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A Bibliometric Analysis of Power Analysis Studies

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Abstract

The primary purpose of this study was to establish a theoretical framework for studies on power analysis conducted in the fields of education, psychology, and statistics for researchers. It also determined which concepts were associated with power analysis over the years and the authors and countries that contributed to the advancement of research regarding this concept. Therefore, the bibliometric characteristics of publications related to power analysis in the Web of Science database were analyzed using the Biblioshiny interface in the R programming language. Our investigation encompassed 515 studies selected based on specific criteria. Data revealed that from 1970 to 2023, these studies originated from 183 sources and involved 1246 authors. Among them, 98 studies were single-authored, and the average number of co-authors per paper stood at 2.88. According to Bradford's Law, Behavior Research Methods, Psychological Methods, and Multivariate Behavioral Research were the most productive journals concerning power analysis, taking up a larger proportion within the core sources compared to other journals. These journals were among the top three in terms of the number of publications, h-index, total number of citations, and publication rankings. These journals were followed by Structural Equation Modeling-A Multidisciplinary Journal, Frontiers in Psychology, and Educational and Psychological Measurement. An examination of studies on power analysis in education, psychology, and statistics according to Lotka's Law indicated that the relevant literature is insufficient and needs further development.

Keywords: Power analysis, bibliometric analysis, Biblioshiny, WOS

Introduction

One of the factors determining the quality of studies in a scientific research process is how the steps of the research are carried out. In this context, the sample representing the population of the research becomes crucial as much as identifying the research problem (Güler, 2022). In research, when considering factors such as accessibility, cost, and time, studies are generally conducted on a sample that represents the relevant population. In this context, the sample size representing the population is also important for the accuracy of statistical decisions. Indeed, applying the same method with different sample sizes in two separate studies can lead to different statistical decisions. Working with excessively large or small samples can lead to specific challenges. As the sample size increases, even a small difference can become significant. Considering the clinical research, working with an excessive number of patients can bring along not only financial challenges but also ethical concerns and various risks (Cohen et al., 2003). Additionally, testing the efficacy of a drug with an insufficient number of patients can result in erroneous conclusions. In many comparative studies, the accuracy of the H1 alternative hypothesis statement—which posits a difference between the compared conditions—should mirror reality. Consequently, the power of these tests is vital in research (Tabachnick & Fidell, 2013; Stevens, 2009). The purpose of many inferential statistics is to test specific hypotheses about potential group differences or correlations between variables (Cohen et al., 2018; Rossi, 2012; Sink & Mvududu, 2010). Statistical power refers to the probability of rejecting the false null hypothesis (H_0; Cohen, 1988). The probability of revealing the desired true effect in the population of a research study is higher with more powerful statistical tests, leading to a more robust outcome. In other words, statistical power is a factor that influences the validity of the decisions made based on the statistical tests used for testing a hypothesis established in a research study. For instance, in a study comparing a characteristic of two or

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more groups, the extent to which the statistical test used can reveal the difference that truly exists is referred to as statistical power. In other words, if there is actually a difference between two or more groups and this difference is confirmed by a statistical decision, then this situation indicates the power of the test for the respective research. Three factors determine the statistical power of a study. One is the significance level, the second is the effect size, and the third is the sample size (Field, 2005; Rossi, 2012; Stevens, 2009).

There are four different situations related to the formulated hypothesis in a research process. Two of these situations lead to a correct decision, while the other two result in an incorrect decision. One of these incorrect decisions is a Type I error, and the other is a Type II error. Type I error occurs when the null hypothesis (H_0) is actually true but is rejected based on a statistical decision. It is also known as alpha (α) error, indicating the significance level of the test. Type II error occurs when the null hypothesis (H_0) is actually false, but it is not rejected based on a statistical decision (Field, 2005). It is also referred to as b. However, 1-b indicates the power of the test. The power of a test takes values between 0 and 1. Values nearing 1 indicate an increase in statistical power. For many years, various studies in educational and social sciences have demonstrated that the power of tests has often been overlooked or that these tests have exhibited low power (Murphy et al., 2014). However, in recent years, studies conducted in these fields have emphasized the importance of having high power in tests. If the power of a study is less than 0.50, its results are often prone to misinterpretation (Murphy et al., 2014). Cozby and Bates (2018) state that the power of tests is generally preferred to range between 0.70 and 0.90 in studies. If researchers do not have a specific benchmark for statistical power regarding their studies, the minimum recommended value for this ratio is 0.80 (Cohen, 1988; Cohen et al., 2018; Süt, 2011). The higher the power of a study, the lower the risk of missing a true effect.

Sample size and effect size can be determined through various methods in power analysis studies. In clinical studies, relevant reference studies in the field are often taken into consideration (Howell, 2010). However, this may not be always feasible in social sciences. Therefore, the researcher can conduct a pilot study before the actual research to estimate the effect size (Ünalan, 2021). When we examine the literature, the power of tests has either been overlooked or not given due importance in many studies conducted in social and educational sciences. However, in recent years, the power of tests has become important even in studies conducted in education and psychology, and reputable journals expect reporting on the power of tests and effect sizes in studies to be published (Cozby & Bates, 2018; Meyners et al., 2020).

The main purpose of this study is to provide researchers in the fields of education, statistics, and psychology who conduct studies on power analysis with a framework related to the relevant literature in these fields. Additionally, it aims to guide researchers who conduct studies on power analysis about which journals and authors to refer to in this regard. Furthermore, it aims to provide insights into collaborations related to the topic, enabling international researchers to access the most frequently engaged institutions in such research. This study also aims to present new trends related to the topic to researchers, enabling them to access relevant information more quickly and easily. In this respect, answers were sought to the following research questions:

1. How are the studies related to power analysis distributed according to years?
2. How are the studies related to power analysis distributed according to countries?
3. How are the studies related to power analysis distributed according to journals?
4. How are the studies related to power analysis distributed according to authors?
5. How are the studies related to power analysis distributed according to collaborative (co-authored) studies?

