

# Exploring the Nexus Between Ankle-Brachial Index and Atherosclerosis: A Bibliometric Analysis From 1989 to 2024

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**Purpose:** Cardiovascular and cerebrovascular diseases related to atherosclerosis represent a leading global health burden, contributing substantially to morbidity, disability, and premature mortality. The Ankle-Brachial Index (ABI) has emerged as a valuable non-invasive tool for screening peripheral artery disease and assessing the burden of systemic atherosclerosis. This bibliometric analysis aims to evaluate the research landscape, key contributors, and evolving trends in ABI and atherosclerosis studies.

**Patients and Methods:** A bibliometric analysis was conducted using data from the Web of Science Core Collection from 1989 to 2024. The data were analyzed using the R package “bibliometrix”, CiteSpace, and VOSviewer to identify research outputs, influential institutions, journals, authors, and keywords.

**Results:** This study included a total of 1896 eligible publications. The number of publications on ABI and atherosclerosis has steadily increased, peaking in 2021. The United States led in research output ( $n = 448$ ) and citation impact ( $n = 29,980$ ), followed by China and Japan. University of California System contributed the most publications, while *Circulation* and *Atherosclerosis* were the most influential journals. Criqui Michael H. emerged as the most cited author, with 5848 citations. Keyword analyses showed that the terms “cardiovascular disease”, “mortality”, “risk factors”, and “prevalence” terms had a high co-occurrence rate, while burst analyses showed that key terms such as “disease”, “epidemiology” and “events” were prominent in recent studies.

**Conclusion:** This bibliometric analysis offers a comprehensive perspective on the role of the ABI in the field of atherosclerosis research, and it offers crucial support for guiding future research directions.

**Keywords:** ankle-brachial index, atherosclerosis, bibliometric analysis

## Introduction

Atherosclerosis, a leading cause of cardiovascular and cerebrovascular diseases, increases with age, placing a significant burden on society and healthcare systems. It involves the deposition of lipid and fibrous tissue in vessel walls, leading to arterial narrowing and hardening, which can result in myocardial infarction, stroke, and peripheral arterial disease.<sup>1</sup> Atherosclerosis often lacks early symptoms, making timely diagnosis vital to reduce cardiovascular risks. The Ankle-Brachial Index (ABI), a non-invasive, cost-effective tool, is widely used to screen for peripheral arterial disease and assess systemic atherosclerosis burden. Its standardization enhances its role in cardiovascular risk evaluation.<sup>2</sup> Recent studies suggest that a low ABI ( $<0.9$ ) is associated not only with peripheral artery disease (PAD) but also with systemic atherosclerosis, including coronary artery disease, cerebrovascular events, and increased carotid intima-media thickness.<sup>3</sup> Furthermore, ABI values are inversely correlated with systemic inflammation markers such as hsCRP, which may reflect the underlying systemic burden of atherosclerosis.<sup>4</sup>

ABI effectively reflects systemic atherosclerotic burden and is strongly linked to vascular calcification, plaque formation, arterial stiffness, and cardiovascular events.<sup>5</sup> In recent years, research has expanded beyond ABI's role in diagnosing PAD, exploring its association with systemic atherosclerosis, inflammatory markers, and metabolic syndrome.<sup>6</sup> Furthermore, several recent studies and clinical recommendations support ABI measurement as a cardiovascular risk modifier, even in individuals without known atherosclerotic cardiovascular disease, thereby aiding in risk stratification and early preventive intervention.<sup>7</sup> Given the growing body of research on ABI and atherosclerosis, it is essential to systematically evaluate the existing literature in order to identify research trends in this field.

Bibliometric analysis is a quantitative method used to assess research output and trends in a given scientific domain. It allows researchers to evaluate publication patterns, collaboration networks, and emerging research themes, providing valuable insights into the development of a field.<sup>8</sup> Previous bibliometric studies have successfully mapped the research landscapes of various medical fields. For instance, existing bibliometric analyses have highlighted the interest in monoclonal antibodies targeting inflammation in atherosclerosis.<sup>9</sup> Additionally, research trends have identified the NLRP3 inflammasome as a key hotspot in atherosclerosis-related inflammation.<sup>10</sup> Despite prior analyses on atherosclerosis topics, no study has specifically explored ABI's expanding scientific discourse beyond PAD. A targeted bibliometric analysis is essential to uncover underexplored connections between ABI and systemic atherosclerosis, highlight leading contributors, and guide future interdisciplinary collaboration. To address this gap, our study aims to conduct a bibliometric analysis of ABI and atherosclerosis, with the goal of identifying key themes and suggesting potential future research directions.

