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From past insights to future challenges: A global bibliometric analysis of hepatic steatosis (1980–2025)

Geçmişin çıkarımlarından geleceğin zorluklarına: Hepatik steatozun global bibliyometrik analizi (1980–2025)

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Abstract

Background: This study aimed to bibliometrically analyze publications on Hepatic Steatosis (HS) indexed in the Web of Science (WoS) database between 1980 and 2025, with the objective of identifying global research trends, leading authors, institutions, and countries, influential journals, collaboration networks, and emerging priority research areas.

Material and Methods: A total of 3,871 articles were evaluated. The scientific mapping of the HS literature was conducted using the Bibliometrix R package and its Biblioshiny interface.

Results: The number of publications on HS has increased rapidly over the past forty-five years, with research largely characterized by teamwork and international collaboration. Prof. Yu Li, Prof. Yuxiu Liu, and Asst. Prof. Hyunbae Kim emerged as the most prominent researchers, while Hepatology, Journal of Hepatology, and PLOS One were identified as the most influential journals. At the country level, China, the United States, and South Korea were the leading contributors. Keyword and thematic analyses highlighted a research focus on metabolic syndrome, inflammation, non-invasive diagnostic methods, and molecular mechanisms.

Conclusions: The findings reveal that HS research demonstrates multidisciplinary progress encompassing both fundamental pathophysiological processes and clinical applications. Research trends and collaboration structures indicate the field is becoming increasingly globalized with substantial scientific impact. In the future, metabolic disorders, the gut microbiota, and targeted molecular therapeutic strategies are expected to be prioritized research themes.

Keywords: Hepatic steatosis; bibliometric analysis; science mapping

ÖZ

Amaç: Bu çalışma, 1980–2025 yılları arasında Web of Science (WoS) veri tabanında yayımlanan Hepatic Steatosis (HS) konulu makaleleri bibliyometrik açıdan inceleyerek küresel araştırma eğilimlerini, önde gelen yazar, kurum ve ülkeleri, etkili dergileri, işbirliği ağlarını ve gelecekteki öncelikli araştırma alanlarını ortaya koymayı amaçlamıştır.

Gereç ve Yöntem: Analiz kapsamında 3871 makale değerlendirilmiştir. HS konusundaki literatürün bilimsel haritalaması, Bibliometrix R paketi ve Biblioshiny arayüzü kullanılarak gerçekleştirilmiştir.

Bulgular: HS alanında yayın sayısının son kırk beş yılda hızlı bir şekilde arttığı, araştırmaların büyük ölçüde ekip çalışması ve uluslararası işbirliği ile yürütüldüğü saptanmıştır. Prof. Yu Li, Prof. Yuxiu Liu ve Asst. Prof. Hyunbae Kim önde gelen araştırmacılar olarak öne çıkarken, Hepatology, Journal of Hepatology ve Plos One en etkili dergiler olarak belirlenmiştir. Ülkeler düzeyinde Çin, ABD ve Güney Kore lider konumdadır. Anahtar kelime ve tematik analizler, metabolik sendrom, inflamasyon, non-invaziv tanı yöntemleri ve moleküler mekanizmalar üzerine odaklanmayı göstermektedir.

Sonuç: Araştırma sonuçları, HS araştırmalarının hem temel patofizyolojik süreçleri hem de klinik uygulamaları kapsayan multidisipliner bir ilerleme sergilediğini ortaya koymaktadır. Araştırma eğilimleri ve işbirliği yapıları, alanın giderek globalleştiğini ve yüksek bilimsel etkiye sahip olduğunu göstermektedir. Gelecekte, metabolik bozukluklar, mikrobiyota ve hedefe yönelik moleküler tedavi stratejileri öncelikli araştırma konuları olarak öne çıkacaktır.

Anahtar kelimeler: Hepatik steatoz; bibliyometrik analiz; bilim haritalama.

Highlights

- HS research has risen markedly since 1980, supported by strong international collaboration.
- China, the USA, and South Korea lead the field.
- Future priorities include metabolic syndrome, inflammation, and non-invasive diagnostics.

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Introduction

Metabolic dysfunction-associated steatotic liver disease (MASLD) is currently the most prevalent chronic liver disease and is strongly associated with metabolic risk factors such as obesity, type 2 diabetes mellitus (T2DM), and dyslipidemia (1,2). Previously referred to as non-alcoholic fatty liver disease (NAFLD), this condition was redefined as MASLD following a 2023 terminology update, while its progressive form characterized by inflammation and fibrosis was designated as metabolic dysfunction-associated steatohepatitis (MASH) (3,4). The shift from NAFLD to MASLD was primarily motivated by the need to adopt a more inclusive and pathophysiologically accurate definition that emphasizes metabolic dysfunction rather than the mere exclusion of alcohol consumption (5). Furthermore, earlier proposals such as metabolic dysfunction-associated fatty liver disease (MAFLD) were also introduced in 2020, aiming to highlight metabolic risk factors (2). However, international consensus now favors MASLD, while some studies still use NAFLD or MAFLD, leading to heterogeneity in the literature (3).

MASLD encompasses a wide clinical spectrum ranging from simple steatosis to cirrhosis and represents a major public health concern due to both liver-related morbidity and cardiometabolic complications (6,7). Given this evolving terminology, the present study adopts the overarching concept of "hepatic steatosis (HS)" as a unifying term to systematically capture all relevant research regardless of the terminology used in different periods. This approach ensures consistency and allows for a comprehensive assessment of the global research landscape.

In recent years, the number of studies focusing on HS has increased substantially worldwide (8). However, the rapid expansion of the literature makes it challenging to systematically identify the most recent trends, research gaps, and leading contributors (9,10). In this context, bibliometric analyses provide a valuable approach to quantitatively assess the volume, impact, and collaborative networks of scientific studies published on a given topic (11,12). While several bibliometric studies have previously addressed NAFLD or MAFLD in isolation (13,14), to the best of our knowledge, no large-scale bibliometric analysis has yet been conducted that integrates the evolving terminology under the unified concept of HS. Therefore, this study not only fills this gap but also provides novel insights into how terminological transitions have influenced research output, citation impact, and scientific collaboration in the field.

The aim of this study is to bibliometrically analyze publications on HS indexed in the Web of Science Core Collection (WoS) database between 1980 and 2025, with the objective of identifying global research trends, leading authors, institutions, and countries, influential journals, and emerging future research directions.

Material and Methods

Study design

The literature search process on HS was structured based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Search Strategy (PRISMA-S) guidelines, which ensure the transparent and reproducible reporting of search strategies in systematic reviews (15). The filtering steps and selection process applied during the literature search are presented in detail in a flow diagram to ensure the methodological rigor and reproducibility of the study **(Table 1)**.

