Factors affecting sex-related reporting in medical research: a cross-disciplinary bibliometric analysis

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Summary

Background Clinical and preclinical studies have shown that there are sex-based differences at the genetic, cellular, biochemical, and physiological levels. Despite this, numerous studies have shown poor levels of inclusion of female populations into medical research. These disparities in sex inclusion in research are further complicated by the absence of sufficient reporting and analysis by sex of study populations. Disparities in the inclusion of the sexes in medical research substantially reduce the utility of the results of such research for the entire population. The absence of sex-related reporting are problematical for the translation of research from the preclinical to clinical and applied health settings. Large-scale studies are needed to identify the extent of sex-related reporting and where disparities are more prevalent. In addition, while several studies have shown the dearth of female researchers in science, few have evaluated whether a scarcity of women in science might be related to disparities in sex inclusion and reporting. We aimed to do a cross-disciplinary analysis of the degree of sex-related reporting across the health sciences—from biomedical, to clinical, and public health research—and the role of author gender in sex-related reporting.

Methods This bibliometric analysis analysed sex-related reporting in medical research examining more than 11·5 million papers indexed in Web of Science and PubMed between 1980 and 2016 and using sex-related Medical Subject Headings as a proxy for sex reporting. For papers that were published between 2008 and 2016 and could be matched with PubMed, we assigned a gender to first and last authors on the basis of their names, according to our gender assignment algorithm. We removed papers for which we could not determine the gender of either the first or last author. We grouped papers into three disciplinary categories (biomedical research, clinical medicine, and public health). We used descriptive statistics and regression analyses (controlling for the number of authors and representation of women in specific diseases, countries, continents, year, and specialty areas) to study associations between the gender of the authors and sex-related reporting.

Findings Between Jan 1, 1980, and Dec 31, 2016, sex-related reporting increased from 59% to 67% in clinical medicine and from 36% to 69% in public health research. But for biomedical research, sex remains largely under-reported (31% in 2016). Papers with female first and last authors had an increased probability of reporting sex, with an odds ratio of 1·26 (95% CI 1·24 to 1·27), and sex-related reporting was associated with publications in journals with low journal impact factors. For publications in 2016, sex-related reporting of both male and female is associated with a reduction of –0·51 (95% CI –0·54 to –0·47) in journal impact factors.

Interpretation Gender disparities in the scientific workforce and scarcity of policies on sex-related reporting at the journal and institutional level could inhibit effective research translation from bench to clinical studies. Diversification in the scientific workforce and in the research populations—from cell lines, to rodents, to humans—is essential to produce the most rigorous and effective medical research.

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Introduction

Sex matters in science. Numerous clinical and preclinical research studies have shown that there are sex-based differences at the genetic, cellular, biochemical, and physiological levels. Indeed, sex accounts for numerous cellular variabilities, including rate of tissue regeneration,[1] plaque formation (with critical implications for coronary artery disease),[2] and susceptibility to neuronal cell starvation.[3] Research on animals and humans has shown sexual dimorphism in cardiovascular disease, pulmonary issues, kidney problems, autoimmune disease, and various neurological conditions.[4,5] Despite this, female participants have often been under-represented or excluded from research, with grave consequences. For example, the inadequate consideration of sex differences in pharmacokinetics and pharmacodynamics[6,7] has led to disastrous results; of the ten drugs withdrawn from the market between 1997 and 2001, eight posed greater health risks for women than for men.[8]

A bias for male samples in preclinical research is often justified by an alleged inconsistency caused by female oestrous cycles; the underlying rationale for this

Research in context

Evidence before this study

We searched PubMed, Web of Science, and Google Scholar on June 2, 2016 (and periodically thereafter) for articles related to sex reporting published from inception, using the search terms "sex reporting", "sex analysis", "sex inclusion", "gender bias", "gender disparities", and "sex factors". These terms were also analysed with regards to bibliometric terms (eg, "citation" and "author"). There were no language restrictions. Our search yielded around 1100 articles on related topics, primarily reinforcing sex-based differences in medicine and the under-representation of women in science. These studies showed that there are strong sex-based differences at the genetic, cellular, biochemical, and physiological levels and argue for the construction of policies for greater sex-related reporting and analysis in medical research. Sex-related reporting is low, but increasing. However, extant studies are often monodisciplinary (or cover only a few specific specialties or diseases) and do not account for the translation from biomedical, to clinical, to public health research. Sex disparities in studied populations have potentially negative effects because research done on one sex in the biomedical phase is then translated and used on patients of the opposite sex in public health research. Furthermore, a growing body of research suggests an association between the sex of the researchers and the outcomes of the research.

Added value of this study

Our findings show that sex-related reporting is generally increasing in research, and how it varies across medical disciplines and specialties. Clinical specialties report on sex much more than do biomedical specialties, with fertility, obstetrics and gynaecology, and urology having the highest incidence of sex-related reporting, and haematology, immunology, and pharmacy having the lowest incidence. When we controlled for confounding factors we found that female first or last authors had a higher probability of sex-related reporting than male authors, female authors are more likely to report studying females or both sexes, and journals with high impact factors are less likely to report sex. This evidence forms a contemporary and comprehensive analysis that complements earlier studies of rates of sex-related reporting and provides a novel extension of research showing the association between sex-related reporting and author gender.