## Materials and Methods

### Search Strategies and Data Collection

A literature search was conducted in the Web of Science Core Collection (WoSCC), specifically using the Science Citation Index Expanded (SCIE) and the Social Sciences Citation Index (SSCI).<sup>11</sup> The search strategy was designed to ensure both comprehensiveness and specificity to the research theme: (TS = (“ankle brachial index” OR “ankle brachial Pressure Index” OR “ankle arm index”)) AND TS = (“Atherosclerosis\*” OR “Atherogenesis\*”).<sup>12,13</sup> To ensure a comprehensive overview of the research landscape, the time frame was set from the publication date of the first relevant article (January 1, 1989) to the date of data retrieval (December 31, 2024). Only articles published in English were considered. Data was collected in text format, including publication and citation counts, article titles, author information, institutional affiliations, countries/regions, journals, and keywords, all of which were used for the subsequent bibliometric analysis.

### Statistical Analysis

The bibliometric analysis was conducted using VOSviewer (V 1.6.20), CiteSpace (V 6.3.R1), and the R package “bibliometrix” (V 4.3.3). VOSviewer is a multifunctional software tool that plays a key role in mapping collaborations between countries, institutions, and authors, as well as journal co-authorship, coupling, and keyword co-occurrence.<sup>14</sup> Using VOSviewer, we can visualize and explore the complex networks of cooperation and relationships within academic fields, gaining deep insights into the connections between authors, institutions, publications, and keywords. In the co-occurrence network map, the size of the nodes represents the number of objects, the thickness of the lines indicates the strength of the links, and the color of the nodes reflects different clusters or time trends.

CiteSpace was used to conduct a time-slice analysis of burst keywords from January 2004 to December 2024. The time slice was set to one year, with nodes designated as keywords. For keyword analysis, the threshold was set to the top 5 entries per slice, and the Pathfinder algorithm combined with network merging was applied for pruning optimization.

Additionally, the R package “bibliometrix” is a crucial tool for comprehensive bibliometric analysis.<sup>15</sup> It supports the entire process of data import, transformation, analysis, and scientific visualization, making it well-suited to meet the needs of bibliometric research.

The h-index, m-index, and g-index are used to quantitatively assess the academic impact of individuals and journals,<sup>16,17</sup> while the 2023 impact factor (IF) and journal ranking, or quartile (JCR), obtained from Journal Citation Reports (Clarivate Analytics), were employed to evaluate journal influence.<sup>18</sup>

## Results

### An Overview of Publications

The initial dataset comprised 2328 records. After excluding 432 non-article or non-English publications, 1896 eligible publications remained, as illustrated in the flowchart in [Figure 1](#). The analysis revealed that 10,758 authors from 7152 institutions across 87 countries/regions contributed to the research. These publications appeared in 563 journals and cited 40,424 references.

The number of publications related to ABI and atherosclerosis has shown a steady growth trend. The line chart indicates a noticeable increase in the number of publications with several significant inflection points. In 2020, the annual number of publications experienced the highest increase with an addition of 25 articles compared to the previous year. The maximum annual count was reached in 2021 when the number of articles peaked at 113 ([Figure S1](#)).

