The effect of the COVID-19 pandemic on the gender gap in research production within academia

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Abstract

The amount of research produced is an important metric for evaluating academic success. However, research production is often biased against female academics relative to male academics, selecting against female academics to succeed. Additionally, reports show lockdown conditions from the COVID-19 pandemic may have introduced extra service, teaching, caregiving, and domestic roles for female academics at the expense of research production. We perform a meta-analysis using 45 effect sizes from 25 studies to investigate the effect of the pandemic on the gender gap in research production within academia and what factors influence this. We find that overall, the pandemic has increased the gender gap in research production within academia, but that the size of the gap is not different across research fields, authorship positions (first, middle or last) or according to the degree of the gender gap before the pandemic.

Introduction

Academic success is highly dependent on research production, commonly measured as the number of publications, and the type of authorship (first, middle or last) [1] . Academics producing more research, particularly as first or last authors, are evaluated better during hiring, promotion, and grant-allocation decisions. Yet academia seldom considers that research production is often biased against female academics [2]. Subsequently, this effect "snowballs" by denying female academics equity in representation and funding, which further increases the gender gap in research production[3]. This is unfair to female academics and detrimental to academia because gender diversity improves collective decision-making, innovation and produces knowledge that is more meaningful to wider society [4]–[7].

During the COVID-19 pandemic, several reports suggested lockdown measures may have exacerbated a gender gap in academia by increasing social obligations of female academics at the expense of their research production [8]. Within academic institutions, female academics are more likely to take up service and teaching loads [9], [10], so tasks required in transitioning to "working-from-home" and online teaching may be disproportionately taken up by female academics. Before the pandemic, female academics were already more occupied with care and domestic duties relative to male counterparts: women are more likely to be single parents than are men, male academics are four times more likely to have full-time care-giving partner than are women [11] and even in dual-academic couples, women are more likely to take up domestic duties [12]. Closures of schools and childcare access during the pandemic may therefore have increased the caregiving demands for female academics with children taking up extra teaching and domestic responsibilities at the expense of research production [13]–[16]. Meanwhile, male academics are not as likely to occupy teaching, service, care, or domestic roles. Closures of academic institutions and "work-from-home" conditions during the pandemic may instead enable male academics to allocate even more time to research tasks such as analysing, writing manuscripts and grants, and maintaining more active online presence in the academic network.

The degree to which the pandemic has compounded a gender gap in research production might be different between research fields. Research production in fields that are more dependent on physical laboratories or field-work, such as in medical or biological sciences are potentially impacted more during the pandemic than less equipment-intensive computational or mathematical fields [17], [18]. In these fields, there may be less support measures in place for female academics to work at home, without interruption, away from research facilities because these working conditions were not previously common. Accordingly, studies that compare fields show a more pronounced gender gap in research production within medical and biological sciences over physics, mathematics and computer sciences during the pandemic [19]–[21]. Furthermore, the pandemic may have induced stronger gender gaps in research according to authorship position (first, middle or last) [20]. Additional service, teaching, caregiving, and domestic roles taken up by female academics during the pandemic may limit their ability to perform research (as first authors) or lead research (as last authors) but enable them to continue supporting research (as middle authors). This is particularly so for academics in the biological and medical sciences because in these fields, access to laboratories or the field to perform research was not accessible during the pandemic. Although one review qualitatively collates separate findings of the pandemic effect on the gender gap in research production[22], these are not quantitatively explored, with no assessment of patterns between different research fields or authorship positions.

To assess the extent to which the COVID-19 pandemic has impacted female academics, we quantitatively compare change in academia's gender gap of research production before and during the COVID-19 pandemic by conducting a systematic review and meta-analysis. We outline the following two hypotheses and their corresponding predictions that we test in our study:

1) Have social changes from the pandemic increased the gender gap in research production in academia?
    a. We predict that across academia, the gender gap in research production has increased during the pandemic.
    b. We do not predict to find evidence of publication bias.
    c. Although research production can be measured through either survey-responses or the number of publishing authors, we predict this does not change the research production gender gap during the pandemic.
2) Has the pandemic affected the gender gap in publishing authors differently depending on a) research field or b) authorship position sampled or c) the previous of gender gap size in research production?
    a. We predict the pandemic has increased the gender gap more for fields that require working in laboratories or in the field such as medical and biological sciences, as there are less support measures in place for female academics to work at home, with family, away from research facilities compared with less equipment-sensitive fields such as mathematical, physical, computer or social sciences.
    b. We predict the pandemic has increased the gender gap more in first and last, rather than middle authorship positions as female academics have been more limited in undertaking leading research roles, but not supportive research roles in lockdown conditions.
    c. We predict the pandemic has increased the gender gap more for research fields of a given authorship position that already had a previously greater gender gap because these lacked gender-equitable support measures to prevent female academics experiencing research production setbacks.

Methods

We carried out a systematic review following PRISMA guidelines [23] to identify, select and critically evaluate relevant research through data collection and analysis.

