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Mapping the knowledge structure of research on insulin resistance and metabolic syndrome: a global perspective

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Abstract

Background Insulin resistance is a major pathogenic factor that plays a crucial role in the development of metabolic syndrome and has been proposed as one of its underlying causes. Most diagnostic criteria for metabolic syndrome do not directly include insulin resistance. Furthermore, research on insulin resistance continues to provide information on the development and treatment of metabolic syndromes and related health conditions. Therefore, this bibliometric analysis aimed to investigate the current research status and identify possible future research hotspots in the area of metabolic syndrome and insulin resistance by analyzing Scopus-based studies.

Methods To collect published data on metabolic syndrome and insulin resistance, this study used the Scopus database as its data source without a particular starting date but including records up to December 31, 2022. The gathered documents were then exported to VOSviewer v.1.6.18 to analyze and visualize country collaborations and identify research areas of high interest.

Results The study presents an overview of 1932 records between 1988 and 2022, focusing on metabolic syndrome and insulin resistance. Of these records, 77.33% were original journal articles, while 13.30% were review articles. Additionally, 9.35% of the documents fall under other types of publication, including letters, notes, and editorials. The United States came out on top with 463 items, accounting for 23.96% of the contributions in this field, followed by Japan in second place with 119 items (6.16%). China ($n=113$, 5.85%) and the United Kingdom ($n=113$, 5.85%) ranked third. Most publications on metabolic syndrome and insulin resistance focus on key terms related to the pathogenesis of insulin resistance syndrome, the use of waist circumference as a crucial clinical indicator to evaluate the risk of metabolic syndrome, and the association between metabolic syndrome and oxidative stress and a pro-inflammatory state.

Conclusions This study presents the first bibliometric analysis of publications focusing on metabolic syndrome and insulin resistance. The findings of this study offer a comprehensive global perspective on the research carried out on metabolic syndrome and insulin resistance and can be an invaluable source for future research.

Keywords Metabolic syndrome, Insulin resistance, Scopus, Bibliometric, VOSviewer

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Introduction

Despite the fact that the term metabolic syndrome or 'insulin resistance syndrome' was coined only in the late 1980s by G.M. Reaven, with the description of syndrome X [1, 2], the history of this syndrome can be traced back to a much earlier period. As early as almost 90 years ago, numerous researchers identified the frequent co-occurrence of various syndrome components, including hypertension, and have used several names to describe this clustering [3]. Metabolic syndrome and insulin resistance are two related conditions that can cause serious health problems if left untreated.

Hypertension, elevated glucose levels, excess abdominal adiposity, and abnormal levels of cholesterol or triglycerides distinguish metabolic syndrome. These conditions, as mentioned above, increase the likelihood of acquiring severe health complications, such as diabetes, cardiovascular disease, and stroke. Furthermore, insulin resistance in metabolic syndrome is characterized by cellular resistance to the insulin hormone, which is crucial in regulating blood glucose levels. Consequently, the human body must increase its insulin production to regulate blood glucose levels, potentially resulting in elevated blood sugar levels and the development of type 2 diabetes [4–6].

Insulin resistance is the predominant etiological factor for a group of disorders characterized by impaired glucose tolerance, hyperinsulinemia, dyslipidemia, and hypertension. It is widely recognized as a significant contributor to the onset of metabolic syndrome and the associated health hazards. Implementing dietary and physical activity modifications has effectively managed insulin resistance, thus mitigating the risk of developing metabolic syndrome and its associated complications. In specific cases, healthcare professionals may prescribe medications to effectively regulate blood pressure, cholesterol, or blood sugar levels [7, 8].

Despite growing scholarly attention in this area, there is an apparent gap in the literature on the examination of publication patterns related to metabolic syndrome and insulin resistance. The absence of a comprehensive examination of research advancements requires investigation, discerning, and scrutinizing emerging trends in this field to inform future research trajectories. Bibliometric analysis is a quantitative methodology for investigating scholarly publications within a particular field. This approach uses citation counts, publication patterns, and coauthorship networks [9, 10]. Using bibliometric analysis, researchers can discern prevalent research trends, significant areas of interest, and influential academic institutions. Additionally, it facilitates monitoring research productivity and evaluating its impact [9, 10].

In contrast, systematic reviews aim to synthesize and summarize research studies [11, 12]. Remarkably, although numerous investigations on research productivity within insulin resistance have been conducted [13–18], a notable absence of bibliometric analysis has been observed, specifically in relation to the correlation between metabolic syndrome and insulin resistance. By employing bibliometric analysis, one can examine the relationship and identify prominent countries, institutions, academic journals, and research themes within this particular domain. This methodology enables researchers to acquire a deeper understanding of the present condition of this field and identify possible directions for future investigation. Furthermore, by analyzing trends over time, bibliometric analysis can help identify emerging areas of research interest and predict future developments in this area. This information can guide research funding decisions and inform the development of research programs and policies. Consequently, the literature on metabolic syndrome and insulin resistance can be bibliometrically analyzed to provide useful information on the current state of research on the subject and help identify areas for further research.

Methods

Data sources

The Scopus database is the data source for the study, and there are no fixed starting points for the study, but it includes the data until 31 December 2022. Scopus has the following advantages over competing databases [19–22]: First, Scopus indexes a larger number of journals and shows more linguistic diversity than other databases. In fact, the number of journals indexed in Scopus is almost the same as the number of combined journals indexed in PubMed and Science Web. Second, most publications indexed in PubMed are also indexed in Scopus, indicating that Medline is fully indexed in Scopus. Third, Scopus covers journals in all research fields, including medicine, health care, mathematics, computer science, and social sciences. Fourth, Scopus allows researchers to develop complex and comprehensive search queries with various Boolean operators. Finally, Scopus allows researchers to extract and analyze data, including statistical analysis and mapping, to better understand research trends and patterns [22].

