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Bibliometric Analysis of Gender Authorship Trends and Collaboration Dynamics over 30 Years of *Spine* 1985-2015

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Study Design. Bibliometric analysis.

Objective. To study bibliometric changes over the last thirty years of *Spine*. These trends are important regarding academic publication productivity.

Summary of Background Data. Inflation in authorship number and other bibliometric variables has been described in the scientific literature. The issue of author gender is taking on increasing importance as efforts are being made to close the gender gap.

Methods. From 1985-2015, 10 year incremental data for several bibliometric variables was collected, including author gender. Standard bivariate statistical analyses were performed. Trends over time were assessed by the Cochran linear trend. A $p < 0.05$ was considered statistically significant.

Results. Inclusion criteria were met for 1566 manuscripts. The majority of the manuscripts were from North America (51.2%), Europe (25.2%), and Asia (20.8%). The number of manuscripts, authors, countries, pages, and references all increased from 1985 to 2015. There was a slight increase in female first authors over time (17.5% to 18.4%, p=0.048). There was no gender change over time for corresponding authors (14.3% to 14.0%, p = 0.29). There was an 88% increase in the percentage of female first authors having male corresponding authors (p=0.00004), and a 123% increase in male first authors having female corresponding authors (p=0.0002). The 14-18% of female authors in *Spine* is higher than the ~5% female membership of the Scoliosis Research Society and North American Spine Society.

Conclusion. Manuscripts in *Spine* over the past 30 years have shown a significant increase in the number of authors, collaborating institutions and countries, printed pages, references, and number of times each manuscript was cited. There has been a mild increase in female first authorship, but none in corresponding authorship. Increases in female authorship will likely require recruitment of more females into the discipline rather than providing females in the discipline with authorship opportunities.

Key Words: authorship - bibliometric - gender - Spine - time - trends - change - geographic region - mentorship

Level of Evidence: N/A

Efforts are now being made to promote collaboration within the scientific community. The advent of technology and the internet has made it easier for researchers to collaborate with others from different institutions and countries to produce work that is mutually beneficial for all [1-5]. We posit that advancements in technology increases the speed and ease of communication over large distances and thus increases collaboration. As publications have become increasingly important at all stages of academic careers from medical school applications to obtaining grants and tenure, we anticipated that the number of co-authors listed on publications would also increase over time similar to other disciplines [6-16].

Efforts are also being made to close the gender gap, not only in medicine, but all of society. In 2014, women received a majority of doctoral degrees yet there are significantly fewer women at the professor level in academia [17]. Women only comprise 8% of top earners in professional fields [18, 19]. In the field of science, gender inequalities as well as pay and hiring differences still exist [20]. Recently there has been a focus on gender trends in society and whether women can overcome the apparent barriers hindering their career development. In medicine women have a more difficult time advancing compared to men in the same field [21]. The reason for this gender gap is often unclear, yet an explanation is desirable. Indeed, as women make up approximately 50% of the world population [22, 23], and currently greater than 50% of medical school graduates are women [24], it would seem that more than 15.9% [25] of women should hold higher level professional positions within the medical field [26]. While women comprise 47% of medical students and 46% of residents, they only account for 21% of full time professors [26]. In neurosurgery and orthopaedic surgery, females account for 15% and 13% of residency positions in the US and 12% and 4.3% of surgeons at academic medical schools respectively [27]. There were two major purposes of this study: to determine if publication trends in *Spine* demonstrate similar findings regarding gender and if there are changes demonstrating increased collaboration.

MATERIAL AND METHODS

Data Collection

A bibliometric analysis of *Spine* over the last 30 years was performed by selecting one year from each decade: 1985, 1995, 2005, and 2015. This methodology has been previously validated [12, 16, 28-33]. A PubMed search was conducted in which editorials, commentaries, and letters were excluded and results imported into EndNote X7 (Thomson Reuters, New York, NY, 2013). The entries were reviewed to eliminate those in the incorrect year (e.g. electronic publication ahead of print, where the printed publication was in the following year) as well as memorandums, meeting notes, and abstracts. The extracted data was placed into an Excel file for further manipulation, collecting the names of the first and corresponding authors of each publication. The corresponding author position was noted (e.g. 1st, 2nd, 3rd, …, or last position), as was manuscript length (total number of pages), number of references, and number of times the manuscript was cited. Citation data was obtained from a Scopus search during the month of December 2016.