Table 1. Search strategy suitable for PRISMA-S and workflow of analysis

Stage	Description	Criteria / Filters	Number of Articles	Analysis
1. Database selection	Selection of database for bibliometric analysis and literature review	Web of Science	—	**Performance Analysis** Main Information Publications Annual Scientific Production and Citation Per Year Sources' Local Impact Most Local Cited Document Authors' Local Impact Countries' Scientific Production **Collaboration Network Analysis** Authors Network Analysis
2. Search date	Date of literature search	6.08.2025	—	
3. Search terms	Title Search	Hepatic Steatosis	6364	
4. Publication type filter	Selection of specific publication types	Article or Review Article	4175	
5. Index filter	Selection of specific indexes	SCI_EXPANDED OR ESCI	4168	
6. Language	Restriction of publication	English	4118	

filter	language			Institutions Network Analysis Countries Network Analysis **Word and Thematic Analysis** Word Cloud From Author's Keywords Trend Topics Thematic Map
7. Year filter	Exclusion of publications from the year 2025	1980 - 2024	3871	
8. Final dataset	Articles included in the analysis	Remaining after applying all filters above	3871	

The synonymous or closely related keywords were merged, with the terms following the comma consolidated under the term preceding the comma. For example: non-alcoholic fatty liver disease, nonalcoholic fatty liver disease; non-alcoholic fatty liver disease, non-alcoholic fatty liver disease (NAFLD); non-alcoholic fatty liver disease, NAFLD; endoplasmic reticulum stress, ER stress; high-fat diet, high fat diet; non-alcoholic steatohepatitis, nonalcoholic steatohepatitis; triglycerides, triglyceride; AMP-activated protein kinase, AMPK.

In this study, the WoS database, one of the most commonly used sources for bibliometric analyses and literature searches, was employed. Different databases vary considerably in their journal coverage, whereas WoS is among the most widely preferred academic resources for bibliometric research (16).

The data search was performed in the WoS database on August 6, 2025. In the subsequent stage, the retrieved records were refined and filtered. A total of 6,364 documents were initially identified under the title "Hepatic Steatosis." When restricted to the document types "Article OR Review Article," the number decreased to 4,175. Limiting the WoS index to "SCI-EXPANDED OR ESCI" yielded 4,168 documents, while restricting the language to "English" resulted in 4,118 documents. Since new publications continue to be indexed, articles published in 2025 were excluded, yielding a final dataset of 3,871 publications, which were included in the analysis.

For the analysis of the retrieved dataset, the Bibliometrix package was utilized. Bibliometrix is a recent open-source software developed in R, designed to perform science mapping and bibliometric analyses (12).

In this study, a total of 3,871 articles were analyzed in three sections. The first section presents a performance analysis of publications in the field of HS, the second section focuses on collaboration analysis, and the third section covers keyword and thematic analysis.

Ethical Approval

Ethics committee approval is not required for bibliometric studies.

Results

Performance Analysis

Figure 1 illustrates the overall profile of scientific output on HS. The dataset covers studies published between 1980 and 2024, comprising a total of 3,871 documents authored by 20,911 different researchers. Notably, only 25 publications were single-authored, indicating that research in this field is predominantly conducted through collaboration.

The publications included 983 references and received a total of 93,737 citations. This high citation count highlights the strong foundation upon which HS research is built and underscores the critical role of previous studies in shaping the field. The mean publication age was 8.3 years, reflecting that most of the research remains up-to-date and aligned with ongoing scientific developments.

The rate of international collaboration was 20.05%, demonstrating substantial contributions from multiple countries and confirming the global relevance of HS research. Each document was co-authored by an average of 8.21 researchers, further supporting the finding that the field is largely driven by teamwork.

The annual growth rate was calculated as 14.21%, underscoring the rapid increase in research activity and the growing scientific interest in HS. Moreover, each publication received an average of 43.37 citations, suggesting that studies in this domain hold significant influence within the scientific community.

Finally, a total of 5,475 author keywords were identified, indicating that HS research encompasses a broad spectrum of topics and involves in-depth exploration across various subfields. Collectively, these findings highlight the dynamic growth of the field, its extensive collaborative networks, and its considerable global scientific impact.

Figure 1. Main information publications

Figure 2 illustrates the annual scientific production on HS and the average number of citations per year between 1980 and 2024. The early period (1980–1990) was characterized by very limited output (1–5 publications annually) and low citation rates (<1), reflecting minimal scientific attention to HS during that decade.

From the mid-1990s onward, a gradual rise in both publications and citations was observed, with notable peaks in the late 1990s and early 2000s. By 2004, the number of publications reached 30 with an unusually high citation average (11.8), indicating increased visibility of HS in both clinical and basic science research. The subsequent years (2005–2010) showed a steady growth in publication numbers (50–80 annually), while citation averages stabilized around 6.

A sharp increase occurred after 2010, when annual outputs exceeded 100 papers. Although productivity expanded rapidly, citation averages gradually declined, suggesting that growth in quantity was not matched by proportional gains in research impact.

Since 2014, HS research has entered a "publication boom," peaking at 347 articles in 2022. However, citation averages have continued to decline, reaching 1.7 in 2024, partly due to the limited time for recent papers to accumulate citations. Overall, the data highlight an exponential increase in HS-related research over the past two decades, but also a decline in average influence. These trends indicate that future impactful studies will likely require innovative topics, multidisciplinary designs, and stronger methodological frameworks. The trend line analysis confirmed a strong fit ($R^2 = 0.9774$), validating the observed growth trajectory.

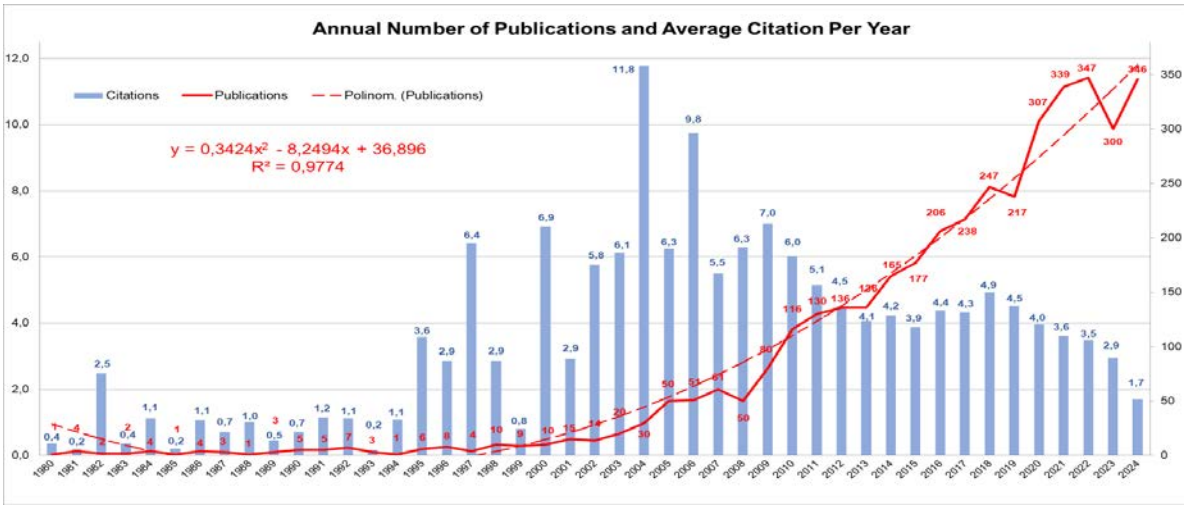


Figure 2. Annual scientific production and average citation per year

Table 2 presents the impact of leading researchers in the academic literature on HS, including various bibliometric indicators such as h-index, g-index, m-index, total citations (TC), number of publications (NP), and the year of first publication (PY_start). These metrics assess the influence of authors not only through their productivity but also through the citation impact of their contributions.