Search process

We carried out the literature search process in three steps: 1) a scoping search, 2) an initial search with pre-selected author terms, 3) a refined search using terms as recommended by the litsearchR 1.0.0 package. We performed a scoping search to determine if there were over ten texts with primary research investigating differences by gender in academic production before and during the pandemic. The scoping search was conducted on 30/06/2021 by Google searching combinations of synonyms for 1) the COVID-19 pandemic, 2) gender, 3) academia, 4) inequality and 5) production. The scoping search identified 21 original research publications with quantitative metrics investigating differences in academic production by gender before and during the pandemic (scoped texts). Of these 21 articles, 14 were indexed by Web of Science, and 17 (including the same 14 from Web of Science) were indexed by Scopus.

Terms for the initial search were selected by scanning the title, abstract and keywords of scoped texts. We constructed an initial Boolean search string according to the PICO (Population, Intervention, Comparator, Outcome) framework [24]. Population was represented by "academia", Intervention by "pandemic", Comparator by "gender" and Outcome by "inequality" and "production". A sixth concept group contained terms used to exclude irrelevant studies that did not investigate studies in our hypotheses. Terms within concept groups were connected by the Boolean OR operator, and the concept groups were connected by the AND or AND NOT operators, enabling searches for any combination that includes one term from each of the six concept groups (Table S1). Terms in the initial search were selected by scanning the title, abstract and keywords of scoped texts. The initial search in Scopus generated 769 texts, published from 2020 onwards, including 14/17 (82.4%) scoped texts indexed by Scopus.

To improve the efficiency of finding scoped texts from our initial search 12/769 (1.5%), we imported all 769 texts into R using litsearchR. Using litsearchR, potential key terms were extracted from the title, abstract and keywords of texts using the Rapid Automatic Keyword Extraction algorithm. A ranked list of important terms was then created from building a key term co-occurrence network (Table S2). Six high-strength terms within the key term co-occurrence matrix, describing research not relevant to our study, such as those of an epidemiological or experimental nature, were added to the AND NOT operator concept group to exclude texts mentioning these terms. Table 1 describes terms of the refined Boolean search string and their respective concept groups. The refined search generated 700 total texts combined from Scopus (126 texts, including 14/17 articles found in the scoping search), the Web of Science core collection (199 texts), EBSCO (276 texts) and Proquest (99 texts) from 2020 onwards. The final search hit rate had an efficiency of 11% (14/126) on Scopus, above the 10% recommended hit rate [25]. After removing duplicates, 580 articles remained to enter the study screening stage.

Table 1. Final Boolean search string used in full literature search broken down into terms and their respective concept groups. Wildcards (*) were used to return results containing different word endings. Texts were limited to those since 2020. Searches were conducted on 27/07/2021. Terms in italics were added using litsearchR.

Concept group	PICO group	Terms
Academia	Population	(academi* OR author* OR database* OR journal* OR research OR scien*)
Gender	Population	AND (female* OR gender OR male* OR men OR women)
Pandemic	Intervention	AND (coronavirus OR covid OR pandemic)
Inequality	Comparator	AND (bias* OR disparit* OR disproportion* OR fewer OR gap OR "gender difference*" OR imbalance* OR inequalit* OR inequit* OR parity OR "sex difference*" OR skew* OR unequal)
Productivity	Outcome	AND (performan* OR publication* OR publish* OR productiv*)
Exclusion of biomedical studies	Population	AND NOT (experiment OR laboratory OR mortality OR surviv* OR *"acute respiratory"* OR *gis* OR *icu* OR *risk* OR *rna* OR *symptoms*))

<u>Study screening</u>

To be included in our meta-analysis, a study had to quantitively investigate gender differences in production within academia before and during the pandemic. Thus, we screened the titles, abstract and keywords to keep only those suggesting the study investigated: 1) academia, 2) genders, 3) pandemic and 4) some measure of production (supplementary materials table 3). To ensure repeatability of the screening process, we used Rayyan.ai [26] to blind the inclusion or exclusion of 420 randomly selected texts by two reviewers. The agreement rate between reviewers was 97%, with 49 articles that both authors agreed to include, ten articles one author included but the other excluded, 357 articles which both excluded, and 4 articles were excluded by one and included by another author, which resulted in a, "strong" [27] to "near perfect" [28] Cohen's kappa of 0.86. Here, both reviewers included 49 articles, both excluded 357 articles and 14 articles were included by one but excluded the other. All 14 articles with discrepancy in inclusion were passed to the next screening stage. Of the remaining 160 texts, we included 18 and excluded 162 during the initial screen. Overall, out of the 580 texts from the from the final search, 81 were included (supplementary materials, figure 1) in the full text screening. Full texts were then screened, including studies that had: 1) for both genders, 2) some metric of academic production measured, 3) for before the pandemic compared with during the pandemic. Texts mentioning all criteria as secondary data were excluded. Thus, 25 articles that all contained necessary metrics to calculate the effect size, were kept for data extraction, excluding 56 articles (Figure S1).