Author gender was determined for the first and corresponding authors using the method described by Mimouni et. al. [34]. Each author's first name was entered into "Baby Name Guesser" at http://www.gpeters.com/names/baby-names.php, which gives the most likely gender and a gender ratio. A ratio equal to or above 3.0 was considered to be a correct gender. For those below 3.0 a Google search was performed to determine the gender. If that was unsuccessful, the entry was excluded for gender analyses.

Countries were grouped into six regions defined by the country from which the corresponding author originated. North America included the United States and Canada. The European continent, including Russia and Turkey was defined as Europe. All Asian countries beginning west of Turkey, including the Middle East and Israel were considered to be Asia. Latin America was defined as Mexico, Central America, and South America. Africa and Australia/New Zealand were the other regions. The state/province was obtained for those whose institution was located in the United States or Canada.

Statistical Analyses

Continuous data are reported as the mean ± 1 standard deviation. Discrete data are reported as percentages. Analyses between groups of continuous data were performed using non-parametric tests due to the data not having normal distributions (Mann-Whitney U – 2 groups; Kruskal-Wallis test – 3 or more groups). Differences between groups of discrete data were analyzed by the Fisher's exact test (2 x 2 tables) and the Pearson's χ^2 test (greater than 2 x 2 tables). Trends over time for categorical variables were assessed using the Cochran linear trend test (2 x k tables). A $p < 0.05$ was considered statistically significant. Statistical analyses were performed with Systat 10 software™ (Chicago, IL, 2000).

RESULTS

There were 1566 manuscripts that met the inclusion criteria. The number of manuscripts increased from 154 in 1985 to 446 in 2015 (Table 1). The number of authors, countries, pages, and references all increased between 1985 and 2015 (Table 1). We confirmed that the general page format was similar and did not impact these observations. The number of times each manuscript was cited increased from 2.8±3.2 in 1985 to 4.6±5.2 in 2005; however, there was a decrease to 2.0±2.6 in 2015. Because the 2015 manuscripts only had one year to be cited from the time data was collected, we normalized citation data from all years by dividing the number of times the manuscript was cited by the age of the article (1 for 2015, 11 for 2005, 21 for 1995, and 31 for 1985). The number of normalized citations increased from 1985 to 2005 (2.8 to 4.6), but then dropped to 2.0 for 2015. Between 2005 and 2015 there was a striking shift in the corresponding author position, with the majority moving from the first to last author position (Figure 1A). The number of single authors decreased over time from 13.0% in 1985 to 0.9% in 2015 (Cochran linear trend, ($p < 10^{-6}$).

Analyses by Region

The manuscripts originated from North America (51.2%), Europe (25.2%), Asia (20.8%), Australia/New Zealand (2.4%), and South America (0.4%); there were none from Africa. Due to the limited number of manuscripts from South America and Africa, these regions were excluded from further analysis. Manuscripts from Asia were from Japan (44.7%), China (26.1%), Korea (13.8%), and Taiwan (5.4%) with all other Asian countries contributing the remaining 10% of manuscripts. For Australia/New Zealand, Australia contributed 90.0% of the manuscripts and New Zealand contributed 10.0%. For Europe, the breakdown was United Kingdom (21.1%), Germany (13.5%), Netherlands (11.5%), Sweden (9.7%), and France (6.7%). For North America, the United States contributed 89.2% and Canada 10.8%. This was further broken down by states and provinces (Figure 2).

