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Bibliometric Analysis of Female Authorship Trends and Collaboration Dynamics over *JBMR*®'s 30-Year History

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Abstract

In academia, authorship is considered a currency, and is important for career advancement. As the *Journal of Bone and Mineral Research* (*JBMR*®) is the highest-ranked journal in the field of bone, muscle, and mineral metabolism, and is the official publication of the American Society for Bone and Mineral Research, we sought to examine authorship changes over *JBMR*®'s 30-year history. Two bibliometric methods were used to collect the data. The "decade method" included all published manuscripts throughout one year in each decade over the past 30 years starting with the inaugural year, yielding 746 manuscripts for analysis. The "random method" examined 10% of published manuscripts from each of the 30 years, yielding 652 manuscripts for analysis. Using both methods, the average number of authors per manuscript, numerical location of the corresponding author, number of collaborating institutions, number of collaborating countries, number of printed manuscript pages, and the number of times each manuscript was cited all significantly increased between 1986 and 2015 ($p < 10^{-4}$). Using the decade method, there was a significant increase in the percentage of female first authors over time from 35.8% in 1986 to 47.7% in 2015 ($p = 0.02$) and this trend was confirmed using the random method. The highest percentage of female first authors in 2015 was in Europe (60.0%), and Europe also had the most dramatic increase in female first authors over time (more than double in 2015 compared with 1986). However, the overall number of female corresponding authors did not significantly change during the past 30 years. With the increasing demands of publishing in academic medicine, understanding changes in publishing characteristics over time and by geographical region is important. These findings highlight *JBMR*®'s authorship trends over the past 30 years, demonstrate those countries having the most changes, and where challenges still exist.

Keywords

bibliometric; authorship trends; gender; time; country

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Introduction

Although women comprise 49.6% of the world population (1) and many countries have more female than male undergraduate and graduate collegiate students, there are relatively few female full professors in academia (2). Gender inequality in science is still widespread and disparities in hiring and earnings still persist (3). Recently, there has been an increased focus on gender-based trends to examine whether women can break the "glass ceiling," or the invisible gender barriers hindering career development. Previous studies have demonstrated slower career advancement for women in academic medicine compared with their male counterparts (4). Women have made significant gains in the medical profession; in 2014 47% of medical school matriculates and 38% of surgery residents were female (5). Even though the proportion of women entering surgical fields has increased, their advancement in academic surgical positions continues to lag. Women account for less than 30% of clinical faculty across all specialties and for less than 15% of clinical faculty in surgical specialties (6).

As academic institutions worldwide value manuscript publications for career advancement and the tenure and promotion process, it is important to follow authorship trends over time and the extent to which any gender gap still exists. The number of publications for an author is "currency" in the academic profession, and is used to gain admission to medical school/ residency, to compete for funding and research grants, and achieve promotion in academic ranks.

Collaboration is a mutually beneficial relationship entered into by two or more parties to achieve common goals. In the scientific community, the parties are researchers in the same or different departments, and can be at different institutions, states, countries and continents. Interdisciplinary collaboration requires commitment to a definition of goals, yet enables researchers to solve complex, modern, multifaceted issues. Although researchers are competing against themselves for funding while the culture of science has traditionally been more guarded, technology allows researchers to form relationships with mutual respect and trust (7, 8).

The American Society for Bone and Mineral Research or ASBMR is arguably the premiere society for scientists studying bone and mineral metabolism. The ASBMR current membership is approximately 50% female, and its official journal is the *Journal of Bone and Mineral Research* or *JBMR*®. As 2016 was *JBMR®'s* 30th anniversary, it was felt that this would be an excellent time to review *JBMR®* authorship trends over time.

Methods

This bibliometric analysis covers the past 30 years of *JBMR®'s* published manuscripts. Analyses were done in two different ways. The first was a complete analysis of one year in each decade: 1986, 1995, 2005, and 2015. The second was a 10% sample of manuscripts randomly selected from each year. Throughout the remainder of the manuscript the first method of analysis will be termed the decade method and the second the random method. The number of male versus female authors, the percentage of female first authors, and the percentage of female corresponding authors were assessed for each year. The data was grouped by geographic regions, allowing analysis by different parts of the world.

Authorship proliferation and the growing team-based approach to research was also studied. An increasing number of authors per publication may be evidence of increased collaboration (9, 10). As the complexity of multidisciplinary research increases, we would expect that more recent publications involve more authors, institutions, and countries. Finally, academic institutions value not only the quantity of publications, but also the quality of the publications. A measure of the quality of *JBMR®'s* published manuscripts was determined by the number of references used per manuscript, how many times each manuscript has been cited, and how these trends have changed with time.

Details of the Data Collection Processes

The year 2015 was designated as the starting year because it was the most recent year with complete PubMed information as we began collecting data in 2016. Data was collected for each year back to 1986, the inaugural year of *JBMR®*, which afforded a historical analysis. A PubMed search was performed for each year. Editorials, letters, and commentaries were excluded from the search, and the citations for the remaining entries were downloaded into EndNote X7 (Thomson Reuters, New York, NY, 2013). The entries were viewed manually to eliminate those published electronically in the desired year, but not published in hard print until the following year. All entries without authors were excluded, as well as memorandums, meeting notes, and abstracts. The citation data was then exported into Microsoft Excel (Redmond, WA, 2013).

For the decade method of analysis, all manuscripts from each of the years 2015, 2005, 1995, and 1986 were entered in the Excel file. For the random method, 10% of manuscripts were randomly selected for each year from 1986 through 2015. The random selection was performed by giving each manuscript in every year a number. The =RAND() function was used to assign each manuscript a random number greater than or equal to zero and less than 1. Any changes to the spreadsheet caused this function to generate new numbers, so the column with the =RAND() function was copied and then pasted as a value to preserve the initial values produced by the function. Using this random value, the manuscripts were sorted from smallest to largest and the first ten percent of entries for each year were selected for further analysis as described above. Entries that did not meet our criteria for analysis were excluded and the subsequent manuscript was used.