6. How are the studies related to power analysis distributed according to the common keywords used?

Method

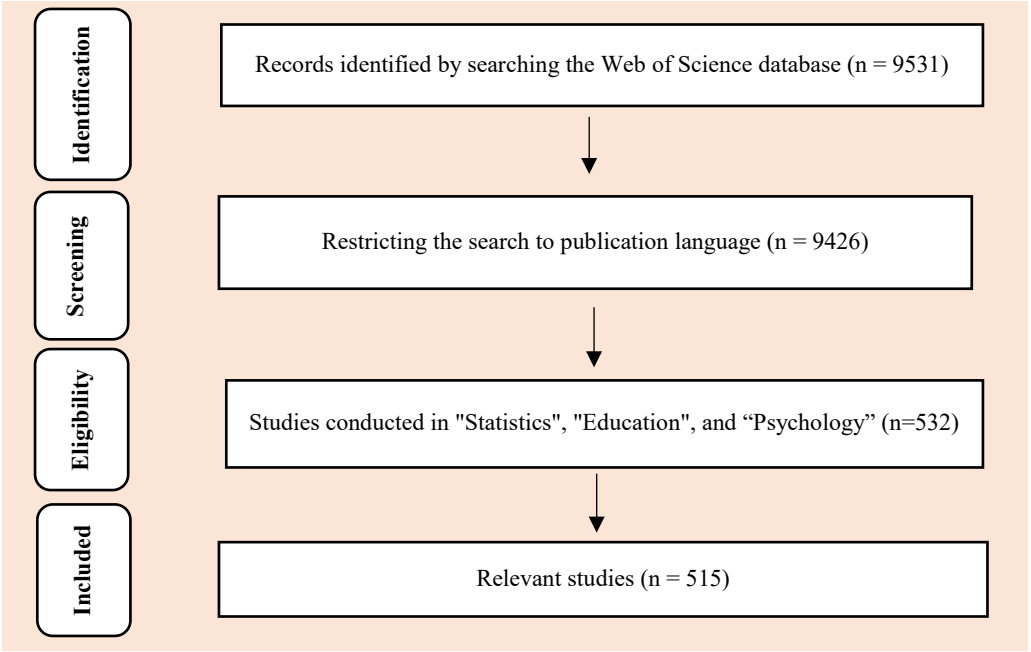
In this study, data related to power analysis were extracted from the Web of Science (WOS) database, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). The reason for choosing the WOS database was to access high-quality articles specifically on the mentioned topic. These data include articles focused on power analysis from January 1970 to July 2023.

Selection Strategies and Criteria

The sample of this study was determined using the criterion sampling technique of purposive sampling methods. A literature review was carried out focusing on topics linked to the keyword "Power analysis" within the WOS database. Specifically, studies concentrated on the fields of education, psychology, and statistics were prioritized for inclusion. After listing these studies, fields such as medicine, engineering, computer science, ecology, environmental sciences, law, communication, veterinary medicine, and women's studies were excluded. The inclusion criteria were employed in selecting the studies included in the research. Studies meeting the following inclusion criteria were included: Studies conducted between 1970 and May 2023, studies conducted in education, psychology, and statistics, the publication language is English, and studies including the concept of power analysis in the relevant fields. Figure 1 presents the PRISMA flow chart created based on these criteria.

Figure 1

The PRISMA Flow Chart



Two researchers independently retrieved a total of 515 studies on "Power analysis" from the WOS database using the same inclusion criteria. The retrieved studies were examined through bibliometric analysis. The study was conducted using document analysis, one of the descriptive analyses in qualitative research methods. Both descriptive and evaluative bibliometric analyses were used in this study. The reason for choosing descriptive bibliometrics was to reveal trends in studies in the literature related to power analysis according to countries, publication years, and subjects. Descriptive bibliometrics was employed because it targets measuring productivity, while evaluative bibliometrics was employed because it focuses on measuring the use of relevant literature. Descriptive bibliometrics enables revealing the distribution and trends of the literature according to authors, subjects, publication years, countries, languages, and so on. Evaluative bibliometrics, on the other hand, enables analyzing

the relationships between publications, authors, and countries through citations made by authors (Osareh, 1996).

Data Analysis Technique

This study employed a bibliometric analysis to analyze the data. Bibliometric analysis is a data analysis method used for statistical analyses and evaluation of scientific studies. The WOS database was used to search for relevant studies.

The Bibliometrix software was used to analyze the data in this study (Aria & Cuccurullo, 2017). The Biblioshiny interface was used through the R software for data inclusion criteria. Both descriptive and evaluative bibliometrics were used in the process of obtaining findings in the study. In descriptive bibliometrics, fundamental information about power analysis and descriptive information regarding the sources and authors were examined. In evaluative bibliometric analysis, common keyword analysis, co-authorship analysis, and other conceptual networks were determined to reveal trends, current topics, and research areas related to power analysis. Besides, graphics were generated for the networks of most-cited authors and most cited publications, respectively.

Results

The results are presented under two main headings (descriptive and evaluative bibliometrics).

Results of Descriptive Bibliometrics

This section presents findings related to the distribution of 515 studies on "Power Analysis" in the WOS database by years and researchers' collaboration and productivity. Data related to basic information regarding power analysis are reported in Table 1.

Table 1
Basic Information on Bibliometric Analysis

Timespan	1970:2023
Sources (Journals, Books, etc.)	183
Documents	515
Annual growth rate %	7.1
Average age of documents	10.6
Average number of citations per article	212.4
DOCUMENT CONTENT	
Keywords Plus (ID)	1213
Author's Keywords (DE)	1391
AUTHORS	
Authors	1246
Single-author articles	98
AUTHOR COLLABORATION	
Single-author documents	116
Co-authors per article	2.88
International co-authorship %	20.58
Articles	414
Articles, book chapter	15
Articles, early access	24
Articles, proceedings papers	6

According to Table 1, 515 studies on power analysis were published between 1970 and 2023. The number of citations was 212.4 on average. Of 1246 authors, 98 published single-author studies. The annual average citation graph for studies related to power analysis and the number of articles written over the years are illustrated in Figure 2a and Figure 2b.

