Footprint and Imprint

An Ecologic Time-Trend Analysis of Cardiovascular Publications in General and Specialty Journals

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ABSTRACT

Studies have demonstrated strong associations between publication source and citations, as well as investigatory analysis of collaboration effects, in general and medical literature, but are limited to specific journals or short duration of time. This study sought to analyze time trends in cardiovascular research publications in leading general and specialty journals and to determine the association between collaboration and citation index. Cardiovascular publications were retrieved from Web of Knowledge by a cardiovascular bibliometric filter, and annual publication volumes in 8 general and specialty journals were compared. Univariable linear regression models were used to determine global and journal-specific trends for overall publication, cardiovascular publication, proportion of cardiovascular publication, collaboration, and citations. Cardiovascular publications increased (1999 to 2008) by 36% and number of sources by 74%. Volume increased in *European Heart Journal* (beta: 18.4, 95% confidence interval [CI]: 10.6 to 26.3) and decreased in *Circulation* (beta: −42.9, 95% CI: −79.3 to −6.5), *Annals of Internal Medicine* (beta: −1.9, 95% CI: −3.5 to −0.3), and *Lancet* (beta: −11.2, 95% CI: −14.7 to −7.8). Number of contributing countries increased in 3 journals: *BMJ* (beta: 0.8, 95% CI: 0.2 to 1.5), *European Heart Journal* (beta: −1.2, 95% CI: 0.8 to 1.7), and *New England Journal of Medicine* (beta: 1.6, 95% CI: 0.6 to 2.7). Fraction of collaborative publications increased (beta: 1.1 to 2.9) in all but *Annals of Internal Medicine*. Collaboration was associated with a higher median actual citation index ($p < 0.0001$). We found increasing trends in collaboration and citation in both general and specialty journals. Contribution by country in selected journals was disproportionate and under-represents total cardiovascular research in low- and middle-income countries.

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Scientific publication in peer-reviewed journals has been increasing over the past several decades [1]. The introduction of electronic-based publishing and open source journals further allows for expansion of the field and may partially alleviate pressure to publish in top-ranked and peer-reviewed journals. Previous studies have shown perception and recognition of research, through subsequent citations, is primarily associated with source of publication and journal impact factor, a metric that does not reflect individual quality of a publication [2–4]. Collaboration in research has demonstrated benefits in knowledge sharing, is increasingly more feasible, and has been found to be more prevalent in medical literature [5,6]. Our objectives were to analyze time trends in cardiovascular research publication quantity (footprint) in leading general and specialty journals and to determine the association between collaboration and citation index as a measure of quality (imprint). We also aimed to compare and contrast these measures by international collaboration on publications.

MATERIALS AND METHODS

Data collection

We have developed a cardiovascular bibliometric filter of search terms to extract cardiovascular publications from Thomsen Reuters' Web of Knowledge (WOK) with >90% precision (specificity) and >90% recall (sensitivity) through iterative testing [7]. The filter was applied to a search of WOK. We included all articles, reviews, and conference proceedings published in the 10 most recent years with 5 full years of citations available, which reflects publications from years 1999 through 2008 [8]. Cardiovascular publications retrieved from WOK were batch processed and consolidated to master files for each year. Citation reports were matched with retrieved cardiovascular publication records. Records were excluded from analysis if no citation report was matched or if the addresses of authors could not be determined from the downloaded record.

We calculated actual citation index (ACI) for each cardiovascular publication as the average of running 5-year post-publication citation counts, including year of publication. We extracted publication data for 201 countries from addresses of all contributing authors. We assigned integer counts to each country contributing to a particular cardiovascular publication and assigned fractional (complete-normalized) counts on the basis of the relative contribution of a country toward publication of a paper. Number of unique addresses by country is weighted to the total number of unique addresses contributing to the publication [1]. For example, the authors of this

manuscript are affiliated with 3 institutions, 2 in the United States and 1 in India. The fractional counts for this publication would be 0.67 (United States) and 0.33 (India). Collaborative status of each cardiovascular publication was indicated where 2 or more unique countries contributed. Authorship and country contribution were not weighted on the basis of position.

We selected 8 journals as exemplars of trends in cardiovascular research publications on the basis of prominence in either general medical or cardiovascular literature: *Annals of Internal Medicine, British Medical Journal (BMJ), Circulation, European Heart Journal, Journal of the American College of Cardiology (JACC), JAMA: Journal of the American Medical Association (JAMA), The Lancet,* and *New England Journal of Medicine (NEJM)*. For comparison with cardiovascular publication data in these journals, we further retrieved publicly available indicators, namely impact factor (IF) and total publications per year, from Thomson Reuters Journal Citation Reports [9].

Statistical analysis

Linear regression models were used for all time trend analysis. Time was scaled such that intercepts predict values for 1999 and beta coefficients represented predictive values for each successive year. Model fit was assessed by analysis of trends in residuals. We first determined global trends in cardiovascular research volume and publication sources through univariable regression of all complete records from the cardiovascular bibliometric search of WOK by year [8]. Journal-specific models were then constructed to analyze trends in overall publication, cardiovascular publication, and proportion of cardiovascular to overall publication for general medical journals.

