The impact of Zika virus on children's development: a review using bibliometric analysis

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Abstract
The aim of this bibliometric review was to explore and discuss the scope and limitations of the literature addressing the consequences of Zika Virus infection and the damages caused to child development. The intention was to comprehensively demonstrate the collaboration network among countries and institutions and track emerging trends. A systematic literature review was performed using the Web of Science database from 2016 to June 2022. The VOSviewer tool was used for bibliometric analysis to examine the co-authorship, co-occurrence of keywords, and co-citation of journals, authors, and references in the literature. We obtained data from 161 studies published in 44 categories, with paediatrics and clinical neurology as the main categories. Three main research trends on the topic were identified, one highlights congenital Zika syndrome and the relationship between cerebral palsy and epilepsy. The other trends address the relationship between infection in pregnancy, geographic location, and the characteristics of the neurodevelopment of children affected by the disease. Our study provides a comprehensive overview of the current state of Zika virus research, as it relates more specifically to effects on child development. The information obtained in this study sheds light on the patterns of global collaboration and affinity of research institutions, especially in Brazil, which concentrates on the largest number of publications.
Keywords: congenital syndrome; microcephaly; neurodevelopment.

Zika vírus e o impacto no desenvolvimento infantil: uma revisão baseada em análise bibliométrica

Resumo
O objetivo dessa revisão bibliométrica foi explorar e discutir a amplitude e as restrições da literatura que aborda as consequências da infecção pelo Zika Vírus e os danos ocasionados ao desenvolvimento infantil. O intuito foi demonstrar de forma abrangente a rede de colaboração entre países e instituições e rastrear tendências emergentes. Uma revisão sistemática da literatura foi realizada usando o banco de dados Web of Science de 2016 a junho de 2022. A ferramenta VOSviewer foi usada para análise bibliométrica para examinar a coautoria, concorrência de palavras-chave e cocitação de periódicos, autores e referências na literatura. Obtivemos dados de 161 estudos publicados em 44 categorias diferentes, com pediatria e neurologia clínica como as principais categorias. Foram identificadas três principais tendências de pesquisa sobre o tema, uma das quais destaca a síndrome congênita do zika e a relação entre paralisia cerebral e epilepsia. As outras tendências abordam a relação entre infecção na gravidez, localização geográfica e características no neurodesenvolvimento de crianças acometidas pela infecção. Nosso estudo fornece uma visão abrangente do estado atual da pesquisa do vírus Zika, no que se refere mais especificamente aos efeitos no desenvolvimento infantil. As informações obtidas neste estudo lançam luz sobre os padrões globais de colaboração e afinidade das instituições de pesquisa, especialmente no Brasil, que concentra o maior número de publicações.
Palavras-chave: *síndrome congênita; microcefalia; neurodesenvolvimento.*

1. Introduction

The Zika Virus was first isolated in 1947 on the Entebbe Peninsula, Uganda; in the first 60 years, it was confirmed in the equatorial zone in Africa and Asia, later spreading to Yap Island in 2007, and reaching Latin America in 2015 (SONG *et al.,* 2017; PETERSEN *et al*., 2016). Zika virus infection occurs mainly by Aedes aegypti and Aedes albopictus mosquitoes, but there are reports of peri-natal and sexual transmission (SUN *et al.,* 2021).

An outbreak of Zika virus infections in Brazil attracted the attention of the world population due to the hypothesis that the infection is related to damage to pregnancy and an increase in the number of newborns with microcephaly. According to studies, the connection between cases of microcephaly and neonatal neurological disorders with congenital ZIKV infection is already well understood, not only in Brazil, but in other countries and regions, such as Colombia, French Polynesia, Panama, and Martinique (CARDOSO *et al.,* 2015). However, it is important to emphasize the need to know the main clinical evidence about the consequences generated in the development of children affected by the Zika virus to contribute to feeding a database of information with important references for the diagnosis and follow-up of children with congenital Zika virus syndrome. One way to analyze the scientific findings on problems related to the Zika Virus in children is through bibliometric analysis.

Bibliometric analysis is a statistical tool that has been widely used to provide qualitative and quantitative data on publications considered to be of high impact and that integrate specific subjects (WANG; MANIRUZZAMAN, 2022). In this way, bibliometric research constructed from research databases can clarify and disseminate, in any field of science, the patterns and trends of world scientific literature (MÖRSCHBÄCHER; GRANADA, 2022). Therefore, bibliometric analysis is an effective methodology to accumulate additional evidence about the Zika Virus and its impacts on child development, serving as a support for future studies, given that no study has presented a bibliometric analysis focused on the consequences and delays in the development of children infected by the Zika Virus.

Therefore, the purpose of this review was to examine the literature regarding the implications of Zika Virus infection and its impact on child development. The goal was to present the latest research approaches and trends in this field, aiming to comprehensively illustrate the collaborative network among countries and prominent institutions. Additionally, this review aims to offer a convenient and adaptable method for identifying and monitoring emerging trends, thereby aiding in the formulation of public health policies and furthering research in areas with significant knowledge gaps and advances in clinical practices.

2. Methods

In the Methods section, the methodological approach used to conduct the study and data collection was described. This section provides essential details for the replication of the research conducted.

2.1. Data source

The selection and refinement of data is a critical part of bibliometric research (ARORA; CHAKRABORTY, 2021). To choose the database, the terms Zika and child development were used as topics for a search in the Web of Science, Scopus, PubMed, and Virtual Health Library (BVS) databases. The number of publications in each database was considered when choosing the data source. Figure 1 shows that the Web of Science database has the largest collection of publications on the Zika virus and child development from the first records in January 2016 to the date of the consultation in June 2022. Furthermore, when analyzing the documents found in the different databases, it was observed that only the Web of Science collection included all or most of the documents published in international journals when compared to the other databases. Thus, it was considered that only the documents collected from the Web of Science were sufficient to understand the current situation of scientific research on the Zika virus and child development.

Figure 1 – Evolution in the number of publications on the Zika virus indexed in different databases. Results of the search for documents on Zika and child development in the BVS, PubMed, Scopus, and Web of Science databases
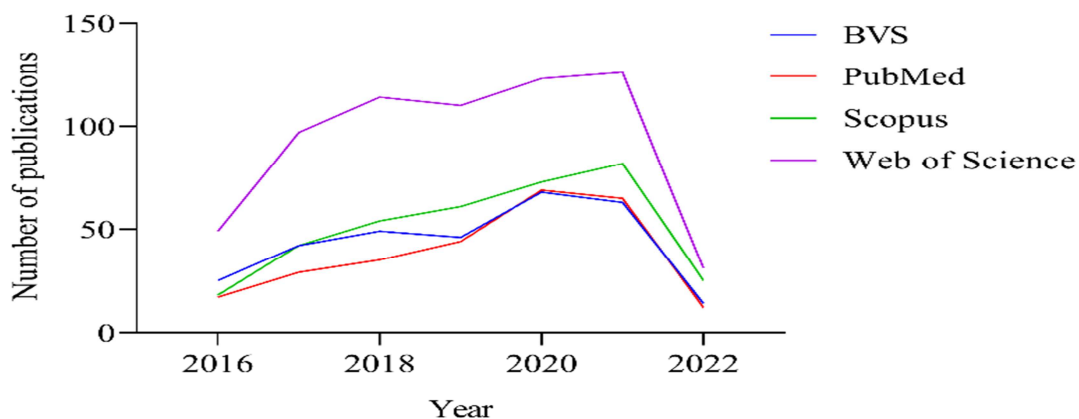
The Web of Science has been used as a database in several review studies and bibliographic analyses because it is one of the largest collections of scientific data (HUMBOLDT-DACHROEDEN; RUBIN; SYLVESTER FRID-NIELSEN, 2020; WANG *et al.,* 2022; ZHAO, 2022). This international multidisciplinary source collects scientific publications of great impact on the scientific world and is an essential database for bibliometric studies that provide indicators of scientific production (RUIZ-FRESNEDA *et al.,* 2022). Therefore, Web of Science was chosen for this study, where information on all authors and their affiliations, abstracts, keywords, cited references, and names of institutions were collected from each publication, which allowed an in-depth exploration of scientific knowledge about the Zika virus and the development of children.

