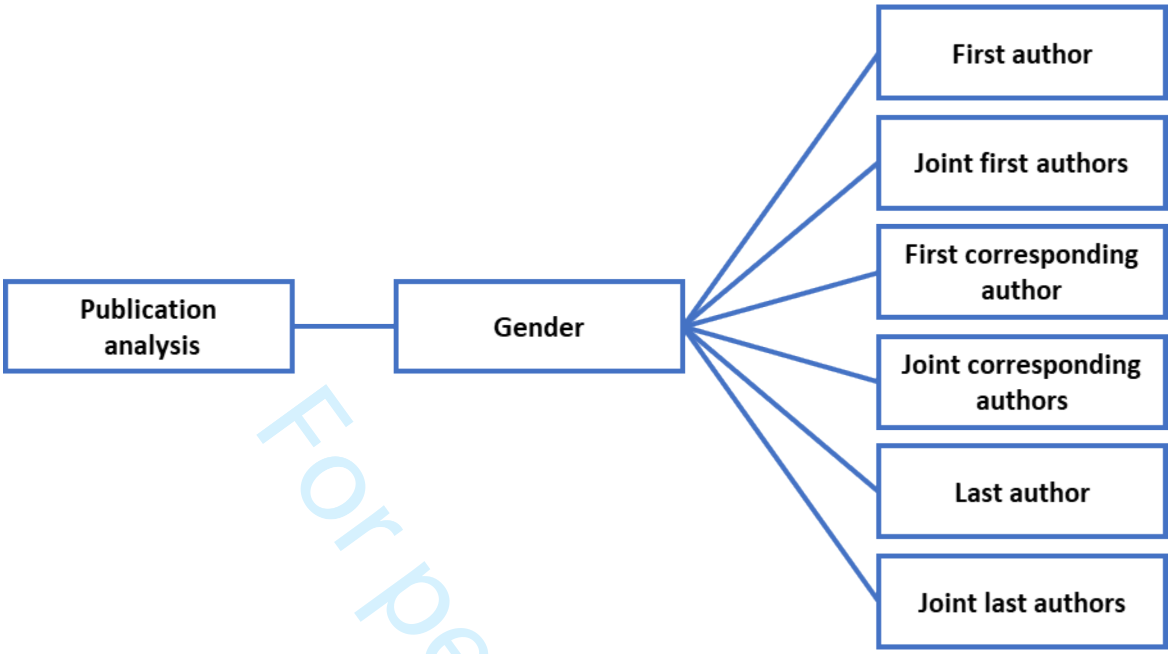
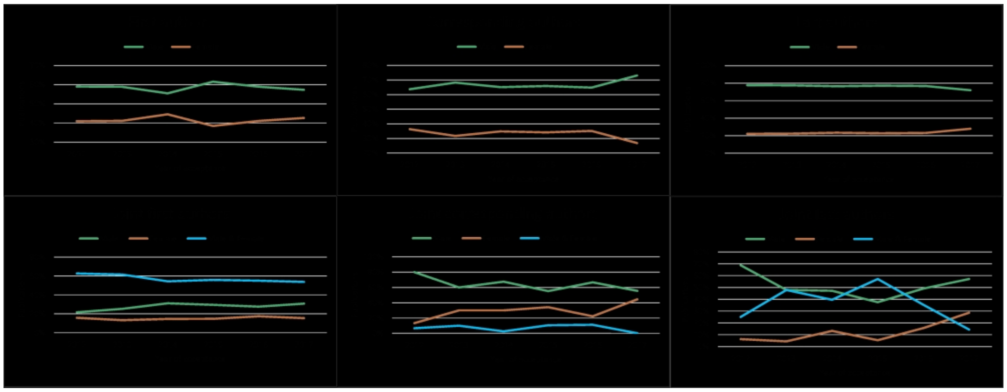


Figure 1 Publication analysis workflow.



381x146mm (300 x 300 DPI)

STROBE Statement

Checklist of items that should be included in reports of observational studies

Section/Topic	Item No	Recommendation	Reported on Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Pages 1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Pages 4-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	Pages 4-5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Pages 5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up: N/A *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls: N/A *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants: Pages 5-6	
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed N/A *Case-control study*—For matched studies, give matching criteria and the number of controls per case N/A	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 6
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 6
Bias	9	Describe any efforts to address potential sources of bias	Page 3
Study size	10	Explain how the study size was arrived at	Page 6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 6
		(*b*) Describe any methods used to examine subgroups and interactions	Page 6
		(*c*) Explain how missing data were addressed	N/A
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	N/A

Section/Topic	Item No	Recommendation	Reported on Page No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	No participants were used in this study. Scientific publications were used only. Pages 6-9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	Supplementary file 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1 on page 7 and Table 2 on page 8
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	Pages 7-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Pages 8-9
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Pages 3 & 10

Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 10
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 10
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 11

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Gender parity in scientific authorship in a National Institute for Health Research Biomedical Research Centre: A bibliometric analysis

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Keywords:	NATURAL SCIENCE DISCIPLINES, EDUCATION & TRAINING (see Medical Education & Training), Change management < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Organisational development < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, STATISTICS & RESEARCH METHODS

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Gender parity in scientific authorship in a National Institute for Health Research Biomedical Research Centre: A bibliometric analysis

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ABSTRACT

Objective: Scientific authorship is a vital marker of success in academic careers and gender equity is a key performance metric in research. However, there is little understanding of gender equity in publications in biomedical research centres funded by the National Institute for Health Research (NIHR). This study assesses the gender parity in scientific authorship of biomedical research.

Design: A retrospective descriptive study.

Setting: NIHR Oxford Biomedical Research Centre.

Data: Data comprised 2409 publications that were either accepted or published between April 2012 and March 2017. The publications were classified as basic science studies, clinical studies (both trial and non-trial studies), and other studies (comments, editorials, systematic reviews, reviews, opinions, book chapters, meeting reports, guidelines and protocols).

Main outcome measures: Gender of authors, defined as a binary variable comprising either male or female categories, in six authorship categories: first author, joint first authors, first corresponding author, joint corresponding authors, last author and joint last authors.

Results: Publications comprised 39% clinical research (n=939), 27% basic research (n=643), and 34% other types of research (n=827). The proportion of female authors as first author (41%), first corresponding authors (34%) and last author (23%) was statistically significantly lower than male authors in these authorship categories ($P < 0.001$). Of total joint first authors (n=458), joint corresponding authors (n=169), and joint last authors (n=229), female only authors comprised statistically significant ($P < 0.001$) smaller proportions i.e. 15% (n=69), 29% (n=49) and 10% (n=23) respectively, compared to male only authors in these joint authorship categories. There was a statistically significant association between gender of the last author(s) with gender of the first author(s) ($P < 0.001$), first corresponding author(s) ($P < 0.001$) and joint last author(s) ($P < 0.001$). The mean impact factor (IF) of journals was statistically significantly higher when the first corresponding author was male compared to female (Mean IF: 10.00 vs. 8.77, $P = 0.020$); however, the IF of journal was not statistically different when there were male and female authors as first authors and last authors.

Conclusions: Although there are increasing trends of female authors as first authors (41%) and last authors (23%) (when compared with the current literature), female authors are still underrepresented compared to male authors in all six categories of scientific authorship in biomedical research. Further research is needed to encourage gender parity in different categories of scientific authorship. Male corresponding authors are more likely to publish articles in prestigious journals with high impact factor and both male and female authors at first and last authorship positions publish articles in journals with almost equal impact factor.

Strengths and limitations of this study

- This is the first study to investigate gender parity in six categories of scientific authorship: first authors, first corresponding authors, last authors and three joint authorship categories i.e. joint first authors, joint corresponding authors and joint last authors in biomedical research.
- This study provides an important benchmark on gender equity in scientific authorship for other NIHR funded centres and organisations in England.
- This study provides evidence that male first corresponding authors are more likely to publish articles in prestigious journals with high impact factor compared to female first corresponding authors.
- Both male and female authors at first and last authorship positions publish articles in journals with almost equal impact factor.
- The generalisability of the findings of this study may be limited due to differences in medical specialities, research areas, institutional cultures, and levels of support to individual researchers.
- Using secondary sources for determining the gender of authors may have limitations, which could be avoided by seeking relevant information from original authors and institution affiliation at the time of submission.

Keywords: Responsible Research and Innovation, Gender Equity, Scientific Authorship, National Institution for Health Research, Biomedical Research Centres, Evaluation, Translational Research Organisations, Translational Research, Basic Science Research, Journal Impact Factor, Journal Prestige.

INTRODUCTION

Promoting Responsible Research and Innovation (RRI) is a major strategy of the "Science with and for Society" work programme of the European Union's (EU) Horizon 2020 Framework Programme for Research and Innovation[1]. RRI aims to build capacity and develop innovative ways to connect science to society [2]. The RRI approach enables all societal members (such as researchers, citizens, policymakers, businesses and third sector organisations) to work together during the research and innovation process in order to better align research and innovation with the values, needs and expectations of the society [1,2]. The RRI strategy includes the "keys" of public engagement, open access, gender, ethics and science education, and two further "keys": sustainability and social justice, which have been added recently [3]. The idea is that by prioritising these key components of RRI, it would help make science more attractive to young people and society, and raise awareness of the meaning of responsible science [2].

We have focussed on the 'gender' element of the RRI because it is imperative to advance gender equality within research institutions, as well as within the design and content of research and innovation [1]. The issue of enhancing female participation in economic decision-making has become prominent in the national, European and international spheres, with a particular focus on the economic dimension of gender diversity [4]. In order to achieve a fair female participation within positions of power, it is recommended that women should hold half of the total seats in board rooms [5], however, a ratio between 40% and 60%, also known as a "gender balance zone" 6], is considered acceptable – a threshold that is set by the European Commission [4].

