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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-037935
Article Type:	Original research
Date Submitted by the Author:	21-Feb-2020
Complete List of Authors:	Dam, Rinita; University of Oxford, Radcliffe Department of Medicine Shah, Syed Ghulam Sarwar; Oxford University Hospitals NHS Foundation Trust, NIHR Oxford Biomedical Research Centre; University of Oxford, Radcliffe Department of Medicine Milano, Maria; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Edmunds, Laurel; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Henderson, Lorna; Oxford University Hospitals NHS Foundation Trust, NIHR Oxford Biomedical Research Centre Hartley, Catherine; Bodleian Health Care Libraries Coxall, Owen; Bodleian Health Care Libraries Ovseiko, Pavel; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Buchan, Alastair; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Kiparoglou, Vasiliki; Oxford University Hospitals NHS Foundation Trust, NIHR Oxford Biomedical Research Centre
Keywords:	BASIC SCIENCES, 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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1 A retrospective analysis of gender parity in scientific authorship in a 2 biomedical research centre

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21 Word count: 4377 (excluding references)

22 ABSTRACT

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

27
28 **Design:** A retrospective descriptive study.

29 **Setting:** NIHR Oxford Biomedical Research Centre.

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

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

34 **Results:** Publications comprised clinical research (39%, n=939), basic research (27%, n=643), and
35 other types of research (34%, n=827). The proportion of female authors as first author (41%), first
36 corresponding authors (34%) and last author (23%) was statistically significantly lower than male
37 authors in these authorship categories. Of total joint first authors (n=458), joint corresponding
38 authors (n=169), and joint last authors (n=229), female only authors comprised statistically
39 significant smaller proportions i.e. 15% (n=69), 29% (n=49) and 10% (n=23) respectively, compared
40 to male only authors in these joint authorship categories. There was a statistically significant
41 association between gender of the last author(s) with gender of the first author(s) (χ^2 33.742, $P <$
42 0.001), corresponding author(s) (χ^2 540.774, $P <$ 0.001) and joint last author(s) (χ^2 91.291, $P <$ 0.001).

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

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3 47 **Strengths and limitations of this study**
4

- 5 48 • This is the first study to investigate gender parity in six categories of scientific authorship:
6 49 first authors, first corresponding authors, last authors and three joint authorship categories
7 50 i.e. joint first authors, joint corresponding authors and joint last authors in biomedical
8 51 research.
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11 52 • This study provides an important benchmark on gender equity in scientific authorship for
12 53 other NIHR funded centres and organisations in England.
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15 54 • The generalisability of the findings of this study may be limited due to differences in medical
16 55 specialities, research areas, institutional cultures, and levels of support to individual
17 56 researchers.
18
19
20 57 • Using secondary sources for determining the gender of authors may have limitations, which
21 58 could be avoided by seeking relevant information from original authors and institution
22 59 affiliation at the time of submission.
23
24
25

26 61 **Keywords:** Responsible Research and Innovation, Gender Equity, Scientific Authorship, National
27 62 Institution for Health Research, Biomedical Research Centres, Evaluation, Translational Research
28 63 Organisations, Translational Research, Basic Science Research.
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64 INTRODUCTION

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

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

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

96 In the UK, women currently outnumber men in medical schools[11], however, a persistent gender
97 disparity in scientific publications remains[10,12–23]. While the proportion of women as first and
98 senior authors of original medical research has increased over the past few decades[24], women are
99 still significantly underrepresented as authors of research articles in medical journals, especially as
100 first and senior authors[14,22,23,25]. For example, in radiology the proportion of women as first
101 author increased from 8% in 1978 to 32% in 2013 and senior author increased from 7% in 1978 to
102 22% in 2013[23]. Similarly, in gastroenterology the proportion of women as first author increased
103 from 9% in 1992 to 29% in 2012, and senior author increased from 5% in 1992 to 15% in 2012[14].

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3 104 The profile of gender equity in higher education and research has been raised by the introduction of
4 105 Athena SWAN-linked funding incentives by the NIHR[26–28]. While Athena SWAN awards are useful
5 106 markers of achievement for higher education institutions and research institutes, they alone are
6 107 insufficient to assess and monitor the progress of NIHR BRCs towards gender equity[29]. Currently,
7 108 the proportion of women and the rate of their achievements are not tracked routinely by the NIHR
8 109 BRCs and little is known about how much women contribute to scientific research and innovation in
9 110 the BRCs. It is important to inform the acceleration of women’s advancement and leadership in
10 111 translational research in line with the stated objectives of the NIHR within the UK and RRI within the
11 112 wider European research area through the collection of gender-disaggregated bibliometric data and
12 113 analysis of scientific authorship by gender.

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17 114 For addressing the paucity of empirical research on women’s advancement and leadership in
18 115 translational research in the UK and Europe, a recent study on gender equity in Neurology suggests
19 116 the need for institutions to take a systematic approach to addressing gender disparities that involve
20 117 customised, defined metrics and transparent reporting to stakeholders[30].

21
22
23 118 The aim of this study was to assess the gender parity in six types of scientific authorship in
24 119 biomedical research.

25 26 120 **METHODS**

27 28 29 121 *Study design*

30 122 A retrospective descriptive study.

31 32 33 123 *Setting*

34 124 This study was conducted at the NIHR Oxford BRC, which is research collaboration between the
35 125 Oxford University Hospitals NHS Foundation Trust and the University of Oxford[31]. The aim of NIHR
36 126 BRCs is to support translational research and innovation to improve healthcare for patients[32].
37 127 During the study period (April 2012-March 2017), the NIHR Oxford BRC was awarded £96m to
38 128 support research across nine research themes, five cross-cutting themes, and a range of
39 129 underpinning platforms. The research themes included Blood, Cancer, Cardiovascular, Dementia and
40 130 Cerebrovascular Disease, Diabetes, Functional Neuroscience and Imaging, Infection, Translational
41 131 Physiology, and Vaccines. The crosscutting themes included Genomic Medicine, Immunity and
42 132 Inflammation, Surgical Innovation and Evaluation, Biomedical Informatics and Technology, and
43 133 Prevention and Population Care. The major underpinning platforms included a Biorepository,
44 134 Education and Training, Public Engagement, and Research Governance. It is a contractual
45 135 requirement to report the number of BRC supported publications published by researchers funded
46 136 or supported by the NIHR research funds on an annual basis. Additionally, the NIHR uses bibliometric
47 137 analyses to inform eligibility for NIHR funding[33,34]. This study was carried out as part of a wider
48 138 programme of research on the markers of achievement for assessing and monitoring gender equity
49 139 in translational research organisations[29].

140 **Data**

141 Data comprised translational research publications published by researchers funded or supported by
142 the NIHR Oxford BRC. The eligibility criteria for inclusion of a publication were funding or support by
143 the NIHR Oxford BRC and publication between April 2012 and March 2017. Based on these criteria,
144 2409 publications were identified. These publications were classified as: basic science studies,
145 clinical studies (both trial and non-trial studies), and other studies (comments, editorials, systematic
146 reviews, reviews, opinions, meeting reports, guidelines and protocols).

147 **Main outcome measures**

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

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

171 **Determination of gender of authors**

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

181 independently (CH). Consensus was achieved through discussion between the researchers on data
182 fields that did not match the assigning of the gender of authors and types of authorship (Figure 1).

183 **Statistical analysis**

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

188 **Patient and public involvement statement**

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

190 **RESULTS**

191 **Type of research study**

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

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

Year (Accepted)	Types of research studies Count (%)				Total Count (%)
	Basic science	Clinical trial	Clinical study - Not a trial	Other*	
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)

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

199 **Authorship type and Gender**

200 Table 2 presents an overview of gender of authors by types of authorship. This highlights that male
201 authors were statistically significant more likely to be first authors (59%, χ^2 972.938, $P < 0.001$), first
202 corresponding authors (66%, χ^2 242.970, $P < 0.001$) and last authors (77%, χ^2 702.411, $P < 0.001$)
203 (Table 2). Furthermore, analyses of joint authorship categories revealed that the proportion of
204 'female only' authors was statistically significantly lower than 'male only' authors in the joint
205 corresponding authors (29%, χ^2 79.858, $P < 0.001$) and joint last authors categories (10%, χ^2 56.550,

206 P<0.001) (Table 2). However, in the joint first authors category, the proportion of 'male and female'
 207 as joint first authors (57%, χ^2 128.467, P <0.001) was statistically significantly higher than male only
 208 and female only first authors (Table 2).