The h-index is a widely used measure of scientific productivity and academic influence, indicating that an author with an h-index of h has at least h publications, each cited at least h times (17). The g-index emphasizes the impact of highly cited works; an author has a g-index of g if their top g papers together received at least g^2 citations, thereby giving more weight to the most influential publications (18). The m-index is obtained by dividing the h-index by the number of years since the author's first publication, providing a fairer assessment for early-career researchers (17).

Among the most prominent contributors, Li Y (h-index= 27, TC= 3955, NP= 47) and Liu Y (h-index= 25, TC= 2087, NP= 33) stand out with both high productivity and strong citation performance. Having entered the field in the early 2010s (Li Y in 2010; Liu Y in 2011), they have maintained consistent impact, as reflected by their relatively high m-index values (1.688 and 1.667, respectively).

Kim H (h-index= 21, NP= 38) and Wang H (h-index= 20, NP= 30), who began publishing in 2008, also occupy a mid-to-high level in terms of both output and citation impact. Notably, Shulman GI, with only 21 publications, has achieved an exceptionally high citation count (TC= 3600, h-index= 18). His comparatively low m-index (0.75) is attributable to his earlier entry into the field (2002), highlighting his role as one of the pioneering contributors whose foundational studies shaped subsequent research.

Researchers from China and South Korea occupy a substantial proportion of the list. Names such as Zhang J, Zhang Y, Chen Y, Kim HJ, Lee JH, Li J, Liu J, Fan JG, Wang J, Chen X, Choi MS, and Choi Y have emerged as key actors since 2008, producing between 20–40 publications each with moderate-to-high citation impact. Particularly noteworthy are Zhang Y (m-index= 1.143) and Li L (m-index= 1.667), who, despite beginning their academic contributions more recently (2012 and 2017, respectively), have rapidly established significant influence in the field.

Table 2. Authors' local impact

Source	H-Index	G-Index	M-Index	TC	NP	TC/NP	PY_start
Hepatology	62	90	1.771	14737	90	163.74	1991
Journal Of Hepatology	44	55	1.467	6546	55	119.02	1996
Plos One	35	59	2.059	3992	98	40.73	2009
Scientific Reports	29	45	2.231	2453	87	28.20	2013
Diabetes	28	34	1.12	4696	34	138.12	2001
Nutrients	27	41	2.25	1926	77	25.01	2014
Journal Of Biological Chemistry	25	33	0.962	3937	33	119.30	2000
Am. J. Physiol. Endocrinol. Metab.	24	34	1.091	3018	34	88.76	2004
Journal of Lipid Research	24	40	1.043	2383	40	59.58	2003
Journal of Nutritional Biochemistry	23	39	1.211	1639	39	42.03	2007
Am. J. Physiol. Gastrointest. Liver Physiol.	22	32	1.048	1897	32	59.28	2005
Liver International	22	39	1.1	1550	43	36.05	2006
Food & Function	21	29	1.615	954	42	22.71	2013
J. Gastroenterol. Hepatol.	20	31	0.8	1804	31	58.19	2001
Molecular Nutrition & Food Research	20	28	1.111	1136	28	40.57	2008
J. Agric. Food Chem.	19	28	1.118	995	28	35.54	2009
Radiology	19	24	0.864	2853	24	118.88	2004
World Journal of Gastroenterology	19	27	0.704	1394	27	51.63	1999
Biomedicine & Pharmacotherapy	18	27	1.8	783	32	24.47	2016
Frontiers In Pharmacology	18	27	1.636	735	28	26.25	2015

Abbreviations: NP = Number of publications, TC = Total citations, TC/NP = Citations per paper, PY_start = Publication year starting Am. J. Physiol. Endocrinol. Metab.: American Journal Of Physiology-Endocrinology And Metabolism, Am. J. Physiol. – Gastrointest. Liver Physiol.: American Journal of Physiology-Gastrointestinal and Liver Physiology, J. Gastroenterol. Hepatol.: Journal of Gastroenterology and Hepatology, J. Agric. Food Chem.: Journal of Agricultural And Food Chemistry.

Table 3 presents the most locally cited (LC) publications in the field of HS and compares their global citation (GC) performance. The table also includes the publication age (YYP), annual average local and global citations (LC/YYP and GC/YYP), and the local-to-global citation ratio (LC/GC), enabling an assessment of both field-specific impact and broader academic visibility.

The most influential publication in HS is Browning JD (2004, Hepatology), which ranks highest in both local citations (LC= 179) and annual global citation rate (GC/YYP= 136.86). This demonstrates exceptional influence both within and beyond the field (LC/YYP= 8.524; LC/GC= 6.23%), indicating that while the paper is widely cited, the majority of citations originate from outside the HS research community. Similarly, Browning's early works, including J Clin Invest (2004) and Szczepaniak (2005), show strong impact at both local and global levels (e.g., Szczepaniak GC/YYP= 62.75; LC/YYP= 6.20).

Notably, Bedogni (2006, BMC Gastroenterol) exhibits a very high annual global citation rate (GC/YYP= 114.53) with an LC/GC ratio of 5.01, suggesting that most citations come from outside the HS field, reflecting broader interdisciplinary influence.

The LC/YYP metric balances differences in publication age, highlighting that papers such as Browning (2004), Lee JH (2010), and Sasso (2010) maintain high annual citation rates within the field. Meanwhile, GC/YYP emphasizes which publications generate wide interdisciplinary recognition, with Browning, Bedogni, and Li Y standing out as highly influential beyond HS research.

Table 3. Most local cited documents

Document	YP	LC	LC/YYP	GC	GC/YYP	LC/GC Ratio%
Browning Jd. 2004. Hepatology	2004	179	8.524	2874	136.86	6.23
Browning Jd. 2004. J Clin Invest	2004	159	7.571	1730	82.38	9.19
Szczepaniak Ls. 2005. Am J Physiol-Endoc M	2005	124	6.200	1255	62.75	9.88
Lee Jh. 2010. Digest Liver Dis	2010	116	7.733	1112	74.13	10.43
Postic C. 2008. J Clin Invest	2008	114	6.706	978	57.53	11.66
Bedogni G. 2006. Bmc Gastroenterol	2006	109	5.737	2176	114.53	5.01
Sasso M. 2010. Ultrasound Med Biol	2010	107	7.133	666	44.40	16.07
Li Y. 2011. Cell Metab	2011	94	6.714	1433	102.36	6.56
Park Sh. 2006. Radiology	2006	82	4.316	419	22.05	19.57
Bellentani S. 2000. Ann Intern Med	2000	76	3.040	991	39.64	7.67
Bohte Ae. 2011. Eur Radiol	2011	72	5.143	417	29.79	17.27
Tang A. 2013. Radiology	2013	57	4.750	432	36.00	13.19
Lee Ss. 2010. J Hepatol	2010	56	3.733	297	19.80	18.86
Dasarathy S. 2009. J Hepatol	2009	52	3.250	487	30.44	10.68
Ferré P. 2010. Diabetes Obes Metab	2010	51	3.400	562	37.47	9.07
Idilman Is. 2013. Radiology	2013	51	4.250	318	26.50	16.04
Kammoun Hl. 2009. J Clin Invest	2009	48	3.000	601	37.56	7.99
Boyce Cj. 2010. Am J Roentgenol	2010	48	3.200	194	12.93	24.74
Purushotham A. 2009. Cell Metab	2009	46	2.875	931	58.19	4.94
Myers Rp. 2012. Liver Int	2012	46	3.538	281	21.62	16.37