From the perspective of gender equality in academia and scientific research, gender parity in scientific authorship is an important measure of achievement. The term gender parity refers to "the equal contribution of women and men to different dimensions of life" and it is operationalised as a "relative equality in terms of numbers and proportions of women and men" for a particular indicator" [7]. Gender (dis)parity in scientific authorship has important implications for gender equity in academic advancement [8] because scientific authorship is commonly used as a measure of academic productivity that is used for performance management, reward, and recognition [9,10]. The acceleration of women's advancement and leadership in research is one of the stated objectives of the National Institute of Health Research (NIHR) in the United Kingdom (UK) and it is imperative for the RRI in the wider European research area. Yet, there is limited research concerning gender equity in scientific authorship of translational research funded through NIHR biomedical research centres (BRCs).

In the UK, women currently outnumber men in medical schools [11]; however, a persistent gender disparity in scientific publications remains [10,12–23]. While the proportion of women as first and senior (last) authors of original medical research has increased over the past few decades [24], women are still significantly underrepresented as authors of research articles in medical journals, especially as first and senior authors [19,20,22,25], which are considered as prestigious authorship positions [10,14]. For example, in radiology the proportion of women as first author increased from 8% in 1978 to 32% in 2013 and senior author increased from 7% in 1978 to 22% in 2013 [20]. Similarly, in gastroenterology the proportion of women as first author increased from 9% in 1992 to 29% in 2012, and senior author increased from 5% in 1992 to 15% in 2012 [22].

The profile of gender equity in higher education and research has been raised by the introduction of Athena SWAN-linked funding incentives by the NIHR [26–28]. While Athena SWAN awards are useful markers of achievement for higher education institutions and research institutes, they alone are insufficient to assess and monitor the progress of NIHR BRCs towards gender equity [29]. Currently, the proportion of women and the rate of their achievements are not tracked routinely by the NIHR BRCs and little is known about how much women contribute to scientific research and innovation in the BRCs. It is important to study the acceleration of women's advancement and leadership in translational research in line with the stated objectives of the NIHR within the UK and RRI within the wider European research area through the collection of gender-disaggregated bibliometric data and analysis of scientific authorship by gender.

The primary objective of this study was to assess the gender parity in six types of scientific authorship in biomedical research. The secondary objective was to assess whether male and female authors publish articles in journals with different prestige levels.

METHODS

Study design

A retrospective descriptive study.

Setting

This study was conducted at the NIHR Oxford BRC, which is research collaboration between the Oxford University Hospitals NHS Foundation Trust and the University of Oxford [30]. The aim of NIHR BRCs is to support translational research and innovation to improve healthcare for patients [31]. During the study period (April 2012-March 2017), the NIHR Oxford BRC was awarded £96m to support research across nine research themes, five cross-cutting themes, and a range of underpinning platforms. The research themes included Blood, Cancer, Cardiovascular, Dementia and Cerebrovascular Disease, Diabetes, Functional Neuroscience and Imaging, Infection, Translational Physiology, and Vaccines. The crosscutting themes included Genomic Medicine, Immunity and Inflammation, Surgical Innovation and Evaluation, Biomedical Informatics and Technology, and Prevention and Population Care. The major underpinning platforms included a Biorepository, Education and Training, Public Engagement, and Research Governance. Staff who have all or part of their salary funded through the BRC award are members of the NIHR faculty. Between April 2012 and March 2017, there were 73.64% principal investigators (scientists that have won research grants and are ultimately responsible for the conduct of research studies); 59.76% NIHR investigators (scientists leading and undertaking research); 31.85% NIHR associates (staff supporting research that are led by others) and 52.97% NIHR trainees (those who are engaged in research training leading to a higher degree by research) that were male. It is a contractual requirement to report the number of BRC supported publications published by researchers funded or supported by the NIHR research funds on an annual basis. Additionally, the NIHR uses bibliometric analyses to inform eligibility for NIHR funding [32,33]. This study was carried out as part of a wider programme of research on the markers of achievement for assessing and monitoring gender equity in translational research organisations [29]. During the same study period, the NIHR Oxford BRC was awarded with external funding from research councils, research charities, the Department of Health, industry collaborators and non-commercial organisations. Research councils have provided the highest amount of external funding with an amount of £265.5m. However, current data from the NIHR Oxford BRC are not available at an individual level; hence, it is not possible to present this data according to gender.

Data

Data comprised translational research publications published by researchers funded or supported by the NIHR Oxford BRC. The eligibility criteria for inclusion of a publication were funding or support by the NIHR Oxford BRC and publication between April 2012 and March 2017. Based on these criteria, 2409 publications were identified. These publications were classified as: basic science studies, clinical studies (both trial and non-trial studies), and other studies (comments, editorials, systematic reviews, reviews, opinions, meeting reports, guidelines and protocols).

Main outcome measures

The main outcome measures were: (1) Gender of authors, defined as a binary variable comprising, either male or female categories, (2) Six categories of scientific authorship: first author, joint first authors, first corresponding author, joint corresponding authors, last author and joint last authors (Figure 1). These categories are conventionally associated with the highest amount of contribution, credit and prestige [10,14].

<Insert> **Figure 1** Publication analysis workflow. <Here>

First author was defined as the first-named author of the publication. Publications that consisted of single authors were categorised as first authors. We considered the first author to be the main intellectual contributor in the publication, in terms of study design, data collection and analysis, and manuscript writing. Joint first authors were defined as two or more authors who were named as equal contributors and mentioned as joint first authors of the publication. The first corresponding author was defined as the only author who was reported as a corresponding author in the publication and his/her contact details such as an institutional address and/or an email address were provided for correspondence in the publication. Joint corresponding authors were defined as two or more authors who were listed or marked as corresponding authors and their contact details were provided for correspondence in the publication. Last author was defined as the last-named author of a publication. The last author was considered to be a group leader or principal investigator who may have provided significant intellectual contribution or supervision of the research work as well as acquisition of research funding [14,34]. Joint last authors were defined as two or more authors who were named as equal contributors in the publication and their names were mentioned as joint last authors in the publication. A major confounding factor, for which we could not control, was the informal nature of the conventions for the sequence and role of authors [34]. Although conventions for scientific authorship are well established in biomedical sciences [35,36], they may vary between different research areas and even between different research groups within the same area.

Determination of gender of authors

The gender of the authors was defined as a binary variable comprising either male or female categories, which were determined based on the first name of authors in all six categories of authorship included in the analysis. When the first names of authors were initialled in the publication or were difficult to associate with either male or female gender, further information was sought through searching their institutional webpages and online social network sites such as the LinkedIn and ResearchGate. We also used Gender APIs (gender-api.com and genderapi.io) when it was not possible to ascertain the gender of the authors by the above-mentioned sources. In addition, we contacted five authors directly via email to ascertain their gender. After completing data coding by two researchers (MJM and RD), to ensure the accuracy of data coding, 10% of the data were checked independently (CH). Consensus was achieved through discussion between the researchers on data fields that did not match the assigning of the gender of authors and types of authorship (Figure 1).

Gender of authors and journal prestige

For assessing whether male and female authors publish articles in less, equal or more prestigious journals, we used journal impact factor as a proxy for the prestige of a journal. We extracted data on journal impact factors from the Journal citation report 2019 and for a few articles, we used the latest available impact factor reported on the journal websites.

Statistical analysis

Data were analysed using frequencies including counts and percentages. Chi-square tests were used for identifying statistically significant differences and associations between male and female authors in various categories of authorship. Cochrane linear trend test was used to determine trends over time using Slezák et al tool [37]. T-Tests were used to determine differences in the mean impact factor of journals with publications by male and female authors in all three authorship categories. The level of significance was set at $p < 0.05$. Data were analysed using the IBM SPSS Statistics for Windows, Version 25.0 (Armonk, NY: IBM Corp.). Visualisations were created in the Microsoft Excel and BoxPlotR – a free online tool [38].

Patient and public involvement statement

There was no patient or public involvement in the study design.

RESULTS

Types of publication

Table 1 presents an overview of the types of publication by year. Clinical research studies (both trial and non-trial studies) comprised 39% (n=939), basic science research 27% (n=643) and a third of publications (34%, n=827) included other types of publication, such as systematic reviews, reviews, research protocols, editorials, guidelines, opinions, comments, and meeting reports.

Table 1. Number and types of publication by year of acceptance

	Types of publication Count (%)				
Year (Accepted)	**Basic science**	**Clinical trial**	**Clinical study - Not a trial**	**Other***	**Total Count (%)**
2012†	75 (27.6)	18 (6.6)	90 (33.1)	89 (32.7)	272 (100)
2013◊	151 (28.2)	27 (5.0)	183 (34.2)	174 (32.5)	535 (100)
2014◊	122 (22.2)	29 (5.3)	204 (37.2)	194 (35.3)	549 (100)
2015◊	137 (24.7)	48 (8.7)	158 (28.5)	211 (38.1)	554 (100)
2016◊	137 (31.8)	31 (7.2)	120 (27.8)	143 (33.2)	431 (100)
2017‡	21 (30.9)	5 (7.4)	26 (38.2)	16 (23.5)	68 (100)
Total	**643 (26.7)**	**158 (6.6)**	**781 (32.4)**	**827 (34.3)**	**2409 (100)**

†April-December, ◊January-December ‡January-March, *systematic reviews, reviews, research protocols, editorials, guidelines, opinions, comments, and meeting reports

Authorship type and Gender

Table 2 presents an overview of gender of authors by types of authorship. Male authors were statistically significant more likely to be first authors (59%, *P* <0.001), first corresponding authors (66%, *P* <0.001) and last authors (77%, *P* <0.001)) (Table 2). Furthermore, analyses of joint authorship categories revealed that the proportion of 'female only' authors was statistically significantly lower than 'male only' authors in the joint corresponding authors (29%, *P* <0.001) and joint last authors categories (10%, *P* <0.001) (Table 2). However, in the joint first authors category, the proportion of 'male and female' as joint first authors (57%, *P* <0.001) was statistically significantly higher than male only and female only first authors (Table 2).