The full names of the first and corresponding authors, as well as the country of origin and state or province for those in the USA or Canada based on institutional affiliation, were collected for all manuscripts. The position of the corresponding author within the author list (e.g. 1,2,3…last author), number of references cited, manuscript length (total page number), and the number of times each manuscript had been cited were tabulated. The manuscript citation number was obtained from a Scopus search.

Author gender was determined for the first and corresponding authors using the method of *Mimouni et. al.* (11). The first name of each author was entered into the "Baby Name

Guesser” at http://www.gpeters.com/names/baby-names.php, which gives the most likely gender and a gender ratio. Any ratio above 3.0 was considered to be correct. When a first or corresponding author’s name resulted in a ratio below 3.0, we performed a Google search to find the web site of the author’s affiliated institution or other articles that referred to the author as male or female. The results of this search were used to assign the correct gender. When such a search did not find the author’s gender, the entry was excluded. Using these criteria, 4.4% percent of first authors and 1.5% of corresponding authors were excluded for the decade method. No manuscripts were excluded for the random method, because another article was randomly selected when either the first or corresponding author gender could not be identified.

Countries were grouped into regions defined by the country of the corresponding author (Figure 1). The USA and Canada were designated as North America. Mexico, Central, and South America were designated as Latin America. The European continent, including Russia and Turkey, was designated as Europe. Asia was defined as all Asian countries west of Turkey yet including the Middle East and Israel. The other regions were Africa, and Australia/New Zealand.

Continuous data are reported as the mean ± 1 standard deviation. Discrete data are reported as frequencies and percentages. Analyses between groups of continuous data were performed using non-parametric tests due to the data having non-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 × 2 tables) and the Pearson’s χ^2 test (greater than 2 × 2 tables). Trends over time for categorical variables were assessed using the Cochran linear trend test. For certain linear trends, the percentages were modeled with linear regression analyses giving the best fit equation with its coefficients, r^2 and p values. For all statistical analyses a $p < 0.05$ was considered statistically significant. Statistical analyses were performed with Systat 10 software™ (Chicago, IL, 2000).

Results

For the decade method, 746 manuscripts met the inclusion criteria: there were 55 from 1986, 237 from 1995, 230 from 2005, and 224 from 2015. For the random method, there were a total of 652 manuscripts.

Analyses by Region

Due to the small number of manuscripts published from Africa or Latin America, these regions were excluded from further analyses. The number of manuscripts from each region was non-uniform in distribution ($p < 10^{-6}$) (Figure 1). For the decade method, the percentage of manuscripts from the 4 major regions was: 56.7% (North America), 26.1% (Europe), 10.6% (Asia), and 5.7% (Australia/New Zealand); for the random method the percentages were 54.9% (North America), 27.3% (Europe), 12.3% (Asia), and 4.5 % (Australia/New Zealand). These percentages were not statistically different ($p = 0.2$). For both methods of analysis, there were no significant differences in percentage by region over time.

The total number of manuscripts published by individual countries and/or states/provinces is shown in Figure 2. For the decade method, manuscripts originating from Asia primarily came from Japan (68.6%), China (10.0%), Israel (8.6%), Korea (7.1%), and Taiwan (4.3%) (Figure 2A). All other Asian countries contributed less than 2% of the publications. For Australia/New Zealand, 88.4% of the manuscripts were from Australia and 11.6% from New Zealand (Figure 2B). For Europe, 20.9% of published manuscripts originated from the United Kingdom, 14.1% from France, 11.5% from Germany, 8.4% from the Netherlands, 7.9% from Italy, 7.4% from Sweden, and 6.8% from Denmark and Finland. All other European countries contributed less than 5% of the manuscripts (Figure 2C). For North America, the United States contributed 92.9% and Canada 7.1%. North America was further divided by state/province. Corresponding authors located in New England and California, followed by Texas and Minnesota, had the highest number of published manuscripts. Specifically, 16.5% originated from California, 9.0% from Massachusetts, 8.3% from New York, 7.5% from Pennsylvania, 7.3% from Texas, and 5.4% from Minnesota. All other states/provinces contributed less than 5% (Figure 2D).

For the random method (Figures 2E–H), the findings were the same, and the p value for differences between the decade and random methods is given at the end of each sentence. Manuscripts originating from Asia primarily came from Japan (68.8%), China (11.3%), Korea (8.9%), Israel (6.3%), and Taiwan (3.8%) ($p = 0.84$). For Australia/New Zealand, 86.2% of the manuscripts were from Australia and 13.8% from New Zealand ($p = 0.8$). For Europe, 28.1% of published manuscripts originated from the United Kingdom, 12.4% from Germany, 10.7% from the Netherlands, 9.6% from France, 6.7% from Italy, 5.6% from Denmark, 4.5% from Finland, and 3.9% from Sweden ($p = 0.5$). For North America, the United States contributed 91.6% and Canada 8.4% ($p = 0.5$). Specifically, 14.4% originated from California, 7.5% from New York, 7.0% from Pennsylvania, 6.4% from Massachusetts, 5.9% from Minnesota, and 5.6% from Texas. All other states/provinces contributed less than 5% (Figure 2H).

Analyses Over Time and Region by Time

Using the decade method, the number of manuscripts published each year increased from 55 in 1986 to 225 in 2015. The average number of authors on each manuscript increased from 4.1 ± 1.6 in 1986 to 8.5 ± 4.2 in 2015 (Figure 3A). The numerical position of the corresponding author increased from 2.3 ± 1.8 in 1986 to 6.3 ± 4.9 in 2015 (Figure 3B). The number of institutions collaborating on manuscripts increased from 1.4 ± 0.6 in 1986 to 3.4 ± 3.1 in 2015 (Figure 3C). The number of countries collaborating on each manuscript increased from 1.1 ± 0.3 in 1986 to 1.6 ± 1.2 in 2015 (Figure 3D). The number of printed pages increased from 7.6 ± 2.2 in 1986 to 10.0 ± 2.6 in 2015 (Figure 3E). To validate the analysis on the number of printed pages, we examined manuscripts in the journals for each of the four years to confirm similar layout and font size. The number of references per manuscript increased from 30.1 ± 10.8 in 1986 to 46.4 ± 2.5 in 2015 (Figure 3F). The number of times each manuscript was cited increased from 30.0 ± 36.0 in 1986 to 50.6 ± 49.8 in 1995 and to 77.0 ± 78.1 in 2005, but dropped to 4.3 ± 5.6 in 2015. Because the 2015 manuscripts have only had one year to be cited, these values were normalized by dividing the number of times cited by the age of the article (1 for 2015, 11 for 2005, 21 for

1995, and 30 for 1986). The results were 1.00 ± 1.20 for 1986, 2.41 ± 2.37 for 1995, 7.00 ± 7.10 for 2005, and 4.29 ± 5.62 for 2015 (Figure 3G). All of these changes over time were significant ($p < 10^{-6}$). The same trends were noted using the random method. Supplementary Table 1 provides a comparison for the continuous variables between the decade and random methods.