209 **Table 2.** Authorship categories and gender of authors

Authorship type	Gender of authors			Chi-Square Test χ^2 (p)
	Count (%)			
Number of publications in the category	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.

210 ***Gender of authors by type of research studies***

211 Analysis of gender of authors by types of research studies (i.e. basic science, clinical trials, non-trial
 212 clinical studies and other research) showed that the proportions of male only authors were
 213 statistically significantly higher than the proportions of female only authors in three authorship
 214 categories: first authors (χ^2 8.606 (df 3), P = 0.035), first corresponding authors (χ^2 36.955 (df 9), P <
 215 0.001) and last authors (χ^2 10.314 (df 3), P= 0.016). The analysis by type of research studies also
 216 revealed that there were no significant differences between the proportions of male only and
 217 female only authors in all three joint authorship categories: joint first authors (χ^2 5.549 (df 6), P =
 218 0.476), joint corresponding authors (χ^2 9.021 (df 6), P = 0 .172) and joint last authors (χ^2 8.433 (df 6),
 219 P = 0 .208).

220 ***Yearly trends in Authorship by gender***

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

226 ***Association between same gender across authorship categories***

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

230 Furthermore, there were statistically significant associations between the same gender in the last
231 author category with the same gender of first author(s) (χ^2 33.742 (df 2), $P < 0.001$), corresponding
232 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,
233 there was no statistically significant association between the male and female last authors with the
234 respective gender of joint first authors (χ^2 4.29 (df 2), $P = 0.117$).

235 **DISCUSSION**

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

239 In the first author category the proportions of female authors and male authors were within the
240 40%-60% "gender balance zone"[6]. The greatest gender imbalance was observed in the last author
241 category where 'female only' authors comprised only 23%. Nonetheless, this proportion is higher
242 than other studies reporting similar analyses[11,16,24].

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

249 This study extends understanding of gender-based trends in scientific authorship (Figure2) by
250 showing encouraging incremental changes in gender parity in authorship in a biomedical research
251 setting. Previous research examined the gender gap in authorship within the medical literature
252 reporting an upward trend for female first authors from 6% in 1970 to 29% in 2004 and female last
253 authors from 4% in 1970 to 19% 2004. However, it was limited to US based institutions[12]. A similar
254 UK based study covering the same period (i.e. 1970-2004) also showed upward trends for female
255 first authors increasing from 11% in 1970 to 37% in 2004 and female last authors from 12% in 1970
256 to 17% in 2004[24]. In addition, a recent study by Filardo et al.[16] examined the prevalence of
257 female first authorship of original research published in six high impact general medical journals
258 between February 1994 and June 2014 revealed that the adjusted probability of an article having a
259 female first authorship increased significantly from 27% in 1994 to 37% in 2014[16]. However,
260 despite the proportion of female first authors varied greatly by journal, men were generally more
261 likely to be first authors than women[16]. Compared to previous studies mentioned above, our study
262 provides evidence of higher and increasing gender equity in the first authors, last authors and other
263 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

1
2
3 303 from NIHR funding by gender and consider establishing processes for analysing gender equity in
4 304 scientific authorship over time.

305 **Contributors**

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

311 **Funding**

312 This study is funded by the European Union's Horizon 2020 research and innovation programme
313 award STARBIOS2 under grant agreement No. 709517 and by the National Institute for Health
314 Research (NIHR) Oxford Biomedical Research Centre, grant BRC-1215-20008 to the Oxford University
315 Hospitals NHS Foundation Trust and the University of Oxford. The views expressed are those of the
316 authors and not necessarily those of the NHS, the NIHR, or the Department of Health and Social
317 Care.

318 **Competing interests**

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

328 **Ethics**

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

337 **Acknowledgements**

338 The authors wish to thank Professor Helen McShane for reviewing the draft manuscript and making
339 comments and suggestions for improving it.

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4 340 **Patient consent for publication**

5 341 Not required.

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8 342 **Data sharing statement**

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10 343 No additional data available.

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486 Additional files list

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

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

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Supplementary File 1

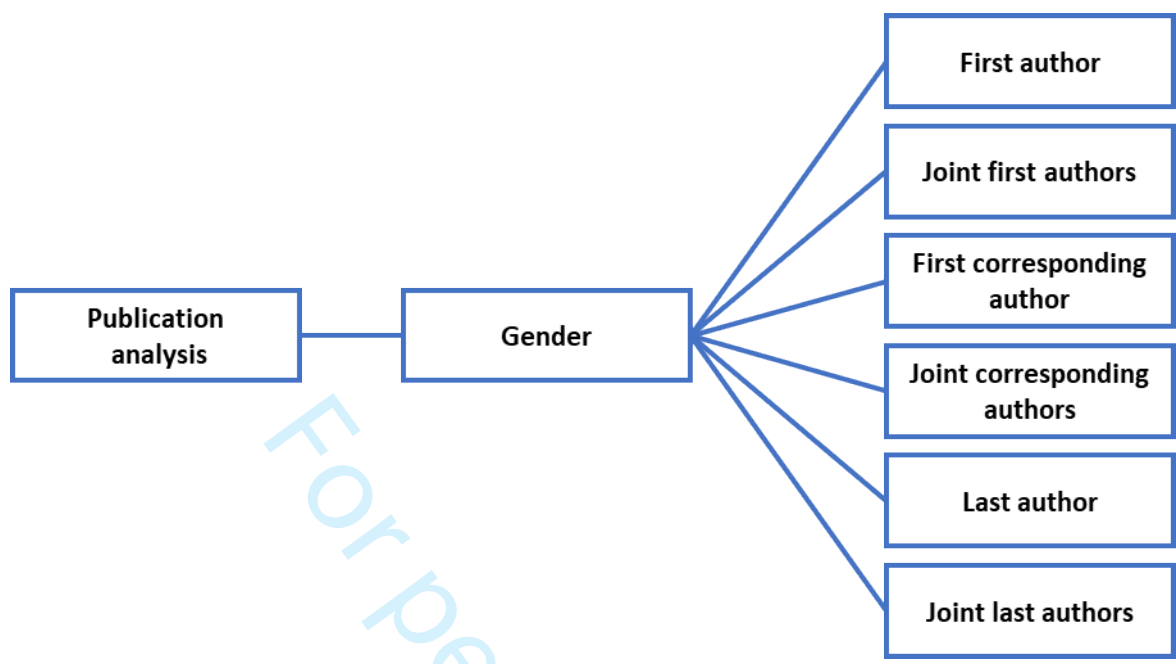
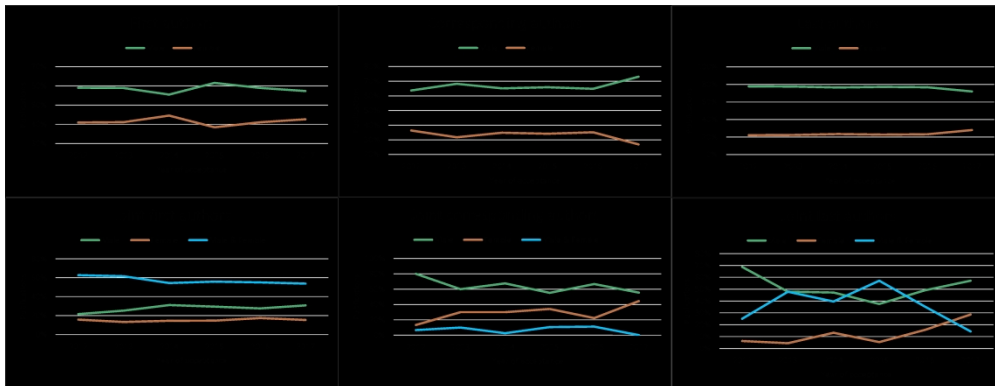


Figure 1 Publication analysis workflow.