Table 2. Authorship type and gender of authors

Authorship type Number of publications in the category	**Gender of authors** Count (%)			**Significance** p-value
	Male only	Female only	Male and female	
First author (n=2409)	1413 (58.7)	994 (41.3)	N/A*	<0.001
First corresponding author (n=2409)	1565 (65.0)	806 (33.5)	N/A	<0.001
Last author (n=2409)	1853 (76.9)	553 (23.0)	N/A	<0.001
Joint first authors (n=458)	127 (27.7)	69 (15.1)	262 (57.2)	<0.001
Joint corresponding authors (n=169)	107 (63.3)	49 (29.0)	13 (7.7)	<0.001
Joint last authors (n=229)	108 (47.2)	23 (10.0)	98 (42.8)	<0.001

*N/A= not applicable.

Gender of authors by types of publication

Table 3 presents an analysis of gender of authors by types of publication (i.e. basic science, clinical trials, non-trial clinical studies and other research). The analysis showed that the proportions of male only authors were statistically significantly higher than the proportions of female only authors in three authorship categories: first authors (*P*=0.035), first corresponding authors (*P* <0.001) and last authors (*P*=0.016) (Table 3). There were no significant differences between the proportions of male only and female only authors in all three joint authorship categories: joint first authors (*P*=0.476), joint corresponding authors (*P*=0.172) and joint last authors (*P*=0.208). Only the statistically significant associations are shown in Table 3.

Table 3. Gender of authors by publication type

	Publication Type Count (%)				**Significance**
Type of research	**Basic science**	**Clinical trial**	**Clinical study - Not a trial**	**Other**	**p-value**
First author† (n=2407)					**0.035**
Male	371 (57.8)	92 (58.6)	433 (55.4)	517 (62.6)	
Female	271 (42.2)	65 (41.4)	348 (44.6)	310 (37.5)	
First corresponding author†† (n=2371)					**<0.001**
Male	446 (69.4)	100 (63.3)	465 (59.5)	554 (67.0)	
Female	191 (29.7)	56 (35.4)	307 (39.3)	252 (30.5)	
Last author (n=2406)					**0.016**
Male	503 (78.3)	125 (79.6)	570 (73.1)	655 (79.2)	
Female	139 (21.7)	32 (20.4)	210 (26.9)	172 (20.8)	

Yearly trends in Authorship by gender

Figure 2 presents the yearly trends in scientific authorship by gender. In all authorship types and across all five years of publication, the proportion of male and female authors varied (Figure 2). The analysis showed women were significantly underrepresented across all years and authorship types. Interestingly, joint first authorship indicated a higher proportion of 'male and female' authors compared to 'male only' and 'female only' authors (Figure 2). We also ran a Cochrane linear trend test to show whether there was any significant change over time. The results revealed that the test was not significant for all six authorship types and years of publications (for all six categories).

<Insert> Figure 2 Yearly trends in scientific authorship by gender (male and female), April 2012 - March 2017. **<here>**

Association between same gender across authorship categories

There was a statistically significant association (*P* < 0.001) between the same gender in first authorship and first corresponding authorship categories and the first author and joint first authors [Table 4(a)].

Furthermore, there were statistically significant associations (*P* < 0.001) between the same gender in the last author category with the same gender of first author(s), first corresponding author(s), Joint corresponding authors and joint last authors [Table 4(b)].

However, there was no statistically significant association between the male and female last authors with the respective gender of joint first authors (*P*=0.117). Only the statistically significant associations are shown in Tables 4(a) and 4(b).

Table 4 (a). Association between same gender across authorship categories

	First author Count (%)		Significance
	Male	**Female**	**p-value**
First corresponding author (n=2371)			**<0.001**
Male	1236 (79)	329 (21)	
Female	158 (19.6)	648 (80.4)	
First joint authors (n=457)			**<0.001**
Male only	124 (97.6)	3 (2.4)	
Female only	10 (14.5)	59 (85.5)	
both male and female	140 (53.6)	121 (46.4)	

Table 4 (b). Association between same gender across authorship categories

	Last author Count (%)		Significance
Authorship type	**Male**	**Female**	**p-value**
First author† (n=2406)			**<0.001**
Male	1146 (61.8)	267 (48.3)	
Female	707 (38.2)	286 (51.7)	
First corresponding author (n=2370)			**<0.001**
Male	1429 (78.4)	136 (24.7)	
Female	394 (21.6)	412 (75.3)	
Joint corresponding authors(n=168)			**<0.001**
Male only	104 (84.5)	3 (6.7)	
Female only	13 (10.6)	36 (80)	
Both male and female	6 (4.9)	6 (13.3)	
Joint last authors (n=229)			**<0.001**
Male only	106 (63.9)	2 (8.2)	
Female only	2 (1.2)	21 (33.3)	
Both male and female	58 (34.9)	40 (63.5)	

Gender of authors and journal prestige

Of 2388 journal articles, 96.6% (n=2307) were published in journals having an impact factor (mean =9.58 (±12.16), median = 5.36, minimum = 0.39, maximum = 74.7) while only 3.4% (n=81) articles were published in journals having no impact factor. There was no statistically significant difference in the mean journal impact factor by male and female first and last authors; however, the mean journal impact factor was statistically significantly higher for male first corresponding authors compared to female first corresponding authors (Table 5, Figure 3).

Table 5. Impact factor of journals and authorship categories by gender

	Mean	**Standard deviation**	**95% CI**	**P- Value**
First author				0.171
Male	9.88	12.46	9.18, 10.58	
Female	9.14	11.73	8.37, 9.92	
First corresponding author				**0.020**
Male	10.00	12.72	9.34, 10.67	
Female	8.77	10.95	7.97, 9.57	
Last author				
Male	9.34	11.76	8.77, 9.91	0.115
Female	10.40	13.38	9.21, 11.59	

<Insert> Figure 3 Impact factor of journals and authorship categories by gender. **<Here>**

In all three categories of authorship, male and female authors published articles in almost same top ten journals with the highest impact factor (Table 6).

Table 6. Top ten highest impact journals with publications by male and female authors

		First Author		First corresponding author		Last author	
Journal	**Impact Factor (2019)**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
New England Journal of Medicine	74.699	✓	✓	✓	✓	✓	✓
Nature Reviews Drug Discovery	64.797		✓		✓		✓
The Lancet	60.392	✓	✓	✓	✓	✓	✓
Nature Reviews Cancer	53.03	✓	✓	✓	✓	✓	
JAMA (Journal of American Medical Association)	45.54	✓	✓	✓	✓	✓	✓
Nature	42.778	✓	✓	✓	✓	✓	✓
Science	41.845	✓	✓	✓	✓	✓	✓
Nature Reviews Immunology	40.358	✓	✓	✓	✓	✓	✓
Cell	38.637	✓	✓	✓		✓	
Nature Medicine	36.13	✓	✓	✓		✓	
Nature Reviews Microbiology	34.209	✓		✓		✓	
The Lancet Oncology	33.752				✓		✓
Journal Of Clinical Oncology	32.956				✓		✓
The BMJ	30.223						✓

DISCUSSION

We retrospectively analysed the gender parity of authors in six categories of authorship of scientific publications that were published over a five-year period. Our analysis shows that the number of female authors were underrepresented across all six categories of authorship [10,39,40].

In the first author category the proportions of female authors and male authors were within the 40%-60% “gender balance zone” [6]. The greatest gender imbalance was observed in the last author category where ‘female only’ authors comprised only 23%. Nonetheless, this proportion is higher than other studies reporting similar analyses [11,13,24].

To the best of our knowledge, this study presents the first analysis of joint authorship in three categories. Secondly, it demonstrates underrepresentation in female only authors in six categories of scientific authorship [41]. Thirdly, the analysis highlights gender inequity with female underrepresentation in prestigious authorship positions compared to male in biomedical research. This is consistent with other fields including: epilepsy, lung cancer, dermatology, eating disorders and in medicine in general [14,16,42–44].

This study extends understanding of gender-based trends in scientific authorship (Figure 2) by showing encouraging incremental changes in gender parity in authorship in a biomedical research setting. Previous research examined the gender gap in authorship within the medical literature reporting an upward trend for female first authors from 6% in 1970 to 29% in 2004 and female last authors from 4% in 1970 to 19% 2004. However, it was limited to US based institutions [12]. A similar UK based study covering the same period (i.e. 1970-2004) also showed upward trends for female first authors increasing from 11% in 1970 to 37% in 2004 and female last authors from 12% in 1970 to 17% in 2004 [24]. In addition, a recent study by Filardo et al. [13] examined the prevalence of female first authorship of original research published in six high impact general medical journals between February 1994 and June 2014 revealed that the adjusted probability of an article having a female first authorship increased significantly from 27% in 1994 to 37% in 2014 [13]. However, despite the proportion of female first authors varied greatly by journal, men were generally more likely to be first authors than women [13]. Compared to previous studies mentioned above, our study provides evidence of higher and increasing gender equity in the first authors, last authors and other four categories of scientific authorship in biomedical research (Table 2).

