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University performance in cardiovascular research: A TOPSIS-based bibliometric analysis of highly cited publications

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A B S T R A C T

Cardiovascular disease remains the leading cause of mortality worldwide, driving substantial research investment and necessitating robust evaluation of institutional research performance. This study employed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to evaluate and rank the research performance of 30 leading universities based on their contributions to the top 100 highly cited cardiovascular medicine articles from 2010–2026, extracted from Scopus. Three evaluation criteria were selected: Unique Authors (minimized as a resource input measure), Total Citations (maximized as an impact indicator), and Number of Papers (maximized as a productivity measure), with equal weights (33.3% each) assigned to all criteria. TOPSIS analysis revealed substantial variation in institutional performance, with Harvard University emerging as the top-performing institution (TOPSIS score: 0.6050), demonstrating dominance across all criteria with 228 unique authors, 9,430 citations, and 83 papers, followed by Cleveland Clinic (0.4882), University of Toronto (0.4537), and Mayo Clinic (0.4158). US institutions dominated the ranking, accounting for 27 of 30 universities with an average TOPSIS score of 0.4112, while Canadian institutions achieved an average of 0.4078. The analysis identified an "efficiency gap" between high-citation, low-paper institutions (e.g., UCSF with 87.4 citations per paper and 1.3 authors per paper) and those demonstrating the inverse pattern. The findings highlight the dominance of US institutions, varying institutional strategies (high-volume vs. high-impact approaches), and the concentration of research activity among leading academic medical centers, with the TOPSIS methodology offering a robust framework for multidimensional research evaluation that can inform institutional benchmarking, strategic planning, and resource allocation in cardiovascular medicine.

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1. Introduction

Cardiovascular diseases (CVDs) remain the foremost cause of morbidity and mortality globally, accounting for approximately 17.9 million deaths annually and representing 32% of all global fatalities (World Health Organization, 2021; Virani et al., 2021). The substantial disease burden has driven intensive research efforts across academic institutions worldwide, resulting in an exponential growth of cardiovascular medicine literature over recent decades (Shuaib et al., 2015; Sperti et al., 2024). The period between 2020 and 2026 has witnessed transformative developments in cardiovascular medicine, with artificial intelligence (AI) and machine learning (ML) emerging as particularly impactful areas (Itchhaporia, 2022; Johnson et al., 2018; Krittanawong et al., 2017).

The recent literature reflects a profound shift toward digital health technologies and AI applications in cardiovascular care. Itchhaporia (2022) provided a comprehensive review of AI and ML applications in cardiovascular medicine, highlighting their potential to transform clinical practice through improved diagnostic accuracy, risk stratification, and personalized treatment approaches. Similarly, Haq et al. (2022) examined current insights and future prospects for AI in cardiovascular

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medicine, noting that ML algorithms are increasingly being developed for applications spanning heart failure, electrophysiology, valvular heart disease, and coronary artery disease. The integration of deep learning techniques has shown particular promise in cardiac imaging, enabling automated interpretation of echocardiograms, cardiac MRI, and CT angiography with accuracy approaching that of expert clinicians (Sengupta & Shrestha, 2019; Seetharam et al., 2019).

The emergence of large language models (LLMs) and generative AI has opened new avenues in cardiovascular medicine. Quer and Topol (2024) explored the potential for LLMs to transform cardiovascular medicine, noting applications in medical image interpretation, multimodal AI, and integration of electronic health record data with imaging, genomics, and biosensors. Schepart et al. (2023) evaluated current awareness, perceptions, and clinical use of AI-enabled digital health tools, identifying key challenges including limited knowledge, insufficient usability, cost constraints, and poor electronic health record interoperability. Oikonomou and Khera (2025) addressed the critical need for designing AI systems that are scalable, accessible, and accurate across diverse geographical settings, emphasizing representativeness, interoperability, and quality assurance.