2.2. Eligibility criteria and selection of studies

To search the Web of Science database, the terms "Zika" and "child development" were entered into the search field, and 650 publications were found. The terms Zika and child development were defined according to two factors: i) the increase in recent cases of Zika virus infection; ii) a previous search for Zika virus that highlighted the main terms present in the relevant scientific studies.

No filters were added to the search, and all the results were evaluated considering as an exclusion criterion study that did not address the effect of contact with the Zika virus on child development. To evaluate the studies, the titles, keywords, and abstracts of the publications indexed in the database from the Web of Science were evaluated. The verification of publications aims to reduce contamination to accurately reflect the literature on the topic under discussion. This screening procedure led to the elimination of 489 publications. Data were exported to EndNote (myendnoteweb.com) to check for duplicate references. No duplicate references were found. The final sample consisted of 161 publications registered between January 2016 and June 2022 regarding the effects of the Zika virus on child development.

2.3. Bibliometric analysis and the VOSviewer tool

Bibliometrics initially applied to the area of Information Sciences, consists of analyses based on extraction techniques, classification, and evaluation of knowledge banks that allow the elaboration of structural images and diverse syntheses of investigative domains (WANG *et al.,* 2022). Through qualitative and quantitative analysis of publications, bibliometric analysis can use characteristics of literature metrology to estimate contributions from a given field, discover boundaries, and predict emerging trends for a specific topic (QIN *et al.,* 2022). Since the grouping of publications is a significant problem in bibliometric studies (HUANG *et al.,* 2022), VOSviewer was selected as the main tool for the visual analysis of the selected literature. VOSviewer creates bibliometric maps based on network data, plotting the network structure across a cluster of similar data (HELHA; WANG, 2022). To collect related information between authors, keywords, journals, and institutions from the

data collected from the Web of Science database, the VOSviewer[1] v.1.v.6.v.17 tool was used in the analysis of co-authorship, co-occurrence of keywords, and co-citation.

2.4. Co-citation analysis

Co-citation analysis makes it possible to visualize the structure of the knowledge base and map the interrelationship of research in the field of study, considering the most cited documents (FOROUDI *et al*., 2021). Co-citation analysis is commonly used in bibliometric studies to identify the frequency of co-citation of any two authors; the higher frequency, the closer their academic relationship (ZHAO, 2022). In this study, we used the co-citation analysis of journals, authors, and references in the literature on the Zika virus and child development. For the analysis of the most cited journals and authors, the complete counting method was used, establishing as a criterion the minimum number of 20 citations per author. Thus, out of 2913 authors found, 39 were included in the analysis. In the analysis of co-citation of references, as an analysis criterion, the minimum number of 13 citations per reference was established; therefore, of the 3522 cited references, 51 were included in the analysis. The construction of the co-citation network was due to the strength of the association. The maximum number of 1000 lines was set to display the 1000 most consistent links between nodes.

2.5. Co-author analysis

Co-authorship analysis examines interactions between scholars in an area of research, as co-authorship is a formal form of intellectual collaboration between scholars, and therefore it is important to understand the relationships of authors to each other while also evaluating attributes associated with authors, such as affiliated institutions and countries (DONTHU *et al.,* 2021). For co-authorship analysis, the authors' affiliation was evaluated, and how the network of collaborations between affiliations, countries, and regions of researchers who study the children development who were infected by the Zika virus was formed. As a criterion, documents with more than 25 affiliations per document were excluded from the analysis. A minimum number of 5 documents per affiliation has been defined. Applying the criteria for analysis, of the 374 organizations mentioned as affiliations of the authors, 23 were selected. The construction of the collaboration network was due to the strength of the association. The maximum number of 1000 lines was set to display the 1000 most consistent links between nodes.

2.6. Co-occurrence analysis

A co-occurrence analysis is an analysis method that detects the co-occurrence of diverse information in articles (ZHAO, 2022). The construction of keyword co-occurrence maps allows researchers to interpret topics in high future trends within the search domain, using the number of citations that each keyword (FOROUDI *et al.,* 2021). Unlike citation analysis, keyword co-occurrence analysis is a technique that examines the actual content of the publication itself, whose words used in the analysis are derived from "author's keywords" and, in their absence, can also be extracted from "article titles", "abstract", and "full text" (DONTHU *et al.,* 2021).

A co-occurrence analysis of keywords was performed using the author's keywords. The complete counting method was used, and the criterion established for analysis was the minimum number of 5 occurrences per keyword. Therefore, from the 538 keywords identified, 29 were selected. A keyword patch file was uploaded to merge synonyms. The construction of the co-occurrence network was due to the strength of the association. The maximum number of 1000 lines was set to display the 1000 most consistent links between nodes.

3. Results

In this section, the main quantitative and qualitative data collected from the literature were presented, such as publication trends, citation patterns, collaboration networks, and critical research points related to the topic of interest. In this section, the evaluation of the results was discussed,

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[1] VOSviewer. Available at: https://www.vosviewer.com

shedding light on the existing body of knowledge and contributing to a better understanding of the evolution and direction of the field.

3.1. Web of Science publication records

A total of 161 documents were retrieved, covering the period between 2016 and 2022. These documents are composed of 131 original articles (81.37%), 22 review articles (13.66%), 3 meeting abstracts (1.86%), 2 early access articles (1.24%), 2 conference articles (1.24%) and 1 letter (0.62%). The dataset collected from the Web of Science featured publications in 44 different categories. Most publications are in the Pediatrics category (31.88%), followed by Clinical Neurology (15.63%), Public Environmental Occupational Health (11.25%), Infectious Diseases (10.63%), General Internal Medicine (7.50%), Tropical Medicine (7.50%), Oral Surgery Medicine of Dentistry (6.88%), Developmental Biology (5.00%), Immunology (5.00%) and Parasitology (5.00%).

Figure 2 displays the association between the number of publications and citations in the Web of Science database, specifically focusing on the relationship between the Zika virus and child development outcomes during the period from 2016 to 2020. This timeframe exhibited an annual growth rate in publications. However, from 2021 to June 2022, there was a decline in the number of publications, possibly attributed to the heightened emphasis on the Covid-19 pandemic.

