Do gendered citation advantages influence field participation? Four unusual fields in the USA 1996-2017

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Gender inequalities in science are an ongoing concern, but their current causes are not well understood. This article investigates four fields with unusual proportions of female researchers in the USA for their subject matter, according to some current theories. It assesses how their gender composition and gender differences in citation rates have changed over time. All fields increased their share of female first-authored research, but at varying rates. The results give no evidence of the importance of citations, despite their unusual gender characteristics. For example, the field with the highest share of female-authored research and the most rapid increase had the largest male citation advantage. Differing micro-specialisms seems more likely than bias to be a cause of gender differences in citation rates, when present.
Keywords: Citation analysis; Gender differences; cell biology, surgery, veterinary, orthopedics; sports medicine

Introduction

Despite substantial and ongoing gender differences in academia, such as male majorities in Science Technology, Engineering and Mathematics (STEM) (Su, Rounds, & Armstrong, 2009; Su & Rounds, 2015) and female majorities Health care, Elementary Education and the Domestic sphere (HEED) in the USA (Tellhed, Bäckström, & Björklund, 2017), the reasons for these imbalances are unclear and are unlikely to involve any biological differences in innate abilities (Ceci & Williams, 2011). It has been hypothesised that males are more attracted to research things whereas females prefer research involving people (Su & Rounds, 2015) and that some STEM fields have cultures that alienate females (Cheryan, Ziegler, Montoya, & Jiang, 2017). Another theory is that females are more likely to select an academic discipline based on its societal value whereas males are more likely to value personal advancement opportunities (Diekman, Brown, Johnston, & Clark, 2010; Diekman, Steinberg, Brown, Belanger, & Clark, 2017; Diekman & Steinberg, 2013). Gender differences have substantial international variations, such as with the success of female computer scientists in Malaysia (Othman & Latih, 2006). There are also changes over time. For example, within medical schools in the USA, there was a female majority (50.7%) of new students (matriculants) in 2017 for the first time (AAMC, 2017), although it seems likely that some medical specialisms continue to have a majority of male starters, for complex reasons (Ku, 2011). There is evidence of gender convergence in research participation but it is worryingly slow in some areas (Holman, Stuart-Fox, & Hauser, 2018). This article assesses how research fields have changed their gender composition over time in the hope of getting insights into how they have evolved into their current state. A recent STEM initiative argues that "cultural transformation" is needed to make adequate progress (Carr, Helitzer, Freund, Westring, McGee, Campbell, & Villablanca, in press).

The citation rate of female-authored research has been compared to the citation rate of male-authored research to investigate whether the work of female researchers is undervalued and less likely to be cited. This might explain higher female attrition and lower promotion chances, assuming that citations influence these decisions. Overall, there is little

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evidence of gender differences in citation rates in the USA (Elsevier, 2017; Larivière, Ni, Gingras, Cronin, & Sugimoto, 2013; Larivière, & Sugimoto, 2017), with an apparent slight average advantage for females (Thelwall, 2018), despite the higher self-citation rates of males (King, Bergstrom, Correll, Jacquet, & West, 2017). In contrast, female researchers seem to write fewer journal articles than do males in the USA, although this could be partly due to being more likely to be in teaching-intensive roles or part-time jobs (Ceci & Williams, 2011) or writing better quality articles (Hengel, 2018). It is not clear whether general societal inequalities, such as females tending to spend more time in unpaid carer roles and women taking longer career breaks for childcare, affect research fields differently. For example, there may be types of research that are inherently inflexible or field-specific cultures that are not supportive towards people needing flexibility for non-work responsibilities.

This study investigates first-author gender in four Scopus fields: Cell Biology; Veterinary; Surgery; and Orthopedics and Sports Medicine. These were chosen for unusual gender characteristics in the USA. Cell Biology and Veterinary are not people-related fields but have relatively high proportions of female-authored research. Both Surgery and Orthopedics and Sports Medicine are people-related health fields with mostly male-authored research. Thus, these four fields are exceptions to the people/things theory (Su & Rounds, 2015). Since current theories of gender differences in reasons for interest in a topic cannot explain their researcher demographics, they are likely candidates for alternative explanations, such as the influence of citations, or prejudice that might express itself in citations. Three of the categories are narrow fields in Scopus and Veterinary is a broad field, but includes fewer articles than the other three and so is more comparable than narrow veterinary fields. The following general research question drives the study.

