

Internet of Things and Health: A literature review based on Mixed Method

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Abstract

The integration of technological advances into health sciences has promoted their development, but also generated setbacks and difficulties for digital transformation. In different areas, technology has modified the processes of diagnosis, teaching and learning, treatment and monitoring, which is why the study of new technologies and the models that support their introduction is essential. Internet of Things is one of these models, which, in turn, includes different models, devices and applications. Due to its breadth of exploitation options and benefits, in the health area this concept has been adopted and particularized as the Internet of Medical Things. With the purpose of achieving an approximation to the main trends and characteristics, a literature review study was conducted, based on mixed methods. Two studies were carried out with a sequential strategy, the first being bibliometric and the second a scoping review. The main results allowed us to describe the main trends in terms of bibliometric indicators, a thematic analysis in terms of areas, populations, benefits and limitations. It is concluded that there is a need for new interdisciplinary studies and lines for future research are presented.

Keywords: Internet of Things; Health; mixed methods.

Received on 14 September 2023, accepted on 9 January 2024, published on 19 January 2024

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doi: 10.4108/eetiot.4909

1. Introduction

The Health Sciences, influenced by the socioeconomic context in which they are produced, have undergone multiple changes.^{1 2 3} Areas such as rehabilitation, medicine and nursing, to name a few, have been modified by the irruption, not always organized and planned, of technology.^{4 5 6 7} Although there are many disciplines and processes to point out, some of them stand out, such as teaching and learning in

virtual environments.^{8 9 10 11 12 13} the use of artificial intelligence for various purposes^{5 14 15 16} telemedicine and health services in virtual environments, or through technology, to improve quality and broaden access.^{17 18 19 20 21 22 23} among others. However, these advances are accompanied by challenges, among which are the study of psychological and social factors.^{24 25 26 27 28 29} technology acceptance and barriers to technology integration^{30 31 32 33} The establishment of human relationships, collaboration networks and the transfer of processes to digital environments.^{34 35 36 37 38 39 40} the proper handling of data in decision making^{41 42}

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^{43 44 45 46 47 48 49}as well as others that point to novelty and uniqueness as cornerstones of multi- and interdisciplinary innovation in the human sciences and especially in the health sciences.^{50 51 52 53 54 55 56}

Whether from constructivist and human-centered perspectives or from positivist approaches, these challenges must be addressed in order to better understand their impact, as well as their efficiency and effectiveness in achieving new results and transformations.⁵⁷ Therefore, it is vital to study both the models that guide the introduction and integration of new technologies and their influence on individuals, groups, organizations and communities.⁵⁸

In this sense, although multiple models, approaches or platforms in themselves can be highlighted, a particular concept that has gained both popularity and validity stands out: *Internet of Things* (IoT).^{59 60 61 62 63} This has generated a lot of attention, both in the health area and in other related or unrelated areas, due to the wide range of options for its exploitation, as well as the variety of industries that are linked to its development.^{64 65 66}

During Covid-19, IoT technologies gained prominence in the area of healthcare.^{67 68 69 70 71 72 73} This, although due to different factors related to the complex global scenario experienced, is especially related to the benefits offered, which, in addition to offering a set of individual benefits, also contributes to alleviate the pressure on local and regional health services.^{59 67 74 75 76} In addition to measuring certain variables, obtaining metrics, both in real time and in standard storage in a cloud, IoT technology provides facilities for decision making in integrated systems, quality control of environmental values, allows the longitudinal study of the behavior of several variables and promises to assist in the near future the *delivery of* various forms of medical action.^{77 78 79 75}

The concept of IoT, although diverse and scattered, brings together several key words: data, electronic devices, sensors, cloud, monitoring.⁸⁰ While some authors claim that the concept offers ample opportunities, but is far from being a "real" solution to the problems facing global health, the key idea is the use of information provided by electronic devices connected to the Internet.⁸¹ The key idea is the use of information provided by electronic devices connected to the Internet.⁸²