Using the decade method of analysis, there were significant differences in the numbers of authors (Figure 4A) (p = 0.002) and corresponding author position by region (Figure 4B) (p = 0.0005). There was a trend (p = 0.056) that the number of collaborating institutions differed by region (Figure 4C). There was a significant difference in the number of countries collaborating on each manuscript by region (Figure 4D) (p = 0.003). Manuscripts originating from Europe had the most country collaborations (1.6 ± 1.2), followed by Australia/New Zealand (1.5 ± 0.9), Asia (1.4 ± 0.7), and North America (1.3 ± 1.0). The number of printed pages differed significantly by region (Figure 4E) (p = 0.018). Those from Asia had the most (9.3 ± 2.6), followed by North America (8.7 ± 2.7), Australia/New Zealand (8.5 ± 2.4), and Europe (8.3 ± 2.2). There were no differences by region of origin for the number of references (Figure 4F) (p = 0.5). The number of times the manuscript was cited using normalized data was 4.5 ± 6.0 for Europe, 4.5 ± 4.1 for Australia/New Zealand, 4.4 ± 5.9 for North America, and 3.3 ± 3.2 for Asia (Figure 4G). Although a trend was observed by region, these changes were not significant (p=0.09).

The results were very similar using the random method of analysis. The corresponding author position varied markedly by region: Asia (5.9 ± 4.0), Europe (3.8 ± 3.8), North America (3.4 ± 3.3), and Australia/New Zealand (2.2 ± 2.4) ($p < 10^{-6}$). The number of countries collaborating on each manuscript by region were Europe (1.6 ± 0.9), North America (1.4 ± 1.2), Australia/New Zealand (1.4 ± 1.1), and Asia (1.3 ± 0.6) (p = 0.001). The number of printed pages also differed; Asia (9.5 ± 2.2), North America (8.9 ± 2.5), Europe (8.5 ± 2.6), and Australia/New Zealand (7.9 ± 2.2) (p = 0.004). There were no differences by region in number of references cited using normalized data (p = 0.3), number of authors (p = 0.7), or number of institutions (p = 0.5).

Corresponding Author Analysis

Using the decade method of analysis, the corresponding author position increased over time (Figure 3B). In 1986, the corresponding author position was 2.3 and increased to 6.3 by 2015 ($p < 10^{-6}$). The results were similar using the random method, and increased from 2.7 in 1986 to 7.4 in 2015 (p = 0.0002).

Using the decade method, the corresponding author was the first author 56% of the time and last author 38% of the time in 1986 (Figure 5). Similar numbers were seen for 1995. In 2005, the percentage of corresponding author as first author dropped to 47% and the last author increased to 48%. This trend continued in 2015, as the corresponding author was first author 32% of the time and last author 68% of the time. In 2015 the corresponding author was always either the last or the first author. Due to the small numbers for each year in the random method the same total numbers were not ascertained regarding first/last positions. However, linear regression analyses over time were performed and documented the same trends (Figure 5).

Gender Distribution of Authors over Time by Region

Using the decade method, there was a significant increase in the number of female first authors over time ($p = 0.003$, Cochran linear trend): 35.8% in 1986, 33.5% in 1995, 37.4% in 2005, and 47.7% in 2015 (Figure 6A). There was a dramatic and significant increase in female first authors over time in Europe ($p = 0.00007$, Cochran linear trend), from 28.6% in 1986 to 60.0% in 2015. Although the data for North America showed an increase in female first authors from 38.5% in 1986 to 46.6% in 2015, this increase was not significant ($p = 0.6$, Cochran linear trend). The data for Australia/New Zealand and Asia were based on small sample sizes and neither proved to be significant. There was an increase in female corresponding authors over time; in 1986, 18.2% of corresponding authors were female, and in 2015, 35.3% were female ($p = 0.03$, Cochran linear trend) (Figure 6B). When broken down by region, there were no significant changes in the percentage of female corresponding authors.

The random method demonstrated the same trends. The number of female first authors increased from 16.7% in 1986 to 50.0% in 2015 ($p = 0.00003$, Cochran linear trend). There was also a significant increase in female corresponding authors from 16.7% in 1986 to 45.8% in 2015 ($p = 0.0005$, Cochran linear trend). Due to the small numbers in the random sampling, differences by region could not be analyzed for each year. We thus created groups of 3 years (1986–1988, 1989–1991, etc). When analyzing using these condensed groups, the trends in differences by region were very similar. There was a significant increase in the number of female first authors over all (29.2% in the years 1986–1988, 46.2% in the years 2013–2015, $p = 0.0005$, Cochran linear trend). The same trend was seen in North America (35.0% in the years 1986–1988, 50% in the years 2013–2015, $p = 0.0001$, Cochran linear trend) and Europe (0% in the years 1986–1988, 55% in the years 2013–2015, $p = 0.03$, Cochran linear trend). Again, the data for Australia/New Zealand and Asia were based on small sample sizes and neither proved to be significant. There was an increase in female corresponding authors from 25.0% in the years 1986–1988 to 38.5% in 2013–2015 ($p = 0.001$, Cochran linear trend). When analyzing by region, there was an increase in female corresponding authors for North America (30.0% in the years 1986–1988, 39.1 % in the years 2013–2015, $p = 0.004$, Cochran linear trend), and a trend for an increase in female corresponding authors in Europe (0% in the years 1986–1988, 45% in the years 2013–2015, $p = 0.053$, Cochran linear trend). Again, for female corresponding authors, the data for Australia/New Zealand and Asia were based on small sample sizes and neither proved to be significant.