We estimated global trends in numbers of countries with authors of cardiovascular publications through a linear model including all complete records from the cardiovascular bibliometric search of WOK [8]. Journal-specific models were then constructed to analyze trends in authorship by country. Fractional counts for each country were summed by year and journal and were converted to proportion of total authorship. Proportional authorship by year and journal was ranked to identify changes and patterns. Proportional authorship by country was compared between these selected journals and all cardiovascular publications. Trends in collaboration among all cardiovascular publications and by journal were estimated by univariable linear models. We calculated statistical significance of differences in ACI between collaborative and single-country publications using nonparametric Wilcoxon rank sum test. Statistical analysis was carried out using SAS (version 9.3, Cary, North Carolina). All tests for significance were completed with 2-sided alpha < 0.05.

Ethics

This analysis did not meet criteria for research on human subjects. No institutional review board approval was sought.

RESULTS

All cardiovascular publications

We extracted 465,120 records and 450,052 citation reports from WOK. Complete records were retained with matched citations reports to total 430,712 publications used in analysis from 7,276 unique sources (Table 1). Naïve univariable linear regression of year on total cardiovascular publications indicates an annual increase of 1,697 (95% confidence interval [CI]: 993 to 2,401) publications between 1999 and 2008. Analysis of residuals indicated improved model fit with addition of a quadratic term, suggesting exponential growth of cardiovascular publications by year ($beta_{year}$: −1123, 95% CI: −2251 to 5; $beta_{year^2}$: 313, 95% CI: 193 to 434). Similar results were found in univariable analysis of the number of publication sources by year; model fit again improved with the inclusion of a quadratic term ($beta_{year}$: −152, 95% CI: −298 to −6; $beta_{year^2}$: 37, 95% CI: 21 to 52) in the model (Online Table 1). From 1999 to 2008, volume of cardiovascular publications increased by 36%, and the number of sources increased by 74%.

Annual publication data by journal

We used 8 (3 specialty and 5 general) exemplar journals to evaluate trends in publications over the past decade (Online Table 2). Figures 1A and 1B demonstrate trends in overall publications (1999 to 2008) and those captured with our cardiovascular bibliometric filter over the same period. Our filter retrieved 19,826 cardiovascular publications from these selected journals, of which 95.3% (18,899) had a complete address and citation report. From 1999 to 2008, total publication volume increased in only 1 journal (*European Heart Journal* [beta: 20.2, 95% CI: 11.5 to 28.9]), remained unchanged in 1 journal (*JACC* [beta: −0.8, 95% CI: −12.6 to 10.9]), and decreased in all others (*Annals of Internal Medicine* [beta: −6.7, 95% CI: −9.8 to −3.7], *BMJ* [beta: −55.3, 95% CI: −71.5 to −39.0], *Circulation*

TABLE 1. Cardiovascular publications retrieved and retained from Web of Knowledge by cardiovascular bibliometric filter

Year	Publications Downloaded From Web of Knowledge	Citations Downloaded From Web of Knowledge	Final Matched Records
1999	40,661	40,254	37,849
2000	41,603	41,408	39,876
2001	41,306	40,171	38,996
2002	41,891	41,214	37,881
2003	43,490	42,489	40,034
2004	44,656	43,676	41,685
2005	46,864	45,440	43,091
2006	47,929	47,680	45,257
2007	52,437	52,437	51,584
2008	55,284	55,284	54,459
Total	456,121	450,052	430,712

[beta: −41.4, 95% CI: −78.8 to −4.0], *JAMA* [beta: −18.6, 95% CI: −26.6 to −10.6], *Lancet* [beta: −78.5, 95% CI: −109.0 to −47.9], and *NEJM* [beta: −6.6, 95% CI: −13.0 to −0.2]). The proportional change in overall (cardiovascular and noncardiovascular) publication volume between 1999 and 2008 ranged from −73.9% (*Lancet:* 1,108 publications in 1999 to 289 in 2008) to 65.4% (*European Heart Journal*: 179 publications in 1999 to 296 in 2008).

We found similar trends in cardiovascular publications alone. Publication volume increased between 1999 and 2008 in *European Heart Journal* (beta: 18.4, 95% CI: 10.6 to 26.3), remained unchanged in *JACC*, and decreased in *Circulation* (beta: −42.9, 95% CI: −79.3 to −6.5). Among general journals, both *Annals of Internal Medicine* (beta: −1.9, 95% CI: −3.5 to −0.3), and *Lancet* (beta: −11.2, 95% CI: −14.7 to −7.8) published fewer cardiovascular research publications over 1999 to 2008, whereas cardiovascular publication trends in *BMJ*, *JAMA*, and *NEJM* did not change. The proportional change in cardiovascular publication volume between 1999 and 2008 ranged from −67% (*Lancet:* 138 publications in 1999 to 46 in 2008) to 68% (*European Heart Journal*: 169 publications in 1999 to 284 in 2008).

We further estimated trends in the proportion of cardiovascular publications to overall publication volume for general journals. The proportion ranged from 6% (*BMJ*, 1999) to 34% (*JAMA*, 2007) and suggested an increase over time. However, when tested by linear regression, the proportion of cardiovascular publications to total publications increased only in *JAMA* (beta: 1.7, 95% CI: 0.6 to 2.7).