RQ: Do fields with unexpectedly low proportions of females also have unusually low female citation rates. Is the same true for males?

Background

Cell biology

Cell biology has been singled out historically as a female-unfriendly research topic, with one paper arguing that feminist critique must be performed by scientists analysing data (Beldecos, Bailey, Gilbert, Hicks, Kenschaft, Niemczyk, & Wedel, 1988). The issue is that cell biology is related to fertility, which has a historical background of male attempts to control it. This suggests that cell biology may be more directly relevant to women and that female perspectives, running against societal gender norms, may give innovative research ideas. These are two possible causes of greater female participation and success in cell biology. There is little contemporary research that gives a gender perspective to cell biology, however, and it is not clear that contemporary cell biology has a substantial fertility focus.

In the wider life sciences, females form a higher share of researchers in the US than in the physical sciences (Ceci & Williams, 2011). In terms of publishing, females in the US contribute 42% of published research in Biochemistry, Genetics and Molecular Biology (Elsevier, 2017, p. 24-27, lower bars). An early study found female life scientists in the US to be more frequently in leadership roles in small businesses rather than academia (or large businesses), as a side-effect of the flexible network structure of small-scale commercial biotechnology work (Smith-Doerr, 2004). Another early study found female academic life scientists to patent at 40% of the rate of males (Ding, Murray, & Stuart, 2006). Based on interviews with biologists and physicists in the US, females were less likely to be discouraged from a life science career. Females in one study were more likely to describe an emotional engagement with the life sciences, both in terms of animals and cells being communicating (implicitly in the context of cells) lifeforms and for the realistic hope of providing societal health benefits (Ecklund, Lincoln, & Tansey, 2012). Thus, scientific females may find the life sciences more interesting and socially useful than other career options.

Surgery

Females are a minority within surgery in the US, but with an increasing trajectory (Moulton, Seemann, & Webster, 2013; Nkenke, Seemann, Vairaktaris, Schaller, Rohde, Stelzle, & Knipfer, 2015; Valsangkar, Zimmers, Kim, Blanton, Joshi, Bell, & Koniaris, 2015; see also: Figueiredo, Rodrigues, Troncon, & Cianflone, 1997). Females have almost never been given awards by specialist surgery societies in the USA for orthopedic surgery, head and neck surgery, and plastic surgery (Silver, Slocum, Bank, Bhatnagar, Blauwet, Poorman, & Parangi, 2017). Within surgery, males tend to have higher status, be involved in higher status specialisms, and be more highly paid; multiple theories have been proposed to explain this (Sanfey, Crandall, Shaughnessy, Stein, Cochran, Parangi, & Laronga, 2017). In the past, differences in carer responsibilities were insufficient to explain the lower success rates of female surgeons (Schroen, Brownstein, & Sheldon, 2004). Masculine professional cultures are a possible reason why females may not feel comfortable as a surgeon, however (Moulton, Seemann, & Webster, 2013). Interviews with eight senior female academic surgeons in Canada found contradictory evidence of a belief that gender discrimination was pervasive within surgery but that it did not affect them (Webster, Rice, Christian, Seemann, Baxter, Moulton, C. & Cil, 2016). An American Society of Plastic Surgeons survey of members and candidates found that females were more likely to report experiencing bias or sexism (Furnas, Garza, Li, Johnson, Bajaj, Kalliainen, & Rohrich, 2018). Thus, the relatively high proportion of males in surgery may be primarily due to cultural factors, whether explicit discrimination against females or a female-unfriendly professional ethos.

Orthopedics and Sports Medicine

Sport is a traditionally male activity in terms of participation rates and interest. Females may not always be taken seriously in leadership roles, even in a mixed gender context (Schull, Shaw, & Kihl, 2013). The Title IX civil rights law in the US (implicitly and in practice) outlawed excluding females from sports in education, leading to increased female participation, but not gender parity (Antunovic, 2017). The continued greater importance given to male professional sports, for example, is clear from the low mass media coverage given to females in the US (Cooky, Messner, & Musto, 2015). There is anecdotal evidence that sports physicians are usually male (Thompson, 2016), presumably due to a greater male interest in competitive sport.