### National Landscape and Research Distribution

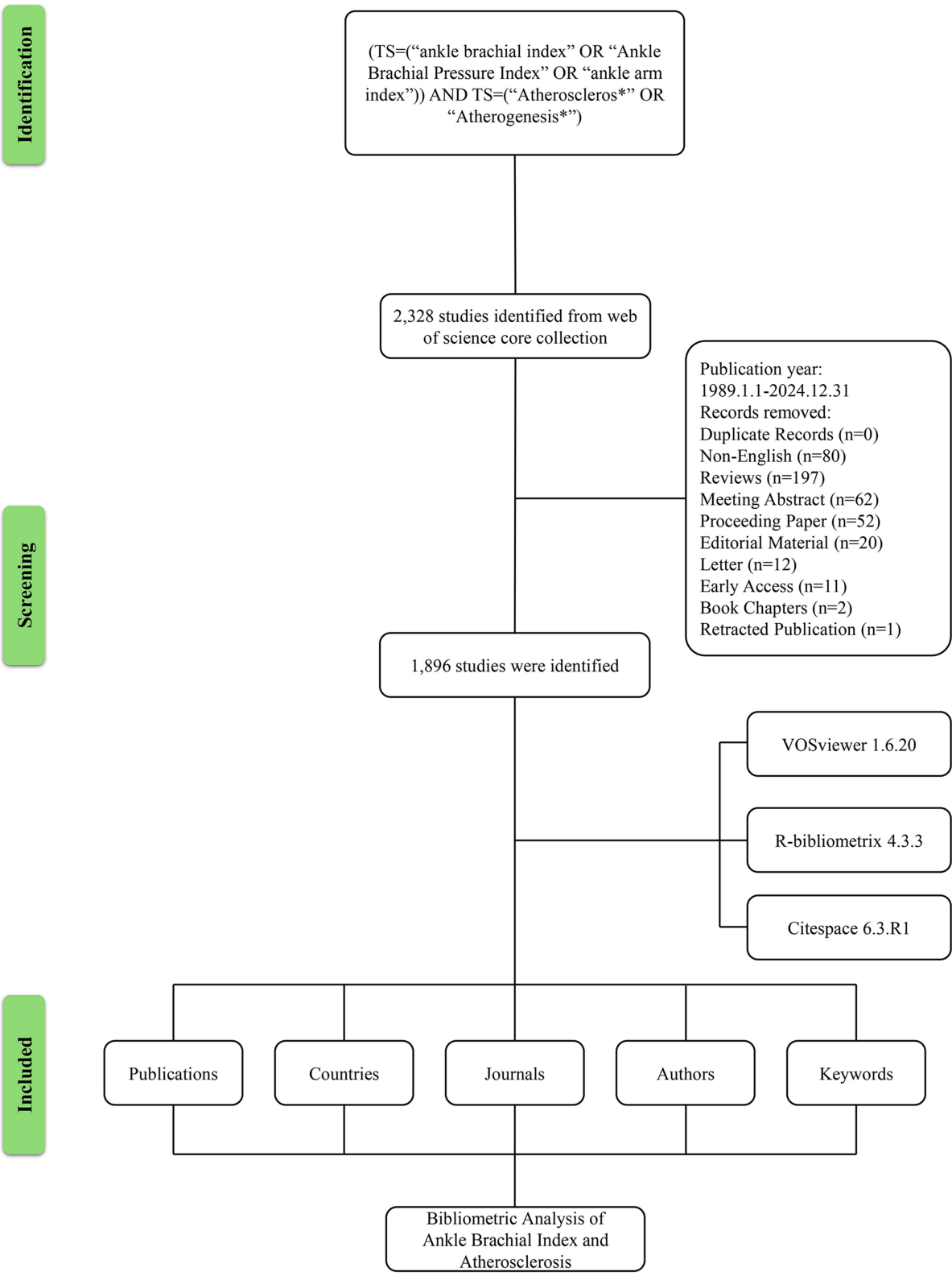
A total of 87 countries published articles in this field. The top 20 productive countries generated 1698 articles, accounting for 89.6% of the papers worldwide. The United States was the most prolific country, publishing 448 articles, followed by China (277) and Japan (189). In terms of total citations, the United States ranked first with 29,980 citations, followed by the United Kingdom (7549) and the Netherlands (6349). The highest average citations per article were observed in the United Kingdom (88.8), followed by the Netherlands (73.8) and the United States (66.9) ([Table S1](#)). In terms of publications across multiple countries, the United States ranks first with 78,448 publications, followed by China (36,277) and the Netherlands (17,861). ([Figure S2a](#)). In addition, 56 countries with a minimum of 3 document in co-occurrence network were analyzed with VOSviewer ([Figure S2b](#)). Among them, the United States (282) had the highest total link strength with other countries, followed by and the United Kingdom (154) and Italy (116).

