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Trends in scientific output on artificial intelligence and health in Latin America in Scopus

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Abstract

Introduction: technological developments in artificial intelligence and health are necessary for Latin American health systems.
Objective: to describe the trends in scientific production on artificial intelligence and health in Latin America in Scopus.
Method: This is a retrospective bibliometric study of Latin American authors' scientific production on artificial intelligence and health in Scopus between 2012 and 2021. Production, visibility and impact indicators were used. VOSviewer and SciVal were used for data analysis.
Results: 2871 articles were published, with a variation between 2012 and 2021 of 94.98%. 2,397 articles were original, and 2,741 were written in English. 58.3% were published in first-quartile journals, the most productive being Sensors (Ndoc=79) and Plos One (Ndoc=66). 64,128 citations were received (mean of 22.3 citations per article). Brazil was the most productive country (Ndoc=1420), and the institution was the University of São Paulo (Ndoc=288). 498 thematic groups were identified, and 1376 themes. 54% of the articles had international collaboration and 3.3% with academic-corporation collaboration.
Conclusions: there is a growing scientific production on artificial intelligence and health in Latin America, written mainly in English, medical, engineering and computer science research areas, disseminated in specialized magazines in the first quartiles. Brazil and its institutions were the top producers. The main topics were predictive models and the application of artificial intelligence for classifying, diagnosing and treating diseases.

Keywords: Artificial Intelligence; Health Sciences; Medicine; bibliometrics; scientific output; Latin America

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1. Introduction

The term Artificial Intelligence (AI) is attributed to John McCarthy, who in 1956 used it to refer to the possibility of supplying information to equipment, devices and/or electronic systems, which, based on it, could simulate the processes inherent to human thought and will [1,2].
AI comprises the simulation of cognitive processes and human reasoning by systems and the interaction of equipment and machines with information [3–5]. The current volume of

available information conditions the need for a group of professions related to Data Sciences, generating opportunities for the development of AI -by being able to interact with a more significant number of data, increasingly readable- which in turn opens up other career niches, such as prompt engineering as an area to optimize natural language processing.[6]

The use of AI in people's health care significantly influences the reduction of costs, which benefits health systems and their users. Its application in Medicine and Nursing has been described, with implications for care, administration, and education [7–9].

An example is the image classification algorithm proposed by Siddamallappa Ujjappanahalli [10], with 99% accuracy for tumor detection. Similarly, progress in the metaverse has been associated with the development of AI and the new implications this would have for services, including health services [11–14].

A study carried out by Islam et al. [15] showed the existence of an interest on the part of the scientific community in the use of AI for diagnosis, detection, epidemic trends, classification and reuse of drugs in the context of epidemics such as COVID-19. The study found the efficiency and diversity of AI applications (such as machine learning and deep learning) for patient detection, early treatment, and improved patient care.[16,17] In addition, he envisions further implementation of AI in clinical practice, which will help to deal with future pandemics. An example of this interest is a research carried out for the construction of a computerized system for the detection of COVID-19 based on computed tomography, developed by Yang et al [18].

Another application of AI in the health field occurs in scientific research and publication.[19] Optimizing researchers' time in terms of writing scientific articles and improving the quality of these using ChatGPT as an assistant for writing have been proposed. However, this impacts logical thinking and reasoning processes [20–22].

Therefore, the need for education in the use of AI is pointed out so that it is beneficial for scientific-technical development in the health area, requiring the will of the states to finance research projects in this research area [8,23].

Bibliometrics is an invaluable tool for evaluating science.[24] It uses indicators that measure scientific production, quality, visibility and impact.[25,26] Analyzing scientific production trends makes it possible to identify emerging areas and areas of opportunity, cooperation, themes, funding entities and other topics of interest that evaluators and decision-makers can use.

Although several studies have been developed that analyze scientific production in artificial intelligence and health [15,27–30], those that analyze research in this area in Latin America are scarce. Given this knowledge gap, the present investigation was developed to describe the trends in scientific production on artificial intelligence and health in Latin America.

2. Methods

An observational, descriptive, longitudinal and retrospective study of the scientific production on artificial intelligence and health published in journals indexed in Scopus, prepared by authors with Latin American affiliation, in 2012-2021, was carried out. Articles published in journals indexed in Scopus, where at least one of the authors declared affiliation with a Latin American country, were included.