Orthopedics is concerned with the musculoskeletal system, often from the perspective of surgery. Female-authored orthopedic research has increased more slowly than average for academia, reaching only 6.5% of first authorships by 2007 (Okike, Liu, Lin, Torpey, Kocher, Mehlman, & Biermann, 2012). The high proportion of males in Orthopedics may be due to its association with sports and surgery, both of which are male interests.

Veterinary

Veterinary education switched from almost exclusively male in the early 1970s to gender parity in 1985-86, with a female majority in the current decade (AVMC, 2017). There is approximate gender parity in Veterinary publishing in the US (Elsevier, 2017, p. 24-27, lower bars). The greater number of females may be due to eliminating gender discrimination, a reduction in the importance of strength, and veterinarians being portrayed as caring in fiction (Lofstedt, 2003). The caring and nurturing role of veterinarians seems to be an important reason why females choose this career (Irvine & Vermilya, 2010), and comforting pet owners can be an important component of veterinary work (Morris, 2012). Female veterinarians were shown to be more empathetic towards both animals and owners in one Italian study (Colombo, Crippa, Calderari, & Prato-Previde, 2017).

It is not clear whether female veterinarians believe themselves to be more caring and nurturing or want to be associated with a caring and nurturing profession because it is a female-appropriate activity. In contrast, lower pay and decreased autonomy may have made the profession less attractive to males (Lofstedt, 2003). There may also be second-order effects from the increased numbers of female role models and a perception of veterinary science as being a female activity.

Methods

The research design was to extract authors and citation counts for articles in all four fields 1996-2017, using first author gender as a proxy for article gender and using first names to detect gender. The year 1996 was chosen as the starting point because Scopus increased its coverage in this year. First author genders were investigated because these tend to contribute most to an article (Larivière, Desrochers, Macaluso, Mongeon, Paul-Hus, & Sugimoto, 2016) even if alphabetical authorship is sometimes applied in maths and economics (Levitt & Thelwall, 2013).

Standard journal articles (excluding reviews) for each of the selected fields were downloaded with a year-specific Scopus query of the following form, where 1307 is the code for Cell Biology:

SUBJMAIN(1307) AND DOCTYPE(ar) AND SRCTYPE(j) AND AFFILCOUNTRY("United States")

Two additional fields were analysed as comparators: Physiology (Biochemistry, Genetics and Molecular Biology); Biomedical Engineering (Engineering). These Scopus narrow fields had about average proportions of female researchers in the USA in 2017.

First author genders were inferred from a list of first names that are gendered in the USA. This list was formed of first names that were in the top 10,000 in the 1990 USA census and had at least 90% use by the same gender, as previously used in a study of academic gender (Larivière, Ni, Gingras, Cronin, & Sugimoto, 2013). Names not found in this list were checked with an online gender detection service that guesses gender from social media profiles (as used in: Bonham, & Stefan, 2017), thus combining two prior methods. Judgements from GenderAPI.com were accepted if there were at least 50 samples and at least 90% were of the same gender. Articles from people using initials in their articles instead of first names or with first names that this process did not assign a gender to were excluded, as were articles from people with rare or relatively gender-neutral names, such as Shannon. The excluded people probably account for a high proportion from minority cultures in the USA since their names are less likely to meet the threshold for inclusion. Cultures with gender neutral first names, such as Sikh, would also tend to be excluded.

The primary data source used, the US Census, classifies people by biological sex rather than socialised gender. This article nevertheless uses the terms male/female rather than man/woman for two reasons. First, a person with a biological sex that does not match their gender is free to choose a first name that reflects that gender, so, in practice, the first name heuristic is likely to reflect gender more accurately than biological sex. In practice, the two are usually the same. Second, this article focuses on behaviours that seem likely to have much greater social influences than biological sex influences, and so gender is more salient than sex.