Although some studies support the idea that the realization of IoT models in the health sector does not occur in a singular way, but is another area of technological application, the truth is that its variety of formats and modes of use have led to the widespread use of related concepts such as Internet of Medical Things (IoMT).^{83 84 85} This *framework* includes applications for monitoring the general state of health,

specific vital signs, remote or app-assisted diagnostics, special care systems for the elderly, medication dosing or the execution of medical procedures,⁸⁶ the dosage of medications or the precise execution of medical treatments.^{67 87 88 89 90 91} As can be seen, the possibilities are vast and its popularity and impact has increased in various areas, primarily in medicine, nursing and rehabilitation, although the convergence in the sports area also stands out due to the multiple uses given to IoT-based technology. However, its introduction in specialized medical services or as a personalized healthcare service offering has faced, and still faces, several limitations.^{92 93} Among the most notable are the lack of an adequate model for its use, the uncritical or ad-hoc application of IoT-based technologies, issues related to the security and use of data, effective integration with human systems, acceptance by users and specialists, among others.^{59 94 95 96}

Thus, it is essential to achieve a better understanding of the behavior of the field and its trends; the identification of journals, authors and institutions interested in the subject, as well as to achieve a mapping of the main disciplines, keywords and future areas of attention.⁹⁷ In addition, a better understanding of the internal trends, main topics of interest and other aspects of the use of IoT-based technology in the Health Sciences is vital.

2. Methods

In order to achieve the purposes established for the study, a complex design with a mixed approach was conducted. To this end, two independent protocols were developed with sequential implementation, one a bibliometric study and the other a qualitative review with a broad design (scoping review). The methodological elements of each protocol are described below.

2.1. Bibliometrics study

It was decided to carry out a bibliometric analysis of the field of study due to the breadth of sources identified during the first phase of the research (*screening*). Due to the results of this approach, the large amount of bibliometric data available and the need to establish the academic structure of the field, a protocol aimed at indicators was chosen.^{98 99 100 101 20} The final design was based on previous studies with similar goals.^{102 103 98 104 105 77 106 107}

Table 1. Indicators, bibliometric analysis and questions.

Indicators and procedures	Objectives	Contributions to the field of study
Related to publication metrics	Identify temporal patterns in publications related to IoT and Health.	Exploration of the main publication trends (number of publications per year, location).
Related to publication citations	Identify the institutions most interested in scientific production in IoT and Health Sciences.	Contribution to the visibility of the main projects and their standardized impact.

Related to citation/publication metrics Network analysis (clustering/visualization)	Determining manuscript types and citation metrics Determine the main areas and relationships between disciplines	Evaluate the behavior of citation metrics and their behavior by areas. Assessment of the main areas of convergence, intersection and use of IoT in Health Sciences.
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As a result, this study provided various metrics that facilitated a diagnosis of the evolution of the field in the period 2013-2022 in the Scopus database. We started with the analysis of the total number of publications and their distribution according to type of scientific production (*conference proceedings, article, review, etc.*), compared the citation impact of the field with respect to the world average and the expected behavior using the *Field-Weighted Citation Impact* metric, and paid specific attention to the cluster formed by the

main categories, disciplines and interactions between areas of knowledge.

The Sci-Val and VOSviewer tools were used to visualize the data and process the information, based on an extensive review of similar studies, the use of a simple search strategy and the generation of a keyword database for the qualitative study (see Figure 1).