Gender Differences by Corresponding and First Author Position

Using the decade method, there was an increasing trend of both female first and corresponding authors. The total percentage of female first authors with female corresponding authors was 15.9%. This increased over time, being 4.5% in 1986, 11.1% in 1995, 13.8% in 2005, and 22.1% in 2015. This trend was borderline significant upon linear regression analysis and can be represented by the equation % per year group = $-776 + 0.40(\text{year})$, $r^2 = 0.89$, $p = 0.055$. For male corresponding and first author positions, there was no significant difference over time. Similarly, there were no differences over time for a male first author having a female corresponding author or vice versa.

Using the random method, there was an increasing trend of both female first and corresponding authors. The total percentage of female first authors with female corresponding authors was 12.3%. This increased over time, being 8.3% in the years 1986–1988, and 20.8% in the years 2013–2015, but was not significant upon linear regression analysis ($p = 0.7$). For male corresponding and first author positions, the total percentage was 50.6%, and decreased over time, from 66.7% years 1986–1988 to 41.7% in the years 2013–2015. This was significant upon linear regression, and can be represented by the equation % per year = 2037 – 0.99(year), $r^2 = 0.61$, $p = 0.007$, where year is 1987, 2000, etc (the midpoint of the 3-year groupings). There were no differences over time for a male first author having a female corresponding author or vice versa.

Differences by Method of Analysis

Bibliometric analyses can be completed by studying each and every year individually, but this is very resource intensive. Can selective techniques be used with similar results? In this study, two different methods were used: 1) Random: sampling 10% of the manuscripts for each and every year, and 2) Decade: all manuscripts for selected years separated by a decade. When comparing the results between the random and decade methods for each of the years 1986, 1995, 2005 and 2015, there were essentially no differences (Supplementary Table 1). Similarly, the trends by region and over time between the two methods were essentially the same, as shown by the many analyses above.

Discussion and Conclusions

Publications carry increasing importance for career development in academic medicine and have become a measure of productivity of one’s scholarly work. To determine if progressive ideas of gender equality have impacted female authorship in the bone and mineral research field, we studied the gender of the first and corresponding author of manuscripts published in *JBMR®* over the past 30 years.

In general, when the first author is not the corresponding author, the first author is typically considered the more junior colleague and completes much of the research and manuscript preparation. Corresponding authors are generally considered those who generated the research idea or in whose laboratory the research was conducted; however, they may not have physically completed the research. These definitions are generalizations, and have varied over time, between specialties/fields, and between countries, but many references support this general concept. These general definitions are the basis for our discussion (12, 13, 14). Here we report that female first authors of *JBMR®* manuscripts have increased across all of the regions studied, and have risen almost 12% over the past thirty years (Figure 6A). When broken down by individual regions, only Europe (both random and decade methods) and North America (random method) demonstrated a significant increase over time. While having manuscripts as first author positively impacts career development in academic medicine, corresponding authorship may be a better indicator of career advancement in academia (15, 16). Our study shows that the percentage of female corresponding authors has almost doubled over the past 30 years, which was significant ($p = 0.03$ – decade method, $p = 0.001$ – random method, Cochran liner trend). While females accounted for 35% of *JBMR®'s* corresponding authors in 2015, 50% of ASBMR members were female.

In 2015, parity in authorship and ASBMR membership between males and females was closer for first author position (47.7%) than corresponding author position (35.3%). This difference mirrors the numbers of females in training or early stages of academic careers versus those in more senior positions. Indeed, in academic medicine, women account for 56% of instructors, 44% of assistant professors, 34% of associate professors, and 21% of full professors (6). The number of female first and corresponding authors has increased over the past 30 years suggesting that upcoming decades will show continued improvement in authorship gender parity.

We also studied if there was a relationship between the gender of the first author and the gender of the corresponding author (when the corresponding author was not also the first author). We looked at this as a possible reflection of whether same-gender mentorship was more prevalent than mixed-gender mentorship, which has been suggested by some (17, 18). Over the past 30 years, *JBMR®* has seen a growing trend in the number of manuscripts having both first and corresponding female authors. The r^2 value was high at 0.89 and significance was almost achieved (p=0.055, decade method). Similarly, a previous study (19), which also demonstrated a disproportionately low proportion of female corresponding authors in academic radiology, found a significant tendency for more junior female physicians to publish with more senior female physicians. Of note, the percentage of *JBMR®* manuscripts with male authors in both the first and corresponding author position did decrease over time (random method) while *JBMR®* manuscripts with opposite genders in the first and corresponding author positions did not change significantly over time. As mentioned above, we assumed the first author to be a mentee of the corresponding author. If the percentage of female first authors is increasing, it can be implied that female authors receive more first author opportunities with female senior authors because the percentage of female first authors with male senior authors has not increased with time. This could be due to junior female investigators seeking out senior female mentors in their academic pursuits or to female senior investigators purposefully seeking to mentor junior female investigators. This may have important implications regarding interventions for decreasing the gender gap and in improving the promotion and/or retention of female researchers in academic medicine, in general, and the bone and mineral research field, in particular. Finding that a gender association appears to exist between female first and senior authors suggests that gender specific mentorship may improve or enable academic career advancement for women.

In addition to examining gender authorship trends in *JBMR®* over the past 30 years, many other variables were examined, such as the relative position of the corresponding author. The percentage of manuscripts with the corresponding author in the first author position has been decreasing, and those with corresponding author in the last author position has been trending upward. The numerical position of the corresponding author has increased almost three-fold since 1986 (Figure 3B). Similarly, the average number of authors has more than doubled over the past 30 years (Figure 3A). With an increasing number of authors listed on each manuscript and of manuscripts with the corresponding author in the last author position, it is understandable that the chronological corresponding author position has increased over time.