Extracting variables

Effect size: We extracted 46 effect sizes from 25 studies investigating the effect of the pandemic on academic research production between genders, before and during the pandemic. Five measures of the effect sizes were already calculated within the articles (1 lasso regression, 2 Somers' delta, 1 ordered logistic regression and 1 logistic regression) and we recorded these as such. For the other 41 effect sizes, we entered summary data (N=34) or statistics (N=7) into Campbell collaboration's effect size calculator to calculate a standardised mean difference (d) effect size [29]. For effect sizes calculated using summary data, 33 used the proportion of female authors before and after the pandemic and 1 used the number of women and men experiencing a negative or non-negative effect of the pandemic). For effect sizes calculated using statistics, 1 used the f-test statistic and sample size from a general linear model investigating the effect of gender on perceived work production, 2 used means and standard deviation of female and male academics rating perceived production changes on a Likert scale, 4 used chi-square comparing proportions of female and male academics that experienced production changes due to the pandemic. We calculated multiple effect sizes from one study if they were for different research fields or authorship positions. We set the sign for effect sizes as negative if the pandemic had increased the gender gap in research production and positive if the pandemic had decreased the gender gap in research production.

Variance: For 5 effect sizes already calculated by the study, 2 provided variance as standard error which we squared [30], and 3 provided variance as 95% confidence intervals which we divided by 1.96 and then squared [31]. For the other 41 effect sizes, variance was provided by the Campbell collaboration calculator [29] when calculating effect sizes.

Study type: We recorded the study type as either survey-study (N=8) or publication-study (N=38). Survey-studies measure production change during the pandemic for each gender based on academics self-reporting their gender and research production change as negative or non-negative (N=3) a Likert scale (N=2), number of publications (N=2), research time (N=1). Publication-studies record the number of female and male authors before and during the pandemic at a given authorship position for a given research field.

Research field (publication-studies): For publication-studies, we recorded the research field sampled as either biological sciences (N=8), medical sciences (N=24), physical sciences (N=5) or social sciences (N=1).

Authorship position (publication-studies): For publication-studies, we recorded whether first (N=12), middle (N=3), last (N=11), corresponding (N=6), or the total (N=6) authors were studied. To improve samples sizes, we recorded one effect size studying submitting authors, as studying corresponding authors [32] and we recorded two effect sizes studying sole authors, as studying last authors [33].

Analyses

We conducted all analyses in R 3.6.2 [34] using the 'metafor' package 3.0.2 [35]. We fitted separate models for each prediction. All models included the publication effect as a random effect to control for dependency in effect sizes obtained from the same study. To test prediction 1, the first model investigated the overall effect size. One effect size (0.6961, lower bound 95% confidence interval: 0.3181, upper bound 95% confidence interval: 1.0741) from Camerlink et al.[36] was 0.7685 higher than (-0.0724, 95% confidence intervals (CI)= -0.1288 to -0.0160) the overall effect size. We excluded this as an outlier because 82.5 % (n = 94) of respondents identified as female, with only 20 respondents identifying as male, limiting the reliability of the effect size. We then performed the same model and all subsequent models without this effect size.

The second model tested prediction 2 by including study-type (publication-study or survey-study) as a moderator of effect size. The third model tested prediction 3 by including research field as a moderator of effect size for publication-studies. The fourth model tested prediction 4 by including authorship position as a moderator on effect size for publication-studies. The fifth model tested prediction 5 by including the proportion of female authors before the pandemic as a moderator on effect size for publication-studies.

We investigated for publication bias in our dataset by performing Egger's test, a linear regression of the effect sizes on their standard errors weighted by their inverse variance. Orchard plots for figures 1, 2, 3 and 4 were created to using the 'orchaRd' package 0.0.0.9000 [37] and the forest plot for figure 5 and the funnel plot for figure 6 were created using the 'metafor' package 3.0.2 [35]. Code for plots and analyses can be found in the supplementary materials.

Results

Hypothesis 1a: Has the pandemic increased the gender gap in research production across academia?

In line with prediction 1a, across all samples, after controlling for multiple effect sizes from the same study, we found a significantly increased gender gap during the pandemic at -0.0822 (95% CI= -0.1333 to 0.0312, SE= 0.0260, p-value= 0.0016, figure 1).