The proportion of female authors in a field was estimated by dividing the number of female first-authored articles, as detected above, by the number of male or female first-authored articles, also as detected above. This is likely to be a gender biased estimate unless both genders have an equal chance of being detected from their first names, which seems unlikely. To correct for this, genders of the first authors of 1000 randomly selected USA articles were checked by searching for an online profile and examining it for gendered pronouns or pictures, finding a gender for 88% of records. The first name rules identified the correct gender 96.8% of the time but found a slightly higher proportion of the males. Male first authored article counts were multiplied by 1.027 (the human-detected male percentage divided by the first name male percentage estimate) and numbers of female-authored articles were multiplied by 0.957 (the human-detected female percentage divided by the first name female percentage estimate) to compensate.

Average citation counts were calculated using geometric means, which are more appropriate than arithmetic means because citation count data is highly skewed (Thelwall & Fairclough, 2015; Zitt, 2012). Confidence intervals were calculated using the normal distribution formula on the intermediate logged data during the geometric mean calculations (Thelwall & Fairclough, 2015). The data set is not a random sample from a population but confidence intervals can be interpreted in the social sciences sense (Berk, Western, & Weiss, 1995) as the range of values that could reasonably have been obtained by researchers operating under the same conditions.

Results

All fields experienced a substantial increase in the proportion of female-authored articles between 1996 and 2017, although the rate of increase varied (Figure 1). The steepest slope is for Veterinary, although Surgery also has a steep increase. Orthopedics and Sports Medicine seemed to have a constant female proportion 2004-2017 and Cell Biology has a very shallow increase 2004-2017.

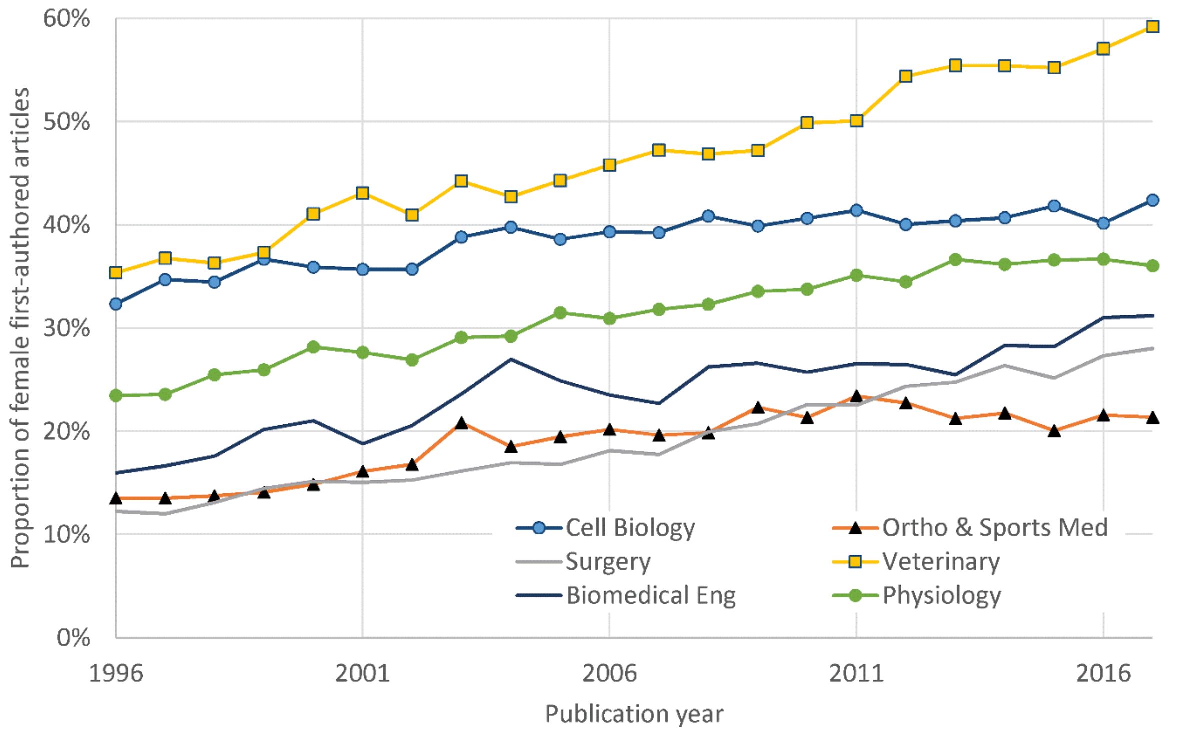

Figure 1. Articles with a female first author from the USA as a percentage of articles with a male or female first author from the USA, as detected from first names. Percentages are

estimates since an unknown proportion of each gender was identified. Numbers of male first authored articles were multiplied by 1.027 and numbers of female-authored articles were multiplied by 0.957 to correct for a slightly higher rate of detecting females through first names. See the other figures for sample sizes.