The integration of precision medicine approaches has also gained significant traction in cardiovascular research. Sethi et al. (2023) compiled a comprehensive review of precision medicine in cardiovascular diseases, emphasizing the role of "omics" technologies (genomics, transcriptomics, epigenomics, proteomics, metabolomics, and microbiomics) in enabling deep phenotyping and individualized patient care. Currie and Delles (2018) provided foundational insights into precision medicine applications, noting that while cardiovascular medicine often relies on noninvasive diagnostic procedures and symptom-based disease management, other disciplines have already moved toward molecular diagnostics. The application of pharmacogenomics in cardiovascular therapy has become increasingly relevant, with studies demonstrating the clinical utility of genotype-guided prescribing for antiplatelet therapy, statins, and anticoagulants (Magavern et al., 2022; Magavern et al., 2026).

The COVID-19 pandemic significantly impacted cardiovascular research and clinical practice, accelerating the adoption of digital health technologies and telemedicine. Kadoya et al. (2021) surveyed healthcare workers in Japan regarding COVID-19 knowledge and preparedness, revealing substantial knowledge gaps regarding infection prevention measures. Similarly, Yates et al. (2022) conducted a multi-centre prospective cohort study examining the effect of the pandemic on elective cardiac surgery waiting lists, demonstrating significant delays to treatment. Piskulic et al. (2021) conducted a rapid review of virtual visits in cardiovascular disease, finding that telemedicine was non-inferior or more effective in reducing hospitalizations compared to traditional in-clinic care. The pandemic also highlighted the importance of remote monitoring technologies, with Dagher et al. (2020) noting that wearables and digital health tools are "here to stay" in cardiovascular medicine.

Bibliometric analysis provides a quantitative and objective method to identify research trends, influential authors, and institutions within a field, guiding both researchers and funding bodies (Shuaib et al., 2015; Khan et al., 2019). While several bibliometric studies of cardiovascular research have been conducted (Cheng & Ye, 2025; Sperti et al., 2024; Kim et al., 2023; Sourrouille et al., 2024), many have focused primarily on citation trends, leading countries, and key journals without extensively covering institutional collaboration patterns, thematic evolution, and multidimensional performance metrics. The present study addresses these gaps by employing the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to evaluate and rank institutional research performance based on highly cited cardiovascular literature.

The evolution of cardiovascular medicine has been marked by several paradigm shifts over the past decades. Ryan (2002) highlighted the seminal contributions of the coronary angiogram to cardiovascular medicine over five decades, noting its role in enabling natural history studies, surgical revascularization, percutaneous interventions, and thrombolytic therapy. Braunwald (2012) traced the rise of cardiovascular medicine, emphasizing the impact of three great discoveries—the X-ray, the sphygmomanometer, and the electrocardiograph—on the development of modern cardiology. Van der Wall (2013) reviewed milestones in cardiovascular medicine, while Alfonso et al. (2021) and Escaned et al. (2021) provided annual updates on interventional cardiology, demonstrating the rapid pace of innovation in the field.

The leadership and organization of cardiovascular research have been topics of significant discussion. Fuster et al. (2009) examined academic careers in cardiovascular medicine, providing guidance for trainees and early-career investigators. Walsh (2018) addressed the underrepresentation of women as leaders in cardiovascular medicine, noting that despite increasing numbers of women in medical training, cardiology remains a male-dominated specialty. Arnett (2015) discussed the importance of recruitment and retention of women in cardiovascular medicine and research. Kohno et al. (2018) surveyed early-career cardiologists in Japan, finding that satisfaction with training decreased over time, particularly in emerging subspecialties.

Ethical considerations in cardiovascular research and practice have received increasing attention. Ronco et al. (2024) examined conflicts of interest in clinical practice, discussing how various conflicts may influence trials at multiple levels, from research question formulation to result reporting. Kirkpatrick et al. (2012) explored management of conflicts of interest in cardiovascular medicine, noting that strategies including disclosure, limitations, and eliminations are employed in varying degrees. Kirkpatrick and Kim (2006) addressed ethical issues in heart failure, emphasizing the importance of end-of-life care and shared decision-making.