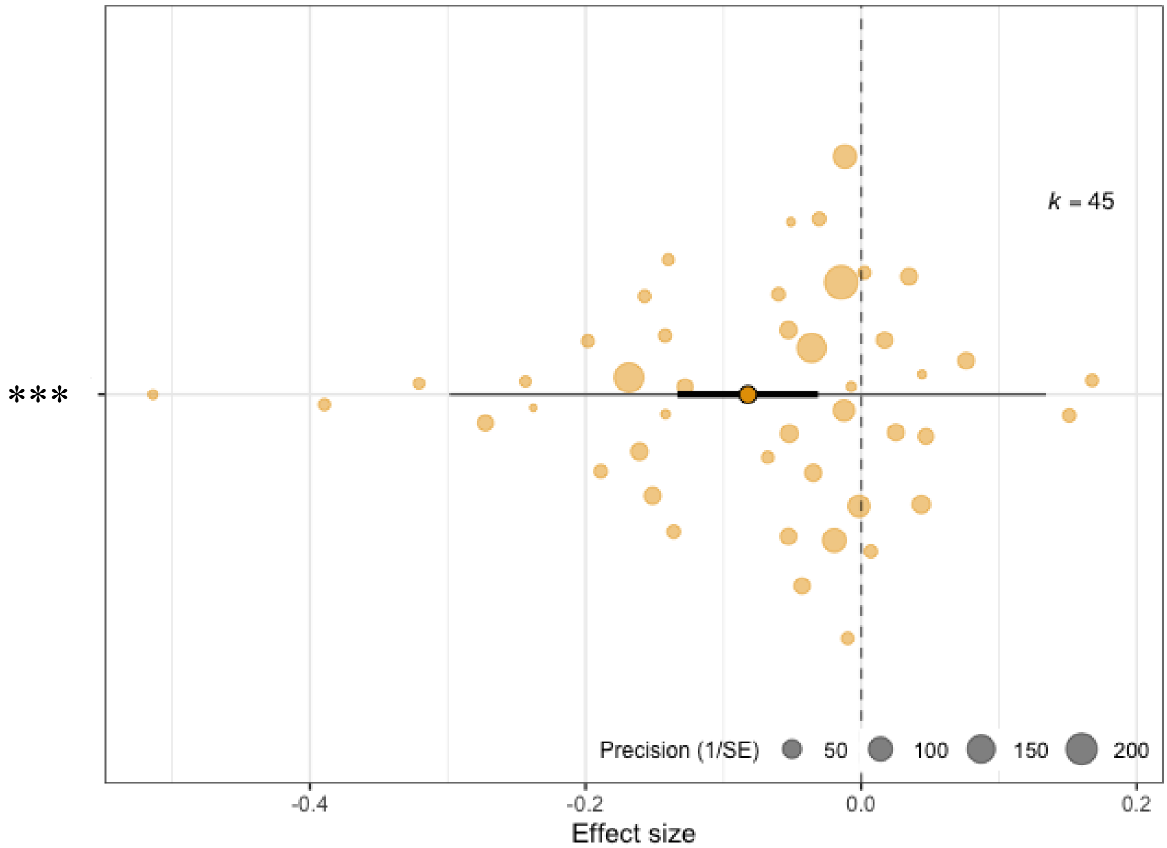

Figure 1. Orchard plot showing all (k) 45 effect sizes (yellow points) of the pandemic on gender gap in research production within academia in our study. Effect size precision in relation to the standard error is denoted by the size of the point. The mean effect size is the dark yellow point outlined black and vertically centred. The 95% confidence interval for the mean effect size is the horizontal thick black bar and the 95% prediction interval of the expected spread of effect sizes based on between-study variance is the horizontal thin black bar. The vertical dashed line is at effect size 0.

Hypothesis 1b: Is there evidence of publication bias?

In line with prediction 1b, we found no evidence of publication bias in the dataset according to Egger's regression (estimate= -0.7958, SE= 0.60099, t-value= -1.324, p-value= 0.1924). Visually, the funnel plot suggests consistency in effect size independent of sample size (figure 2).

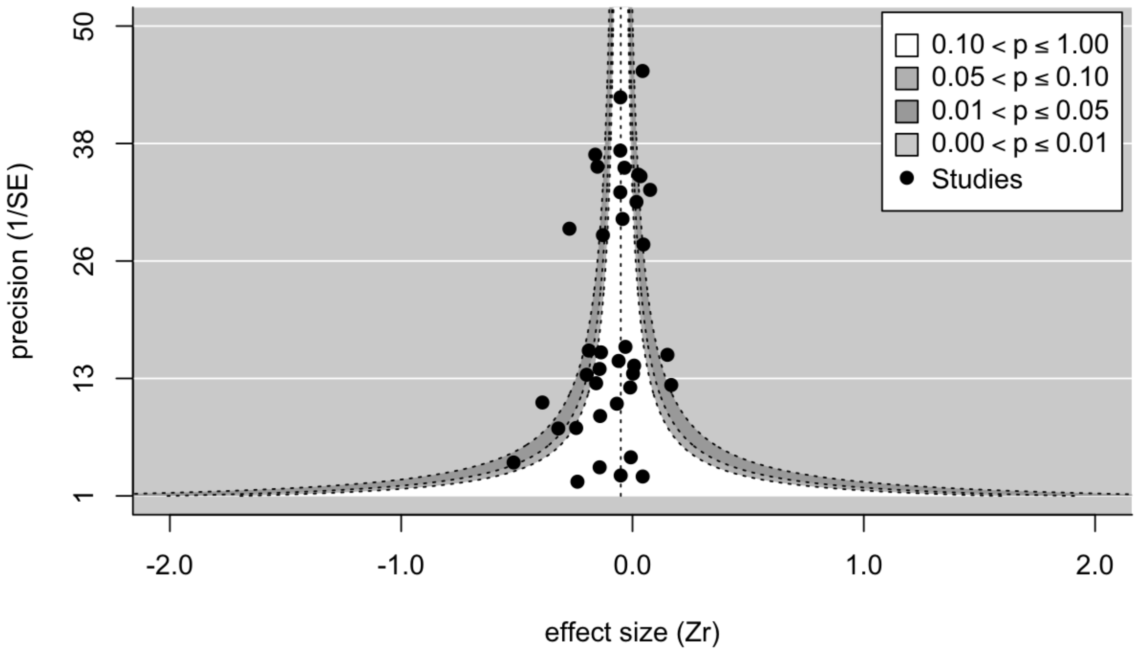

Figure 2. Funnel plot of all 45 effect sizes and their precision as a function of standard error. Vertical dashed line is the summary effect size. Legend outlines levels of statistical significance for effect sizes based on their precision.

Hypothesis 1c: Does the way in which research production is measured influence how much the pandemic has increased a gender gap in research production?

