**Journal of Actuarial, Finance and Risk Management (JAFRM)**
e-ISSN:28303938
Vol. 4(2), December, 2025.
http://e-journal.president.ac.id/presunivojs/index.php/JAFRM/index

# A Review of Kruskal-Wallis Test Applications in Scientific Research

Syifa Nurulfajri Rustin[1], Samsul Arifin[2,]

[1,2]*Department of Data Science, Faculty of Engineering and Design, Institut Teknologi Sains Bandung, Bekasi, West Java, 17530, Indonesia*

[*]*Corresponding author: samsul.arifin@itsb.ac.id*

Receive: Septermber 22, 2025, Revised: January 6, 2026 Accepted: January 11, 2026

***Abstract***— *The Kruskal-Wallis test is a widely applied non-parametric statistical method for comparing multiple independent groups. Despite its frequent usage in various disciplines, limited bibliometric studies have been conducted to examine research trends, influential authors, and collaborations related to this test. This study aims to analyze the bibliometric landscape of Kruskal-Wallis test research using Scopus as the primary database and Scopus-AI as a secondary source for validation. The dataset consists of journal articles published in English between 2021 and 2025, retrieved using the search query TITLE-ABS-KEY (kruskal AND wallis AND test) with additional filters for document type and language. The bibliometric analysis was conducted using VOSviewer, focusing on co-authorship networks, keyword co-occurrence, citation analysis, bibliographic coupling, and co-citation patterns. The results reveal key research clusters, emerging trends, and highly influential publications. The keyword analysis highlights the interdisciplinary applications of the Kruskal-Wallis test, particularly in biomedical research, machine learning, and social sciences. Citation network analysis identifies high-impact authors and journals, while co-authorship mapping illustrates significant global research collaborations. By integrating Scopus-AI as a second opinion, this study strengthens the validity of findings and uncovers additional insights that may not be evident from conventional bibliometric searches. The results provide a comprehensive overview of research developments related to the Kruskal-Wallis test, offering valuable guidance for future studies and interdisciplinary applications.*

***Keywords***— *Bibliometric Analysis, Kruskal-Wallis Test, VOSviewer, Research Trends, Scopus, Scopus-AI.*

## I. INTRODUCTION

The Kruskal-Wallis Test is a widely used non-parametric statistical method for comparing multiple independent groups when normality assumptions are not met. It is particularly useful in various fields such as medicine, social sciences, and engineering, where researchers analyze ranked data to determine significant differences among groups. Despite its extensive application, there has been limited investigation into the trends, influential works, and research collaborations surrounding this statistical test. A bibliometric analysis can provide a comprehensive overview of the development and impact of Kruskal-Wallis Test-related research over time [1], [2]. Existing studies primarily focus on methodological improvements, practical applications, or comparisons with other statistical techniques. However, there is a lack of systematic reviews analyzing how research on the Kruskal-Wallis Test has evolved, which journals or institutions contribute the most, and which researchers have played a key role in advancing this area. By addressing this gap, a bibliometric analysis can offer valuable insights into the current state of research, collaboration patterns, and emerging trends in this domain. Such an analysis can help guide future research efforts and identify potential interdisciplinary applications [3].

The urgency of conducting a bibliometric study on the Kruskal-Wallis Test stems from the increasing use of non-parametric methods in modern data analysis. With the rise of complex and high-dimensional datasets, traditional parametric assumptions are often violated, leading to a greater reliance on robust statistical tests such as Kruskal-Wallis. Understanding the publication trends and citation networks can help researchers and educators refine their methodologies, improve teaching materials, and develop new applications in various scientific disciplines [4], [5]. Furthermore, as statistical methodologies continue to evolve, it is essential to recognize the

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key contributors and influential studies in the field. A bibliometric analysis using tools such as VOSviewer can reveal co-authorship networks, co-citation patterns, and thematic clusters related to the Kruskal-Wallis Test. This can facilitate knowledge dissemination, foster collaborations, and highlight underexplored areas in need of further research. The following figure provides an overview of how to use Vosviewer [6], [7].