Figure 2a
Annual publication rates

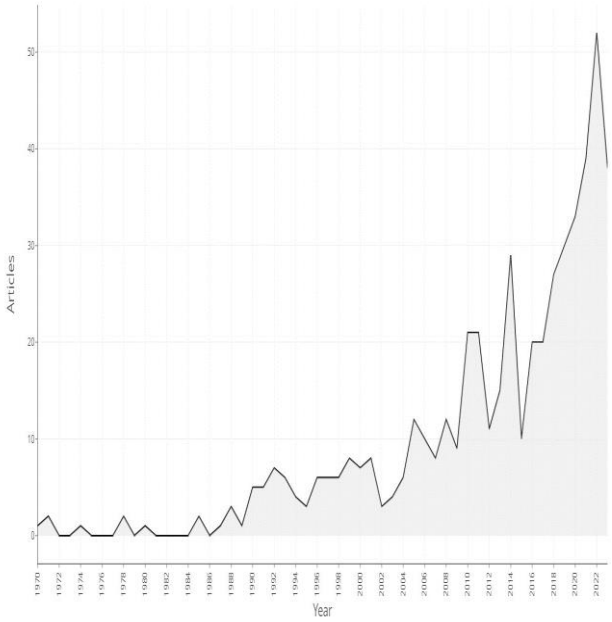
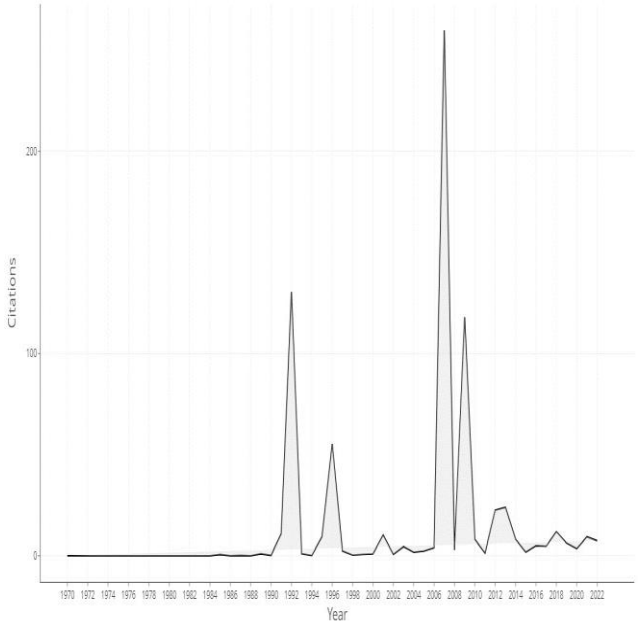


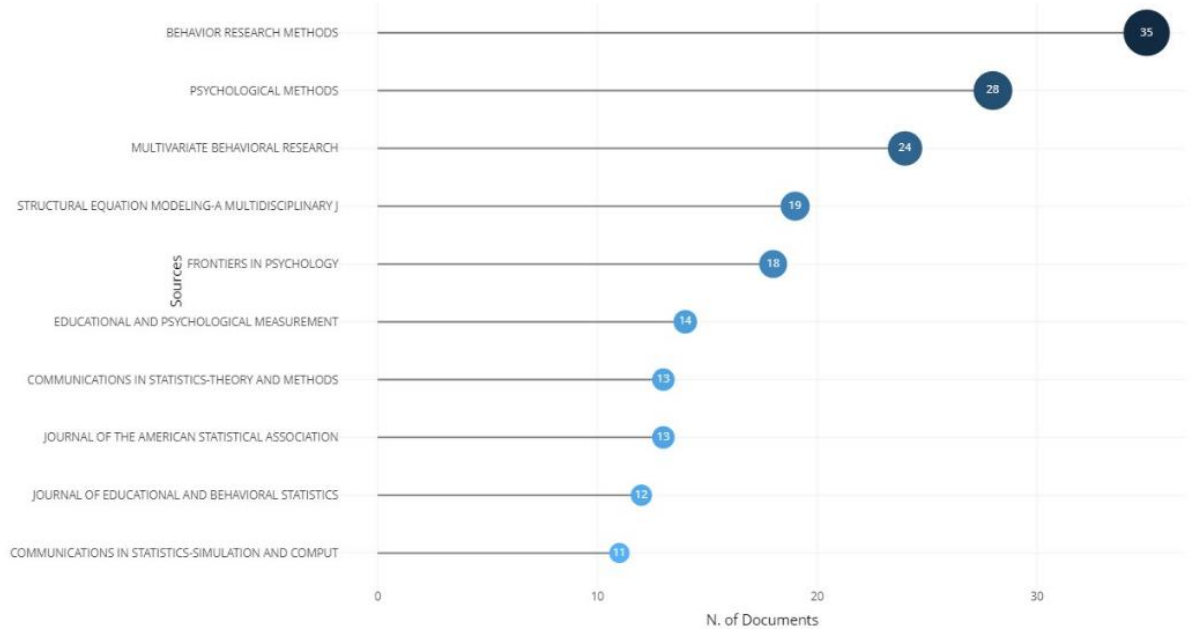
Figure 2b
Annual average citation graph



As illustrated in Figure 2a, the proportion of articles regarding power analysis started to increase from 2016 onwards. However, there were fluctuations in the rate of increase between 2006 and 2016, but there was a rapid increase after 2016. Before 2006, there were a very limited number of studies related to power analysis in education, psychology, and statistics.

The annual average citation graph illustrated in Figure 2b shows that the annual average citation count was below one before 1990. However, it increased from 118.01 in 2007 to 259.78 in 2009. In addition, the number of citations made on power analysis decreased from 2015 onward. The journals with the highest number of published articles are illustrated in Figure 3 to determine the most influential sources related to power analysis.