Contrary to predication 1c, studies measuring self-reported changes to research production during the pandemic based on surveys (survey-studies), have a more pronounced, and significant (-0.1569, 95% CI= -0.2588to -0.0549, SE= 0.0520, p-value= 0.0026) effect size than for studies that compared the number of authors of each gender before and during the pandemic (publication-studies) (-0.0584, 95% CI= -0.1146 to -0.0022, p-value= 0.0417, SE= 0.0287), though there is weak evidence these are significantly different (p-value= 0.0973, figure 2).

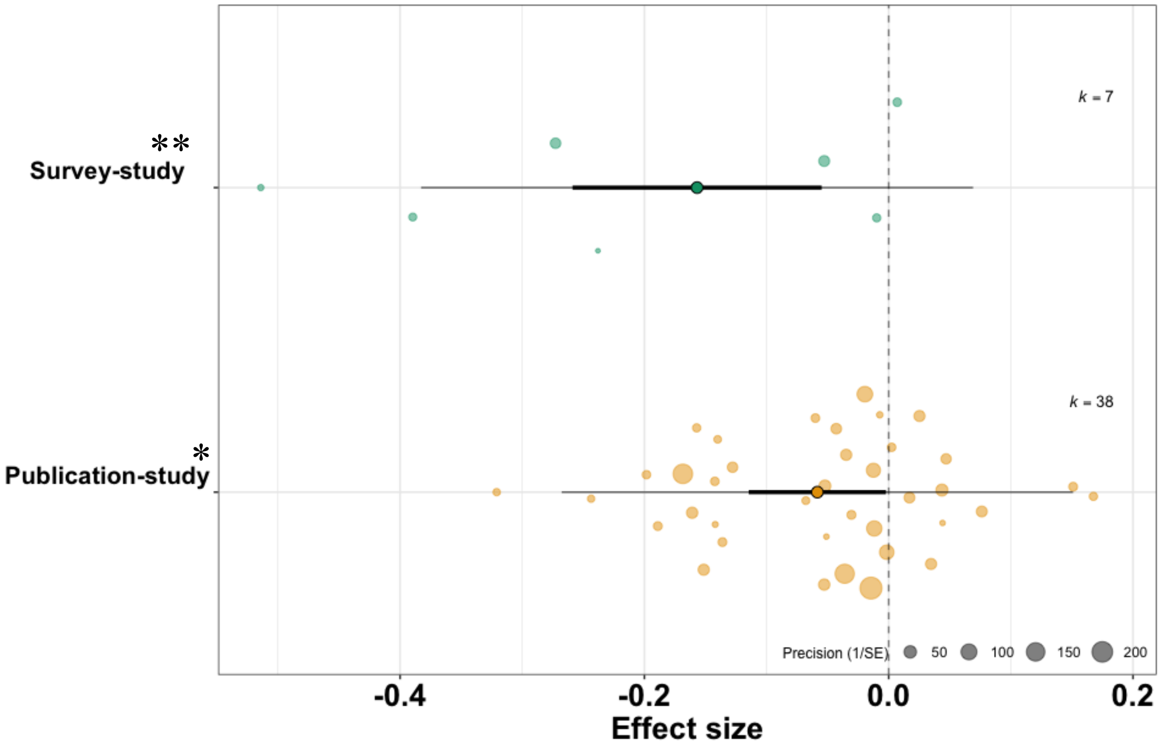

Figure 2. Orchard plots comparing the distribution of effect sizes depending on the type of study (publication studies in green and self-reported studies in yellow). Effect size precision in relation to the standard error is denoted by the size of the point. Mean effect sizes are the darker coloured points outlined black and vertically centred. The 95% confidence interval for the mean effect size is the horizontal thick black bar and the 95% prediction interval of the expected spread of effect sizes based on between-study variance is the horizontal thin black bar. The vertical dashed line is at effect size 0.

Hypothesis 2a: Has the pandemic affected the gender gap in publishing authors differently?

Contrary to prediction 2, we found no evidence of a significant differential impact of research field on effect size (QM (df=3)= 1.9135, p-value= 0.5906, figure 3), though the majority (63.2%, 24/38) of effect sizes come from studies in medical sciences. Effect sizes from medical sciences are significantly negative (-0.0715, 95% CI= -0.1260 to -0.0170, SE= 0.0278, p-value= 0.0102), though those from social, physical, or biological sciences are not. Effect sizes from the physical and biological sciences are also close to zero.