Figure 2 – Production data and citation of Zika virus documents. Number of documents retrieved from the Web of Science database and the relationship with the number of citations in the period between 2016 and June 2022
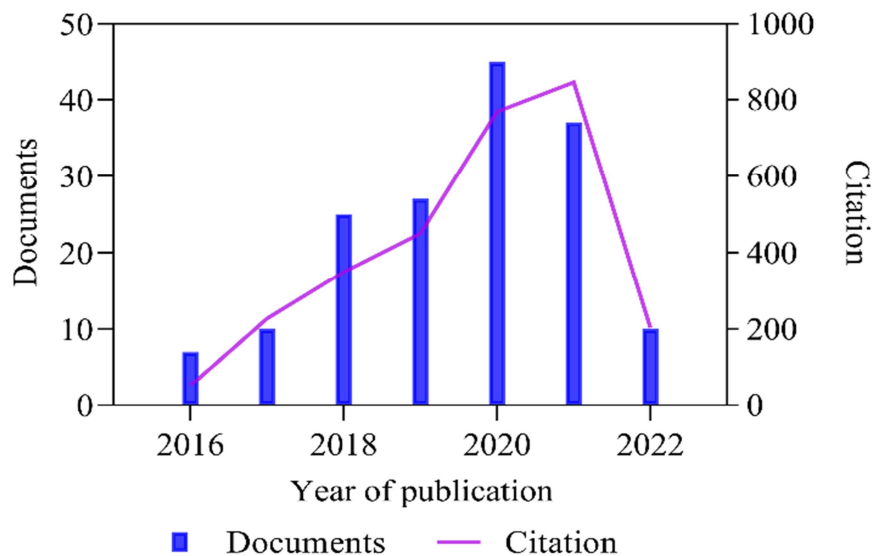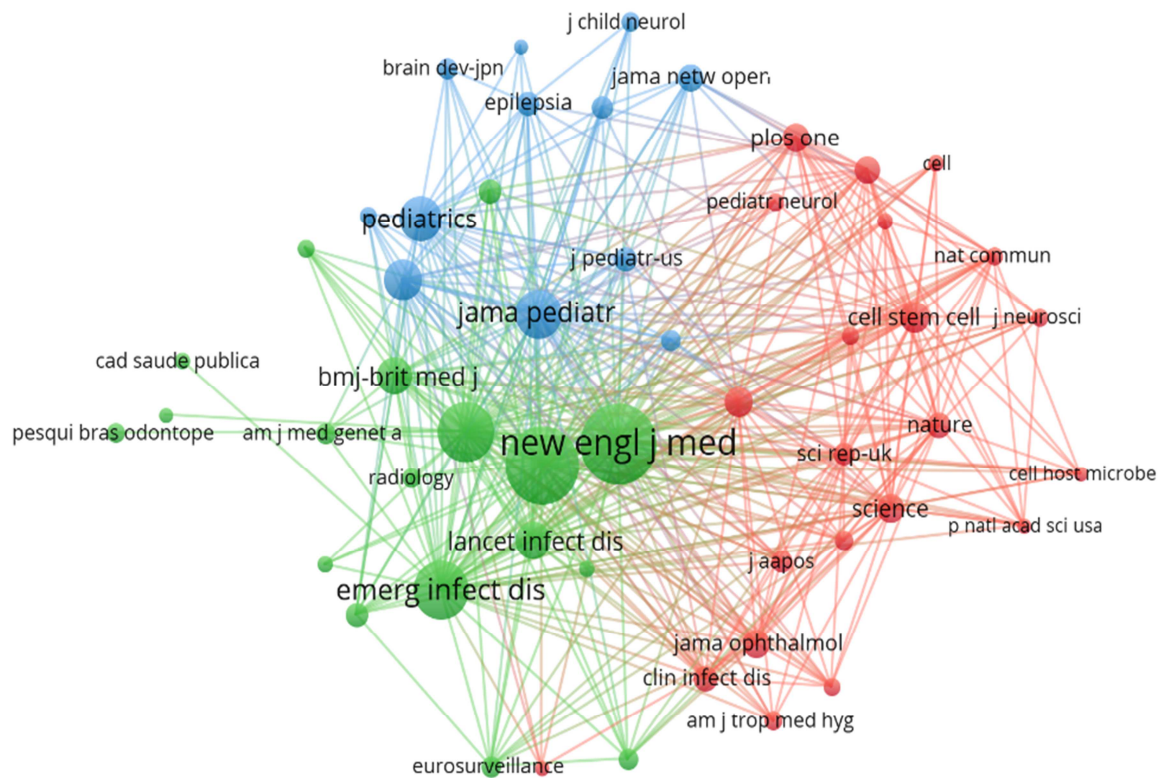

Source: research data

The number of records on the Web of Science shows an exponential growth trend until 2020. From January 2021 until June 2022, the number of publication records in the database decreased. The reduction in the number of publications about the Zika virus in 2021 may be related to the Covid-19 pandemic. In terms of citations, the number of citations grows every year, with a reduction observed only in 2022, which can be explained by the period in which the database was consulted.

3.1. Distribution of cited journals

In Figure 3, we find the co-citation network of journals with a minimum participation of 20 articles on the Zika virus and child development. The most-cited journals are represented by larger circles. The New England Journal of Medicine ranked first with the highest number of citations among published articles ($n = 290$), followed by Morbidity and Mortality Weekly Report (MMWR) ($n = 271$), Lancet ($n = 179$), Emerging Infectious Diseases Journal ($n = 174$), JAMA Pediatrics ($n = 131$), Pediatrics ($n = 114$), Science ($n = 58$), BMJ-British Medical Journal ($n = 88$), Developmental

Medicine & Child Neurology (*n* = 96) and Cell Stem Cell (*n* = 63). Furthermore, it can be seen in Figure 3 that 3 clusters are formed. The grouping into 3 clusters was also observed in the co-citation analysis between authors.

Figure 3 – Co-citation network between journals. Periodicals with a minimum productivity of 20 articles on Zika virus and child development from 2016 to 2022 were considered for the study. The size of the spheres reflects the co-citation frequency of the journals. Colors separate clusters by similarities

Source: research data

3.2. Author's co-citation

Authors who contributed to publications registered in the Web of Science database, where each one published 5 (five) or more articles on the Zika virus and child development between the period 2016 to June 2022. The largest record of documents was related to Cynthia A. Moore, with 12 documents and a total of 940 citations. In terms of citations, Figure 4 shows the co-citation network between the authors of the evaluated publications.