The globalization of cardiovascular research has been examined through various bibliometric studies. Gal et al. (2019) identified hot topics and trends in cardiovascular research, finding that growth in clinical and population research emphasizes improving patient outcomes through novel treatments, risk stratification, and prevention. Zacca-González et al. (2018) characterized scientific output and specialization in Latin American countries, noting that cardiology and cardiovascular medicine are among the most productive subjects in the region. Onat (2012, 2014, 2016, 2017) conducted serial analyses of Turkey's publication output in cardiovascular medicine, documenting trends in quantity and quality over time. Rodriguez-Granillo et al. (2013) quantified scientific output in cardiovascular medicine, revealing that global output is highly polarized and closely related to economic indicators.

Institutional research performance evaluation has become increasingly sophisticated, with multiple criteria considered beyond simple publication counts. The TOPSIS methodology, employed in this study, provides a multi-criteria decision-making framework that can integrate multiple performance dimensions (Brignardello-Petersen et al., 2018; Kaul, 2021). This approach has been applied in various fields for ranking and evaluation, offering advantages over single-metric approaches by providing a balanced assessment of institutional performance across multiple criteria.

The recent literature reflects a profound shift toward digital health technologies and AI applications in cardiovascular care. Itchhaporia (2022) provided a comprehensive review of AI and ML applications in cardiovascular medicine, highlighting their potential to transform clinical practice (Ronco et al., 2024). Similarly, Haq et al. (2022) examined current insights and future prospects for AI in cardiovascular medicine, noting that ML algorithms are increasingly being developed for applications spanning heart failure, electrophysiology, valvular heart disease, and coronary artery disease (Haq et al., 2022). Oikonomou and Khera (2025) addressed the critical need for designing AI systems that are scalable, accessible, and accurate across diverse geographical settings, emphasizing representativeness, interoperability, and quality assurance (Oikonomou & Khera, 2025).

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The emergence of digital health and precision medicine has transformed cardiovascular care delivery. Turakhia et al. (2016) highlighted the outlook of digital health for cardiovascular medicine, identifying challenges but also extraordinary opportunities for improving patient care through technology. Antoniades et al. (2021) reviewed the year in cardiovascular medicine 2020 with a focus on digital health and innovation, examining the rapid adoption of digital technologies during the

COVID-19 pandemic. Meder and Radke (2019) discussed digital cardiology, noting that technical developments enable ever more detailed insights into disease processes and allow optimized planning and performing of tailored interventional, surgical, or pharmacotherapies. Bax and Delgado (2021) provided an overview of imaging advances in cardiovascular medicine, while Bueno and Vardas (2021) reviewed progress in preventive cardiology and population health. Niazi et al. (2020) examined cardiovascular care in the era of machine learning-enabled personalized medicine, reviewing past research in personalized cardiovascular medicine and identifying areas well-positioned for future investigation.

The application of molecular biology and genetics has fundamentally changed cardiovascular research and practice. Williams (1990) provided an early editorial commentary on molecular biology in cardiology, highlighting opportunities for clinical applications. Bing (1995) discussed Homer W. Smith's contribution to cardiovascular medicine, recognizing his foundational work in renal and cardiovascular physiology. Krychtiuk et al. (2017) examined monoclonal antibodies and antisense technology as emerging therapeutic approaches in cardiology, discussing PCSK9 inhibition and interference with the immune system as promising targets. Maron et al. (2020) made the case for bringing birthweight to adult cardiovascular medicine, highlighting the importance of early-life factors in cardiovascular disease risk.

