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# Global Research Trends and Future Directions in Selenium's Role in Child Development: A Bibliometric Analysis

## Selenyumun Çocuk Gelişimindeki Rolüne İlişkin Küresel Araştırma Trendleri ve Gelecekteki Yönlendirmeler: Bibliyometrik Analiz

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**ABSTRACT**

**Aim:** Selenium is an essential trace element for the human body, which significantly affects the growth and development of children. This study aimed to investigate the effects of selenium on child development, analyze emerging concepts, and predict future trends.
**Material and Methods:** Using comprehensive search strategies in the Scopus and Web of Science Core Collection databases, 155 articles in English were identified. Publications, citations, prominent authors, collaboration networks, and influential journals were analyzed using the tools Biblioshiny and Bibliometrics R.
**Results:** A steady growth trajectory was shown, with publications and research findings over the past 51 years demonstrating an increasing awareness of the positive effects of selenium on child development and growth. The United States and China were identified as the leading contributors. Peking University, Charité - Universitätsmedizin Berlin, and Humboldt University were the leading institutions, with Skalny A. and Chen J. identified as the most prolific authors. Biological Trace Element Research has emerged as the leading journal for disseminating knowledge in this field. In addition, keyword analysis revealed the importance of terms such as "selenium," "human," and "child." Overall, this comprehensive study, the product of a global collaboration on selenium and its relationship to child growth, provides an in-depth study of selenium.
**Conclusion:** The results of this analysis highlight future research priorities and the need for continued research in this area, advocating for expanded interdisciplinary studies to further explore the mechanisms and broader effects of selenium on child development and health.
**Keywords:** Bibliometrics; selenium; child development; growth; children.

**ÖZ**

**Amaç:** Selenyum, çocukların büyümesi ve gelişimini önemli ölçüde etkileyen, insan vücudu için gerekli temel bir eser elementtir. Bu çalışmanın amacı, selenyumun çocuk gelişimi üzerindeki etkisini incelemek, ortaya çıkan kavramları analiz etmek ve gelecekteki eğilimleri öngörmektir.
**Gereç ve Yöntemler:** Scopus Web of Science Core Collection veri tabanlarında kapsamlı arama stratejileri kullanılarak 155 İngilizce makale belirlenmiştir. Yayınlar, atıflar, önde gelen yazarlar, iş birliği ağları ve etkili dergiler, Biblioshiny ve Bibliometrics R araçları kullanılarak analiz edilmiştir.
**Bulgular:** Son 51 yılda yapılan yayınlar ve araştırma bulguları, selenyumun çocuk gelişimi ve büyümesi üzerindeki olumlu etkilerine ilişkin farkındalığın arttığını göstererek istikrarlı bir büyüme eğilimi göstermektedir. Amerika Birleşik Devletleri ve Çin, başlıca katkı sağlayan ülkeler olarak öne çıkmıştır. Pekin Üniversitesi, Charité - Universitätsmedizin Berlin ve Humboldt Üniversitesi önde gelen kurumlar olurken, Skalny A. ve Chen J. en üretken yazarlar olarak belirlenmiştir. Biological Trace Element Research dergisi, bu alandaki bilginin yaygınlaştırılmasında önde gelen dergi olarak ortaya çıkmıştır. Ayrıca, anahtar kelime analizi "selenium", "insan" ve "çocuk" gibi terimlerin önemini ortaya koymuştur. Genel olarak, selenyum ve çocuk büyümesiyle ilişkisi üzerine küresel bir iş birliğinin ürünü olan bu kapsamlı çalışma, selenyum hakkında derinlemesine bir çalışma sunmaktadır.
**Sonuç:** Bu analizin sonuçları, gelecekteki araştırma önceliklerini ve bu alanda devam eden araştırmalara duyulan ihtiyacı vurgulayarak selenyumun çocuk gelişimi ve sağlığı üzerindeki mekanizmalarını ve daha geniş etkilerini daha fazla incelemek için disiplinler arası araştırmaların genişletilmesini savunmaktadır.
**Anahtar kelimeler:** Bibliyometri; selenyum; çocuk gelişimi; büyüme; çocuklar.

## INTRODUCTION

Selenium is an essential trace element involved in the cell cycle and immune function, modulating growth and development, and is a component of selenoproteins in the antioxidant defense system, thereby limiting oxidative damage (1). The production of reactive oxygen species is regulated by selenoproteins and, in turn, plays a key role in protein folding, lipid biosynthesis, and calcium regulation (2).

The impact of selenium on the growth and development of a child is evident already in the prenatal period. During pregnancy, the need for this micronutrient increases significantly due to its role in the formation of fetal organs and systems (3). Selenium deficiency is associated with growth retardation, metabolic disorders, and cognitive impairment in children (4). A recent review highlights the importance of selenium and selenoproteins in antioxidant defense, thyroid hormone synthesis, immune response regulation, and bone metabolism, making them essential for normal physical and neurocognitive development. Compelling evidence suggests that selenium deficiency can lead to decreased immune function and cognitive impairment, while maintaining adequate levels of the element promotes optimal health and development in children. These findings highlight the need for monitoring and timely correction of selenium status in pregnant women and children as a public health measure (5).

Selenium deficiency remains a significant global problem: low levels of this micronutrient have been reported in China, Eastern Europe, and Central Asia (6-8). In recent years, there has been an increase in the number of both original and review papers devoted to the effects of selenium on children's health. In parallel, bibliometric studies are appearing that analyze global research on selenium, including its role in the pathogenesis of thyroid disease and its content in drinking water (9,10).

Optimal physical and cognitive development of children is a public health priority. According to recent data, 10-16% of children worldwide experience developmental delays, and approximately 200 million children from socially disadvantaged families do not achieve their cognitive potential due to a combination of poverty and chronic growth retardation (11-13). These facts highlight the need for a detailed study of the role of essential micronutrients, including selenium, in shaping children's health.

Despite the obvious importance of selenium, existing data on its effects on growth and development remain limited and fragmented. Therefore, the aim of this study was a comprehensive bibliometric analysis of publications devoted to the effects of selenium on child growth and development, to identify key scientific trends, leading research groups, and promising areas for future work. This allows not only to quantify the volume of existing research but also to trace the evolution of key concepts and thematic clusters, forming a holistic view of the global scientific landscape in this field.