Figure 4 – Co-citation network of authors. Periodicals with a minimum participation of 20 citations in publications on the Zika virus and child development from 2016 to June 2022 were considered for the study. The size of the spheres reflects the authors' co-citation frequency. Colors separate clusters by similarities and lines indicate collaboration between authors
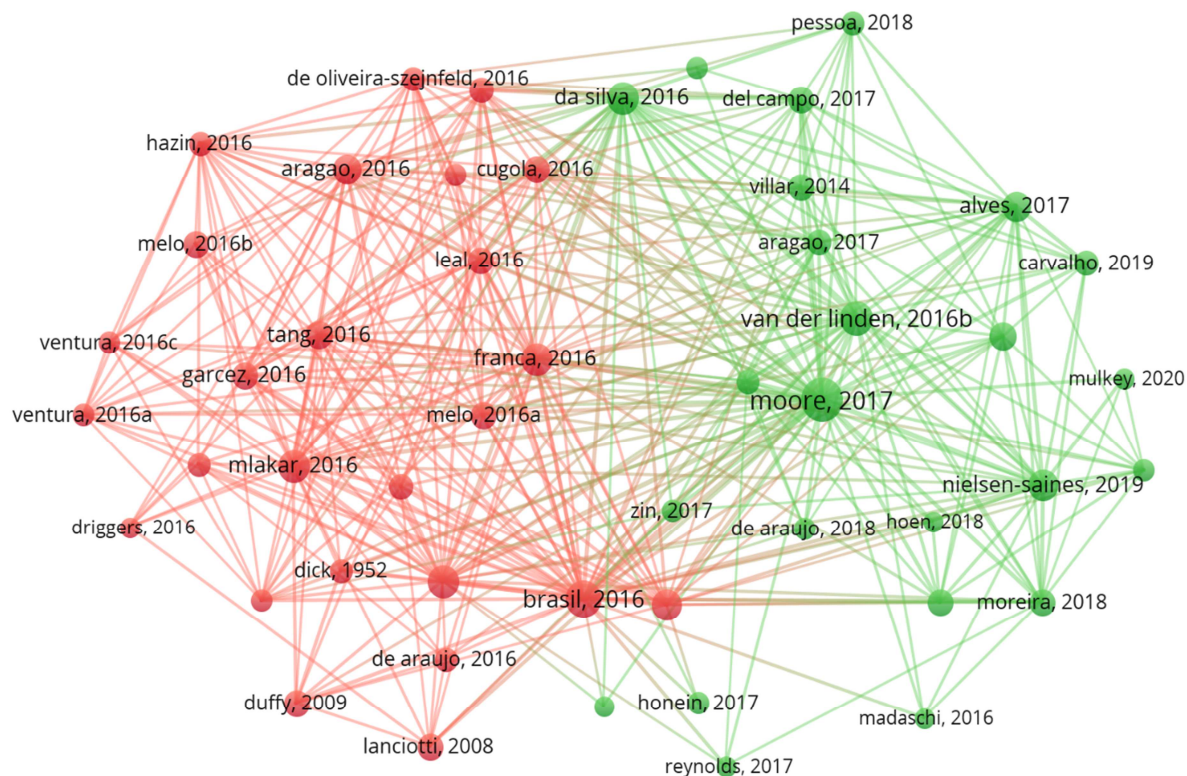
Source: research data

Vanessa Van Der Linden, another author with great prominence on the subject, contributes scientifically to the outcomes of Zika virus infection in children in terms of motor development by conducting studies on abnormal postures and movements in children with congenital Zika virus syndrome (VAN DER LINDEN *et al.*, 2020). This author forms a cluster with researchers such as Mariana C. Leal, who collaborated with research that evaluated the relationship between the Zika virus and dysphagia development in infants with microcephaly (LEAL *et al.*, 2017).

In terms of the characterization and standardization of abnormalities in congenital Zika syndrome, author Cynthia A. Moore makes a comprehensive and relevant contribution to informing clinicians and better-characterizing outcomes caused by Zika virus infection (MOORE *et al.*, 2017). In the same cluster, Patrícia Brasil studies the transmission of the Zika virus in children and the relationship with abnormalities (BRASIL *et al.*, 2016; BRASIL *et al.*, 2020).

3.3. Co-citation of references

The 50 most-cited publications among documents collected on the Web of Science were evaluated (Figure 5). The publications were cited at least 13 times among the authors. Through the analysis of the co-citation of references, we observed the formation of two clusters. The first cluster is composed of 27 references, one of the articles that represents it addresses clinical manifestations of Zika virus disease in mothers and the repercussions of acute Zika virus infection in babies (BRASIL *et al.*, 2016). It was noticed when evaluating cluster 1 that the main aspects reported are the association of infection during pregnancy with the Zika virus and outcomes in children.

Figure 5 – Most cited references in documents selected to study the Zika virus in children's development. The size of the spheres reflects the citation frequency of the references. Colors separate clusters by similarities

Source: research data

In cluster 2, we observed the delineation of the entire spectrum of anomalies caused by the Zika virus infection. Moore *et al.* (2017) characterized anomalies caused by congenital Zika syndrome. Such information provided support for pediatric physicians who may be called upon to evaluate and treat affected children and infants, for which the author and collaborators review the most recent evidence (background to publication period in 2017) to better characterize congenital Zika syndrome.

3.4. Top research institutions and countries

The 161 articles were published by authors with affiliations in 39 countries/regions participating in Zika virus and child development research. Among the countries/regions observed, Brazil published the largest number of studies in the evaluated time frame (67.5%), followed by the United States of America (46.9%), England (14.4%), Colombia (5.6%), and Germany (4.4%). Brazil's impressive participation in research on the outcomes of Zika virus infection on child development may be related to the alarming scale of the most recent outbreak in Brazil, where 440,000-1,300,000 cases were reported (WIKAN; SMITH, 2016). In addition, key contributors to research on the Zika virus and child development are found in the United States of America and England (total link strengths of 78 and 46).

The literature search revealed the participation of 398 research institutions with publications relevant to the area of knowledge; 23 contributed to the publication of at least 5 documents. The Oswaldo Cruz Foundation and the University of São Paulo published the largest number of articles, both with 18 records, followed by the Federal University of Pernambuco (*n* = 17), Federal University of Bahia (*n* = 17), and London School of Hygiene & Tropical Medicine (*n* = 16). The collaboration network between the authors' research institutions with at least 5 registered documents is shown in Figure 6.

Figure 6 – Collaboration network between research institutions. Co-author research institutions with a minimum participation of 5 documents were considered. The size of the spheres reflects the frequency of occurrence of the institutions. Colors separate clusters by similarities and lines indicate collaboration between institutions
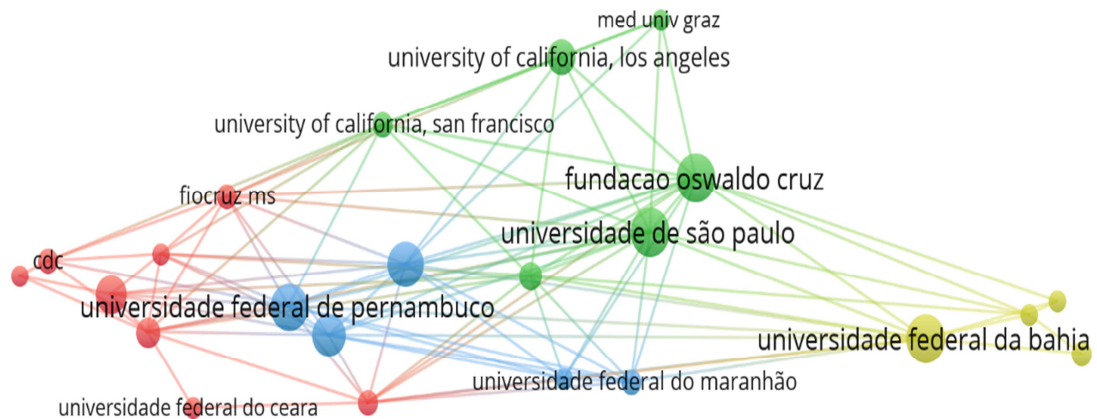
The Oswaldo Cruz Foundation appears to be the largest contributor, with 413 citations. Most researchers affiliated with this institution have primarily studied the neurological outcomes and heterogeneous development of children with congenital Zika syndrome. The London School of Hygiene & Tropical Medicine, Universidade Federal de Pernambuco, and Universidade de São Paulo were important collaborators of Fundação Oswaldo Cruz, with total link strengths of 42, 41, and 41, respectively.