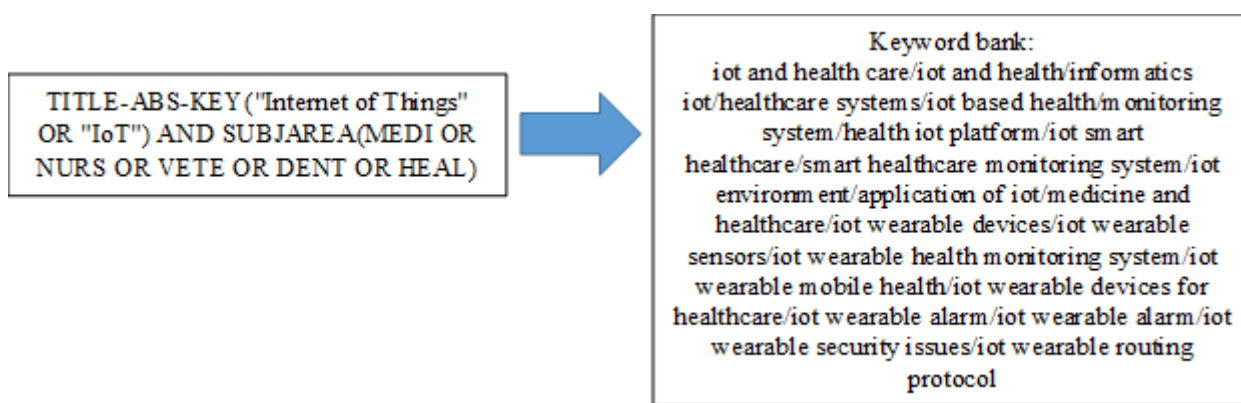


Figure 1. Search strategy.

2.2. Scoping review

This type of methodology has proven to be especially useful in emerging areas or as a tool to support or complement broad or positivist studies.¹⁰⁸ For the design of this protocol, a

PICO model was used as a basis, similar to the proposals made by previous studies.¹⁰⁹ In this sense, a system of questions was used to adapt the PICO model to the field of study (see Table 2).

Table 2. Questions for adapting the PICO model.

Indicator	Ask
Development of indicators for future studies	What are the main trends, areas of health sciences and interactions with other areas?
Examine areas and determine possible gaps	What are the main populations under study? What are the main IoT formats used? What are the main benefits and the main limitations?
Explore areas for future study and establish research needs/objectives	What are the least explored areas in the integration of IoT models in Health Sciences? What essential elements should future studies consider in terms of their design? What questions stand out and should be answered in future approaches?

The search strategy was based on triangulation, specifically of sources and researchers. To this end, during the first phase, authors 1 and 2 conducted an independent search using the *keyword* identified with the help of the Google academic

search engine, the use of the my library tool and the export of the most relevant studies identified to Sotero (N=33). Once the database was created in Sotero, author 3 conducted an independent evaluation of the quality, relevance in terms of the questions and objectives, as well as the methodological

rigor followed. The criteria established by the APA, specialists in mixed methodology and similar studies were used for this purpose.^{110 111}. Following this evaluation, articles were discarded due to relevance (n=8) and due to the lack of a stated methodology (n=10). The remaining articles were subjected to a joint evaluation by the author team and a final sample was selected for in-depth analysis (n=9).^{67 74 75 83 85 112 113 114 115}

A three-phase protocol was used for the thematic analysis, in order to triangulate the data and the perspectives of each researcher and to achieve an adequate integration and discussion of the main results.¹¹⁶ We used an adaptation of the methodology for conducting thematic analysis in interdisciplinary health teams proposed by Saunders et al.¹¹⁷ and the procedures were reviewed in terms of similar studies.

Table 3. Phases of the thematic analysis.

Phase	Procedures
Initial approach	<ol style="list-style-type: none"> 1. Individual in-depth reading. 2. Key notes: memos, codes and proposed categories. 3. Elaboration of the individual thematic proposal. 4. Group discussion of the results of phase 1.
2. Coding and contrasting.	<ol style="list-style-type: none"> 1. Initial assessment of data saturation 2. Comparison of the codes and preparation of the single codebook. 3. Review of the uncoded data and contrasting evidence.
3. Thematic analysis.	<ol style="list-style-type: none"> 1. Closing of the analysis and determination of data saturation. 2. Individual proposal of topics, discussion of the proposal and closing of the thematic proposal. 3. Writing of the thematic synthesis.