Authorship by country

Among all 8 journals, 97 countries (31 high-income Organization for Economic Cooperation and Development [OECD], 12 high-income non-OECD, 33 upper-middle income, 12 lower-middle income, and 9 low-income) contributed toward ≥1 cardiovascular publication over the study period [10,11]. The number of countries contributing to cardiovascular publications increased between 1999 and 2008 (beta: 1.5, 95% CI: 0.4 to 2.6). The number of countries contributing to cardiovascular publications ranged from 8 (*JAMA*, 2001, and *Annals of Internal Medicine*, 2008) to 45 (*Circulation*, 2007). We found statistically significant increases by year in the number of authors from different countries contributing to a cardiovascular publication in *BMJ* (beta: 0.8, 95% CI: 0.2 to 1.5), *European Heart Journal* (beta: 1.2, 95% CI: 0.8 to 1.7), and *NEJM* (beta: 1.6, 95% CI: 0.6 to 2.7) (Online Table 3).

Proportions of summed fractional counts to total number of cardiovascular publications were used to rank the relative contribution of each country toward annual publications in each journal (Table 2). Within selected journals, 13 countries hold the top 3 ranks (including ties) for annual publication volume, all of which are classified high-income OECD by the World Bank [10,11]. Over all 8 journals and 10 years, the top 3 ranked countries for fractional contribution were the United States (43.3%), the United Kingdom (8.9%), and Germany (7.8%). Contributions from upper-middle—income countries primarily are from China and Taiwan, combined accounting for 50% of total authorship among their income group. Brazil, Argentina, and South Africa are the only other countries in this income group accounting for more than 5% of the group authorship. India accounts for 51% of the total authorship in lower-middle—income countries.

High-income OECD countries accounted for 97.8% of the authorship among these journals during this time. Only 2.0% of the authorship was by upper-middle—income countries, and the remaining 0.2% was distributed among other income groups. Within the entire set of cardiovascular publications from WOK, fractional authorship is 87.8% from high-income OECD; 0.7% from high-income non-OECD; 8.8% from upper-middle—income countries; 1.2% from lower-middle—income countries; and 0.1% from low-income countries. Publications with authors from high-income OECD and low-income countries composed a

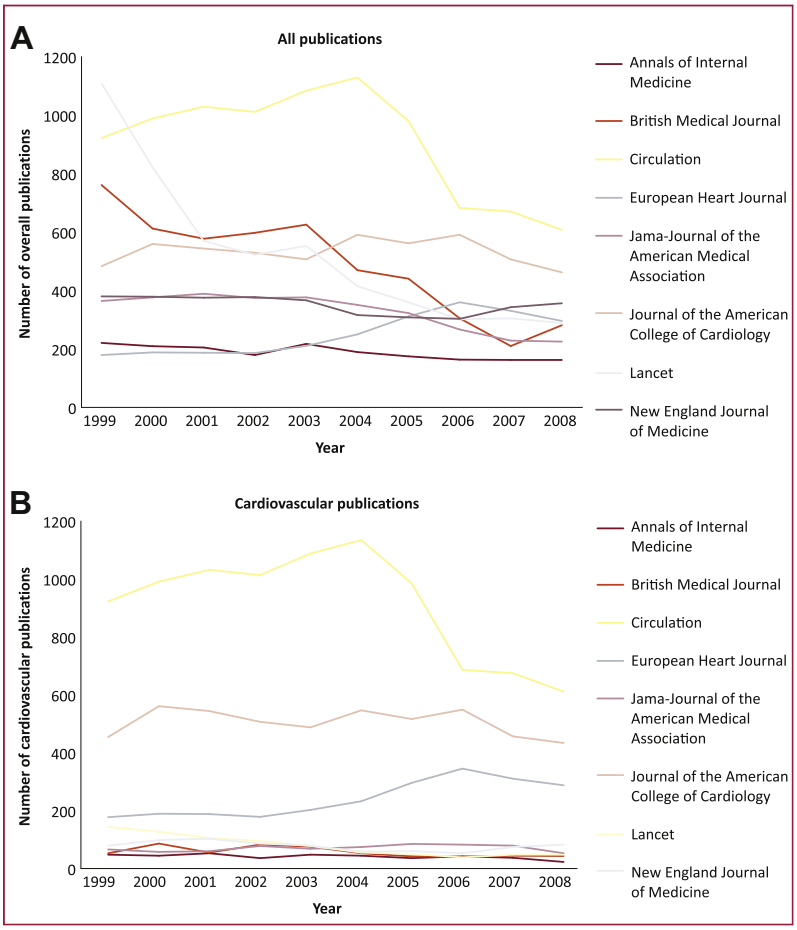

FIGURE 1. Annual publication volumes. Volumes by year and journal of all publications (A) and cardiovascular specific articles, reviews, and conference proceedings (B). All publications information retrieved from the Thomsen Reuters database. Cardiovascular publications retrieved from Web of Knowledge by cardiovascular bibliometric filter.