## MATERIAL AND METHODS

### Eligibility Criteria and Data Source

This bibliometric analysis included original and review articles published in English investigating the effect of selenium on child development and growth. Data were collected from the Scopus and Web of Science databases, and all relevant metadata were extracted in both BibTeX and text formats. The collected data were compiled into an Excel file in RStudio.

### Search Strategy

An extensive search using advanced search options in the Scopus and Web of Science databases was conducted. A combination of Boolean and Wildcard search operators was used to select relevant keywords (Tables 1 and 2).

The search was conducted in March 2024, and the full search strategy is detailed in Figure 1. In the selection of articles, articles without relevance determined by their titles, abstracts, and full text content were systematically excluded. Based on the obtained results, 131 research, and 24 review articles were imported for bibliometric analysis.

### Inclusion and Exclusion Criteria

To ensure maximum relevance and quality of the retrieved articles, along with the inclusion criteria of articles in English that focused on the beneficial effects of selenium on child development and growth, the following exclusion criteria were applied:

Articles not available in full text: Abstracts or abstracts with incomplete or missing text were excluded to ensure the completeness of the analysis.

Duplicate articles: Duplicate articles from the same or different databases were excluded to avoid duplication of data, as each unique article was considered only once in the analysis.

Conference abstracts without full peer review: This criterion ensured that only articles that had undergone rigorous peer review were included in the analysis.

Articles in other languages: To ensure consistency of language in the analysis, articles written in languages other than English were excluded and screened to facilitate data extraction and analysis.

### Bibliometric Analyses

Data management and bibliometric analysis were performed with RStudio (RStudio 2023.09.1+494, PBC, Boston, MA) bibliometric package (version 4.1.3), using the Biblioshiny web applications. Specifically, the bibliometric analysis covered a period of 51 years for research articles and 45 years for review articles, focusing

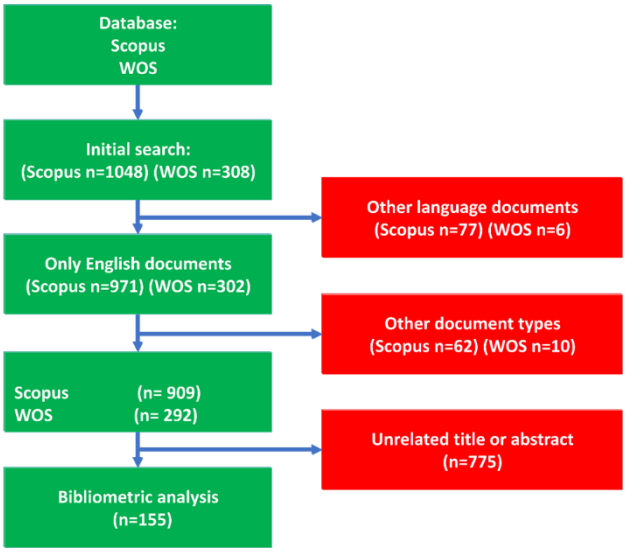



**Figure 1.** Flowchart for selecting articles

**Table 1.** Search strategy in the Scopus database

| Query |
|---|
| (TITLE-ABS-KEY (“Selenium”) AND TITLE-ABS-KEY (“Child” OR “Children” OR “Preschool Child” OR “Children, Preschool” OR “Preschool Children” OR “Child Preschool” OR “Adolescents” OR “Adolescence” OR “Teens” OR “Teenagers” OR “Teen” OR “Teenagers” OR “Teenager” OR “Youth” OR “Youths” OR “Adolescents”) AND TITLE-ABS-KEY (growth and development” OR “Development” OR “Growth” OR “Development and Growth” OR “Development, Adolescent” OR **“**Adolescent Development**”** OR “Child Development”) AND (LIMIT-TO (LANGUAGE, "English"))) |

**Table 2.** Search strategy in the Web of Science database

| No | Queries |
|---|---|
| #1 | “Selenium” (Title) or “Selenium” (Author Keywords) or “Selenium” (Abstract) |
| #2 | “Child” or “Children” or “Preschool Child” or “Children, Preschool” or “Preschool Children” or “Child Preschool” or “Adolescents” or “Adolescence” or “Teens” or “Teenagers” or “Teen” OR “Teenagers” or “Teenager” or “Youth” or “Youths” or “Adolescents (Title) or Child” or “Children” or “Adolescents” or “Adolescence” or “Teens” or “Teenagers” or “Teen” OR “Teenagers” or “Teenager” or “Youth” or “Youths” or “Adolescents (Author Keywords) or Child” or “Children” or “Adolescents” or “Adolescence” or “Teens” or “Teenagers” or “Teen” OR “Teenagers” or “Teenager” or “Youth” or “Youths” or “Adolescents” (Abstract) |
| #3 | “Growth and development” or “Development” or “Growth “Development and Growth” or “Development, Adolescent” or **“**Adolescent Development**”** or “Child Development” (Title) growth and development” OR “Development” or “Growth “Development and Growth” or “Development, Adolescent” or **“**Adolescent Development**”** or “Child Development” (Author Keywords) growth and development” or “Development” or “Growth “Development and Growth” or “Development, Adolescent” or **“**Adolescent Development**”** or “Child Development” (Abstract) |
| #4 | #1 and #2 and #3 |

on publication and citation rates, and citation trends, respectively. Prolific institutions were identified based on the number of articles related to the impact of selenium on child development within this timeframe.

Authors with significant contributions were identified based on the frequency of their published articles. The follow-up evaluation included the identification of the 10 most frequently cited papers and leading journals.

This study examined the interactions over the past nine years of 10 leading journals, research fields, and countries that contributed to research on selenium and child development. Connections were visualized on a world map, and global research collaboration was demonstrated. A TreeMap visualization of the 20 most frequently used keywords in articles published on this topic. At the same time, the "Thematic Map" divided the topics into four areas: core subjects, specialized subjects, emerging or declining subjects, and common core subjects.