3. Results

The following is a synthesis of the main results achieved by each study, as well as a synthesized contrast of both. The limitations of the study are also discussed, as well as assessments for future research.

3.1. Bibliometric study: IoT and Health

Analysis of the first bibliometric indicator yielded a total of 7612 documents retrieved and 24752 authors involved in research and manuscript writing. These data suggest a clear trend towards collaboration and scientific production based on research teams and the use of laboratories (Table 4). As can be seen, the importance of inter-author collaborations is confirmed, as single-author papers received fewer citations than expected, while international collaborations far exceed the expected average.

Type of collaboration	Ndoc	%Ndoc	Cpd	FWCI
International collaboration	1357	17.8%	14,4	2,62
Only national collaboration	2097	27.5%	7,4	1,65
Only institutional collaboration	3574	47.0%	6,5	1,35
No collaboration	584	7.7%	5,2	0,85

Table 4. Type of collaboration

Another important result found is that of geographical distribution, which showed significant regional development in Asia, Europe, the Middle East, Australia (Oceania cannot be mentioned) and North America. In Latin America, Brazil stands out, but there is little or no scientific activity in the

remaining countries, which could be explained by the necessary technological infrastructure and the high costs in the production of *wearables* and other technologies required for IoT models.

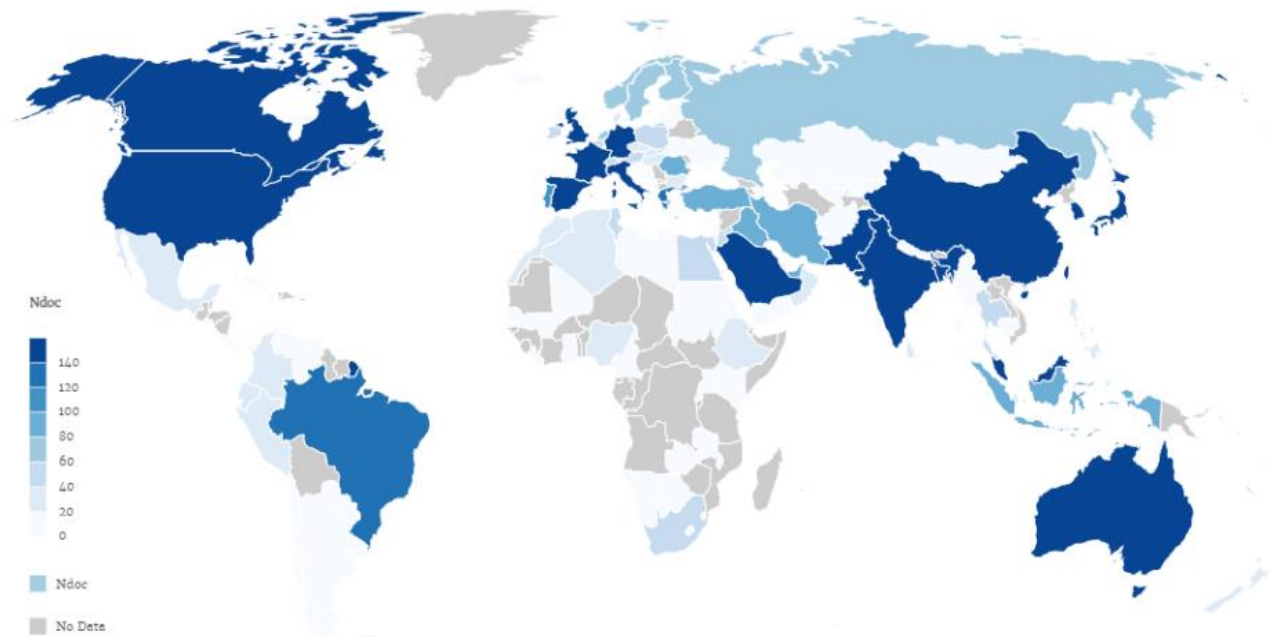


Figure 2. Geographic distribution.