TABLE 2. Annual percentage of publication volume by authors from top contributing countries

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Annals of Internal Medicine										
1st	67.7 (US)	70.3 (US)	66.4 (US)	62.3 (US)	69.3 (US)	68.1 (US)	74.7 (US)	57.2 (US)	66.7 (US)	60.1 (US)
2nd	8.4 (IT)	10.3 (CA)	13.4 (CA)	6.4 (NL)	15.6 (CA)	7.8 (CA)	11.4 (CA)	8.1 (CA)	15.3 (CA)	11.1 (UK)
3rd	4.2 (JP & DE)*	5.2 (JP)	3.9 (CH & NL)*	4.7 (UK)	4.9 (NL)	5.5 (UK)	4.3 (UK)	6.3 (FR)	4.4 (UK)	10.7 (CA)
BMJ—British Medical Journal										
1st	68 (UK)	77.9 (UK)	61.8 (UK)	80.1 (UK)	59.6 (UK)	70.8 (UK)	47.4 (UK)	54.4 (UK)	65.6 (UK)	44 (UK)
2nd	9.9 (CA)	4 (US)	9.1 (CA)	6.4 (US)	14.5 (CA)	12.9 (US)	13 (CA)	8.3 (DK)	10.7 (US)	16 (US)
3rd	4.3 (CH & DK)*	3.3 (CA & NZ)*	7.2 (US)	3.8 (AU)	7 (US)	4.6 (CA)	6.3 (US)	7.8 (US)	7.5 (CA)	6.8 (NL)
Circulation										
1st	45.2 (US)	48 (US)	49.7 (US)	47.3 (US)	50.2 (US)	46.3 (US)	52.6 (US)	54.1 (US)	53.7 (US)	55.4 (US)
2nd	8.2 (DE)	9.2 (DE)	8.5 (DE)	9.2 (JP)	9.4 (DE)	8 (DE)	7.9 (DE)	6.8 (DE)	7.2 (UK)	6.9 (DE)
3rd	8.1 (JP)	7.7 (JP)	7.8 (JP)	8.3 (DE)	6.7 (JP)	6.7 (JP)	6.6 (UK)	5.8 (UK)	7.1 (DE)	5.7 (UK)
European Heart Journal										
1st	17.9 (UK)	21.6 (UK)	20.4 (UK)	19.3 (UK)	15.5 (UK)	12.3 (DE)	15.1 (DE)	15.4 (DE)	14.5 (US)	14.1 (DE)
2nd	11.8 (SE)	13.3 (DE)	15.2 (IT)	14.2 (NL)	10.6 (DE)	11.9 (IT)	13.3 (IT)	13.7 (US)	12.3 (DE)	13.4 (US)
3rd	11.4 (DE)	8.5 (NL)	12.3 (DE)	10.6 (IT)	10.5 (US)	11.3 (UK)	10.5 (US)	13.3 (IT)	10.2 (UK)	10.9 (UK)
JAMA—Journal of the American Medical Association										
1st	85 (US)	82.4 (US)	78.1 (US)	75.5 (US)	74 (US)	66.1 (US)	60.7 (US)	64.9 (US)	63.9 (US)	68.6 (US)
2nd	6.2 (CA)	4.4 (DE)	8.2 (CA)	7.2 (CA)	5.6 (CA)	8.2 (CA)	9.8 (CA)	8.3 (CA)	12.8 (CA)	7 (NL)
3rd	4.4 (IT)	3 (CA)	4.4 (NL)	3.3 (NL)	3.1 (FR)	7.5 (IT)	4.6 (DE)	5.2 (NL)	2.8 (DE)	4.8 (UK)
Journal of the American College of Cardiology										
1st	48.4 (US)	47.9 (US)	43.6 (US)	42.3 (US)	43.8 (US)	52.4 (US)	47.2 (US)	48.6 (US)	49.7 (US)	52.1 (US)
2nd	8 (DE)	8.3 (JP)	12.6 (JP)	8.7 (JP)	7.9 (DE)	6.4 (DE)	7.9 (JP)	7 (IT)	6.1 (UK)	5.9 (DE & IT)*
3rd	7.7 (JP)	8 (DE)	7.9 (DE)	8.3 (DE)	7.7 (JP)	5.6 (JP)	7.4 (IT)	6.8 (NL)	5.6 (IT)	5.7 (UK)
Lancet										
1st	23.9 (UK)	27.4 (UK)	23.2 (UK)	29.2 (UK)	27.6 (UK)	31.6 (UK)	37.3 (UK)	26.4 (US)	37 (US)	21.1 (US)
2nd	15.2 (US)	13.7 (US)	18.7 (US)	20.4 (US)	20.4 (US)	21.4 (US)	17.7 (US)	17.7 (CA)	16 (UK)	15.6 (UK)
3rd	11.9 (DE)	9.7 (DE)	10.5 (NL)	6.4 (DE)	11.1 (DE)	9.2 (DE)	5.9 (SE)	11.2 (UK)	8 (JP)	11.4 (CA)
New England Journal of Medicine										
1st	62.3 (US)	65.4 (US)	63.7 (US)	53.4 (US)	54.9 (US)	54.9 (US)	60.7 (US)	47.2 (US)	49.3 (US)	51.1 (US)
2nd	8.8 (CA)	7.3 (CA)	7.1 (CA)	7.5 (UK)	7.5 (CA)	9.1 (CA)	10 (UK)	9.9 (CA)	13.5 (UK)	9.3 (UK)
3rd	6.1 (IT)	4.1 (DE)	5.2 (DE)	7.3 (DE)	5.9 (IT)	5.1 (DE)	5.2 (NL)	6.8 (DE)	5.1 (FR)	7.4 (CA)

AU, Australia; CA, Canada; CH, Switzerland; DE, Germany; DK, Denmark; FR, France; IT, Italy; JP, Japan; NL, Netherlands; NZ, New Zealand; SE, Sweden; UK, United Kingdom; US, United States.