Search strategy

The database was accessed on March 3, 2023. A search formula was used using the combination of terms through Boolean operators (OR, AND) to search for information. The term AFILLCOUNTRY was used to establish the countries of affiliation of the authors, as well as the period 2012-2021. The search strategy had two blocks, a first block of terms related to artificial intelligence and its applications (artificial intelligence or machine learning or neural network or deep learning or natural language process or thinking computer system); and a second part related to the health area (health or Medic* or disease). The terms used were selected based on several studies [28,29,31] and contextualized to the present objective.

Articles published in 2022 were excluded, as they may contain incomplete bibliometric information. Other document types were excluded, such as books, book chapters, and conference proceedings.

The resulting search strategy was as follows:

(((TITLE-ABS-KEY ("artificial intelligence") OR TITLE-ABS-KEY("machine learning") OR TITLE-ABS-KEY("neural network") OR TITLE-ABS-KEY("deep learning") OR TITLE-ABS-KEY("natural language process") OR TITLE-ABS-KEY("thinking computer system")) AND (TITLE-ABS-KEY(health) OR TITLE-ABS-KEY(Medic*) OR TITLE-ABS-KEY(disease))) AND (AFFILCOUNTRY (Brazil) OR AFFILCOUNTRY (Mexico) OR AFFILCOUNTRY (Argentina) OR AFFILCOUNTRY (Chile) OR AFFILCOUNTRY (Colombia) OR AFFILCOUNTRY (Venezuela) OR AFFILCOUNTRY (Cuba) OR AFFILCOUNTRY (Peru) OR AFFILCOUNTRY (Uruguay) OR AFFILCOUNTRY (Puerto Rico) OR AFFILCOUNTRY (Ecuador) OR AFFILCOUNTRY (Costa Rica) OR AFFILCOUNTRY (Panama) OR AFFILCOUNTRY (Trinidad and Tobago) OR AFFILCOUNTRY (Jamaica) OR AFFILCOUNTRY (Bolivia) OR AFFILCOUNTRY (Guatemala) OR AFFILCOUNTRY (Barbados) OR AFFILCOUNTRY (Paraguay) OR AFFILCOUNTRY (Guadeloupe) OR AFFILCOUNTRY (Nicaragua) OR AFFILCOUNTRY (El Salvador) OR AFFILCOUNTRY (Dominican Republic) OR AFFILCOUNTRY (Grenada) OR AFFILCOUNTRY (Honduras) OR AFFILCOUNTRY (French Guiana) OR AFFILCOUNTRY (Haiti) OR AFFILCOUNTRY (Martinique) OR AFFILCOUNTRY (Bermuda) OR AFFILCOUNTRY (Guyana) OR AFFILCOUNTRY (Saint Kitts and Nevis) OR AFFILCOUNTRY (Bahamas) OR AFFILCOUNTRY (Netherlands Antilles) OR AFFILCOUNTRY (Falkland Islands) OR AFFILCOUNTRY (Malvinas) OR AFFILCOUNTRY (Belize) OR AFFILCOUNTRY (Suriname) OR AFFILCOUNTRY (Dominica) OR AFFILCOUNTRY (

Cayman Islands) OR AFFILCOUNTRY (Virgin Islands) OR AFFILCOUNTRY (Antigua and Barbuda) OR AFFILCOUNTRY (Virgin Islands) OR AFFILCOUNTRY (Saint Lucia) OR AFFILCOUNTRY (Aruba) OR AFFILCOUNTRY (Montserrat) OR AFFILCOUNTRY (Saint Vincent and the Grenadines) OR AFFILCOUNTRY (Turks and Caicos Islands) OR AFFILCOUNTRY (Anguilla) OR AFFILCOUNTRY (South Georgia and the South Sandwich Islands))) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"re") OR LIMIT-TO (DOCTYPE,"ed") OR LIMIT-TO (DOCTYPE,"no") OR LIMIT-TO (DOCTYPE,"le") OR LIMIT-TO (DOCTYPE,"er")) AND (LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013) OR LIMIT-TO (PUBYEAR,2012))

Data extraction and analysis

The data obtained were exported in CVS format for processing in other programs. In addition, they were exported to SciVal for analysis using the tool's modules. SciVal is integral to Elsevier's research intelligence ecosystem, bringing clarity and focus to research planning, performance, and processes [32].