Search strategy

We conducted a comprehensive search on 24 February 2023, specifically targeting studies related to metabolic syndrome and insulin resistance using the Scopus database. The approach used to collect the data for the current study is as follows:

- **Step 1**: It is necessary to thoroughly examine the literature on metabolic syndrome and insulin resistance, including systematic reviews and meta-

analyses. The aim is to determine relevant keywords for searching.

- **Step 2** involved extracting terms related to metabolic syndrome from the Medical Subject Headings (MeSH) in PubMed and previous systematic and meta-analyses that included metabolic syndrome [23–25] using the Scopus Engine. The following 'terms' were entered as 'Article Title': ("Metabolic Cardiovascular Syndrome" OR "Syndrome X" OR "Reaven's Syndrome" OR "Insulin Resistance Syndrome" OR "Atherothrombogenic Syndrome" OR "Metabolic Syndrome*" OR "Metabolic X Syndrome" OR "Dysmetabolic Syndrome X" OR "Cardiometabolic Syndrome" OR "Plurimetabolic Syndrome" OR "Reaven syndrome" OR "MetS").
- In **Step 3**, the publications identified in Step 2 were filtered to include only those with the phrases "insulin resistance and related terms" in their titles. Terms associated with insulin resistance were chosen from various systematic reviews and meta-analyses [26–28], and the resulting terms, "insulin resistance" or "insulin sensitivity," were included in the titles of the articles.

The validity of the search strategy

To ensure more accurate results, the search strategy focused solely on the title when searching for terms related to metabolic syndrome and insulin resistance. Expanding the search to include other fields, such as abstracts or keywords, would have identified publications that were not relevant to the topic, resulting in false positive data. The researchers found that the use of search elements in the title alone increased specificity while only slightly reducing sensitivity [29–31]. The primary reason for generating false positive results through keyword searches is that Scopus treats keywords as authors and indexes them as "EMTRE medication terms," "EMTREE medical terms," and "Medline keywords." Therefore, the authors opted to use only the title search instead of one that included the title, abstract, and keywords. In the current study, two methods were used to collect data on the research output of the 30 most active authors to ensure that no false negative results were obtained. The first method involved gathering information on the number of publications for each author through a search strategy, while the second method involved analyzing the research output of the authors by scrutinizing their Scopus profiles. The degree of agreement between the two methods was assessed using SPSS and the interclass correlation coefficient. A score above 95% and a p-value less than 5% indicated the high validity of the search strategy [11, 32, 33]. The present study showed a correlation of 0.973% and a p-value of 0.002, suggesting that there was excellent agreement between the two methods and that the search strategy had high validity.

Bibliometric analysis

The bibliometric technique, which had previously been described in studies [16, 21, 22], was used and resulted in the generation of the following bibliometric indicators after exporting the refined findings to Microsoft Excel. (1) Growth pattern, (2) type of publications, (3) main countries, (4) core institutions, (5) core funding agencies, (6) h-index, (7) core journals with their impact factors (IF), and (8) top 10 articles cited.

Visualization analysis

The study used VOSviewer 1.6.18, a software tool that assists in constructing and visualizing bibliometric networks. By employing VOSviewer, it is possible to create scientifically based knowledge networks that depict the advancement of research domains, global collaborations, and potential research hotspots [34, 35]. Within the context of this investigation, VOSviewer was employed to analyze the co-occurrence of terms in the titles and abstracts of academic publications. By analyzing the frequency with which certain terms appear together in these publications, VOSviewer can identify clusters of related terms that are likely to be associated with specific research topics or themes. The tool then assigns different colors to each of these clusters to help users visually identify them. By optimizing the co-occurrence network, the investigation was able to perform a cluster analysis of research hotspots, which can help identify emerging trends and areas of interest within a particular field of study [34, 35].

Statistical analysis

In this study, Scopus data were first exported to Microsoft Office Excel® and then transferred to Microsoft Word® as part of the process. Microsoft Excel 2013 and VOSviewer version 1.6.18 were used to generate figures, and descriptive statistics are presented as frequencies and percentages. The data obtained from Scopus were analyzed using the Statistical Package for Social Sciences software (IBM-SPSS, version 21.0). The results of the bibliometric analysis, including information on countries, cited publications, funding agencies, journals, and institutions, were ranked with a focus on the top ten in each category. In cases with similar rankings, a gap was left between subsequent ranking numbers.

Results

Distribution features of the relevant literature

This study describes 1932 Scopus-indexed documents between 1988 and 2022 on metabolic syndrome and insulin resistance. Of these documents, 77.33% were