## RESULTS

### Search Results

A total of 1048 and 308 papers were initially retrieved from the Scopus and Web of Science databases, respectively. After applying eligibility criteria and excluding 930 ineligible studies, a total of 155 papers were considered for this bibliometric analysis (Figure 1).

### Key Attributes of the Encompassed Studies

In total, 155 articles (131 research and 24 review) were identified and analyzed. The average citation rate of these articles was 20.58 for research articles, while the review articles averaged 43.62 citations per document. Table 3 presents the 10 most cited documents in research and review articles. 131 research articles involving the collaboration of 767 authors, sourced from 83 documents, were included. In addition, a total of 2788 references and 384 authors' keywords were identified for research articles. Review articles, on the other hand, encompassed 670 references and 137 authors' keywords.

### Trend of Publication and Citation

Over the 51 years from 1973 to 2024, the number of published scientific articles on the effects of selenium on the development and growth of children has significantly increased. The lowest number of studies was published between 1974 and 1982, with only seven studies during this period. The highest number of publications was recorded in 2022, reaching 16 (Figure 2A). When examining the trend of average annual citations, there was a notable rise in the average total citations per article in 2009, reaching 5.9 (Figure 2B). From 1979 to 2024, there was a rise in the quantity of published review articles examining the impacts of selenium on child development and growth. The years between 1979 and 2005 had the lowest scientific publication rate. Conversely, 2020 was the most productive year in terms of publications, with a total of three articles (Figure 2C). Analyzing the trends in average annual citations during the same timeframe, it is evident that the total number of citations reached its peak in 2014 at 13.3 and has declined since then (Figure 2D).

Further analysis of the co-citation patterns of the most cited articles in Table 3 revealed several intellectual clusters. One focuses on fundamental biological mechanisms (e.g., selenoproteins and antioxidant activity), another on clinical and epidemiological aspects (growth, development, and neurobehavioral outcomes in children), and a third brings together studies on maternal nutrition and pregnancy. These relationships demonstrate that the most cited papers do not exist in isolation but rather form complementary research streams that, taken together, define the modern paradigm for studying selenium in the context of child health.

**Table 3.** Ranking of the top 10 highly cited research and review articles

| | Ranking | Authors | Year | Journal | Total Citations |
|---|---|---|---|---|---|
| **Research Articles** | 1 | Adu-Afarwuah et al. (14) | 2007 | Am J Clin Nutr | 263 |
| | 2 | Wu et al. (15) | 2015 | J Clin Endocrinol Metab | 168 |
| | 3 | Zuo et al. (16) | 2006 | Biol Trace Elem Res | 140 |
| | 4 | Chin et al. (17) | 1992 | Am J Clin Nutr | 114 |
| | 5 | Di Cosmo et al. (18) | 2009 | J Clin Endocrinol Metab | 94 |
| | 6 | Kavanaugh-McHugh et al. (19) | 1991 | JPEN J Parenter Enteral Nutr | 74 |
| | 7 | Hu et al. (20) | 2015 | J Reprod Med | 68 |
| | 8 | Reeves et al. (21) | 1989 | JPEN J Parenter Enteral Nutr | 68 |
| | 9 | Ellis et al. (22) | 2008 | BMJ | 65 |
| | 10 | Lopez-Sobaler et al. (23) | 2017 | Nutrients | 57 |
| **Review Articles** | 1 | Ahamed and Siddiqui (24) | 2007 | Clin Nutr | 206 |
| | 2 | Golden MH. (25) | 2009 | Food Nutr Bull | 159 |
| | 3 | European Food Safety Authority (26) | 2014 | EFSA Journal | 146 |
| | 4 | Oh et al. (27) | 2020 | Nutrients | 110 |
| | 5 | Bedwall et al. (28) | 1993 | Med Hypotheses | 75 |
| | 6 | Korhle J. (29) | 2020 | Curr Opin Endocrinol Diabetes Obes | 56 |
| | 7 | Lewicka et al. (30) | 2017 | Ginekol Pol | 51 |
| | 8 | Yakoob and Lo (31) | 2017 | J Dev Behav Pediatr | 38 |
| | 9 | Neve J. (32) | 1992 | Biol Trace Elem Res | 36 |
| | 10 | Wong T. (33) | 2012 | Curr Opin Clin Nutr Metab Care | 34 |