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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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up: N/A	
		<i>Case-control study</i> —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	
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants: Pages 5-6	
Variables	7	(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	N/A
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	N/A
		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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	N/A
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A
		<i>Cross-sectional study</i> —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

1	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
2				
3	Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 10
4	Other Information			
5				
6	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
7				

8 **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.*

9 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is
 10 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
 11 Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-037935.R1
Article Type:	Original research
Date Submitted by the Author:	17-Sep-2020
Complete List of Authors:	Shah, Syed Ghulam Sarwar; Oxford University Hospitals NHS Foundation Trust, NIHR Oxford Biomedical Research Centre; University of Oxford, Radcliffe Department of Medicine Dam, Rinita; University of Oxford, Radcliffe Department of Medicine Milano, Maria; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Edmunds , Laurel ; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Henderson, Lorna; Oxford University Hospitals NHS Foundation Trust, NIHR Oxford Biomedical Research Centre Hartley, Catherine; Bodleian Health Care Libraries Coxall, Owen; Bodleian Health Care Libraries Ovseiko, Pavel; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Buchan, Alastair; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Kiparoglou, Vasiliki; Oxford University Hospitals NHS Foundation Trust, NIHR Oxford Biomedical Research Centre
Primary Subject Heading:	Medical publishing and peer review
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

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4 1 **Gender parity in scientific authorship in a National Institute for**
5 2 **Health Research Biomedical Research Centre: A bibliometric analysis**
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44 21 Word count: 5542 (excluding references)
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22 ABSTRACT

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

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28 **Design:** A retrospective descriptive study.

29 **Setting:** NIHR Oxford Biomedical Research Centre.

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

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

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

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

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3 57 **Strengths and limitations of this study**
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- 5 58 • This is the first study to investigate gender parity in six categories of scientific authorship: first
6 59 authors, first corresponding authors, last authors and three joint authorship categories i.e.
7 60 joint first authors, joint corresponding authors and joint last authors in biomedical research.
8
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10 61 • This study provides an important benchmark on gender equity in scientific authorship for
11 62 other NIHR funded centres and organisations in England.
12
13 63 • This study provides evidence that male first corresponding authors are more likely to publish
14 64 articles in prestigious journals with high impact factor compared to female first corresponding
15 65 authors.
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18 66 • Both male and female authors at first and last authorship positions publish articles in journals
19 67 with almost equal impact factor.
20
21
22 68 • The generalisability of the findings of this study may be limited due to differences in medical
23 69 specialities, research areas, institutional cultures, and levels of support to individual
24 70 researchers.
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26
27 71 • Using secondary sources for determining the gender of authors may have limitations, which
28 72 could be avoided by seeking relevant information from original authors and institution
29 73 affiliation at the time of submission.
30

31 74 **Keywords:** Responsible Research and Innovation, Gender Equity, Scientific Authorship, National
32 75 Institution for Health Research, Biomedical Research Centres, Evaluation, Translational Research
33 76 Organisations, Translational Research, Basic Science Research, Journal Impact Factor, Journal Prestige.
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77 INTRODUCTION

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

89 We have focussed on the ‘gender’ element of the RRI because it is imperative to advance gender
90 equality within research institutions, as well as within the design and content of research and
91 innovation [1]. The issue of enhancing female participation in economic decision-making has become
92 prominent in the national, European and international spheres, with a particular focus on the
93 economic dimension of gender diversity [4]. In order to achieve a fair female participation within
94 positions of power, it is recommended that women should hold half of the total seats in board rooms
95 [5], however, a ratio between 40% and 60%, also known as a “gender balance zone” [6], is considered
96 acceptable – a threshold that is set by the European Commission [4].

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

109 In the UK, women currently outnumber men in medical schools [11]; however, a persistent gender
110 disparity in scientific publications remains [10,12–23]. While the proportion of women as first and
111 senior (last) authors of original medical research has increased over the past few decades [24], women
112 are still significantly underrepresented as authors of research articles in medical journals, especially
113 as first and senior authors [19,20,22,25], which are considered as prestigious authorship positions
114 [10,14]. For example, in radiology the proportion of women as first author increased from 8% in 1978
115 to 32% in 2013 and senior author increased from 7% in 1978 to 22% in 2013 [20]. Similarly, in
116 gastroenterology the proportion of women as first author increased from 9% in 1992 to 29% in 2012,
117 and senior author increased from 5% in 1992 to 15% in 2012 [22].

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3 118 The profile of gender equity in higher education and research has been raised by the introduction of
4 119 Athena SWAN-linked funding incentives by the NIHR [26–28]. While Athena SWAN awards are useful
5 120 markers of achievement for higher education institutions and research institutes, they alone are
6 121 insufficient to assess and monitor the progress of NIHR BRCs towards gender equity [29]. Currently,
7 122 the proportion of women and the rate of their achievements are not tracked routinely by the NIHR
8 123 BRCs and little is known about how much women contribute to scientific research and innovation in
9 124 the BRCs. It is important to study the acceleration of women’s advancement and leadership in
10 125 translational research in line with the stated objectives of the NIHR within the UK and RRI within the
11 126 wider European research area through the collection of gender-disaggregated bibliometric data and
12 127 analysis of scientific authorship by gender.

13 128 The primary objective of this study was to assess the gender parity in six types of scientific authorship
14 129 in biomedical research. The secondary objective was to assess whether male and female authors
15 130 publish articles in journals with different prestige levels.

131 **METHODS**

132 *Study design*

133 A retrospective descriptive study.

134 *Setting*

135 This study was conducted at the NIHR Oxford BRC, which is research collaboration between the Oxford
136 University Hospitals NHS Foundation Trust and the University of Oxford [30]. The aim of NIHR BRCs is
137 to support translational research and innovation to improve healthcare for patients [31]. During the
138 study period (April 2012-March 2017), the NIHR Oxford BRC was awarded £96m to support research
139 across nine research themes, five cross-cutting themes, and a range of underpinning platforms. The
140 research themes included Blood, Cancer, Cardiovascular, Dementia and Cerebrovascular Disease,
141 Diabetes, Functional Neuroscience and Imaging, Infection, Translational Physiology, and Vaccines. The
142 crosscutting themes included Genomic Medicine, Immunity and Inflammation, Surgical Innovation
143 and Evaluation, Biomedical Informatics and Technology, and Prevention and Population Care. The
144 major underpinning platforms included a Biorepository, Education and Training, Public Engagement,
145 and Research Governance. Staff who have all or part of their salary funded through the BRC award are
146 members of the NIHR faculty. Between April 2012 and March 2017, there were 73.64% principal
147 investigators (scientists that have won research grants and are ultimately responsible for the conduct
148 of research studies); 59.76% NIHR investigators (scientists leading and undertaking research); 31.85%
149 NIHR associates (staff supporting research that are led by others) and 52.97% NIHR trainees (those
150 who are engaged in research training leading to a higher degree by research) that were male. It is a
151 contractual requirement to report the number of BRC supported publications published by
152 researchers funded or supported by the NIHR research funds on an annual basis. Additionally, the
153 NIHR uses bibliometric analyses to inform eligibility for NIHR funding [32,33]. This study was carried
154 out as part of a wider programme of research on the markers of achievement for assessing and
155 monitoring gender equity in translational research organisations [29]. During the same study period,
156 the NIHR Oxford BRC was awarded with external funding from research councils, research charities,
157 the Department of Health, industry collaborators and non-commercial organisations. Research

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3 158 councils have provided the highest amount of external funding with an amount of £265.5m. However,
4 159 current data from the NIHR Oxford BRC are not available at an individual level; hence, it is not possible
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6 160 to present this data according to gender.
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8 161 **Data**

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10 162 Data comprised translational research publications published by researchers funded or supported by
11 163 the NIHR Oxford BRC. The eligibility criteria for inclusion of a publication were funding or support by
12 164 the NIHR Oxford BRC and publication between April 2012 and March 2017. Based on these criteria,
13 165 2409 publications were identified. These publications were classified as: basic science studies, clinical
14 166 studies (both trial and non-trial studies), and other studies (comments, editorials, systematic reviews,
15 167 reviews, opinions, meeting reports, guidelines and protocols).
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18 168 **Main outcome measures**