Abbreviations: Year of Publication (YP). YYP= Year 2025-Year of Publication. Global Citations (GC). Local Citations (LC)

Table 4 assesses the bibliometric performance of the most influential journals in HS research. Key indicators include h-index, g-index, m-index, TC, NP, TC/NP, and PY_start, allowing a quantitative comparison of each journal's contribution to the field.The journals with the highest overall impact are Hepatology (h-index= 62, g-index= 50, TC= 14,737, TC/NP= 163.74) and Journal of Hepatology (h-index= 44, TC/NP= 119.02), which have published high-quality, widely cited HS research since the early 1990s (1991 and 1996, respectively).

In the mid-to-high impact group, Diabetes (TC/NP= 138.12) and Radiology (TC/NP= 118.88) are notable. Although total publication counts are relatively low (34 and 24), the per-article citation impact is substantial, reflecting strong interdisciplinary interest in HS within metabolic diseases and imaging research.

High productivity with moderate impact is observed in Plos One (NP= 98, TC/NP= 40.73) and Scientific Reports (NP= 87, TC/NP= 28.20). These open-access, multidisciplinary journals achieve large publication volumes, though

per-article citation impact remains lower than the field's leading journals. Similarly, Nutrients (NP= 77, TC/NP= 25.01) is frequently selected for nutrition-focused HS studies.

Specialized journals such as Journal of Nutritional Biochemistry (h-index= 23, TC/NP= 42.03), Liver International (h-index= 22, TC/NP= 36.05), and Journal of Gastroenterology and Hepatology (h-index= 20, TC/NP= 58.19) show a balanced profile in both productivity and citation impact.

Emerging platforms such as Biomedicine & Pharmacotherapy (PY\start= 2016, m-index=1.8) and Frontiers in Pharmacology (PY\start=2015, m-index=1.636) have demonstrated rapid early productivity, although per-article citation impact remains limited.

Overall, HS research achieves high visibility not only in hepatology-focused journals but also across metabolism, nutrition, biochemistry, imaging, and pharmacology journals. Core journals such as Hepatology and Journal of Hepatology provide high citation impact, whereas interdisciplinary journals like Diabetes and Radiology serve as strategically important venues for broader research dissemination.

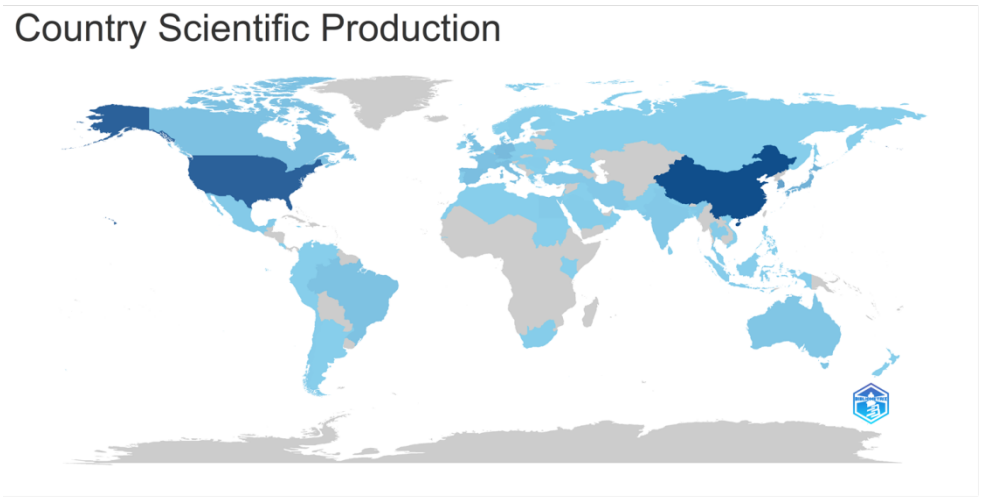
Table 4. Sources' local impact

Element	H-Index	G-Index	M-Index	TC	NP	PY_start
LI Y	27	47	1,688	3955	47	2010
LIU Y	25	33	1,667	2087	33	2011
KIM H	21	38	1,167	1547	38	2008
WANG H	20	30	1,111	1235	30	2008
SHULMAN GI	18	21	0,75	3600	21	2002
WANG Y	17	32	0,81	1370	32	2005
ZHANG J	16	29	0,8	859	29	2006
ZHANG Y	16	32	1,143	1073	41	2012
CHEN Y	15	21	0,938	908	21	2010
KIM HJ	15	23	0,833	2017	23	2008
LEE JH	15	21	0,833	2192	21	2008
LI J	15	29	0,882	895	36	2009
LI L	15	23	1,667	545	27	2017
LIU J	15	26	0,938	879	26	2010
ZHANG L	15	29	0,833	883	30	2008
FAN JG	14	19	0,778	829	19	2008
WANG J	14	23	0,824	557	32	2009
CHEN X	13	20	0,867	630	20	2011
CHOI MS	13	14	0,722	732	14	2008
CHOI Y	13	17	0,867	584	17	2011

Abbreviations: NP: Number of publications, TC: Total citations, PY_start: Publication year starting

Figure 3 illustrates the scientific contributions of different countries in HS research. based on institutional affiliations reported by authors in their publications. It should be noted that these figures reflect the total institutional contributions rather than the number of individual authors or publications.

China leads with the highest institutional contribution (4,133), establishing itself as the global leader in HS research. The United States follows with 3,474 contributions, highlighting its strong research capacity in this field. In Asia, South Korea (1,320) and Japan (839) have made significant contributions. Among European countries, Germany (609), Italy (490), and Spain (479) are the most prominent. France, Canada, the United Kingdom, and Brazil fall within the mid-to-upper range of contributions (360–390), demonstrating considerable global involvement. The Netherlands (266) and Australia (233) also show high international visibility. Türkiye ranks at a moderate level with 173 institutional contributions, comparable to India (169) and Iran (167). Countries with lower levels of institutional contributions include Denmark, Mexico, Egypt, Austria, Switzerland, Thailand, Sweden, Saudi Arabia, and Israel.