Our study identified a strong association between same gender and authorship types showing if the first author of a publication was male, it was highly likely that the first corresponding author of the same publication would also be male. Similarly, the likelihood of the first author being female was higher, if the first corresponding author was also female [45]. Likewise, there appeared to be a significant association of male and female last authors with the respective gender of first authors. Previous research has highlighted males and females were more likely to be first authors on papers if the last authors were of the same gender; however, these were not conducted in a translational research setting [20,46–48]. There was also a strong association of male and female last authors with the respective gender of corresponding authors [45].

However, due to the differences in gender equity between different research areas and medical specialties, where a centre-specific mix of research themes is likely to influence gender equity in scientific authorship, it is difficult to make direct comparisons across the literature.

Overall, our results build an important evidence base in biomedical research settings concerning gender parity and support the findings from previous studies where analysis of scientific authorship by gender has been used as an important marker of gender equity [12,24,49–51].

We also studied differences between male and female authors in publishing articles in high impact journals. Our results revealed that male first corresponding authors were more likely to publish articles in high impact factor journals compared to female first corresponding authors (Table 5). These findings suggest that female first corresponding authors are less likely to publish articles in high impact journals. We also found that male and female first and last authors were more likely to publish articles in journals with impact factors that were not statistically significantly different (Table 6, Figure 3). Our findings show that both the male and the female biomedical researchers publish articles at prestigious authorship positions i.e. first and last authors in journals with high impact factors. Our findings are contrary to the findings of earlier research by Bendels et al who reported that female researchers were less likely to publish in high impact factor journals at prestigious authorship positions [49]. Dissimilarities in the findings of our study and the study by Bendels et al [49] could be due to the differences in journals analysed, research disciplines included and the time period covered. Our analysis included a wide range of journals in which researchers affiliated with the NIHR Oxford BRC published translational research from April 2012 to March 2017 while Bendels et al analysed only Nature Index journals in four disciplines i.e. Life Science, Multidisciplinary, Earth and Environmental and Chemistry covering publication period from January 2008 to May 2016 [49].

Implications for policy and practice

While NIHR BRCs routinely collect bibliometric data on publications arising from the NIHR-funded research, and report to the NIHR (the funder), to the best of our knowledge, this data is not routinely analysed by gender. Our study supports the feasibility of using NIHR BRCs funded or supported research publications for analysing scientific authorship by gender. While retrospective analysis of the gender of authors in scientific publications is labour-intensive and has limitations, there is an opportunity to begin to track this prospectively. As more data becomes available, this would enable longitudinal analysis of scientific authorship by gender, which could be useful for tracking progress towards gender equity and related issues such as markers of achievement across all NIHR BRCs.

In addition, since the acceleration of women's advancement and leadership in translational research is one of the stated objectives of the NIHR, investigating the extent of gender equity in scientific authorship may usefully inform strategies to accelerate women's advancement and leadership in NIHR-funded research. Moreover, bibliometric analyses used by the NIHR to inform competition for NIHR funding may incorporate the gender dimension into the analysis, which could provide additional information on the competitiveness for NIHR funding [52,53].

CONCLUSION

Our results show that while first authorship is within the 40%-60% gender balance zone, a greater gender disparity is prevalent in other types of scientific authorship in biomedical research. The proportion of female authors is significantly lower than the proportion of male authors in all six categories of authorship included in our analysis. This study also demonstrates the feasibility of analysing scientific authorship by gender, which could provide useful insight about gender equity in scientific publications, which may be a useful marker of achievement. Overall, our study demonstrates that it is feasible to analyse the available bibliometric data on publications arising from NIHR funding by gender and consider establishing processes for analysing gender equity in scientific authorship over time. In addition, our study provides evidence that male first corresponding authors are more likely to publish articles in prestigious journals with high impact factor while both male and female authors at first and last authorship positions publish articles in journals with almost equal impact factor.

Contributors

LDE conceived the study. RD and MJM coded the data. SGSS analysed the data and created visualisations. RD and SGSS drafted the manuscript. PVO contributed to the conception of the study and co-wrote parts of the manuscript. CRH and OC participated in data collection. VK, LRH, and AMB contributed to the conception of the study, facilitated access to the publications and coordinated the study. All authors read, contributed to and approved the final manuscript.

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Hospitals NHS Foundation Trust and the University of Oxford. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR, or the Department of Health and Social Care.

Competing interests

VK is Chief Operating Officer and LRH is Clinical Research Manager at the National Institute for Health Research (NIHR) Biomedical Research Centre, Oxford. AMB is a senior medical science advisor and co-founder of Brainomix, a company that develops electronic ASPECTS (e-ASPECTS), an automated method to evaluate ASPECTS in stroke patients. MJM, LDE and PVO were funded by STARBIOS2 and the National Institute for Health Research (NIHR) Oxford Biomedical Research Centre (BRC). PVO is a member of the NIHR Advisory Group on Equality, Diversity, and Inclusion, a member of the European Association of Science Editors Gender Policy Committee, and a member of the Athena SWAN Self-Assessment Team of the Radcliffe Department of Medicine, University of Oxford. The other authors declare no competing interests.

Ethics

The University of Oxford Clinical Trials and Research Governance Team reviewed the study and deemed it exempt from full ethics review on the grounds that it falls outside of the Governance Arrangements for Research Ethics Committees (GAfREC), which stipulate which publications are required to have ethics review. A wider programme of research on the activities of the NIHR Oxford Biomedical Research Centre from 2017 to 2022 received ethics clearance through the University of Oxford Central University Research Ethics Committee (R51801/ RE001), the Health Research Authority (IRAS ID 228049) and the Oxford University Hospitals NHS Foundation Trust Management (PID 12779).

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Data sharing statement

No additional data available.

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Additional files list

Figure 1 Publication analysis workflow.
The workflow shows the process of extracting data according to gender from six types of authorship.

Figure 2 Yearly trends in scientific authorship by gender (male and female), April 2012 - March 2017.
This plot represents the yearly variation of the proportion of male and female authors according to six types of authorship between the years of publication/acceptance from 2012 to 2017.

Figure 3 Impact factor of journals and authorship categories by gender.
This figure shows the boxplots of impact factors of journals in which male and female authors published articles.

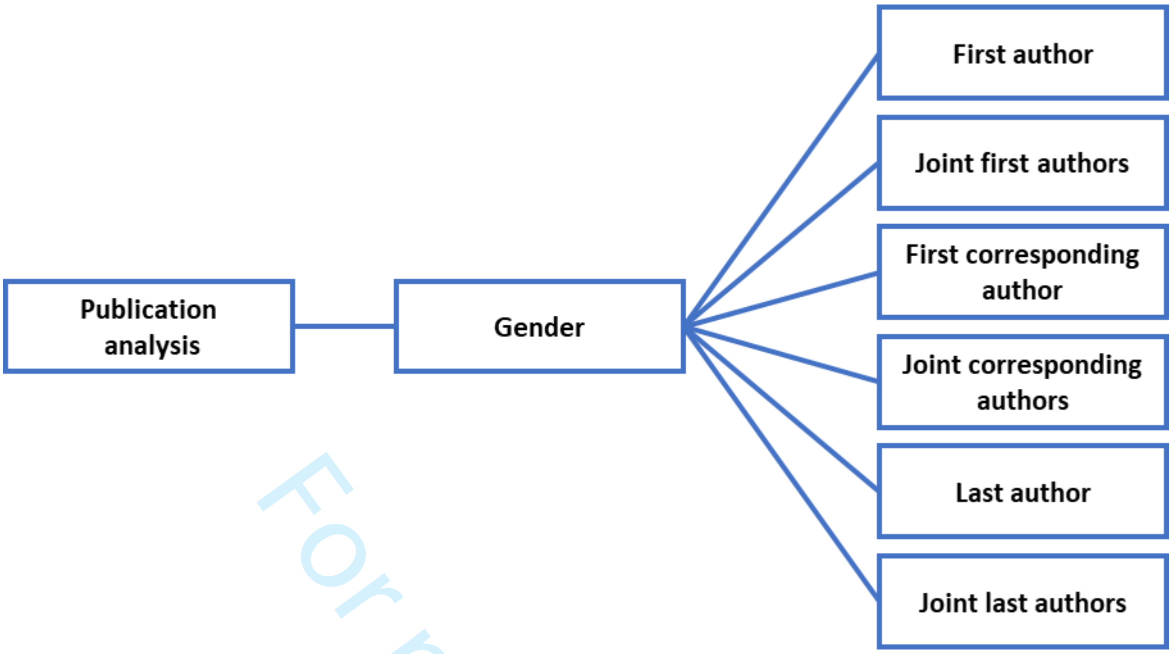
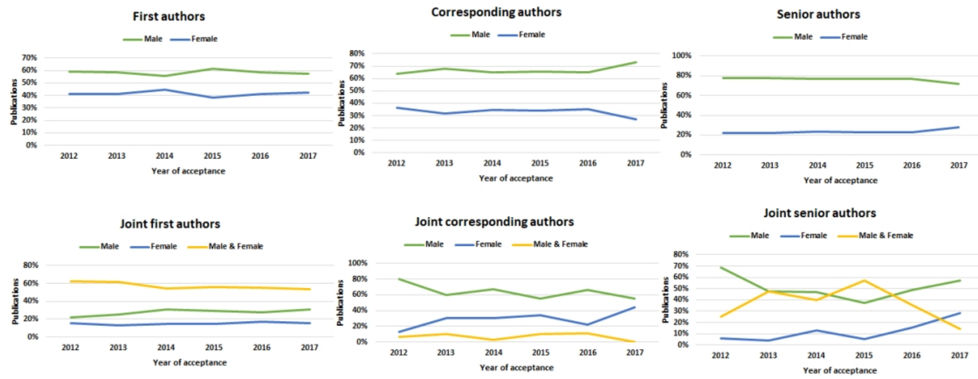


Figure 1 Publication analysis workflow.