There were significant differences by region (Table 1). Asia had the highest average author number (6.1) and Australia/New Zealand the lowest (4.3). The position of the corresponding author was the highest in Asia (3.3) and the lowest in Europe (1.9). The number of normalized citations per year was highest for Australia/New Zealand (4.2) and the lowest for Asia (2.6). There were no differences by region for the number of institutions, references, or article length. The number of single authored manuscripts did not vary by region (Figure 1B)

North America had 52.7% of corresponding authors as first authors, 9.6% as second authors, and 29.4% as last authors with the remainder in other positions (Figure 1B). Europe had a similar distribution with 67.0% of corresponding authors as first authors, 9.7% as second authors, and 18.7% as last authors with the rest being in another position. Australia/New Zealand had 55.3% of corresponding authors being first, 5.3% of authors being second, 28.9% of authors being last with the rest being in another position. Asia showed 51.9% of corresponding authors being first authors, 8.0% being second authors, and 34.9% of corresponding authors being last authors, with the remainder in other positions.

Gender Distribution of Authors Over Time and by Region

There was a slight increase in female first authors over time from 17.5% to 18.4% (Cochran linear trend, $p=0.048$) (Figure 3A). For all regions combined as well as Europe and North America, there was a similar overall trend for an increase in the number of female first authors from 1995 through 2015, but a drop from 1985-1995 (Figure 3A). Asia and Australia/New Zealand had no female first authors in 1985, but the number of total manuscripts submitted that year from those regions was small, 11 and 2, respectively. There was no change over time in gender for corresponding authors overall from 14.3% to 14.0% (Cochran linear trend, $p = 0.29$) (Figure 3B).

Gender Relationship Between Corresponding and First Author Positions

There were no differences over time in the percentage of manuscripts in which the first and corresponding author was both female or both male (Table 2). There was an 88% increase in the percentage of female first authors having male corresponding authors from 1985-2015 (Cochran linear trend, p=0.00004), and a 123% increase in male first authors having female corresponding authors (Cochran linear trend, p=0.0002).

DISCUSSION

Manuscript publication is important in career advancement and development in academic medicine [2, 35-42]. Publications are also helpful in gaining admission into highly competitive programs for both graduate school and residency programs alike [43]. As such, it is useful to examine publication trends. This 30-year bibliometric analysis of *Spine* studied these publication trends. Over the past 30 years there was a significant increase in the number of authors, institutions, and countries involved with manuscripts published in *Spine*. The increase in the number of authors is a well known phenomenon in academic medicine [6, 8, 11, 12, 14, 16]. In *Spine*, the number of authors doubled from 1985 to 2015; however, this increase varied by region. Overall, Asia had the most authors on each manuscript, followed by North America, Europe, and Australia/New Zealand. This substantial increase over time could be explained by increased collaboration amongst authors or an increase in the complexity of the research being performed [6, 8, 12, 16]. Indeed, it appears that collaborations increased over time as the number of authors per manuscript increased 103% and the number of countries involved per manuscript increased 18%. In general, collaborations should benefit all parties, whereby a common goal is achieved [4, 44]. Collaborations can arguably be better accomplished today compared to 30 years ago because of technological advances such as the Internet, telecommunications, and file sharing capabilities [1, 45-48].

These technological advances are likely responsible for the increase in the number of references as it is easier for authors to search and obtain appropriate literature related to their topic of interest. Advances in technology may also play a role in the increasing number of times that manuscripts in *Spine* are cited between 1985 and 2005, since it has become easier to identify appropriate manuscripts. There was a decline in *Spine* citations in 2015 compared to 2005, likely due to the fact that the 2015 manuscripts were only available for one year for other authors to find and cite.