Figure 3
The most relevant journals



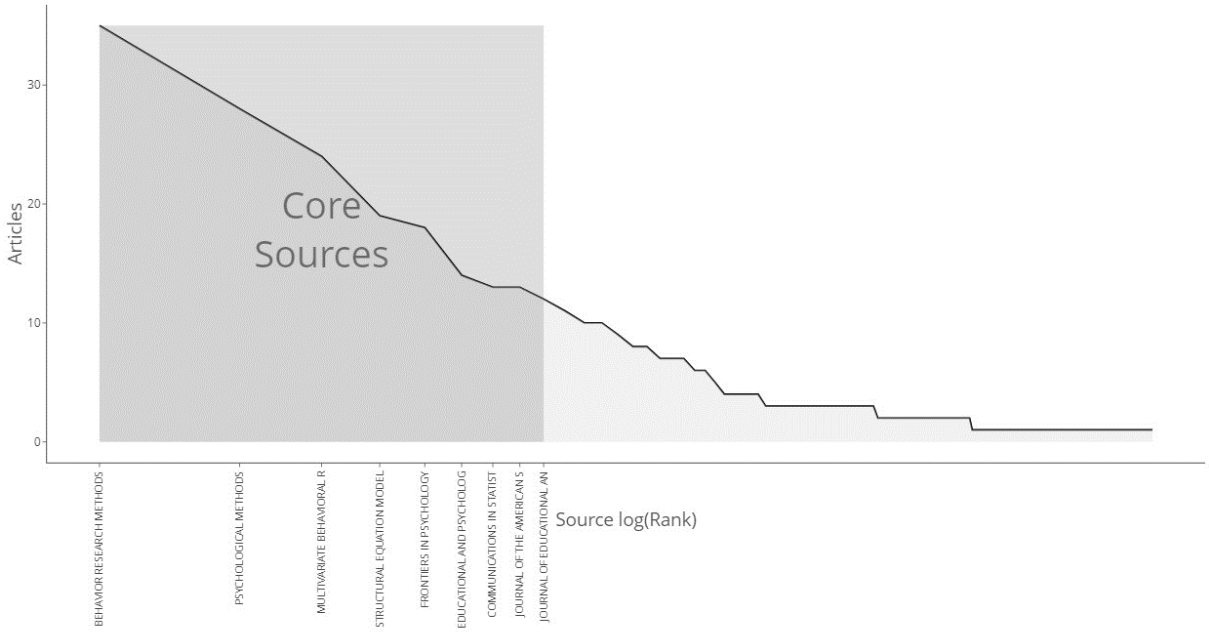
As seen in Figure 3, the journal with the highest number of articles published on power analysis was the Journal of Behavior Research Methods, with 35 published articles. Furthermore, 28 studies were published in the Journal of Psychological Methods and 24 in the Journal of Multivariate Behavioral Research. The h-indexes, total number of citations (TNC), and number of publications (NP) of the journals are shown in Table 2.

Table 2
The h-Index, TNC, and NP of Journals

Journal	h-Index	TNC	NP
Psychological Methods	20	7871	27
Behavior Research Methods	14	48812	30
Multivariate Behavioral Research	11	2766	24
Structural Equation Modeling-A Multidisciplinary Journal	10	564	19
Frontiers In Psychology	8	3457	15
Journal Of Educational And Behavioral Statistics	8	1028	11
Journal Of The American Statistical Association	8	440	12
Behavior Research Methods Instruments & Computers	7	2993	8
Educational And Psychological Measurement	6	417	10
Advances In Methods And Practices In Psychological Science	5	349	6

Table 2 presents ten journals with the highest h-indexes. Considering the results in Table 2, the journal with the highest h-index is the second in productivity ranking. Additionally, considering the total number of citations and publications, this journal holds the second position. Psychological Methods, which has the second highest number of publications and citations, ranks second according to the h-index value. The graph obtained based on Bradford's Law, showing the distribution within the journals in the literature regarding power analysis, is presented in Figure 4.

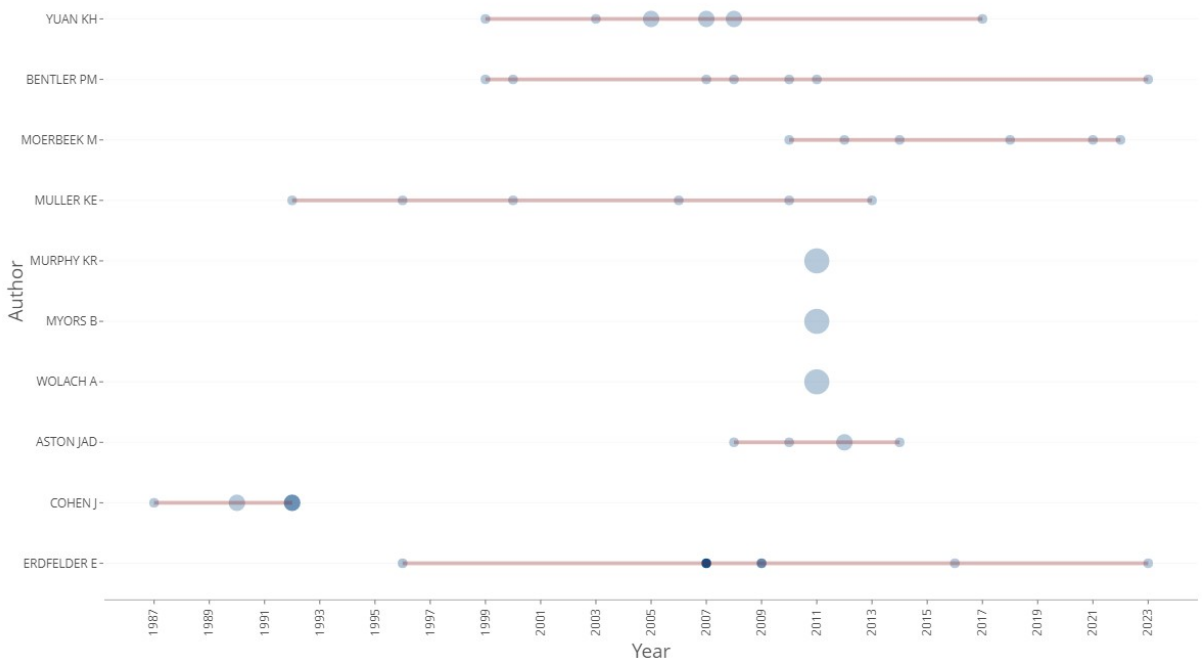
Figure 4
The Bradford law graph



The Bradford Law Graph presented in Figure 4 represents the productivity of the journals. According to this law, journals in a specific field are ranked based on the number of publications they contain. These journals are then grouped into three segments, each containing an equal number of publications. The group with the least number of journals is referred to as the core. The most productive journals are located in the core group, while in the other groups, the number of journals increases while the

publication count remains the same as the core group. In other words, productivity drops in other groups. According to Bradford's Law, the journals Behavior Research Methods, Psychological Methods, and Multivariate Behavioral Research occupy a larger proportion within the core sources compared to other journals. These journals are among the top three in terms of publication count, h-index, total citation count, and publication count rankings. These journals are followed by the journals Structural Equation Modeling-A Multidisciplinary Journal, Frontiers in Psychology, and Educational and Psychological Measurement, respectively. Findings regarding authors' publication productivity over the years are presented in Figure 5.