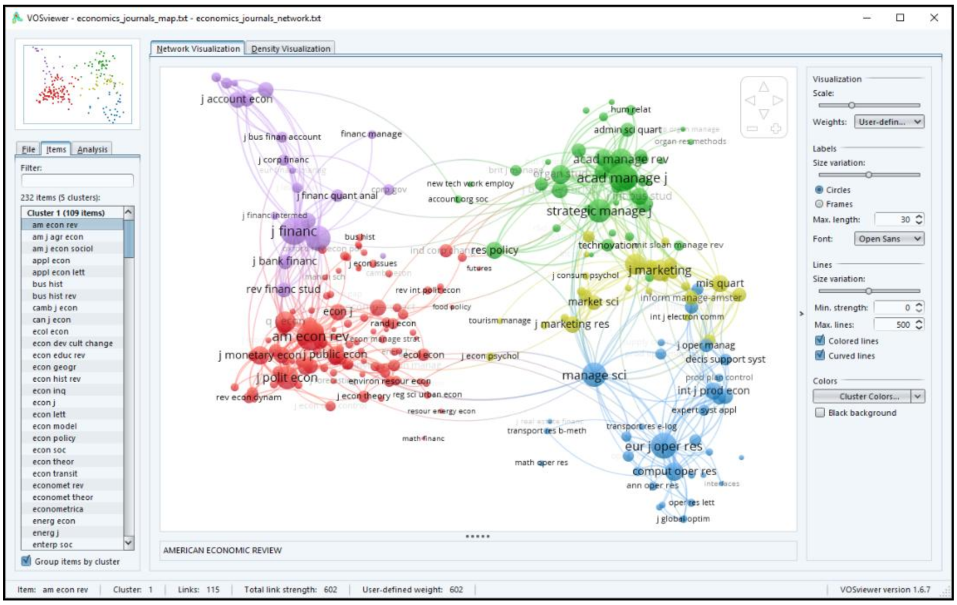


*Figure 1.Illustration of using Vosviewer [8]*

This study aims to bridge the existing research gap by providing a comprehensive bibliometric analysis of Kruskal-Wallis Test-related publications. By analyzing citation trends, keyword co-occurrences, and authorship patterns, we seek to uncover the intellectual structure of this research domain. The findings of this study will not only contribute to a better understanding of the historical and current landscape of Kruskal-Wallis research but also serve as a reference for future investigations in non-parametric statistical methodologies [9], [10]. The theoretical description of the Kruskal-Wallis test has been streamlined to emphasize only the essential features necessary for contextualizing the bibliometric analysis. As the test is already well established in statistical literature, this study shifts its focus from methodological exposition toward understanding publication patterns, interdisciplinary adoption, and the evolution of research themes surrounding the test. This refinement ensures that the introduction remains aligned with the objectives of bibliometric inquiry rather than reiterating textbook definitions [11], [12].

## II. Methodology

The Kruskal-Wallis test is a widely used non-parametric statistical method for comparing multiple independent groups. Its applications span various scientific disciplines, including medicine, psychology, and social sciences. Despite its extensive use, limited bibliometric studies have been conducted to analyze publication trends, influential authors, and research collaborations related to the Kruskal-Wallis test. This study aims to fill this gap by conducting a bibliometric analysis using VOSviewer to map the development of research on the Kruskal-Wallis test in recent years [13], [14]. To conduct this bibliometric analysis, data was collected from the Scopus database, a widely recognized source for peer-reviewed journal articles. The search query used was: TITLE-ABS-KEY (kruskal AND wallis AND test) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2023) OR LIMIT-TO (PUBYEAR, 2024) OR LIMIT-TO (PUBYEAR, 2025)). This search criterion ensures that only journal articles published in English between 2021 and 2025 are included, providing a recent and relevant dataset [15], [16].