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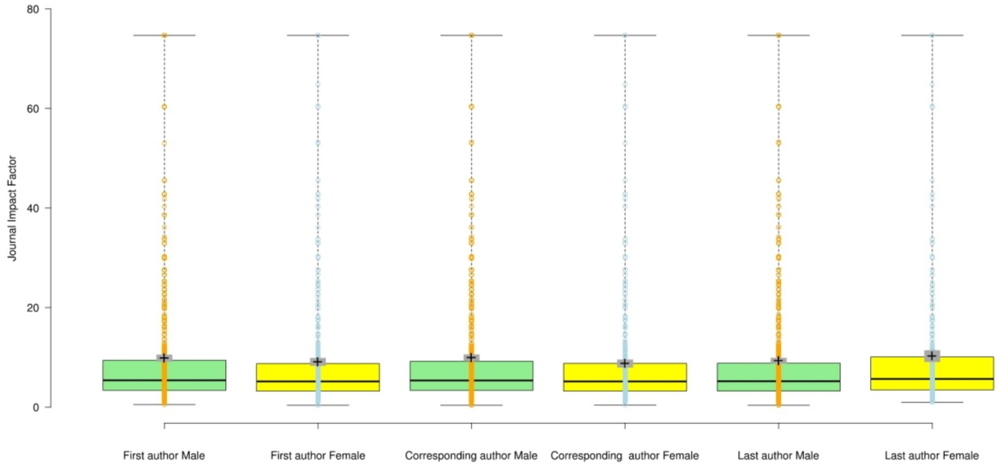

Journal Impact Factor
80
60
40
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First author Male
First author Female
Corresponding author Male
Corresponding author Female
Last author Male
Last author Female

STROBE Statement

Checklist of items that should be included in reports of observational studies

Section/Topic	Item No	Recommendation	Reported on Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Pages 1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Pages 4-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	Pages 4-5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Pages 5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up: N/A *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls: N/A *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants: Pages 5-6	
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed N/A *Case-control study*—For matched studies, give matching criteria and the number of controls per case N/A	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 6
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 6
Bias	9	Describe any efforts to address potential sources of bias	Page 3
Study size	10	Explain how the study size was arrived at	Page 6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 6
		(*b*) Describe any methods used to examine subgroups and interactions	Page 6
		(*c*) Explain how missing data were addressed	N/A
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	N/A

Section/Topic	Item No	Recommendation	Reported on Page No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	No participants were used in this study. Scientific publications were used only. Pages 6-9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	Supplementary file 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1 on page 7 and Table 2 on page 8
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	Pages 7-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Pages 8-9
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Pages 3 & 10

Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 10
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 10
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 11

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Gender parity in scientific authorship in a National Institute for Health Research Biomedical Research Centre: A bibliometric analysis

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Secondary Subject Heading:	Ethics, Medical education and training, Medical management, Health informatics
Keywords:	NATURAL SCIENCE DISCIPLINES, EDUCATION & TRAINING (see Medical Education & Training), Change management < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Organisational development < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, STATISTICS & RESEARCH METHODS

Gender parity in scientific authorship in a National Institute for Health Research Biomedical Research Centre: A bibliometric analysis

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ABSTRACT

Objective: Scientific authorship is a vital marker of achievement in academic careers and gender equity is a key performance metric in research. However, there is little understanding of gender equity in publications in biomedical research centres funded by the National Institute for Health Research (NIHR). This study assesses the gender parity in scientific authorship of biomedical research.

Design: A descriptive bibliometric study.

Setting: NIHR Oxford Biomedical Research Centre (BRC).

Data: Data comprised 2409 publications that were either accepted or published between April 2012 and March 2017. The publications were classified as basic science studies, clinical studies (both trial and non-trial studies), and other studies (comments, editorials, systematic reviews, reviews, opinions, book chapters, meeting reports, guidelines and protocols).

Main outcome measures: Gender of authors, defined as a binary variable comprising either male or female categories, in six authorship categories: first author, joint first authors, first corresponding author, joint corresponding authors, last author and joint last authors.

Results: Publications comprised 39% clinical research (n=939), 27% basic research (n=643), and 34% other types of research (n=827). The proportion of female authors as first author (41%), first corresponding authors (34%) and last author (23%) was statistically significantly lower than male authors in these authorship categories ($P < 0.001$). Of total joint first authors (n=458), joint corresponding authors (n=169), and joint last authors (n=229), female only authors comprised statistically significant ($P < 0.001$) smaller proportions i.e. 15% (n=69), 29% (n=49) and 10% (n=23) respectively, compared to male only authors in these joint authorship categories. There was a statistically significant association between gender of the last author with gender of the first author ($P < 0.001$), first corresponding author ($P < 0.001$) and joint last author ($P < 0.001$). The mean journal impact factor (JIF) was statistically significantly higher when the first corresponding author was male compared to female (Mean IF: 10.00 vs. 8.77, $P = 0.020$); however, the JIF was not statistically different when there were male and female authors as first authors and last authors.

Conclusions: Although the proportion of female authors is significantly lower than the proportion of male authors in all six categories of authorship analysed, the proportions of male and female last authors are comparable to their respective proportions as principal investigators in the BRC. These findings suggest positive trends and the NHIR Oxford BRC doing very well in gender parity in the senior (last) authorship category. Male corresponding authors are more likely to publish articles in prestigious journals with high impact factor while both male and female authors at first and last authorship positions publish articles in equally prestigious journals.

Strengths and limitations of this study

- This is the first study to investigate gender parity in six categories of scientific authorship: first authors, first corresponding authors, last authors and three joint authorship categories i.e. joint first authors, joint corresponding authors and joint last authors in biomedical research.
- The proportions of male and female last (senior) authors are comparable to their respective proportions as principal investigators in this setting, suggesting strong evidence of attainment of gender parity in this category of scientific authorship
- This study offers an important benchmark on gender equity in scientific authorship for other NIHR funded BRCs and organisations in England.
- This study provides evidence that male first corresponding authors are more likely to publish articles in prestigious journals with high impact factor compared to female first corresponding authors, whilst both male and female authors at first and last authorship positions publish articles in prestigious journals with almost equal impact factor.
- The generalisability of these findings may be limited due to differences in medical specialities, research areas, institutional cultures, and levels of support to individual researchers.

Keywords: Responsible Research and Innovation, Gender Equity, Scientific Authorship, National Institute for Health Research, Biomedical Research Centres, Evaluation, Translational Research Organisations, Translational Research, Basic Science Research, Journal Impact Factor, Journal Prestige.

INTRODUCTION

Promoting Responsible Research and Innovation (RRI) is a major strategy of the "Science with and for Society" work programme of the European Union's (EU) Horizon 2020 Framework Programme for Research and Innovation (R&I) [1]. RRI aims to build capacity and develop innovative ways to connect science to society [2]. The RRI approach enables all societal members (such as researchers, citizens, policymakers, businesses and third sector organisations) to work together during the research and innovation process in order to better align research and innovation with the values, needs and expectations of the society [1,2]. The RRI framework includes public engagement, open access, gender equity, ethics and science education as the main "keys" for governance, and two further "keys": sustainability and social justice/inclusion for general policy [3]. The idea is that by prioritising these key components of RRI, it would help make science more attractive to young people and society, and raise awareness of the meaning of responsible science [2].

We have focussed on the 'gender equity' element of the RRI because it is imperative to advance gender equality within research institutions, as well as within the design and content of R&I [1]. The issue of enhancing female participation in economic decision-making has become prominent in the national, European and international spheres, with a particular focus on the economic dimension of gender diversity [4]. In order to achieve a fair female participation within positions of power, it is recommended that women should hold half of the total seats in board rooms [5], however, a ratio between 40% and 60%, also known as a "gender balance zone" [6], is considered acceptable – a threshold that is set by the European Commission [4].

From the perspective of gender equity in academia and scientific research, gender parity in scientific authorship is an important measure of achievement [7]. The term gender parity refers to "the equal contribution of women and men to different dimensions of life" and it is operationalised as a "relative equality in terms of numbers and proportions of women and men" for a particular indicator" [8]. Gender (dis)parity in scientific authorship has important implications for gender equity in academic advancement [9] because scientific authorship is commonly used as a measure of academic productivity that is used for performance management, reward, and recognition [10,11]. The acceleration of women's advancement and leadership in research is one of the stated objectives of the National Institute for Health Research (NIHR) in the United Kingdom (UK) and it is imperative for the RRI in the wider European research area. Yet, there is limited research concerning gender equity in scientific authorship of translational research funded through NIHR biomedical research centres (BRCs).

In the UK, women currently outnumber men in medical schools [12]; however, a persistent gender disparity in scientific publications remains [11,13–24]. While the proportion of women as first and senior (last) authors of original medical research has increased over the past few decades [25], women are still significantly underrepresented as authors of research articles in medical journals, especially as first and senior (last) authors [20,21,23,26], which are considered as prestigious authorship positions [11,15]. For example, in radiology the proportion of women as first author increased from 8% in 1978 to 32% in 2013 and senior author increased from 7% in 1978 to 22% in 2013 [21]. Similarly, in gastroenterology the proportion of women as first author increased from 9% in 1992 to 29% in 2012, and senior author increased from 5% in 1992 to 15% in 2012 [23].