Indicators

The following bibliometric indicators of production, visibility and impact were studied:

- Number of documents (Ndoc): Total number of documents published.
- Percentage of documents (% Ndoc) concerning the total number of articles studied.
- Variation rate (Tvar) is the variation (increase or decrease) of scientific production concerning the previous year or the first year of a period. It was calculated from Tv=[(Np-Np0)Np*100], where Np is the total number of articles published in the last year of the analysis period, and Np0 is the total number of articles published in the first year of the analysis period. (16)
- Type of articles: according to the types defined in Scopus.
- Language: according to the language of writing the manuscript.
- Type of access: according to the type of access used to publish each article.
- Thematic areas: based on the area(s) assigned to the journal and articles. Each Scopus journal is assigned to one or several thematic areas based on the topics covered in their articles.
- Quartiles (Q): Journal quartiles are defined by journal metrics CiteScore, SNIP (Source-Normalized Impact per Paper) or SJR (SCImago Journal Rank). CiteScore, SNIP, or SJR percentiles are used to calculate each quartile: Q1 (≤ top 25 percentile), Q2 (26-50 percentile), Q3 (51-75 percentile), and Q4 (76-100 percentile).
- SCImago Journal Rank (SJR): it is calculated through an algorithm that considers the relevance and quality of the citations received, where citations from more important journals have a greater weight in the metric calculation.
- H-index: it is determined that there is an h-index if h of the documents published by the entity has at least h citations each.
- Field Weighted Citation Impact (FWCI): Indicates how the number of citations received by an entity's journals compares to the average number of citations received by similar journals.
- Number of authors (Naut): refers to the number of authors affiliated with the institution with articles published on AI and health in journals indexed in Scopus.

Co-occurrence and co-authorship networks

The VOSviewer program was used to build the co-authorship and term co-occurrence networks. In both cases, the fractional counting method was selected, and a scale of 1 and a variation of 0.5 were used, taking the occurrence as the magnitude of weight.

3. Results

During the study period, 2871 articles were identified. An increasing trend was found, with 2021 being the most productive year (Ndoc=978), with a variation of 94.98 % concerning the production volume in 2012. The highest variation rate was shown between 2017-2018 (Tvar=44.35).

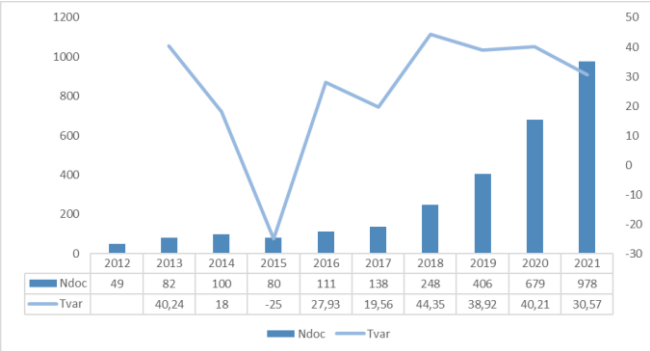

Figure 1. Distribution by year of Latin American scientific production on Artificial Intelligence and Health, 2012-2021.

A predominance of original articles was found (Ndoc=2397), followed by review articles (Ndoc=363), editorials (Ndoc=55), letters (Ndoc=27), notes (Ndoc=21) and errata (Ndoc=8).

Regarding the articles' publication languages, it was observed that most of them were written in English (2741), while 108 were published in Spanish, 48 in Portuguese, 2 in Italian and 1 in French.

Regarding access to articles, 1,730 were observed under all accesses, 1,361 in the green category, 1,118 gold access, 208 bronze access, and 113 hybrid gold.

Multiple thematic areas were identified under which the articles were grouped. The five most productive subject areas in descending order were: Medicine (Ndoc=1190), Computer Science (Ndoc=1051), Engineering (Ndoc=712), Biochemistry, Genetics and Molecular Biology (492) and Neurosciences (247).

19.5% of the articles were published in the top 10% of most cited journals. It was found that, based on the SJR score, 58.3% of the articles were published in Q1 journals, 26.3% in Q2 journals, 9.7% in Q3 journals, and 5.6% in Q4 journals.

The most productive journals were Sensors (Ndoc=79), Plos One (Ndoc=66) and the Irish Computer Methods And Programs In Biomedicine (Ndoc=59), all three Q1; The table shows the 10 most productive magazines and their characteristics.

Table 1. Most productive journals.