After retrieving the data, it was pre-processed to remove duplicates and incomplete records. Only publications containing essential bibliographic information such as title, authors, affiliations, abstracts, and references were included. This process ensured that the dataset was comprehensive and suitable for bibliometric analysis. The refined dataset was then exported in RIS or CSV format for further analysis using VOSviewer. Additionally, as a second opinion, we also incorporated insights obtained from Scopus-AI, a tool that provides AI-generated summaries, research trends, and topic interconnections. This helped validate our findings and identify potential additional insights that might not be immediately evident from the conventional Scopus search alone [17], [18]. VOSviewer was used to conduct various bibliometric analyses, including co-authorship analysis, co-occurrence of keywords, citation analysis, bibliographic coupling, and co-citation analysis. The parameters selected for VOSviewer included a minimum citation threshold for authors and documents, allowing the identification of influential researchers and highly cited papers. Additionally, keyword co-occurrence analysis was performed to explore the most frequently used terms in Kruskal-Wallis-related research, providing insights into emerging trends and thematic developments [19], [20]. This study contributes to a better understanding of the research landscape surrounding the Kruskal-Wallis test. By identifying key authors, major research clusters, and citation networks, this analysis provides valuable insights into the evolution of studies on the topic. The integration of Scopus-AI as a supplementary source strengthens the robustness of our findings, ensuring that the analysis captures a comprehensive perspective on the field. The following sections present a detailed discussion of the findings and their implications for statistical and applied research. Illustration of the use of Scopus-AI in this research can be understood through the following Figure 1 [21], [22].

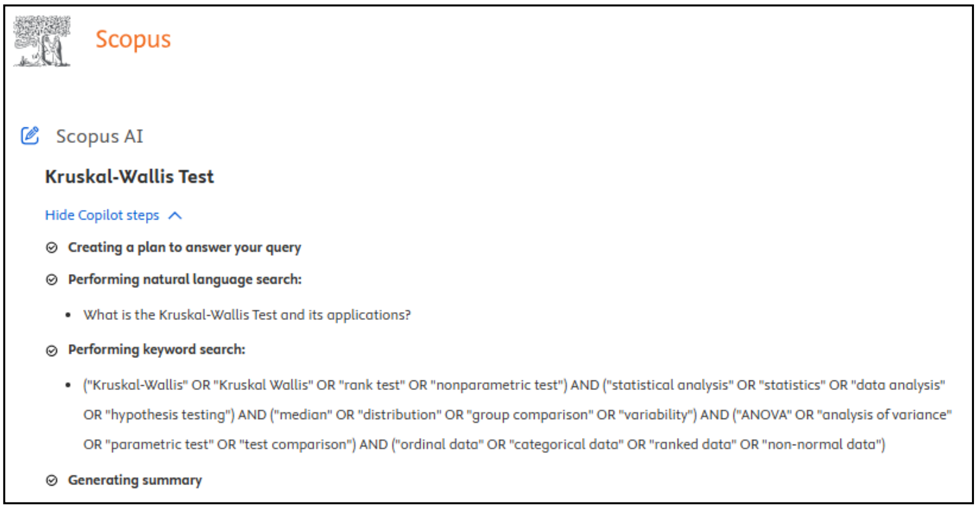


*Figure 2. The process of using Scopus-AI in this research [23].*

To strengthen the analytical depth of this study, quantitative bibliometric indicators were incorporated alongside the visual network maps generated through VOSviewer and Scopus-AI. Specifically, the analysis now includes annual publication trends, citation counts, dataset h-index, and collaboration metrics across countries and institutions. These numerical indicators provide a clearer empirical foundation to support the observed patterns in co-authorship, keyword co-occurrence, citation networks, and bibliographic coupling. By integrating both visual and quantitative measures, the study offers a more comprehensive and robust evaluation of research activities related to the Kruskal-Wallis test, thereby enhancing its methodological contribution within the field of statistical bibliometrics [24], [25]. Although the primary dataset in this study focuses on publications from 2021–2025 to capture the most recent research dynamics, earlier literature from 2010–2020 was also reviewed qualitatively to contextualize long-term developments in the application of the Kruskal-Wallis test. These earlier works reveal foundational methodological contributions, including refinements to post-hoc procedures, power analysis, and applications in genetics and behavioral sciences. Incorporating this historical context ensures that the present study does not isolate recent trends from their methodological origins but instead embeds them within a broader evolutionary trajectory of non-parametric statistical research [26], [27], [28].

## III. RESULT AND DISCUSSION

The results and discussion section presents findings obtained from two analytical tools, VOSviewer and Scopus-AI, to provide a comprehensive understanding of the Kruskal-Wallis test. First, the analysis using VOSviewer will be explored, focusing on bibliometric insights, keyword co-occurrence networks, and research trends related to the test. This will help identify key themes, influential studies, and the broader research landscape. Following this, the discussion will transition to findings derived from Scopus-AI, which provides a structured conceptual mapping of the Kruskal-Wallis test, including its related statistical methods, applications in various fields, and methodological significance. By integrating these two perspectives, this section aims to offer both a data-driven bibliometric analysis and a conceptual understanding of the test's relevance and applications [29], [30].