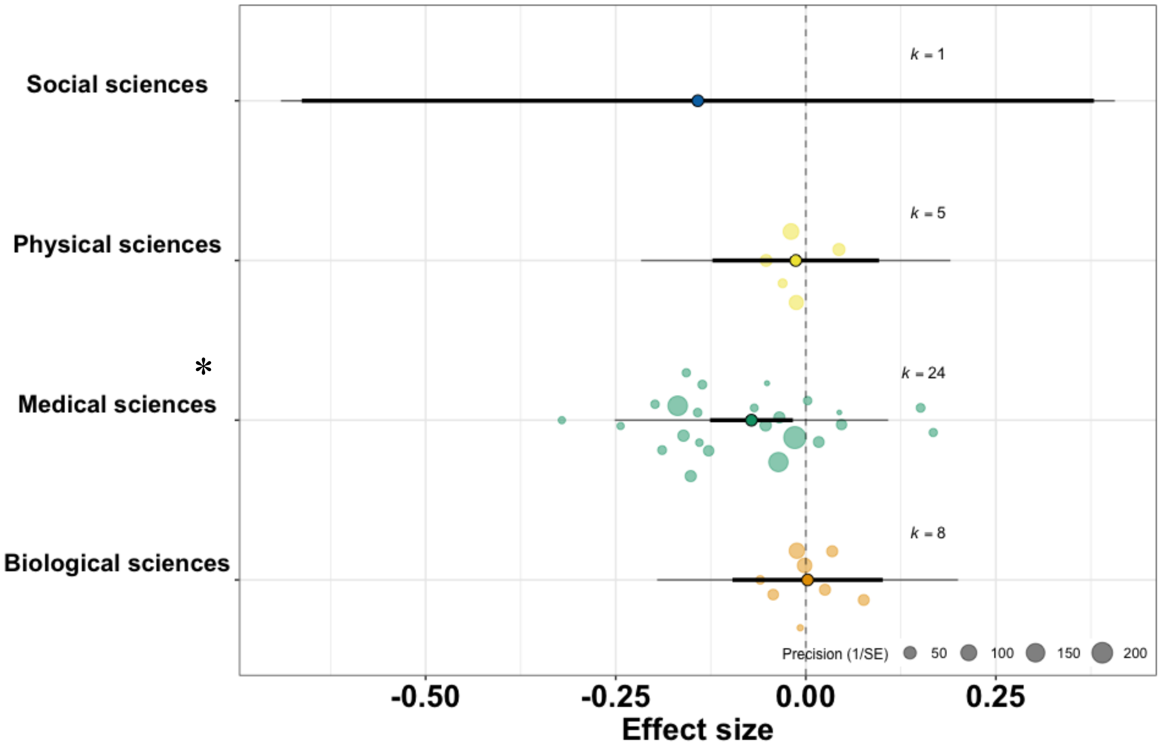

Figure 3. Orchard plot comparing the distribution of effect sizes depending on the research fields sampled in publication studies. Effect size precision in relation to the standard error is denoted by the size of the point. Mean effect sizes are the darker coloured points outlined black and vertically centred. The 95% confidence interval for the mean effect size is the horizontal thick black bar and the 95% prediction interval of the expected spread of effect sizes based on between-study variance is the horizontal thin black bar. The vertical dashed line is at effect size 0.

Hypothesis 2b: Has the pandemic affected the gender gap in publishing authors differently depending on authorship position?

Contrary to prediction 2, we found no evidence of a significant differential impact of authorship position on effect size (QM(df = 5) = 0.9006, p-value = 0.9702, figure 4), though only the pool of first authors experienced a significant gender gap during the pandemic (-0.0615, 95% CI= -0.1222 to -0.0008, SE= 0.0310, p-value= 0.0470).