### Institutional Contributions to ABI and Atherosclerosis

A total of 7152 institutions contributed to this field. The top 10 institutions with the highest research outputs were displayed in [Figure S2c](#). University of California System in the United States was the leading institution with a total publication number of 232, followed by Johns Hopkins University in the United States (184) and Harvard University (164). In addition, the study revealed the cooperative relationship among 117 institutions that published a minimum of 8 documents. Among total link strength, University of Washington had the highest number of collaborations with other countries (344), followed by University of California San Diego (334) and Johns Hopkins University (242) ([Figure S2d](#)).

### Journal Contributions and Impact Analysis

A total of 672 (35.4%) of the studies were published in top 20 journal based on H-index ([Table S2](#)). Among the analyzed journals, *Atherosclerosis* (H-index: 40), *Circulation* (H-index: 28), and *Vascular Medicine* (H-index: 23) held the top three positions in H-index rankings. In terms of total publications, *Atherosclerosis* ranked first with 136 publications, followed by *Angiology* (58), and *Vascular Medicine* (53). For total citations, *Circulation* ranked first with 5913 citations, *Atherosclerosis* was second with 2627, and *Journal of the American College of Cardiology* ranked third with 2272 citations. High-impact journals such as *Circulation* (IF: 35.5) and *Diabetes Care* (IF: 14.8) also stood out in the analysis. Most of the journals analyzed were placed in JCR Q1 and Q2. Besides, the co-occurrence networks of journals contained 99 journals with at least 4 publications. The three key journals with the highest total link strength in co-occurrence networks were *Atherosclerosis* (779), *Circulation* (656), and *Journal of the American College of Cardiology* (325) ([Figure S3a](#)). Additionally, the coupling network of journals contained 99 journals with at least 4 publications. The three key journals with the highest total link strength in coupling networks were the *Atherosclerosis* (58,476), *Vascular Medicine* (27,785), and *Angiology* (23,012) ([Figure S3b](#)).



**Figure 1** Flowchart. Flow diagram illustrating the identification, screening, eligibility, and inclusion of articles retrieved from the Web of Science Core Collection. Note: Some articles were classified under multiple document types but excluded only once, which may explain the discrepancy in exclusion counts.

## Analysis of Publications and Cooperation Among Authors

A total of 10,755 authors contributed to this field's publications. The top 20 authors ranked by the highest H-index were listed in [Table S3](#). Among the analyzed authors, Criqui Michael H. had the highest H-index (30), followed by Fowkes FGR (23) and Allison Matthew A. (22). In terms of total publications, Criqui Michael H. ranked first with 65 publications, followed by Allison Matthew A. with 40, and Matsushita Kunihiro and McDermott Mary M. with 31 each. Regarding total citations, Criqui Michael H. was the most cited author (5848), followed by McDermott Mary M. (4115) and Hofman A. (3983). Additionally, the M-index indicated significant scientific advancements for Criqui Michael H. (1.50), Matsushita Kunihiro (1.25), and Allison Matthew A. (1.10). The co-occurrence network of research findings on ABI and atherosclerosis was visualized in [Figure S3c](#), with the research results broadly categorized into 6 groups. The most collaborations with others were made by Criqui Michael H. (219), followed by Allison Matthew A. (123) and McDermott Mary M. (114), in order of total link strength.

## Research Hot Spots and Trend Analysis

The study included 126 keywords with a minimum frequency of 20 occurrences. The top five keywords with the most frequent occurrence were “mortality” (561 occurrences), “risk-factors” (426 occurrences), “prevalence” (386 occurrences), “cardiovascular-disease” (362 occurrences), and “association” (326 occurrences). From 2010 to 2012, “c-reaction protein (CRP)”, “arm index”, and “vascular disease” emerged as key themes. Between 2012 and 2014, the “mortality”, “prevalence”, “stroke” and “blood pressure” became prominent keywords in related studies. From 2014 to 2016, the research focus deepened further, such as “prediction”, “meta analysis”, “events” and “risk” became a major topic during this period ([Figure S4a](#)).

The burst analysis of keywords in a slice from 2004 to 2024 was performed to reveal the evolution trend. The blue lines stood for the time span. The red lines represented the burst period. The strength of the top 20 keywords with the strongest bursts varied from 6.40 to 16.58 ([Figure S4b](#)). This study revealed that the term “arm index” exhibited the highest burst intensity, followed by “peripheral vascular disease”, “arterial stiffness”, and “disease”. Terms like “random forest”, “arm index” and “peripheral vascular disease” had the longest time span of outbreaks. Since 2017, the keywords “disease”, “subclinical atherosclerosis”, “arterial stiffness”, “epidemiology”, “management” and “events” had been more prominently concentrated, indicating promising developments. It was worth noting that “disease”, “epidemiology” and “events” burst lasted until 2024.