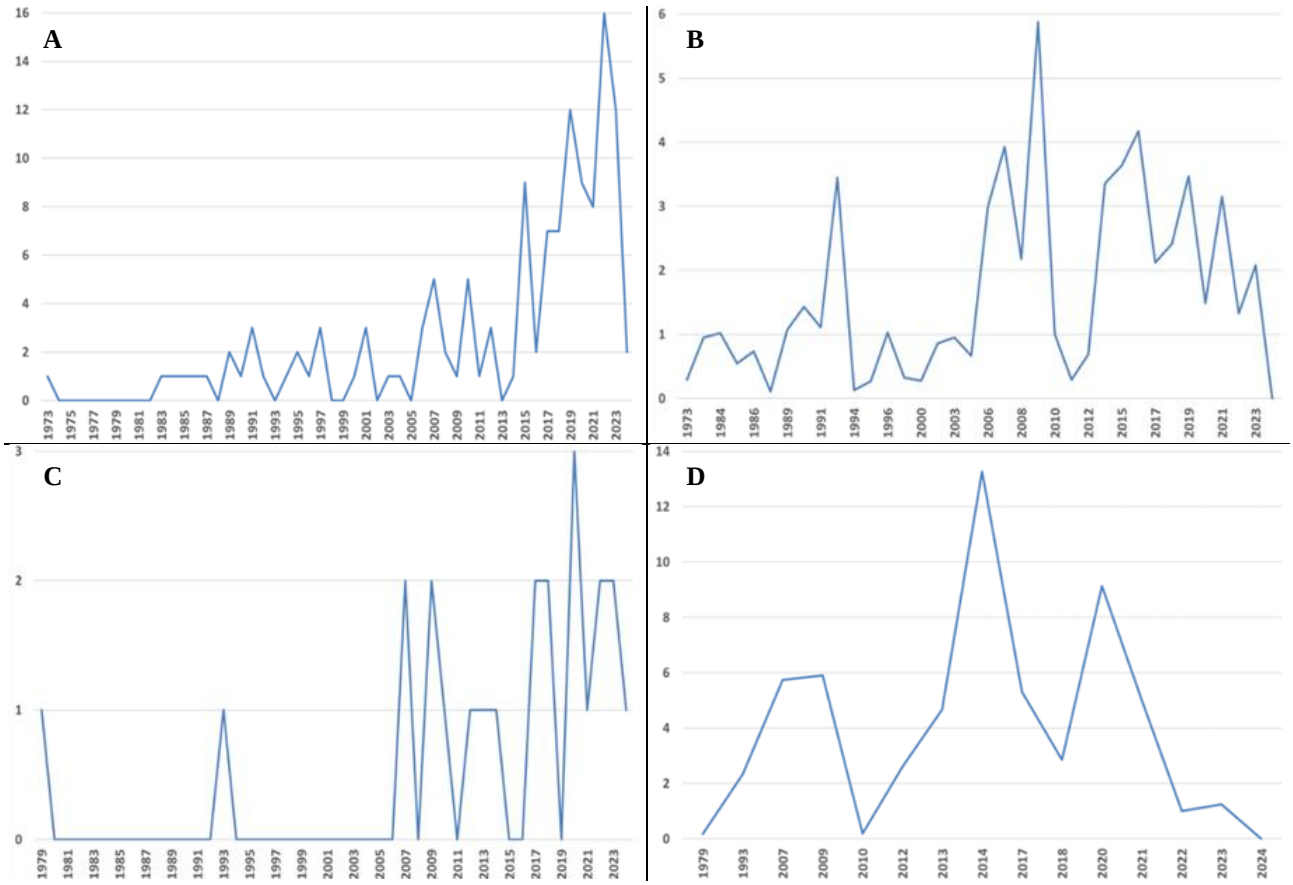



**Figure 2.** Annual trends in number of **A)** research articles and **B)** citations, as well as **C)** review articles and **D)** citations

**Mapping Research Trends: Co-occurrence Network Mapping and Cluster Analysis**

The term selenium occupies a central position on the map, underscoring its interconnections with other trace elements and health-related topics in publications (Figure 3A). Red nodes capture a broad spectrum of studies addressing selenium's role across demographic groups, particularly terms linked to human health such as "human", "trace element", "male", "female", "infant", and "body mass". Green nodes emphasize maternal and perinatal aspects with keywords such as "pregnancy", "birth weight", and "heavy metals", while the purple cluster highlights child-focused terms like "children" and "adolescent", reflecting the scientific interest in selenium's developmental effects.

Figure 3B further illustrates the dense relationships among selenium, human, and child, revealing that these three terms form a tightly connected core of the network. Their proximity indicates that studies on selenium are largely framed within human health contexts, with a notable concentration on pediatric outcomes. For example, the purple nodes associated with "child" and "selenium" include "preschool child", "adolescent", and "dietary supplement", pointing to investigations of selenium's influence across different childhood stages and nutritional interventions. The green cluster reinforces the link to reproductive health and early development through terms like "pregnancy", "newborn", and "trace elements". Meanwhile, the red nodes relate to mechanisms such as "pathogenesis" and "malnutrition", and the blue cluster captures conditions tied to selenium deficiency and antioxidant defense, including "antioxidant" and "oxidative stress".

These interconnections demonstrate that research on selenium is not only centered on the element itself but also intricately integrates human and child health outcomes, highlighting its cross-cutting role in both maternal and pediatric contexts.

**Most Relevant Affiliation**

Peking University, Charité - Universitätsmedizin Berlin, and Humboldt University are notable institutions that have contributed significantly to the study of the effects of selenium on child development and growth. Peking University has established a strong reputation as a leading educational institution in China, thanks to its extensive research and active participation in international academic publications. Its impact on global medical science is evident through its significant achievements in medical research and healthcare. In addition, the Charité - Universitätsmedizin Berlin, one of the largest university hospitals in Europe, and the prestigious Humboldt University of Berlin are known for their influential research in various disciplines and their constant commitment to high-quality education. When examining the review articles on the topic of selenium effects on child development and growth, the University of Adelaide, University of Milan and Nanjing Maternity and Child Health Hospital, Sichuan University, and University of Cape Town also emerged as leading institutions in their respective fields and are significant global research contributors. The University of Adelaide is constantly conducting ground-breaking research for its innovative achievements. Similarly, the University of Milan, Italy's leading academic institution, has contributed significantly to influential research in a number of academic fields.

**Most Contributing Authors and Their Collaboration Network**

In analyzing the effects of selenium on child development, Skalny A. was found as one of the most influential authors of review articles among those with the largest number of publications and highest reputation, while a significant number of articles (n=2 each) were written by Chen J., Fulkoni V., and Papanikolaou I. These results demonstrate the contributions of these authors to the literature on selenium and child development.

**Most Productive Journals**

Of the original research articles, 12 were published in the Journal of Biological Trace Element Research, followed by 10 articles in the Journal of Trace Elements in Medicine and Biology and 7 articles in the Journal of Nutrients. In the category of review articles, 3 were published in the Journal of Nutrients. These journals are the main platforms for disseminating findings regarding the role of selenium in child development and growth.

**World Research Production and Collaborations**

Figure 4 shows 50 prominent international collaborations in this area of research, illustrating significant scientific findings related to the effects of selenium on child development. Notably, the United States ranks among the top ten contributors with 13 major international research collaborations. Frequent collaborations are seen between the