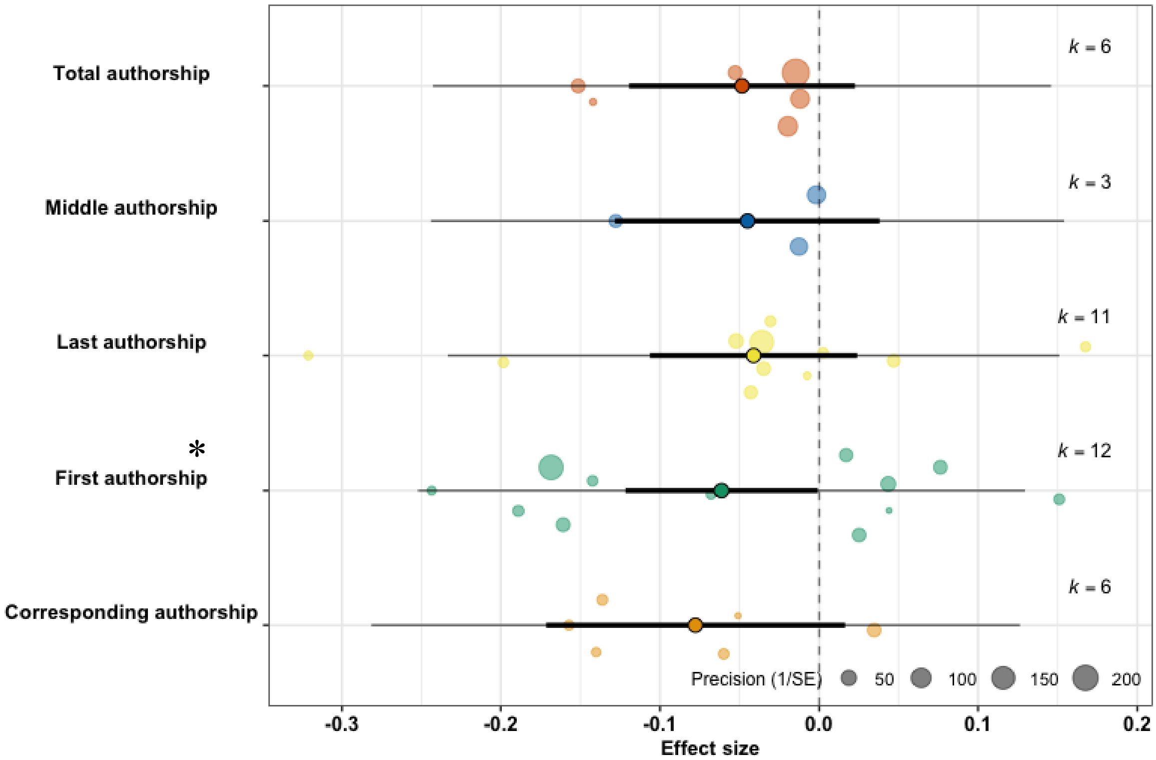

Figure 4. Orchard plot comparing the distribution of effect sizes depending on the authorship position sampled in publication studies. Effect size precision in relation to the standard error is denoted by the size of the point. Mean effect sizes are the darker coloured points outlined black and vertically centred. The 95% confidence interval for the mean effect size is the horizontal thick black bar and the 95% prediction interval of the expected spread of effect sizes based on between-study variance is the horizontal thin black bar. The vertical dashed line is at effect size 0.

Hypothesis 2c: Has the pandemic increased the gender gap in publishing authors more for research fields of a given authorship position that already had a previously greater gender gap?

Contrary to prediction 3, we found no evidence that research fields of a given authorship position, which had a smaller proportion of female authors experienced a more pronounced gender gap during the pandemic (QM(df = 1) = 2.5092, p-value= 0.1132, figure 5).

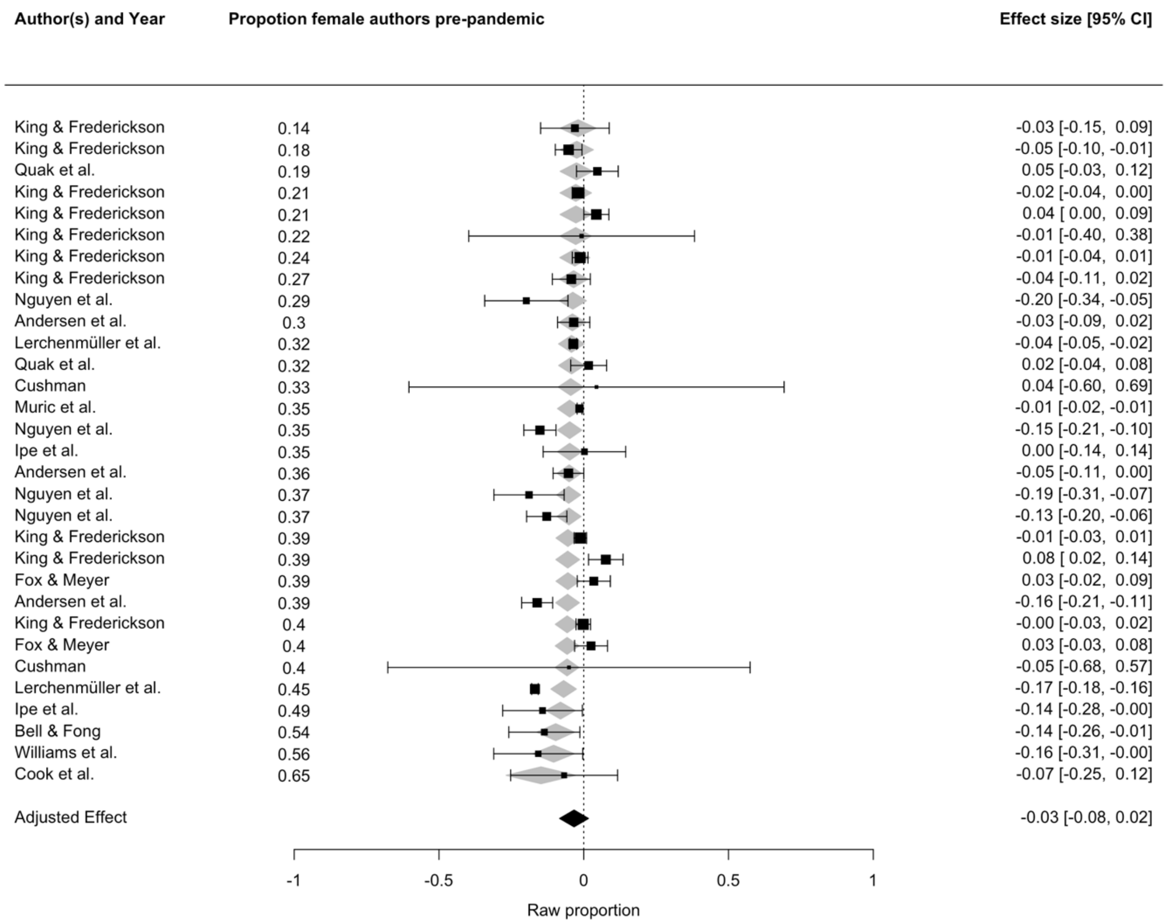

Figure 1. Forest plot of effect sizes ascendingly ordered by the proportion of female authors in the publications sampled pre-pandemic. Effect sizes and confidence intervals are represented by black squares and horizontal lines respectively. The model-predicted effects corresponding to the proportion of female authors in publications sampled pre-pandemic are indicated by grey-shaded polygons.