For most subjects and years, the average citation count for female-authored research is similar to that for male first-authored research (Figures 2-7).

Two fields have a tendency female-authored research to be more cited. Female-authored Biomedical Engineering research is more highly cited in 17 out 22 years, one of which is statistically significant (in the sense of non-overlapping confidence intervals, although this is a conservative comparison). Female-authored Surgery research is more highly cited in 14 out 22 years, 3 of which are statistically significant.

One field has a tendency male-authored research to be more cited. Male-authored Veterinary research is more highly cited in 20 out 22 years, 3 of which are statistically significant.

Two fields have no overall gender difference. Female-authored Physiology research is more highly cited in 11 out 22 years, none of which are statistically significant. Female-authored Orthopedics and Sports Medicine research is more highly cited in 9 out 22 years, none of which are statistically significant.

Female-authored Cell Biology research is initially less cited (but not statistically significantly) but then becomes consistently more cited after 2008 (statistically significantly in three cases).

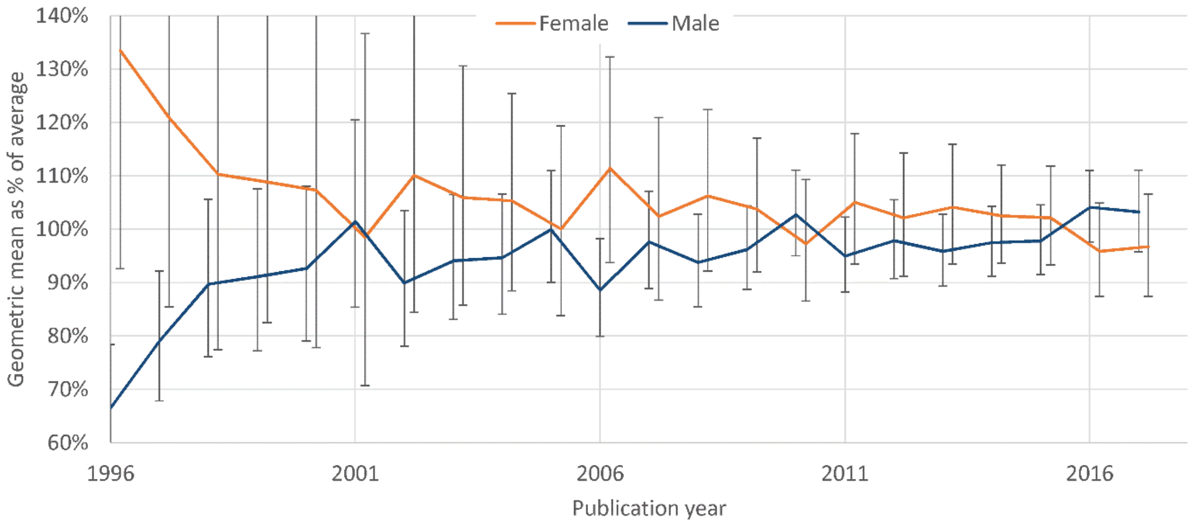

Figure 2. Biomedical Engineering: Average (geometric mean) citations per article by first author gender for USA research. Figures are expressed as a percentage of the year average. Female years have an offset of 0.2 added so that the error bars do not overlap (male: 19240; female: 7200; all: 60838, including ungendered).