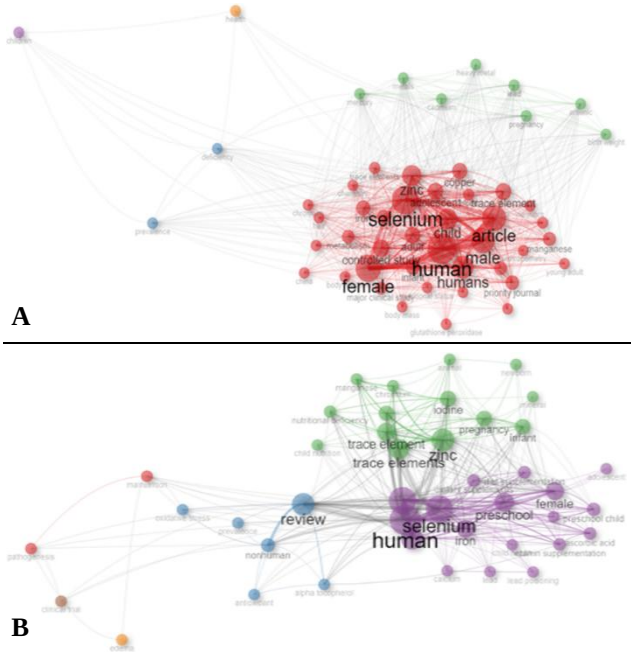



**Figure 3.** Network mapping of co-occurrence of the keywords plus of the **A)** research articles, and **B)** review articles related to the effect of selenium on child development and growth, published from 1973 to 2024

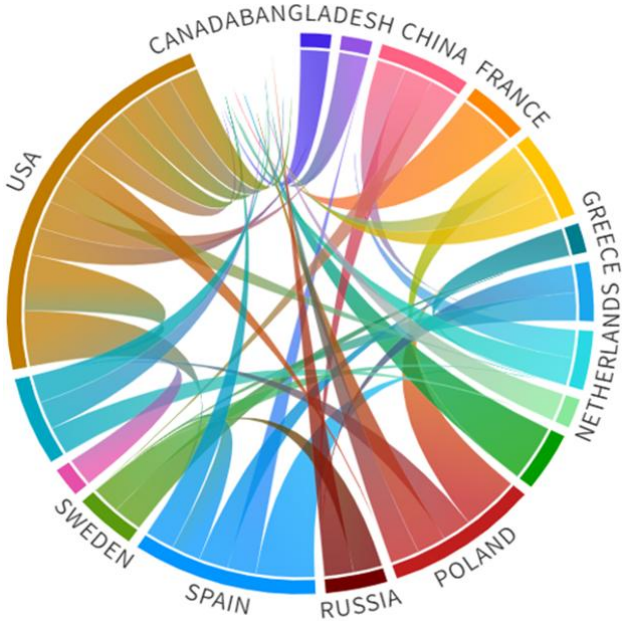



**Figure 4.** A visual representation of collaborative networks of countries releasing scientific articles on the field

United States and Spain, the United States and the United Kingdom, Spain and the Netherlands, Poland and Germany, Norway and the Congo, France and Morocco, with 2 copies per pair. The analysis also shows that the United States is the leading contributor among the top 10 countries (n=13), followed by Spain (n=8) and the Netherlands (n=7). According to bibliometric data, collaboration on review articles is limited, which was due to the small number of review publications.

Figures 5A and 5B provide a broader overview of the global distribution of scientific output in this field. Figure 5A shows the top ten countries with the highest number of publications, with the United States, China, and Japan leading the way. It also shows the dominance of the United States with more than 500 publications, followed by China and Japan with about 400 and 250 publications, respectively. European countries such as Germany, the United Kingdom, and Spain also contributed significantly, albeit to a lesser extent. Figure 5B draws attention to a diverse group of countries, highlighting the contributions of countries such as India, Ireland, and Canada. Of these, India had a significant impact with over 200 publications. On various bibliometric indicators, Germany and the United States again stand out, highlighting their systematic research efforts. Furthermore, the data shows a broad global interest in the field, with active participation from both developed and developing countries.

**A Tag Clouds Analysis**

This visualization helps to identify not only the main research directions but also the emphases of scientific discourse. Among them, the most frequently occurring terms are selenium, child, woman, micronutrient, pregnancy, infant, preschooler, and adolescent, which reflect the attention of researchers in different fields to the role of selenium at different stages of child development and in the context of maternal health. In particular, the scientific community repeatedly emphasizes the importance of adequate selenium levels during pregnancy and breastfeeding as a key factor for optimal growth and development of the child, as well as the importance of maternal selenium levels during pregnancy and breastfeeding. The special role of selenium in the relationship between maternal selenium intake during pregnancy and the child's birth weight is also emphasized. Thus, the tag cloud reflects a shift in research focus from the general role of micronutrients in maintaining maternal and child health to the specific contribution of selenium to maintaining maternal and child health, as well as the optimal range of its intake.

Figure 6A presents a tag cloud constructed based on keyword frequency analysis. This visualization not only highlights the main research areas but also reflects the thematic structure of the field. The most frequently occurring terms, selenium, human, child, female, male, infant, zinc, iron, adolescent, man, and woman, form several overlapping clusters. On the one hand, they indicate interest in micronutrients and their metabolic interactions (e.g., with zinc and iron), and on the other, attention to different age groups (from infants to adolescents) and gender differences. Thus, the tag cloud summarizes the key research areas and demonstrates the comprehensive nature of the study of selenium's role in child health and development. Figure 6B presents a tag cloud constructed based on term frequency analysis. Here, the emphasis shifts to the clinical and nutritional context. The most frequently discussed topics include selenium, child, woman, trace element, pregnancy, infant, preschooler, and adolescent. This keyword configuration highlights the importance of selenium during critical developmental periods, from the prenatal period and pregnancy to infancy and preschool age. Thus, research focuses on how adequate or insufficient selenium intake impacts child growth and health, as well as maternal trace element status as a key developmental factor.

**A Three-Fields Analysis**

To illustrate the contributions of the top ten journals, authors, and keywords to researches on the effects of selenium on the child development and growth, a graphical

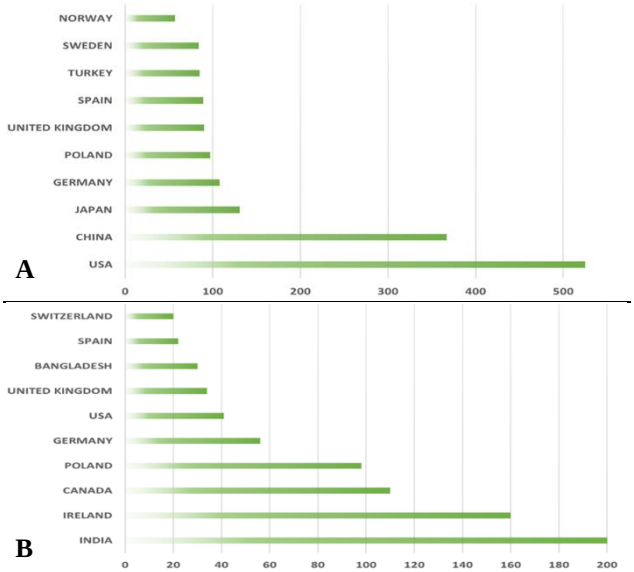



**Figure 5.** Top 10 countries with the most cited **A)** research and **B)** review articles on selenium in child development




**Figure 6.** Visualization of main research topics through tag clouds of **A)** research articles and **B)** review articles on the effects of selenium on child development and growth

representation of the interaction of these domains were created. This figure shows the input and output interactions of these respective domains in Figures 7A and 7B.