*Denotes a tie for rank.

slightly higher proportion of total volume within these selected journals than in comparison with all sources. Upper-middle—income countries had consistently lower proportion of total volume in these selected journals in comparison with all sources (Online Figs. 1A to 1C).

Collaboration and citations

Of 18,899 publications in our analysis, the proportion of collaborative publications ranged from 25% (1999) to 52% (2008) by year. The fraction of collaborative cardiovascular publications increased (beta: 1.1 to 2.9) by year in all selected journals with exception of *Annals of Internal Medicine* (Fig. 2, Online Table 3). The proportion of publications from 2 or more countries ranges from 9.5% (*Annals of Internal Medicine*, 2000) to 54.4% (*Lancet*, 2008). Along with increases in collaboration, we found increases in the median ACI among all journals that correlate with increases in impact factor (Table 3). By Z approximation of Wilcoxon rank sum test, we found the median ACI of a collaborative cardiovascular publication was significantly higher (Z score: 17.69, $p < 0.0001$) than that of one authored in a single country.

DISCUSSION

Summary of results

Over a study period of 1999 to 2008, we found that research publication volume in 8 exemplar cardiovascular specialty and general medical journals decreased over time.

Our bibliometric filter, however, retrieved larger volumes each successive year and suggested exponential increases in cardiovascular publications. We found the number of sources for cardiovascular publications likewise increased during this time and at a higher proportion (36% vs. 75%).

Trends in cardiovascular publication among these 8 journals were comparable. We found that cardiovascular publication as a proportion of total volume increased by 28% in *JAMA* and remained steady in all other general medical journals. Although volume decreased and proportion remained steady, we found statistically significant increases in the number of countries represented in cardiovascular publications at *BMJ*, *European Heart Journal,* and *NEJM*. We also found significant increases in proportion of collaborative publication in all journals except *Annals of Internal Medicine*. Collaborative articles were statistically significantly associated with higher median ACI. This finding is consistent with results from a previous study of *NEJM, JAMA,* and *Lancet* articles published in 1999 and 2000, which found that group authorship was associated with an absolute 11.1 (95% CI: 2.7 to 19.5) higher annual citation rate [12].

Reasons for publication trends

These results suggest the increase in cardiovascular publication volume may be a result of increases in the number of sources or changes in policy at journals for classifying countable items [13]. The decreases we observed may be attributable to changes in journal policy and practice, such as movement to online publications, reduction in frequency of issues, and launch of specialty publications under parent journals. For example, decreases in overall publication volumes at *Lancet* may be directly attributable to the launch of 3 specialty journals during this time: *Lancet Oncology* (2000), *Lancet Infectious Diseases* (2001), and *Lancet Neurology* (2002). Other changes in publication volumes may be attributed to turnover of editorial staff. Dr. Joseph Loscalzo was appointed editor of *Circulation* in 2004, and Dr. Fiona Godlee was appointed editor-in-chief of *BMJ* in 2005. Both time points correlate with changes in overall publication volumes at their respective journals.

The observed decreases in total publication and cardiovascular publication volumes are not a result of decreasing quality among these journals as measured by citations and IF. Within all included journals, the relative size of ACI and IF increased over the study period, perhaps suggesting trends of increasing selectivity and higher quality of publications.

Comparison by income group

We found that proportion of collaboration in cardiovascular publications increased in parallel with ACI. Additional analysis may further delineate whether these results are causal or confounded by publication in journals with high IF. Trends in collaboration have been reported by both medical and general science studies and have even been quantified by mathematical models for collaboration networks [6]. Estimates of collaboration proportion in publications range from 34% to 43% and are encompassed by the results found in our study (25% to 52%) [5].

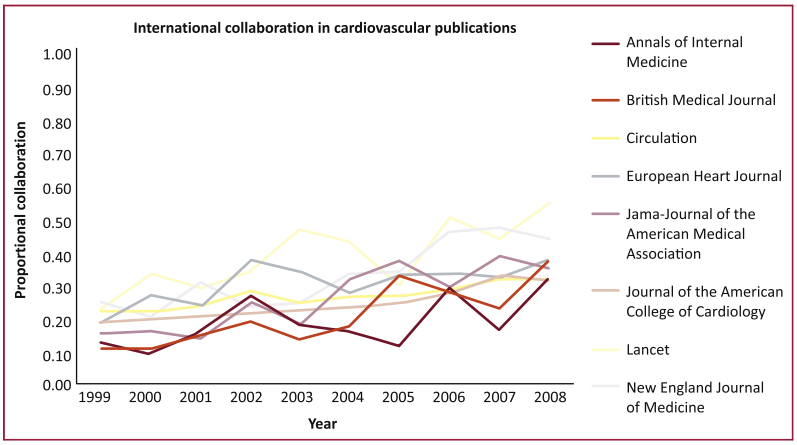

FIGURE 2. Collaboration in cardiovascular publications. Percentage of all cardiovascular publications authored in 2 or more countries, by year and journal.