3.5. Top search terms

Of the 538 keywords provided by the authors of 161 articles retrieved from the Web of Science database, 29 keywords occurred more than 5 times and were used in our analysis, and the co-occurrence network was formed (Figure 7). The most used words were "child" (n =84), "Zika" (n =78), "virus infection" (n = 48) and "microcephaly" (n = 41).

Figure 7 – Author's keyword network. Authors with a minimum of 5 occurrences in articles between the period from 2016 to June 2022 were considered in the study. The size of the spheres reflects the occurrence of the word. Colors separate clusters by similarity
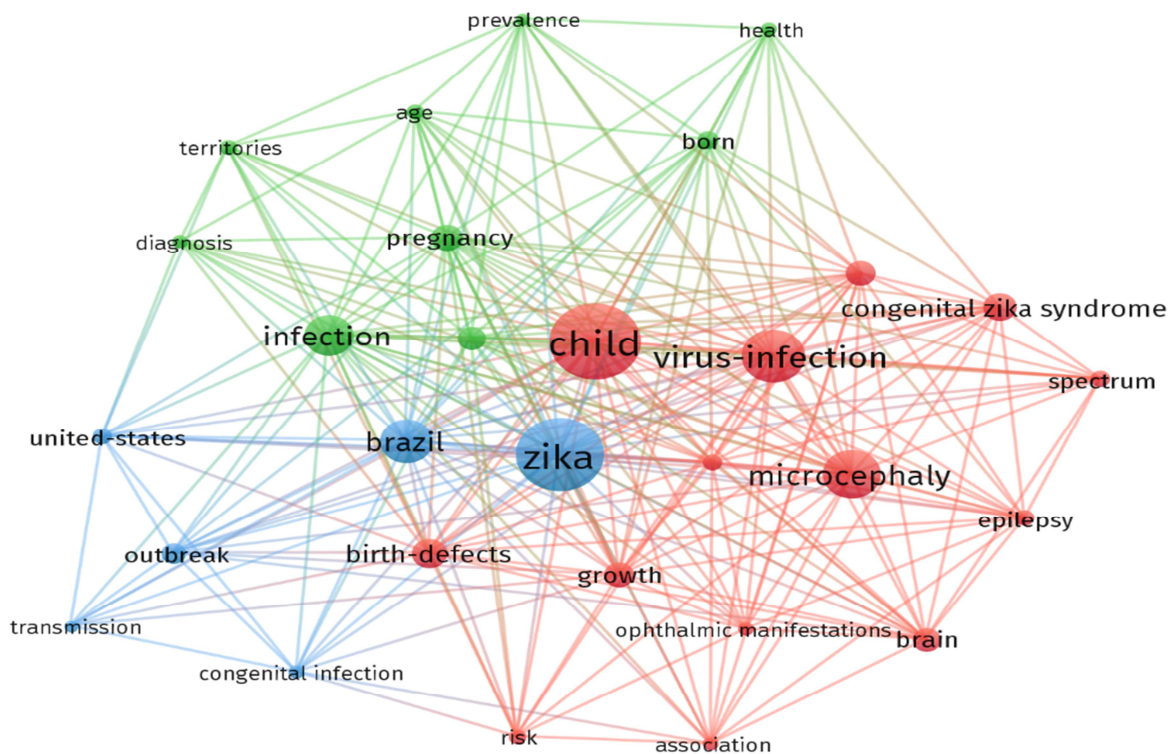
The keywords formed 3 clusters where we can identify related topics according to the strength of the link. The largest cluster is formed by 14 keywords, and the main topic addressed is related to anomalies caused by Zika virus infection in children. In this cluster, the words "congenital Zika syndrome", "cerebral palsy" and "epilepsy" stand out as the words with the highest occurrence in the years following 2019. The second largest cluster is formed by 9 keywords, highlighting the relationship between the territory and the history of Zika virus infection in pregnant women, and how these characteristics related to the neurodevelopment of children. Within this cluster, the prominence of the word "neurodevelopment" is noticed as one of the research trends in the scientific field in the period after 2019. The third cluster shows the relationship between the effects of virus transmission related to geographic location and the diagnosis of congenital infection.

4. Discussion

It is known that several studies available in the literature have already elucidated the link between the Zika virus and Congenital Zika syndrome (CZS), however, with each study developed, new questions arise that culminate in the propulsion of new research involving the most diverse specialties of medicine in relation to the different organs and systems affected by the Zika virus.

In terms of bibliometric studies on the development of children diagnosed with Zika virus infection, our study offers coverage of several journals indexed in the largest database, the Web of Science, geographic coverage globally, and leading authors and research institutions relevant to advancing the development of specific knowledge about the effects of Zika virus infection on the development of children. In addition, based on the research carried out on the Web of Science, it was possible to construct an overview of the current literature on the topic addressed, highlighting the main manifestations and clinical characteristics associated with congenital Zika virus syndrome.

Based on the accumulated number of publications from 2016 to June 2022 on the subject studied in this article, it can be seen that there has been a significant increase in studies that address the Zika virus and its relationship with anomalous development in infected children. This can be explained by the emergence of the first cases of microcephaly and successively an alarming outbreak of cases in 2016 in Brazil, awakening the scientific community to seek answers based on the damage

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caused in the development of fetuses. However, the results showed that until June 2022, there was a decrease in publications on the subject (Figures 1 and 2), suggesting a possible association with the interest and need to research the new coronavirus, since it is a period where critical moments of a pandemic scenario were experienced. Another possible justification for this attenuation in the number of publications would be the budget cuts that occurred in universities and public institutions in Brazil, thus hindering the progress of scientific research, since Brazil is the country with the highest number of studies and where important research institutions are concentrated, such as the Fundação Oswaldo Cruz.

Despite the significant number of studies on Zika virus infection, much can still be explored, and our study helps scientists to carry out research using numerous strategies to improve diagnostic practices and follow-up of children's development, thus enabling them to contribute to improving the quality general life of the developing children and their families.

By analyzing the co-citation network of journals, it was possible to verify the journals that had the greatest influence in the medical field, which covers the specific topic addressed in this study, with an emphasis on the New England Journal of Medicine, considered the leading international journal, with the most relevant publications on Biomedical Science and Clinical Practice. Publications in journals with high impact and a high reputation indicate the importance of the topic, paying attention to the issues raised in the research domain (KABYL *et al.*, 2022). Therefore, in the future, there is a potential tendency to direct studies towards improving the quality of life of children diagnosed with Zika virus infection with anomalies that impact their development, considering factors such as the influence of geographic location and socioeconomic factors.