The importance of publications for academic career advancement may explain why the number of authors per manuscript is increasing. The drive for academic advancement and the general lack of negative incentives against the inclusion of multiple authors may result in authorship inflation. In support of this idea, a previous study (20) surveyed authors and showed that individuals may accept undeserved authorship to aid in academic promotion. A common reason for the inclusion of additional coauthors was to gain favor or a form of repayment. Authorship implies prestige and credit, but this should come with accountability for the published work. It has been argued that each author must be able to take public responsibility for the contents of a manuscript (21, 22) and that there may be no penalty for including more authors in a manuscript (23, 24). Thus, the increasing number of co-authors on manuscripts may dilute accountability, while not diluting credit. That said, the increase in the number of co-authors, over time, may also reflect the changing approaches to solving problems. Science is much more collaborative today than it was 30 years ago (25, 26).

Over the past 30 years, *JBMR®* has seen an increase in the number of institutions and countries collaborating on studies, suggesting that the degree of domesticity is decreasing over time. By region, Europe shows the most international cross-fertilization and has the largest number of countries collaborating per manuscript (Figure 4D). Although not explored here, this trend may stem from Europeans being able to work in the EU and the free circulation of goods, capital, people, and services within the EU. Additionally, previous studies suggested that the trend in Europe could be explained by clusters of smaller countries that have lower domesticity due to their need to collaborate more externally when compared with larger or more geographically isolated countries (27, 28).

The increasing degree of transcontinental and institutional collaboration can be explained in part by the technological advances seen over the past several decades. Collaboration has become easier as highly integrated and interactive research teams are now able to communicate through telecommunications and video conferencing. Further, advances in computer technologies have improved communications with the use of email, being able to securely transfer data, and being able to more easily search the internet for experts with which one could collaborate. Communication is essential for scientists to work together, as it helps establish, strengthen, and maintain team dynamics. Interdisciplinary efforts are becoming more critical for scientific discovery and this form of close contact enables researchers to trust and share a vision with collaborators in other states, countries, or continents (29). Thus, research continues to progress in an era of multifaceted and difficult problems.

Regarding the geographical location of the corresponding author, manuscripts primarily were contributed by authors from North America and Europe (Figure 1). A closer look at each region (Figure 2) revealed that Japan had the highest output in the Asia region, Australia in the Australia/New Zealand region, the United Kingdom in the Europe region, and the United States in the North America region. Overall, North America had the most manuscripts with California, New York, Pennsylvania, and Massachusetts contributing the most manuscripts. These findings were the same for both methods of analysis. This trend makes sense because these states contain the largest cities with many research-focused academic institutions.

JBMR® is one of the highest impact journal in the bone, muscle, and mineral metabolism field and has reached the top 10 in the field of endocrinology and metabolism. Additionally, *JBMR®*'s impact factor has stayed steady around 6, being 6.527 in 2005 and most recently 6.284 in 2016. As impact factor reflects the number of times that an average manuscript in the journal has been cited in the past two years (30), it is important to note that number of citations/*JBMR®* manuscript increased seven-fold between 1986 to 2005, after normalizing by article age. Even after normalization, however, there is still a marked reduction observed in 2015 compared to 2005. This reduction is reasonable given the short duration of time for each manuscript to be cited, because the publication process often takes more than one year.

Between 1986 and 2015, manuscripts published in *JBMR®* have increased in the average number of authors, collaborating institutions and countries, references, printed pages, citations received, and female first authors. The results were the same for both the decade and random method. There have been significant gender changes over the past 30 years in *JBMR®*. While gender parity has not been achieved for female corresponding authors, increasing numbers of female first authors and women in the field should result in further improvements in the coming years.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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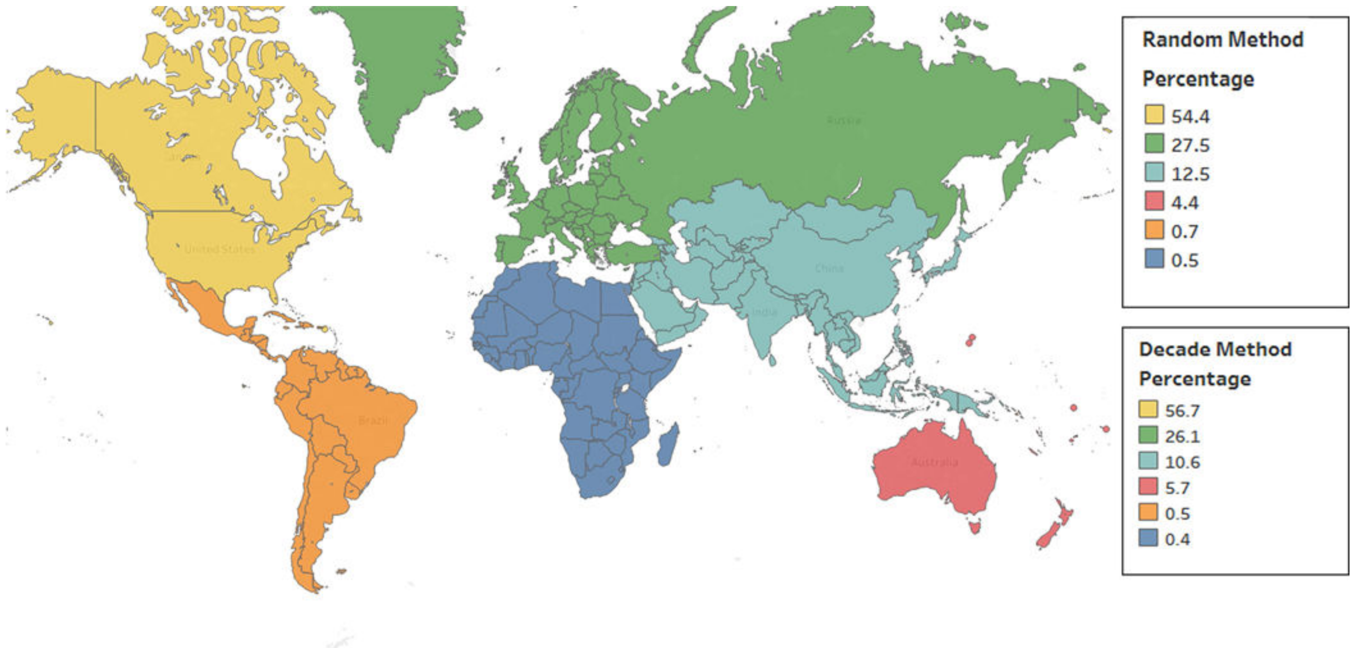

Figure 1.
Countries were separated into six regions for analyses: North America (yellow), Latin America (orange), Europe (green), Africa (blue), Australia/New Zealand (red), and Asia (blue-green). The overall percentage of manuscripts published from each region (all years combined) is noted for both the decade method and the random method.