Ethical considerations and workforce diversity have received increasing attention in cardiovascular medicine. Simon et al. (2020) addressed equity, diversity, and inclusiveness in cardiovascular medicine and health care, emphasizing the importance of addressing disparities in cardiovascular outcomes. Coats (2007) welcomed Tsung O Cheng as Roving Ambassador for Chinese Cardiovascular Science, highlighting the importance of international collaboration in advancing cardiovascular medicine. Shurlock (2011) questioned whether it will only be possible to deliver the best cardiovascular medicine in 'capital cities' in the future, discussing the concentration of cardiovascular expertise and its implications for healthcare delivery. Sossalla and Schmitto (2009) discussed the significance of academic collaboration within cardiovascular medicine and surgery, emphasizing the importance of scientific teamwork in both clinical and research settings.

The definition and understanding of cardiovascular disease have evolved considerably. Alpert (2014) discussed defining myocardial infarction for future care, noting the importance of accurate diagnosis and classification for patient management. Califf (2016) examined the future of cardiovascular medicine from the regulatory perspective, discussing the role of the FDA in ensuring safety and efficacy of new therapies. Vardas (2012) assessed cardiovascular medicine in 2025, outlining priorities for the field including the need for innovation in diagnosis and treatment. Topol (2019) discussed high-performance medicine and the convergence of human and artificial intelligence, arguing that AI will fundamentally change the practice of medicine. Ko et al. (2017) provided an erratum regarding metabolomic profiling in relation to new-onset atrial fibrillation from the Framingham Heart Study, highlighting the importance of rigorous scientific methodology.

Training and education in cardiovascular medicine have evolved to meet changing demands. Damp et al. (2013) evaluated the effects of transesophageal echocardiography simulator training on learning and performance in cardiovascular medicine fellows, finding that simulator training improves proficiency and helps speed learning. The ACC Clinical Competencies for Nurse Practitioners and Physician Assistants (Rodgers et al., 2020) established standards for advanced practice providers in cardiovascular medicine, recognizing their increasingly important role in cardiovascular care delivery.

The globalization of cardiovascular research has been examined through various bibliometric studies. Shoaib and Borer (2025) and Hopkins and Sroussi (2025) provided bibliometric perspectives on the top 100 most cited articles in cardiovascular research, identifying trends, authors, journals, origins, and gender representation. These studies complement the present analysis by providing context for understanding institutional research performance and impact patterns. Gal et al. (2019) identified hot topics and trends in cardiovascular research, finding that growth in clinical and population research emphasizes improving patient outcomes through novel treatments, risk stratification, and prevention. Zacca-González et al. (2018) characterized scientific output and specialization in Latin American countries, noting that cardiology and cardiovascular medicine are among the most productive subjects in the region. Onat (2012, 2014, 2016, 2017) conducted serial analyses of Turkey's publication output in cardiovascular medicine, documenting trends in quantity and quality over time. Rodriguez-Granillo et al. (2013) quantified scientific output in cardiovascular medicine, revealing that global output is highly polarized and closely related to economic indicators.

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TOPSIS is a multi-criteria decision-making method widely used in various fields for ranking and evaluating alternatives based on multiple conflicting criteria. The method identifies the ideal solution (maximizing benefits and minimizing costs) and the negative-ideal solution (minimizing benefits and maximizing costs), then ranks alternatives based on their relative closeness to the ideal solution. This study applies TOPSIS to evaluate the research performance of 30 leading universities in cardiovascular medicine, considering three criteria: Unique Authors (as a measure of research collaboration breadth), Total Citations (as a measure of research impact), and Number of Papers (as a measure of research productivity).

2. Materials and Methods

2.1 Data Source and Extraction

This study utilized a Scopus-exported dataset containing the top 100 highly cited articles in cardiovascular medicine (2010–2026). The dataset was retrieved on July 5, 2026, from the Scopus database, which is recognized for its comprehensive coverage of peer-reviewed literature and citation analysis capabilities. The selection criteria ensured inclusion of both original research and review articles with high citation impact.

Data extracted from each record included: author names, author affiliations, article title, publication year, source title, volume, issue, page numbers, cited by count, DOI, link, affiliations, authors with affiliations, and abstract. For institutional analysis, affiliations were systematically processed to identify unique institutional names and countries.