Discussion

We find that overall, the pandemic has slightly and significantly increased a gender gap in academic production (-0.0822, 95% CI= -0.1333 to 0.0312, figure 1). These findings are consistent with longstanding ideas that female academics perform different roles to men within academic and home environments at the expense of their research production and that the pandemic has compounded this inequality [38]–[47].

Survey-studies based on academics self-reporting their research production, show weak evidence of a more pronounced effect size (p-value= 0.0973, figure 3) than studies that measure the proportion of women authors in publications (survey-studies: -0.1569, 95% CI= -0.2588 to-0.0549, SE= 0.0520, p-value= 0.0026, vs. publication-studies: -0.0584, 95% CI= -0.1146 to -0.0022, SE= 0.0287, p-value= 0.0417). The strong effect size for individual, survey-studies may suggest the reduction of publishing female authors during the pandemic is due to the reduction in production of each female academic, and not from less female academics leaving academia or in career-breaks, or a biased review process in journals [48]–[51]. There may be an overrepresentation of academics completing the survey who have strong opinions about the pandemic's effect on research production. Alternatively, using surveys to measure self-reported production at the time may better reflect the gendered impact of the pandemic in academia, resulting in larger effect sizes for these studies. The publication process is often lengthy, so if female academics have less time to perform or write up research, it may mean they are underrepresented as authors in subsequent years, instead of the period of lockdown during the pandemic.

Our analyses suggest the pandemic has not differentially impacted the proportion of female authors according to their research field. However, lack of statistical significance in our model may result from most effect sizes coming from studies in medical sciences with few in other disciplines. It is likely that for this reason, the medical sciences show the strongest evidence of a reduction in female authors during the pandemic. Another interpretation is that the medical sciences have experienced a sharp increase in publication production during the pandemic [52], potentially exaggerating the gender gap in authorship more, relative to publications in other fields. Journals in medical sciences, strongly sped-up the publication process to combat COVID-19 [53], [54] meaning patterns of gendered authorship of publications in medical sciences are more representative of the abilities of female and male academics to carry out research at the time of the pandemic than for other research fields. It would be important to monitor the gendered authorship of publications over the next few years to investigate carry-over effects.

We find that the pandemic has increased the gender gap in authors across all authorship positions. Though inferences about differences between authorship positions are limited due to small sample sizes, our study suggests there is an effect of the pandemic increasing the gender gap in the pool of first authors. The likely explanation for this is that most studies investigated gendered patterns in first authorship positions because they are the most important, generating a large enough sample size for a significant negative effect. Alternatively, the mechanisms that act in academia to limit the representation of female academics in first authorship positions are likely to remain during the pandemic, on top of additional caregiving, domestic and service roles induced by lockdowns. First authors often take responsibility for most work conducted in the publication, including data collection, analysis and writing, which female academics may struggle to continue with from increased non-research workloads.

We find that the degree of gender bias before the pandemic as reflected by the proportion of female authors in the pool of authors for a given research field of a specific authorship position does not exacerbate the gender gap in publications. Conversely, our model suggests an opposite, though non-significant trend of academic populations that had less of a gender bias experiencing the largest increase in gender disparity of authorship during the pandemic. It is possible that the pandemic has stalled progress towards gender equity in publishing. If we assume those populations that have more female authors are because they offer more equitable support measures for women, then the reduction in female authors during the pandemic may be because these support measures have been overridden or erased. Even research fields with strong gender-equitable cultures may not have been able to counter societal expectations within the home environment for female academics to deprioritise research.

The effect of moderators such as research field and authorship position on effect sizes are limited by our small sample size. In our future version of this study, we will include more articles through backwards and forwards searching which hopefully can improve our sample size. Additionally, our study does not disentangle whether the increased gender gap during the pandemic reflects a temporal trend for an increasing gender gap[55], or whether the pandemic created additional pressures for female academics. To investigate this, we can repeat this study in the future comparing the gender gap during the pandemic with after the pandemic. If the gender gap in research production has decreased after the pandemic despite temporal trends, then it suggests lockdown conditions were associated with an increased gender gap.

Nevertheless, there is an overall effect across 45 effect sizes suggesting the pandemic has increased a gender gap in research production. Our results are not likely to be impacted by publication bias in our dataset as our funnel plot shows effect sizes are spread vertically symmetrical and cluster around the mean effect size. There is therefore a risk that female academics are now even more disadvantaged in the hiring or promotion process. Academia should acknowledge the negative effect of the pandemic on female academics to prevent perpetuating this bias [56]. Research production during the pandemic should be held to a different standard than other years and considered on an individual basis, not relative to other academics who may experience less challenges during the pandemic. Production other than research could be evaluated as some researchers have had to take up additional support, service and teaching roles [57], [58]. Extra credit could be given for those who have simultaneously juggled research with significant and challenging care roles such as raising children or assisting elderly relatives. Closing the gender pay gap may help compensate female academics for additional tasks and their associated costs undertaken during the pandemic and aid those working remotely. Careful consideration should be given to awarding promotion clock extensions to mitigate loss of production during the pandemic, as this may unintentionally select against female academics because it extends the length of time during which men can disproportionately produce more research. Overall, our study highlights how the pandemic may have exacerbated a gender gap in academic research production, which academic institutions should acknowledge and accommodate when valuing academics for career progression.

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