The vast majority (97.8%) of cardiovascular publications in this analysis were authored, at least in part, by individuals from high-income OECD countries, a consistent finding in previous bibliometric analyses and other fields, including epidemiology [14–18]. The remainder was largely accounted for by upper-middle–income countries (Argentina, Brazil, China, Taiwan, and South Africa) and by a small fraction by a lower-middle–income country (India).

We found that in comparison to all sources, among these selected journals, high-income and low-income countries were published at higher rates, and upper-middle– and lower-middle–income countries were published at lower rates. During this same period, upper-middle–income countries had some of the highest relative growth in total publication volume. These results suggest that while collaboration is increasing in exemplar journals, representation by country in these selected journals is slightly disproportionate from the distribution of all cardiovascular research (87.8% high-income OECD, 8.8% upper-middle–income countries, and 1.2% lower-middle–income countries).

These results support the need to strengthen and improve the interface with research programs in upper-middle– and lower-middle–income countries. Sustained investments are required to develop a pipeline of trainees and mentors who can formulate research questions, execute studies, and disseminate findings through peer-reviewed publications.

Near the endpoint of this study (2008), several initiatives were launched to increase the capacity for chronic disease research in low- and middle-income countries. For example, the Global Alliance for Chronic Disease evolved from an announcement (November 2007) of the Grand Challenges

TABLE 3. Annual journal impact factor and citations from cardiovascular publications

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Annals of Internal Medicine										
Impact factor	10.10	9.83	11.13	11.41	12.43	13.11	13.25	14.78	15.52	17.46
Median citations* (range)	5.8 (0–48.4)	6.4 (0–45.6)	5.2 (0.4–68.2)	9.9 (0.8–9.2)	9 (0–31.2)	8.9 (0–40.8)	8.2 (0–21.8)	11.3 (0.4–48)	7.2 (0–68.6)	7.6 (0.8–34.4)
Citation ratio†	1.5	1.7	1.8	0.9	1.5	1.6	0.6	1.1	0.8	2.0
BMJ—British Medical Journal										
Impact factor	5.14	5.33	6.63	7.59	7.21	7.04	9.05	9.25	9.72	12.83
Median citations (range)	7 (0.2–32.8)	3.2 (0–103.8)	4.1 (0–32.6)	2.8 (0–210.4)	2.9 (0–53.4)	3.2 (0–43.2)	5.7 (0.2–37.8)	6 (0.2–41.2)	3.8 (0–44.4)	4.4 (0–38.2)
Citation ratio	1.5	1.7	2.2	0.5	0.6	1.6	1.8	1.3	1.1	0.9
Circulation										
Impact factor	9.90	10.89	10.52	10.26	11.16	12.56	11.63	10.94	12.76	14.60
Median citations (range)	5.4 (0–83)	5.6 (0–96.6)	5.6 (0–64.4)	6.4 (0–195.6)	6.2 (0–184.2)	6.2 (0–255.4)	6 (0–84.2)	7 (0–194.4)	7.4 (0–166.6)	6.6 (0–253.2)
Citation ratio	1.2	1.1	1.2	1.1	1.4	1.1	1.2	1.2	1.3	1.3
European Heart Journal										
Impact factor	3.21	3.84	5.15	6.13	6.00	6.25	7.34	7.29	7.92	8.92
Median citations (range)	2.4 (0–26.2)	2.7 (0–35.6)	2.6 (0.2–96.8)	3 (0–54.2)	3 (0–96.2)	4 (0–50.4)	4 (0–176)	4.2 (0,–94.4)	4.6 (0–160.4)	4.8 (0–212.2)
Citation ratio	1.5	1.1	1.8	1.2	1.0	1.0	0.9	1.4	1.5	0.9
JAMA—Journal of the American Medical Association										
Impact factor	11.44	15.40	17.57	16.59	21.46	24.83	23.49	23.18	25.55	31.72
Median citations (range)	10.5 (0.6–73.2)	9.8 (0.8–76.6)	10 (0.2–117.6)	20.7 (1.4–227.8)	18 (0–544.8)	17 (0.2–139)	19.3 (0.2–119)	16.9 (0–103)	23 (1–95.4)	19.8 (0.8–76.4)
Citation ratio	1.7	1.3	1.8	1.2	1.0	1.4	1.3	1.3	1.1	1.3
Journal of the American College of Cardiology										
Impact factor	7.37	7.08	6.37	6.28	7.60	9.13	9.20	9.70	11.05	11.44
Median citations (range)	3.4 (0–33)	3.2 (0–31.6)	3.8 (0–42.2)	4.2 (0.2–83.8)	4.8 (0–68)	5.1 (0–60)	5.4 (0–109)	6.2 (0–109)	6.8 (0–71)	8 (0–90.2)
Citation ratio	1.2	1.1	1.2	1.4	1.1	1.4	1.0	1.0	1.3	1.1
Lancet										
Impact factor	10.20	10.23	13.25	15.40	18.32	21.71	23.88	25.80	28.64	28.41
Median citations (range)	5.1 (0–194)	6.4 (0–154.6)	10.2 (0–123)	11.2 (0.8–421.6)	13.8 (0.2–131.4)	19.5 (0–193.8)	21 (0–118.2)	18.7 (0.6–85.8)	25.1 (0.4–116.4)	25.1 (3.8–90)
Citation ratio	1.3	2.0	1.1	1.2	0.9	1.3	1.6	0.8	1.1	1.1
New England Journal of Medicine										
Impact factor	28.86	29.51	29.07	31.74	34.83	38.57	44.02	51.30	52.59	50.02
Median citations (range)	17.1 (0–605.6)	14.7 (0–392.6)	21.6 (0–231)	14.6 (0–194.4)	25.2 (0–193.8)	33.2 (2.6–228.4)	33.4 (6.4–261.2)	38.8 (0.4–125.6)	24.5 (0–272.8)	27.4 (0–318)
Citation ratio	1.4	0.7	2.3	2.8	1.4	1.4	1.3	1.3	1.5	2.1