2.2 Data Processing

To enable institutional-level analysis, several preprocessing steps were performed:

1. **Affiliation mapping:** Each author's affiliation was extracted and mapped to a standardized institutional name. For example, "Harvard Medical School" and "Harvard University" were grouped under Harvard University. This standardization involved:
    - Manual review of all unique affiliation strings
    - Consolidation of naming variants (e.g., "Cleveland Clinic" vs. "Cleveland Clinic Foundation")
    - Country assignment based on institutional location
2. **Author uniqueness:** Each author was associated with their primary institutional affiliation. The "Unique Authors" metric represents the total number of distinct researchers (author IDs) affiliated with each institution across the 100 articles.
3. **Citation aggregation:** Total citations were aggregated at the institutional level by summing the "Cited by" counts for all articles with at least one author affiliated with that institution.
4. **Paper count:** Papers were counted at the institutional level, with articles counted once for each institution having at least one author affiliate.

2.3 TOPSIS Methodology

The TOPSIS method was implemented using the following steps:

Step 1: Decision matrix construction

A decision matrix X with m alternatives (universities) and n criteria was constructed.

Step 2: Normalization

The normalized decision matrix was calculated using vector normalization:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad \text{for } i = 1,..,m; j = 1,..,n$$

Step 3: Weighted normalized matrix

The weighted normalized matrix was calculated by multiplying normalized values by criterion weights:

$$v_{ij} = w_j \times r_{ij} \quad \text{for } i = 1,...,m; j = 1,...,n$$

where w_j represents the weight of criterion j (33.3% for all criteria).

Step 4: Ideal and negative-ideal solutions

The positive ideal solution (A^+) and negative ideal solution (A^-) were determined:

$$A^+ = \left\{v_1^+,...,v_n^+\right\} = \left\{\left(\max_i v_{ij} \mid j \in J^+\right), \left(\max_i v_{ij} \mid j \in J^-\right)\right\}$$
$$A^- = \left\{v_1^-,...,v_n^-\right\} = \left\{\left(\min_i v_{ij} \mid j \in J^+\right), \left(\max_i v_{ij} \mid j \in J^-\right)\right\}$$

Step 5: Distance calculation

The distances from each alternative to the ideal and negative-ideal solutions were calculated using Euclidean distance:

$$D_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^+\right)^2} \quad \text{for } i = 1,...,m$$
$$D_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^-\right)^2} \quad \text{for } i = 1,...,m$$

Step 6: Closeness coefficient calculation

The relative closeness coefficient (C_i) was calculated:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad \text{for } i = 1,...,m$$

Step 7: Ranking

Universities were ranked in descending order of C_i (higher scores indicate better performance).

2.4 Decision Criteria and Weighting

Three criteria were selected based on their relevance to institutional research performance evaluation:

Criterion	Direction	Justification
Unique Authors	Minimize	Represents resource input; lower author counts indicate greater efficiency
Total Citations	Maximize	Measures research impact and influence
Number of Papers	Maximize	Measures research productivity and output

Equal weights (33.3%) were assigned to all criteria, reflecting equal importance of efficiency, impact, and productivity in research evaluation.

2.5 Statistical Analysis

Descriptive statistics (mean, median, range) were calculated for each criterion. Country-level aggregation and subgroup analyses were performed to compare performance across geographical regions. Average citations per paper and authors per paper were calculated to provide additional efficiency metrics.

3. Results

3.1 TOPSIS Ranking Results

The TOPSIS analysis revealed substantial variation in institutional research performance. Table 1 presents the complete ranking of the 30 universities with their TOPSIS scores and criterion values.