Country	Frequency
CHINA	4133
USA	3474
SOUTH KOREA	1320
JAPAN	839
GERMANY	609
ITALY	490
SPAIN	479
FRANCE	390
CANADA	383
UK	361
BRAZIL	360
NETHERLANDS	266
AUSTRALIA	233
TURKEY	173
INDIA	169
IRAN	167
DENMARK	137
MEXICO	126
EGYPT	111
AUSTRIA	104
SWITZERLAND	99
THAILAND	90
SWEDEN	87
SAUDI ARABIA	69
ISRAEL	62

Figure 3. Countries' scientific production

Collaboration Network Analysis

Collaboration network analysis is a bibliometric approach used to map and quantify relationships among researchers, institutions, or countries, providing insights into the social structure of a research field. Nodes represent actors, while links denote co-authorship relationships. Network metrics such as centrality, density, and clustering help identify influential researchers and key collaboration hubs (19,20).

This method not only depicts current collaboration patterns but also highlights leading authors, pioneering institutions, and potential future partnerships, while indicating the level of scientific integration at regional and global scales (21). Publications on Hepatic Steatosis were retrieved from Web of Science, with author, institution, and country information extracted and analyzed using Biblioshiny, VOSviewer, CiteSpace, and Gephi.

The authors' collaboration network is shown in **Figure 4a.** Nodes represent researchers, and edges indicate collaborative links, with node size reflecting influence based on publication output and co-authorship intensity. The analysis included 33 nodes, and the Louvain algorithm was used for cluster detection. The red cluster is centered on Li Y and Zhang Y, showing dense collaborations with Liu Y, Zhang J, and Wang H, indicated by large node sizes representing high productivity and citation impact. The blue cluster is centered around Kim H, with strong links to Lee JH, Lee JY, Lee JM, Lee SG, Park JY, and Park J, reflecting intensive intra-group co-publication activity. The green cluster represents a collaboration network centered on Li J and Wang J, with strong links to Liu J and other green nodes. This cluster demonstrates both internal cohesion and significant connections with the purple cluster, reflecting active international and interdisciplinary collaborations. The purple cluster is centered on Wang Y, including authors such as Wang Q, Tsui PH, Chen X, and Zhang I. Strong links with the green cluster indicate that this group is both independently productive and engaged in inter-cluster collaborations. In the overall network, thick edges represent frequent and strong collaborations, while thin edges indicate less frequent co-authorship. Notably, bridges between the green–purple and green–red clusters highlight key collaborative pathways, illustrating the presence of robust regional and global research networks in Hepatic Steatosis.

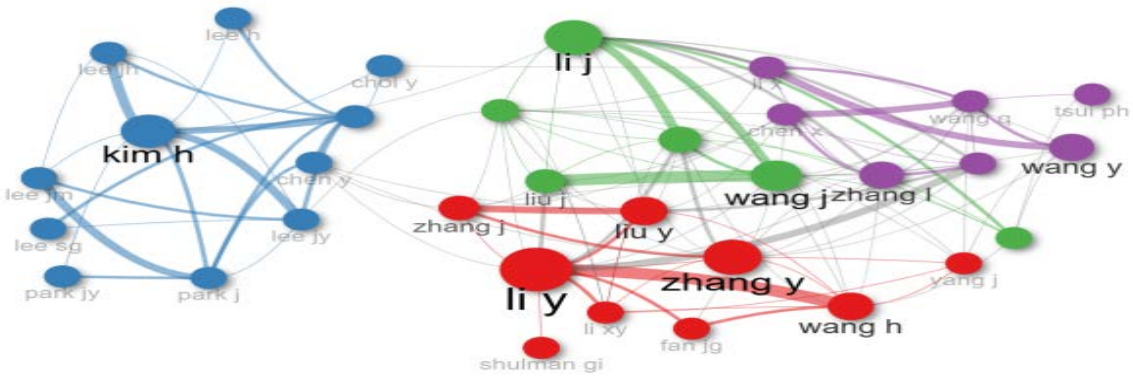


Figure 4a. Collaboration network analysis (Authors)

The Institutional Collaboration Network was analyzed using 20 nodes with the Louvain algorithm. Each node represents an institution, and multiple clusters are distinguished by color **(Figure 4b).** The University of California System occupies a central position with the highest centrality, indicating extensive collaborative activity and a major contribution to publication output. The US Department of Veterans Affairs and Veterans Health Administration (VHA) dominate the brown cluster, with thick connections reflecting high co-publication levels. Harvard University and Harvard University Medical Affiliates form the blue cluster, demonstrating a broad national and international collaboration network. The green cluster, centered on Yonsei University, Yonsei University Health System, and Seoul National University (SNU), represents an East Asia–focused research group with dense internal collaboration but limited links to other major centers. The orange cluster includes China-based institutions such as the Chinese Academy of Sciences and Shanghai Jiao Tong University, while the purple cluster highlights the University of Texas System and University of Texas Southwestern Medical Center. These clusters are active regionally but have fewer links compared to central global actors.

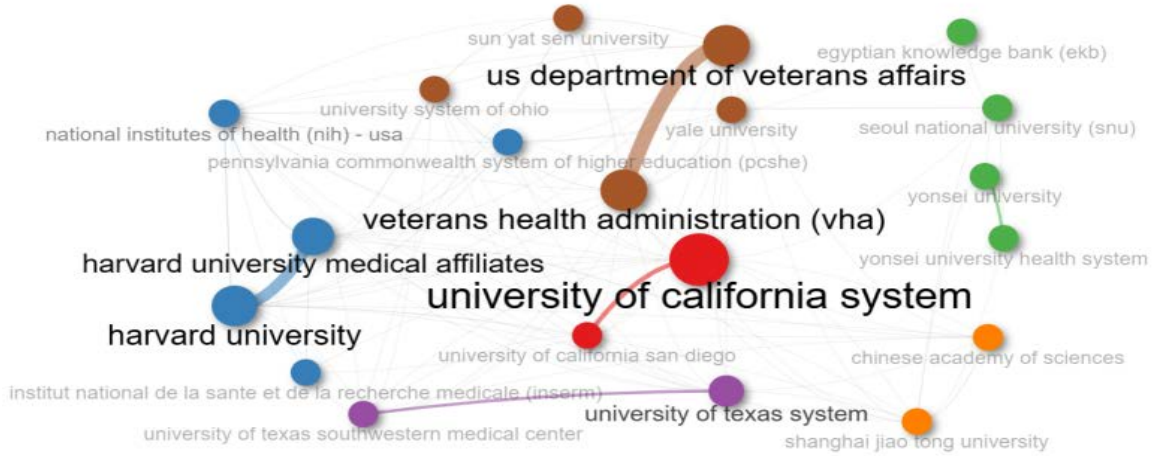


Figure 4b. Collaboration network analysis (Institutions)

The Countries Collaboration Network was analyzed using 30 nodes and the Louvain algorithm, with each node representing a country **(Figure 4c).** The network is divided into two main clusters. The red cluster includes Asia-Pacific and North American countries, with the USA and China as central actors. Thick edges between these two countries reflect high co-publication activity. The USA maintains strong connections with Canada, Japan, Korea, and Australia, while China collaborates with Türkiye, Mexico, Iran, and Saudi Arabia. Node sizes indicate both countries' central role in global publication output and collaboration networks. The blue cluster consists mainly of European countries and others such as India, Brazil, and Israel. Germany, the UK, France, Italy, Sweden, and the Netherlands exhibit high centrality with dense and balanced connections, representing strong regional collaboration. Despite high internal connectivity, the blue cluster has comparatively weaker links with the central red cluster (USA–China).