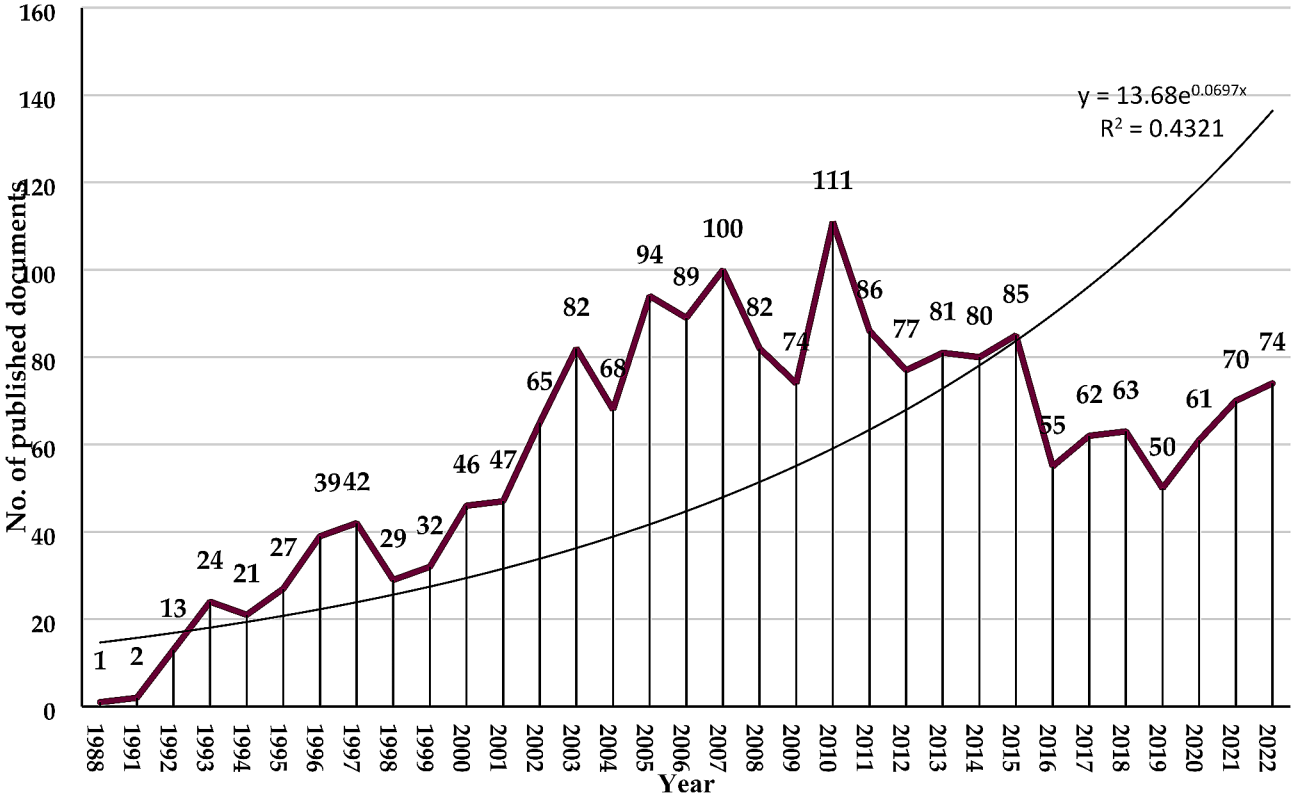

Fig. 1 The annual number of publications related to metabolic syndrome and insulin resistance

Table 1 The top 10 countries/regions to study metabolic syndrome and insulin resistance

Ranking	Country	No. of documents	%
1st	United States	463	23.96
2nd	Japan	119	6.16
3rd	China	113	5.85
3rd	United Kingdom	113	5.85
5th	Italy	102	5.28
6th	France	87	4.50
7th	Spain	78	4.04
8th	South Korea	74	3.83
9th	Sweden	66	3.42
10th	Brazil	65	3.36
10th	Germany	65	3.36
10th	India	65	3.36

original journal articles, 13.30% were review articles, and 9.35% were classified as other types of publications, such as letters, notes, or editorials.

Evolution over time

Figure 1 shows the annual number of publications on metabolic syndrome and insulin resistance during this period. The percentage share of global research output on this topic was 11.9% before 2000, 38.66% between 2000 and 2009, and 49.4.3% between 2000 and 2022 (Fig. 1). According to the data presented in Fig. 1, the number of documents published annually from 1988 to 2022 follows a low production pattern during the first decade (1988–1997), a significant increase from 2000 to 2015, a decrease between 2016 and 2019, and then a subsequent increase after 2019. The growth rate in publications is nonlinear; the highest number of publications occurred in 2010. Furthermore, there was a moderate positive correlation between time and the number of publications ($r=0.68$, $p<0.001$) during the study period.

Contributions of countries to global publications

The contributions of the top 10 countries to publications on metabolic syndrome and insulin resistance from 1988 to 2022 are listed in Table 1. A total of 119 countries contributed to research related to metabolic syndrome and insulin resistance, and the top 10 combined countries were responsible for 72.97% of all published articles. The United States came out on top with 463 items, accounting for 23.96% of the total, followed by Japan in second place with 119 items (6.16%). China ($n=113$, 5.85%) and the United Kingdom ($n=113$, 5.85%) ranked third. The study used VOSviewer to analyze countries with more than ten publications on the topic. A total of 38 eligible countries were considered, and three VOSviewer clusters were studied to determine centrality and connections to other countries (see Fig. 2). The United States, the United Kingdom, and China were the largest in terms of the