Journal	Country	Ndoc	Q 2021	H-index
Sensors	Switzerland	79	Q1	196
Plos One	USA	66	Q1	367
Computer Methods And Programs In Biomedicine	Ireland	59	Q1	115
IEEE Access	USA	58	Q1	158
Computers In Biology And Medicine	United Kingdom	55	Q1	102
Applied Sciences	Switzerland	49	Q2	75
Scientific Reports	United Kingdom	39	Q1	242
International Journal Of Environmental Research And Public Health	Switzerland	36	Q1	138
Expert Systems With Applications	United Kingdom	33	Q1	225
IEEE Latin America Transactions	United Kingdom	32	Q3	29

The articles received 64,128 citations, averaging 22.3 citations per article. It was observed that 169 patents cited some of the articles analyzed, with 2014 being the one with the highest number of patents citing scientific production (56 patents). A rate of 58.9 patent citations per 1,000 articles published on AI and health in Latin America was identified.

Scientific production by countries and institutions

The Latin American countries that made the most significant volume of contributions were analyzed, identifying themselves in descending order: Brazil (Ndoc=1420), Mexico (Ndoc=551), Colombia (Ndoc=336), Chile (Ndoc=236), Argentina (Ndoc= 191), Ecuador (Ndoc=98), Peru (Ndoc=73), Cuba (Ndoc=59), Venezuela (Ndoc=26) and Costa Rica (Ndoc=19).

The analysis of the 10 most productive institutions showed the University of São Paulo as the top producer of scientific articles on AI and health (Ndoc=288). Six of the ten most productive institutions corresponded to Brazil (Table 2).

Table 2. Most productive institutions on artificial intelligence and health.

Institución	País	Ndoc	Naut
Universidade de São Paulo	Brazil	288	632
Universidade Estadual de Campinas	Brazil	112	271
Consejo Nacional de Investigaciones Científicas y Técnicas	Argentina	102	233
Universidade Federal do Rio Grande do Sul	Brazil	89	188
Universidade Federal de Minas Gerais	Brazil	85	186
Universidade Federal de São Paulo	Brazil	84	141
Universidad Nacional Autónoma de México	Mexico	81	138
Instituto Politécnico Nacional	Mexico	78	143
Universidad de Chile	Chile	77	152
Universidade Estadual Paulista Júlio de Mesquita Filho	Brazil	70	124

Table 3 shows the ten organizations that have financed the most significant number of research on AI and health, highlighting the National Council for Scientific and Technological Development (Ndoc=539) and the Coordenação de Perfeiçoamento de Pessoal de Nível Superior (Ndoc=409).

Table 3. Funding organizations for publications on AI and Health.

Institution	Ndoc
Conselho Nacional de Desenvolvimento Científico e Tecnológico	539
Coordenação de Aperfeiçoamento de Pessoal de Nível Superior	409
Fundação de Amparo à Pesquisa do Estado de São Paulo	197
Consejo Nacional de Ciencia y Tecnología	159
National Institutes of Health	150
Fundação de Amparo à Pesquisa do Estado de Minas Gerais	66
Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro	51
European Regional Development Fund	47
Fundação para a Ciência e a Tecnologia	45
Fondo Nacional de Desarrollo Científico y Tecnológico	41

Thematic analysis and co-occurrence of terms

The topic analysis in SciVal identified 498 thematic groups or clusters, resulting in the main TC.0 (Algorithms; Computer Vision; Models. [Ndoc=150; FWCI=3.32; PP=99,799]) and TC1500 (COVID-19; SARS-CoV-2; Coronavirus [Ndoc=148; FWCI=3.14; PP=100]). 1,376 topics were identified, the most productive being T.4338 (Object Detection; Deep Learning; IOU [Ndoc=101; FWCI=4.03; PP=99.997]) and T1100120 (Radiological Findings; Clinical Features; COVID-19; [Ndoc=80; FWCI=3.37; PP=100]).
In the analysis with VOSviewer, 301 words were identified with a co-occurrence greater than 30. The words with the highest occurrence were human (1541), humans (1198), and machine learning (1140). 5 clusters were identified: cluster 1 “red” -92 elements- (main node: machine learning: (total link strength: 1112); cluster 2 “green” -72 elements- (main node: female (total link strength: 593); cluster 3 “blue” -70 elements- (main node: human (total link strength: 1541); cluster 4 “yellow” -47 elements- (main node: article (total link strength: 1096); cluster 5 “purple” -20 elements- (main node: algorithm (total link strength: 410).