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20 169 The main outcome measures were: (1) Gender of authors, defined as a binary variable comprising,
21 170 either male or female categories, (2) Six categories of scientific authorship: first author, joint first
22 171 authors, first corresponding author, joint corresponding authors, last author and joint last authors
23 172 (Figure 1). These categories are conventionally associated with the highest amount of contribution,
24 173 credit and prestige [10,14].
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27 174 <Insert> **Figure 1** Publication analysis workflow. <Here>
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29 175 First author was defined as the first-named author of the publication. Publications that consisted of
30 176 single authors were categorised as first authors. We considered the first author to be the main
31 177 intellectual contributor in the publication, in terms of study design, data collection and analysis, and
32 178 manuscript writing. Joint first authors were defined as two or more authors who were named as equal
33 179 contributors and mentioned as joint first authors of the publication. The first corresponding author
34 180 was defined as the only author who was reported as a corresponding author in the publication and
35 181 his/her contact details such as an institutional address and/or an email address were provided for
36 182 correspondence in the publication. Joint corresponding authors were defined as two or more authors
37 183 who were listed or marked as corresponding authors and their contact details were provided for
38 184 correspondence in the publication. Last author was defined as the last-named author of a publication.
39 185 The last author was considered to be a group leader or principal investigator who may have provided
40 186 significant intellectual contribution or supervision of the research work as well as acquisition of
41 187 research funding [14,34]. Joint last authors were defined as two or more authors who were named as
42 188 equal contributors in the publication and their names were mentioned as joint last authors in the
43 189 publication. A major confounding factor, for which we could not control, was the informal nature of
44 190 the conventions for the sequence and role of authors [34]. Although conventions for scientific
45 191 authorship are well established in biomedical sciences [35,36], they may vary between different
46 192 research areas and even between different research groups within the same area.
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53 193 **Determination of gender of authors**

54 194 The gender of the authors was defined as a binary variable comprising either male or female
55 195 categories, which were determined based on the first name of authors in all six categories of
56 196 authorship included in the analysis. When the first names of authors were initialled in the publication
57 197 or were difficult to associate with either male or female gender, further information was sought
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3 198 through searching their institutional webpages and online social network sites such as the LinkedIn
4 199 and ResearchGate. We also used Gender APIs (gender-api.com and genderapi.io) when it was not
5 200 possible to ascertain the gender of the authors by the above-mentioned sources. In addition, we
6 201 contacted five authors directly via email to ascertain their gender. After completing data coding by
7 202 two researchers (MJM and RD), to ensure the accuracy of data coding, 10% of the data were checked
8 203 independently (CH). Consensus was achieved through discussion between the researchers on data
9 204 fields that did not match the assigning of the gender of authors and types of authorship (Figure 1).

205 ***Gender of authors and journal prestige***

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

210 ***Statistical analysis***

211 Data were analysed using frequencies including counts and percentages. Chi-square tests were used
212 for identifying statistically significant differences and associations between male and female authors
213 in various categories of authorship. Cochran linear trend test was used to determine trends over time
214 using Slezák et al tool [37]. T-Tests were used to determine differences in the mean impact factor of
215 journals with publications by male and female authors in all three authorship categories. The level of
216 significance was set at $p < 0.05$. Data were analysed using the IBM SPSS Statistics for Windows, Version
217 25.0 (Armonk, NY: IBM Corp.). Visualisations were created in the Microsoft Excel and BoxPlotR – a free
218 online tool [38].

219 ***Patient and public involvement statement***

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

221 **RESULTS**

222 ***Types of publication***

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

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

Year (Accepted)	Types of publication Count (%)				Total Count (%)
	Basic science	Clinical trial	Clinical study - Not a trial	Other*	
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)

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

230 *Authorship type and Gender*

231 Table 2 presents an overview of gender of authors by types of authorship. Male authors were
232 statistically significant more likely to be first authors (59%, $P < 0.001$), first corresponding authors (66%,
233 $P < 0.001$) and last authors (77%, $P < 0.001$) (Table 2). Furthermore, analyses of joint authorship
234 categories revealed that the proportion of 'female only' authors was statistically significantly lower
235 than 'male only' authors in the joint corresponding authors (29%, $P < 0.001$) and joint last authors
236 categories (10%, $P < 0.001$) (Table 2). However, in the joint first authors category, the proportion of
237 'male and female' as joint first authors (57%, $P < 0.001$) was statistically significantly higher than male
238 only and female only first authors (Table 2).

239 **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

54 *N/A= not applicable.

240 *Gender of authors by types of publication*

241 Table 3 presents an analysis of gender of authors by types of publication (i.e. basic science, clinical
242 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

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

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

269 **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
<i>Male</i>	1236 (79)	329 (21)	
<i>Female</i>	158 (19.6)	648 (80.4)	
First joint authors (n=457)			<0.001
<i>Male only</i>	124 (97.6)	3 (2.4)	
<i>Female only</i>	10 (14.5)	59 (85.5)	
<i>both male and female</i>	140 (53.6)	121 (46.4)	

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

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

271 ***Gender of authors and journal prestige***

272 Of 2388 journal articles, 96.6% (n=2307) were published in journals having an impact factor (mean
 273 =9.58 (\pm 12.16), median = 5.36, minimum = 0.39, maximum = 74.7) while only 3.4% (n=81) articles were
 274 published in journals having no impact factor. There was no statistically significant difference in the
 275 mean journal impact factor by male and female first and last authors; however, the mean journal
 276 impact factor was statistically significantly higher for male first corresponding authors compared to
 277 female first corresponding authors (Table 5, Figure 3).

278 **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	

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

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

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

Journal	Impact Factor (2019)	First Author		First corresponding author		Last author	
		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						✓

283 **DISCUSSION**

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

287 In the first author category the proportions of female authors and male authors were within the 40%-
 288 60% “gender balance zone” [6]. The greatest gender imbalance was observed in the last author
 289 category where ‘female only’ authors comprised only 23%. Nonetheless, this proportion is higher than
 290 other studies reporting similar analyses [11,13,24].

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

297 This study extends understanding of gender-based trends in scientific authorship (Figure 2) by showing
 298 encouraging incremental changes in gender parity in authorship in a biomedical research setting.
 299 Previous research examined the gender gap in authorship within the medical literature reporting an
 300 upward trend for female first authors from 6% in 1970 to 29% in 2004 and female last authors from
 301 4% in 1970 to 19% 2004. However, it was limited to US based institutions [12]. A similar UK based
 302 study covering the same period (i.e. 1970-2004) also showed upward trends for female first authors

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3 303 increasing from 11% in 1970 to 37% in 2004 and female last authors from 12% in 1970 to 17% in 2004
4 304 [24]. In addition, a recent study by Filardo et al. [13] examined the prevalence of female first
5 305 authorship of original research published in six high impact general medical journals between
6 306 February 1994 and June 2014 revealed that the adjusted probability of an article having a female first
7 307 authorship increased significantly from 27% in 1994 to 37% in 2014 [13]. However, despite the
8 308 proportion of female first authors varied greatly by journal, men were generally more likely to be first
9 309 authors than women [13]. Compared to previous studies mentioned above, our study provides
10 310 evidence of higher and increasing gender equity in the first authors, last authors and other four
11 311 categories of scientific authorship in biomedical research (Table 2).

12 312 Our study identified a strong association between same gender and authorship types showing if the
13 313 first author of a publication was male, it was highly likely that the first corresponding author of the
14 314 same publication would also be male. Similarly, the likelihood of the first author being female was
15 315 higher, if the first corresponding author was also female [45]. Likewise, there appeared to be a
16 316 significant association of male and female last authors with the respective gender of first authors.
17 317 Previous research has highlighted males and females were more likely to be first authors on papers if
18 318 the last authors were of the same gender; however, these were not conducted in a translational
19 319 research setting [20,46–48]. There was also a strong association of male and female last authors with
20 320 the respective gender of corresponding authors [45].