Table 1
University Rankings Based on TOPSIS Analysis

Rank	University	TOPSIS Score	Unique Authors	Citations	Papers
1	Harvard University	0.6050	228	9430	83
2	Cleveland Clinic	0.4882	122	5141	38
3	University of Toronto	0.4537	79	3243	32
4	Mayo Clinic	0.4158	89	3310	25
5	University of California, San Francisco	0.4138	12	787	9
6	Baylor College of Medicine	0.4135	32	1372	15
7	Northwestern University	0.4083	16	489	11
8	University of Pennsylvania	0.4049	31	1644	8
9	University of California, San Diego	0.4037	17	621	8
10	University of Washington	0.4028	18	519	9
11	University of Texas Southwestern Medical Center	0.4023	22	781	9
12	University of Colorado	0.4012	21	643	9
13	Stanford University	0.4011	55	2066	16
14	Tufts University	0.4004	14	519	5
15	Ohio State University	0.3996	20	581	8
16	University of California, Los Angeles	0.3984	20	503	8
17	Case Western Reserve University	0.3979	16	614	4
18	University of Michigan	0.3978	23	692	8
19	University of North Carolina	0.3971	13	431	3
20	University of Pittsburgh	0.3967	17	497	5
21	Vanderbilt University	0.3965	24	565	9
22	Emory University	0.3959	15	501	3
23	University of Chicago	0.3959	21	646	6
24	Johns Hopkins University	0.3954	38	1173	12
25	University of Florida	0.3943	30	769	10
26	Icahn School of Medicine at Mount Sinai	0.3941	28	836	8
27	Yale University	0.3928	33	1014	9
28	Duke University	0.3900	88	2772	22
29	University of Alberta	0.3854	40	989	10
30	University of Ottawa	0.3843	24	190	5

3.2 Top-Performing Institutions

Harvard University (Rank 1, TOPSIS Score: 0.6050)

Harvard demonstrated exceptional performance across all criteria, with 228 unique authors contributing to 83 papers that accumulated 9,430 citations. The institution's average citations per paper (113.6) and authors per paper (2.7) reflect efficient, high-impact research production.

Cleveland Clinic (Rank 2, TOPSIS Score: 0.4882)

Cleveland Clinic showed strong performance with 38 papers accumulating 5,141 citations. Notably, the institution achieved the highest average citations per paper (135.3) among top performers, indicating exceptional per-paper impact.

University of Toronto (Rank 3, TOPSIS Score: 0.4537)

As the top-ranked non-US institution, the University of Toronto demonstrated balanced performance with 32 papers, 3,243 citations, and 79 unique authors.

Mayo Clinic (Rank 4, TOPSIS Score: 0.4158)

Mayo Clinic achieved strong efficiency metrics with 25 papers yielding 3,310 citations, and the highest authors per paper (3.6) among top 5 institutions, suggesting extensive collaboration within research teams.

University of California, San Francisco (Rank 5, TOPSIS Score: 0.4138)

UCSF demonstrated remarkable efficiency with only 12 unique authors across 9 papers achieving 787 citations, yielding the highest “collaboration efficiency” among top 5 institutions (1.3 authors per paper).

3.3 Country-Level Analysis

The analysis revealed significant geographic concentration of research performance. US institutions dominated the ranking, accounting for 27 of 30 universities and achieving an average TOPSIS score of 0.4112. Canadian institutions (University of Toronto, University of Alberta, University of Ottawa) ranked 3rd, 29th, and 30th respectively, with an average score of 0.4078.

Table 2

Average Performance by Country

Rank	Country	Avg TOPSIS Score	Universities
1	USA	0.4112	27
2	Canada	0.4078	3

3.4 Efficiency Metrics Analysis

The efficiency analysis revealed interesting patterns across the top 10 institutions. **Cleveland Clinic** and **Mayo Clinic** achieved the highest average citations per paper (135.3 and 132.4, respectively), suggesting a focused, high-impact research strategy where quality is prioritized over quantity. **University of California, San Francisco** showed the lowest author-to-paper ratio (1.3), indicating either highly efficient research production or concentrated expertise within a small group of productive researchers. **Harvard University**, while ranking first overall, demonstrated balanced performance with 113.6 citations per paper and 2.7 authors per paper, reflecting its position as a comprehensive research institution with broad collaborative networks. **University of Toronto** (101.3 citations/paper, 2.5 authors/paper) and **Baylor College of Medicine** (91.5 citations/paper, 2.1 authors/paper) showed efficient research output relative to their author contributions.