## Discussion

### General Information

This bibliometric analysis reveals significant growth in ABI and atherosclerosis research, with close collaboration patterns within the field. Keyword analysis suggests that future research hotspots will continue to focus on epidemiology and related areas, providing researchers with reliable insights for identifying research frontiers.

The United States leads in this field due to substantial funding, notably from the NIH. Major institutions, such as Johns Hopkins University and the University of California system, have contributed significantly through multi-center studies like the Multi-Ethnic Study of Atherosclerosis (MESA), which helped validate the ABI as a crucial tool for cardiovascular risk assessment.<sup>19</sup> The increasing focus on ABI in countries like China and Japan reflects a growing recognition of its utility, though citation impact remains relatively lower compared to the United States.<sup>20</sup>

In Europe, institutions in the United Kingdom and the Netherlands have advanced ABI research through population-based studies, reinforcing its role as a non-invasive method for early disease detection.<sup>7</sup> High-impact journals such as *Circulation* and *Atherosclerosis* have played a central role in disseminating influential ABI-related findings.<sup>21</sup>

Leading researchers, notably Criqui Michael H. and McDermott Mary M., have been pivotal in establishing ABI's role in cardiovascular risk assessment. Their work in large-scale epidemiological studies, particularly MESA, provided strong evidence linking ABI abnormalities with atherosclerosis progression and adverse outcomes.<sup>22</sup> Collaborations through institutions such as the University of California System and Northwestern University facilitated interdisciplinary studies that bridged diagnostic innovation and clinical application.

## Research Hotspots and Trends Analysis

### Co-Occurrence Analysis

Keyword co-occurrence analysis of ABI and atherosclerosis research from 1989 to 2024 revealed an evolving focus, highlighting how the field has expanded from basic epidemiological assessments to more specialized clinical applications. To contextualize this evolution in keyword trends, recent clinical and mechanistic studies further reinforce this trajectory. ABI has consistently been associated with subclinical carotid and coronary atherosclerosis, as demonstrated in large-scale studies such as MESA and ARIC.<sup>23,24</sup> Moreover, experimental work suggests that abnormal ABI reflects both intimal atherosclerotic plaque and medial calcification, particularly in diabetes, offering insight into arterial remodeling mechanisms.<sup>25</sup> These findings provide a translational bridge linking vascular biomechanics with systemic cardiovascular outcomes.

In parallel, literature over the past two decades has revealed both consensus and ongoing debate within ABI research. It is widely agreed that a low ABI (<0.9) serves as a strong and independent predictor of cardiovascular disease and subclinical atherosclerosis. Large-scale cohorts such as MESA and ARIC have consistently demonstrated that individuals with low ABI values are at elevated risk for coronary artery calcium, increased carotid intima-media thickness, and adverse cardiovascular events.<sup>23,26</sup> However, important discrepancies remain. There is no universally accepted standard for ABI measurement, as some studies calculate ABI using the higher ankle systolic pressure while others use the lower, leading to inconsistent thresholds and comparability issues across studies.<sup>27</sup> Furthermore, the prognostic interpretation of high ABI values (>1.4) remains controversial. While initially thought to reflect healthy arterial function, high ABI is now recognized in some populations—particularly those with diabetes or chronic kidney disease—as a marker of arterial medial calcification and reduced arterial compressibility.<sup>25</sup> Moreover, emerging research suggests that ABI trajectories over time—such as persistent decline—may better predict myocardial infarction and heart failure risk than a single static measurement, especially in high-risk populations.<sup>28</sup> These unresolved methodological and interpretive issues underscore the need for standardized measurement protocols and population-specific thresholds.