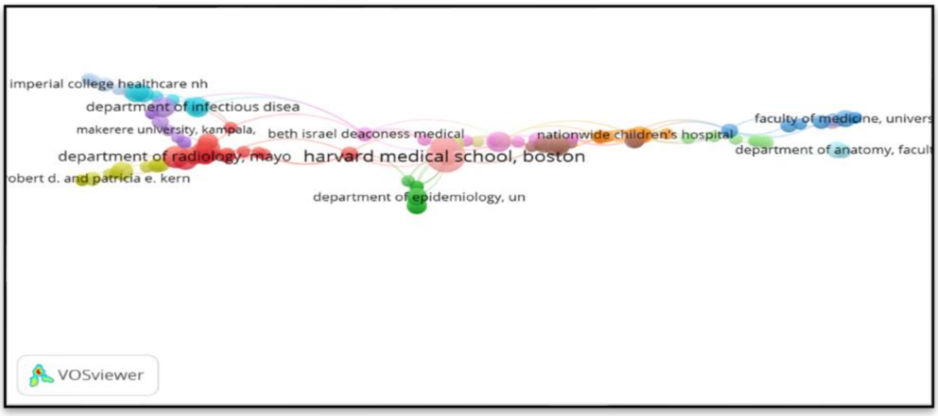


*Figure 3. Visualization from VosViewer for Co-Authorship by Organizations*

Figure 1 is a visualization of the collaboration network between organizations in scientific publications. Each dot represents an institution or research organization, while the lines connecting the dots indicate collaboration in academic publications [31]. Different colors indicate clusters or groups of institutions that have higher levels of collaboration among themselves. The size of the text reflects the extent to which an organization is involved in the collaborative network, with larger institutions, such as Harvard Medical School, Boston, and the Department of Radiology, Mayo, contributing significantly to research collaboration. The structure of this network shows a pattern of global academic collaboration, with a few institutions acting as key hubs that bridge the various research clusters. The colors indicate clusters or groups of institutions that have higher levels of collaboration in scientific publications. Major clusters, such as red, green, blue, and yellow, indicate tight-knit research communities, with institutions such as Harvard Medical School, Boston, and the Department of Radiology, Mayo (red) contributing significantly to academic collaboration, while the Department of Epidemiology, UN (green) focuses more on epidemiological studies. The blue cluster, which includes the Faculty of Medicine and the Department of Anatomy, indicates collaboration in basic medicine, while the yellow and orange clusters, such as Nationwide Children's Hospital, have more limited connections but still play a role in the research network. The relationships between clusters, characterized by numerous cross-color connections, indicate the existence of multidisciplinary and inter-institutional collaboration, with some organizations serving as key hubs in the global scientific network [32], [33].