In addition, a pronounced trend towards an increase in publications per year was identified in this indicator, especially in the period between 2019-2022. Another important data yielded by the bibliometric analysis of this indicator is the impact, measured by the number of

publications in quartile 1 journals (scimagojr Q1), although this number represents about one third of the remaining publications combined (Q2, Q3, Q4) (see Figure 3).

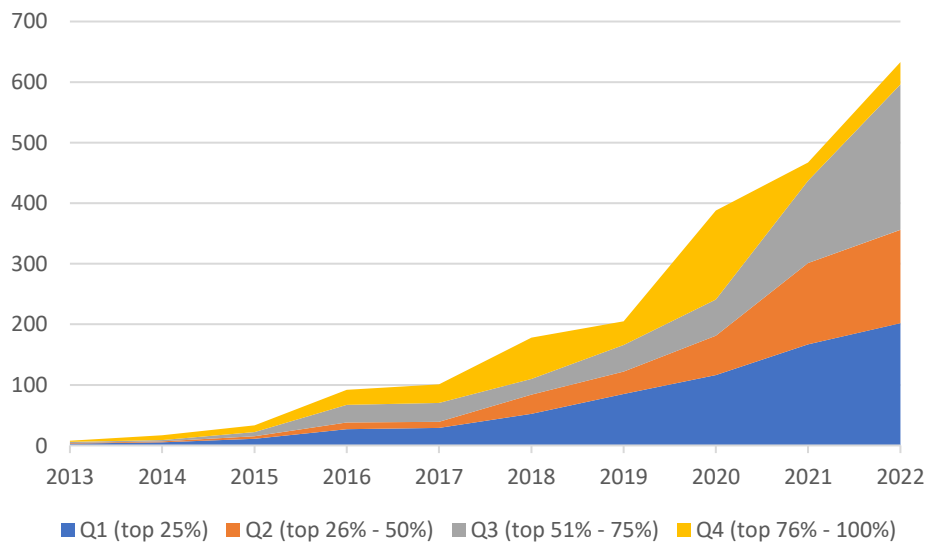


Figure 3. Distribution by years and quartiles.

Indicator 2 identified the main institutions in terms of scientific production (see Table 5). Except for one French government agency, the rest of the institutions are academic

and located in India. These results are conditioned by the normalized impact, with a clear tendency to exceed the expected average number of citations.

Table 5. Main Institutions.

Institution	Sector	Country	Ndoc	Cpd	FWCI
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Anna University	academic	India	404	5,2	2,3
Vellore Institute of Technology	academic	India	134	6,6	2,64
University of Pune	academic	India	84	6,5	3,05
SRM Institute of Science and Technology	academic	India	78	3,1	1,23
Amrita Vishwa Vidyapeetham	academic	India	74	6,9	1,71
Amity University, Noida	academic	India	72	5,7	2,23
CNRS	government	France	69	5,9	1,28
University of Mumbai	academic	India	50	5,6	1,38
Uttaranchal University	academic	India	48	0,8	1,36
Chitkara University	academic	India	45	6,2	2,61

Regarding the third indicator, there is a significant accumulation of manuscripts in conference format, with a total number of publications that far exceeds the other publication formats combined (see Table 6). These data suggest a gradual process of teaching the main models, discussion of opportunities and challenges, as well as other necessary assessments during the consolidation of a field or discipline.

Table 6. Types of publication

Publication types	Ndoc
Conference Paper	5126
Article	1290
Chapter	595
Review	296

Conference	112
Review	
Editorial	61
Book	35
Others	97

In terms of areas, as expected, medicine stands out, although other disciplines such as dentistry, nursing, health professions, psychology and neurosciences are also present (see Table 7). The social sciences and decision-making studies also stand out. As will be seen below, this is a truly complex field, with multidisciplinary contributions, dispersed and in a period of consolidation, which points to the need for future studies to generate true interdisciplinary approaches and not mere applications of imported knowledge or technologies.