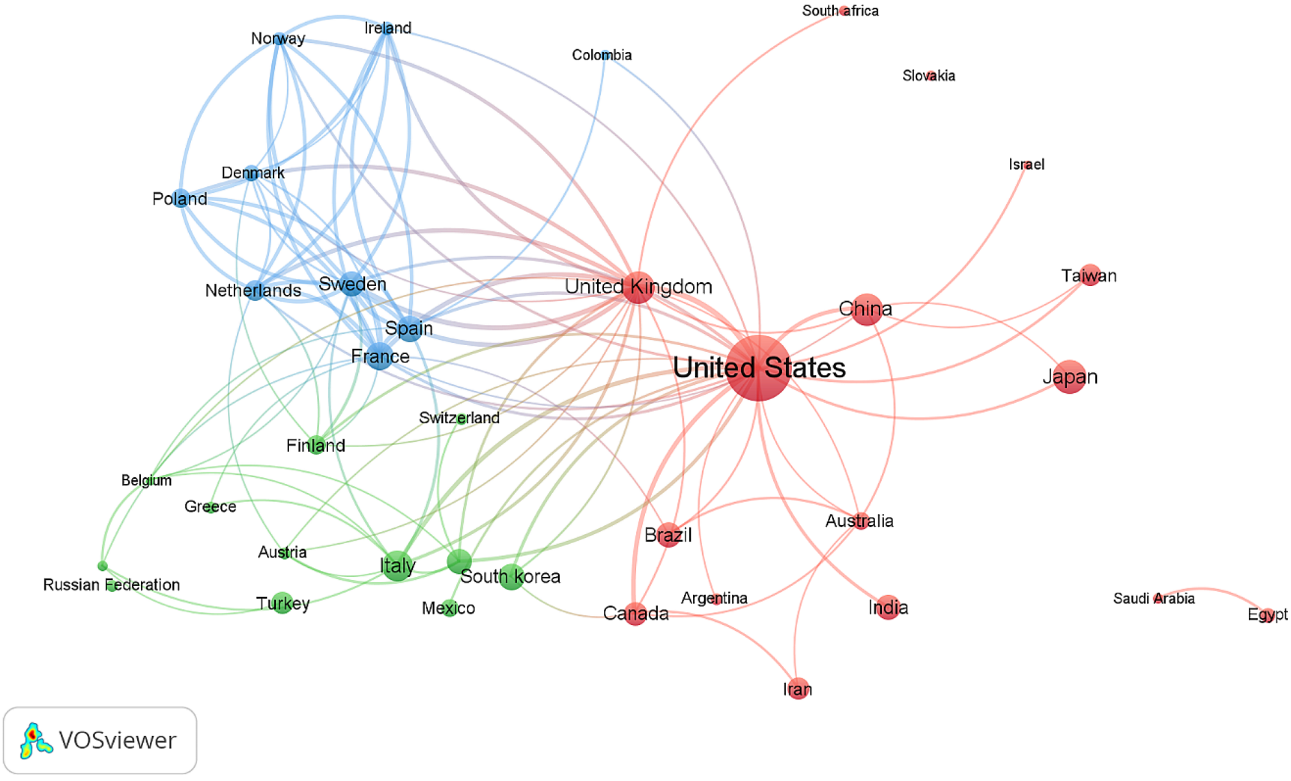

Fig. 2 A network of countries and regions collaborating to study metabolic syndrome and insulin resistance. The cooperation map revealed that 38 countries and regions had produced at least 10 publications on the subject

Table 2 Top 10 institutions contributing to research related to metabolic syndrome and insulin resistance

Ranking	Institute	Country	No. of documents	%
1st	*INSERM*	France	58	3.00
2nd	*Harvard Medical School*	USA	31	1.60
3rd	*University of Texas Health Science Center at San Antonio*	USA	29	1.50
4th	*Icahn School of Medicine at Mount Sinai*	USA	25	1.29
5th	*Uppsala Universitet*	Sweden	22	1.14
6th	*Helsingin Yliopisto*	Finland	17	0.88
7th	*Instituto de Salud Carlos III*	Spain	16	0.83
8th	*VA Medical Center*	USA	16	0.83
8th	*Université Paris-Saclay*	France	16	0.83
9th	*Universidade de São Paulo*	Brazil	15	0.78
9th	*University of Washington*	USA	15	0.78
9th	*Sahlgrenska Universitetssjukhuset*	Sweden	15	0.78

number of publications and collaborations within the red cluster. The extent of their interaction and strength were reflected in the number and width of their connections.

Contributed institutions

Table 2 shows the ranking of the leading ten institutions according to the number of publications they produced. Collectively, these institutions contributed to 14.24% ($n=275$) of all publications analyzed. In particular, *INSERM* emerged as the leading contributor, with 58 articles on metabolic syndrome and insulin resistance, followed by *Harvard Medical School* with 31 articles, the *University of Texas Health Science Center at San Antonio* with 29 articles, and the *Icahn School of Medicine at Mount Sinai* with 25 articles.

Contributed funding agencies

Table 3 shows the top ten funding agencies ranked by productivity. Among these agencies, the *National Heart, Lung, and Blood Institute (NHLBI)* was the most productive, with 98 articles (5.07%), followed by the *National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)*, with 72 articles (3.73%), and the *National Institutes of Health (NIH)*, with 63 articles (3.26%).

Table 3 The top 10 funding agencies contributing to research related to metabolic syndrome and insulin resistance

Ranking	Funding agencies	Country	No. of documents	%
1st	*National Heart, Lung, and Blood Institute*	USA	98	5.07
2nd	*National Institute of Diabetes and Digestive and Kidney Diseases*	USA	72	3.73
3rd	*National Institutes of Health*	USA	63	3.26
4th	*National Center for Research Resources*	USA	49	2.54
5th	*National Natural Science Foundation of China*	China	28	1.45
6th	*National Institute on Aging*	USA	19	0.98
7th	*Japan Society for the Promotion of Science*	Japan	18	0.93
8th	*Conselho Nacional de Desenvolvimento Científico e Tecnológico*	Brazil	12	0.62
8th	*Eunice Kennedy Shriver National Institute of Child Health and Human Development*	USA	12	0.62
8th	*Medical Research Council*	UK	12	0.62

Table 4 The top 10 journals publishing articles on metabolic syndrome and insulin resistance

Ranking	Journal/source title	No. of documents	%	IF *
1st	*Diabetes Care*	74	3.83	17.152
2nd	*Diabetes*	36	1.86	9.337
2nd	*Metabolism Clinical and Experimental*	36	1.86	13.934
4th	*Diabetologia*	35	1.81	10.460
5th	*Metabolic Syndrome and Related Disorders*	33	1.71	2.363
6th	*Journal of Clinical Endocrinology and Metabolism*	30	1.55	6.134
7th	*International Journal of Obesity*	23	1.19	5.551
8th	*Atherosclerosis*	21	1.09	6.847
9th	*Arteriosclerosis Thrombosis and Vascular Biology*	20	1.04	10.541
9th	*Endocrine Practice*	20	1.04	3.701

*Impact factors were retrieved from the 2021 Journal Citation Reports (Clarivate Analytics)

Contributed journals

This study compiled a list of the top ten journals with the highest number of publications in Table 4, which collectively contributed 16.98% ($n=328$) of all the published articles analyzed. Regarding the topic of metabolic syndrome and insulin resistance, *Diabetes Care* was the leading journal with the highest number of publications ($n=74$), followed by *Diabetes* ($n=36$) and *Clinical and Experimental* ($n=36$).