Figure 2.
Map of **A)** Asia; **B)** Australia/New Zealand; **C)** Europe; and **D)** North America, showing the countries or states/provinces contributing published manuscripts from data obtained via the decade method (upper row). Map of **E)** Asia; **F)** Australia/New Zealand; **G)** Europe; and **H)** North America, showing the countries or states/provinces contributing published manuscripts from data obtained via the random method (lower row). Dark blue shading represents highest percentage of manuscripts published in the country or state/province. White indicates no manuscripts were published in the country or state/province.

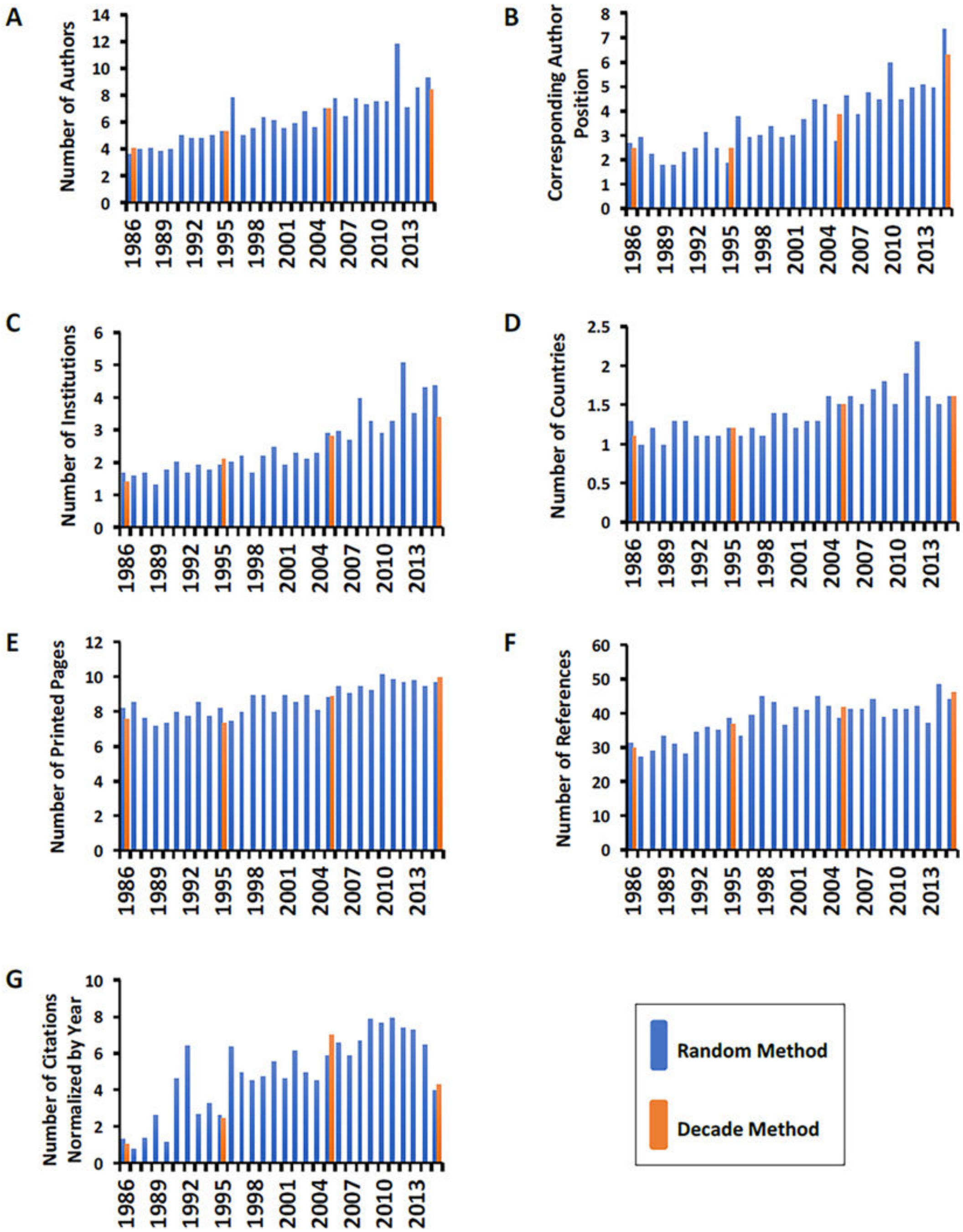

Figure 3.

Trends over time using random (blue) and decade (orange) method. A) Number of co-authors. B) Corresponding author position. C) Number of institutions collaborating on published manuscripts. D) Number of countries from which authors on manuscripts reside. E) Length of published manuscripts. F) Number of references cited within each manuscript. G) Number of times each published manuscript was cited in other manuscripts (normalized based on number of years since publication). Data are presented as the mean. The standard deviation is provided in Supplemental Table 1.