Implications of all the available evidence

There has been an increase in sex-related reporting over the past 40 years, particularly in clinical research and public health, but sex remains widely under-reported in biomedical studies. This disparity can be addressed through policies at several levels; funding agencies should mandate sex-related reporting in proposals and journal editors should insist upon sex-related reporting in submissions. Sex-related reporting should be a necessary requirement for ethical and replicable medical science. Furthermore, this research suggests several consequences of the demographic composition of the scientific workforce and the distribution of labour on scientific teams. Women are under-represented in leadership positions and are more likely to do experimentation than to be responsible for research design. Our research suggests that these findings are probably related to lower rates of sex-related reporting and analysis, particularly for female populations. Diversification of the scientific workforce is essential to produce the most rigorous and effective medical research.

exclusion was that a homogeneous sample that limited diversity as much as possible would enable the isolation of key variables and lead to more coherent results. However, recent empirical research has shattered the myth of female variability, finding that males exhibit greater variability than females on several traits.[9–13]

Recognising that the costs of omission are far greater than any downside of inclusion, the 1993 Revitalization Act in the USA mandated the increased enrolment of women in clinical trials for government-funded research. By 2013, more than half of all participants in US National Institutes of Health (NIH)-funded clinical research studies were female[9] and there was a strong increase in sex-inclusive research. However, male bias during that same time increased in animal studies[10] and dominated research of cultured cells.[14,15]

The continued avoidance of sex-related reporting and analysis in preclinical studies reduces the ability to replicate research, gain knowledge on sexual dimorphism, and identify heterogeneity within female samples. It also reduces effectiveness of research translation—potentially augmenting the risks—of clinical studies on humans. To address this problem, the NIH issued a policy in 2014 that called for balanced use of male and female cells and animals in preclinical studies, unless sex-specific exclusion could be rigorously justified.[16]

The sex of the research participant or sample is not the only place where sex matters in scientific research. Studies increasingly emphasise the importance of the demographic characteristics of the scientist and the interaction between scientists and those studied.[17] For example, one study found that male laboratory technicians increased the stress of rodents under study, particularly female rodents.[18] Furthermore, the presence of female investigators might lead to increased sex analysis in research.[19,20]

However, the extant literature fails to provide a contemporary and cross-disciplinary analysis of the degree of sex-related reporting across the health sciences—from biomedical, to clinical, to public health research—and the role of author gender in sex-related reporting. We aimed to address this gap.

See Online for appendix

Methods

Overview

This bibliometric analysis involved a large-scale analysis of more than 11·5 million articles. We aimed to provide a comprehensive analysis of sex-related reporting across all specialties of biomedical, clinical, and public health research between 1980 and 2016; to test the association between author gender and sex-related reporting in medical research; and to examine factors that are associated with sex-related reporting in medical research.

There is considerable variation in the use of terms to describe sex-related reporting. Sex inclusion is often used to describe the inclusion of male and female populations in a study and sometimes to refer exclusively to the inclusion of minority populations in a domain. Sex analysis is used to refer to the use of sex as an analytic variable in a study (thereby requiring the inclusion of both sexes). Sex reporting usually denotes the identification of the sex of the included population. In the present study, Medical Subject Headings (MeSH) are used as a proxy for sex reporting. We, therefore, use the term "sex-related reporting" to denote studies that include the specified MeSH.

We use the term sex to discuss the samples or populations under study and use gender to refer to the author on papers. Gender of authors is determined by names, which provide—within a reasonable margin of error—the perceived gender of the authors. This distinction is deceptively simple: the concept of sex is usually understood as involving biological attributes, such as reproductive, hormonal, genetic, and metabolic differentiation between male and female.[21] By contrast, gender is a concept that includes cultural and psychosocial factors linked to sex but is often determined as a type of "embodied social structure".[22] However, because it is often difficult to assess what is due to sex or gender, or both, the notions are often conflated in medical research. For example, there is a sex-based difference between a female human's autoimmune response, which is generally higher than that of male humans owing to hormonal differences,[23] but gender differentiation might also modulate immune disorders because of external exposure (eg, chemical, viral, bacterial).[24] In this research, we use the notion of sex to characterise populations, samples, and cells, knowing that this could be linked to gender; conversely, we use gender when considering the authors of the research, acknowledging that this factor is also related to sex.

Ethics review and approval was not required for this study because it uses publicly available data from scholarly docucuments.