### Inflammation and Diagnostic Tools Exploration

From 2010 to 2012, research trends highlighted the critical role of inflammatory processes in atherosclerosis, alongside significant advancements in diagnostic tool development. For instance, CRP, a prominent inflammatory biomarker, gained recognition for its potential in diagnosing vascular diseases such as atherosclerosis.<sup>29</sup> Alongside this, the “arm index” was explored as a diagnostic tool for assessing blood flow and detecting vascular conditions. This focus significantly advanced the understanding of atherosclerosis mechanisms, leading to early detection tools that contributed to more accurate diagnostics and subsequent treatment strategies.<sup>30</sup>

### Transition From Diagnostic Tools to Prognostic Indicators

From 2012 to 2014, research trends underscored the growing significance of the ABI as a potential prognostic indicator, highlighting its increasing role in predicting long-term outcomes such as stroke and cardiovascular events.<sup>12,31</sup> However, it is important to clarify that these are associative findings derived primarily from observational cohort studies rather than causal inferences. For example, in a recent prospective cohort, individuals with ABI values at the lower end of the reference range exhibited significantly higher incidence of stroke and cardiovascular events, even after adjusting for traditional risk factors.<sup>32</sup> Such findings support ABI's utility as a risk stratification tool, but do not establish a direct causal relationship with adverse outcomes. Nonetheless, the consistent associations observed across diverse cohorts have informed preventive health strategies, particularly for individuals with borderline or declining ABI values.

These bibliometric trends reflect not only academic interest but also parallel changes in clinical practice. ABI has been increasingly integrated into cardiovascular risk stratification frameworks, particularly for early identification of subclinical atherosclerosis and prediction of long-term outcomes. For example, large cohort studies have demonstrated that a low ABI (<0.9) is associated with increased risk of first-onset heart failure, stroke, and coronary heart disease, especially in older adults and individuals with comorbidities. Moreover, recent evaluations support ABI as a practical and non-invasive diagnostic and prognostic tool, with high applicability in primary care and outpatient settings.<sup>33</sup> Integrating ABI into traditional risk models, such as Framingham-REGICOR, has been shown to significantly improve

cardiovascular event prediction among intermediate-risk populations.<sup>34</sup> These findings have contributed to ABI being recognized as a risk-enhancing factor in preventive guidelines, though its implementation in routine care remains variable. Together, these developments illustrate how bibliometric growth in ABI research is increasingly aligned with its clinical adoption and utility in cardiovascular prevention strategies.

Building on these clinical recommendations, recent longitudinal evidence has increasingly emphasized ABI's relevance to clinical outcomes. In a large national cohort, individuals with borderline ABI (0.91–0.99) had significantly elevated risk for stroke, myocardial infarction, and cardiovascular death compared to those with normal ABI, particularly in the presence of diabetes or chronic kidney disease.<sup>35</sup> Moreover, ABI decline over time was associated with higher rates of kidney function deterioration and heart failure hospitalizations,<sup>36</sup> highlighting its potential role in long-term disease surveillance beyond atherosclerosis.

### Standardization and Precision Medicine

By 2014–2016, the field of ABI research embraced a new era centered on “prediction”, “meta-analysis”, “events” and “risk”, signifying the maturation of ABI as an essential tool for cardiovascular risk stratification. Large-scale meta-analyses began to consolidate the value of ABI in predicting cardiovascular events.<sup>12,37</sup> Furthermore, ABI was integrated into prediction models alongside traditional risk factors, significantly improving cardiovascular risk assessments in clinical settings. For example, one study that included the ABI in a risk prediction model along with traditional risk factors, such as those used in the Framingham Risk Score, demonstrated an improvement in net reclassification, particularly in intermediate-risk subjects.<sup>38</sup>

The field has shifted from biomarker discovery, such as C-reactive protein and ABI, to epidemiological studies, and now to predictive model development. Early research focused on biomarkers' diagnostic potential, followed by epidemiological validation and clinical integration of predictive models. Current efforts emphasize advanced statistical models to enhance ABI's predictive accuracy for atherosclerosis mechanisms and risk stratification.

### Burst Keyword Analysis and Future Directions

Burst keyword analysis reveals evolving research priorities. From 2004–2011, PVD research surged alongside advances in non-invasive diagnostics and ABI's validation as a prognostic tool. The MESA study linked low ABI (<0.9) to subclinical atherosclerosis, solidifying PVD's role in cardiovascular risk stratification.<sup>39</sup> Post-2011, focus shifted to early vascular dysfunction markers, prioritizing preclinical risk prediction over late-stage disease management, with arterial stiffness emerging as a key biomarker for vascular aging before symptomatic PVD.<sup>40,41</sup>