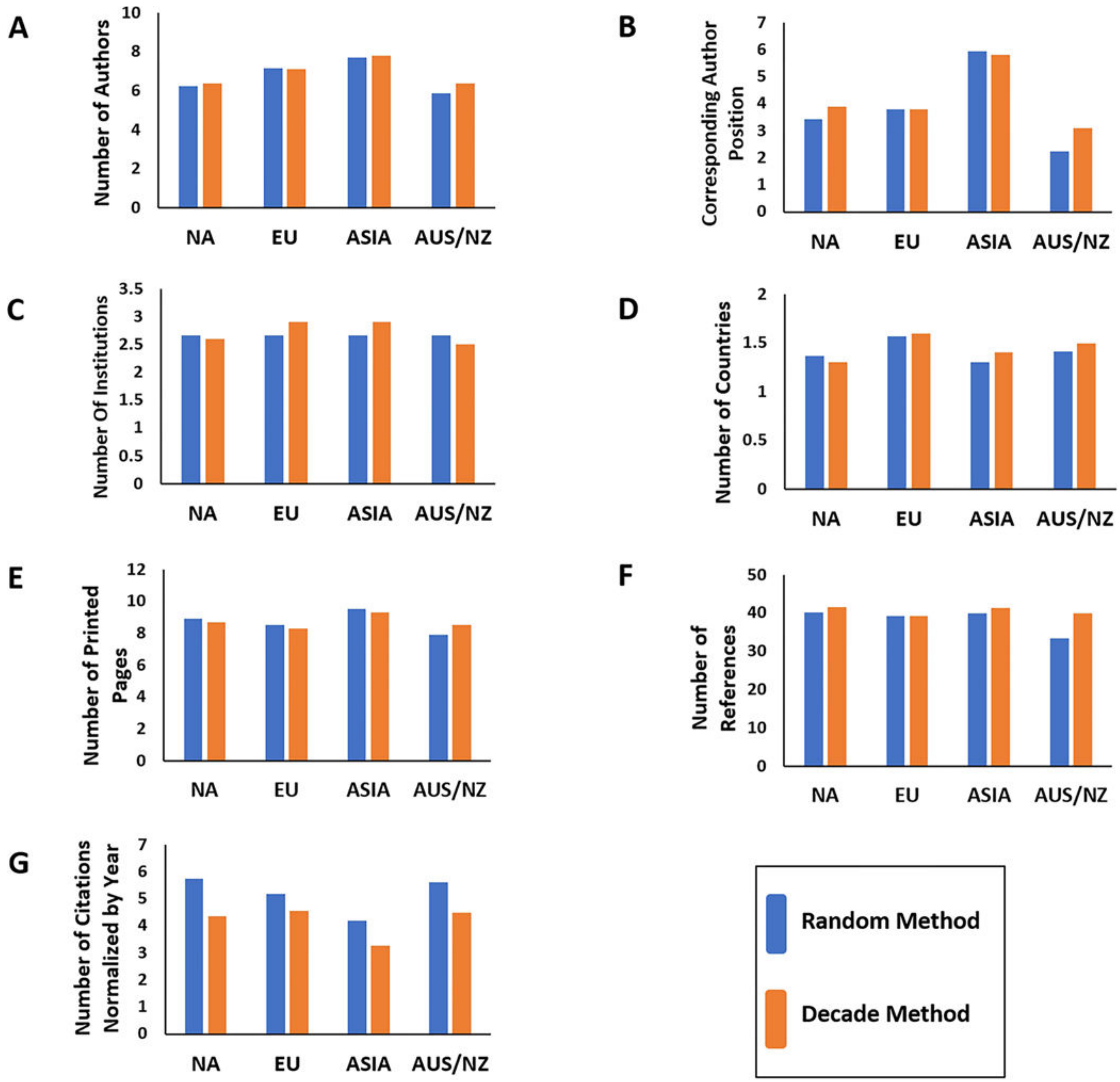

Figure 4.

Trends by region using random (blue) and decade (orange) method. A) Number of co-authors. B) Corresponding author position. C) Number of institutions. D) Number of countries. E) Length of published manuscripts. F) Number of references per manuscript. G) Number of times each published manuscript was cited in other manuscripts (normalized based on number of years since publication). Data are presented as the mean. The standard deviation is provided in Supplemental Table 1. North America = NA, EU = Europe, Aus/NZ = Australia/New Zealand.

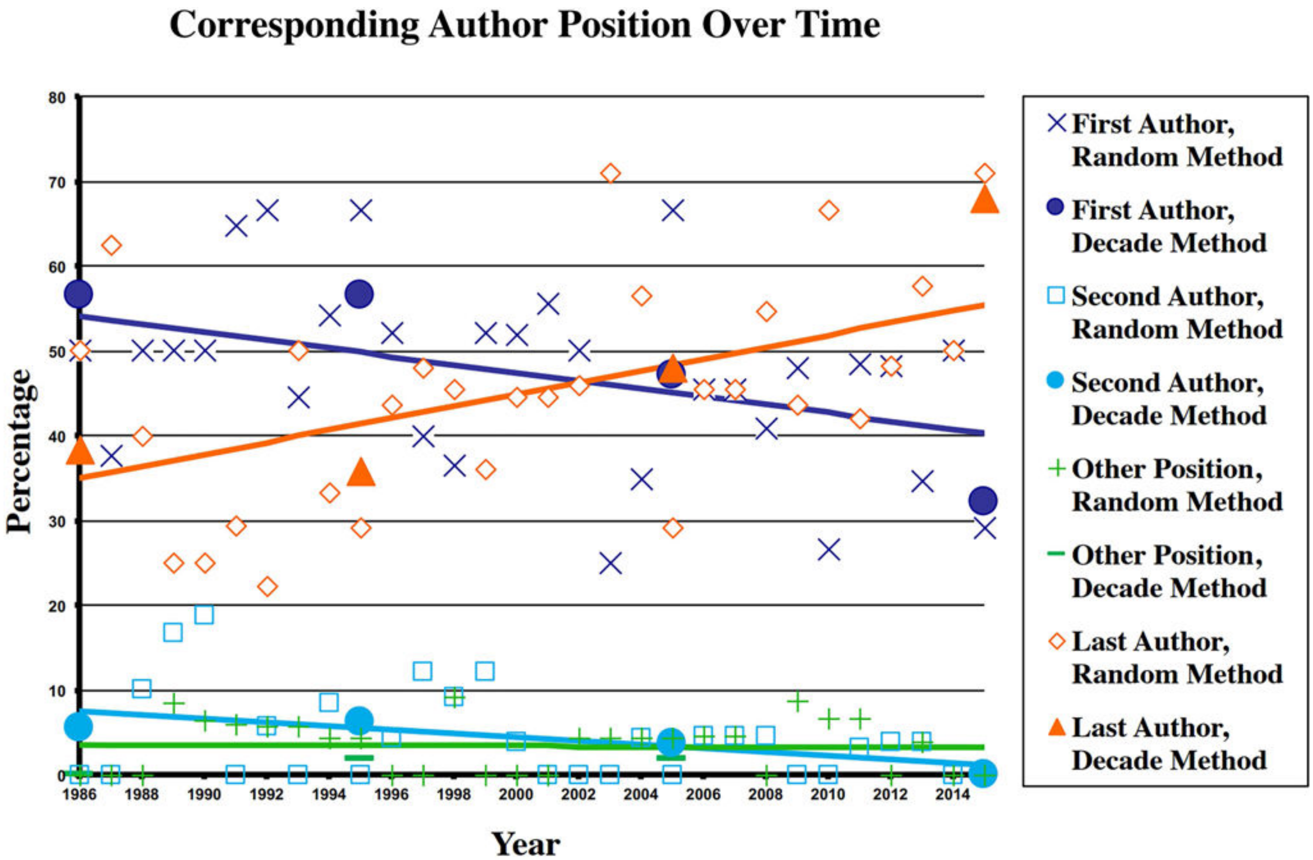

Figure 5.