PubMed

For the **bulk download website** see https://www.nlm.nih.gov/databases/download/pubmed_medline.html

We downloaded data from PubMed via the US National Library of Medicine bulk download website. Raw XML data were transformed into a relational SQL database that allows for the compilation of bibliometric indicators. We used all MeSH associated with sex (major and non-major topics) to retrieve papers that report sex (appendix pp 2–5). To have mutually-exclusive categories of papers, we categorised papers by reporting only female, only male, both sexes, or no sex. Given the concerns that have been raised regarding the use of classification systems for the examination of sex in clinical and public health data,[25,26] we did a validation exercise to check for false negatives and false positives in our data. Our analysis is based on the assumption that those studies reporting on the sex of humans, animals, and cell cultures include an indicative sex-related MeSH. To test the use of MeSH for sex-related reporting, we used a specialties-based stratified sampling of articles that did and did not include a sex-related MeSH (appendix pp 2–3). Although MeSH are indicative of sex-related reporting, this method shows that they cannot be used as an indicator of sex analysis.

Web of Science

To obtain citation data, journal disciplinary classification, and journal impact factors, and to assign genders to authors, we matched papers indexed in PubMed with their equivalent record in Clarivate Analytics' Web of Science. We used three sets of matching keys: digital object identifiers; title, publication year, first author, and starting page; and volume, publication year, first author, and starting page. Additional matching was also done using the title, publication year, first page, and journal name, using a conversion table for journal names based on the set of papers matched using the three keys. Fuzzy logic was used when titles were not identical.

Between 1980 and 2016, 88·2% (16 192 312 papers) of PubMed papers published in journals indexed by the Web of Science (n=18 349 143) were matched; this percentage increases from 81·9% (182 898 papers) in 1980 to 89·0% (890 763 papers) in 2016, mostly due to the greater presence of digital object identifiers. Papers matched with Web of Science were attributed to a discipline and a specialty on the basis of the classification developed for and used by the US National Science Foundation.[27] 11 572 428 papers were matched between PubMed and Web of Science over the 1980–2016 period, once the matches were restricted to the fields of biomedical research, clinical medicine, and public health (as per the National Science Foundation field and subfield classification) and to research and review articles. Public health covers papers on public health and health policy, geriatrics, and nursing, among others. Contrary to the Web of Science subject categories, this classification scheme classifies each journal into one discipline and one specialty. Journal impact factors were corrected for the asymmetry between numerator and denominator,[28] which means that only citations received by articles and reviews were counted in the numerator.

Gender assignment of researchers

Web of Science began indexing given names of researchers in 2008, which allows for the assignation of a perceived gender to authors. For 3 298 951 papers that were published between 2008 and 2016 and could be matched with PubMed we assigned gender of first and last authors—which can be considered in medicine as dominant authorship positions[29]—using their names, according to our gender assignment algorithm.[30] More details on the algorithm, which has also been used by Santamaría and Mihaljević[31] and Karimi and colleagues,[32] can be found in the supplementary materials of our previous work.[30] The algorithm assigned a gender to 72·4% (2 387 311 of 3 298 951) of first authorships and 76·0% (2 508 420) of last authorships. 11·8% (390 723) of first author names and 12·4% (407 760) of last author names were not assigned a gender because only initials were given, and 15·8% (520 917) of first author names and 11·6% (382 771) of last author names could not be confidently assigned a gender.

Regression analysis

We used logistic regression models to study associations between the gender of the authors and sex-related reporting, controlling for the number of authors, representation of women in specific diseases (f_mesh) and in countries (f_country), continents, year, and specialty areas. The dependent variable of our models was the reporting (SR=1) or non-reporting (SR=0) of sex. We removed papers for which we could not determine the gender of either the first or last author and created two tables for single-author papers and multi-author ones. We used logistic regression and ordinary least squares linear regression models to analyse the data. Full details of these analyses is given in the appendix (pp 6–30).

Role of the funding source

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. CRS, Y-YA, BM, and VL had access to the data. All authors were responsible for the decision to submit the manuscript.

Results

Between Jan 1, 1980, and Dec 31, 2016, sex-related reporting increased from 59% to 67% in clinical medicine and from 36% to 69% in public health research (figure 1). A growing number of public health papers focused on female-only populations (from 8% in 1980 to 11% in 2016). By 2016, 54% (10 745) of public health studies reported both male and female populations. In public health, single sex studies focused more often on females than on males (11% *vs* 4%). Sex-related reporting in clinical studies increased from 59% in 1980 to 67% in 2016; however, until 2007, male participants were included more often than female participants were. The move to report both sexes occurred much later in clinical studies than in public health; more than 50% of papers in public health indicated sex-related reporting in 2016, compared with 43% of clinical medicine papers. Despite calls for reform, sex remains under-reported in biomedical research; almost 70% of papers in 2016 did not report on the sex of study samples. Although the proportion of studies that incorporate both sexes has moderately increased in 2006, this change appears to be due to a decrease in the number of single-sex studies, rather than an increase in any type of reporting.