In the author co-citation analysis, it was seen that the largest number of citations was related to the research developed by the author Cynthia A. Moore, a reference researcher in the area, and according to the results, she led the ranking of publications between the period of 2016 and June 2022, with 12 documents and a total of 940 citations up to the date of analysis. The results pointed to other eminent authors on the network, such as Camila V. Ventura, Vanessa van der Linden, Patrícia Brasil and Lavinia Schuler-Faccini. Among the main themes and fields studied by these most cited authors, research on the characterization and standardization of abnormalities in congenital Zika syndrome, clinical, and molecular aspects associated with neural development, ophthalmological disorders, and the motor development of children with congenital syndrome stand out of the Zika virus.

Our analysis of the co-citation of references showed the formation of two clusters: i) Clinical manifestations of Zika virus disease in mothers and the repercussions of acute Zika virus infection in babies. During pregnancy, several factors can cause damage to fetal development, such as infectious agents that have the ability to cross the placental barrier and promote cytotoxicity, interruption of the cell cycle with consequent mitotic inhibition, and vascular lesions, which can induce aggressive reparative response that hinders fetal and child neurodevelopment up to two years of age (ABTIBOL-BERNARDINO *et al.,* 2020; ROSA *et al.,* 2020); ii) The delineation of the entire spectrum of anomalies caused by the Zika virus infection. CZS consists of a set of neurological changes in fetuses and live births resulting from exposure to the Zika virus in the prenatal phase (QUILIÃO *et al.,* 2020; PESSOA *et al.,* 2018). The anomalies include: i) changes in cranial morphology with a partially collapsed skull; ii) brain anomalies follow by neurological sequelae including cognitive, sensory, and motor disabilities; iii) ocular anomalies follow by macular scarring and focal pigmentary retinal mottling; iv) congenital contractures (MOORE *et al*., 2017).

According to a study carried out by Matiello *et al.* (2021), microcephaly is accompanied by specific brain lesions, such as subcortical calcifications. In severe cases of microcephaly, ocular changes, congenital contractures, hydrocephalus, muscle tone, postural changes, and severe early hypertonia (MOORE *et al.,* 2017) are observed, which may occur due to programmed cell death of the nervous system during fetal development resulting from Zika virus replication (QUILIÃO *et al.,* 2020).

The Ophthalmological disorders evidenced in children affected with CZS occur due to neurosensory changes caused by calcifications, culminating in several sequelae, and visual impairments due to damage to the optic nerve, chorioretinal, and macular atrophy, abnormalities in pigment epithelium, and macular pigment production, among other modifications (OLIVEIRA *et al.,*

2020; SCHULER-FACCINI *et al.,* 2022). Costa *et al.* (2020) analyzed visual alterations in babies suspected of having a maternal Zika virus infection in the first trimester of pregnancy and in those affected by microcephaly. According to the findings obtained, chorioretinal atrophy, focal spots of the retinal pigment, and abnormalities in the optic nerve were significantly related to Zika virus infection. Vision is a very important sense because it plays an essential role in communication and social integration in the development of motor and space skills. Therefore, early diagnosis, interventions, and visual stimulation allow these children to develop and explore the environment (PAIXÃO *et al.,* 2022).

Despite all the knowledge about the effects of congenital Zika virus syndrome on the central nervous system, the understanding of some phenotypic characteristics requires further studies and clarification, as there are gaps involving the milder cases when compared to the more severe cases. Another gap to be filled is based on the exposure of children to the Zika virus during the gestational period and who do not develop CZS (Congenital Zika Virus Syndrome) at birth but who, during the first years of life, may have mild disorders (CALVET *et al.,* 2016).

Thus, the analyses presented in this article are of great importance to the scientific community because they offer an exhaustive overview of the current situation and future research paths aimed at the effects of Zika virus infection on the development of children. In addition, our comprehensive study will contribute to the formation of beneficial collaborations between authors, institutions, and countries with the aim of significantly improving research in this field and, as a consequence, sharing knowledge to enable monitoring and improving the quality of life of these children.

5. Limitations

A certain set of limitations in bibliometric analyses must be considered when interpreting the results. These limitations include the research methodology, where only the Web of Science database was used in the search. Therefore, publications that were not indexed on the Web of Science could not be examined and analyzed. However, 10% of the documents analyzed were manually evaluated, which shows that the method used in the study is valid and that the results obtained are accurate. Despite the inevitable limitations of the study, we believe that the results presented here can serve as a basis for future research and promote a valid discussion of the scientific literature on the development of children infected with the Zika virus.

6. Conclusion

The scientific literature on the outcomes of Zika virus infection on children's development began in 2016 and has grown rapidly with the outbreak in Brazil. By reviewing publications over more than five years, this bibliometric analysis provided insights such as patterns of collaboration and research hot spots. It was concluded from the co-authorship analysis that only 23 of the 374 had 5 or more publications on the subject, which shows the high fragmentation at the individual and institutional levels. Brazil is a true hegemony of scientific production on this subject, contributing 67.5% of the articles, a reflection of the great outbreak that occurred in Brazil, that triggered the need for research in this area of study.

Future perspectives present a trend in the study of anomalies related to Zika virus infection. There is a need for more studies that portray the monitoring of the growth and development of these children and thus contribute to new interventions and monitoring of the growth of the infection and its clinical manifestations, favoring the updating of health professionals, and giving guidelines on how to monitor and treat these children in the long term and what needs to be improved in public policies and in the management strategies of this infection. Therefore, these findings allow the scientific community to look into the existing gaps in research on the effect of Zika virus infection on the development of children, making it possible to identify emerging themes and frontiers from the results presented in this research that can guide future research.

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Conflict of interests

The authors declare no conflict of interest.

References

ABTIBOL-BERNARDINO, M. R.; PEIXOTO, L. F. A. A.; DE OLIVEIRA, G. A.; ALMEIDA, T. F.; RODRIGUES, G. R. I.; OTANI, R. H.; CHAVES, B. C. S.; RODRIGUES, C. S.; DE ANDRADE, A. B. C. A.; REDIVO, E. F.; FERNANDES, S. S.; CASTILHO, M. C.; BENZECRY, S. G.; BÔTTO-MENEZES, C.; MARTINEZ-ESPINOSA, F. E.; ALECRIM, M. G. C. Neurological findings in children without congenital microcephaly exposed to zika virus in utero: a case series study. **Viruses**, v. 12, n. 11, 1335, 2020. DOI: https://doi.org/10.3390/v12111335.

ARORA, S. D.; CHAKRABORTY, A. Intellectual structure of consumer complaining behavior (CCB) research: a bibliometric analysis. **Journal of Business Research**, v. 122, p. 60-74, 2021. DOI: https://doi.org/10.1016/j.jbusres.2020.08.043.