Table 7. Main areas.

Subject Area	Ndoc	Ncit	Naut	Cpd	FWCI
Medicine	6989	57815	22887	8,3	1,69
Computer Science	5882	37181	18530	6,3	1,57
Engineering	3345	21112	11165	6,3	1,77
Decision Sciences	2649	13240	8720	5	1,67
Social Sciences	1269	10250	4148	8,1	1,43
Health Professions	1022	12365	3484	12,1	1,36
Energy	919	3200	3205	3,5	1,8
Physics and Astronomy	849	5462	3033	6,4	1,7
Mathematics	731	2971	2429	4,1	1,61
Business, Management and Accounting	463	4490	1523	9,7	2,42
Biochemistry, Genetics and Molecular Biology	306	5383	1357	17,6	2,08
Agricultural and Biological Sciences	185	1348	707	7,3	3,08
Environmental Science	183	2178	677	11,9	1,23
Nursing	134	1683	501	12,6	1,82
Materials Science	115	2507	590	21,8	2,13
Chemical Engineering	103	2624	517	25,5	2,94
Neuroscience	65	1067	241	16,4	1,76

Pharmacology, Toxicology and Pharmaceutics	52	318	201	6,1	1,03
Psychology	41	503	124	12,3	1,39
Immunology and Microbiology	34	346	155	10,2	1,7
Economics, Econometrics and Finance	33	269	86	8,2	2,14
Veterinary	27	347	123	12,9	1,81
Arts and Humanities	15	97	38	6,5	1,19
Dentistry	15	280	56	18,7	4,9
Chemistry	10	390	40	39	1,57
Earth and Planetary Sciences	1	0	1	0	0

Figure 4 shows precisely the accumulation of relevant studies in specific areas, especially mathematics, computer science and physics, although the contribution of chemical and materials sciences is also evident. Contrasting these results

with those of indicator 2 confirms the need to produce interdisciplinary science and advanced studies that transcend the application of general principles.