The profile of gender equity in higher education and research has been raised by the introduction of Athena SWAN-linked funding incentives by the NIHR [27–30]. While Athena SWAN awards are useful markers of achievement for higher education institutions and research institutes, they alone are insufficient to assess and monitor the progress of NIHR BRCs towards gender equity [31]. Currently, the proportion of women and the rate of their achievements are not tracked routinely by the NIHR BRCs and little is known about how much women contribute to scientific R&I in the BRCs. It is important to study the acceleration of women's advancement and leadership in translational research in line with the stated objectives of the NIHR within the UK and RRI within the wider European research area through the collection of gender-disaggregated bibliometric data and analysis of scientific authorship by gender.

The primary objective of this study was to assess the gender parity in six types of scientific authorship in biomedical research. The secondary objective was to assess whether male and female authors publish articles in journals with different prestige levels.

METHODS

Study design

A descriptive bibliometric study.

Setting

This study was conducted at the NIHR Oxford BRC, which is research collaboration between the Oxford University Hospitals NHS Foundation Trust and the University of Oxford [32]. The NIHR BRCs supports translational research and innovation to improve healthcare for patients [33]. During the study period (April 2012-March 2017), the NIHR Oxford BRC was awarded £96m to support research across nine research themes, five cross-cutting themes, and a range of underpinning platforms. The research themes included Blood, Cancer, Cardiovascular, Dementia and Cerebrovascular Disease, Diabetes, Functional Neuroscience and Imaging, Infection, Translational Physiology, and Vaccines. The crosscutting themes included Genomic Medicine, Immunity and Inflammation, Surgical Innovation and Evaluation, Biomedical Informatics and Technology, and Prevention and Population Care. The major underpinning platforms included a Biorepository, Education and Training, Public Engagement, and Research Governance. Staff who have all or part of their salary funded through the BRC award are members of the NIHR faculty. During the study period (April 2012- and March 2017), there were 74% (n=1268) male and 26% (n=454) female principal investigators (scientists that have won research grants and are ultimately responsible for the conduct of research studies); 60% (n=600) male and 40% (n=404) female NIHR investigators (scientists leading and undertaking research, lead researchers, other senior researchers and research assistants); and 53% male (n=446) and 47% (396) female NIHR trainees (those engaged in research training leading to a higher degree by research). It is a contractual requirement to report the number of BRC supported publications published by researchers funded or supported by the NIHR research funds on an annual basis. Additionally, the NIHR uses bibliometric analyses to inform eligibility for its funding [34,35]. This study was carried out as part of a wider programme of research on the markers of achievement for assessing and monitoring gender equity in translational research organisations [7,31].

Data

Data comprised translational research publications published by researchers funded or supported by the NIHR Oxford BRC. The eligibility criteria for inclusion of a publication were: funding or support by the NIHR Oxford BRC and publication or acceptance between April 2012 and March 2017. Based on these criteria, 2409 publications were identified. These publications were classified as: basic science studies, clinical studies (both trial and non-trial studies), and other studies (comments, editorials, systematic reviews, reviews, opinions, meeting reports, guidelines and protocols).

Main outcome measures

The main outcome measures were: (1) Gender of authors, defined as a binary variable comprising, either male or female categories, (2) Six categories of scientific authorship: first author, joint first authors, first corresponding author, joint corresponding authors, last author and joint last authors (Figure 1). These categories are conventionally associated with the highest amount of contribution, credit and prestige [11,15].

<Insert> **Figure 1** Publication analysis workflow. <Here>

First author was defined as the first-named author of the publication. Publications that consisted of single authors were categorised as first authors. We considered the first author to be the main intellectual contributor in the publication, in terms of study design, data collection and analysis, and manuscript writing. Joint first authors were defined as two or more authors who were named as equal contributors and mentioned as joint first authors of the publication. The first corresponding author was defined as the only author who was reported as a corresponding author in the publication and his/her contact details such as an institutional address and/or an email address were provided for correspondence in the publication. Joint corresponding authors were defined as two or more authors who were listed or marked as corresponding authors and their contact details were provided for correspondence in the publication. Last author was defined as the last-named author of a publication. The last author was considered to be a group leader or principal investigator who may have provided significant intellectual contribution or supervision of the research work as well as acquisition of research funding [15,36]. Joint last authors were defined as two or more authors who were named as equal contributors in the publication and their names were mentioned as joint last authors in the publication. A major confounding factor, for which we could not control, was the informal nature of the conventions for the sequence and role of authors [36]. Although conventions for scientific authorship are well established in biomedical sciences [37,38], they may vary between different research areas and even between different research groups within the same area.

Determination of gender of authors

The gender of the authors was defined as a binary variable comprising either male or female categories, which were determined based on the first name of authors in all six categories of authorship. When the first names of authors were initialled in the publication or were difficult to associate with either male or female gender, further information was sought through searching their institutional webpages and online social network sites such as the LinkedIn and ResearchGate. We also used Gender APIs (gender-api.com and genderapi.io) when it was not possible to ascertain the gender of the authors by the above-mentioned methods. In addition, we contacted five authors directly via email to ascertain their gender. After completing data coding by two researchers (MJM and RD), to ensure the accuracy of data coding, 10% of the data were checked independently (CH). Consensus was achieved through discussion between the researchers on data fields that did not match the assigning of the gender of authors and types of authorship (Figure 1).

Gender of authors and journal prestige

For assessing whether male and female authors publish articles in less, equal or more prestigious journals, we used journal impact factor as a proxy for the prestige of a journal. We extracted data on journal impact factors from the Journal citation report 2019; and for a few articles we used the latest available impact factor reported on the journal websites.

Statistical analysis

Data were analysed using frequencies including counts and percentages. Chi-square tests were used for identifying statistically significant differences and associations between male and female authors in various categories of authorship. Cochrane linear trend test was used to determine trends over time using a Microsoft Excel add-in tool by Slezák et al[39]. T-tests were used to determine differences in the mean impact factor of journals with publications by male and female authors in three authorship categories: first, first corresponding and last authors. The level of significance was set at $p < 0.05$. Data were analysed using the IBM SPSS Statistics for Windows, Version 25.0 (Armonk, NY: IBM Corp.). Visualisations were created in the Microsoft Excel and BoxPlotR – a free online tool [40].

Patient and public involvement statement

There was no patient or public involvement in the study design.

RESULTS

Types of publication

Types of publications included clinical research studies (both trial and non-trial studies) comprised 39% (n=939), basic science research 27% (n=643) and a third of publications (34%, n=827) included other types of publication, such as systematic reviews, reviews, research protocols, editorials, guidelines, opinions, comments, and meeting reports (Table 1).

Table 1. Number and types of publication by year of acceptance

Year (Accepted)	Types of publication Count (%) Basic science	Clinical trial	Clinical study - Not a trial	Other*	Total Count (%)
2012†	75 (27.6)	18 (6.6)	90 (33.1)	89 (32.7)	272 (100)
2013◊	151 (28.2)	27 (5.0)	183 (34.2)	174 (32.5)	535 (100)
2014◊	122 (22.2)	29 (5.3)	204 (37.2)	194 (35.3)	549 (100)
2015◊	137 (24.7)	48 (8.7)	158 (28.5)	211 (38.1)	554 (100)
2016◊	137 (31.8)	31 (7.2)	120 (27.8)	143 (33.2)	431 (100)
2017‡	21 (30.9)	5 (7.4)	26 (38.2)	16 (23.5)	68 (100)
Total	**643 (26.7)**	**158 (6.6)**	**781 (32.4)**	**827 (34.3)**	**2409 (100)**

†April-December, ◊January-December ‡January-March, *systematic reviews, reviews, research protocols, editorials, guidelines, opinions, comments, and meeting reports

Authorship type and Gender

Table 2 presents an overview of gender of authors by types of authorship. Male authors were more likely to be first authors (59%, *P* <0.001), first corresponding authors (66%, *P* <0.001) and last authors (77%, *P* <0.001) (Table 2). In the three joint authorship categories analysed, the proportion of 'female only' authors was statistically significantly lower than 'male only' authors in two categories i.e. joint corresponding authors (29%, *P* <0.001) and joint last authors categories (10%, *P* <0.001) (Table 2). However, in the joint first authors category, the proportion of 'male and female' as joint first authors (57%, *P* <0.001) was statistically significantly higher than 'male only' and 'female only' joint first authors (Table 2).

Table 2. Authorship type and gender of authors

Authorship type Number of publications in the category	**Gender of authors** Count (%)			**Significance** *P*-value
	Male only	Female only	Male and female	
First author (n=2409)	1413 (58.7)	994 (41.3)	N/A*	<0.001
First corresponding author (n=2409)	1565 (65.0)	806 (33.5)	N/A	<0.001
Last author (n=2409)	1853 (76.9)	553 (23.0)	N/A	<0.001
Joint first authors (n=458)	127 (27.7)	69 (15.1)	262 (57.2)	<0.001
Joint corresponding authors (n=169)	107 (63.3)	49 (29.0)	13 (7.7)	<0.001
Joint last authors (n=229)	108 (47.2)	23 (10.0)	98 (42.8)	<0.001

*N/A= not applicable.

Gender of authors by types of publication

Table 3 shows gender of authors by types of publication (i.e. basic science, clinical trials, non-trial clinical studies and other research). The proportions of 'male only' authors were statistically significantly higher than the proportions of 'female only' authors in three authorship categories: first authors (*P*=0.035), first corresponding authors (*P* <0.001) and last authors (*P*=0.016) (Table 3). There were no significant differences between the proportions of 'male only' and 'female only' authors in all three joint authorship categories: joint first authors (*P*=0.476), joint corresponding authors (*P*=0.172) and joint last authors (*P*=0.208). Only the statistically significant associations are shown in Table 3.