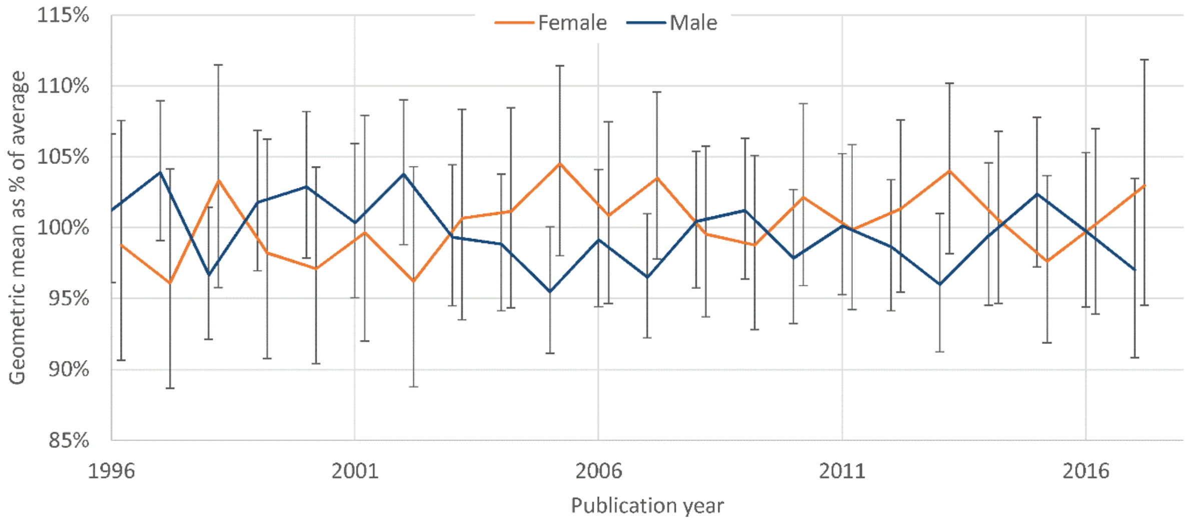

Figure 3. Physiology: as Figure 2 (male: 41247; female: 19984; all: 126573, including ungendered).

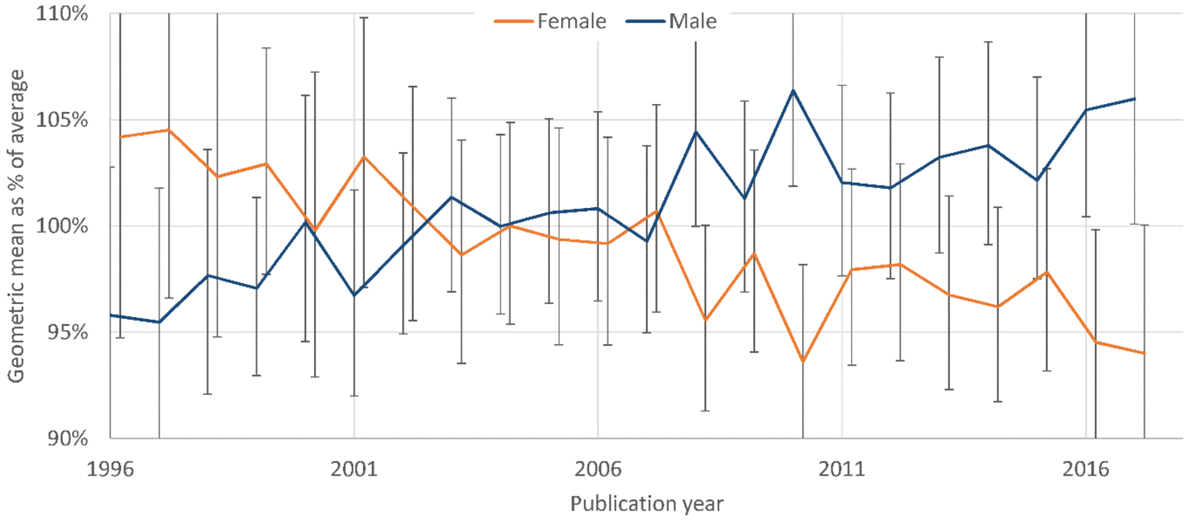

Figure 4. Cell Biology: as Figure 2 (male: 53500; female: 36188; all: 170213, including ungendered).