21 321 However, due to the differences in gender equity between different research areas and medical
22 322 specialties, where a centre-specific mix of research themes is likely to influence gender equity in
23 323 scientific authorship, it is difficult to make direct comparisons across the literature.

24 324 Overall, our results build an important evidence base in biomedical research settings concerning
25 325 gender parity and support the findings from previous studies where analysis of scientific authorship
26 326 by gender has been used as an important marker of gender equity [12,24,49–51].

27 327 We also studied differences between male and female authors in publishing articles in high impact
28 328 journals. Our results revealed that male first corresponding authors were more likely to publish
29 329 articles in high impact factor journals compared to female first corresponding authors (Table 5). These
30 330 findings suggest that female first corresponding authors are less likely to publish articles in high impact
31 331 journals. We also found that male and female first and last authors were more likely to publish articles
32 332 in journals with impact factors that were not statistically significantly different (Table 6, Figure 3). Our
33 333 findings show that both the male and the female biomedical researchers publish articles at prestigious
34 334 authorship positions i.e. first and last authors in journals with high impact factors. Our findings are
35 335 contrary to the findings of earlier research by Bendels et al who reported that female researchers
36 336 were less likely to publish in high impact factor journals at prestigious authorship positions [49].
37 337 Dissimilarities in the findings of our study and the study by Bendels et al [49] could be due to the
38 338 differences in journals analysed, research disciplines included and the time period covered. Our
39 339 analysis included a wide range of journals in which researchers affiliated with the NIHR Oxford BRC
40 340 published translational research from April 2012 to March 2017 while Bendels et al analysed only
41 341 Nature Index journals in four disciplines i.e. Life Science, Multidisciplinary, Earth and Environmental
42 342 and Chemistry covering publication period from January 2008 to May 2016 [49].

343 ***Implications for policy and practice***

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

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

358 **CONCLUSION**

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

370 **Contributors**

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

376 **Funding**

377 This study is funded by the European Union's Horizon 2020 research and innovation programme
378 award STARBIOS2 under grant agreement No. 709517 and by the National Institute for Health
379 Research (NIHR) Oxford Biomedical Research Centre, grant BRC-1215-20008 to the Oxford University

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

382 **Competing interests**

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

392 **Ethics**

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

400 **Acknowledgements**

401 The authors wish to thank the editors and reviewers who provided constructive feedback and
402 suggestions which improved this work. The authors also wish to thank Professor Helen McShane for
403 reviewing the initial draft manuscript and making comments and suggestions for improving it.

404 **Patient consent for publication**

405 Not required.

406 **Data sharing statement**

407 No additional data available.

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549 Additional files list

- 550 **Figure 1** Publication analysis workflow.
551 The workflow shows the process of extracting data according to gender from six types of authorship.
552 **Figure 2** Yearly trends in scientific authorship by gender (male and female), April 2012 - March 2017.
553 This plot represents the yearly variation of the proportion of male and female authors according to six
554 types of authorship between the years of publication/acceptance from 2012 to 2017.
555 **Figure 3** Impact factor of journals and authorship categories by gender.
556 This figure shows the boxplots of impact factors of journals in which male and female authors
557 published articles.

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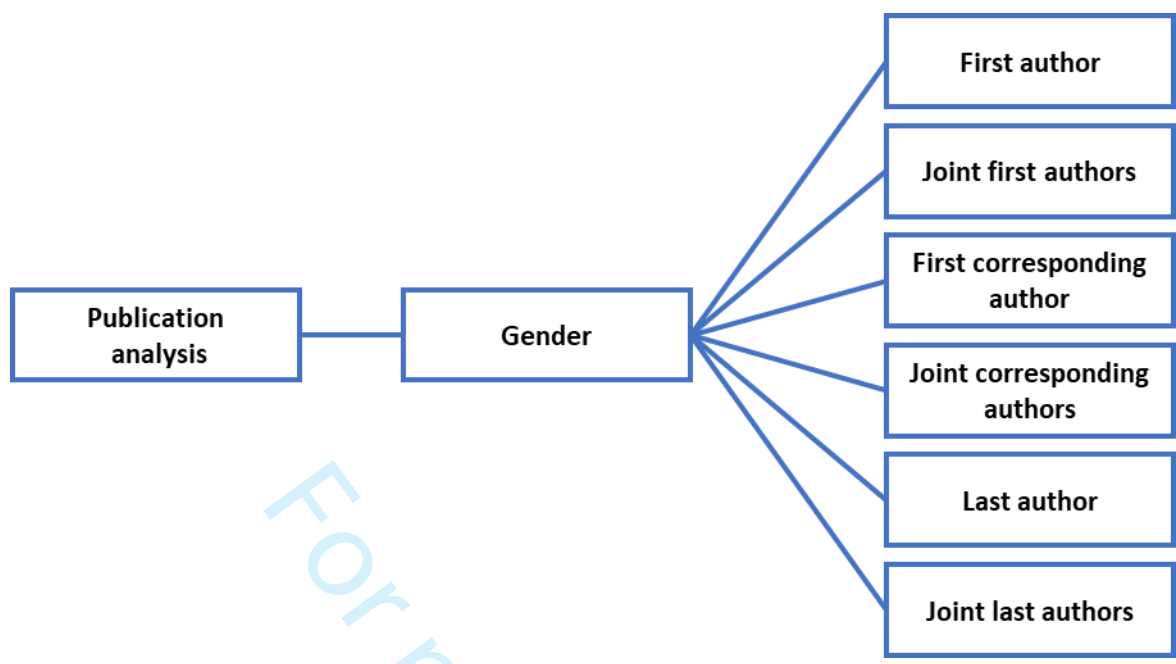
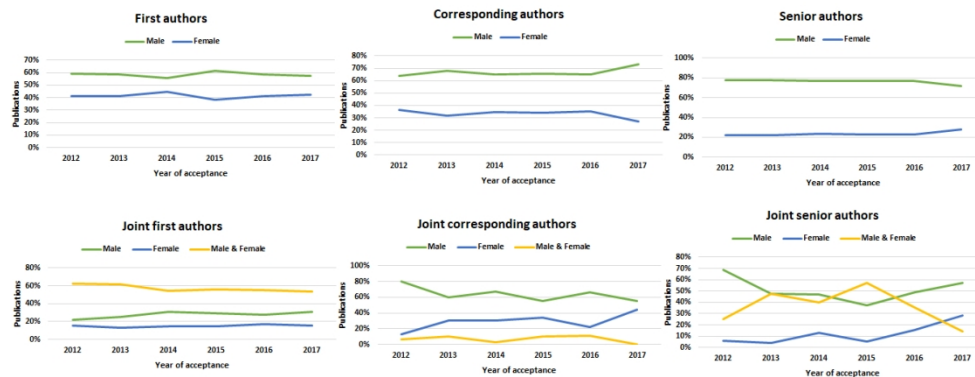


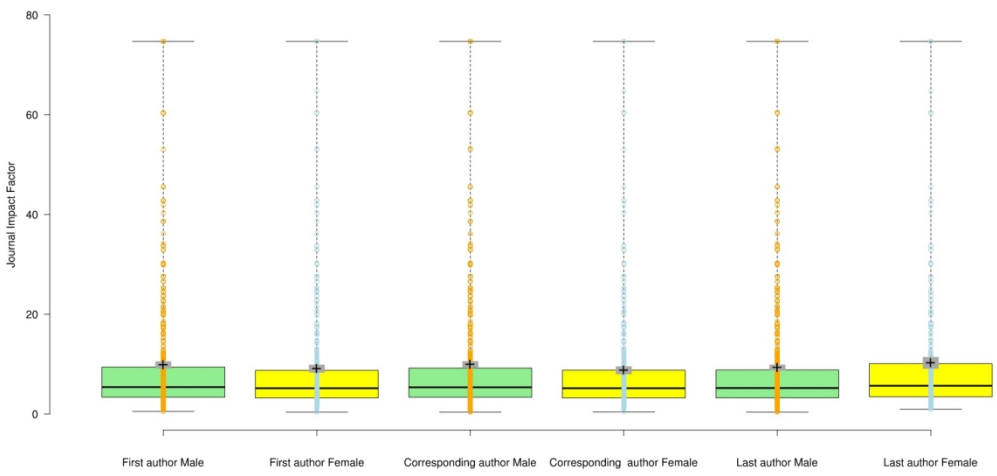
Figure 1 Publication analysis workflow.