Table 3. Gender of authors by publication type

	Publication Type Count (%)				**Significance**
Type of research	**Basic science**	**Clinical trial**	**Clinical study - Not a trial**	**Other**	***P*-value**
First author† (n=2407)					**0.035**
Male	371 (57.8)	92 (58.6)	433 (55.4)	517 (62.6)	
Female	271 (42.2)	65 (41.4)	348 (44.6)	310 (37.5)	
First corresponding author†† (n=2371)					**<0.001**
Male	446 (69.4)	100 (63.3)	465 (59.5)	554 (67.0)	
Female	191 (29.7)	56 (35.4)	307 (39.3)	252 (30.5)	
Last author (n=2406)					**0.016**
Male	503 (78.3)	125 (79.6)	570 (73.1)	655 (79.2)	
Female	139 (21.7)	32 (20.4)	210 (26.9)	172 (20.8)	

Yearly trends in Authorship by gender

Figure 2 presents the yearly trends in scientific authorship by gender. In all authorship types and across all five years of publication, the proportions of male and female authors varied (Figure 2). Women were significantly underrepresented across all years (April 2012 - March 2017) and authorship types. Interestingly, joint first authorship indicated a higher proportion of 'male and female' authors compared to 'male only' and 'female only' authors (Figure 2). a to show whether there was any. The results of Cochrane linear trend test revealed no significant change over time for all six authorship types over the years of publications.

<Insert> Figure 2 Yearly trends in scientific authorship by gender (male and female), April 2012 - March 2017. **<here>**

Association between same gender across authorship categories

There was a statistically significant association (*P* < 0.001) between the same gender i.e. male gender in first author and first corresponding author categories and female gender in first author and joint first authors categories[Table 4(a)].

Furthermore, there were statistically significant associations (*P* < 0.001) between the same gender in the last author category with the same gender of first author, first corresponding author, Joint corresponding author and joint last author categories [Table 4(b)].

However, there was no statistically significant association between the male and female last authors with the respective gender of joint first authors (*P*=0.117). Only the statistically significant associations are shown in Tables 4(a) and 4(b).

Table 4 (a). Association between same genders across authorship categories

	First author Count (%)		Significance
	Male	**Female**	***P*-value**
First corresponding author (n=2371)			**<0.001**
Male	1236 (79)	329 (21)	
Female	158 (19.6)	648 (80.4)	
First joint authors (n=457)			**<0.001**
Male only	124 (97.6)	3 (2.4)	
Female only	10 (14.5)	59 (85.5)	
both male and female	140 (53.6)	121 (46.4)	

Table 4 (b). Association between same genders across authorship categories

	Last author Count (%)		Significance
Authorship type	**Male**	**Female**	***P*-value**
First author† (n=2406)			**<0.001**
Male	1146 (61.8)	267 (48.3)	
Female	707 (38.2)	286 (51.7)	
First corresponding author (n=2370)			**<0.001**
Male	1429 (78.4)	136 (24.7)	
Female	394 (21.6)	412 (75.3)	
Joint corresponding authors(n=168)			**<0.001**
Male only	104 (84.5)	3 (6.7)	
Female only	13 (10.6)	36 (80)	
Both male and female	6 (4.9)	6 (13.3)	
Joint last authors (n=229)			**<0.001**
Male only	106 (63.9)	2 (8.2)	
Female only	2 (1.2)	21 (33.3)	
Both male and female	58 (34.9)	40 (63.5)	

Gender of authors and journal prestige

Of 2388 journal articles, 96.6% (n=2307) were published in journals having an impact factor (mean = 9.58 (±12.16), median = 5.36, minimum = 0.39, maximum = 74.7) while only 3.4% (n=81) articles were published in journals having no impact factor. There was no statistically significant difference in the mean journal impact factor (JIF) by gender of first and last authors; however, the mean JIF was statistically significantly higher for male first corresponding authors compared to female first corresponding authors (Table 5, Figure 3).

Table 5. Journal impact factor and authorship categories by gender

	Mean	**Standard deviation**	**95% CI**	***P*- Value**
First author				0.171
Male	9.88	12.46	9.18, 10.58	
Female	9.14	11.73	8.37, 9.92	
First corresponding author				**0.020**
Male	10.00	12.72	9.34, 10.67	
Female	8.77	10.95	7.97, 9.57	
Last author				
Male	9.34	11.76	8.77, 9.91	0.115
Female	10.40	13.38	9.21, 11.59	

<Insert> Figure 3 Impact factor of journals and authorship categories by gender. **<Here>**

DISCUSSION

We studied gender parity in the authorship of translational research publications (n=2409) produced by researchers affiliated with the NIHR Oxford BRC, which is one of the biggest amongst 20 NIHR BRCS in the UK. We determined gender of authors in six different categories of authorship that included three types of joint authorships in biomedical research, which is the most unique feature of this study and to our best knowledge it has been done for the first time in this study.

In the first author category, we found proportions of female authors and male authors within the 40%-60% "gender balance zone" [6]. In the last (senior) author category, the observed proportion of female last authors (77%) was lower than male last authors (23%) but it was higher than reported in other studies [12,14,25]. In the context of biomedical research in the UK, principal investigators (PIs) are typically last authors [41]. In the current study setting i.e. NIHR Oxford BRC, the proportion of male PIs was 74% and the remaining 26% PIs were female during the period of analysis. Thus, it appears that the representation of male and female last authors was proportionate to their respective proportions as PIs in the BRC. These findings suggest positive trends and the NHIR Oxford BRC doing very well in gender parity in the senior (last) authorship category.

This study extends understanding of gender-based trends in scientific authorship (Figure 2) by showing encouraging incremental changes in gender parity in authorship in a biomedical research setting. Previous research examined the gender gap in authorship within the medical literature reporting an upward trend for female first authors from 6% in 1970 to 29% in 2004 and female last authors from 4% in 1970 to 19% 2004. However, it was limited to US based institutions [13]. A similar UK based study covering the same period (i.e. 1970-2004) also showed upward trends for female first authors increasing from 11% in 1970 to 37% in 2004 and female last authors from 12% in 1970 to 17% in 2004 [25]. In addition, a recent study by Filardo et al. [14] examined the prevalence of female first authorship of original research published in six high impact general medical journals between February 1994 and June 2014 revealed that the adjusted probability of an article having a female first authorship increased significantly from 27% in 1994 to 37% in 2014 [14]. However, despite the proportion of female first authors varied greatly by journal, men were generally more likely to be first authors than women [14]. Compared to previous studies mentioned above, our study provides evidence of higher and increasing gender equity in the first authors, last authors and other four categories of scientific authorship in biomedical research (Table 2).

We found a strong association between same gender and authorship types showing if the first author of a publication was male, it was highly likely that the first corresponding author of the same publication would also be male. Similarly, the likelihood of the first author being female was higher, if the first corresponding author was also female [42]. Likewise, there appeared to be a significant association of male and female last authors with the respective gender of first authors. Previous research has highlighted males and females were more likely to be first authors on papers if the last authors were of the same gender [21,43–45]; however, these were not conducted in a translational research setting. Our findings also revealed a strong association of male and female last authors with the respective gender of corresponding authors [45].

However, due to the differences in gender equity between different research areas and medical specialties, where a centre-specific mix of research themes is likely to influence gender equity in scientific authorship, it is difficult to make direct comparisons across the literature.

In regards to gender parity in authorship scientific publications, which is an important marker of achievement for gender equity [7], our study builds an important evidence base in biomedical research settings and our results support previous studies [13,25,46–48].

We found that male first corresponding authors were more likely to publish articles in high impact factor journals compared to female first corresponding authors (Table 5). The practice of corresponding author varies between institutions, academic disciplines and countries [49] but usually the first corresponding author is either a researcher who has done major research work or a senior investigator who is overall responsible for the research study/project [15,36,50]. We do not have sufficient information to ascertain whether male first corresponding authors in our study were investigators or junior researchers or doctoral candidates. However, our findings suggest that female first corresponding authors are less likely to publish articles in high impact journals.

More importantly, our study shows that both the male and the female biomedical researchers publish articles at prestigious authorship positions i.e. first and last authors in journals with high impact factors (Figure 3) and no statistical association between the gender of first and last authors and the journal impact factor were identified [51]. In contrast, Bendels et al reported that female researchers were less likely to publish in high impact factor journals at prestigious authorship positions [46]. This could be due to the differences in journals analysed, research disciplines included and the time period covered. Our analysis included a wide range of journals in which researchers affiliated with the NIHR Oxford BRC published translational research from April 2012 to March 2017 while Bendels et al analysed only the Nature Index journals in four disciplines i.e. Life Science, Multidisciplinary, Earth and Environmental and Chemistry covering publication period from January 2008 to May 2016 [46].

Implications for policy and practice

While NIHR BRCs routinely collect bibliometric data on publications arising from the NIHR-funded research, and report to the NIHR (the funder), to the best of our knowledge, this data is not routinely analysed by gender. Our study provides the feasibility of using NIHR BRCs funded or supported research publications for analysing scientific authorship by gender. While retrospective analysis of the gender of authors in scientific publications is labour-intensive and has limitations, there is an opportunity to begin to track this prospectively. As more data becomes available, this would enable longitudinal analysis of gender in scientific authorship, which could be useful for tracking progress towards gender equity and related issues such as markers of achievement across all NIHR BRCs [7].

In addition, since the acceleration of women's advancement and leadership in translational research is one of the stated objectives of the NIHR, investigating the extent of gender equity in scientific authorship may usefully inform strategies to accelerate women's advancement and leadership in NIHR-funded research. Moreover, bibliometric analyses used by the NIHR to inform competition for NIHR funding may incorporate the gender dimension into the analysis, which could provide additional information on the competitiveness for NIHR funding [52,53].