Changes in corresponding author position. Dark blue represents the corresponding author as the first author; light blue represents the corresponding author as the second author; orange represents the corresponding author as the last author; and green represents any other position. The bold lines represent the best fit line from linear regression analysis using the random data. The large symbols represent the decade method values, and the smaller symbols the yearly data using the random method. For the first author position, the best fit line (dark blue line) is represented by the equation: % = 997.6 – 0.48(year), $r^2 = 0.14$, $p = 0.039$. For the second author position, the best fit line (light blue line) is represented by the equation % = 441 – 0.22(year), $r^2 = 0.13$, $p = 0.046$. For the last author position, the best fit line (orange line) is represented by the equation % = −1360 + 0.70(year), $r^2 = 0.23$, $p = 0.008$. There was no linear change over time for the other author position as seen by the straight green line ($p = 0.89$).

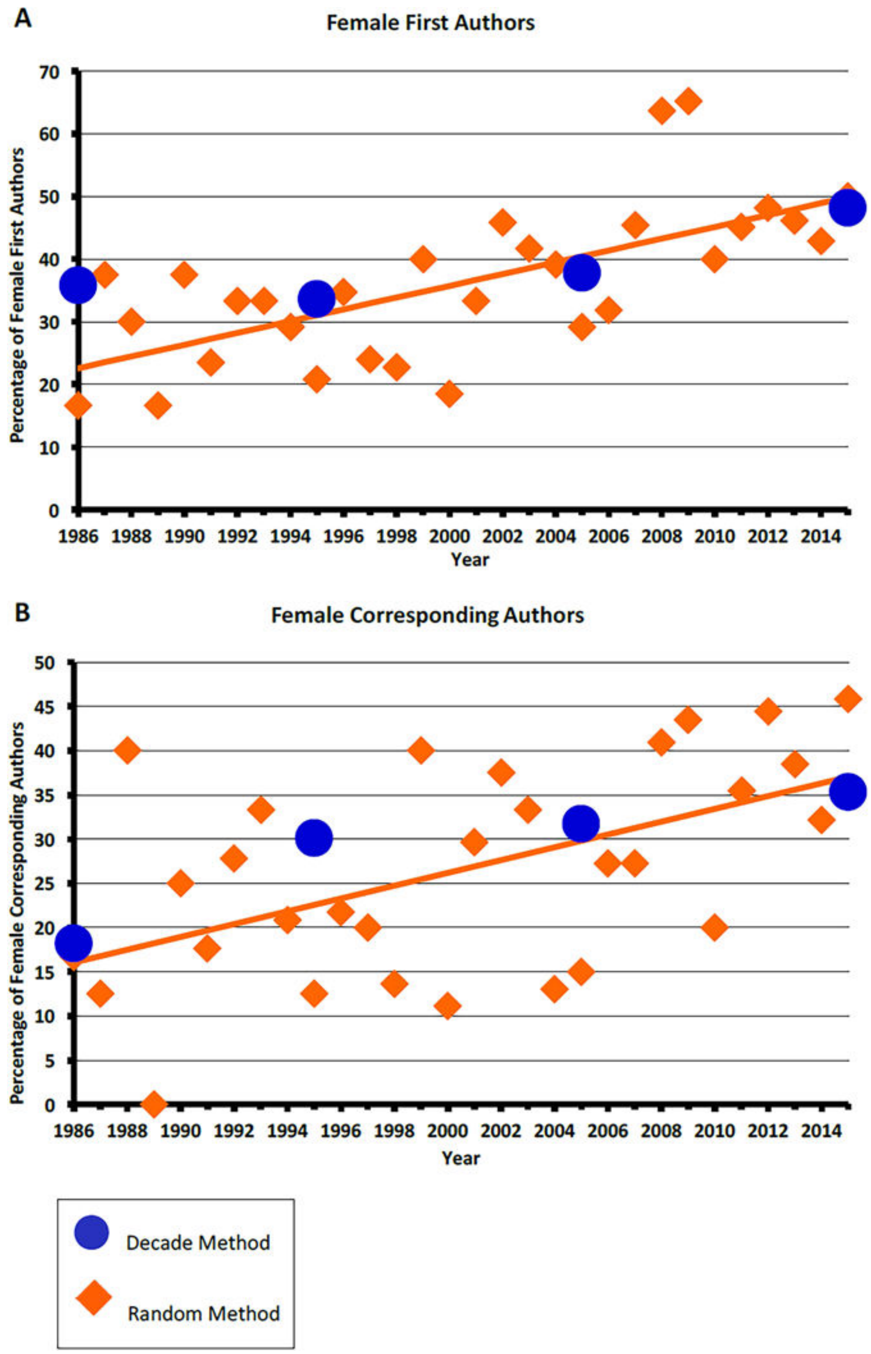

Figure 6.

Changes over time in the percentage of female first (A) and corresponding authors (B). The best fit random method is shown in orange (open triangles the actual data points, solid line the best fit linear regression analysis), and the decade method in gray circles for that respective year. For the random method the best fit linear regression for female first authors is represented by the equation: %female 1^{st} authors = −1844.6 + 0.94(year), $r^2 = 0.45$, p =

0.00005. The best fit linear regression for female corresponding authors is represented by the equation: %female corresponding authors = −1420.4 + 0.72(year), $r^2 = 0.28$, $p = 0.0025$.