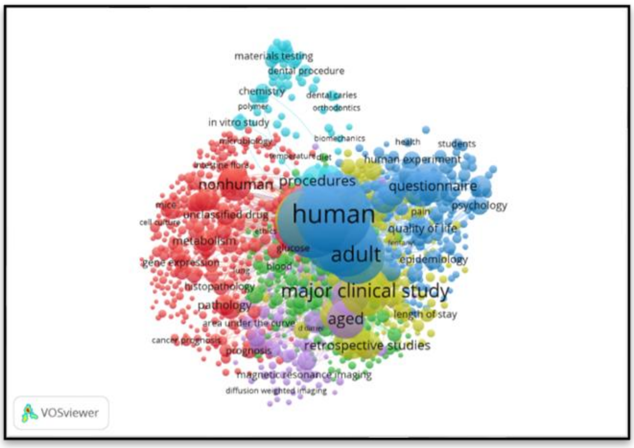


*Figure 4. Visualisasi Co- Occurrence by All keywords*

Figure 2 is a visualization of the relationship between keywords in scientific publications based on co-occurrence analysis using VOSviewer, where the size of the keyword indicates the frequency of its occurrence, while the color reflects the group of studies with a close relationship. The blue color groups research related to human health, psychology, and quality of life, with dominant keywords such as "human," "adult," "questionnaire," and "epidemiology". The red color focuses on non-human experimental research, including metabolic and laboratory studies with keywords such as "nonhuman procedures," "metabolism," and "pathology". 0020 The green color reflects medical and clinical studies, especially related to disease diagnosis and prognosis, seen from keywords such as "major clinical study," "retrospective studies," and "prognosis". The yellow color refers to more advanced clinical research, covering elderly patients and statistical analysis methods in Health research. The purple color indicates a focus on medical imaging, such as "magnetic resonance imaging" and "diffusion weighted imaging," which play an important role in disease diagnosis. Meanwhile, the cyan (light blue) color represents studies in the fields of dentistry, biomechanics, and chemistry, with keywords such as "dental procedure," "materials testing," and "biomechanics". Overall, this visualization illustrates the close relationship between research fields and shows major trends in scientific publications [34], [35].

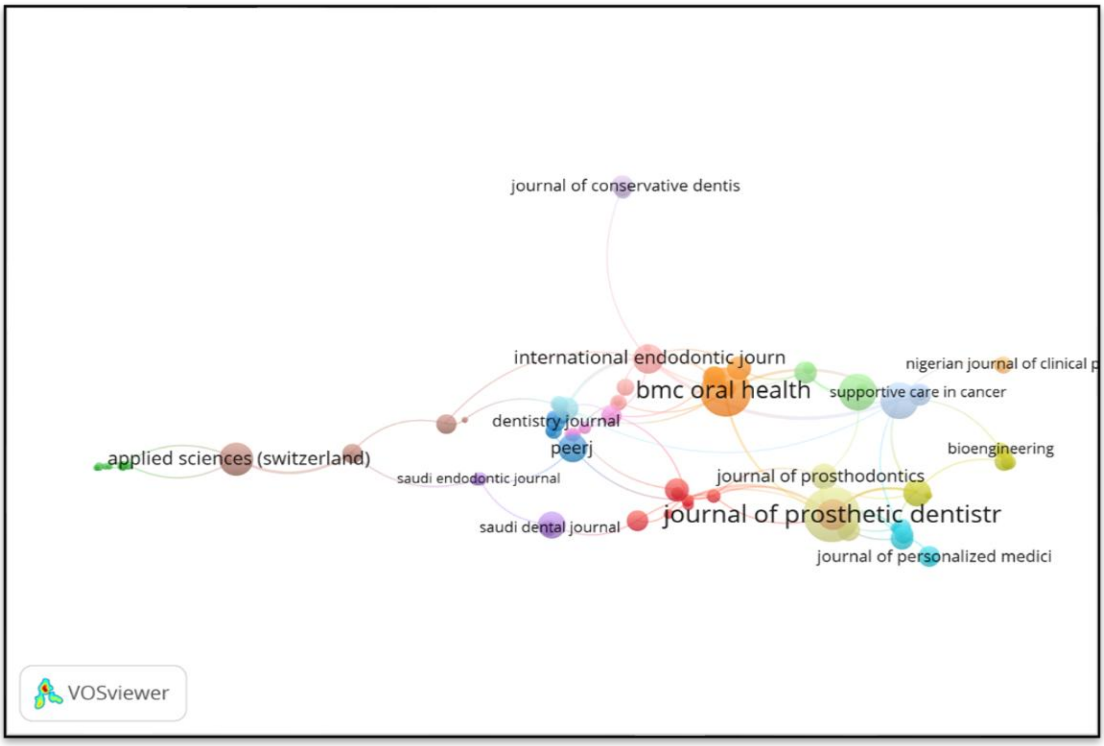


*Figure 5. Visualisasi Citation by sources*

Figure 3 shows the citation relationships between scientific publication sources in the field of dentistry and medicine. Each node represents a scientific journal, with the size of the node reflecting the number of citations received by the journal [6]. Different colors group journals based on their topical or disciplinary relevance [7]. For example, orange (such as BMC Oral Health) indicates journals with many citations in the field of oral health. Red (such as Journal of Prosthetic Dentistry) indicates journals focused on prosthodontics and dental restorations. Green (such as Applied Sciences Switzerland) indicates journals related to interdisciplinary research, including engineering and bioengineering. Blue (such as PeerJ) indicates journals related to general dentistry and clinical research. The lines connecting the nodes represent the citation relationships between journals, where the thicker the line, the stronger the citation relationship between them. This visualization helps identify the most influential journals in a particular field as well as the patterns of scientific communication between these journals [3], [36], [37].