**Tree Map and Thematic Map**

A tree map visualization displaying the 20 most frequently used keywords in research articles (Figure 8A) and review articles (Figure 8B) on the effects of selenium on child growth and development indicated that selenium and child are the most frequently used words. Another aspect of the analysis is the creation of a strategic thematic map based on the author's keywords, which are recurring terms related to the effects of selenium on child growth and development (Figures 9A and 9B). This analysis will inform future researchers about future directions and methodological approaches in this field. The thematic map is structured along two axes: the x-axis (centrality), which indicates the relevance and interconnectedness of research topics, and the y-axis (density), which indicates the level of development and coherence within a given topic. Based on these characteristics, it is possible to determine whether a topic is highly developed and central, specialized but isolated, emerging and declining, or fundamental but undeveloped. The thematic map is divided into four quadrants. The upper left quadrant (Q2, highly specialized but isolated topics) contains well-developed but poorly integrated topics. The research areas in the upper right quadrant (Q1, emerging topics) are well-developed and broadly interconnected with other topics, forming the core of the field. The lower right quadrant (Q4, core but underdeveloped topics) contains key concepts that form the basis of the research area but require further research. The lower left quadrant (Q3, emerging or declining topics) contains research areas that are gaining popularity or losing relevance. The size of each circle in the thematic map represents the frequency of occurrence of the term. Figure 9A shows that the Q1 quadrant, which represents the motor topics, contains well-developed and central topics such as "nutritional status", "anthropometry", "human", "selenium", "female", and "pregnancy". These studies show that the role of selenium is not only covered at the biochemical level, but also has direct links to clinical and public health aspects such as nutritional status, body composition (anthropometry), and women's health during pregnancy. In Q2, keywords such as "disease", "glutathione peroxidase activity", "neurodevelopment", and "serum selenium" are not yet sufficiently developed, contributing less to the overall progress of the field. In principle, they can be considered as potential growth points for future research, as they include research areas on the role of selenium in the pathogenesis of diseases and its influence on antioxidant enzyme activity and nervous system development, as well as on the marker value of serum selenium. Between Q3 and Q4, the terms "children", "zinc deficiency", and "association" indicate that they are not yet fully developed, but are potential and developing topics for future research, i.e., they focus on the analysis of the relationship between selenium and zinc deficiency, especially in the pediatric population. Q4 contains fundamental but underdeveloped topics such as "selenoprotein P area", "deficiency", "growth", and "risk", which are important for the advancement of the field. This study focuses on the molecular role of selenoproteins, the effects of selenium deficiency on growth and development, and the health risk




**Figure 7.** Three-fields graph showing the relationships and interactions between top ten journals, authors, and keywords that published **A)** research and **B)** review articles on the effects of selenium on child development and growth

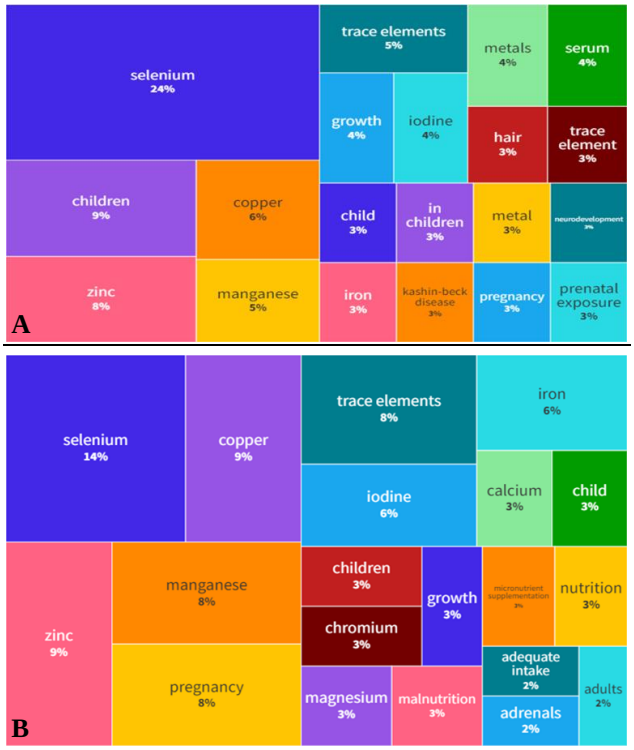



**Figure 8.** Tree map visualization depicting the top 20 keywords in **A)** research and **B)** review articles focused on the effects of selenium on child development and growth

factors, and provides an important scientific foundation for deepening the fundamental knowledge in this field. The keywords "infant", "heavy metals", and "biomarkers" in Q3 have relatively low density and centrality, and represent a peripheral topic that is covering the potential of the research field. The density ranking of research articles is Q4>Q2>Q1=Q3, indicating that the Q4 is the highest in terms of internal structure. In terms of centrality, the result

is Q2>Q4>Q3=Q1, indicating that Q2 plays a key integrative role in the research field. While Q1 and Q3 are at a low level. The topic map in Figure 9B divides the research topics into four quadrants. Q1 contains influential and well-studied topics such as "child", "selenium", "zinc", "pathogenesis", "lactation", and "supplementation". Between Q2 and Q1, there are researched keywords such as "selenoprotein P", "prenatal exposure", and in Q3, there are unexplored and centralized keywords such as "selenium deficiency". Between Q3 and Q4, there is "metabolism", and in Q4, there is "edema". In Q1, keywords such as "child", "selenium", "zinc", "pathogenesis", "lactation", and "supplementation" are well-developed central topics in the field, leading the field of research on child health and maternal factors related to selenium and zinc. The terms "selenoprotein P" and "prenatal exposure" located at the intersection of Q1 and Q2 indicate the importance of the direction of research on molecular-level mechanisms and antenatal effects. "selenium deficiency" in Q3 is associated with low density. The rank order for review articles is similar to the research articles, with density ranked as Q2>Q4>Q1=Q3, and centrality ranked as Q4>Q2>Q1=Q3, also reflecting a descending order from high to low.