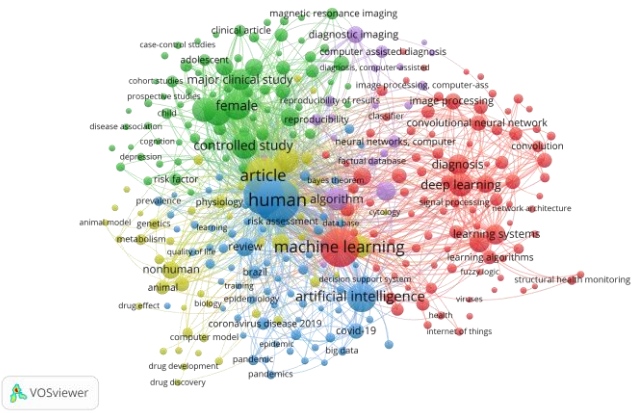

Figure 2. Cooccurrence of terms.

Analysis of author productivity, collaboration, and co-authorship network

The most productive authors were Víctor Hugo Costa de Albuquerque (Ndoc=42; Ncit=2264; h-Index=56), Pedro Pedrosa Reboucas Filho (Ndoc=32; Ncit=1123; h-Index=27), and Joel JPC. Rodríguez (Ndoc=30; Ncit=1695; h-Index=80). Regarding collaboration, 54% of the articles had international collaboration, 26% national, 17.7% institutional, and 2.3% were written by a single author. Only 3.3% of the articles were written in academia-corporation collaboration.
The figure shows the co-authorship network of researchers with more than five publications containing 63 authors. Researcher Víctor Hugo Costa from Albuquerque highlighted it as more productive.

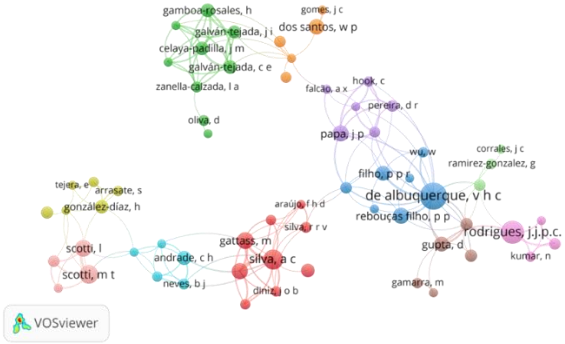

Figure 3. Co-authorship networks.

4. Discussion

Research on AI and health showed an increasing trend. This fact may be related to the advances in science and technology achieved in recent years and the increased interest in artificial intelligence and process automation. These results coincide with the reports by Fosso Wamba et al. [28] and Xuan Tran et al. [29], who identified a growth in global production in this area, more accelerated since 2014.
A similar trend has been observed in other computer science and data science areas, such as the metaverse, which has been recognized as an emerging research area [33–36].
An expected fact is the predominance of original articles among scientific production; as well in the field of technical sciences, computer science, and health, practice, and experimentation are the ones that generate the greatest contributions. Similar results were reported by Binkheder et al. [37] in an investigation carried out in Saudi Arabia.
Even though this work is oriented towards scientific production in the Latin American area, a predominance of articles written in English was found.[38,39] This fact is influenced from the researchers' perspective by several factors. However, two are most significant: English is considered the language of science globally, and the most important journals in the field of computer science and health are published in English. Added to this is the researchers' desire to be cited, which is difficult to achieve in a scientific ecosystem led by non-Spanish speakers.
Regarding the research areas to which the articles respond, Islam et al. [15] identified Computer Sciences, Multidisciplinary Sciences, Electronics and Electronic Engineering, and Applications and Medical Informatics as the main ones. Although these results partially coincide with ours, it can be said that the difference lies in the fact that both studies were carried out in different databases (Web of Science vs Scopus), where the classifications of the research areas are different. However, these findings show the transdisciplinarity and multidisciplinarity of science, especially artificial intelligence in health.
Regarding the results of this study, it can be considered that medicine provides the general theoretical support to which AI will be applied, computer sciences offer computer support, and engineering technical support and infrastructure. Hence they are identified. as more productive areas. For their part,