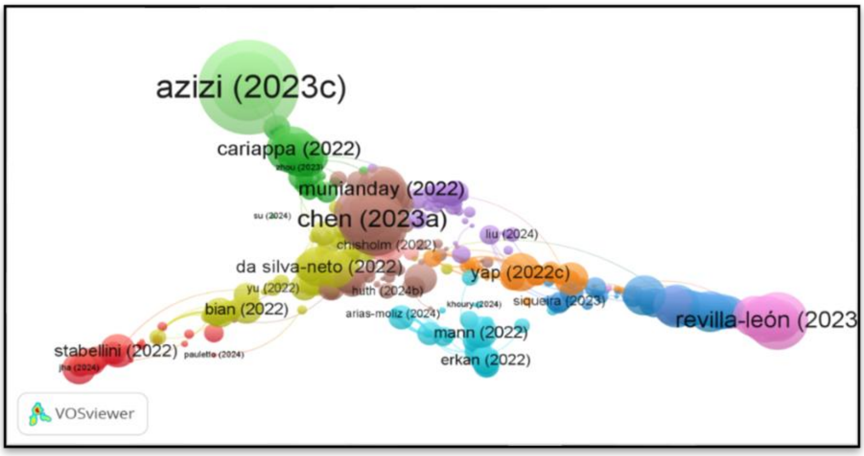


*Figure 6. Visualisasi Bibliographic Coupling by Documents*

Figure 4 is a visualization of Bibliographic Coupling by Documents from VOSviewer, which shows the relationships between documents based on shared references. Each node represents a single document, with the size of the node reflecting the number of citations it receives. Different colors indicate groups of documents that have strong reference relationships. For example, green (such as Azizi, 2023c) indicates a group of documents with many shared references, making them central in the citation network. Yellow (such as Bian, 2022) and red (such as Stabellini, 2022) indicate other groups of documents that have strong connections within a particular field but are distinct from the green group. Blue (such as Revilla-León, 2023) and purple (such as Munianday, 2022) depict groups of documents that have connections in more specific references. The lines connecting the nodes reflect the degree of reference similarity between documents, where the thicker the line, the greater the reference overlap between the documents. This visualization helps in understanding how documents in a field are connected to each other based on the references they use [38], [39].

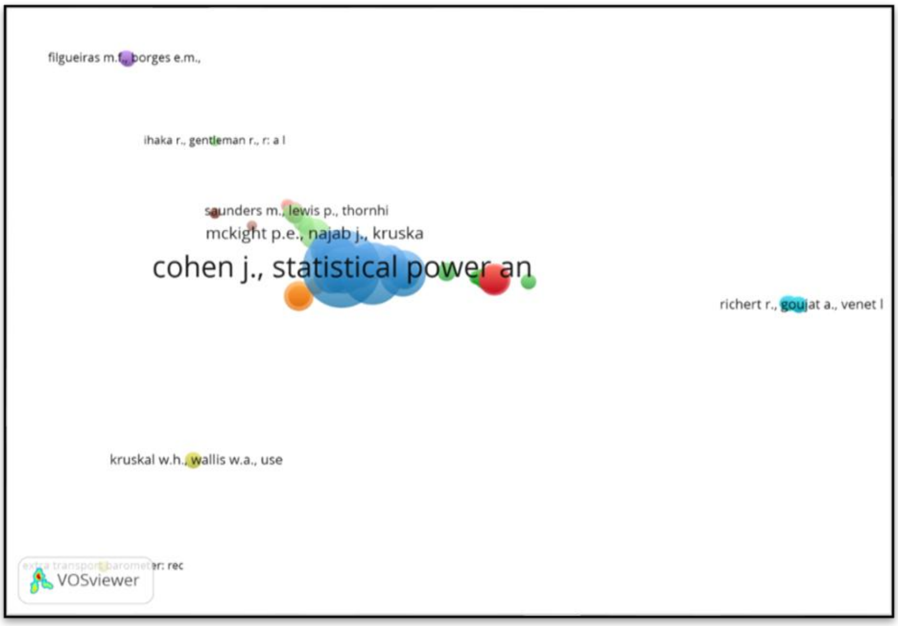


*Figure 7. Visualisasi Co - Citation by Cited references*

Figure 5 shows Co-Citation by Cited References using VOSviewer, illustrating how references cited together in the scientific literature are related to each other. Each node represents a frequently cited reference in a research document. The size of the node indicates how often the reference is cited, with the largest node being the reference to Cohen J. on statistical power, which is central to this network. Different colors indicate groups of references