**Analysis of Global Scientific Publication Distribution**

Figure 10A illustrates the global distribution of scientific publications by country, with varying shades on a world map representing the level of research activity. Countries with the highest number of publications, such as China and the USA, are depicted in dark, while those with fewer publications appear in lighter shades. Figure 10B, similarly, displays the geographic distribution of scientific publications by country, using shades to indicate activity levels. The most active countries, including the USA and several nations in Europe and Asia, are highlighted in dark, reflecting a higher volume of publications, whereas lighter shades represent countries with lower publication counts.

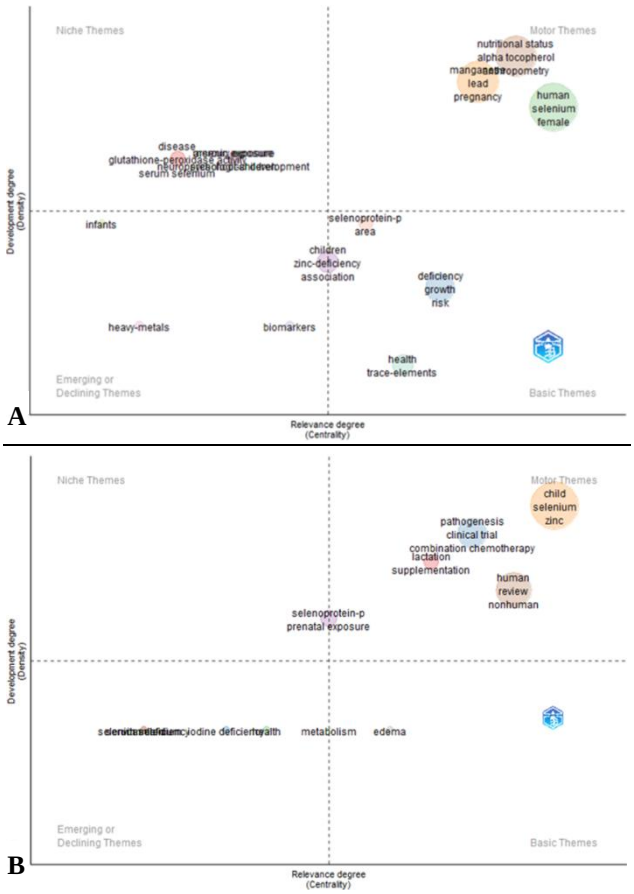



**Figure 9.** Topic map based on commonly used keywords in the **A)** research and **B)** review articles, illustrating the recurring terms and their thematic significance in the context of the selenium on child development and growth

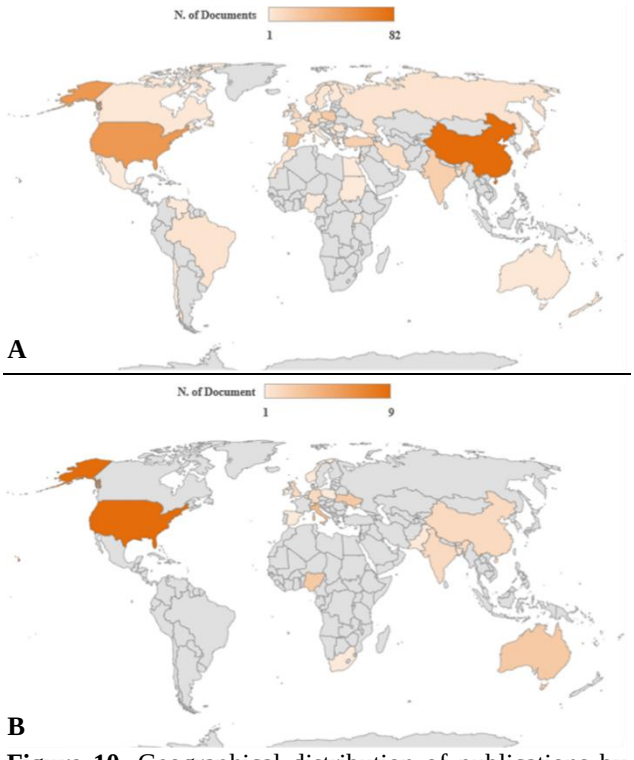



**Figure 10.** Geographical distribution of publications by country in **A)** research and **B)** review articles related to the effects of selenium on child development and growth

## DISCUSSION

Bibliometric analysis and scientific mapping are rapidly developing, and the various results obtained by these methods have increased the interest of the scientific community (34). In particular, bibliometric analysis evaluates the impact of different research areas, researchers, studies and review articles. This approach allows to visually identify important papers, recognize their impact, and deepen the understanding of the broader intellectual context of specific research areas.

This bibliometric study is based on an analysis of scientific publications devoted to selenium and its effects on child growth and development. This analysis not only reflected the dynamics of publication activity but also revealed the conceptual and intellectual structure of this field. The number of papers increased steadily from 1973 to 2024, paralleling the expansion of collaborative networks between researchers and institutions. Particularly notable contributions were made by leading institutions such as Peking University, Charité University Hospital Berlin, and Humboldt University, highlighting the growing dynamism of academic exchange and competition.

Moving from the scientific landscape to the substantive research findings, it is noteworthy that cluster analysis of joint meetings and citations highlighted key areas, including

clinical research, informed consent, medical education, and health policy. These clusters reflect both theoretical and applied aspects of bioethical and medical debates, forming the basis for further study of the role of selenium. The combined epidemiological evidence presented in the reviewed studies convincingly supports the critical importance of adequate selenium intake during pregnancy. Large prospective studies have shown that increased selenium intake in the first half of pregnancy is associated with increased birth weight Z-scores and a 9% reduction in the risk of having a low-for-gestational-age infant. These effects persisted after accounting for potential confounders, highlighting the independent role of selenium in maintaining optimal intrauterine development (35).