Figure 5
Authors' productivity over time



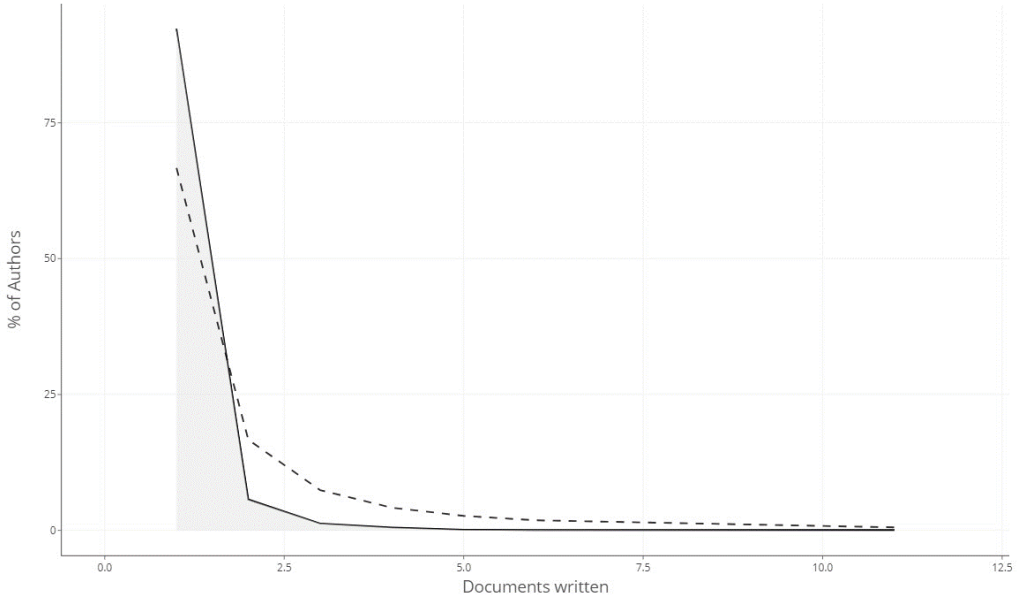
The size and darkness of the circles in Figure 5 indicate the citation strength of the publications. Figure 5 shows that the authors with the highest number of publications on power analysis were Yuan Kh, Bentler PM, and Moerbeek M. Yuan Kh, who continued conducting research on power analysis from 1999 to 2018. However, Yuan Kh., Cohen J., Murphy Kr., and Myors B. were cited more frequently than other authors.

The graph obtained according to Lotka's Law regarding authors' productivity is presented in Figure 6, and the table is provided in Table 3.

Table 3
Author Productivity

Number of written articles	Number of authors	Proportion of authors
1	1114	0.894
2	75	0.06
3	35	0.028
4	9	0.007
5	6	0.005
6	5	0.004
7	1	0.001

Figure 6
Scientific productivity according to Lotka's Law

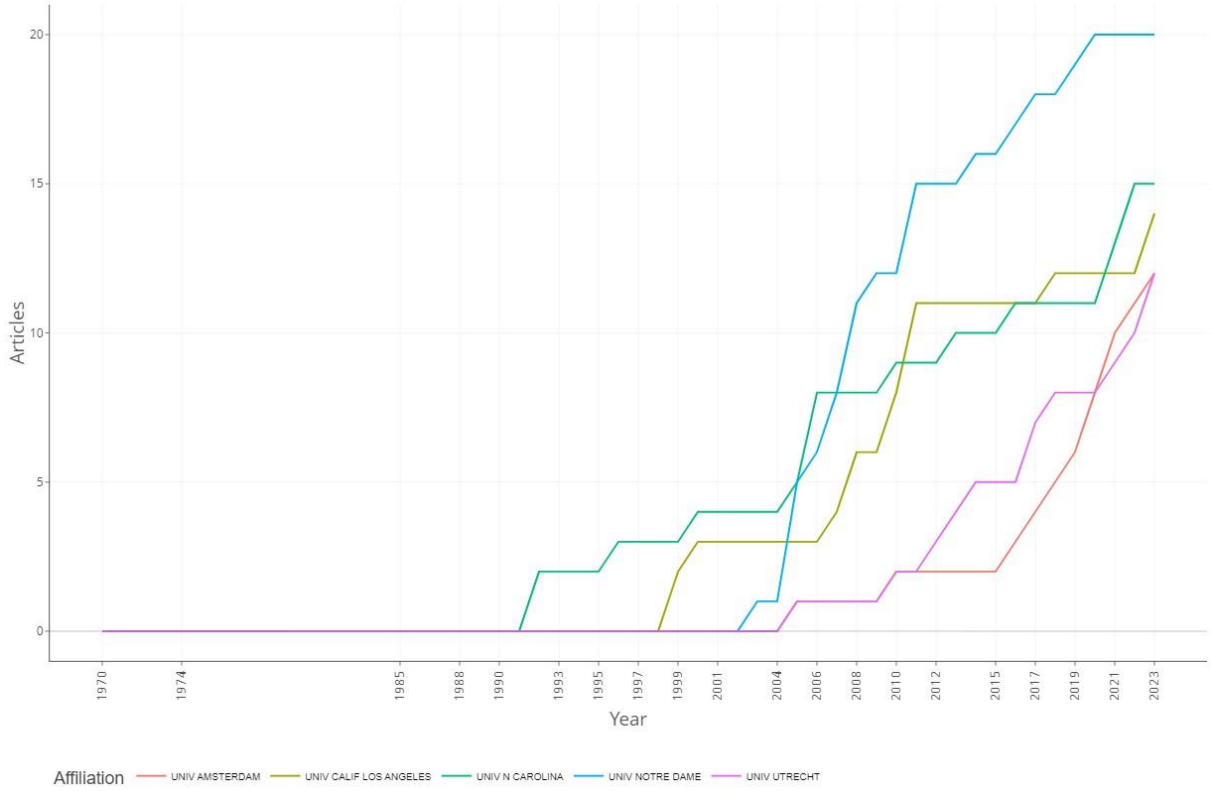


As seen in Figure 6 and Table 3, 89.4% (n = 1114) of the researchers working on power analysis have only published one study regarding this topic, while only 6% (n = 75) have published two studies. Accordingly, the majority of the authors have published only one study on power analysis. According to Lotka's Law, which quantitatively demonstrates the contribution of authors conducting studies in a specific field to the literature and is an indicator of scientific productivity, the number of authors who have made n number of contributions was approximately $1/n^2$ times the number of authors who have made a single contribution. In other words, the proportion of authors with a single contribution among all contributing authors should be a maximum of 60% (Lotka, 1926). In conclusion, it could be stated that the number of authors specializing in power analysis in education, psychology, and statistics is limited.