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e-ISSN:28303938
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that are closely related in the citation pattern, where blue groups reference that are frequently cited together with Cohen J., while red, green, and orange represent other groups of references that have more specific or limited relationships. Some nodes are far from the main group, indicating that they are cited together less frequently or in a more limited context. This visualization helps to understand how scientific sources are related to each other in research [8], [40].

The bibliometric patterns observed in this study reveal several meaningful insights beyond the visual clustering results. Dominant keyword clusters, particularly those linked to biomedical research, epidemiology, and diagnostic imaging, indicate that the Kruskal-Wallis test continues to be strongly positioned as an analytical tool for non-parametric data in health-related disciplines. The emergence of machine learning, related terms within secondary clusters further suggests an ongoing methodological shift, in which the test is increasingly integrated into hybrid statistical–computational workflows. Moreover, the global collaboration networks, notably dominated by institutions in the United States, Western Europe, and East Asia, reflect how methodological innovations commonly originate from regions with strong interdisciplinary research infrastructures. These patterns imply that the development of non-parametric statistical methods is closely tied to cross-regional collaboration, enabling rapid dissemination of methodological refinements and applied innovations [41], [42].

The following results were obtained using Scopus-AI. The Kruskal-Wallis test is a nonparametric statistical method designed to compare three or more independent groups, assessing whether they originate from the same distribution. Unlike ANOVA, it does not assume normality and instead relies on ranking data, making it particularly useful for ordinal or interval data. This test is widely applied in various disciplines, including biomedical research, epidemiology, and social sciences, where normality assumptions often do not hold. If significant differences are found, post-hoc tests such as the Nemenyi test can be employed for pairwise comparisons. The Kruskal-Wallis test calculates a test statistic that follows a chi-square distribution with (k-1) degrees of freedom, where (k) represents the number of groups [43], [44]. The following findings were also derived from Scopus-AI. Despite its flexibility and robustness, the test has some limitations. It does not provide specific pairwise comparisons by default, necessitating additional post-hoc analyses when differences are detected. Additionally, while it performs well in handling non-normal distributions, it may have lower statistical power compared to parametric tests in small sample sizes. To address these limitations, researchers have developed modified versions of the test to handle data uncertainty, such as interval-valued data. The test is implemented in various statistical software packages, including SAS and R, making it accessible for practical applications. Overall, the Kruskal-Wallis test remains a valuable tool for researchers working with nonparametric data across diverse scientific fields [45], [46].