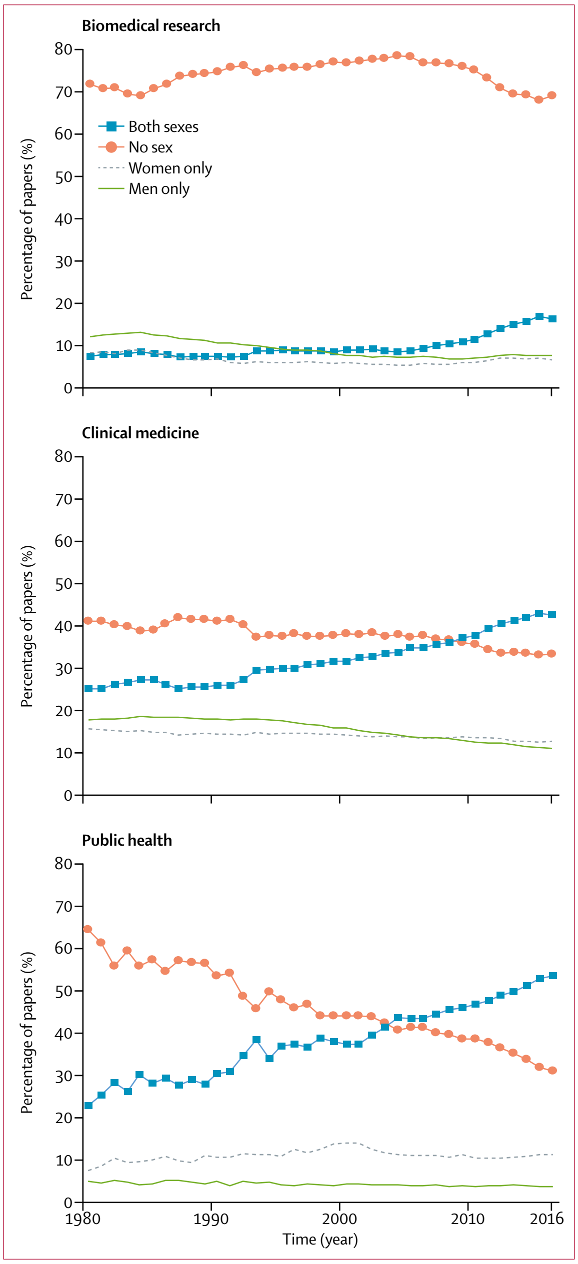

Figure 1: **Percentage of papers addressing sex (MeSH terms), by discipline, 1980–2016**

Fertility (97%), obstetrics and gynaecology (96%), and urology (83%) disciplines have the greatest incidence of sex-related reporting (figure 2). Clinical medicine fields with a cellular or biochemical focus,