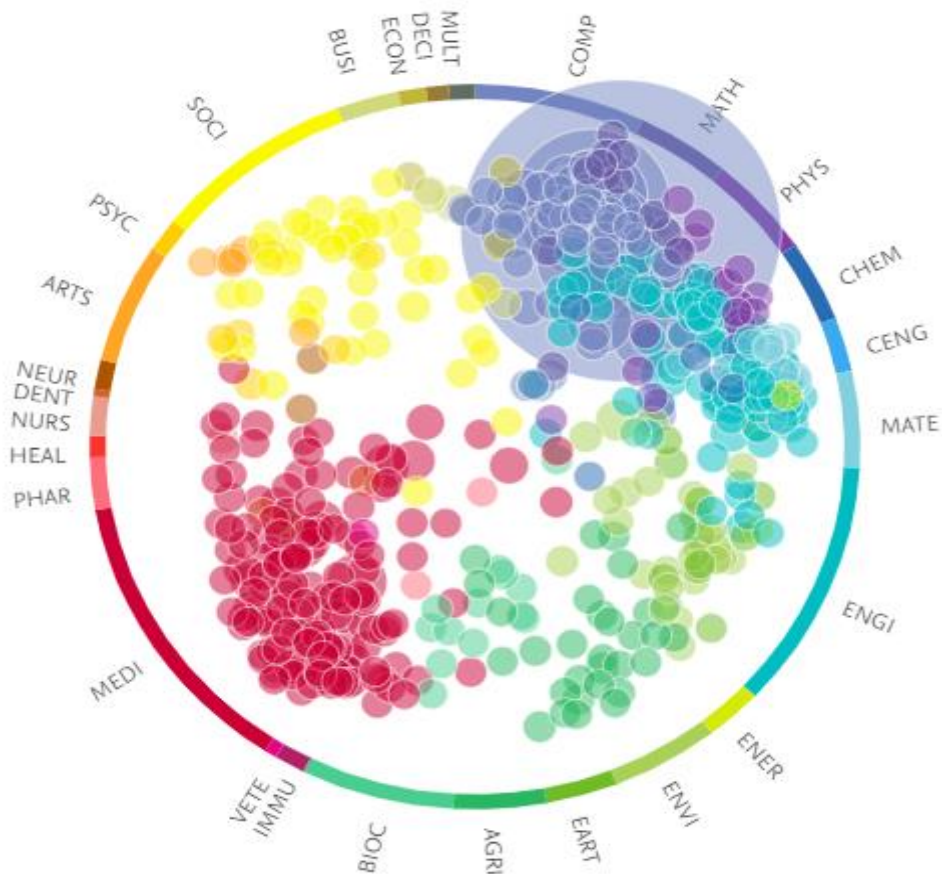


Figure 4. Cluster by topics.

Figure 5, elaborated from the co-occurrence of terms, shows that the main keywords are associated with or used in computer science. This phenomenon could be explained from the analysis of the conceptual and technological components of IoT models and the technologies produced from them. However, the poor co-occurrence represented in thin lines, the dispersed distribution of topics and the poor consolidation of topics stand out.

In general, the analysis and visualization of bibliometric data point to a field in consolidation, to the need for interdisciplinary studies and greater collaboration between related disciplines. In addition, it is vital to encourage the development of conceptual and technological solutions specific to the Health Sciences, with the participation of specialists and complex approaches, gradually replacing proposals made from a single discipline or external disciplines.

models. The former refers to issues related to battery durability, improvements in the appearance or presentation of products, improvement of individual components and expansion of capabilities, especially in terms of data (security, privacy, processing, real-time processing, visualization).

In the second case, reference is made to the conceptual aspects of the exploitation of devices, the incorporation of new technologies and complex learning models through AI (*machine learning, neural networks, cognitive model*). It is worth noting the scarce importance given in the texts consulted to interdisciplinary dialogue and cooperation between teams from different disciplines, despite the fact that several of the limitations, especially those related to integration into everyday life, could be solved through these collaborations.

4. Discussion

In general, it can be stated that the IoMT constitutes a metamodel that includes different conceptual approaches to the use of technology. In the future, these models and associated devices are expected to change the way Health Sciences are understood, especially the monitoring and dosing of treatments. However, it should be noted that the adoption of models and technology must be carefully examined, tested and evaluated before they become widespread^{119 120 121 122}.

Despite the tremendous importance of the technological aspects related to IoT models and their transformation into IoMT, the human aspects of their technological integration need to be deepened in order to limit the impact of barriers and promote digital transformation.^{123 124 125} This means giving greater importance to learning processes, raising awareness of the use of technologies and their benefits, designing schemes and strategies for their effective integration, among others.

In addition, it is important to highlight the main limitations of this study, given its general nature, the selection of a single database, and the insufficient depth in terms of trends and themes within the main lines¹²⁶. Future studies are suggested along the following lines: interdisciplinary nature, integration into everyday life, unique design of the IoMT model and evaluation of the socio-psychological particularities of its implementation.

5. Conclusions

The study concluded that Health Sciences can benefit significantly from the introduction of IoT models and their correct adaptation to the needs and particularities of the environment. Especially in terms of improving access and the quality of data-driven decision making, the incorporation of IoT-based devices could result in greater efficiency and improved functioning of healthcare systems. In addition, the use of this technology could favor health education, self- and collective health awareness, intelligent

monitoring of personal and environmental metrics, among other benefits.

However, in order to achieve these advances, it is necessary to achieve an adequate integration of the technology, substantiate its inclusion in the processes, explore its acceptance by professionals and users in general, as well as assess the limitations of such integration. In conclusion, it is necessary to direct new studies, with an interdisciplinary approach, towards a better understanding and development of IoMT models.

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