CONCLUSION

Although, the proportions of female authors is significantly lower than the proportions of male authors in all six categories of authorship included in our analysis, first authorship is within the 40%-60% gender balance zone and the proportion of male and female last authors is proportionate to their respective proportions as principal investigators in the NIHR Oxford BRC This may suggest a positive trend in gender parity in the senior (last) author category in scientific publications produced by the BRC during April 2012-Match 2017. . This study provides evidence that both male and female authors at first and last authorship positions publish articles in journals with almost equal impact factor; however, male first corresponding authors are more likely to publish articles in prestigious journals with high impact factor. We also conclude that it is feasible to analyse bibliometric data on publications arising from NIHR funding by gender and consider establishing processes for monitoring gender equity in scientific authorship as an important marker of achievement in the context of NIHR BRCs [7].

Contributors

LDE conceived the study. RD and MJM coded the data. SGSS analysed the data and created visualisations. RD and SGSS drafted the manuscript. PVO contributed to the conception of the study. PVO and LH co-wrote parts of the manuscript. CRH and OC participated in data collection. VK, LRH, and AMB contributed to the conception of the study, facilitated access to the publications and coordinated the study. All authors read, contributed to and approved the final manuscript.

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Competing interests

VK is Chief Operating Officer and LRH is Clinical Research Manager at the National Institute for Health Research (NIHR) Biomedical Research Centre, Oxford. AMB is a senior medical science advisor and co-founder of Brainomix, a company that develops electronic ASPECTS (e-ASPECTS), an automated method to evaluate ASPECTS in stroke patients. MJM, LDE and PVO were funded by STARBIOS2 and the National Institute for Health Research (NIHR) Oxford Biomedical Research Centre (BRC). PVO is a member of the NIHR Advisory Group on Equality, Diversity, and Inclusion, a member of the European Association of Science Editors Gender Policy Committee, and a member of the Athena SWAN Self-Assessment Team of the Radcliffe Department of Medicine, University of Oxford. The other authors declare no competing interests.

Ethics

The University of Oxford Clinical Trials and Research Governance Team reviewed the study and deemed it exempt from full ethics review on the grounds that it falls outside of the Governance Arrangements for Research Ethics Committees (GAfREC), which stipulate which publications are required to have ethics review. A wider programme of research on the activities of the NIHR Oxford Biomedical Research Centre from 2017 to 2022 received ethics clearance through the University of Oxford Central University Research Ethics Committee (R51801/ RE001), the Health Research Authority (IRAS ID 228049) and the Oxford University Hospitals NHS Foundation Trust Management (PID 12779).

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Patient consent for publication

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Data sharing statement

No additional data available.

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Additional files list

Figure 1 Publication analysis workflow.
The workflow shows the process of extracting data according to gender from six types of authorship.

Figure 2 Yearly trends in scientific authorship by gender (male and female), April 2012 - March 2017. This plot represents the yearly variation of the proportion of male and female authors according to six types of authorship between the years of publication/acceptance from 2012 to 2017.

Figure 3 Impact factor of journals and authorship categories by gender. This figure shows the boxplots of impact factors of journals in which male and female authors published articles.

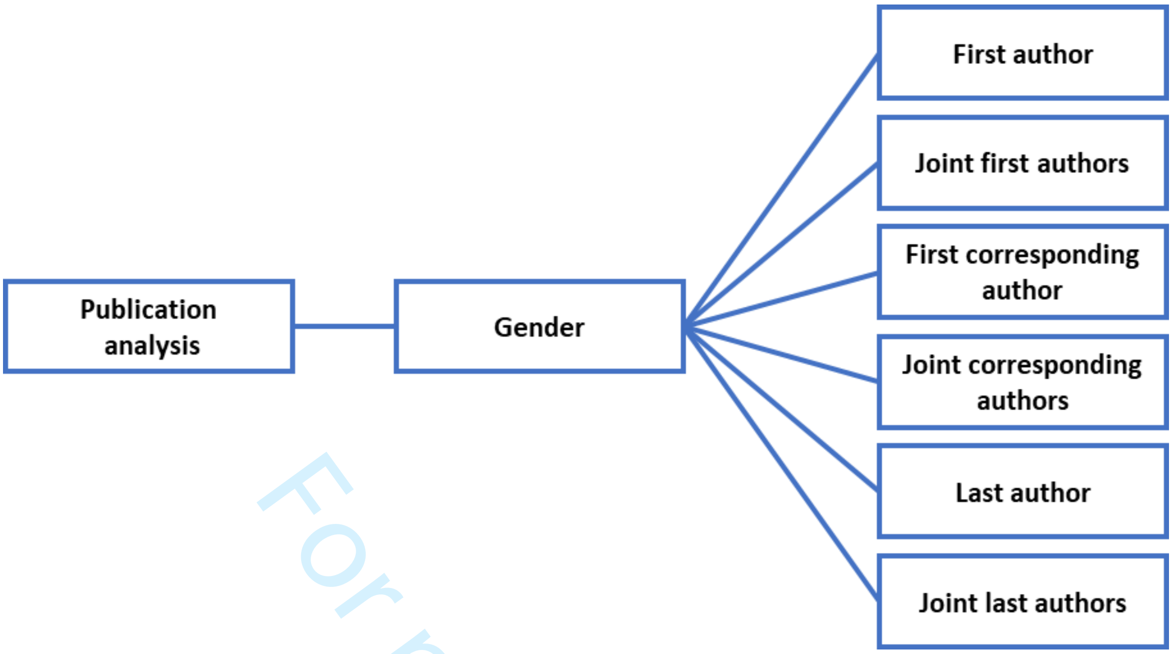
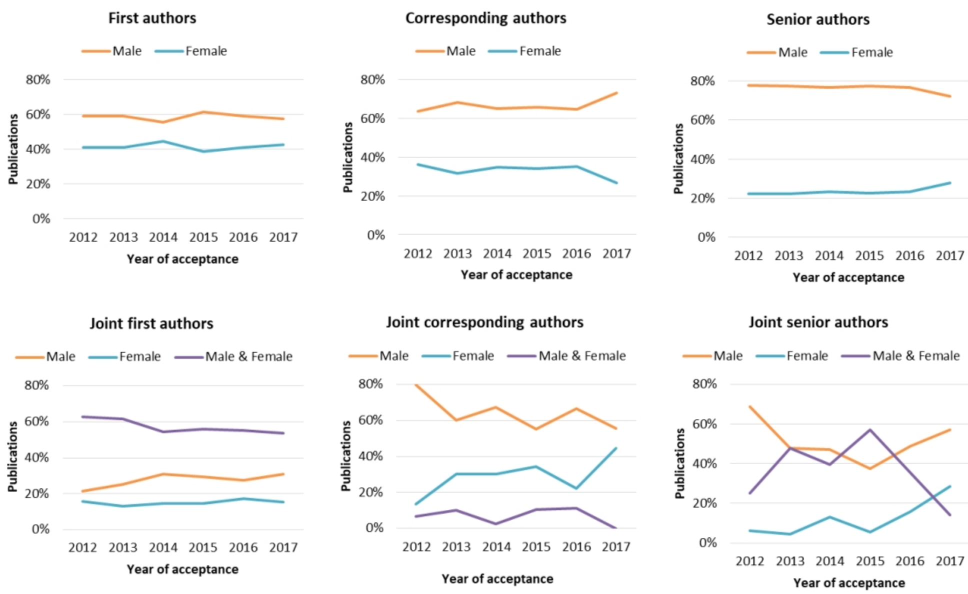


Figure 1 Publication analysis workflow.


First authors
Male
Female
80%
60%
40%
20%
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Publications
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Year of acceptance
Corresponding authors
Male
Female
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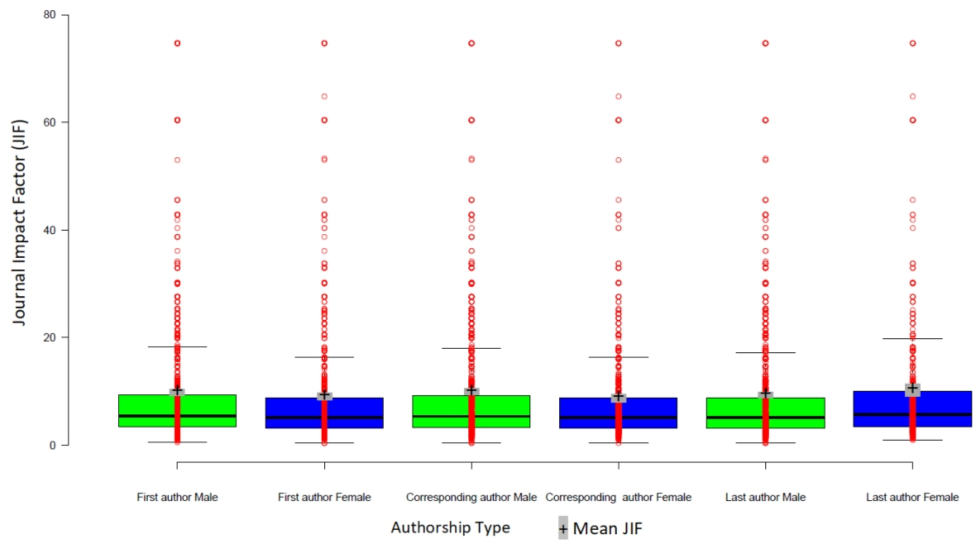
Year of acceptance


Journal Impact Factor (JIF)
80
60
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First author Male
First author Female
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Last author Male
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