Top-cited publications

The documents obtained had a combined citation count of 94,504, with an average of 49.17 citations per document. The retrieved documents had an *h*-index of 149. Of the documents retrieved, 230 had no citations, while 246 received 100 or more citations. The top ten articles by citation count had a total of 12,112 citations [36–45], with citation counts ranging from 618 to 2240 (as shown in Table 5).

Term co-occurrence cluster analysis of research hotspots

A comprehensive examination of the prominent topics covered in metabolic syndrome and insulin resistance was conducted using co-occurrence analysis. Each manuscript was assigned a title and abstract, and VOSviewer identified 151 frequently occurring terms by analyzing the contents of the titles and abstracts. The aim was to determine the most frequently used terms, which were then visualized using a bubble map. The VOSviewer term co-occurrence visualization map arranged the terms into clusters and highlighted their distinctions using various colors. There were three groups (Fig. 3): the green group focused on the pathogenesis of insulin resistance syndrome; the red group focused on waist circumference as a vital sign in clinical practice to assess the risk of metabolic syndrome; and the blue cluster focused on metabolic syndrome associated with oxidative stress and a pro-inflammatory state. The color bar in the lower right corner of the map was used for overlay visualization (Fig. 4). Keywords were colored differently based on the average publication year. For example, yellow–green terms indicated that study fields related to waist circumference as a vital sign in clinical practice to assess the risk of metabolic syndrome and metabolic syndrome associated with oxidative stress and a pro-inflammatory state have become more popular in recent years and have the potential to become focal points in the near future.

Discussion

Using bibliometric analysis, this study explored the field of metabolic syndrome and insulin resistance from 1988 to 2022. The results were visualized using VOSviewer to show the evolution and key areas of the field clearly and quantitatively. In total, 1932 publications on metabolic

Table 5 Top 10 highly cited publications on research on metabolic syndrome and insulin resistance

Ranking	Authors	Title	Year	Source title	Cited by
1st	Kadowaki et al. [41]	"Adiponectin and adiponectin receptors in insulin resistance, diabetes, and the metabolic syndrome"	2006	*Journal of Clinical Investigation*	2240
2nd	Festa et al. [39]	"Chronic subclinical inflammation as part of the insulin resistance syndrome: The insulin resistance atherosclerosis study (IRAS)"	2000	*Circulation*	2036
3rd	Vrieze et al. [45]	"Transfer of intestinal microbiota from lean donors increases insulin sensitivity in individuals with metabolic syndrome"	2012	*Gastroenterology*	1916
4th	Haffner et al. [40]	"Prospective analysis of the insulin-resistance syndrome (syndrome X)"	1992	*Diabetes*	1134
5th	Chitturi et al. [36]	"NASH and insulin resistance: Insulin hypersecretion and specific association with the insulin resistance syndrome"	2002	*Hepatology*	1001
6th	Pereira et al. [44]	"Dairy consumption, obesity, and the insulin resistance syndrome in young adults: The CARDIA study"	2002	*JAMA*	914
7th	Elliott et al. [38]	"Fructose, weight gain, and the insulin resistance syndrome"	2002	*American Journal of Clinical Nutrition*	821
8th	Einhorn et al. [37]	"American College of Endocrinology position statement on the insulin resistance syndrome"	2003	*Endocrine practice*	785
9th	Pagano et al. [43]	"Nonalcoholic steatohepatitis, insulin resistance, and metabolic syndrome: Further evidence for an etiologic association"	2002	*Hepatology*	647
10th	McKeown et al. [42]	"Carbohydrate Nutrition, Insulin Resistance, and the Prevalence of the Metabolic Syndrome in the Framingham Offspring Cohort"	2004	*Diabetes Care*	618