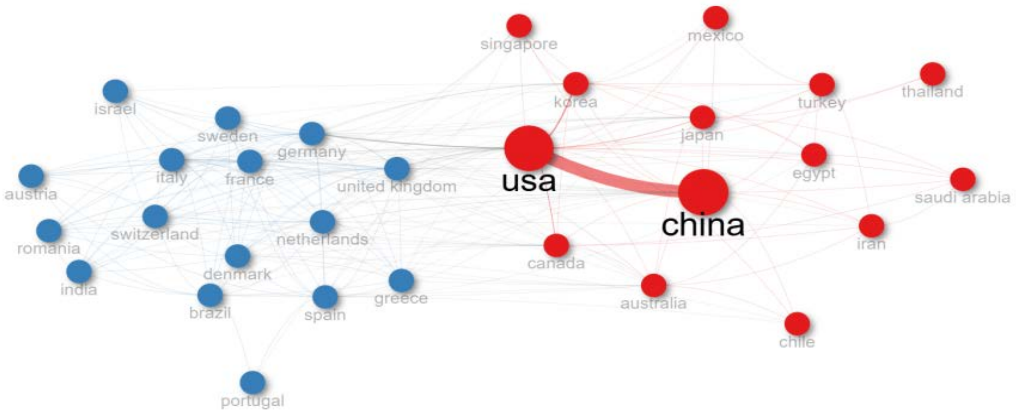


Figure 4c. Collaboration network analysis (Countries)

Overall, the network is characterized by high intra-cluster connectivity and clear leadership of cluster centers. Prominent collaborations between the USA and China suggest that a substantial portion of global publication output is concentrated along this axis, while the Europe-centered blue cluster demonstrates strong internal collaboration but relative detachment from the global network's main hubs.

Word and Thematic Analysis

Keyword analysis has become an essential tool in bibliometrics, enabling the identification of emerging research themes and providing insights for advancing HS research (22). Keyword co-occurrence networks and word clouds facilitate the detection of interrelated research areas and the temporal evolution of key terms (23).

Figure 5a. Word cloud from author's keywords

Figure 5a presents a word cloud illustrating the principal research foci and trends within the HS literature. The most frequent keywords include Hepatic Steatosis (1,124 occurrences), Non-Alcoholic Fatty Liver Disease – NAFLD (n=876), and Steatosis (n=339), indicating that research predominantly addresses non-alcoholic hepatic fat accumulation and general steatosis pathophysiology. Metabolic syndrome components such as Obesity (n=304), Fatty Liver (n=289), and Insulin Resistance (n=236) are also highly represented, highlighting the strong interplay between obesity, insulin resistance, and hepatic lipid accumulation. Pathophysiological mechanisms including Inflammation (n=137), Oxidative Stress (n=109), Lipid Metabolism (n=116), and Endoplasmic Reticulum Stress (n=75) emphasize the critical role of inflammatory and oxidative processes in disease progression.

Overall, the literature indicates that HS research primarily focuses on metabolic dysfunction, inflammation, oxidative stress, and fibrosis development, while non-invasive imaging methods and molecularly targeted therapeutic approaches are increasingly emphasized.

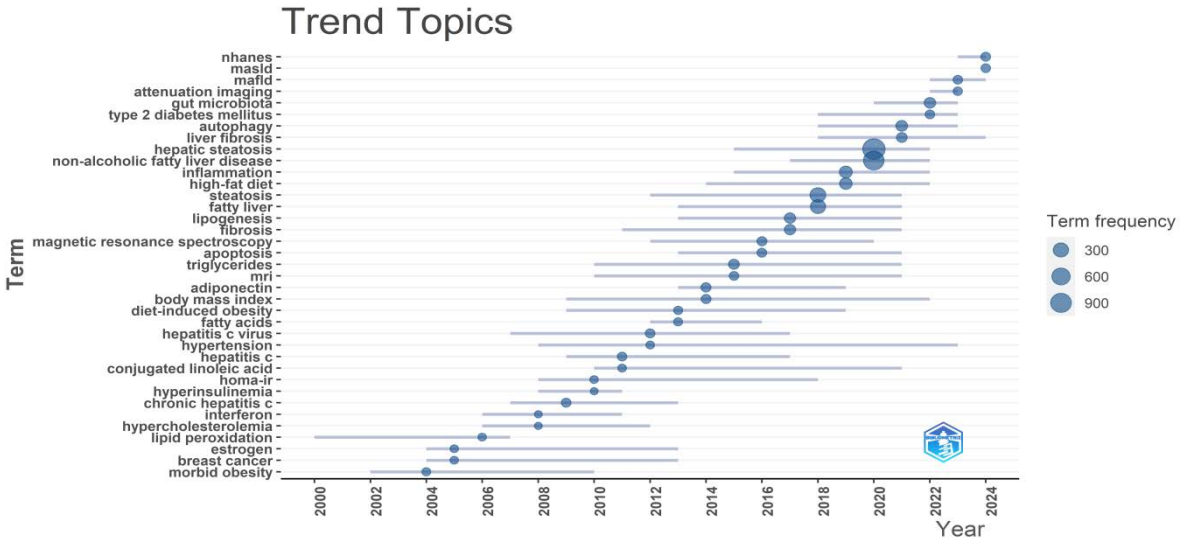


Figure 5b. Trend topics

Figure 5b visualizes the temporal evolution of keywords, showing which terms became prominent during specific years. Only keywords appearing at least five times per year are depicted. Line lengths indicate the duration of keyword usage, while node sizes represent usage frequency and relative prominence in the literature.

In the early 2000s, terms such as Morbid Obesity, Breast Cancer, Estrogen, Lipid Peroxidation, and

Hypercholesterolemia appeared with small nodes and short lines, indicating limited and transient research focus. Between 2005 and 2010, keywords including Interferon, Chronic Hepatitis C, Hyperinsulinemia, HOMA-IR, and Conjugated Linoleic Acid gained visibility but remained mostly confined to specific subfields. Post-2010, topics such as Hepatitis C, Hepatitis C Virus, Fatty Acids, Diet-Induced Obesity, Body Mass Index, and Adiponectin are represented with medium-sized nodes and longer lines, reflecting sustained and broader research interest. During this period, MRI and MRS emerged as increasingly used imaging modalities in HS research. From 2014 onward, keywords related to metabolic and pathophysiological processes-including Fibrosis, Lipogenesis, Fatty Liver, Steatosis, and High-Fat Diet-display long lines and medium-to-large nodes, indicating both consistent inclusion in the literature and high research volume. Inflammation, NAFLD, and HS show the largest nodes and longest lines, underscoring their status as core topics in the field.