A primary goal of this work was to evaluate changes in authorship trends based on the gender of the first and/or corresponding author. Although the overall number of female first authors almost doubled between 1995 and 2015, there were still only 17% female first authors in 2015. For corresponding authors, no differences were observed over time and remained steady between 9-14%. These numbers seem low since women make up approximately 50% of the population and comprise 47% of medical students and 46% of residents [22-25]. However, a very different interpretation can be made when looking at surgical specialties; women comprise only 18% of surgical residents [27]. The North American Spine Society (NASS) and Scoliosis Research Society (SRS) membership data shows that 5.4% and 3.3%, respectively, of associate members are female, and 5.3% and 5.2% of active members are female (personal communication RTL, August 2017). It needs to be remembered, however, that some of these active and associate members may not be spine surgeons but rather PhD researchers. The exact proportion of this is unknown, but not likely large, and the exact impact of this on female authorship is unknown. The 2016 membership data of the American Academy of Orthopaedic Surgeons membership (AAOS) [49] noted that 9.1% consider themselves to be spine subpsecialists; the female proportion of the subpsecialist groups was not given. However, females comprise 6.5% of the entire AAOS membership [49]. If the proportion of women in each subspecialty is the same, then it could be estimated that 6.5% of the 9.1% would be women, or 0.6% of the overall AAOS membership would be female spine subspecialists. However, it is likely less than this 6.5%, since only 3% of orthopaedic spine fellowship applicants were women between 2000 and 2014 [50], and only 15 of all 3640 (0.4%) orthopaedic fellowship applicants. For neurosurgeons, 17% of recently matched residents were women [51], and 13% of female fellowship trained neurosurgeons are spine subspecialists. Thus, at best, 13% of the 17% female neurosurgeons would be female spine neurosurgeons, or 2.2%. Therefore, it may be considered positive that upwards of 14-17% of manuscripts published in *Spine* contained female first and/or corresponding authors in light of the fact that the female composition in these societies is approximately 5% and recent trainees 0.4% to 2.2%.

Of interest, when examining the four different gender combinations for first and corresponding author (e.g. both male first and corresponding author, both female first and corresponding author, male first and female corresponding author, or female first and male corresponding author), no differences were noted between same gender authors. However, a significant increase in both female first and male corresponding author (4-fold increase from 1985 to 2015) and male first and female corresponding author (6-fold increase from 1985 to 2015) combinations were observed. The former finding is somewhat surprising in that previous studies have shown that women tend to prefer to be mentored by other women [48].

In conclusion, manuscripts in *Spine* over the past 30 years have shown a significant increase in the number of authors, collaborating institutions and countries, printed pages, and references. The recent adoption of a 2,700 word limit for regular manuscripts in *Spine* may decrease the number of printed pages in the future; at this present time there are no limits on the number of authors in *Spine*. Although a significant 70% increase in female first authors occurred from 1995 to 2015, only 17% of first authors in *Spine* in 2015 were female. No differences in percentage of female corresponding authors were observed over time, and in 2015, 14% of corresponding authors were female. However, these percentages are higher than the percentage of women currently listed as active or associate members of NASS and SRS, two societies in which many academic spine surgeons are members. While there is certainly room for improving female authorship in the field, it likely will require recruitment of more females into the field rather than altering practices related to providing those females in the field with authorship opportunities.

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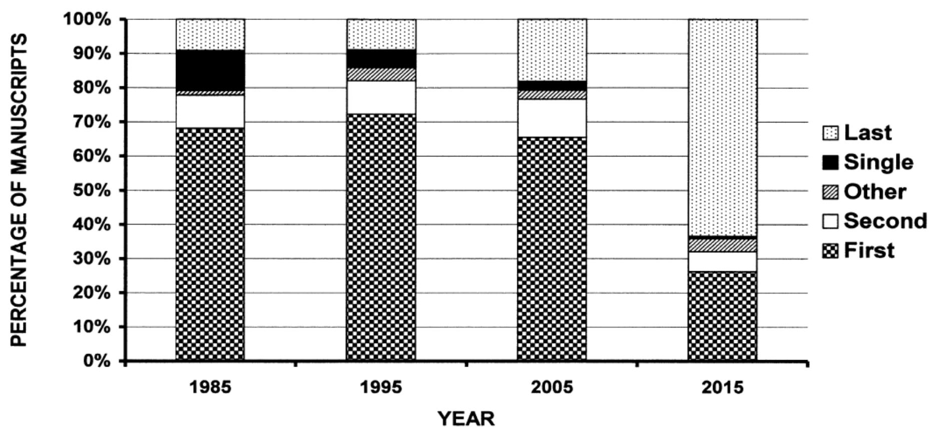
Figure Legends:

Figure 1: Corresponding author position.