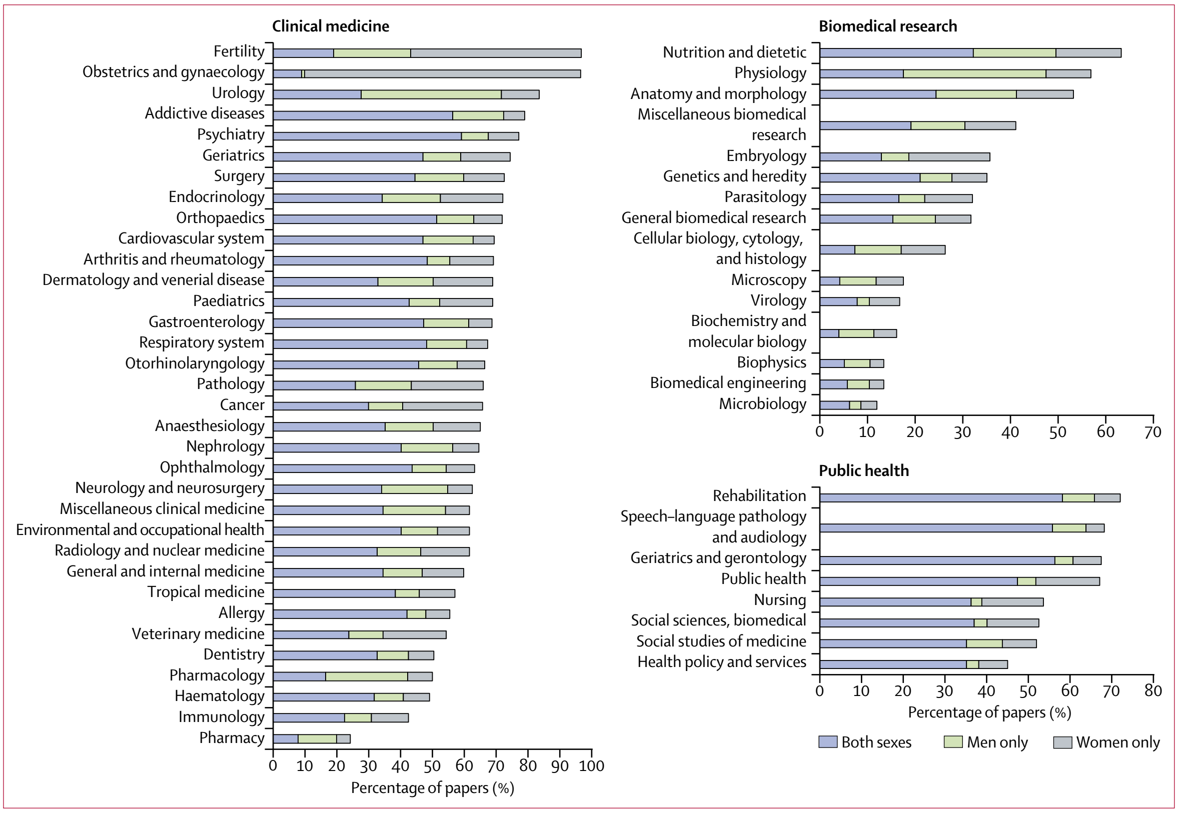

Figure 2: Percentage of papers addressing sex (MeSH terms), by specialty, 1980–2016

	Total sample	Female–female	Female–male	Male–female	Male–male
Sex reported?					
Yes	1 127 989	180 136	305 738	147 174	494 941
No	890 708	117 959	246 861	119 971	405 917

Table: Sex-related reporting, by sex of first and last authors

such as haematology (49%), immunology (42%), and pharmacy (24%), have the lowest levels of sex-related reporting. These findings are similar to the distribution of sex-related reporting in biomedical research, in which only nutrition (63%), physiology (57%), and anatomy and morphology (53%) have a majority of papers reporting on the sex of the research population. Furthermore, in biomedical research, male participants are studied more often than female participants are. Public health research has the largest percentage of sex-related reporting in all three domains, with a norm towards including both sexes in the analysis—54% in 2016.

We estimated logistic regression models to study associations between the gender of the authors and sex-related reporting. From 3 298 951 papers, we removed papers for which we could not determine the gender of either the first or last author (n=1 192 430) and created two tables for single-author papers (n=87 824) and multi-author ones (n=2 018 697; table). Further details and alternative models are given in the appendix (pp 3–4). When we controlled for the number of authors, representation of women in specific diseases (f_mesh) and in countries (f_country), continents, year, and specialty areas, having female first or last authors was positively associated with sex-related reporting (figure 3). The effect size is the largest when both first and last authors are female, with an OR of 1·26 (95% CI 1·24–1·27). The number of authors is also associated with the reporting of sex. Having twice as many authors corresponds to an OR of 1·96 (1·94–1·97). Compared with North America, papers from all other regions, particularly Africa, are more likely to report sex. This variation might stem from the different prevalence of research topics across regions rather than biases or norms. Finally, the effect size of the year variable is almost zero, suggesting that most of the temporal variation can be explained by other factors, such as an increasing number of female authors and papers from outside the USA.

Current academic incentive structures value the publishing of research in journals with high journal impact factors. However, journals with high impact factors are not examples of best practices regarding sex-related reporting. Papers with sex-related reporting are more likely to appear in lower-impact journals than are