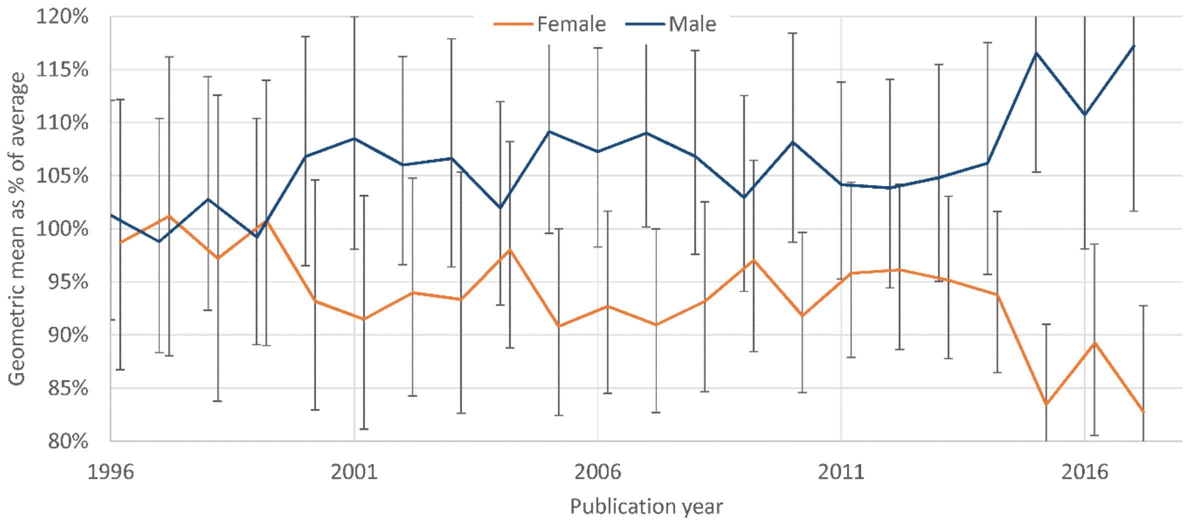

Figure 5. Veterinary: as Figure 2 (male: 13497; female: 12959; all: 40639, including ungendered).

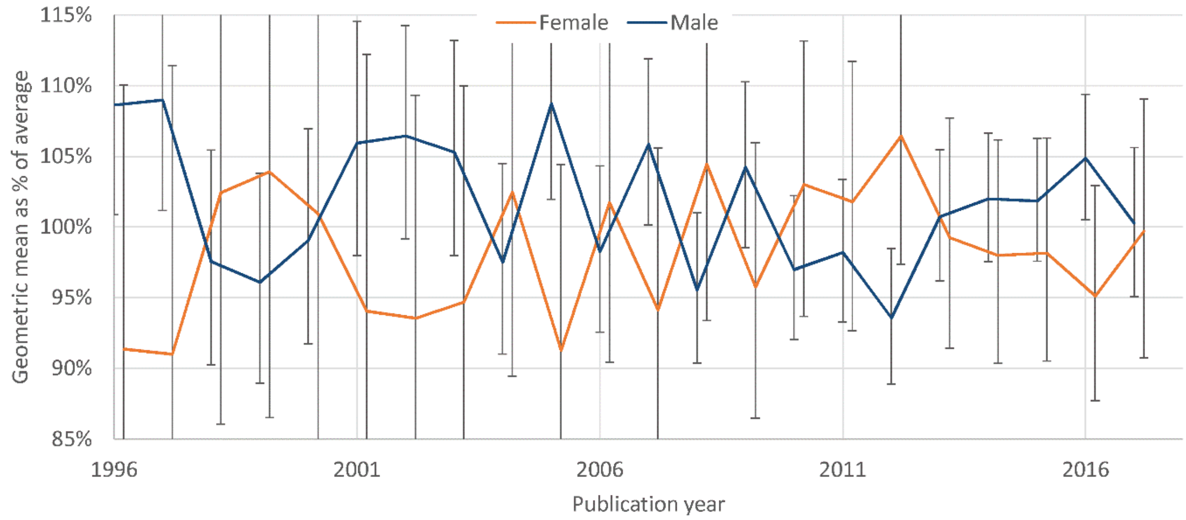

Figure 6. Orthopedics and Sports Medicine: as Figure 2 (male: 47780; female: 12721; all: 80247, including ungendered).

Figure 7. Surgery: as Figure 2 (male: 86564; female: 23871; all: 153823, including ungendered).