A: By year.



B: By geographic region. NA = North America, EU = Europe, AUSNZ = Australia/New Zealand.

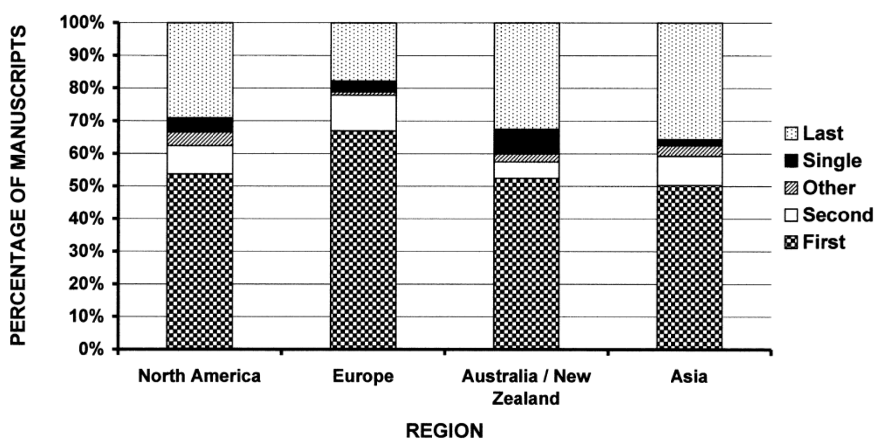


Figure 2: Distribution of manuscripts by state and province in North America.