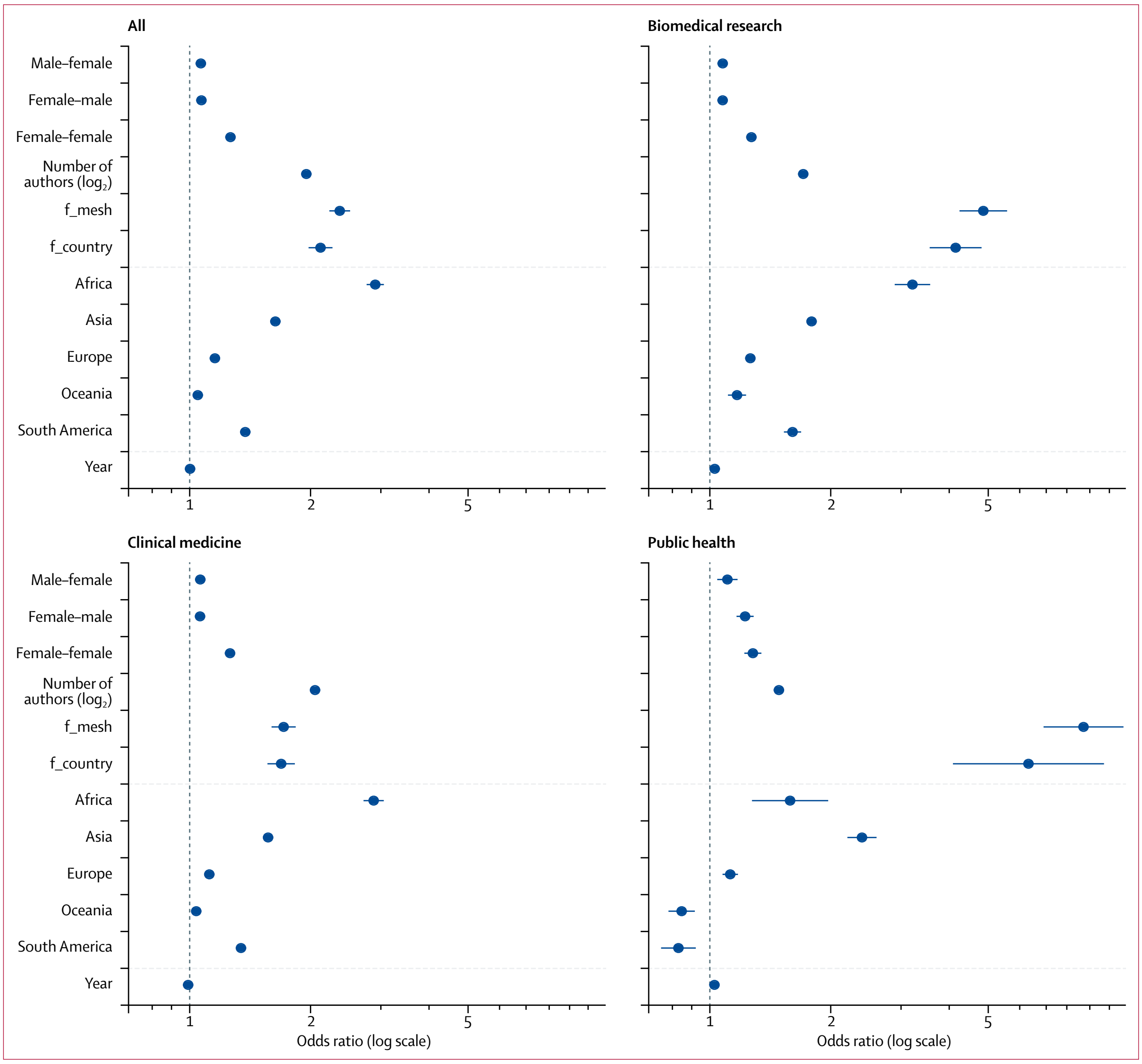

Figure 3: **Odds ratio of sex-related reporting from the logistic regression analysis**
Throughout our models, the reference variable for sex combination of first and last authors is male–male and that for the geography is North America. Error bars are 95% CI. The effect of having female author(s) is positive across all cases. See the appendix (pp 6–30) for regression tables, including those for the SR_M, SR_F, and SR_B models.

those without sex-related reporting, even when controlling for specialty of publication (figure 4). For example, for publications in 2016, sex-related reporting of both male and female sex is associated with a reduction of –0·51 (95% CI –0·54 to –0·47) in the journal impact factor.

Discussion

This bibliometric analysis shows that, over the past 40 years, sex-related reporting has increased in clinical medicine and public health but not biomedical research, where only 31% of papers reported on sex in 2016. For clinical medicine and public health, percentages of sex-related reporting reached 67% and 69%, respectively, in 2016. This finding confirms trends that have implied increasing rates of sex-related reporting;[33] however, this is the first study to examine a large proportion of the literature over time that is inclusive of all disciplines and specialties.

Our results show strong variation in sex-related reporting across disciplines. Some of these differences might seem intuitive; it is perhaps unsurprising that women are studied most often in gynaecology. However, some of these imbalances can lead to grave consequences. Bias with regards to fertility studies has created a dangerous double standard in some clinical trials in which women must have contraceptive requirements but men do not, even when paternal drug exposure might lead to fetal harm.[34] Sex-related reporting is the first step towards improving ethical standards of research in regards to sex.