BRASIL, P.; PEREIRA JUNIOR, J. P.; MOREIRA, M. E.; NOGUEIRA, R. M. R.; DAMASCENO, L.; WAKIMOTO, M.; RABELLO, R. S.; VALDERRAMOS, S. G.; HALAI, U.-A.; SALLES, T. S.; ZIN, A. A.; HOROVITZ, D. *et al*. Zika virus infection in pregnant women in Rio de Janeiro. **The New England Journal of Medicine**, v. 375, n. 24, p. 2321-2334, 2016. DOI: https://dx.doi.org/10.1056/NEJMoa1602412.

BRASIL, P.; VASCONCELOS, Z.; KERIN, T.; GABAGLIA, C. R.; RIBEIRO, I. P.; BONALDO, M. C.; DAMASCENO, L.; PONE, M. V.; ZIN, A.; TSUI, I.; ADACHI, K.; PEREIRA JUNIOR., J. P.; GAW, S. L.; CARVALHO, L.; CUNHA, D. C.; GUIDA, L.; ROCHA, M.; CHERRY, J. D.; WANG, L.; ALIYARI, S. *et al*. Zika virus vertical transmission in children with confirmed antenatal exposure. **Nature Communications**, v. 11, 3510, 2020. DOI: https://doi.org/10.1038/s41467-020-17331-0.

CALVET, G.; AGUIAR, R. S.; MELO, A. S. O.; SAMPAIO, S. A.; FILIPPIS, I.; FABRI, A.; ARAUJO, E. S. M.; SEQUEIRA, P. C.; MENDONÇA, M. C. L.; OLIVEIRA, L.; TSCHOEKE, D. A.; SCHRAGO, C. G.; THOMPSON, F. L.; BRASIL, P., SANTOS, F. B.; NOGUEIRA, R. M. R.; TANURI, A.; FILIPPIS, A. M. B. Detection and sequencing of Zika virus from amniotic fluid of fetuses with microcephaly in Brazil: a case study. **The Lancet. Infectious Diseases**, v. 16, n. 6, p. 653-660, 2016. DOI: https://doi.org/10.1016/S1473-3099(16)00095-5.

CARDOSO, C. W.; PAPLOSKI, I. A. D.; KIKUTI, M.; RODRIGUES, M. S.; SILVA, M. M. O.; CAMPOS, G. S.; SARDI, S. I.; KITRON, U.; REIS, M. G.; RIBEIRO, G. S. Outbreak of exanthematous illness associated with Zika, Chikungunya, and Dengue viruses, Salvador, Brazil. **Emerging Infectious Diseases**, v. 21, n. 12, p. 2274-2276, 2015. DOI: https://dx.doi.org/10.3201/eid2112.151167.

COSTA, M. C. N.; CARDIM, L. L.; TEIXEIRA, M. G.; BARRETO, M. L.; CARVALHO-SAUER, R.; C. O.; BARRETO, F. R.; CARVALHO, M. S. I.; OLIVEIRA, W. K.; FRANÇA, G. V. A.; CARMO, E. H.; ANDRADE, R. F. S.; RODRIGUES, M. S.; VEIGA, R. V.; OLIVEIRA, J. F.; FERNANDES, Q. H. R. F.; COSTA, L. C.; COELHO, G. E., PAIXAO, E. S. Case fatality rate related to microcephaly congenital Zika syndrome and associated factors: a nationwide retrospective study in Brazil. **Viruses**, v. 12, n. 11, 1228, 2020. DOI: https://doi.org/10.3390/v12111228.

DONTHU, N.; KUMAR, S.; MUKHERJEE, D.; PANDEY, N.; LIM, W. M. How to conduct a bibliometric analysis: an overview and guidelines. **Journal of Business Research**, v. 133, p. 285-296, 2021. DOI: https://doi.org/10.1016/j.jbusres.2021.04.070.

FOROUDI, P.; AKARSU, T. N.; MARVI, R.; BALAKRISHNAN, J. Intellectual evolution of social innovation: a bibliometric analysis and avenues for future research trends. **Industrial Marketing Management**, v. 93, p. 446-465, 2021. DOI: https://doi.org/10.1016/j.indmarman.2020.03.026.

HELHA, F.- N. M.; WANG, Y.-P. Trends in complementary and alternative medicine for the treatment of common mental disorders: a bibliometric analysis of two decades. **Complementary Therapies in Clinical Practice**, v. 46, 101531, 2022. DOI: https://doi.org/10.1016/j.ctcp.2021.101531.

HUANG, T.; ZHONG, W.; LU, C.; ZHANG, C.; DENG, Z.; ZHOU, R.; ZHAO, Z.; LUO, X. Visualized analysis of global studies on cervical spondylosis surgery: a bibliometric study based on Web of Science Database and VOSviewer. **Indian Journal of Orthopaedics**, v. 56, n. 6, p. 996-1010, 2022. DOI: https://doi.org/10.1007/s43465-021-00581-5.

HUMBOLDT-DACHROEDEN, S.; RUBIN, O.; FRID-NIELSEN, S. S. The state of One Health research across disciplines and sectors: a bibliometric analysis. **One Health**, v. 10, 100146, 2020. DOI: https://doi.org/10.1016/j.onehlt.2020.100146.

KABYL, A.; YANG, M.; SHAH, D.; AHMAD, A. Bibliometric analysis of accidental oil spills in ice-infested waters. **International Journal Environmental Research and Public Health**, v. 19, n. 22, 15190, 2022. DOI: https://doi.org/10.3390/ijerph192215190.

LEAL, M. C.; VAN DER LINDEN, V.; BEZERRA, T. P.; VALOIS, L.; BORGES, A. C. G.; ANTUNES, M. M. C.; BRANDT, K. G.; MOURA, C. X.; RODRIGUES, L. C.; XIMENES, C. R. Characteristics of dysphagia in infants with microcephaly caused by congenital Zika virus infection, Brazil, 2015. **Emerging Infectious Diseases**, v. 23, n. 8, p. 1253-1259, 2017. DOI: https://doi.org/10.3201/eid2308.170354.

MATIELLO, F. B.; HILARIO, J. S. M.; GONDIM, E. C.; SANTOS, D. N.; MELLO, D. F. Health surveillance and development of children with congenital Zika virus syndrome: an integrative literature review. **Revista Paulista de Pediatria**, v. 40, p. e2020335, 2021. DOI: https://doi.org/10.1590/1984-0462/2022/40/2020335.

MOORE, C. A.; STAPLES, J. E.; DOBYNS, W. B.; PESSOA, A.; VENTURA, C. V.; FONSECA, E. B.; RIBEIRO, E. M.; VENTURA, L. O.; NOGUEIRA NETO, N.; ARENA, F.; RASMUSSEN, S. A. Characterizing the pattern of anomalies in congenital Zika syndrome for pediatric clinicians. **JAMA Pediatrics**, v. 171, n. 3, p. 288-95, 2017. DOI: https://doi.org/10.1001/jamapediatrics.2016.3982.

MÖRSCHBÄCHER, A. P.; GRANADA, C. E. Mapping the worldwide knowledge of antimicrobial substances produced by *Lactobacillus spp.*: a bibliometric analysis. **Biochemical Engineering Journal**, v. 180, 108343, 2022. DOI: https://doi.org/10.1016/j.bej.2022.108343.