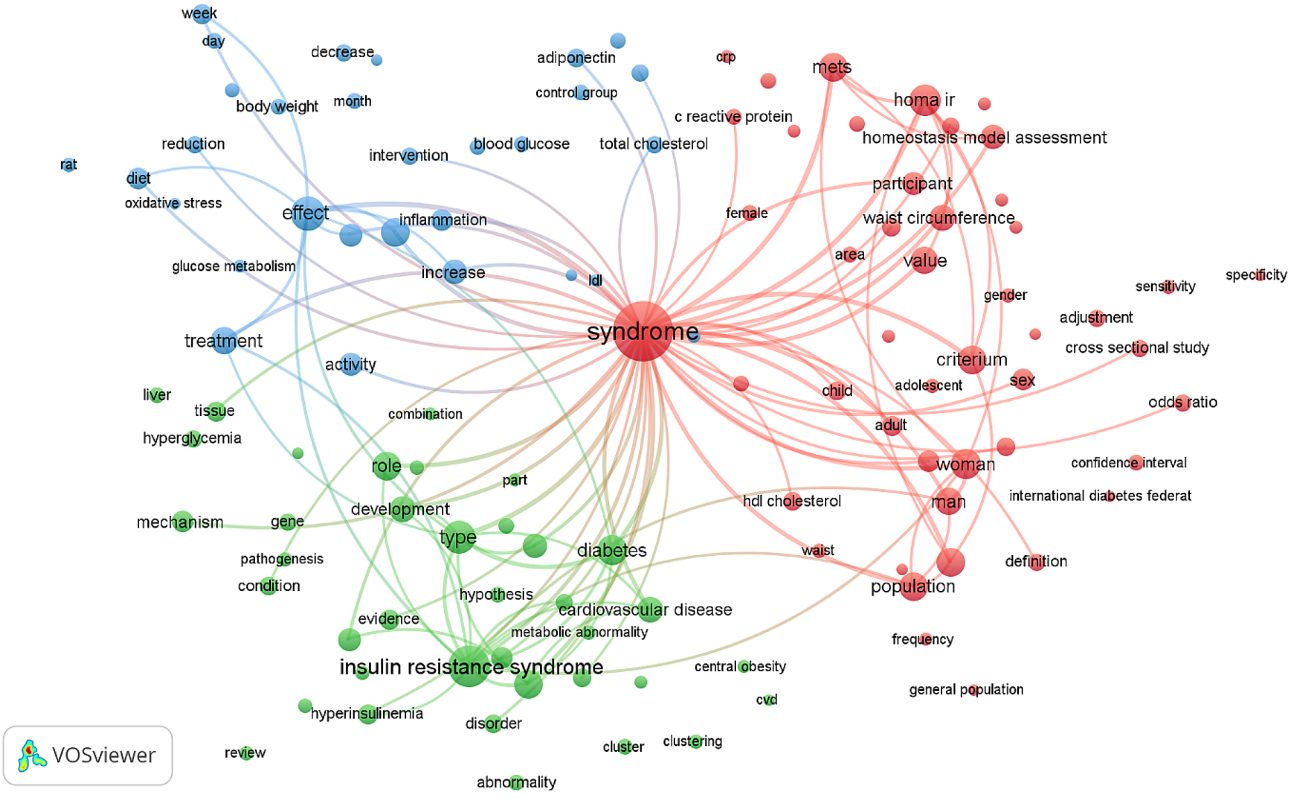

Fig. 3 The clustering and co-occurrence of terms in the title and abstract fields of publications related to metabolic syndrome and insulin resistance. A map of the clusters revealed 195 terms that occurred at least 50 times, which were categorized into five separate clusters. The size of the node and the word in the map represented the frequency of co-occurrence, and the link between nodes indicated their relationship. Nodes sharing the same color were part of the same cluster

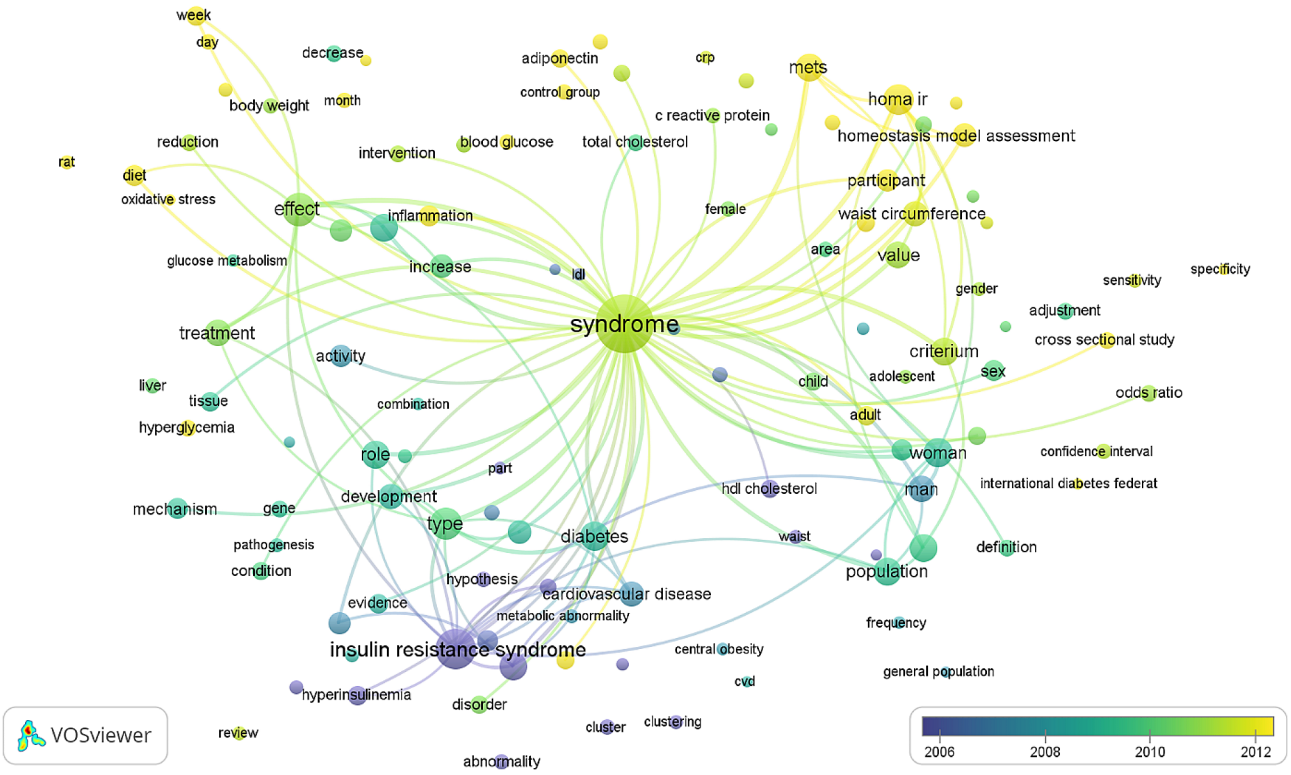

Fig. 4 A visualization map has been created that overlays terms from the titles and abstracts of publications relating to metabolic syndrome and insulin resistance. Each keyword was assigned a different color based on its average appearance time in the overlay visualization map. The color blue was used to represent keywords that appeared earlier in the time course compared to those in yellow and red

syndrome and insulin resistance were examined in the Scopus database. The analysis revealed fluctuations in the number of articles published annually on this topic over the 33 years, with the highest number of publications occurring in 2011. A detailed quantitative analysis was also performed on various aspects, including countries, institutions, funding agencies, journals, and citations.