The changes over time in the productivity of institutions to which researchers producing studies on power analysis are affiliated are presented in Figure 7. According to Figure 7, 232 studies related to power analysis were conducted at the University of North Carolina between 1992 and 2023. After 2013, in particular, there has been an increase in the number of publications in the mentioned university. A total of 198 studies were conducted at the University of California-Los Angeles between 1999 and 2023, with an increase in the number of publications related to power analysis after 2011. Furthermore, 285 studies were conducted at the University of Notre Dame, 76 at the University of Amsterdam, and 93 at the University of Utrecht.

Figure 7

Productivity of researchers' affiliated institutions over time

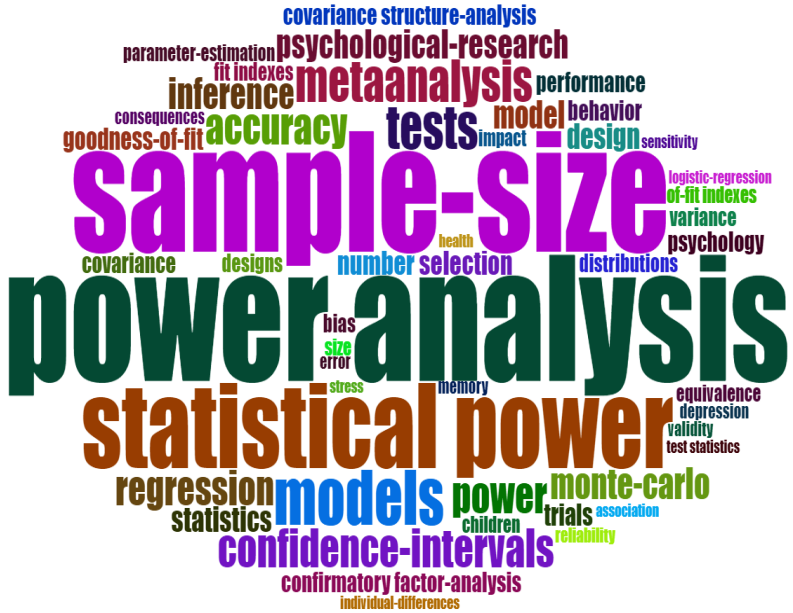


Results of Evaluative Bibliometrics

In the evaluative bibliometric analysis, common keyword analysis, co-authorship analysis, and other conceptual networks were identified to reveal trends in the field of power analysis. The findings related to them are presented below. The most frequently used keywords in publications related to power analysis are presented in Figure 8.

Figure 8

Frequency of keyword use



As illustrated in Figure 8, the keyword "power analysis", written in the largest font, was the most frequently used term. In addition, the keywords "sample size", "statistical power", "models", "tests", and "confidence intervals" were also among the frequently used keywords. Conceptual structure analyses provide valuable insights for researchers working on topics frequently studied in the field. Particularly, they are valuable for identifying trends related to the field.

Figure 9a

Network visualization of keyword formation

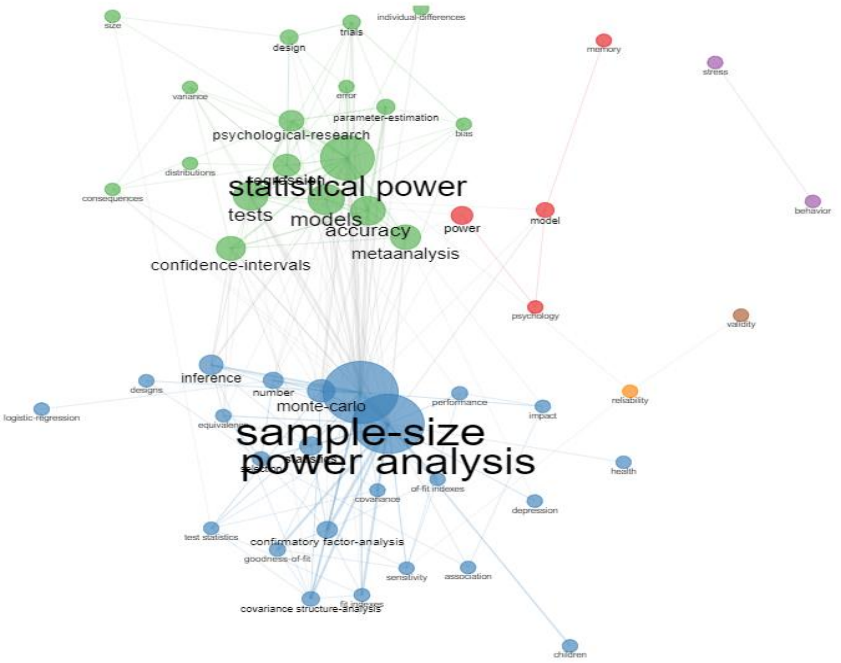
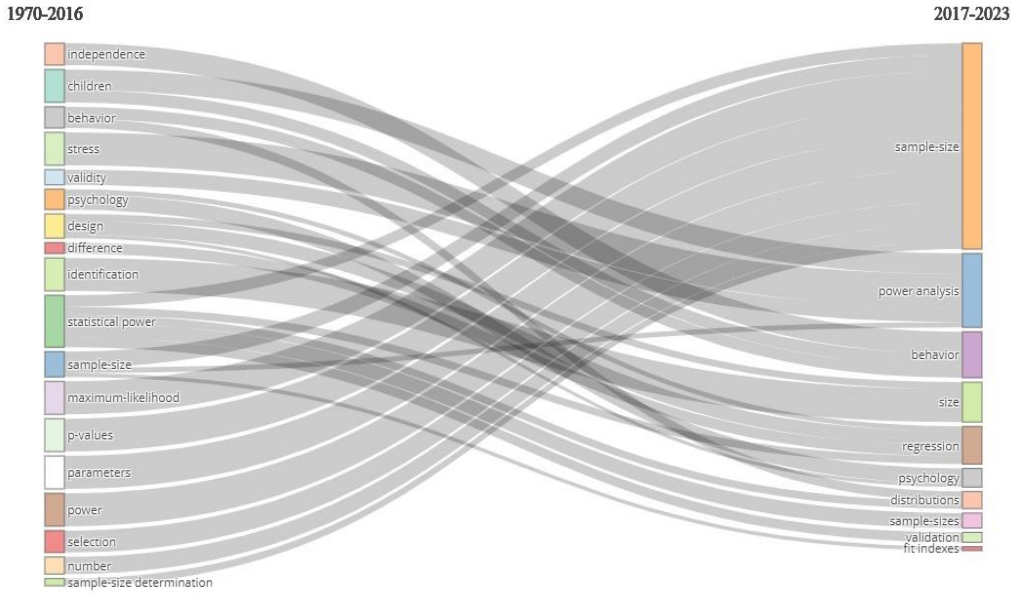