In recent years (2020 onward), emerging trends include Autophagy, Type 2 Diabetes Mellitus, Gut Microbiota, Attenuation Imaging, MAFLD, MASLD, and NHANES. Notably, MAFLD and MASLD reflect rapid adoption of new diagnostic and classification frameworks, while Gut Microbiota and Type 2 Diabetes Mellitus highlight multidisciplinary research into systemic and microbiota-related aspects of HS.

In summary, the thematic evolution reveals a progression from early narrow and low-volume topics to metabolically, inflammatory, and imaging-focused studies post-2010, with recent emphasis on metabolic syndrome components, microbiota, and novel diagnostic approaches.

Figure 6 presents a thematic map of the HS literature generated using Bibliometrix. The map is based on 1,200 author keywords occurring at least five times, with topic clusters identified using the Louvain clustering algorithm. Each cluster is represented by its five most frequent keywords, and node sizes correspond to keyword frequency. Thematic maps are widely used bibliometric tools for examining the main topics and their interconnections within a research field. They effectively visualize the structure, interactions, and developmental trends of the literature (24).

Clusters are categorized along centrality and density axes into four types. Motor themes possess both high centrality and high density, representing foundational topics that drive field development. Niche themes have high density but low centrality, indicating specialized and well-developed subtopics. Emerging or declining themes display low centrality and low density, representing topics either losing relevance or still underdeveloped. Basic themes exhibit high centrality but low density, marking concepts central to the field yet not fully matured (25).

Motor themes, characterized by high centrality and density, guide the development of HS research. The green cluster-Steatosis, Liver, Liver Steatosis, Fibrosis, Controlled Attenuation Parameter-represents current core topics focused on hepatic fat accumulation and fibrosis assessment. The orange cluster-AMP-Activated Protein Kinase, Autophagy, Endoplasmic Reticulum Stress, Adiponectin, PPAR Alpha-captures molecular mechanisms critical to understanding the cellular and biochemical pathophysiology of HS.

Niche themes show high density within their subdomains but limited overall centrality. The gray cluster (Metabolism) reflects studies investigating detailed metabolic processes, while the pink cluster (Fructose) highlights research focused on fructose's role in metabolism and hepatic fat accumulation, representing specialized subfield interests.

Emerging or declining themes, with low centrality and density, indicate either waning or still-developing topics. The purple cluster Fatty Liver, MRI, Ultrasonography, CT, MRS represents imaging methods that were historically important in HS diagnosis but are increasingly replaced by newer diagnostic approaches. The brown cluster Triglycerides, Cholesterol reflects classic metabolic parameters that, while informative, show relatively declining focus.

Basic themes, with high centrality but lower density, form the conceptual backbone of HS research. The blue cluster NAFLD, Lipid Metabolism, Metabolic Syndrome, NASH, Liver Fibrosis defines the clinical and metabolic framework of HS. The red cluster HS, Obesity, Insulin Resistance, Inflammation, High-Fat Diet focuses on pathogenesis, risk factors, and nutritional associations.

Overall, the thematic map indicates that many future research opportunities lie within the basic themes quadrant. High centrality values identify these topics as central to the field, while lower density levels suggest potential for further development. Specifically, NAFLD, Lipid Metabolism, Metabolic Syndrome, NASH, and Liver Fibrosis (blue cluster) are crucial for understanding HS's clinical features, metabolic aspects, and progression. HS, Obesity, Insulin Resistance, Inflammation, and High-Fat Diet (red cluster) represent fundamental areas for investigating pathogenesis, lifestyle factors, and metabolic dysfunction. These themes are likely to guide future

studies on molecular mechanisms, non-invasive diagnostic tools, and targeted therapeutic strategies in HS research.

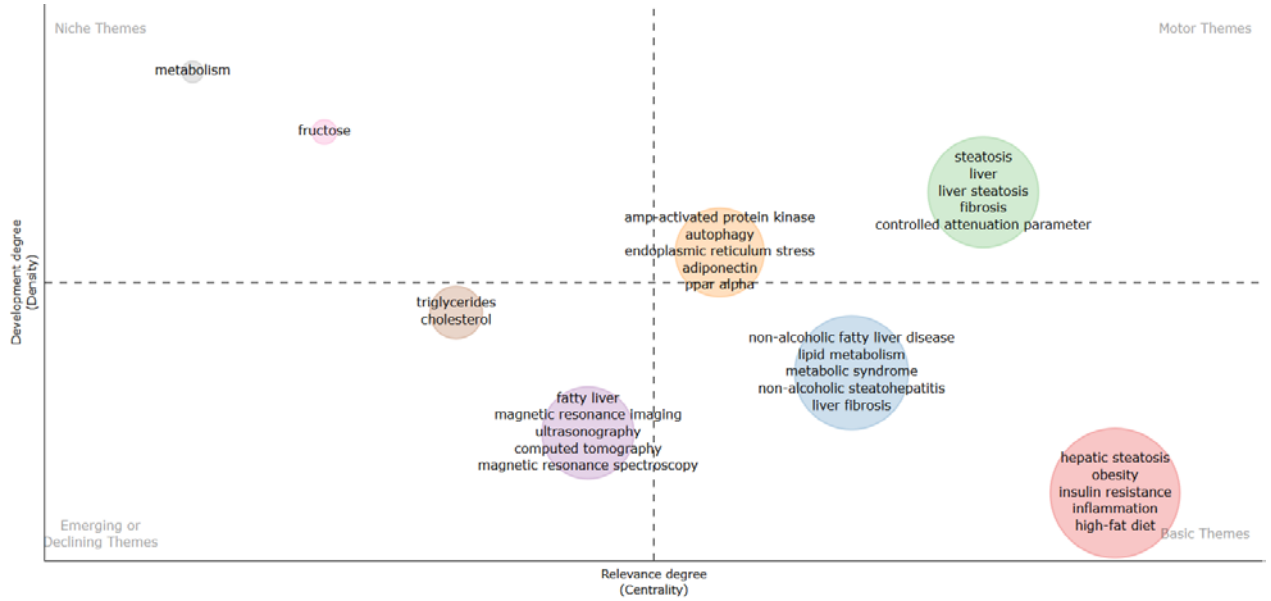


Figure 6. Thematic map

Discussion

The aim of this study was to conduct a bibliometric analysis of HS-related publications indexed in the WoS database over the past 45 years, identifying global research trends, leading authors, institutions, and countries, as well as influential journals and potential future research directions.

The analyzed data reveal that research on HS has experienced rapid growth over the last 45 years. A total of 3,871 articles were produced by 20,911 authors, with single-author publications being relatively rare, indicating that research in this field is largely collaborative and team-oriented. High citation counts and an average publication age of 8.3 years suggest that the literature is both well-established and continually updated in line with current developments. The international collaboration rate exceeding 20% highlights the global significance of HS research and contributions from multiple countries. Additionally, the annual growth rate and high average citation impact indicate increasing interest in the field and the strong influence of this knowledge on the scientific community.