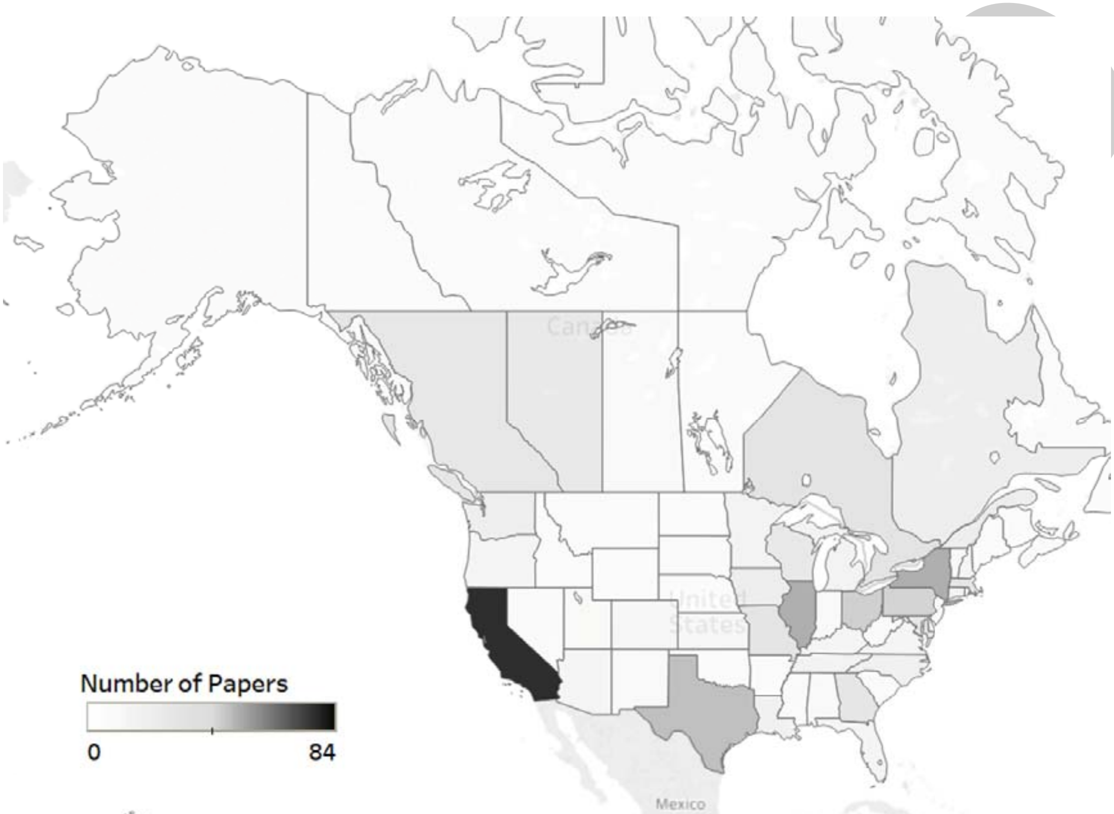
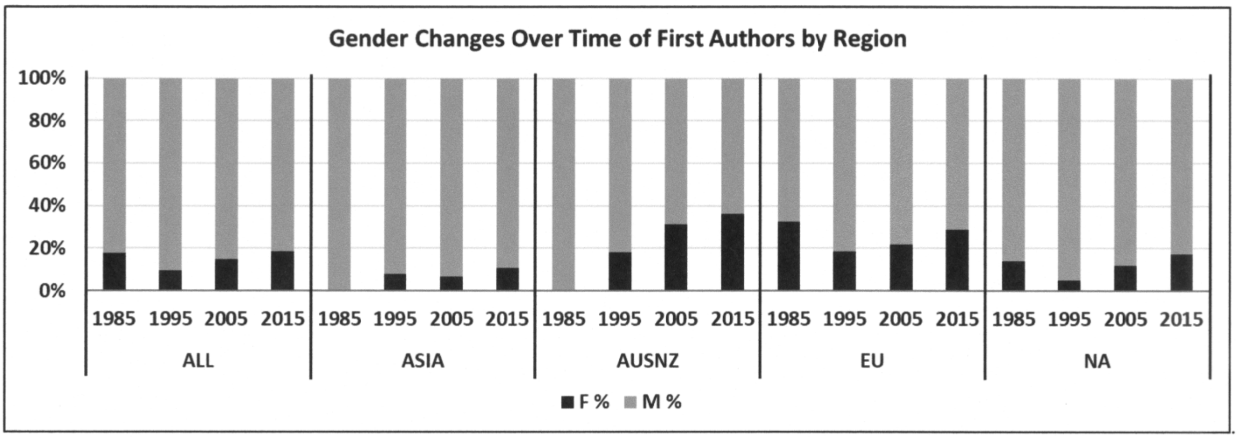


Figure 3. Gender changes over time by region. The percentages indicated are relative to the number of publications in each region by year shown: AUSNZ=Australia/NewZealand, EU=Europe, NA=North America.