For peer review only



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STROBE Statement

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

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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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up: N/A	
		<i>Case-control study</i> —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	
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants: Pages 5-6	
Variables	7	(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	N/A
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	N/A
		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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	N/A
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A
		<i>Cross-sectional study</i> —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

1	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
2				
3	Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 10
4	Other Information			
5				
6	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
7				

8 **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.*

9 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is
 10 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
 11 Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-037935.R2
Article Type:	Original research
Date Submitted by the Author:	08-Dec-2020
Complete List of Authors:	Shah, Syed Ghulam Sarwar; Oxford University Hospitals NHS Foundation Trust, NIHR Oxford Biomedical Research Centre; University of Oxford, Radcliffe Department of Medicine Dam, Rinita; University of Oxford, Radcliffe Department of Medicine Milano, Maria; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Edmunds , Laurel ; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Henderson, Lorna; Oxford University Hospitals NHS Foundation Trust, NIHR Oxford Biomedical Research Centre Hartley, Catherine; Bodleian Health Care Libraries Coxall, Owen; Bodleian Health Care Libraries Ovseiko, Pavel; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Buchan, Alastair; University of Oxford Medical Sciences Division, Radcliffe Department of Medicine Kiparoglou, Vasiliki; Oxford University Hospitals NHS Foundation Trust, NIHR Oxford Biomedical Research Centre
Primary Subject Heading:	Medical publishing and peer review
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

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4 1 **Gender parity in scientific authorship in a National Institute for**
5 2 **Health Research Biomedical Research Centre: A bibliometric**
6 3 **analysis**
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38 22 Word count: 5971 (excluding the abstract, highlights and references)

23 ABSTRACT

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

29
30 **Design:** A descriptive bibliometric study.

31 **Setting:** NIHR Oxford Biomedical Research Centre (BRC).

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

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

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

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

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3 61 **Strengths and limitations of this study**
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- 5 62 • This is the first study to investigate gender parity in six categories of scientific authorship:
6 first authors, first corresponding authors, last authors and three joint authorship categories
7 63 i.e. joint first authors, joint corresponding authors and joint last authors in biomedical
8 64 research.
9 65
- 10
11 66 • The proportions of male and female last (senior) authors are comparable to their respective
12 67 proportions as principal investigators in this setting, suggesting strong evidence of
13 68 attainment of gender parity in this category of scientific authorship
- 14
15
16 69 • This study offers an important benchmark on gender equity in scientific authorship for other
17 70 NIHR funded BRCs and organisations in England.
- 18
19
20 71 • This study provides evidence that male first corresponding authors are more likely to publish
21 72 articles in prestigious journals with high impact factor compared to female first
22 73 corresponding authors, whilst both male and female authors at first and last authorship
23 74 positions publish articles in prestigious journals with almost equal impact factor.
- 24
25
26 75 • The generalisability of these findings may be limited due to differences in medical
27 76 specialities, research areas, institutional cultures, and levels of support to individual
28 77 researchers.

29
30 78 **Keywords:** Responsible Research and Innovation, Gender Equity, Scientific Authorship, National
31 79 Institute for Health Research, Biomedical Research Centres, Evaluation, Translational Research
32 80 Organisations, Translational Research, Basic Science Research, Journal Impact Factor, Journal
33 81 Prestige.
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82 INTRODUCTION

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

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

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

114 In the UK, women currently outnumber men in medical schools [12]; however, a persistent gender
115 disparity in scientific publications remains [11,13–24]. While the proportion of women as first and
116 senior (last) authors of original medical research has increased over the past few decades [25],
117 women are still significantly underrepresented as authors of research articles in medical journals,
118 especially as first and senior (last) authors [20,21,23,26], which are considered as prestigious
119 authorship positions [11,15]. For example, in radiology the proportion of women as first author
120 increased from 8% in 1978 to 32% in 2013 and senior author increased from 7% in 1978 to 22% in
121 2013 [21]. Similarly, in gastroenterology the proportion of women as first author increased from 9%
122 in 1992 to 29% in 2012, and senior author increased from 5% in 1992 to 15% in 2012 [23].

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3 123 The profile of gender equity in higher education and research has been raised by the introduction of
4 124 Athena SWAN-linked funding incentives by the NIHR [27–30]. While Athena SWAN awards are useful
5 125 markers of achievement for higher education institutions and research institutes, they alone are
6 126 insufficient to assess and monitor the progress of NIHR BRCs towards gender equity [31]. Currently,
7 127 the proportion of women and the rate of their achievements are not tracked routinely by the NIHR
8 128 BRCs and little is known about how much women contribute to scientific R&I in the BRCs. It is
9 129 important to study the acceleration of women’s advancement and leadership in translational
10 130 research in line with the stated objectives of the NIHR within the UK and RRI within the wider
11 131 European research area through the collection of gender-disaggregated bibliometric data and
12 132 analysis of scientific authorship by gender.

13 133 The primary objective of this study was to assess the gender parity in six types of scientific
14 134 authorship in biomedical research. The secondary objective was to assess whether male and female
15 135 authors publish articles in journals with different prestige levels.

16 136 **METHODS**

17 137 *Study design*

18 138 A descriptive bibliometric study.

19 139 *Setting*

20 140 This study was conducted at the NIHR Oxford BRC, which is research collaboration between the
21 141 Oxford University Hospitals NHS Foundation Trust and the University of Oxford [32]. The NIHR BRCs
22 142 supports translational research and innovation to improve healthcare for patients [33]. During the
23 143 study period (April 2012-March 2017), the NIHR Oxford BRC was awarded £96m to support research
24 144 across nine research themes, five cross-cutting themes, and a range of underpinning platforms. The
25 145 research themes included Blood, Cancer, Cardiovascular, Dementia and Cerebrovascular Disease,
26 146 Diabetes, Functional Neuroscience and Imaging, Infection, Translational Physiology, and Vaccines.
27 147 The crosscutting themes included Genomic Medicine, Immunity and Inflammation, Surgical
28 148 Innovation and Evaluation, Biomedical Informatics and Technology, and Prevention and Population
29 149 Care. The major underpinning platforms included a Biorepository, Education and Training, Public
30 150 Engagement, and Research Governance. Staff who have all or part of their salary funded through the
31 151 BRC award are members of the NIHR faculty. During the study period (April 2012- and March 2017),
32 152 there were 74% (n=1268) male and 26% (n=454) female principal investigators (scientists that have
33 153 won research grants and are ultimately responsible for the conduct of research studies); 60%
34 154 (n=600) male and 40% (n=404) female NIHR investigators (scientists leading and undertaking
35 155 research, lead researchers, other senior researchers and research assistants); and 53% male (n=446)
36 156 and 47% (396) female NIHR trainees (those engaged in research training leading to a higher degree
37 157 by research). It is a contractual requirement to report the number of BRC supported publications
38 158 published by researchers funded or supported by the NIHR research funds on an annual basis.
39 159 Additionally, the NIHR uses bibliometric analyses to inform eligibility for its funding [34,35]. This
40 160 study was carried out as part of a wider programme of research on the markers of achievement for
41 161 assessing and monitoring gender equity in translational research organisations [7,31].