*Median annual citations per cardiovascular paper with total range.

†Citation ratio is mean number of citations in collaborative versus single country papers.

Global Partnership in *Nature* to fund noncommunicable disease research in low- and lower-middle—income countries [19]. This announcement included research training as a key component of its aims and was followed in 2008 by the creation of the Collaborating Centers of Excellence by the National Heart, Lung, and Blood Institute and UnitedHealth Group [20]. These programs and initiatives, and others like them, are designed to enhance infrastructure and capacity for chronic disease research, but they have yet to be formally evaluated. In an era of recent economic crisis, strengthening research and research training programs may be threatened by decreases in research funding.

Strengths and limitations

Our study is robust in its use of filter with demonstrated high precision and recall over a full 10 years of publication history. The selected journals are representative both of general medical and cardiovascular literature and are applicable to other major journals of similar content and readership. However, our study also has several limitations. First, we included 8 exemplary journals on the basis of importance to the field of cardiovascular research; however, our results of time trends in publications, collaboration, and citations may not be representative of all sources or specialties, especially outside of the medical field [12]. Second, we included only articles, reviews, and conference proceedings, intending to capture all and only those items considered citable in the Thomson Reuters IF, but potentially missing other forms of meaningful publication [13]. Third, fractional authorship was assigned on the basis of addresses of all authors and does not weight or rank authorship by position. Fourth, authorship was not affected by number of authors, but by the number of addresses, which may underestimate counts from authors at the same research center. It is unclear the degree to which this underestimation occurs, particularly in low- and middle-income countries. A more robust data extraction method may provide further granularity into the effect of total number and location of individual authors, if feasible. Fifth, we excluded publications for which we were not able to retrieve addresses. Previous studies have associated missing addresses in WOK with publications with authorship referenced by research project name, which may indicate a collaborative effort [21]. If missing publications were highly collaborative, our results may underestimate the prevalence of collaboration in cardiovascular publications.

CONCLUSIONS

Our results show increasing publication trends in both general and specialty exemplary journals for collaborative cardiovascular research amid a backdrop of decreasing total and cardiovascular publications. We also show that contribution by country in selected journals was disproportionate and under-represents total cardiovascular research in low- and middle-income countries.

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ONLINE TABLE 1. Univariable trends in cardiovascular publication volume and source

Dependent Variable	R^2	Predictors (Beta, 95% CI)		
		Intercept	Year	Year^2
Cardiovascular publications	0.79	35,434 (31,577—39,191)	1,697.2 (993.4—2400.9)	—
	0.97	39,194 (37,014—41,375)	−1122.9 (−2251.3—5.4)	313.3 (192.7—434.0)
Journals	0.75	2,117.7 (166.49—2,566.1)	178.7 (94.8—262.7)	—
	0.95	2,558.8 (2,276.0—2,842.7)	−152.1 (−298.4 to −5.7)	36.8 (21.1—52.4)

CI, confidence interval.