Environmental and socioeconomic conditions are important factors in this regard. For example, studies in regions of China with low selenium soil levels have shown that remoteness of settlements, limited local food choices, and low family income significantly contribute to deficiency in pregnant women and children (36). Similar findings have been confirmed in high-income countries: the ENFAMS study in 2018 by Fabelova et al. (37), using hair selenium concentration as a long-term biomarker, found a positive association between selenium levels and weight-for-age and height-for-age Z-scores in children under six years of age. This demonstrated that even in affluent regions, deficiency can occur among socially vulnerable groups, affecting children's height and weight.

Equally significant is the evidence on the impact of selenium on neurodevelopment. A large Danish cohort study found that each 10 μg/L increase in maternal serum selenium concentration was associated with a 24% reduction in the risk of ADHD symptoms in children and was inversely associated with the risk of ASD symptoms (38). Additionally, analysis of red blood cell selenium levels showed cognitive benefits: each 0.50 μg/g increase was associated with a 3.7-point increase in language comprehension score and, in girls, with a 12-point improvement in psychomotor development (39).

The beneficial effects of selenium also extend to physical growth parameters: a significant positive correlation was found between serum selenium levels and birth weight, as well as between urinary selenium levels and birth weight. These results are consistent with previously published data on a reduced risk of intrauterine growth restriction, improved placental blood flow, and a reduced incidence of preeclampsia (40). The antioxidant properties of selenium and involvement of selenium-dependent enzymes (glutathione peroxidase and thioredoxin reductase) reduce oxidative stress in the placenta, which likely explains the observed beneficial effects. Thus, ensuring adequate selenium levels in pregnant women is a key component in the prevention of neurodevelopmental disorders, particularly ADHD and ASD, and promotes the normal growth and development of the child. These results highlight the need to incorporate selenium monitoring and supplementation into national nutrition programs and maternal and child health strategies, particularly in regions with low selenium soils. Despite encouraging data linking adequate selenium levels with cognitive development and a reduced risk of ADHD and ASD, significant gaps remain in the understanding of the mechanisms of action. Long-term cohort studies and randomized clinical trials are needed to confirm causal relationships and determine optimal doses for the prevention of neurodevelopmental disorders.

This study presents a comprehensive bibliometric analysis of 50 years of publications mainly related to selenium and child development. As the first study of its kind, this research focuses on providing insights into the trends, geographic distributions, and prolific contributors shaping the field. In particular, the United States has emerged as a major producer of publications on selenium and child development research, highlighting its important role in advancing knowledge in this area. In addition, analyses show the remarkable presence of China, with the majority of the ten most productive institutions originating from this nation. China's dominance in scientific work related to selenium and child development is further highlighted by its leading position in scientific articles showing its growing prominence. The leading positions of the United States and China in studying the role of selenium in child growth and development are explained not only by high scientific interest but also by structural prerequisites: the availability of government funding for biomedical projects, a developed research infrastructure, and the existence of large-scale public health programs aimed at preventing micronutrient deficiencies (41). Comparison of the data with global maps of selenium content in soils shows that regions with documented deficiency (e.g., individual countries in Central Asia, Africa, and Eastern Europe) have significantly fewer publications (42). This also indicates that, despite the high medical significance of the problem in these regions, limited financial and laboratory resources, as well as insufficient epidemiological infrastructure, hinder scientific activity. Thus, the identified patterns indicate that the scientific leadership of individual countries is determined not only by the relevance of the topic but also by socioeconomic and infrastructural conditions. To address regional imbalances in research, expanded international collaboration and support for local programs to monitor and prevent selenium deficiency are needed.

This study is the first to evaluate the effects of selenium on children's growth and development using bibliometric methods. In this bibliometric analysis, the focus is not on the content itself, but rather on the metadata of the articles, including authorship, affiliations, and country of origin. By utilizing empirical data from original articles, efficiency, collaboration, and impact were assessed. A content analysis of the text was not conducted. It is important to note that only full-text articles in English were analyzed, and publications with only English abstracts were excluded. Additionally, some articles from journals published in national languages may not have been included in the analysis. The results of the bibliometric analysis underscore the significance of selenium in the context of children's health and highlight the need for further research to better understand its impact on various aspects of growth and development.

This bibliometric analysis systematically examines the research and review landscape over an extended period and across interdisciplinary data, enabling us to identify long-term trends and key intersections between various scientific fields related to selenium and its recent diverse impacts on child development worldwide. A comprehensive and consistent study was conducted, effectively presenting

and interpreting metadata using a widely recognized and valuable software platform. However, it is important to acknowledge certain limitations of this bibliometric analysis. Only articles from the Scopus and Web of Science databases, and only English-language publications, were included, which may have introduced a bias against publications in other databases. Additionally, it should be noted that the database contains a limited number of studies and reviews related to the keywords "selenium" and "child growth and development." Given these limitations, this bibliometric analysis paves the way for future research and collaboration in this important area of research, contributing to a deeper understanding of the role of selenium in child development, and will help to identify directions for future research.

## CONCLUSION

Global collaboration in the study of selenium and its connection to child growth underscores the link between selenium-related diseases and the potential for preventing certain conditions. The increasing number of publications and citations in recent decades highlights the significance of selenium on child health as a critical area of research. This bibliometric analysis provides both qualitative and quantitative insights into the leading countries, authors, institutions, scientific journals, and patterns of global collaboration in research with a focus on selenium and its impact on child growth and development. Collaborative international studies, conducted by prominent authors and institutions, have played a crucial role in advancing the understanding of selenium's multifaceted effects. These findings emphasize the importance of continuing research in this area and call for expanded interdisciplinary studies to further explore the mechanisms and broader impacts of selenium on child development and health.

**Ethics Committee Approval:** Since our study was not an experimental study including human or animal subject, ethics committee approval was not required.

**Conflict of Interest:** None declared by the authors.

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