162 **Data**

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

169 **Main outcome measures**

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

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

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

194 **Determination of gender of authors**

195 The gender of the authors was defined as a binary variable comprising either male or female
196 categories, which were determined based on the first name of authors in all six categories of
197 authorship. When the first names of authors were initialled in the publication or were difficult to
198 associate with either male or female gender, further information was sought through searching their
199 institutional webpages and online social network sites such as the LinkedIn and ResearchGate. We
200 also used Gender APIs (gender-api.com and genderapi.io) when it was not possible to ascertain the
201 gender of the authors by the above-mentioned methods. In addition, we contacted five authors

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3 202 directly via email to ascertain their gender. After completing data coding by two researchers (MJM
4 203 and RD), to ensure the accuracy of data coding, 10% of the data were checked independently (CH).
5 204 Consensus was achieved through discussion between the researchers on data fields that did not
6 205 match the assigning of the gender of authors and types of authorship (Figure 1).
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9 206 *Gender of authors and journal prestige*

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11 207 For assessing whether male and female authors publish articles in less, equal or more prestigious
12 208 journals, we used journal impact factor as a proxy for the prestige of a journal. We extracted data on
13 209 journal impact factors from the Journal citation report 2019; and for a few articles we used the latest
14 210 available impact factor reported on the journal websites.
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17 211 *Statistical analysis*

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19 212 Data were analysed using frequencies including counts and percentages. Chi-square tests were used
20 213 for identifying statistically significant differences and associations between male and female authors
21 214 in various categories of authorship. Cochran linear trend test was used to determine trends over
22 215 time using a Microsoft Excel add-in tool by Slezák et al[39]. T-tests were used to determine
23 216 differences in the mean impact factor of journals with publications by male and female authors in
24 217 three authorship categories: first, first corresponding and last authors. The level of significance was
25 218 set at $p < 0.05$. Data were analysed using the IBM SPSS Statistics for Windows, Version 25.0 (Armonk,
26 219 NY: IBM Corp.). Visualisations were created in the Microsoft Excel and BoxPlotR – a free online tool
27 220 [40].
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31 221 *Patient and public involvement statement*

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33 222 There was no patient or public involvement in the study design.
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36 223 **RESULTS**

37 38 224 *Types of publication*

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40 225 Types of publications included clinical research studies (both trial and non-trial studies) comprised
41 226 39% (n=939), basic science research 27% (n=643) and a third of publications (34%, n=827) included
42 227 other types of publication, such as systematic reviews, reviews, research protocols, editorials,
43 228 guidelines, opinions, comments, and meeting reports (Table 1).
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230 **Table 1.** Number and types of publication by year of acceptance

Year (Accepted)	Types of publication Count (%)				Total Count (%)
	Basic science	Clinical trial	Clinical study - Not a trial	Other*	
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)

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

234 *Authorship type and Gender*

235 Table 2 presents an overview of gender of authors by types of authorship. Male authors were more
236 likely to be first authors (59%, $P < 0.001$), first corresponding authors (66%, $P < 0.001$) and last
237 authors (77%, $P < 0.001$) (Table 2). In the three joint authorship categories analysed, the proportion
238 of 'female only' authors was statistically significantly lower than 'male only' authors in two
239 categories i.e. joint corresponding authors (29%, $P < 0.001$) and joint last authors categories (10%, P
240 < 0.001) (Table 2). However, in the joint first authors category, the proportion of 'male and female' as
241 joint first authors (57%, $P < 0.001$) was statistically significantly higher than 'male only' and 'female
242 only' joint first authors (Table 2).

243 **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

50 *N/A= not applicable.

244 *Gender of authors by types of publication*

245 Table 3 shows gender of authors by types of publication (i.e. basic science, clinical trials, non-trial
246 clinical studies and other research). The proportions of 'male only' authors were statistically
247 significantly higher than the proportions of 'female only' authors in three authorship categories: first
248 authors ($P=0.035$), first corresponding authors ($P < 0.001$) and last authors ($P=0.016$) (Table 3). There

249 were no significant differences between the proportions of 'male only' and 'female only' authors in
 250 all three joint authorship categories: joint first authors ($P=0.476$), joint corresponding authors
 251 ($P=0.172$) and joint last authors ($P=0.208$). Only the statistically significant associations are shown in
 252 Table 3.

253 **Table 3.** Gender of authors by publication type

Type of research	Publication Type Count (%)				Significance P-value
	Basic science	Clinical trial	Clinical study - Not a trial	Other	
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)	

254 **Yearly trends in Authorship by gender**

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

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

264 **Association between same gender across authorship categories**

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

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

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

274

275 **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
<i>Male</i>	1236 (79)	329 (21)	
<i>Female</i>	158 (19.6)	648 (80.4)	
First joint authors (n=457)			<0.001
<i>Male only</i>	124 (97.6)	3 (2.4)	
<i>Female only</i>	10 (14.5)	59 (85.5)	
<i>both male and female</i>	140 (53.6)	121 (46.4)	

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

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

277 ***Gender of authors and journal prestige***

278 Of 2388 journal articles, 96.6% (n=2307) were published in journals having an impact factor (mean =
 279 9.58 (± 12.16), median = 5.36, minimum = 0.39, maximum = 74.7) while only 3.4% (n=81) articles
 280 were published in journals having no impact factor. There was no statistically significant difference in
 281 the mean journal impact factor (JIF) by gender of first and last authors; however, the mean JIF was
 282 statistically significantly higher for male first corresponding authors compared to female first
 283 corresponding authors (Table 5, Figure 3).

284

285

286 **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	

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

288

289 DISCUSSION

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

295 In the first author category, we found proportions of female authors and male authors within the
 296 40%-60% "gender balance zone" [6]. In the last (senior) author category, the observed proportion of
 297 female last authors (77%) was lower than male last authors (23%) but it was higher than reported in
 298 other studies [12,14,25]. In the context of biomedical research in the UK, principal investigators (PIs)
 299 are typically last authors [41]. In the current study setting i.e. NIHR Oxford BRC, the proportion of
 300 male PIs was 74% and the remaining 26% PIs were female during the period of analysis. Thus, it
 301 appears that the representation of male and female last authors was proportionate to their
 302 respective proportions as PIs in the BRC. These findings suggest positive trends and the NHIR Oxford
 303 BRC doing very well in gender parity in the senior (last) authorship category.

304 This study extends understanding of gender-based trends in scientific authorship (Figure 2) by
 305 showing encouraging incremental changes in gender parity in authorship in a biomedical research
 306 setting. Previous research examined the gender gap in authorship within the medical literature
 307 reporting an upward trend for female first authors from 6% in 1970 to 29% in 2004 and female last
 308 authors from 4% in 1970 to 19% 2004. However, it was limited to US based institutions [13]. A
 309 similar UK based study covering the same period (i.e. 1970-2004) also showed upward trends for
 310 female first authors increasing from 11% in 1970 to 37% in 2004 and female last authors from 12% in
 311 1970 to 17% in 2004 [25]. In addition, a recent study by Filardo et al. [14] examined the prevalence
 312 of female first authorship of original research published in six high impact general medical journals

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3 313 between February 1994 and June 2014 revealed that the adjusted probability of an article having a
4 314 female first authorship increased significantly from 27% in 1994 to 37% in 2014 [14]. However,
5 315 despite the proportion of female first authors varied greatly by journal, men were generally more
6 316 likely to be first authors than women [14]. Compared to previous studies mentioned above, our
7 317 study provides evidence of higher and increasing gender equity in the first authors, last authors and
8 318 other four categories of scientific authorship in biomedical research (Table 2).

11 319 We found a strong association between same gender and authorship types showing if the first
12 320 author of a publication was male, it was highly likely that the first corresponding author of the same
13 321 publication would also be male. Similarly, the likelihood of the first author being female was higher,
14 322 if the first corresponding author was also female [42]. Likewise, there appeared to be a significant
15 323 association of male and female last authors with the respective gender of first authors. Previous
16 324 research has highlighted males and females were more likely to be first authors on papers if the last
17 325 authors were of the same gender [21,43–45]; however, these were not conducted in a translational
18 326 research setting. Our findings also revealed a strong association of male and female last authors
19 327 with the respective gender of corresponding authors [45].

24 328 However, due to the differences in gender equity between different research areas and medical
25 329 specialties, where a centre-specific mix of research themes is likely to influence gender equity in
26 330 scientific authorship, it is difficult to make direct comparisons across the literature.

29 331 In regards to gender parity in authorship scientific publications, which is an important marker of
30 332 achievement for gender equity [7], our study builds an important evidence base in biomedical
31 333 research settings and our results support previous studies [13,25,46–48].