Discussion

The research is limited by the focus on only six subject areas and the Scopus categories, which are based on journal classifications that include journals spanning multiple disciplines. It is also limited by the first name heuristic used, which tends to exclude some cultural groups, ethnic minorities and people with gender neutral names. In addition, the rate of authoring journal articles should not be interpreted as an indicator of field participation because of differing publishing rates and females being more likely to be in teaching-intensive roles (Ceci & Williams, 2011).

There is not a clear relationship between citation advantage and authorship percentage. The field with the highest proportion of females and the largest increase in the proportion of females also has a male citation advantage (Veterinary). In contrast the field with a low proportion of females and a low increase in female share has no gender citation advantage (Orthopedics and Sports Medicine) and one field with a female citation advantage also has a high increase in female share, albeit from a low-medium base (Surgery). Thus, there is no evidence to suggest that citation advantage influences field participation.

The only field in which the gender difference in average citations is large enough to be a potential influence on careers is arguably Veterinary (a male citation advantage of about 15%). The male citation advantage seems unlikely to be the cause of the increasing proportion of Veterinary females. The reason for the difference might be the gender difference is specialism, such as a possible greater male focus on farmed animals (statistically significant terms for males included cows, pigs) and vaccines (vaccine, antigen) in comparison to a greater female focus on topics such as domestic animals (cat, dog), horses (horse), veterinary practice (veterinary, diagnosis, presented), hospitals (hospital) and teaching (teaching, student, university). Thus, the citation difference could be related to gender differences in citation rates micro-specialisms within the Veterinary broad field. More generally, all six fields had at least 148 statistically significantly gendered terms, and so any gender differences in citation practices could be due to micro-specialism differences.

For Cell Biology, the female citation advantage after 2008 coincides with a period of more research publishing in the Cell Biology category of DNA-related issues (e.g., associated with terms mitochondrial, histone), and protein-related topics (e.g., AKT [protein catalyst]), stem cells (ESC [Embryonic stem cells]), and cell life-cycle disruption (e.g., dysregulation). Thus, changing citation patterns could relate to changing research foci within the field.

Table 1. Summary of trends and the top 5 female and male gendered terms for each field.

Field	**Female % in 2017**	**Female % incr. 1996-2017**	**Citation advantage**	**Female terms (top 5)***	**Male terms (top 5)***
Cell Biology	Medium	Low	Female after 2008	Role expression cell required regulate	Method technique application solution resolution
Veterinary	High	High	Male	Cat veterinary teaching hospital retrospective	Cattle calves Acari vaccine antigen
Surgery	Low-medium	High	Female	Breast cancer women participants mastectomy	Technique fixation artery arthroplasty anterior
Ortho & Sport Med	Low	Low	None	Participant women activity physical mineral	Patients arthroplasty technique fixation surgical
Physiology	Medium	Medium	None	Expression protein gene cell proliferation	Recording flow rate measurement power
Biomedical Eng	Low-medium	Medium	Female	Cell scaffold hydrogel culture stem	Paper simulation algorithm noise equation

* Terms with the highest chi-squared value for occurring disproportionately often in the titles, abstracts or keywords of one gender compared to the other. All are statistically significant at the 0.001 level after a Benjamini-Hochberg correction (Benjamini & Hochberg, 1995).

Conclusions

The six fields investigated increased their proportions of female first-authored research over time, albeit at varying rates. There is a clear male citation advantage only in the Veterinary broad field. This relative citation success for males cannot explain the rapid increase in females in this field. There is a clear female citation advantage only in one comparator field and Surgery. Again, the female citation advantage cannot explain the relative lack of females in this area. The results for the six fields investigated therefore give no support for the hypothesis that gender citation advantages could be causes of the unusual gender differences in participation rates.

The evidence of gendered terms suggests that there are different micro-topics of interest for male and female researchers, which could account for any differences in citation rates. Thus, it seems that citations are unlikely to be an explanation for unusual gender profiles (i.e., unusual in terms of current theories). Career decisions (e.g., appointment, tenure, promotion) made with the support of citation data may nevertheless disadvantage females if career gaps for carer responsibilities are ignored. Other causes must therefore be sought for field-specific gender differences in participation rates that current gender-based topics of interest theories cannot explain.

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