the rest of the areas will receive the application of AI, such as Biochemistry, Genetics, and Molecular Biology. In contrast, neurosciences will receive applied knowledge, but at the same time, they will allow the progress of AI learning and the regularities of its logic to be compared with human thought.[40]
The current global policies regarding scientific publication condition that not only what is published matters, but adding value to the place where it is published. In this sense, journals gain prestige among the scientific community according to the databases where they are admitted; Scopus, Web of Science, and PubMed/MedLine are some of the most important. In the same way, it is valued that the articles are published in specialized magazines of the area or branch of knowledge investigated.
In this sense, several investigations identified Plos One as one of the most productive journals, partially coinciding with the rest (mainly Scientific Reports; IEEE Access) [29,31,41]. This result may be determined by the difference among the databases where the bibliometric analysis of the studies was carried out. Still, in the same way, they show orientation towards specialized and internationally prestigious journals.[42] It can also be determined by factors such as prices per publication, the existence of institutional agreements, and the preference of researchers.
Although Guo et al. [31] and Prema et al. [43] did not identify any Latin American country as a high producer in AI and health, growing scientific production is real.
In this sense, Guntijo et al. [41] report in their co-authorship networks between countries the existence of cooperation with Brazil as the largest producer in Latin America. For their part, Xuan Tran et al. [29] identified Brazil as the sixteenth largest producing country in the study area. This result coincides with what is reported here, pointing to Brazil as the most significant scientific producer in the region, which logically coincides with the fact that a large part of the most productive institutions in the region is focused on Brazil.
The analysis of the research areas, research topics, and networks of co-occurrence of terms makes it possible to determine trends in research in artificial intelligence and health. In the present study, such issues as AI-assisted clinical or imaging diagnosis, therapeutic decision-making, or outcome prediction can be considered research trends. Lines such as predictive and decision-making models in situations like pandemics are also interesting. Similarly, interest can be inferred in research on the Internet of Things, its connection with devices at home, and smartwatches for monitoring health status and collecting and processing biological signals. Regarding this, a study carried out by Xuan Tran et al. [29] identified areas related to the development of AI and the study of clinical, diagnostic, and therapeutic planning applications of AI in health, essentially agreeing with the present results. Similarly, the study indicates the scarcity of scientific production regarding ethics in the application of AI in health. In the bibliometric analysis by Islam et al. [15] on the application of AI in the COVID-19 pandemic, it was found, after examining the co-occurrence of keyword terms, an orientation towards the classification, diagnosis, and prediction of COVID-19.
For their part, Fosso Wamba et al. [28] identified the study of biomarkers by AI techniques for investigating health status as an emerging topic, as well as the application of predictions, models, and robotics in health. He found "Machine learning" and "Deep learning" as the main keywords, relating them to the automation of the digitization of health systems. The work pointed out the still insipid existence of research on ethics and responsibility in AI applied to health, identifying it as an area of research opportunity.
Collaboration has become a reality in modern research, resulting from specialization and professionalization of processes. In research fields such as AI and Health, multidisciplinary teams comprised of health personnel, engineers, computer scientists, mathematicians, or others participate, similar to what was reported in the analysis of the research areas analyzed above.
Similarly, the scientific communication patterns in Latin America have been oriented towards open science, driven mainly by Brazil.[44] Part of it is data sharing, creating a collaborative science where data is shared. This could condition the creation of collaborative networks between researchers with similar interests and, therefore, international, national, and inter-institutional co-authorship.
This research has limitations, among them that only the scientific production on the artificial intelligence applied to health was studied in one database (Scopus), leaving out research published in journals in other global databases (Web of Science, Dimensions) and regional infrastructures (SciELO, Redalyc, Amelica, Dialnet). In addition, only articles up to 2021 were studied, excluding 2022 and the first months of 2023, a period in which substantial progress has been made in this field with the implementation of ChatGPT [22,45–47] and others.

5. Conclusions

There is a growing scientific production on artificial intelligence and health in Latin America, marked by the predominance of articles published in English, original type, and open access. There was a transdisciplinarity of science, including medical, engineering, and computer and data science publications. The publication was oriented towards specialized journals ranked in the first quartiles of Scopus. Brazil and its institutions concentrated on the greatest scientific production. International collaboration predominated. The analysis of the co-occurrence of terms and topics showed the orientation of the research towards predictive models, the classification, diagnosis, and treatment of diseases, the application of robotics, and the processing of biological signals for the monitoring of the state of health.

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