Between 2018 and 2022, “arterial stiffness” gained prominence as an independent predictor of cardiovascular events (eg, hypertension, stroke, heart failure) and was linked to chronic diseases and early vascular aging. Advances in non-invasive methods like CAVI and ultrafast ultrasound facilitated its clinical integration.<sup>42,43</sup> After 2022, its research declined as arterial stiffness became routine in clinical risk models, reducing its novelty.<sup>44</sup>

Since 2018, the keyword “management” reflects a shift to tailored PAD therapies, combining ABI with other vascular assessments (eg, toe-brachial index) for improved diagnostics, especially in non-compressible arteries. Aggressive risk factor control (eg, BP <130 mmHg, LDL-C <70 mg/dL) reduced cardiovascular events by 37% in high-risk patients (ABI <0.9).<sup>45,46</sup>

The 2024 focus on epidemiology highlights persistent PAD burden disparities. The ARIC study shows African Americans have a 2.1-fold higher PAD prevalence than non-Hispanic Whites, despite controlling for risk factors.<sup>47</sup> A 10% ABI decline over 5 years predicts a 3.5-fold increased myocardial infarction risk in diabetic individuals.<sup>26</sup> Dynamic risk models integrating ABI trends with sociodemographic factors are needed (33). Static ABI thresholds (<0.9) may be inadequate for diverse populations, requiring adaptive guidelines for race, comorbidities, and disease progression.<sup>45</sup> While ABI is validated for PAD and cardiovascular risk, gaps remain. Low-normal ABI values correlate with higher cardiovascular event rates, but high ABI (>1.3), possibly indicating arterial calcification, is debated.<sup>32</sup> Sex- and ethnicity-specific thresholds are underexplored, with distinct ABI risk patterns in women and non-White groups.<sup>48</sup> Addressing these gaps is vital for tailored prevention and better risk prediction.

Research on ABI and atherosclerosis highlights the need to optimize measurement techniques. As a non-invasive tool, ABI's measurement methods remain uncertain. A single reading may underestimate conditions, with bilateral ankle artery measurements recommended for better accuracy.<sup>49</sup> Statistical methods like Bland-Altman analysis could reduce errors, enhancing reliability.<sup>50</sup> The economic feasibility of large-scale ABI screening needs exploration. While cost-effective for cardiovascular risk prediction, its cost-benefit ratio for populations like those with diabetes or chronic kidney disease requires refinement.<sup>51</sup>

## Strengths and Limitations

There are several highlights of our study. First, this is the first bibliometric analysis to assess the results of 35 years of research in the field of ABI and atherosclerosis worldwide. While previous bibliometric studies in related fields have mapped research outputs and trends, our analysis uniquely contributes by focusing specifically on the landscape of ABI and atherosclerosis. Second, this study provides comprehensive information such as the countries, authors, institutions and journals with the most results. However, this study has several important limitations. First, reliance solely on the WoSCC may have excluded relevant literature indexed in other major databases, such as Scopus, Embase, and PubMed, potentially affecting the comprehensiveness of the results. Second, only English-language publications were included, which may result in a geographic and linguistic bias, favoring literature from Western countries and underrepresenting emerging research from non-English-speaking regions where interest in ABI and atherosclerosis is increasing. Third, citation-based metrics are inherently biased toward older publications, which naturally have more time to accumulate citations. Finally, while tools such as VOSviewer and CiteSpace provide valuable bibliometric visualizations, their co-occurrence-based clustering does not necessarily imply conceptual or thematic agreement among clustered nodes, and should be interpreted with caution.

## Conclusion

This bibliometric analysis provides an overview of research trends in ABI and atherosclerosis from 1989 to 2024. The number of publications has grown steadily, with significant contributions from the United States, China, and Japan. Co-occurrence and burst keyword analyses demonstrated a shift from basic diagnostics to epidemiological modeling and risk prediction. Future research should focus on three critical directions: (1) integrating ABI into dynamic risk prediction models using machine learning; (2) investigating population-specific disparities in ABI interpretation, particularly across sex, ethnicity, and comorbidities; and (3) re-evaluating ABI cut-off thresholds to improve diagnostic sensitivity and applicability across diverse populations.

## Data Sharing Statement

All data generated or analysed during this study are included in this published article.

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Jun Wang and Yanfei Tao are co-first authors for this study.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors declare that they have no competing interests in this work.

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