In terms of influential journals publishing on HS, Hepatology, the official journal of the American Association for the Study of Liver Diseases, ranks first; Journal of Hepatology, the official journal of the European Association for the Study of the Liver, ranks second; and Plos One, an independent platform of the Public Library of Science, ranks third.

Regarding the most cited articles, the top publication is Browning et al.'s 2004 study in Hepatology titled "Prevalence of hepatic steatosis in an urban population in the United States: impact of ethnicity". This research examined liver triglyceride content across a multi-ethnic population, evaluating differences by ethnicity and sex. The study found that HS prevalence was higher in Hispanic individuals and white males compared to other ethnic groups and white females, suggesting that ethnicity and sex may influence steatosis-associated liver disease risk (26).

The second most cited study, also from 2004, by Browning and Horton in J Clin Invest, titled "Molecular mediators of hepatic steatosis and liver injury", investigated the molecular mechanisms underlying obesity-related HS and non-alcoholic steatohepatitis. The findings highlighted that HS can follow a benign course in some cases, whereas steatohepatitis may progress to end-stage liver disease and account for 14% of liver transplants in the USA. Understanding these molecular mechanisms is crucial for advancing disease management and therapeutic strategies (27).

The third most influential study is Szczepaniak et al.'s 2005 publication in Am J Physiol Endocrinol Metab, titled "Magnetic resonance spectroscopy to measure hepatic triglyceride content: prevalence of hepatic steatosis in the general population". This study quantitatively measured hepatic triglyceride content (HTGC) using proton magnetic resonance spectroscopy (MRS) in the Dallas Heart Study cohort, determining a normal upper limit and estimating HS prevalence. MRS proved to be a reliable, non-invasive method for HTGC assessment, revealing a

high HS prevalence (33.6%) in a large US population (28).

Bibliometric analyses also identified the most productive and impactful researchers in HS. Prof. Yu Li (Shanghai Institute for Nutrition and Health, Chinese Academy of Sciences, Metabolic Disease Research Division, China) emerged as the leading author, with both high publication output and citation impact. He is followed by Prof. Yuxiu Liu (Department of Hepatology, Hepatology Research Institute, The First Affiliated Hospital, Fujian Medical University, China), known for contributions to liver disease and metabolic disorders, and Asst. Prof. Hyunbae Kim (Center for Molecular Medicine and Genetics, Wayne State University, USA), recognized for translational research. These findings indicate that research leadership in HS is predominantly centered in China, with notable contributions from the USA. Prior bibliometric studies also report China's rapid increase not only in publication volume but also in highly cited authors, highlighting the pivotal role of regional research strategies in shaping global scientific leadership (29,30).

When evaluating countries based on publication output in HS, China, the USA, and South Korea are prominent. This suggests increasing investment by Asian countries in research on metabolic diseases, obesity, and liver disorders in recent years (31,32). Our findings show that scientific contributions in HS are mainly concentrated in Asia, North America, and Western Europe, while countries from South America and the Middle East are increasingly participating. Similar trends have been reported in recent bibliometric analyses on liver disease and metabolic syndrome, emphasizing Asia's significant rise in scientific output, likely driven by regional epidemiological burdens and investment in research infrastructure (33,34).

Collaboration network analyses provide insights into the relationships among authors, institutions, and countries in HS research, allowing a better understanding of the social structure of scientific production (19,20). Our analyses indicate that author clusters centered around Li Y and Zhang Y, as well as groups led by Kim H, Li J, and Wang J, maintain strong connections both internally and with other clusters. These findings suggest that HS research is largely team-based and internationally collaborative, consistent with reports from other hepatology studies (35).

Institutional collaboration analyses highlight the central roles of the University of California System, Harvard University, and Yonsei University. These institutions enhance scientific productivity and impact through strategic regional and international collaborations. The high productivity of China- and US-based institutions in their respective regions indicates a persistent core–periphery structure within the global scientific network (21).

Country-level collaboration analyses emphasize the central role of the USA and China in global research output. Although Europe-centered clusters maintain strong regional collaborations, their connections to global leaders are comparatively limited. This observation reflects the existence of international asymmetries in HS research and underscores the importance of regional research strategies in shaping scientific leadership (36).

Overall, collaboration network analyses demonstrate that HS research is not only defined by productivity but also by the impact of scientific influence and the dynamics of collaboration. These findings are valuable for identifying leading authors and institutions, guiding future strategic collaborations, and informing global research policy planning.

Keyword and thematic map analyses reveal increasing research focus on metabolic, inflammatory, and diagnostic aspects of HS. The most frequent terms-HS, NAFLD, obesity, insulin resistance, and inflammation-confirm the central role of obesity and metabolic syndrome components in disease pathogenesis. The prominence of molecular keywords such as AMP-Activated Protein Kinase, Autophagy, PPAR Alpha, and Adiponectin underscores the importance of understanding cellular mechanisms and developing targeted therapies (37). The thematic map results indicate that basic themes with high centrality but low-to-moderate density form the main research axes, with substantial potential for further development. These findings point to a continuing multidisciplinary trend, emphasizing emerging research areas such as metabolic syndrome, gut microbiota, and non-invasive diagnostic methods as future priorities.

Study limitations

However, the study has several limitations that may introduce systematic bias. First, only publications indexed in the WoS were included, potentially overlooking relevant articles in other databases such as Scopus, PubMed, or regional repositories, which may lead to an incomplete representation of global research activity. Second, only English-language publications were considered, possibly underrepresenting contributions from non-English-speaking countries and regions, thus introducing a language-related selection bias. Third, bibliometric indicators such as publication counts and citation metrics provide quantitative measures of research output but do not directly assess the scientific quality, clinical relevance, or methodological rigor of individual studies, which may

bias the perceived impact of the research field. Finally, variations in terminology (e.g., HS, NAFLD, MAFLD, MASLD) and keyword selection may result in the omission of relevant studies, further contributing to potential systematic bias. Future studies integrating multiple databases, diverse citation analysis methods, and multidisciplinary evaluations could provide a more comprehensive global perspective on HS research.

Conclusions

This bibliometric analysis comprehensively illustrates the global development of HS research from 1980 to 2025, including leading authors, institutions, journals, and thematic trends. The 3,871 analyzed articles and 20,911 authors demonstrate a rapid increase in collaborative, internationally oriented research over the last 45 years. Leading researchers such as Prof. Yu Li, Prof. Yuxiu Liu, and Asst. Prof. Hyunbae Kim maintain influence through high publication output and citation impact. Journals including Hepatology, Journal of Hepatology, and PLOS One represent the most influential publication platforms in HS research. Keyword and thematic analyses indicate growing interest in metabolic syndrome, inflammation, non-invasive diagnostics, and molecular mechanisms (AMPK, autophagy, PPAR alpha, adiponectin), highlighting the multidisciplinary progression of HS research encompassing both pathophysiological and clinical aspects. Future studies integrating multiple databases, broader linguistic inclusion, diverse citation analysis methods, and multidisciplinary evaluations could mitigate biases and provide a more comprehensive and balanced global perspective on HS research.

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