However, the increase in publication frequency since 2019 could be related to the beginning of the COVID-19 pandemic. New research reveals a link between the severity of COVID-19 and metabolic syndrome and insulin resistance. Numerous studies have consistently shown that metabolic syndrome and insulin resistance significantly increase the chance of developing severe symptoms and unfavorable outcomes [46–49]. The abovementioned conditions are also connected to an increased risk of cardiovascular disease, immune system dysfunction, and inflammation. The immune system's ability to effectively combat COVID-19 can be compromised by several factors, which increase the risk of severe symptoms and long-term complications [50]. Several factors that contribute to the United States' dominant position in this particular field of research were discovered during our investigation. The nation's prominence in this field may be partially attributed to the high incidence of metabolic diseases that exceed 30% [51]. Additionally, the United States is known for its substantial investment in research, a diverse group of field researchers, cutting-edge research infrastructure, and a highly skilled workforce operating on a sizable scale. These elements work together to improve the nation's capacity for research. A country's economy might impact how research funding is distributed and how mobile researchers are. It is important to note that a large body of research has repeatedly shown that the United States leads the world in terms of research productivity [18, 52, 53].

Studying collaboration networks can offer useful perspectives on research partnerships and help identify significant collaborators within a specific discipline. Due to their superior economic resources and investments in science, the United States, the United Kingdom, and China have been deemed to have a clear advantage in this field [54]. These nations have made substantial investments in research and development, creating institutions and universities of the highest caliber. Furthermore, they have implemented policies that encourage international cooperation in science and technology, resulting

in robust global networks of researchers and academic institutions.

The findings of the analysis demonstrate that the academic articles on metabolic syndrome and insulin resistance cover a wide range of interrelated subtopics closely associated with the areas of highest occurrence identified in the study. The study revealed a prominent pattern in which the most frequently cited were centered around these specific subtopics. To accomplish this objective, the research utilized citation analysis and text mining methodologies, facilitating the identification of both extensively cited publications and crucial subtopics. Furthermore, the researchers employed visualization tools to generate maps illustrating the co-occurrence of terms and highlighting the central aspects of the investigation.

In this study, we analyze the terminology used in the field of metabolic syndromes and insulin resistance and identify three major research themes. The first hot issue was using waist circumference as a vital sign in clinical practice to assess the risk of metabolic syndrome. Despite extensive and conclusive evidence over several decades, which clearly indicates that waist circumference provides valuable and unique information beyond body mass index (BMI) in predicting illness and mortality risk, this important measurement is not consistently integrated into clinical practice [55–58]. The present Consensus Statement from the IAS and ICCR Working Group on Visceral Obesity recommends incorporating waist circumference measurements into routine clinical practice, emphasizing its significance in improving patient care and promoting overall well-being [55]. Numerous studies have emphasized the insufficiency of using BMI as a sole measure for evaluating and addressing the cardiometabolic risks linked to heightened adiposity in adult individuals [59–61]. The authors conducted a comprehensive analysis of the available evidence, providing healthcare professionals and professional societies with the necessary tools to regularly include waist circumference assessment in the assessment and treatment of individuals who are overweight or obese [55, 62]. Prior studies have emphasized the significance of focusing on decreasing waist circumference as a crucial goal for addressing detrimental health risks in both males and females [63, 64]. Moreover, substantial evidence supports the notion that consistent engagement in moderate-intensity exercise and/or dietary interventions can lead to significant reductions in waist circumference, which are clinically meaningful [65–67].

Another hotly debated topic that has drawn much interest is the link between metabolic syndrome, oxidative stress, and a pro-inflammatory state. When the body's capacity to detoxify reactive oxygen species (RCO) [55] and their production are out of balance, oxidative stress results. ROS are extremely reactive molecules linked to the pathogenesis of many chronic diseases, including metabolic syndrome [68, 69]. They can harm cells and tissues. According to several studies, individuals with metabolic syndrome have higher blood levels of indicators of oxidative stress, such as malondialdehyde (MDA) and protein carbonyls [70, 71]. Furthermore, people with metabolic syndrome often exhibit increased inflammation [72]. There is broad agreement among academics that persistent low-grade inflammation can exacerbate insulin resistance and interfere with insulin signaling, contributing to the development of metabolic syndromes [73]. Interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-alpha) are two examples of inflammatory cytokines that are known to be elevated in people with metabolic syndrome [74]. The interaction of oxidative stress and inflammation has been suggested to play a role in the emergence and progression of metabolic syndrome [75]. A balanced diet, regular exercise, and stress reduction have greatly reduced oxidative stress and inflammation. All of these actions improve metabolic health. Several prescription drugs and dietary supplements may help metabolic syndrome patients reduce inflammation and oxidative stress [75, 76].

Insulin resistance syndrome pathogenesis is another hot topic. Genetic, environmental, and lifestyle factors complicate insulin resistance syndrome [77, 78]. Impaired insulin signaling, dyslipidemia, inflammation, and other metabolic abnormalities increase the risk of cardiovascular disease and type 2 diabetes [79]. Impairment of insulin signaling, which results in decreased glucose uptake by body cells and elevated blood sugar levels, is one of the main characteristics of insulin resistance syndrome [80]. This may accelerate the onset of type 2 diabetes. Dyslipidemia or abnormal blood lipid levels in insulin resistance syndrome are also typical [81]. People who suffer from this condition frequently have low HDL cholesterol and high triglyceride levels, both of which are risk factors for cardiovascular disease [82]. Insulin resistance syndrome is associated with inflammation and oxidative stress, in addition to these metabolic abnormalities, which can accelerate the development of cardiovascular disease [71, 79]. Obesity, sedentary lifestyles, diets high in saturated and trans fats, and smoking are environmental and lifestyle factors that can increase the risk of developing insulin resistance syndrome. Genetic factors may also influence emergence [7, 76, 79, 83].