Figure 9b

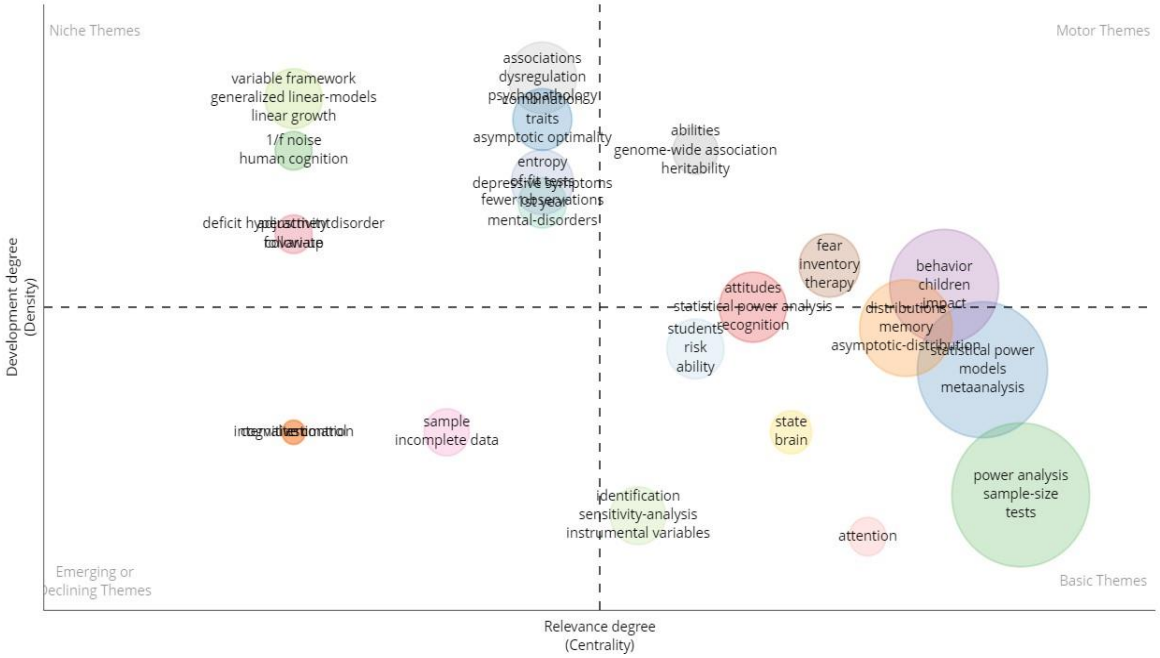
1970-2023 Thematic Evolution in Power Analysis



Conceptual images of the keywords are shown in Figure 9a and Figure 9b. As seen in Figure 9a, each circle represents a keyword, and considering the sizes of the circles, the visualization created using the Louvain Clustering Algorithm confirmed that the most commonly used keywords were “sample size”, “power analysis”, and “statistical power”. The thickening of the lines between circles indicates an increase in the intensity of the relationship between the corresponding words. Figure 9b illustrates how the most important keywords related to power analysis have transformed over time. The use of the thematic map in Figure 10 is common to examine the current state of the power analysis domain and provide insights for future research.