Table 3

Efficiency Indicators for Top 5 Institutions

Rank	Institution	Avg Citations/Paper	Authors/Paper
1	Harvard University	113.6	2.7
2	Cleveland Clinic	135.3	3.2
3	University of Toronto	101.3	2.5
4	Mayo Clinic	132.4	3.6
5	University of California, San Francisco	87.4	1.3
6	Baylor College of Medicine	91.5	2.1
7	Northwestern University	44.5	1.5
8	University of Pennsylvania	205.5	3.9
9	University of California, San Diego	77.6	2.1
10	University of Washington	57.7	2.0

The efficiency analysis reveals diverse institutional research strategies across the top 10 institutions. Cleveland Clinic (135.3 citations/paper, 3.2 authors/paper) and Mayo Clinic (132.4 citations/paper, 3.6 authors/paper) demonstrate a "quality over quantity" approach, where extensive collaboration within research teams potentially enhances research quality and impact. University of Pennsylvania achieved the highest average citations per paper (205.5) among all institutions, demonstrating extraordinary research impact; however, this is based on only 8 papers, suggesting a concentrated, highly selective research strategy targeting high-impact venues. UCSF (87.4 citations/paper, 1.3 authors/paper) and Northwestern University (44.5 citations/paper, 1.5 authors/paper) exemplify a model of focused expertise, where small research teams produce impactful work efficiently. Harvard University and University of Toronto demonstrate a balanced approach, maintaining strong citations per paper while leveraging moderate collaboration networks (2.7 and 2.5 authors/paper, respectively). The wide variation in efficiency indicators reveals an "efficiency gap" between institutions that achieve high citations per paper with limited research teams versus those with larger teams but lower per-paper impact, suggesting that institutional research strategies can be characterized along a continuum from "focused, high-impact" to "broad, collaborative" approaches. The author-to-paper ratio ranges from 1.3 (UCSF) to 3.9 (UPenn), indicating diverse collaboration patterns across institutions, where higher collaboration ratios may enhance research quality through complementary expertise, while lower ratios may reflect efficient, focused research groups.

3.5 The "Efficiency Gap"

A notable finding was the "efficiency gap" between institutions that achieved high citations per paper with limited research teams versus those with large, prolific research groups but lower per-paper impact. Several factors may contribute to this gap:

1. **Focused Expertise vs. Broad Collaboration:** Institutions like UCSF demonstrated highly focused expertise with small research teams, while Harvard's broader network suggests extensive collaboration across multiple research groups.

2. **Research Strategy:** Some institutions may prioritize "blockbuster" publications (high-impact, high-citation), while others pursue a "breadth" strategy (many publications, moderate per-paper impact).

3. **Resource Allocation:** The distribution of research funding, core facilities, and institutional priorities likely influences research output patterns.

4. Discussion

4.1 Interpretation of Rankings

The TOPSIS analysis provides quantitative evidence of institutional research performance in cardiovascular medicine, revealing several important patterns.

The Harvard Dominance: Harvard University's top ranking reflects its comprehensive research ecosystem, combining breadth (83 papers), depth (9,430 citations), and collaboration extent (228 unique authors). This performance aligns with Harvard's position as a global leader in biomedical research, supported by extensive research infrastructure, faculty expertise, and access to major teaching hospitals (Massachusetts General Hospital, Brigham and Women's Hospital, Beth Israel Deaconess Medical Center).

The Cleveland Clinic Model: Cleveland Clinic's second-place ranking demonstrates the effectiveness of focused, high-impact research. With the highest average citations per paper among top performers (135.3), the institution exemplifies how specialized research centers can achieve disproportionate impact through strategic research focus.

The Mayo Clinic Efficiency: Mayo Clinic's performance (4th overall) reflects exceptional per-paper impact (132.4 citations per paper) and high collaborative intensity (3.6 authors per paper). This pattern suggests a "team science" approach that enhances the quality and impact of individual research contributions.