OLIVEIRA, A. M. M.; MELO, E. G. M.; MENDES, M. L. T.; OLIVEIRA, S. J. G. S.; TAVARES, C. S. S.; VAEZ, A. C.; VASCONCELOS, S. J. A.; SANTOS JUNIOR., H. P.; SANTOS, V. S.; MARTINS-FILHO, P. R. S. Oral and maxillofacial conditions, dietary aspects, and nutritional status of children with congenital Zika syndrome. **Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology**. v. 130, n. 1, p. 71-77, 2020. DOI: https://doi.org/10.1016/j.oooo.2020.02.019.

PAIXÃO, E. S.; CARDIM, L. L.; COSTA, M. C. N.; BRICKLEY, E. B.; CARVALHO-SAUER, R. C. O.; CARMO, E. H.; ANDRADE, R. F. S.; RODRIGUES, M. S.; VEIGA, R. V.; COSTA, L. C.; MOORE, C. A.; FRANÇA, G. V. A.; SMEETH, L.; RODRIGUES, L. C.; BARRETO, M. L.; TEIXEIRA, M. G. Mortality from congenital Zika syndrome: nationwide cohort study in Brazil. **The New England Journal of Medicine**, v. 386, n. 8, p. 757-767, 2022. DOI: https://doi.org/10.1056/nejmoa2101195.

PESSOA, A.; VAN DER LINDEN, V.; YEARGIN-ALLSOPP, M.; CARVALHO, M. D. C. G.; RIBEIRO, E. M.; BRAUN, K. V. N.; DURKIN, M. S.; PASTULA, D. M.; MOORE, J. T.; MOORE, C. A. Motor abnormalities and epilepsy in infants and children with evidence of congenital Zika virus infection. **Pediatrics**, v. 141, n. 2, p. S167-S179, 2018. DOI: https://doi.org/10.1542/peds.2017-2038f.

PETERSEN, L. R.; JAMIESON, D. J.; POWERS, A. M.; HONEIN, M. A. Zika virus. **The New England Journal of Medicine**, v. 374, n. 16, p. 1552-1563, 2016. DOI: https://doi.org/10.1056/NEJMra1602113.

QIN, Y.; CHEN, S.; ZHANG, Y.; LIU, W.; LIN, Y.; CHI, X.; CHEN, X.; YU, Z.; SU, D. A bibliometric analysis of endoscopic sedation research: 2001-2020. **Frontiers in Medicine (Lausanne)**, v. 8, 2022. DOI: https://doi.org/10.3389/fmed.2021.775495.

QUILIÃO, M. E.; VENANCIO, F. A.; MARETO, L. K.; METZKER, S. A.; NASCIMENTO, A. I.; VITORELLI-VENANCIO, D. C.; SANTOS-PINTO, C. D. B.; OLIVEIRA, E. F. Neurological development, epilepsy, and the pharmacotherapy approach in children with congenital Zika syndrome: results from a two-year follow-up study. **Viruses**, v. 12, n. 10, 1083, 2020. DOI: https://doi.org/10.3390/v12101083.

ROSA, B. C. S.; CESAR, C. P. H. A. R.; PARANHOS, L. R.; GUEDES-GRANZOTTI, R. B.; LEWIS, D. R. Speech-language disorders in children with congenital Zika virus syndrome: a systematic review. **International Journal of Pediatric Otorhinolaryngololy**, v. 138, 110309, 2020. DOI: https://doi.org/10.1016/j.ijporl.2020.110309.

RUIZ-FRESNEDA, M. A.; JIMÉNEZ-CONTRERAS, E.; RUIZ-FRESNEDA, C.; RUIZ-PÉREZ, R. Bibliometric analysis of international scientific production on pharmacologic treatments for SARS-CoV-2/COVID-19 during 2020. **Frontiers Public Health**, v. 9, 2022. DOI: https://doi.org/10.3389/fpubh.2021.778203.

SCHULER-FACCINI, L.; DEL CAMPO, M.; GARCIA-ALIX, A.; VENTURA, L. O.; BOQUETT, J. A.; VAN DER LINDEN, V.; PESSOA, A.; VAN DER LINDER JÚNIOR, H.; VENTURA, C. V.; LEAL, M. C.; KOWALSKI, T. W.; GERZSON, L. R.; ALMEIDA, C. S.; SANTI, L.; BEYS-DA-SILVA, W.; QUINCOZES-SANTOS, A.; GUIMARÃES, J. A.; GARCEZ, P. P.; GOMES, J. A.; VIANNA, F. S. L. *et al*. Neurodevelopment in children exposed to Zika *in utero*: clinical and molecular aspects. **Frontiers in Genetics**, v. 13, 2022. DOI: https://doi.org/10.3389/fgene.2022.758715.

SONG, B.-H.; YUN, S.-I.; WOOLLEY, M.; LEE, Y.-M. Zika virus: history, epidemiology, transmission, and clinical presentation. **Journal of Neuroimmunology**, v. 308, p.50-64, 2017. DOI: https://doi.org/10.1016/j.jneuroim.2017.03.001.

SUN, H.; BINDER, R. A.; DICKENS, B.; SESSIONS, P. F.; RABAA, M. A.; HO, E. X. P.; COOK, A. R.; CARRILLO, F. B.; MONTERREY, J. C.; KUAN, G.; BALMASEDA, A.; OOI, E.; HARRIS, E.; SESSIONS, O. M. Viral genome-based Zika virus transmission dynamics in a paediatric cohort during the 2016 Nicaragua epidemic. **EBioMedicine**, v. 72, 103596, 2021. DOI: https://doi.org/10.1016/j.ebiom.2021.103596.

VAN DER LINDEN, H.; SILVEIRA-MORIYAMA, L.; VAN DER LINDEN, V.; PESSOA, A.; VALENTE, K.; MINK, J.; PACIORKOWSKI, A. Movement disorders in children with congenital Zika virus syndrome. **Brain & Development**, v. 42, n. 10, p. 720-729, 2020. DOI: https://doi.org/10.1016/j.braindev.2020.06.016.

WANG, J.; MANIRUZZAMAN, M. A global bibliometric and visualized analysis of bacteria-mediated cancer therapy. **Drug Discovery Today**, v. 27, n. 10, 103297, 2022. DOI: https://doi.org/10.1016/j.drudis.2022.05.023.

WANG, Y.; SHAN, C.; TIAN, Y.; PU, C.; ZHU, Z. Bibliometric analysis of global research on perinatal palliative care. **Frontiers in Pediatrics**, v. 9, 2022. DOI: https://doi.org/10.3389/fped.2021.827507.

WIKAN, N.; SMITH, D. R. Zika virus: history of a newly emerging arbovirus. **The Lancet. Infectious Diseases**, v. 16, n. 7, p. E119-E126, 2016. DOI: https://doi.org/10.1016/S1473-3099(16)30010-X.

ZHAO, X. Customer orientation: a literature review based on bibliometric analysis. **Sage Open**, v. 12, n. 1, p. 215824402210798, 2022. DOI: https://doi.org/10.1177/21582440221079804.