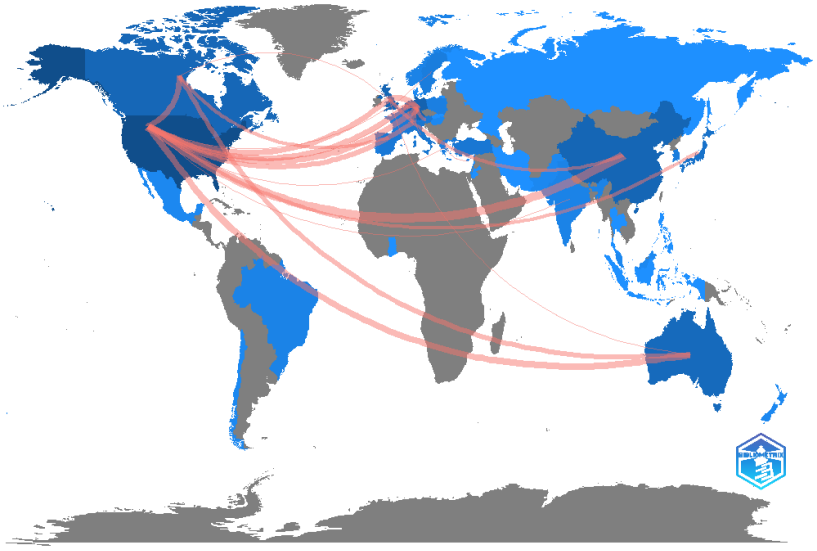
Figure 10

Thematic evolution map



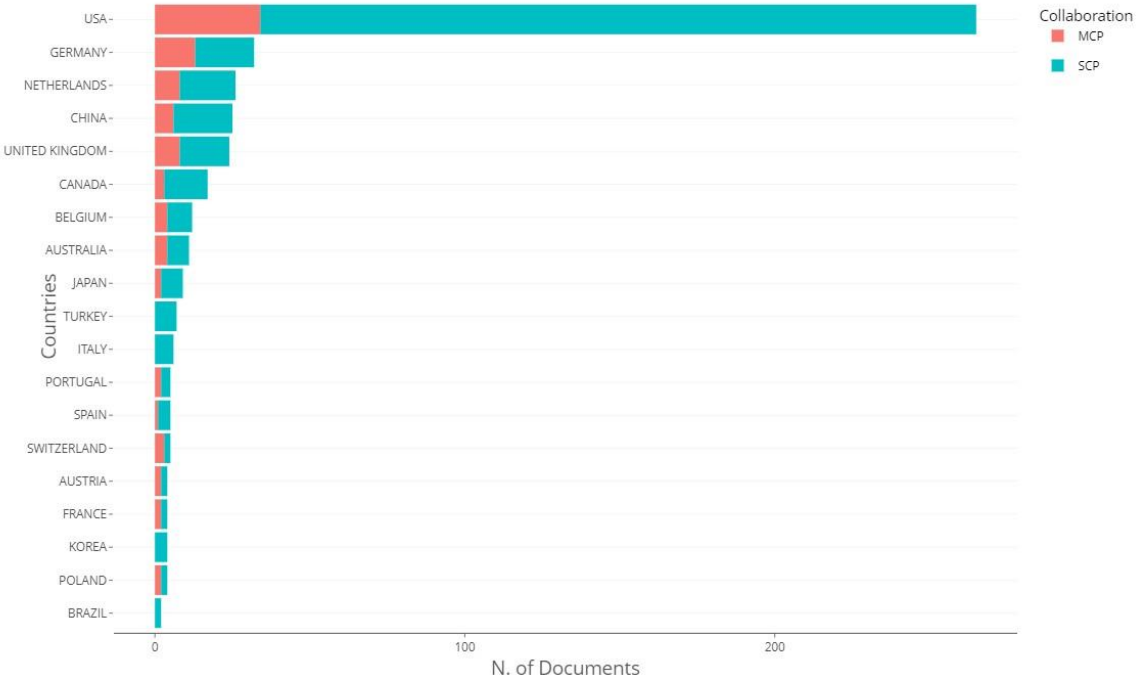
Based on the thematic evolution map depicted in Figure 10, the themes in the upper-right quadrant show significant advancement in power analysis and play a pivotal role in shaping the research area. In the upper-right quadrant, the themes represented by keywords have strong internal connections with each other. In the lower-right quadrant, there are fundamental themes for the field of power analysis. Power analysis is particularly clustered around the keywords statistical power, sample size, and distribution. The themes in this quadrant are of great importance for the research domain. In the upper-left quadrant, marginal themes can be observed. It seems that the themes in this quadrant are not significant enough to shape the research domain. Furthermore, the lower-left quadrant contains themes that are both weakly developed and marginally known. The themes in this quadrant are either in the early stages of development or in a declining trend. Figure 11 depicts a network of collaboration between countries. Figure 11 shows that there is a collaboration between the United States and many countries such as Australia, Canada, and the United Kingdom.

Figure 11
Country Collaboration Map



The number of articles by responsible authors' countries in Figure 12 distributions are included.

Figure 12
Distribution of studies related to power analysis according to countries



According to Figure 12, SCP (Single Country Publications) shows the number of publications by authors in the same country, and MCP (Multiple Country Publications) shows the number of publications made together by authors from different countries. According to both the number of publications by authors from the same country and the number of publications made by authors from different countries together, the USA ranks first, Germany ranks second, and the Netherlands ranks third.

Discussion

The data obtained from the bibliometric analysis were visualized and interpreted through graphs and tables. Both descriptive and evaluative bibliometric approaches were employed to thoroughly examine the study topic. The term "power analysis" was used as a keyword in the WOS database. This study was conducted based on 515 studies that were included considering specific criteria. The analyses were carried out using the R program through the Biblioshiny interface. It was concluded that studies published in the subject area between 1970 and 2023 were obtained from 183 sources. The total number of authors was 1246, the number of single-authored studies was 98, and the number of co-authors per study was 2.88.

An examination of the publication rates of studies on power analysis in education, psychology, and statistics over the years indicated that the proportion of articles related to power analysis began to increase from the year 2016 onward. There were fluctuations in the rate of increase between 2006 and 2016. However, there was a rapid increase after 2016. Before 2006, there were very limited studies related to power analysis in education, psychology, and statistics. One of the reasons for this could be that sample size in studies in the field of health has been considered important in terms of time, cost, and ethics for many years in research. Effect size and power analysis studies have been emphasized, and the required sample size for studies has been determined a priori before conducting the research. However, in recent years, this practice has also gained more attention in the social sciences and educational sciences. In light of all this information, it was concluded that there is a need to increase the number of studies on this subject in education and psychology.

According to Bradford's Law, Behavior Research Methods, Psychological Methods, and Multivariate Behavioral Research were the most productive journals on power analysis, occupying more space than other journals in core resources. These journals are among the top three in terms of the number of publications, h-index, total number of citations, and publication rankings. These journals were followed by Structural Equation Modeling-A Multidisciplinary Journal, Frontiers in Psychology, and Educational and Psychological Measurement journals, respectively. It is particularly important for new researchers who will work on power analysis in education, psychology, and statistics to follow these journals. Yuan Kh., Butler P. M., Moerbeek M., Muller K. E., Murphy Kr., Myors B., and Cohen J. are among the leading authors considering the number of articles they have published regarding power analysis. It is also believed that the works of relevant authors would be important for researchers who are interested in following the literature on the same subject.

The most frequently used keyword was "power analysis", indicating that this keyword has been commonly employed in the literature. Also, the terms "sample size", "statistical power", "models", "tests", and "confidence intervals" were the most frequently used keywords. Conceptual structure analyses provide valuable insights to researchers regarding frequently studied topics in the field. They are particularly valuable for observing trends in the field. The frequent use of keywords such as "sample size" and "confidence intervals" in many studies is likely because the primary purpose of power analysis is to determine the sample size.

This study was conducted using only the WOS database. Bibliometric studies conducted with studies from different databases could be compared with this study. Findings obtained through different programs such as VOSviewer, CiteSpace, and other bibliometric analysis tools that were not used in this study could be compared with the findings of this study.

A great majority of authors have published only once on power analysis, indicating that the number of authors specializing in the field remains limited. According to Lotka's Law, for a field to be considered developed, the number of authors who have published in that field should not exceed 60% of the total number of authors. According to Lotka's Law, those who have published two works should be ¼ of those who have published one work, and those who have published three works should be 1/9 of those who have published one work (Lotka, 1926). When one examines studies related to power analysis in

education, psychology, and statistics according to Lotka's Law, it could be concluded that the relevant literature is insufficient and needs further development.

Declarations

Conflict of Interest: No potential conflict of interest was reported by the author.

Ethical Approval: Secondary data were used in this study. Therefore, ethical approval is not required.

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