The Toronto Benchmark: The University of Toronto's third-place ranking establishes a benchmark for non-US institutions, demonstrating that Canadian research can achieve globally competitive impact. This finding is particularly notable given the concentration of top-ranked institutions in the United States.

4.2 Geographic Concentration of Research Excellence

The dominance of US institutions in the ranking (27 of 30) reflects several factors:

1. **Research Funding:** The National Institutes of Health (NIH) consistently provides substantial funding for cardiovascular research, enabling extensive research programs.
2. **Academic Medical Centers:** The US has a concentration of major academic medical centers with integrated research and clinical programs.
3. **Collaboration Networks:** US institutions have established extensive national and international collaboration networks that enhance research productivity and impact.
4. **Journal Accessibility:** The predominance of English-language journals centered in the US may facilitate higher visibility and citation of US research.

4.3 Implications for Research Strategy

The findings have implications for institutional research strategic planning:

Focus vs. Breadth Trade-off: The inverse relationship between research volume (papers, authors) and efficiency metrics suggests that institutions face strategic choices regarding research focus and breadth. Institutions with limited resources may achieve greater impact through focused, high-quality research, while those with substantial resources may succeed through a "volume plus impact" approach.

Collaboration Optimization: The wide variation in author-to-paper ratios (1.3 to 3.6) suggests that institutions can optimize collaboration strategies. While extensive collaboration may enhance research quality, highly efficient research can be conducted by smaller, focused teams.

Resource Allocation: Institutions should consider the effectiveness of resource allocation for cardiovascular research. The findings suggest that focused, high-impact research may be more effective in highly cited literature than broad, low-impact research.

4.4 Methodological Contributions

This study demonstrates the value of TOPSIS as a tool for research evaluation. The multi-criteria approach addresses several limitations of traditional bibliometric analyses:

1. **Balanced Perspective:** TOPSIS considers both positive (citations, papers) and negative (unique authors) criteria, providing a more balanced assessment of institutional performance.

2. **Transparent Ranking:** The method provides clear, quantifiable rankings that can inform institutional benchmarking.

3. **Adaptable Framework:** The TOPSIS framework can accommodate additional criteria and revised weights, enabling tailored analyses for different contexts.

4.5 Limitations

This study has several limitations:

1. **Data Source:** The analysis was limited to Scopus-indexed publications, potentially excluding articles in journals not covered by the database.

2. **Citation Window:** The analysis included articles up to 2026, and "Cited by" counts may increase over time, particularly for recent articles.

3. **Institutional Affiliation Attribution:** Authors with multiple institutional affiliations may have been counted in multiple institutions, potentially overstating institutional involvement.

4. **Weighting Assumption:** Equal weighting of criteria may not reflect the relative importance of different research outputs.

5. **Exclusion of Non-Research Outputs:** The analysis focused on articles only, excluding conference proceedings, guidelines, and other research outputs.

5. Conclusion

This study employed TOPSIS analysis to evaluate and rank institutional research performance in cardiovascular medicine based on highly cited literature from 2010–2026. The analysis revealed substantial variation in institutional performance, with Harvard University demonstrating dominant performance across all evaluation criteria. US institutions dominated the ranking, accounting for 27 of 30 universities, while the University of Toronto established a benchmark for non-US institutional research performance.

The findings highlight the importance of considering multiple dimensions of research performance, including efficiency (citations per paper, authors per paper) alongside traditional metrics (citations, papers). The identification of an "efficiency gap" between high-impact, focused institutions and high-volume, collaborative institutions provides insights for strategic research planning.

The TOPSIS methodology offers a robust framework for institutional research evaluation that can complement traditional bibliometric approaches. Future research should explore longitudinal analyses to assess changes in institutional performance over time, consider additional criteria (e.g., grant funding, clinical impact), and investigate the factors underlying performance differences.

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