This bibliometric study significantly contributes to existing research on metabolic syndrome and insulin resistance, shedding light on the current research perspective while paving the way for further research in this field. In this discussion, we aim to provide a more thorough analysis of the clinical significance and future implications of the study mentioned above. The clinical significance of a phenomenon or discovery refers to its

practical relevance and impact in the field of medicine or healthcare. First, the objective of this study is to identify and examine current research trends in the field of metabolic syndrome and insulin resistance. Health professionals, researchers, and policymakers must comprehensively understand current research priorities to effectively respond to individuals' ever-changing health needs. Second, the study offers a global perspective on collaboration, dissemination of best practices, and mitigation of the global impact associated with metabolic syndrome. Third, it identifies priority research areas, such as the pathogenesis of insulin resistance syndrome, the use of waist circumference as a clinical indicator, and the relationship between metabolic syndrome, oxidative stress, and inflammation. Healthcare professionals can use these data to enhance assessment and tailor interventions for at-risk patients. Fourth, our study suggests a link between metabolic syndrome, insulin resistance, and the severity of COVID-19, underscoring the clinical importance of effectively controlling metabolic syndrome to reduce the likelihood of catastrophic outcomes from COVID-19.

Looking at possible future prospects for the current study, policymakers and funding agencies can first use the study results to establish research priorities. Second, recognizing metabolic syndrome as a global health problem can offer valuable information for developing public health interventions, enabling governments and health organizations to develop comprehensive approaches to contain incidence, identify its presence, and treat metabolic syndrome more broadly. Third, our research focuses on the impact of lifestyle factors on insulin resistance and metabolic syndrome, highlighting the critical importance of preventive measures. In the future, greater emphasis could be placed on prioritizing lifestyle changes, such as diet and physical activity modifications, as primary therapies. Finally, exploring new research areas, such as the impact of gut microbiota on metabolic disorders, can pave the way for breakthroughs in our understanding of these conditions.

Strengths and limitations

The first study of this kind provides important information about the relationship between metabolic syndrome and insulin resistance. However, this study has some limitations. First, using Scopus as the document retrieval system may have resulted in excluding articles published in unindexed local journals. However, because Scopus is a massive database containing a wide range of health-related publications from many countries, countries with Scopus-indexed journals or English-language articles may have an advantage. As a result, the research findings may have been overestimated. Second, the study was limited to searching solely in the title for the terms "metabolic syndrome and insulin resistance" and their related terms. As a result, publications that use these terms as keywords or within the publication may have been overlooked. Third, the Scopus results represent the data and nature it contains, implying that institutions with multiple Scopus profiles may have dispersed research output and thus do not appear on the active list. The same problem occurs when funding agencies have different names in different published papers. As a result, limiting the findings to those obtained using the recommended Scopus approach is critical when scrutinizing data on the most dynamic institutions and funding organizations. Fourth, the use of absolute citation figures to classify articles in this investigation could have limitations compared to rankings based on average citations per year, as citation counts can vary and escalate over time. Moreover, some recently published papers of high quality may not have received enough citations to make it to the top ten list. Therefore, even though these publications were excluded from the list, it does not imply that they are of lesser significance.

Conclusions

This study presents the first bibliometric analysis of publications on metabolic syndrome and insulin resistance. The United States stands out as the leading contributor to research in the field, having produced the most publications. Japan, China, and the United Kingdom have also contributed significantly. After 2019, a clear trend in scholarly research emerged, with countries with greater economic prosperity demonstrating a greater propensity to conduct research on metabolic syndrome and insulin resistance. Current scholarly research focuses primarily on the importance of waist circumference as a clinical indicator of metabolic syndrome susceptibility. These studies also aim to investigate the connection between metabolic syndrome, oxidative stress, and the pro-inflammatory state. In addition, this study identifies significant research gaps in metabolic syndrome and insulin resistance, particularly in low- and middle-income countries. Immediate attention is required to increase the output of global research, particularly in the fields of epidemiology, patterns, preventive strategies, and national planning. The current study provides a comprehensive overview of global research on metabolic syndrome and insulin resistance, making it an invaluable resource for future studies.

Abbreviations

MeSH	Medical Subject Headings
IF	Impact factor
HMW	High molecular weight
MDA	Malondialdehyde
BMI	Body mass index
ROS	Reactive oxygen species
IL-6	Interleukin-6
TNF-alpha	Tumor necrosis factor-alpha
AT	Adipose tissue

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Author contributions
The research project was conceptualized and designed by Zyoud SH, who also managed and analyzed the data, created figures, contributed significantly to the literature search and interpretation, and wrote the manuscript. Shakhshir M assisted with the conceptualization and methodology of the study, helped interpret the data, contributed to the writing of the manuscript and revised the initial draft. Abushanab AS, Al-Jabi SW, Jairoun A, Shahwan WM, Abu Taha A, Abushamma F, and Koni A participated in data interpretation, manuscript writing, and revision of the initial draft. All authors conducted a critical review and gave their approval before submission of the final manuscript.

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Data availability
All data generated or analyzed during this study are included in this published article. In addition, other data sets used during the current study are available from the corresponding authors upon reasonable request.

Declarations

Ethics approval and consent to participate
Because the current study did not include any human interaction, it does not require the permission of the Ethics Committee.

Consent for publication
Not applicable.

Competing interests
The author declares that he has no competing interests.

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