33 334 We found that male first corresponding authors were more likely to publish articles in high impact
34 335 factor journals compared to female first corresponding authors (Table 5). The practice of
35 336 corresponding author varies between institutions, academic disciplines and countries [49] but
36 337 usually the first corresponding author is either a researcher who has done major research work or a
37 338 senior investigator who is overall responsible for the research study/project [15,36,50]. We do not
38 339 have sufficient information to ascertain whether male first corresponding authors in our study were
39 340 investigators or junior researchers or doctoral candidates. However, our findings suggest that female
40 341 first corresponding authors are less likely to publish articles in high impact journals.

44 342 More importantly, our study shows that both the male and the female biomedical researchers
45 343 publish articles at prestigious authorship positions i.e. first and last authors in journals with high
46 344 impact factors (Figure 3) and no statistical association between the gender of first and last authors
47 345 and the journal impact factor were identified [51]. In contrast, Bendels et al reported that female
48 346 researchers were less likely to publish in high impact factor journals at prestigious authorship
49 347 positions [46]. This could be due to the differences in journals analysed, research disciplines included
50 348 and the time period covered. Our analysis included a wide range of journals in which researchers
51 349 affiliated with the NIHR Oxford BRC published translational research from April 2012 to March 2017
52 350 while Bendels et al analysed only the Nature Index journals in four disciplines i.e. Life Science,
53 351 Multidisciplinary, Earth and Environmental and Chemistry covering publication period from January
54 352 2008 to May 2016 [46].

353 ***Implications for policy and practice***

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

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

369 **CONCLUSION**

370 Although, the proportions of female authors is significantly lower than the proportions of male
371 authors in all six categories of authorship included in our analysis, first authorship is within the 40%-
372 60% gender balance zone and the proportion of male and female last authors is proportionate to
373 their respective proportions as principal investigators in the NIHR Oxford BRC This may suggest a
374 positive trend in gender parity in the senior (last) author category in scientific publications produced
375 by the BRC during April 2012-March 2017. . This study provides evidence that both male and female
376 authors at first and last authorship positions publish articles in journals with almost equal impact
377 factor; however, male first corresponding authors are more likely to publish articles in prestigious
378 journals with high impact factor. We also conclude that it is feasible to analyse bibliometric data on
379 publications arising from NIHR funding by gender and consider establishing processes for monitoring
380 gender equity in scientific authorship as an important marker of achievement in the context of NIHR
381 BRCs [7].

382 **Contributors**

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

388 **Funding**

389 This study is funded by the European Union's Horizon 2020 research and innovation programme
390 award STARBIOS2 under grant agreement No. 709517 and by the National Institute for Health

391 Research (NIHR) Oxford Biomedical Research Centre, grant BRC-1215-20008 to the Oxford University
392 Hospitals NHS Foundation Trust and the University of Oxford. The views expressed are those of the
393 authors and not necessarily those of the NHS, the NIHR, or the Department of Health and Social
394 Care.

395 **Competing interests**

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

405 **Ethics**

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

414 **Acknowledgements**

415 The authors wish to thank the editors and reviewers who provided constructive feedback and
416 suggestions which improved this work. The authors also wish to thank Professor Helen McShane for
417 reviewing the initial draft manuscript and making comments and suggestions for improving it.

418 **Patient consent for publication**

419 Not required.

420 **Data sharing statement**

421 No additional data available.

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573 Additional files list

574 **Figure 1** Publication analysis workflow.

575 The workflow shows the process of extracting data according to gender from six types of authorship.

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4 576 **Figure 2** Yearly trends in scientific authorship by gender (male and female), April 2012 - March 2017.
5 577 This plot represents the yearly variation of the proportion of male and female authors according to
6 578 six types of authorship between the years of publication/acceptance from 2012 to 2017.

8
9 579 **Figure 3** Impact factor of journals and authorship categories by gender.
10 580 This figure shows the boxplots of impact factors of journals in which male and female authors
11 581 published articles.

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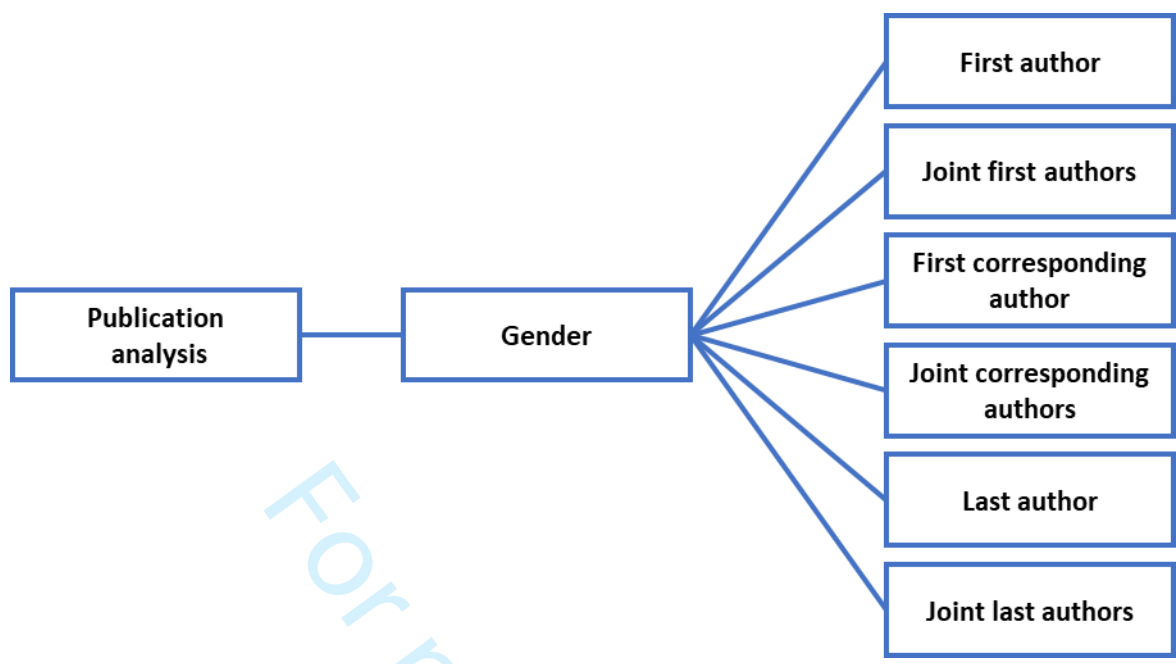
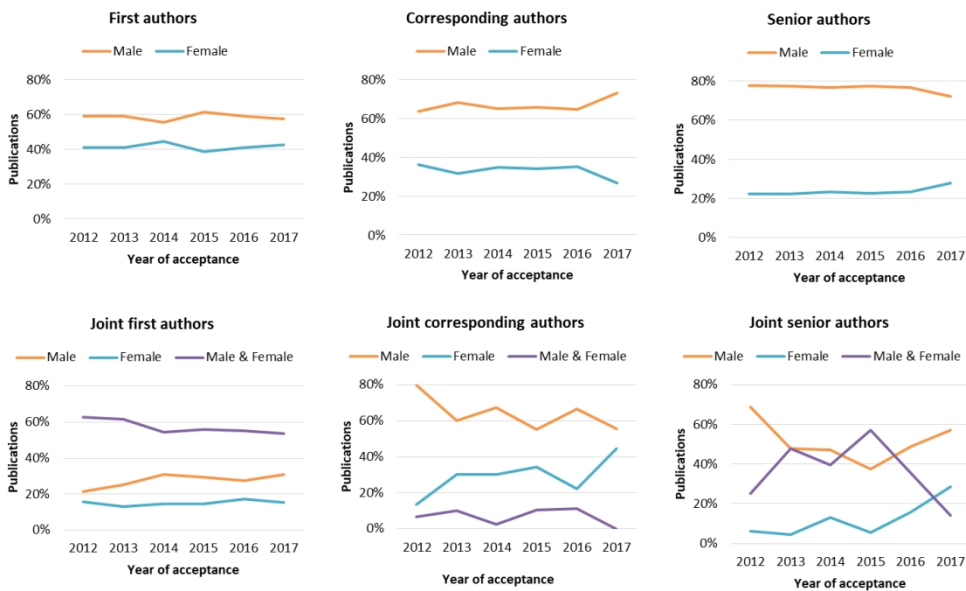


Figure 1 Publication analysis workflow.

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