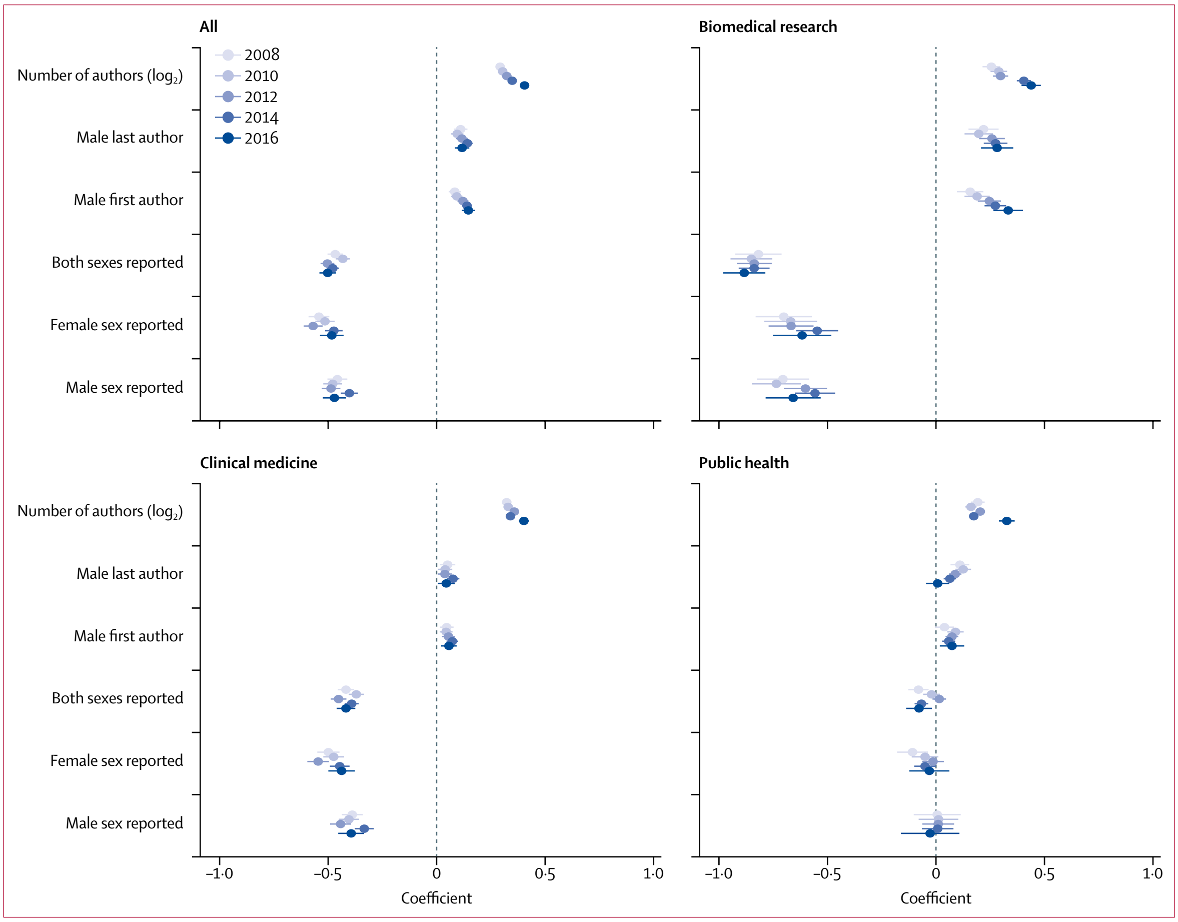

Figure 4: **Effect sizes of independent variables on the impact factor of journals**
Error bars are 95% CIs. Reporting sex is associated with lower impact factors and the effect remains stable over time.

Area of research is only one factor that affects sex-related reporting in medical research. Papers with female first and last authors were more likely to report sex—especially female or both sexes—when we controlled for number of authors, representation of women in diseases, specialties, countries, continents, and publication year. These results complement findings published by Nielsen and colleagues,[19] which, based on the GenderMedDB,[35] showed that female first and last authors were more likely to report on sex. However, our results are based on a larger dataset—3394 versus 1·1 million papers reporting sex analysed in the regressions—with more controls and distinguishing between the sex that is reported (female, male, or both). Although Nielsen and colleagues reported that female authors were more likely to report on sex, they did not show that women were also more likely to study females—which is one of the key contributions of the present study.

Our analysis also provides evidence that research with sex-related reporting is more likely to appear in lower impact journals. Given their higher visibility and credibility ascribed to them, one might argue that high-impact journals have a responsibility to enforce sex-related reporting when warranted. Furthermore, our regional analyses showed that North America had the poorest rates of sex-related reporting across regions, lower than comparatively under-resourced research settings such as Africa. This finding suggests that North American institutions are under-reporting and must be proactive in achieving increased proportions of sex-related reporting in medical research. Analysis of sex-related reporting—at the journals, institutional, or country level—would be facilitated by greater standardisation of reporting practices in bibliographic indexes, which would lead to increased transparency.

The use of indicators to measure science comes with some inherent limitations. We use MeSH as indicators of sex-related reporting in research. Our validation suggests that this approach is relatively accurate at identifying sex reporting, but is inadequate for documenting the extent of sex-related analyses. Further developments are necessary to ensure that sex-related data are provided to publishers and indexers in a nuanced and valid way for future analyses.

We used journal-level classifications to indicate disciplines and specialties, based on the National Science

Foundation classification. Although this approach is standard in bibliometric analyses, it has limitations in the identification of each paper's specific topic and potential misclassification of multidisciplinary research. The bibliometric alternative is the construction of a paper-level classification, but this comes with strong limitations, such as the scarcity of meaningful analytic clusters and the instability of clusters for diachronic analyses.[33] We account for this limitation by including diseases into our model.

There are limitations to the use of authors' names as an indicator of their gender. Compared with self-reported data, gender disambiguation algorithms are restricted in that they can only be applied to those who have a full first name (rather than initials) and have a name that can be classified in a gender-binary way. Therefore, we could not assign a gender to 25·8% of authors of papers we analysed, and this proportion varies by country, with a higher share of unassigned names in Asian countries.

In our regression models, we did not explicitly model the missingness of gender variables and instead used the ignorability assumption, as was done in a similar study.[19] If the missingness of gender variables is strongly affected by unobserved factors, it might have produced biases in our results. Furthermore, as in the aforementioned study,[19] our main models also ignored papers that do not have the disease MeSH terms with associated average female first (last) author fraction; however, models that include such papers and do not use f_mesh produce qualitatively similar results. The impact factor models have similar limitations. The association between the prestige of a journal and coverage of certain diseases associated with sex-related reporting should be taken into account when interpreting our findings.