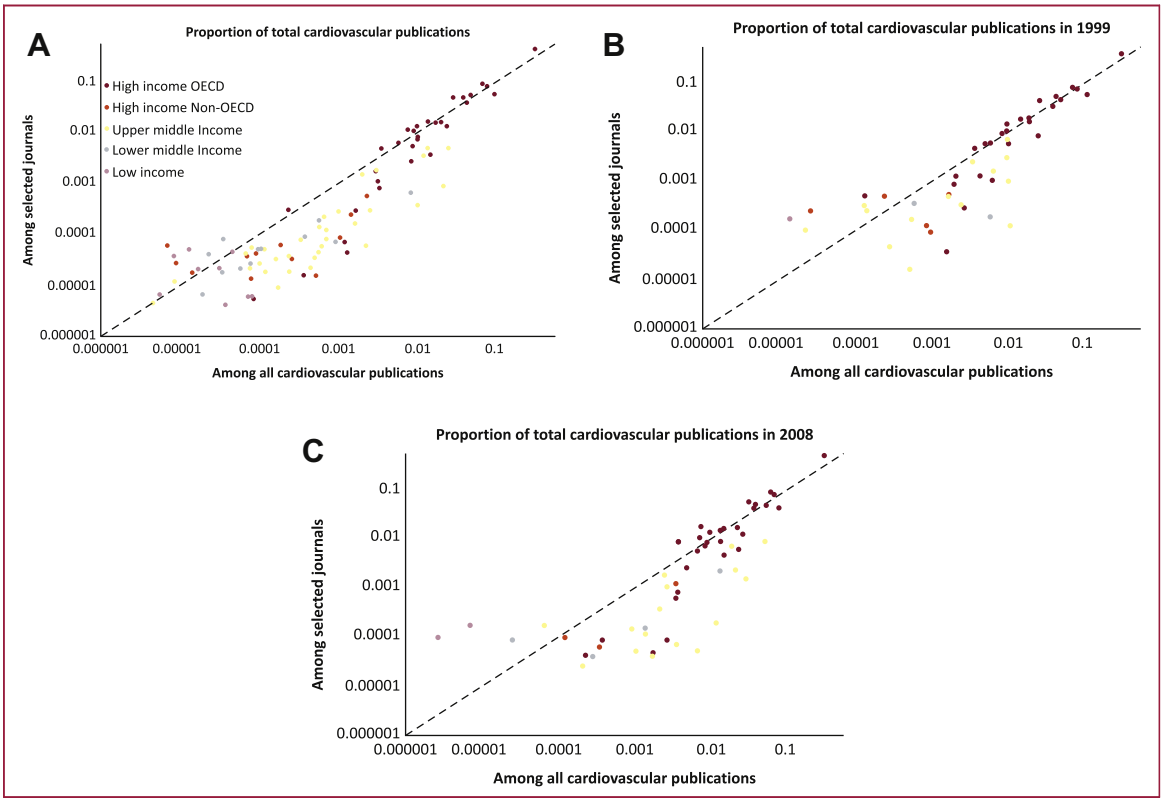
ONLINE TABLE 2. Univariable trends by journal in overall publication volume, cardiovascular publication volume, fractional cardiovascular publications, collaboration, and countries represented by authorship

Journal	Dependent Variable						
	Overall Publications		Cardiovascular Publications		Cardiovascular Publication Proportion		
	Annual Change (Beta, 95% CI)	% Change From 1999	Annual Change (Beta, 95% CI)	% Change From 1999	Annual Change (Beta, 95% CI)	1999 Proportion, %	2008 Proportion, %
Annals of Internal Medicine	−6.7 (−9.8 to −3.7)	−26.7	−1.9 (−3.5 to −0.3)	−54.2	−0.3 (−1.2—0.6)	21.7	13.6
BMJ—British Medical Journal	−55.3 (−71.5 to −39.0)	−63.1	−3.0 (−6.9—0.9)	−12.8	0.8 (0.0—1.7)	6.2	14.6
Circulation	−41.4 (−78.8 to −4.0)	−34.1	−42.9 (−79.3 to −6.5)	−37.2	—	—	—
European Heart Journal	20.2 (11.5—28.9)	65.4	18.4 (10.6—26.3)	68.0	—	—	—
JAMA—Journal of the American Medical Association	−18.6 (−26.6 to −10.6)	−38.2	1.0 (−1.9—3.9)	−21.2	1.7 (0.6—2.7)	18.1	23.1
Journal of the American College of Cardiology	−0.8 (−12.6, 10.9)	−4.3	−6.7 (−19.0—5.7)	−5.9	—	—	—
Lancet	−78.5 (−109.0 to −47.9)	−73.9	−11.2 (−14.7 to −7.8)	−66.7	0.0 (−0.6—0.5)	12.5	15.9
New England Journal of Medicine	−6.6 (−13.0 to −0.2)	−6.3	−3.2 (−6.8—0.5)	2.6	−0.5 (−1.2—0.2)	20.5	22.5

CI, confidence interval.

ONLINE TABLE 3. Univariable trends in number of countries contributing to cardiovascular publications and proportional change in collaboration

	Dependent Variable					
Journal	Countries (Beta, 95% CI)	Countries (1999)	Countries (2008)	Collaborative Fraction (Beta, 95% CI)	1999 Proportion, %	2008 Proportion, %
Annals of Internal Medicine	−0.2 (−1.1−0.8)	13	8	1.4 (−0.3−3.1)	12.5	31.8
BMJ—British Medical Journal	0.8 (0.2−1.5)	10	20	2.6 (1.3−3.8)	10.6	36.6
Circulation	0.8 (−0.1−1.6)	37	38	1.1 (0.6−1.5)	21.7	31.3
European Heart Journal	1.2 (0.8−1.7)	28	39	1.4 (0.2−2.6)	18.3	37.0
JAMA—Journal of the American Medical Association	1.2 (−0.4−2.7)	13	18	2.8 (1.6−4.0)	15.2	34.6
Journal of the American College of Cardiology	0.6 (−0.2−1.4)	34	37	1.5 (1.1−1.9)	18.3	31.4
Lancet	0.4 (−0.4−1.1)	24	33	2.7 (1.1−4.4)	22.5	54.3
New England Journal of Medicine	1.6 (0.6−2.7)	21	36	2.9 (1.6−4.2)	24.4	43.8



ONLINE FIGURE 1. Country-level proportion of authorship within all cardiovascular publications against selected journals in all years (A), 1999 (B), and 2008 (C). Country-level proportion of total authorship within all cardiovascular publications against selected journals, with color coding representing World Bank country income status.