A. For first authors.



B. For corresponding authors.

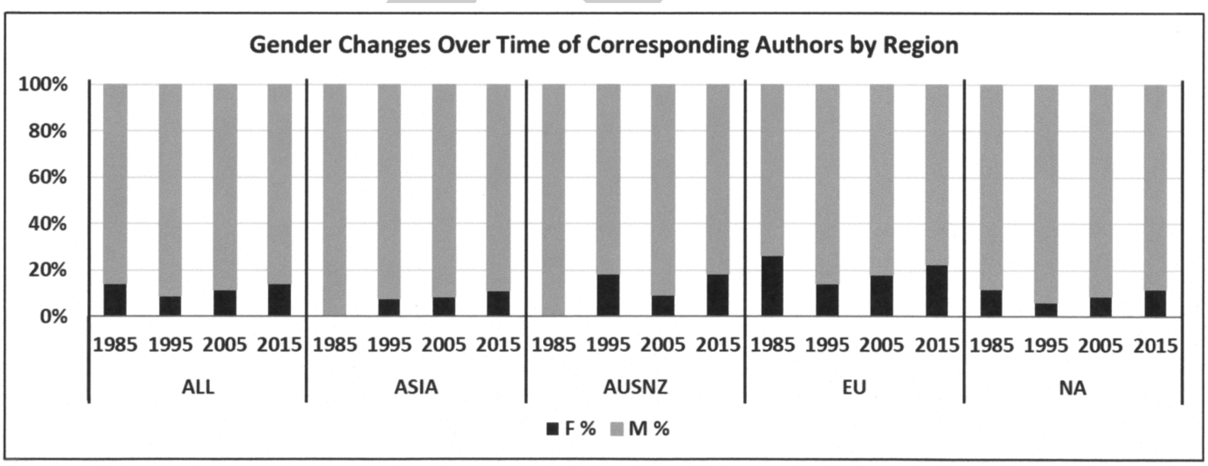


Table 1

Analyses by Region and Changes Over Time

	Publication Year					Region				
Variable	**1985**	**1995**	**2005**	**2015**	**p value**	**North America**	**Europe**	**Asia**	**Australia/ New Zealand**	**p value**
n	154	375	591	446		802	394	325	38	
Author number	3.3 ± 1.7	4.1 ± 1.7	5.1 ± 2.2	6.7 ± 3.0	$<10^{-6}$	5.0 ± 2.8	4.8 ± 2.1	6.1 ± 2.6	4.3 ± 2.2	$<10^{-6}$
Corresponding author position	1.3 ± 0.6	1.4 ± 0.9	1.9 ± 1.8	4.8 ± 3.3	$<10^{-6}$	2.6 ± 2.6	1.9 ± 1.8	3.3 ± 3.1	2.3 ± 2.1	$<10^{-6}$
Number of institutions	1.4 ± 0.7	1.9 ± 1.2	2.1 ± 1.4	3.1 ± 2.3	$<10^{-6}$	2.4 ± 2.0	2.1 ± 1.5	2.1 ± 1.3	2.0 ± 1.2	0.28
Number of countries	1.1 ± 0.3	1.1 ± 0.4	1.2 ± 0.5	1.3 ± 0.9	0.000007	1.2 ± 0.6	1.3 ± 0.7	1.2 ± 0.4	1.3 ± 0.6	0.043
Normalized number of citations	2.80 ± 3.20	3.75 ± 5.40	4.60 ± 5.20	1.97 ± 2.60	$<10^{-6}$	3.75 ± 5.23	3.53 ± 4.04	2.61 ± 3.28	4.24 ± 5.37	0.0012
Number of references	19.4 ± 1.3	26.2 ± 19.8	30.4 ±17.2	30.4 ± 17.8	$<10^{-6}$	28.6 ± 20.1	29.2 ± 17.4	26.4 ± 12.0	31.1 ± 20.6	0.33
Number of pages in paper	4.9 ± 2.5	6.4 ± 2.5	6.4 ± 1.9	7.5 ± 2.8	$<10^{-6}$	6.6 ± 2.5	6.3 ± 2.2	6.5 ± 2.3	7.7 ± 6.0	0.083

Table 2

Gender Combinations of First and Corresponding Authors

	All Years	1985	1995	2005	2015	p value^	p value*
Both 1st and CA female							
Yes	130	18	28	55	29	0.30	0.19
No	1346	136	343	492	375		
% Yes	8.8	11.7	7.5	10.1	7.2		
Both 1st and CA male							
Yes	1300	132	338	483	347	0.28	0.12
No	176	22	33	64	57		
% Yes	88.1	85.7	91.1	88.3	85.9		
1st female, CA male							
Yes	87	9	8	25	45	0.00004	0.000001
No	1389	145	363	522	359		
% Yes	5.9	5.8	2.2	4.6	11.1		

1[st] male, CA female							
Yes	46	4	5	9	28	0.0002	0.000005
No	1430	150	366	538	376		
	3.1	2.6	1.3	1.6	6.9		

CA = corresponding author

* Pearson χ^2 test

^ Cochran linear trend