At the cellular level—especially in the case of in-vitro research with transformed cell lines—many researchers are simply unaware of the sex of the cell line they are using, despite efforts to document these cell lines.[36] Although the process of creating stable and immortalised stem lines does not presently allow for perfect equivalency (leading to comparison) of female and male cell lines, sex identification is nonetheless an important first step.[37] This work is still in its infancy, but a full catalogue of the sex of common cell lines could increase the accuracy and degree of reporting. Science policy—from institutional to federal levels—should insist upon sex-related reporting for these studies.

It is laudable that the NIH has achieved parity in terms of inclusion of females in clinical and health-based studies.[9] Parity at the aggregate level, however, does not mean sex-related reporting and might also obscure some differences at the field level. For example, our results show that female participants are more often studied in virology and cancer, whereas male participants are the focus in neurology and the study of addictive diseases; these disparities could cause distortions in what is known about each sex within these fields. Research that examines both sexes extends the generalisability of the research, reduces the risk of practical health-based interventions and applications, and enhances replicability. It is important that parity be shown at lower levels of analyses to mitigate disparities, particularly in specialties with implications for both sexes.

When working with animal models, many researchers have used male subjects as a default model; the current generation has simply followed tradition. Given the growing importance of animal welfare, Institutional Animal Care and Use Committees ensure validity of research while also promoting the three Rs: replacement (with non-animals; eg, cells or tissue), refinement (reduction of pain, suffering, and distress) and reduction (in the number of animals).[38] If sex inclusion is not properly justified from the onset in the research design, reduction of the sample could make the population base too small for extensive sex stratification. This reasoning reinforces the association between sex-related reporting and research design; sex inclusion is more feasible when planned at the onset during research design.

Sex inclusion is also a matter of scientific integrity. For example, Responsible Conduct of Research (RCR) training, which is obligatory for all publicly funded researchers in the USA, examines issues of gender discrimination with respect to scientists and the inclusion of females in research on humans (eg, clinical trials).[39,40] However, sex inclusion and reporting can and should be discussed in many other areas of research integrity. For example, micro-ethics discussions—often called good laboratory practice—should enable sex identification in effective record keeping, transparent reporting, and any sharing of data or material (such as on Material Transfer Agreements). Sex identification becomes an identifying factor that augments reproducibility and replicability. Research that considers sex differences could ultimately reduce health inequities, making sex-related reporting an ethical obligation and social responsibility.

The International Committee of Medical Journal Editors (ICMJE) has long called for the provision of descriptive data on demographic variables, such as sex and gender,[41] but without much effect on biomedical editors. In 2011, the Institute of Medicine hosted a workshop on sex-related reporting and concluded that although sex-related reporting was both appropriate and feasible, it was "not on the radar screen" for many high profile journals (including *Proceedings of the National Academy of Sciences*, *Science*, and *Nature*).[42] The Institute of Medicine report led to a strengthening of the ICMJE recommendations and the development of guidelines by several other organisations and individuals. In 2012, the European Association of Science Editors began a 3-year project that resulted in the Sex and Gender Equity in Research guidelines for reporting of sex and gender in research.[41] Individual scholars have also proposed guidelines.[43] Despite these initiatives, editors have been slow to adopt universal standards, often deflecting responsibility for sex-related reporting to funders.

Women hold a minority of authorships across the sciences,[30] account for only a third of first-authorships in high-impact medical journals,[44] and are unlikely to hold leadership roles within research teams.[45] Gender is also a factor in grant receipt and amount of funding.[46] As our study suggests, without women leading and designing research, there could be markedly fewer articles with sex-inclusion generally, and studies of women, specifically. This situation suggests that gender disparities in science might not be value neutral, but have consequences for the health of the entire population. Furthermore, women tend to be under-represented on editorial boards, even when accounting for their already low proportion in authorship.[47] This disparity might further compound the issue of adopting stronger guidelines around sex reporting, given that this issue is more prevalent in female-authored research.

In summary, medical education, health-care procurement, service provision, and health policy around the world are expected to be based on the use of the best available scientific evidence. Therefore, intentional or unintentional inclusion of sex biases upstream in research can be particularly pernicious for downstream policy making, service provision, and health and development outcomes. Sex and gender must be taken into account throughout the lifecycle of research. Diversification in the scientific workforce and in the research populations—from cell lines, to rodents, to humans—is essential to produce the most rigorous and effective medical research.

Contributors

CRS, ES, Y-YA, and VL conceived and designed the experiments. CRS, Y-YA, BM, and VL did the experiments. CRS, Y-YA, and VL analysed the data. CRS, Y-YA, ES, and VL wrote the manuscript. All authors approved the final version.

Declaration of interests

We declare no competing interests.

Acknowledgments

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