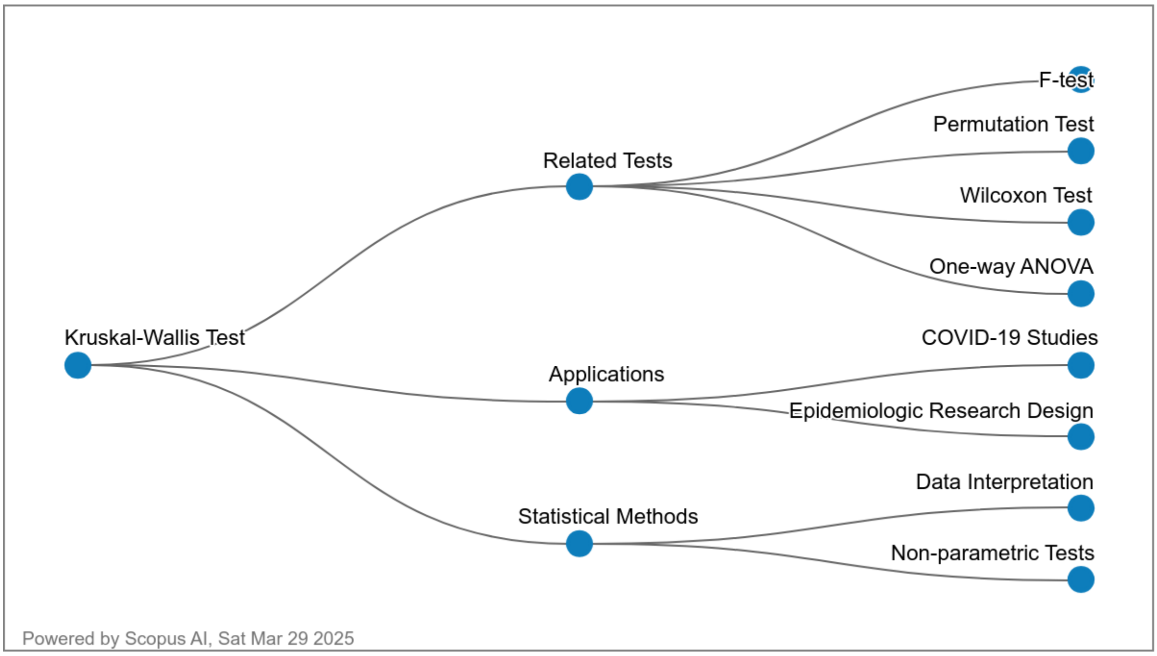


*Figure 8. Concept map obtained from Scopus-AI [47]*

The concept map generated by Scopus-AI illustrates the various aspects of the Kruskal-Wallis test, highlighting its related tests, applications, and statistical methods. The test is closely associated with other statistical methods, including the F-test, Permutation Test, Wilcoxon Test, and One-way ANOVA, which are used in different scenarios for comparing group distributions. In terms of applications, the Kruskal-Wallis test has been widely applied in epidemiologic research design and COVID-19 studies, emphasizing its relevance in medical and public health research. Additionally, the test plays a significant role in statistical methods, particularly in data interpretation and non-parametric tests, reinforcing its utility when normality assumptions are not met. This visualization underscores the broad applicability and methodological connections of the Kruskal-Wallis test in modern statistical analysis [48], [49], [50].

The integration of Scopus-AI provides additional analytical value beyond what can be achieved through traditional bibliometric procedures. While VOSviewer enables network-based mapping of authors, keywords, and citations, Scopus-AI enhances the analysis through automated topic extraction, semantic clustering, and identification of latent research pathways. These AI-driven insights help identify conceptual associations that are not readily visible through citation networks alone, thereby strengthening the validity of the thematic structure identified in this study. The combination of both tools allows for a more holistic bibliometric interpretation, providing both structural and conceptual perspectives on the evolution of Kruskal-Wallis research [51], [52], [53].

## IV. CONCLUSION

This bibliometric study on the Kruskal-Wallis Test highlights its evolving research landscape, key contributing authors, influential publications, and thematic trends. The analysis using VOSviewer reveals that the Kruskal-Wallis Test is widely applied across various disciplines, particularly in medical sciences, social sciences, and engineering. Citation and co-authorship networks indicate that certain researchers and institutions play a central role in advancing the methodology and application of this statistical test. However, while the study successfully maps the research trends, deeper insights into the methodological advancements and interdisciplinary applications remain underexplored. Several open problems emerge from this analysis. First, the evolution of Kruskal-Wallis Test applications in emerging fields, such as artificial intelligence and machine learning, requires further investigation. Second, the impact of alternative non-parametric tests on the declining or growing relevance of the Kruskal-Wallis Test is an area worth exploring. Finally, refining bibliometric analysis with more sophisticated techniques, such as machine learning-based topic modeling, could enhance the understanding of research dynamics in this domain. Future studies should integrate qualitative insights with quantitative bibliometric findings to provide a more comprehensive picture of the field.

Beyond summarizing publication trends, the findings of this study carry several implications for future developments in non-parametric statistical research. The strong presence of Kruskal–Wallis applications in biomedical and engineering fields suggests that demand for robust rank-based methods will continue to grow, particularly in settings involving non-normal, noisy, or high-dimensional data. The increasing integration of the test within machine learning pipelines highlights opportunities for developing hybrid statistical–computational frameworks that combine interpretability with algorithmic efficiency. Furthermore, the identified collaboration networks indicate that methodological innovations are likely to emerge from interdisciplinary and multinational research teams. Future research may focus on expanding non-parametric models for complex datasets, improving post-hoc procedures, and exploring AI-assisted approaches for enhancing non-parametric statistical inference.

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